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A lithostratigraphical framework for onshore Quaternary and Neogene (Tertiary) superficial deposits of Great Britain and the Isle of Man

Geology, Geotechnics and Palaeontology Programme
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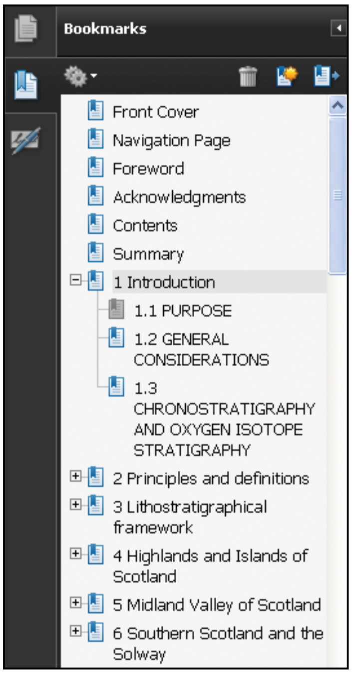

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Granite tors at Peninnis Head, St Mary's, Isles of Scilly, beyond the southernmost extent of grounded ice recorded on the British landmass. *Photograph:* M R McMillan (P766820).

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A lithostratigraphical framework for onshore Quaternary and Neogene (Tertiary) superficial deposits of Great Britain and the Isle of Man

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Keyworth, Nottingham British Geological Survey 2011

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Foreword

This report results from a study by the British Geological Survey (BGS) to rationalise the Quaternary and Neogene (Tertiary) lithostratigraphy of Great Britain (England, Scotland and Wales) and the Isle of Man. The report utilises the new lithostratigraphical framework, published in the Overview Report (McMillan et al., 2005), which employs the full hierarchy of the stratigraphical code: supergroup, group, subgroup and formation (together with smaller units), for the correlation of the onshore Quaternary deposits of Great Britain. This report presents an overview of the framework and defines the groups, subgroups and main formations (the principal mapping units). Important members and beds are also described. Regional correlation charts and representative cross-sections are included to aid an understanding of the framework. The objective of the report is to provide a regional lithostratigraphical scheme for Great Britain and the Isle of Man to aid future Quaternary geoscience, including mapping and correlation (onshore and offshore correlation), and to roll out a lithostratigraphical scheme capable of use in a wide variety of applications.

Acknowledgments

This report represents the culmination of several years' discussion and debate both within the British Geological Survey and with external researchers regarding the application of a lithostratigraphical framework to Quaternary and Neogene (Tertiary) superficial deposits. It follows on from the publication in 2005 of an Overview Report. The authors of the present report thank members of the Geological Society Stratigraphy Commission and specifically the nominated external reviewers: Professor D Q Bowen (Cardiff, University of Wales) and Professor P L Gibbard (University of Cambridge), for their constructive reviews.

For both the Overview and the present report the authors and contributors also acknowledge advice and input received from Dr D T Aldiss, Dr J N Carney, Dr A J Humpage, Dr D J Lowe, Dr J H Powell, Dr C N Waters and Dr D Wilson (all BGS); and Dr E R Connell (University of Aberdeen), Dr A M Hall (University of Edinburgh), Professor J Rose (Royal Holloway, University of London), Dr G S P Thomas (University of Liverpool), Dr W Westerhoff (TNO, Utrecht) and Dr J A Zalasiewicz (University of Leicester).

The report has been prepared as a deliverable of the Geoscience Standards Nomenclature Project (Project Leader, Dr C N Waters) of the National Geoscience Framework Programme (Programme Manager, Dr A S Howard), recently redefined as the UK Geoscience Framework (Team Leader, Dr G A Kirby).

Text and Lexicon definitions of units for draft chapters were contributed to as follows:

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Chapter 5, Midland Valley of Scotland: M A E Browne, A A McMillan, J W Merritt

Chapter 6, Southern Scotland and the Solway: C A Auton, A A McMillan, J W Merritt

Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man: C A Auton, A A McMillan, J W Merritt, G S P Thomas

Chapter 8, Lancashire, Cheshire, Staffordshire and Wales: A A McMillan, J W Merritt, S J Price, M G Sumbler, P R Wilby

Chapter 9, Northumberland, Durham, Yorkshire and the Pennines: A H Cooper, J R Ford, H Kessler, J W Merritt

Chapter 10, East Anglia and the ancestral River Thames: R J O Hamblin, J R Lee, B S P Moorlock, A N Morigi

Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys: M G Sumbler, A Brandon

Chapter 12, Southern England and the Middle to Lower Thames catchments: R A Ellison, J R Ford, A A McMillan

Chapter 13, South-west England: S J Booth, R J O Hamblin, P M Hopson, A A McMillan, B S P Moorlock

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Summary

This report presents the proposed BGS lithostratigraphical framework for the onshore Quaternary and Neogene (Tertiary) superficial deposits of Great Britain (England, Scotland and Wales) and the Isle of Man. The objective of the report is to provide a practical framework to aid future Quaternary correlation, mapping and research, and a stratigraphical scheme capable of use in a wide variety of applications. An overview of the framework was published by McMillan et al. (2005).

A framework that utilises the full hierarchy of the stratigraphical code (supergroup, group, subgroup, formation and smaller units) is proposed. Although the framework is built around the formation, the primary unit for mapping and correlation, it is recommended that some classes of lithogenetically-defined deposits are not accorded formational status. However, at group level the scheme embraces *all* Quaternary and Neogene (Tertiary) superficial deposits, thus enabling a coded lithostratigraphical superscript to be applied to every Quaternary map symbol defined in the BGS Specifications for the preparation of 1:10 000 scale geological maps (Ambrose, 2000). The map specifications are based upon the lithogenetic classification of Quaternary deposits, as outlined in BGS Rock Classification Scheme (RCS) for artificial and natural superficial deposits (McMillan and Powell, 1999). In parts of Great Britain lithostratigraphical mapping at formation level can be regarded only as a long-term objective. Products such as lithostratigraphical maps, cross-sections and three-dimensional models may therefore be regarded as an evolving layer in the geological model.

The unified lithostratigraphical framework for onshore Quaternary deposits is designed to be of use for regional mapping and correlation and may also be of relevance for regional hydrogeological and geotechnical applications. For example the lithostratigraphical classification can be used to enhance geological and hydrogeological domains maps and models depicting landform–sediment associations (McMillan et al., 2000).

The current report is based upon a review of published literature (including BGS geological maps and reports), and expert local knowledge. Extensive reference is made to the Geological Society (London) Special Report No. 23 — *A revised correlation of Quaternary deposits in the British Isles* (Bowen, 1999).

1 Introduction

1.1 PURPOSE

The purpose of this report is to set out mainly at formation level the lithostratigraphical framework for onshore Quaternary and Neogene (Tertiary) superficial deposits of Great Britain (England, Scotland and Wales) and the Isle of Man. Although this report necessarily deals primarily with onshore deposits, the development of the British ice-sheets in present day offshore and nearshore areas is an important consideration, so that deposits, for example of North Sea and Irish Sea basin provenance may be placed in context. The framework has been constructed using established principles of stratigraphy that involve firstly the description and interpretation (lithostratigraphy) of Quaternary units, then correlation by all possible means and finally classification. There should be a clear distinction between factual description based upon observation and inference such as interpreted correlation with chronostratigraphical scales defined by climatic fluctuation or with the oxygen isotope stratigraphical scale derived from ocean sediments.

The Framework, which was outlined in an overview report by McMillan et al. (2005) and in a paper by McMillan (2005), is based upon a review of the extensive British Quaternary scientific literature, including BGS geological maps, memoirs and sheet explanations, volumes of the Geological Conservation Review Series published by the Joint Nature Conservation Committee, Field Guides and Newsletters of the Quaternary Research Association together with the Geological Society (London) Special Report No. 23 — *A revised correlation of Quaternary deposits in the British Isles*, edited by Bowen (1999), a revision of Mitchell et al. (1973a). As discussed below, for practical reasons emphasis is placed on the application of the full hierarchy of lithostratigraphical codes (supergroup, group, subgroup, formation and member) which may have application for regional mapping, classification and correlation (Chapter 2). The group framework is described in Chapter 3 and Tables 1b–8. Chapters 4–13 and Tables 9–19 (regional correlation charts) describe the framework at subgroup, formation and member level, region by region throughout Great Britain. Reference to members and beds is presented in the text and tables, with details of more important members (e.g. terrace deposits of the major English river systems) included in the relevant chapter. More details of most units can be found in the BGS Lexicon of Named Rock Units[1] (available online via http://www.bgs.ac.uk/lexicon/home.cfm). However, full Lexicon entries and Lexicon codes are not yet available for every unit referred to in this report.

Most 'named' lithostratigraphical superficial deposits of Quaternary or Palaeogene–Neogene (Tertiary) age that have appeared on BGS 1:50 000 or 1:63 360 scale New Series maps (see end of References section for list of maps) are referred to in this report, along with other units which may be used for modelling as the framework is developed regionally. Superseded terminology that has been referred to in BGS publications is listed in Appendix 3.

1 In this report BGS Lexicon codes, where assigned, are noted with each unit and in Appendices 2 and 3.

The lithostratigraphical framework aims to:

- Conform as far as possible with international stratigraphical principles for lithostratigraphical classification as provided by the International Union of Geosciences (IUGS) (Hedberg, 1976; Salvador, 1994). Regional application of these Guides is published by the North American Commission on Stratigraphical Nomenclature (NACSN) (1983, 2005) and for the UK by Whittaker et al. (1991) and Rawson et al. (2002).
- Serve as a basis for geological mapping, modelling and correlation
- Assist the user (both the Quaternary specialist and non-specialist) of geological data including BGS maps, memoirs and sheet explanations
- Provide a basis ultimately for a Quaternary lithostratigraphical map of Great Britain and three-dimensional modelling

1.2 GENERAL CONSIDERATIONS

As Powell (1998) has stated, 'In science and engineering, classification is essential if written and oral communications are to be precise and unambiguous.' For onshore Quaternary rocks the application of a strict lithostratigraphical classification presents unique difficulties. A wide range of processes has operated during the Quaternary (the last 2.6 Ma, as proposed[2]; see also Lourens et al., 1996; Ehlers and Gibbard, 2003; Aubry et al., 2005; Zalasiewicz et al., 2006) (Tables 1a, 1b). Deposits are discontinuous, variable in thickness and commonly poorly exposed. The regional significance of unconformities and discontinuities seen in sections or boreholes may be poorly understood. The fragmentary nature of the record, the ill-defined field relationships and the poorly fossiliferous nature of many deposits, with little organic or other dateable material, make the construction of a lithostratigraphical framework a sizeable task.

Where lithostratigraphy has been applied to British Quaternary deposits it has usually been to define locally well-exposed sequences in natural sections, excavations and boreholes where stratigraphical relationships can be observed. National or regional correlation may not be possible. This is reflected in the stratigraphical schemes published by Bowen (1999) in which formations may be restricted to districts where correlation is secure. Tentative correlation may then be made with differently named units of adjoining areas. Many of the lower level units, particularly at member and bed level, referred to in Bowen (1999) have been defined at only a few well-exposed sections or from single boreholes. Such units, as Bowen (1999) confirms, 'are not amenable to systematic and widespread mapping away from their stratotypes'. Nevertheless these units are important for correlation and for inferences about climate.

To address the need to correlate larger bodies of Quaternary deposits regionally, the BGS Superficial Deposits Advisory Group (a Stratigraphical Framework Committee) was tasked to prepare a new lithostratigraphical framework for the onshore Quaternary deposits of Great

Britain. This report and the Overview Report (McMillan et al., 2005) take into account conclusions from two workshops on stratigraphical classification and nomenclature of British Quaternary deposits held at BGS, Keyworth, Nottingham, in February 1998 and February 2001. McMillan and Hamblin (2000) published initial ideas on the framework. The current framework was presented by McMillan (2005) at the TNO International Workshop on Integrated Land-Sea Lithostratigraphic Correlation in Utrecht, The Netherlands (April 2003).

The BGS workshops addressed a number of questions fundamental to the establishment of a workable lithostratigraphical framework that takes as its premise its ability to be applied to geological mapping. Principal conclusions from the workshops and subsequent discussion included the following:

- The formation is the fundamental mapping unit (Hedberg, 1976; North American Commission on Stratigraphic Nomenclature (NACSN), 1983, 2005; Whittaker et al., 1991; Salvador, 1994; Bowen, 1999; Rawson et al., 2002)
- Members and beds may also be mappable units at appropriate scales
- Grouping of formations is desirable, particularly to aid regional mapping (Salvador, 1994) and interpretation by non-geologists
- Groups and subgroups may or may not be composed entirely of named formations (NACSN, 1983) but the establishment of groups without constituent formations should be avoided (Salvador, 1994)
- Lithogenetic descriptors for high-level units (supergroups, groups and subgroups) and for formations (if lithologically heterogeneous) could help to define the framework
- Lithological/grain size descriptors (e.g. sand, gravel) for formations and members are desirable where they clearly convey a dominant lithological/ grain size component of the unit
- Morphological descriptors (e.g. moraine, terrace) for members could be valuable for deposits of well-defined morphology but commonly of variable or poorly known lithology
- It is not necessary or desirable to define all Quaternary units in a formal lithostratigraphy at formation level. In Britain and elsewhere, morpho-lithogenetic classification is a tried-and-tested practical mapping and descriptive tool, and will continue to be used as the primary method for describing Quaternary deposits. Morpho-lithogenetic units are locally mappable sediment-landform assemblages which should be considered without regard to time (Schenck and Muller, 1941; Salvador, 1994). Some morpho-lithogenetic units are not readily amenable to lithostratigraphical classification at formation level because their stratigraphical relationships are poorly known (e.g. mass movement deposits)
- River terrace deposits should be considered as members of formations defined by a single catchment (i.e. the physiographical catchment of a major river and its tributaries)

Traditionally, and in common with many other geological surveys, the BGS has published maps and literature that employ a mixture of lithological, morphological and genetic terminology (Foster et al., 1999). The terminology has been developed by successive generations of survey geologists to map surface Quaternary deposits and to log sections and boreholes. Observation and recording of lithology, structure and morphology of deposits has led to the interpretation of their origin. Mapping practice has led to the refinement of the familiar specification of mapping symbols which feature on BGS maps ranging from the primary mapping scales of 1:10 000 and 1:25 000 to the most commonly published 1:50 000 scale (Ambrose, 2000). The specification corresponds to the hierarchical *Rock Classification Scheme for Natural and Artificial Superficial Deposits* (McMillan and Powell, 1999). The BGS classification now forms the basis of, and the dictionary for, digital products such as the digitised and attributed 1:50 000 scale geological map coverage of Great Britain (DiGMapGB-50), which requires the data to be structured for sensible retrieval of information (McMillan, 2002). Such objectives are common to many geological surveys and similar lithogenetic schemes have been established in many European countries (e.g. in France, Lebret et al., 1993).

In attempting to define a broad framework based upon international and national stratigraphical guidance (North American Commission on Stratigraphical Nomenclature, 1983, 2005; Whittaker et al., 1991, Salvador, 1994; Rawson et al, 2002; see also Chapter 2) the BGS Superficial Deposits Advisory Group identified a number of factors which, if not unique to British and continental north European Quaternary deposits, are unusual in other parts of the stratigraphical column.

- Onshore Quaternary deposits vary greatly in both lateral and vertical extent. Although sequences can attain thicknesses of 200 m or more, commonly component lithostratigraphical formations may be only a few metres thick

2 The position of the base of the Quaternary (indeed the term itself) has been the subject of much debate over many years. As defined in 1996 by IUGS (Gradstein and Ogg, 1996) the base was placed just below the top of the Olduvai magnetosubchron (Aguirre and Passini, 1985), at 1.905 Ma on an astronomically-tuned time scale. This placed a large proportion of the East Anglian Crag and Dunwich groups in the Pliocene. However the base of the Quaternary in the UK has traditionally been taken by BGS to lie at the base of the Red Crag (Mitchell et al., 1973a), implying that the Coralline Crag (the oldest of the Crag Group formations) was the only unit of Neogene (Tertiary) age in East Anglia.

Following continuing debate about the status of the Quaternary and its lower boundary the International Stratigraphic Commission (ISC) jointly with the International Union for Quaternary Research (INQUA) set up a Task Force in 2005. Its interim report set out the proposal to include the Quaternary, with its lower boundary at 2.6 Ma, as a Sub-Era of the Cenozoic Era with the Neogene as a Period spanning both Quaternary and Tertiary Sub-Eras (Aubry et al., 2005) (Table 1a). In this proposal the lower boundary of the Quaternary was decoupled from that of the Pleistocene Epoch (defined as 1.8 Ma). In response the Stratigraphy Commission of the Geological Society (London) proposed that Quaternary be established as a Period and that its base and that of the Pleistocene Epoch should be established at 2.6 Ma (Zalasiewicz et al., 2006) (Table 1a). The proposed lower boundary of the Quaternary (and Pleistocene) corresponds to the GSSP of the Gelasian Stage (for discussion see Pillans, 2004; Gibbard et al., 2005). The Commission further proposed that the Tertiary should be defined as a Period with the Neogene as a Sub-Period below the Quaternary. The proposed change to the base of the Quaternary, which has been supported by many Quaternary scientists, more accurately represents the onset of northern hemisphere glaciations, and is coincident with the Gauss/Matuyama palaeomagnetic Epoch boundary, correlated with the peak of Marine Isotope Stage 103. In May 2009, the ISC elected formally to redefine the base of the Quaternary at 2.6 Ma and also to lower the base of the Pleistocene to this position (Mascarelli, 2009). In June 2009, the Executive Commiteee of the International Union of Geological Sciences ratified this decision (Gibbard et al., 2010). The present BGS Quaternary Stratigraphical Framework adopts the newly ratified proposal (Table 1b).

- By their nature many Quaternary units (e.g. till sheets) are strictly allostratigraphical, i.e. defined and identified on the basis of bounding discontinuities (Räsänen et al., 2009). However, allostratigraphy has not been popularly applied in Britain (Rawson et al., 2002)
- Many Quaternary lithostratigraphical units, being surficial deposits, will have no overlying strata (or bounding surface). However, the associated landform may show characteristic features that can aid the definition of a unit
- The distribution of some mass movement, fluvial and organic deposits can be related to the present day physiography, but caution should be applied when assigning lithostratigraphical classification to units that are unrelated to modern catchments (Section 1.2.2)
- The lithology of many Quaternary deposits is determined by the medium of transport, the depositional environment, and by provenance. Inferred genesis and provenance may aid lithostratigraphical classification of heterogeneous superficial deposits but always there should be a clear distinction made between inference and description. Provenance may not be directly related to the present-day surface distribution of bedrock (level of erosion)
- Weathering characteristics and soil development play an important role in Quaternary stratigraphy

Although Salvador (1994) recommended that differentiation of Quaternary lithostratigraphical units by origin should be avoided, it has long been recognised that such units can be classified in this way. For example, in establishing the Pleistocene stratigraphical framework of Illinois, Willman and Frye (1970) noted that formations, defined by lithology, could also be differentiated by origin into five general types. They commented that 'Although these are genetic groupings, their different origins impart distinctive compositions, grain size and structure and the formations are differentiated on lithology and not on origin.' These authors did not define groups but noted that groupings could be made as the need arises.

This recognition of the link between origin and lithology has guided the development of the proposed framework for Great Britain. Thus, whilst formations are defined on the basis of distinctive lithology, they may be grouped on both lithological criteria and principal sedimentary environment (e.g. glacial, fluvial, marine). For example, the newly proposed facies association scheme of the integrated land and sea stratigraphical model of the Netherlands and the Dutch sector of the North Sea (Laban et al., 2003) assigns formations to broad facies associations (glacigenic, marine and fluvial). As Salvador (1994) notes, 'the degree of change in lithology required to justify the establishment of distinct formations (or other lithostratigraphic units) is not amenable to strict and uniform rules. It may vary with the complexity of the geology of a region and the detail needed to portray satisfactorily its rock framework and to work out its geologic history'. Pragmatic decisions require to be taken about the grouping of formations. For example interbedded marine and fluvial sediments of coastal embayments or fenland may appropriately be grouped together. Additionally, it is evident that the distribution of Quaternary formations can be linked not only to the processes by which they formed or were modified, but also to geographical setting (Sections 1.2.1 and 1.2.2). This too has influenced the establishment of the groups and subgroups (Figures 2–4, Table 1b; Chapters 2 and 3).

1.2.1 Glacigenic deposits

The extent and behaviour of ice-sheets during the Quaternary directly influenced the distribution of a range of glacigenic deposits including diamictons and glaciofluvial deposits. Thus, in Britain the limits of the southernmost (Anglian) ice-sheet and the latest (Devensian) ice-sheet (Figure 2) play an important part in defining the distribution of glacigenic deposits. Early glacigenic deposits of the Anglian ice-sheet are present mainly to the south of the Devensian ice-sheet limit (Bowen, 1973; Bowen et al., 2002 and references therein) and north of a line approximately east-west from Essex to the Bristol Channel (Figure 2). Inferred Anglian deposits also occur, locally, farther north and may be present in the subsurface below deposits of the Devensian ice-sheet. Pre-Devensian deposits may exhibit complex weathering profiles (indicative of a range of climatic conditions) that may aid stratigraphical correlation. Devensian glacigenic deposits are present mainly to the north of the Devensian ice-sheet limit (Figure 2), although some (e.g. glaciofluvial terrace deposits) may extend to the south.

1.2.2 Fluvial deposits

The linking of broad catchment geology to present-day drainage systems may have advantages for a wide range of environmental users (McMillan et al., 2005). Although a river catchment is defined physiographically, lithostratigraphical division of fluvial deposits within that catchment or related catchments is a valid classification. Allowing for glacio-isostatic and relative sea level changes, in practice within each river system Late Devensian to Holocene river terrace and alluvial deposits lying to the north of the Devensian ice-sheet limit (Figure 4) can be related to that system. At, and to the south of, this ice-sheet limit the distribution, elevation and correlation of river terrace deposits is more complicated. River terrace deposits, such as those of the River Thames and its precursors, extend back to pre-Anglian time and have been subject to variations in base level over time (reflecting relative sea level and isostatic changes). Early rivers changed course during and between former glaciations, and deposits of palaeovalleys are common. Therefore lithostratigraphical correlation between formations of different river catchments needs to be applied with caution. The application of lithostratigraphical classification to river terrace deposits is discussed further in Chapters 2 and 3.

1.3 CHRONOSTRATIGRAPHY AND OXYGEN ISOTOPE STRATIGRAPHY

Chronostratigraphy is the element of stratigraphy that deals with the relative time relations and ages of rock bodies (Salvador, 1994). The purpose of chronostratigraphical classification is to organise systematically the rocks into named units (systems, series and stages) that correspond to intervals of geological time (geochronological units including periods, epochs and ages). Some methods for dating and determining the time sequence of Quaternary deposits are described in Appendix 1. The Quaternary is the latest Period of the Cenozoic Era and embraces the Pleistocene and Holocene Epochs (Zalasiewicz et al., 2006; Table 1a).

The concept of time plays little part in establishing or identifying lithostratigraphical units and their boundaries. Lithological character is generally influenced more strongly by the conditions of formation than by the time of origin. Thus caution should always be applied when linking ages to lithostratigraphical boundaries. However, for some deposits where no correlatable stratigraphical relationships are evident (e.g. isolated hill-top deposits) dating techniques (e.g. 14C or terrestrial cosmogenic nuclide dating — Appendix 1) may provide ages allowing the deposits to be placed within the framework.

The British Quaternary has been divided traditionally into climato-stratigraphical temperate 'interglacial' and longer cold 'glacial' stages inferred primarily from the vegetational pollen record (Mitchell et al., 1973a; Rose, 1989a; Gordon and Sutherland, 1993a). However the vegetational response during temperate stages was influenced by variation in altitude and latitude, and, furthermore, the pollen biozone boundaries are diachronous.

Although there is continuing debate about the application of a climate-driven chronostratigraphy and nomenclature (for discussion see Bowen, 1999) reference is made in this report to the British onshore climatostratigraphical stages. These are broadly correlated with the proposed higher status lithostratigraphical units (e.g. groups) (Table 1b). Variation in depositional environment resulting in changes in gross lithological characteristics and lithofacies may be effected by climate change. The British stages are defined from type sections in southern Britain (Mitchell et al., 1973a) (Table 1b). It should be noted that there is, as yet, no formal proposal to replace the stage term 'Wolstonian' (Mitchell et al., 1973a; Gibbard and Turner, 1988; Rose, 1988; Bowen, 1999). This framework report adopts the lithostratigraphical Wolston Glacigenic Formation which may correlate with the Lowestoft Formation of East Anglia (Anglian/Elsterian) (Sumbler, p.37 in Bowen, 1999).

With the exception of some long temporal successions known from Lake Baikal, Columbia, Greece and Italy, the Quaternary onshore record is incomplete. Thus, in addition to correlation with the British and NW European stages, inferred land–sea correlations are also tentatively proposed using the marine isotope stratigraphical scale derived from ocean sediments (Gordon and Sutherland, 1993a; Bowen, 1999). The oxygen isotope stratigraphical framework (strictly not a chronostratigraphical scale) was developed from the analysis of calcareous microfossils preserved in deep ocean floor marine sediments. In this report reference is made to the marine isotope stages from the record of cores V28-238 and Ocean Deep Drilling Project 667 (Shackleton and Opdyke, 1973; Shackleton et al., 1990; Bowen, 1999) (Table 1b).

Marine isotope stages ($\delta^{18}O$ stages, which are designated in a numerical scheme) provide a universal means of subdividing the Quaternary (Emiliani, 1954; Shackleton and Opdyke, 1973). The changing microfaunal assemblages preserve a record of fluctuating oceanic water temperature and the relative proportions of the two common isotopes of oxygen contained in the skeletons provide an indirect record of global ice volume and global sea level (Imbrie et al., 1984; Mix et al., 1995; Clark and Mix, 2002). During glacial periods water is lost from the oceans to form ice-sheets and the oceans become relatively enriched in water containing the heavy isotope of oxygen (18O). The changing ^{18}O content of ocean water can be used as an index of ice-sheet growth and decay although it should be noted that a number of variables (e.g. fluctuating ocean bottom temperatures during the Pleistocene and local hydrological effects) mean that the index cannot be directly related to ice volume as once thought by Shackleton and Opdyke (1973).

The correlation of $\delta^{18}O$ stages to informal climatic events (e.g. interglacials) should be undertaken with caution (Shackleton, 2006). The numerical scheme provides inexact 'high' and 'low' ice volume reference points. The duration of an interglacial, as defined by evidence from onshore Quaternary sequences, may be subject to continued revision. However, evenly numbered $\delta^{18}O$ stages generally refer to cold 'events' and odd numbers to warm 'events' within each global glacial–interglacial cycle. Some $\delta^{18}O$ stages are subdivided: for example, stage 5 is subdivided into 5a–5e (or 5.1 to 5.5, Imbrie et al., 1984). Of these subdivisions 5a, 5c and 5e represent low ice volume events and may be equated with interglacials. Stage 5e is generally accepted to represent a full interglacial and is the approximate equivalent of the Ipswichian (Eemian) climatostratigraphical stage and part of Stage 11 may be correlated with the Hoxnian (Holsteinian) (Table 1b).

2 Principles and definitions

2.1 THE LITHOSTRATIGRAPHICAL CODE AND ITS APPLICATION TO THE QUATERNARY DEPOSITS OF GREAT BRITAIN

Salvador (1994), amplified by Rawson et al. (2002 and references therein) sets out the internationally accepted hierarchy of lithostratigraphical units. The unit-terms are here described in order of rank (Sections 2.1.2–2.1.7).

2.1.1 Naming of lithostratigraphical units

International guidance (Salvador, 1994) recommends that each lithostratigraphical unit should be named after an appropriate geographical feature combined with the appropriate unit-term (e.g. group, formation). To aid the user of the proposed lithostratigraphical framework for Quaternary deposits, especially the non-geologist, it is recommended that both a geographical and a lithological term are included within the unit name (e.g. Clyde Clay Formation). Although the inclusion of a lithological term is discouraged by Salvador (1994), it serves the useful purpose of indicating the dominant component lithology or lithologies. The use of the same geographical term for units of different status (e.g. formation and member) is not recommended except where historical precedent may be an over-riding consideration.

2.1.1.1 Naming of groups and subgroups

One of the distinguishing characteristics of many Quaternary deposits is the rapidity of vertical and lateral changes in lithofacies. Diversity of lithology may constitute a form of unity for bodies of sediment with similar gross depositional characteristics. To highlight this diversity, at the level of group and subgroup (see below), the proposed Quaternary Lithostratigraphical Framework utilises a genetic epithet (e.g. glacigenic, catchments), albeit recognising that genesis is inferred. Whilst this practice is not recommended by Salvador (1994), the proposed nomenclature serves to highlight that the strata are heterolithic superficial deposits that may be readily distinguished from bedrock lithostratigraphical units.

2.1.1.2 Naming of formations and members

For formations it is recommended that lithological descriptors are defined by the dominant grain size (e.g. sand, gravel, silt, clay) or grain size range (e.g. sand and gravel) or lithology (e.g. peat). Morphological descriptors (e.g. moraine) have been used if a landform is considered to be an important attribute, but are generally not recommended. A link may be made between the deposit and the associated landform by referring to the lithogenetic classification and mapping schemes (Chapter 3).

Although genetic epithets for formations should be avoided (Salvador, 1994) the use of the descriptor 'till' is recommended as a useful practical term for the main till sheets (e.g. the Gretna Till Formation). This descriptor is widely accepted across scientific disciplines and is preferred to the term 'diamicton' unless genesis is unclear or controversial (note that not all diamictons are tills). Other lithogenetic terms that have been used previously for formations (e.g. glacigenic, glaciolacustrine, glacial lake, glaciofluvial) are not recommended except where the units are particularly lithologically heterogeneous.

For deposits of fluvial origin it is recommended that formations be geographically named after the principal river valleys (e.g. Severn Valley Formation) or after localities within parts of a catchment for which formation is established (e.g. Maidenhead Formation of the Thames valley). River terrace deposit members may be geographically named or numbered sequentially with reference to the river valley formation name. For terrace surfaces identified by numbers, the first river terrace (First Terrace) is the lowest and youngest. Names may include terms such as 'alluvium' or 'fan' of a named river valley formation. Where correlation is possible between terrace deposits of both a tributary and the principal river these members may be accorded the same name.

2.1.2 Supergroup

2.1.2.1 Definition

A supergroup may be used for several associated groups or for associated formations and groups with significant lithological properties in common (Salvador, 1994).

2.1.2.2 Application

A single supergroup is established for the onshore Quaternary and Neogene (Tertiary) natural superficial deposits of Great Britain and the Isle of Man (Table 1b). A small number of residual and marine superficial deposits of Palaeogene age are also included within the supergroup. The supergroup distinguishes superficial deposits from bedrock.

2.1.3 Group

2.1.3.1 Definition

A group is the formal lithostratigraphical unit next in rank above a formation and is commonly applied to a sequence of contiguous formations with significant diagnostic lithological characteristics (Salvador, 1994).

2.1.3.2 Application

Groups are established for formations of Quaternary and Palaeogene–Neogene (Tertiary) age that reflect the diverse lithologies associated with the principal modes of inferred origin (i.e. coastal/marine, fluvial, glacial and residual). Seven groups are defined (Table 1b).

2.1.4 Subgroup

2.1.4.1 Definition

Salvador (1994) noted that, exceptionally, a group may be divided into subgroups. Rawson et al. (2002) acknowledged that the term subgroup is not in the formal hierarchy but has been usefully employed for subdividing certain groups, for example the Chalk.

2.1.4.2 Application

For Quaternary deposits, subgroups are introduced that are defined on lithological characteristics and geographical extent of component formations (Chapter 3).

Across Great Britain and the Isle of Man a series of catchment subgroups of the Britannia Catchments Group has been defined for fluvial deposits of mid-Pleistocene to Holocene age. The geographical boundaries of the subgroups broadly coincide with physiographic regions defined by modern 'catchment' boundaries (see discussion in Section 2.1.5.3) (Figure 4). The subgroups comprise formations defined by river terrace deposit members, alluvium and associated lithogenetic units. In due course, additional subgroups may be established for the major Scottish island groups (e.g. Shetland, Orkney and the Western Isles; Figure 4). Subgroups of the Dunwich Group have also been defined for pre-Anglian fluvial deposits of the ancestral pre-diversionary Thames and Bytham rivers of southern Britain.

Lying mainly to the north of the Devensian ice-sheet limit (Figure 2), a series of glacigenic subgroups is proposed for formations and lithogenetic units of similar lithology and provenance (Section 3.2.7.1).

2.1.5 Formation

2.1.5.1 Definition

The formation is the primary formal unit of lithostratigraphical classification used to map, describe, and interpret the geology of a region (Salvador, 1994). A formation is generally defined as the smallest mappable unit and has lithological characteristics that distinguish it from adjacent formations (Rawson et al., 2002). However, 'mappability' is a poorly defined criterion, for it depends on the scale of mapping. In Britain, formations should be mappable and readily represented on a 1:50 000 scale map. Component members may be mappable at this scale, but are not necessarily so. In three-dimensional models, scale variations may allow both members and beds to be shown as mappable units.

A formation is defined by a type section (stratotype) or by type area. Where possible, the top and base should be defined but it is recognised that the nature of these boundaries and the bounding deposits may vary laterally. Many Quaternary lithostratigraphical units have no upper boundary defined by an overlying unit because the upper geological surface is the present day land surface. Although Salvador (1994) indicates that formations need not be aggregated into groups, it is here recommended that for Quaternary deposits there is merit in such an approach to aid broad correlation and regional mapping.

2.1.5.2 Application to glacigenic deposits

Formational status may be assigned for any regionally significant mappable unit. The decision to define a unit as a formation commonly rests with the scientist and, as has been demonstrated by Lowe and Walker (1997, fig. 6.2) for glacigenic deposits, this can result in a range of opinions as to the most useful subdivision of units. The key tests include demonstrating type section(s) where the unit top (which may be the land surface) and base can be observed, noting the nature of those boundaries and the lithological and physical characteristics of both the unit and bounding units and tracing lateral continuity, accepting that lateral and vertical lithological variation is likely.

In assessing the definition of formations established in Bowen (1999) it is observed that some include all the superficial deposits of a geographical area (e.g. Clyde Valley Formation of Sutherland in Bowen, 1999). Whilst such units are broadly mappable, a more systematic approach has been adopted in this proposed framework in which significant mappable units are established as formations.

In practice, regionally significant glacigenic units such as till sheets or glaciofluvial sheet deposits may be distinguished as formations. Discontinuous interbedded units may be best assigned member or bed status.

2.1.5.3 Application to fluvial deposits

A single formation is normally considered sufficient to define the fluvial deposits (floodplain alluvium and terrace deposits, which are each defined as members) of a river and its tributaries. However, for drainage basins that have evolved over significant periods of time (e.g. those of the Thames, Trent and Severn) separate formations, defined by terrace deposit members with broadly unified lithostratigraphical characteristics, have been established for both the deposits of the principal river valley and those of tributary valleys. In the case of the Thames, a major river system of Neogene to Quaternary age, Bridgland (2006) has argued the case for assigning formational status to mappable terrace deposits composed of several facets including organic (peat) and lacustrine deposits. However, this report retains member status for terrace deposits (cf. Gibbard, p. 45–58 in Bowen, 1999). Such terrace deposits could be ultimately re-assigned as formations if regional correlation allows. In the current framework, formations of the Thames and its tributaries are established within two groups. The Dunwich Group includes formations of the pre-diversionary river (pre-Anglian). The Britannia Catchments Group (Thames Catchments Subgroup) (Anglian and younger) includes formations of river terrace deposit members within the upper, middle and lower reaches of the main river together with other formations for deposits of major tributary valleys (e.g. the Kennet Valley Formation). Each formation may also include, at member or bed level, interbeds such as peat.

Terrace deposits and alluvium of a present-day river system can be regarded, respectively, as the abandoned and modern parts of the present fluvial system. These deposits can be mapped as members of a river valley formation within a catchments subgroup.

River terrace sequences fall into three categories:

- Terraces representing discrete aggradational events
- Terraces representing multiple incisions of a single (syn- to post-glacial) aggradational event
- A combination of the above

On BGS maps currently no distinction is drawn between discrete aggradational terrace-forming events and the multiple terrace staircases formed by incision and erosion with little or no deposition on the terrace flat. Modern mapping practice would allow truly erosional landforms to be distinguished by form lines only. For recommendations on the mapping, interpretation and classification and of aggradational and erosional terraces see McMillan et al. (2005).

Palaeovalley terrace and 'buried channel' deposits

Terrace deposits of early fluvial systems and 'buried channel' (palaeovalley) deposits may be unrelated to the present day physiography. Where such deposits cannot be correlated with older terrace deposits of present-day valleys it is recommended that they be designated as a separate formation within the Britannia Catchments Group (McMillan et al., 2005).

2.1.5.4 Application to Other Superficial Deposits

Extensive lacustrine deposits, peat and mass movement deposits (e.g. head) may be accorded formation status or merely remain as lithogenetic units within a catchments subgroup or, if related to more than one subgroup, a group

(Section 3.2.5). Similarly, coastal and marine deposits with lateral continuity and lithology may be raised to formational status within a group.

2.1.6 Member

2.1.6.1 Definition

A member is the formal lithostratigraphical unit next in rank below a formation and is always part of a formation (Salvador, 1994). Formations need not be divided either wholly or partially into members. A member may extend from one formation to another (Salvador, 1994).

2.1.6.2 Application

Lithologically distinctive units interbedded within more regionally significant glacigenic formations may be separated as members (cf. Lowe and Walker, 1997). For fluvial deposits, see recommendations under Section 2.1.5.3. For members, grain size descriptors (e.g. sand, gravel, silt) or lithological descriptors (e.g. peat) may be used. For pedostratigraphical units the term 'soil' or 'palaeosol' are recommended.

2.1.7 Bed

A bed is the smallest formal unit in the hierarchy of sedimentary lithostratigraphical units (Salvador, 1994). Bed names are commonly applied to distinctive units that may be thin and laterally restricted or known only from a borehole or single exposure. Some beds may be fossiliferous or yield dateable material (e.g. a soil, peat or bone bed). Bed status tends to be assigned for units with some palaeogeographical, geochronological or specific lithological significance.

2.2 APPLICATION OF THE BGS ROCK CLASSIFICATION SCHEME

2.2.1 Lithogenetic unit

Lithogenetic units are locally mappable assemblages of rock strata, considered without regard to time (Schenck and Muller, 1941; Salvador, 1994). A lithogenetic unit, mappable or otherwise, is defined by its lithology, morphology and inferred mode of origin (genesis). For Great Britain, BGS classifies lithogenetic units according to the BGS Rock Classification Scheme (RCS) for artificial and natural superficial deposits (McMillan and Powell, 1999). The RCS forms the standard for mapping, section and borehole logging and for digital dictionaries and maps (McMillan, 2002). The BGS mapping classification of superficial deposits offers a tried-and-tested method of assigning various attributes to deposits. These include the lithology, morphology, genesis, lithostratigraphy and age of deposit. It is recognised that types of slope (mass movement) deposits (Dines et al., 1940) have been inconsistently mapped and are lithologically poorly known. Unless such deposits can be correlated it is recommended that initially they be assigned only a lithogenetic classification and be informally related to a catchments subgroup or group.

At group and subgroup level the lithostratigraphical framework embraces *all* lithogenetically-defined units, thus enabling a coded lithostratigraphical superscript to be applied to every Quaternary map symbol defined in the BGS Specifications for the preparation of 1:10 000 scale geological maps (Ambrose, 2000). The framework also offers a unique designation for use in digital databases and for digital map production where a strict hierarchy of units is necessary.

3 Lithostratigraphical framework

3.1 INTRODUCTION

The objective of this report is to establish a practical lithostratigraphical framework for Quaternary and Neogene (Tertiary) superficial deposits. To achieve this aim the framework utilises the full hierarchy of lithostratigraphical codes (supergroup, group, subgroup, formation, member and bed). It is concluded that not all deposits (e.g. some surficial mass movement deposits) are capable of being satisfactorily assigned formational status and for these deposits the lithogenetic or morphogenetic classification (McMillan and Powell, 1999) is recommended. However, as noted in Section 2.2.1, all lithogenetic units are assigned to a group. For the BGS framework, the 'top down' approach enables the full classification hierarchy to be employed for complex successions. It also allows traditional morpho-lithogenetic units to be embraced at subgroup and group level on BGS maps where formal lithostratigraphical division has not been attempted. On BGS maps, where formal lithostratigraphical division is possible lithostratigraphical coded superscripts may be added to the standard BGS morpho-lithogenetic symbols (Ambrose, 2000).

The framework establishes a single supergroup, the **Great Britain Superficial Deposits Supergroup**, for the onshore Quaternary and Palaeogene–Neogene (Tertiary) natural superficial deposits of Great Britain and the Isle of Man.

Seven groups are defined (McMillan et al., 2005; McMillan, 2005) (Table 1b, Figure 1):

- **Crag Group:** marine deposits, Pliocene–Pleistocene
- **Dunwich Group:** mainly fluvial deposits of the ancestral Thames and Bytham rivers, early to mid-Pleistocene
- **Residual Deposits Group:** including the Clay-with-flints, Paleocene–Pleistocene
- **British Coastal Deposits Group:** coastal and marine deposits, Pliocene–Holocene, excluding formations of the Crag Group
- **Britannia Catchments Group:** fluvial, organic and mass movement deposits, mid-Pleistocene–Holocene
- **Albion Glacigenic Group:** glacigenic deposits, mid-Pleistocene (pre-Ipswichian)
- **Caledonia Glacigenic Group:** glacigenic deposits, Late Pleistocene (Devensian)

Two of these groups broadly correspond with the event-stratigraphical groups described by Rose (2003). The Crag and Dunwich groups include deposits of Rose's Shallow Marine Systems and Major River Systems, respectively.

It is recognised that in some regions where formations have not been defined, some groups may currently consist solely of lithogenetic units. Such units may be referred to a group. All groups are defined by component formations. Rarely, a formation may stand outside of the group framework. Where appropriate, subgroups defined by formations are established for the groups (currently the Dunwich Group, Britannia Catchments Group, and the two glacigenic groups — see below).

Subgroups, formations and members are listed by group (Tables 2 to 8), and presented in regional correlation charts (Tables 9 to 19) and in alphabetical order (Appendix 2). Superseded terms are shown in Appendix 3. Chapters 4 to 13 describe the lithostratigraphical units region by region. The units are either newly established or have been defined or re-defined on the basis of descriptions in a range of scientific publications including published BGS maps and memoirs and Bowen (1999).

3.1.1 Changes to definitions of formations and members adopted by Bowen (1999)

Particularly in northern Britain some formations established by Bowen (1999) and co-authors are effectively the equivalent of higher level units (e.g. groups) that include all of the superficial deposits occurring in a district. Other formations include only minor elements of the local succession. Nevertheless, many of Bowen's (1999) units, both at formation and member level, have been adopted in the BGS framework with the addition of lithological qualifiers. The status of some members has been changed either to 'formation' where the unit is considered mappable or regionally significant, or to 'bed' where the unit is confined to a single type section. The nomenclature adopted for supergroup, groups and subgroups follows that defined by McMillan (2005) and McMillan et al. (2005).

3.2 GREAT BRITAIN SUPERFICIAL DEPOSITS SUPERGROUP

The supergroup distinguishes superficial deposits from bedrock. Constituent groups and their component units are shown in Tables 1–8. Correlation charts are shown in Tables 9–19.

Name
Great Britain Superficial Deposits Supergroup (GBG) (after McMillan, 2005 and McMillan et al., 2005).

Lithology
The Great Britain Superficial Deposits Supergroup is established for all natural superficial deposits including till (diamicton), sand, gravel, silt, clay and peat.

Formal subdivisions and correlation table
The Great Britain Superficial Deposits Supergroup is subdivided into seven groups (Sections 3.2.1–3.2.7 and Table 1b; Figure 1). Exceptionally, a formation may stand outside a group (e.g. the Castle Eden Fissure-fill Formation).

Type area/Reference section
Great Britain and the Isle of Man. See type areas and sections of component units at group, subgroup, formation, member and bed levels.

Lower and upper boundaries
Generally sharp, unconformable contact with variably weathered bedrock of Neogene (Tertiary) age and older.

The ground surface

Landform description and genetic interpretation
A wide range of landforms from those associated with glacigenic processes to fluvial and marine terraces and planated surfaces.

Thickness
Up to 200 m in onshore Britain.

Distribution and extent
Great Britain (England, Scotland and Wales) and the Isle of Man together with adjacent offshore areas.

Age
Palaeogene–Neogene (Tertiary) to Quaternary.

The focus of this stratigraphical framework report is on superficial deposits of Neogene to Quaternary age. However, the oldest deposits of the **Great Britain Superficial Deposits Supergroup** include the karstic fissure-fill sediments, of Cenozoic and possible latest Mesozoic (Cretaceous) age, that are found on the Durham coast and in the Peak District. These deposits, the Castle Eden Fissure-fill Formation and the Brassington Formation have been assigned formal status but currently remain unattached to a group (Section 9.1). Remanié deposits originating during the Palaeogene including the Clay-with-flints Formation, the Lenham Formation and the Buchan Gravels Formation are assigned to the **Residual Deposits Group** (next section).

Other onshore deposits of Palaeogene age are considered as formal bedrock groups and formations. These units, which will be described in a forthcoming BGS stratigraphical framework report on the Palaeogene, include the Thanet Sand Formation (Paleocene), Lambeth Group (Paleocene), Thames Group (Eocene), Bracklesham Group (Eocene) and Barton Group (Eocene) in south-east England; and the Haldon Gravel Formation (Eocene), Aller Gravel Formation (Eocene), Bovey Formation (Eocene–Oligocene), and the St Agnes Formation (Oligocene) of south-west England.

3.2.1 Residual Deposits Group

The Residual Deposits Group (Tables 1b, 4, 10, 18a, 18b and 19) is established for residual deposits that have undergone modification over lengthy periods during the Cenozoic era (Palaeogene–Neogene, Tertiary) and Quaternary. Included within this group is the **Clay-with-flints Formation**, *a remanié* deposit formed by weathering and solifluction of the original Palaeogene cover and early Quaternary deposits and dissolution of the underlying Chalk of Southern Britain (Pepper, 1973; Catt, 1986; Ellison et al., 2004). Clay-with-flints may be compared with the *argile à silex* of the Paris Basin (Quesnel et al., 2003). These deposits may have resulted primarily from pedogenesis and clay illuviation during interglacials and cryoturbation under periglacial conditions.

The deeply weathered **Buchan Gravels Formation** of north-east Scotland and the **Lenham Formation** of Kent are also assigned to the Residual Deposits Group. The former comprises flint and quartzite remnant gravels have undergone prolonged weathering during the Pliocene (Neogene) (Merritt et al., 2003).

Name
Residual Deposits Group (RESID) (after McMillan, 2005 and McMillan et al., 2005).

Lithology
Typical deposits include the Clay-with-flints Formation of southern Britain and the Buchan Gravels Formation of north-eastern Scotland. Clay-with-flints lithologies include reddish brown clay with large unworn flint cobbles, yellow fine- to medium-grained sand, reddish brown clayey silt and sandy clay. Buchan Gravels lithologies include well-rounded gravel and cobbles of quartzite and flint with sand, silt and kaolinitic clay.

Formal subdivisions and correlation table
Subdivided into the Clay-with-flints Formation, Lenham Formation and Buchan Gravels Formation. Tables 1b, 4, 10, 18a, 18b and 19.

Type area/Reference section
Type area: In southern Britain, the type area of the Clay-with-flints coincides with the outcrop of the Chalk (Cretaceous) over the North Downs, the Chiltern Hills and as far west as Somerset and Dorset.

Type areas
In north-east Scotland, the type areas of the Buchan Gravels Formation are the Buchan Ridge and Windyhills, west of Peterhead.

Lower and upper boundaries
Irregular and unconformable contact with bedrock of Neogene (Tertiary) age or older. In the case of Clay-with-flints, dissolution of underlying chalk has resulted in local development of pipes and hollows that are infilled with the residual deposits.

Generally the ground surface or overlain unconformably by Quaternary deposits.

Landform description and genetic interpretation
Mainly remanié deposits and other units that have undergone dissolution and disturbance, formed by weathering and solifluction of original Palaeogene bedrock and Neogene (Tertiary) to Early Quaternary superficial deposits. Some units may have originated in fluvial, marine or coastal environments.

Thickness
Clay-with-flints Formation: 2–10 m; Buchan Gravels Formation: greater than 25 m.

Distribution and extent
Southern Britain across the Chalk outcrop, northern England and north-eastern Scotland (Buchan) (for grid references see stratotype details).

Age
Palaeogene to Cromerian.

3.2.2 Crag Group

The Crag Group (Tables 1b, 2, 15, 18a and 18b) is established for mainly marine deposits of East Anglia that formed during the Pliocene and Early Pleistocene. The group straddles the currently recommended age of 2.6 Ma for the base of the Quaternary (Gradstein et al., 2004; Aubry et al., 2005; Zalasiewicz et al., 2006).

These deposits lie mainly to the south of the Devensian ice-sheet limit (Figure 2) and their distribution is unrelated to the present-day physiography. The term 'Crag' originates from the descriptions in the 18th and 19th centuries with formations being established in the 20th century (for a review of the literature see Reid, 1890; Funnell and West, 1977; Arthurton et al., 1994; Moorlock et al., 2000a). The name is probably derived from the Celtic word 'cregga', meaning a shell, because shells constitute a large part of some of the beds. The group is defined with reference to stratotypes in Suffolk of the four principal constituent formations recognised in East Anglia (Table 2), namely the **Coralline Crag Formation** (Balson et al., 1993), the **Red Crag Formation** (term first used by Funnell and West, 1977; with members defined from the Aldeburgh–Sizewell transect borehole, Suffolk, Zalasiewicz et al., 1988), a redefined **Norwich Crag Formation** (Chillesford Church Pit, Suffolk, Funnell and West, 1977; Mathers and Zalasiewicz, 1988) and a newly defined **Wroxham Crag Formation** (Hamblin, 2001a; Rose et al., 2001; Moorlock et al., 2002a; to include the marine members of the Cromer Forest Bed series of Funnell and West, 1977). Hamblin et al. (1997) correlated the onshore deposits of the Red Crag Formation with the Westkapelle Ground Formation of the southern North Sea, which contains pollen spectra of Thurnian type (Cameron et al., 1992). Onshore deposits of the redefined Norwich Crag Formation (Antian/Bramertonian–Baventian age) are correlated with the offshore Smith's Knoll Formation (Hamblin et al., 1997). Marine strata that succeed the Baventian regression form the Wroxham Crag Formation (Rose et al., 2001), the oldest part of which (including the Sidestrand Member, formerly of the Norwich Crag Formation) may correlate with the Winterton Shoal Formation offshore (Hamblin et al., 1997).

The **Stanmore Gravel Formation** of the Middle and Lower Thames, thought to be a correlative of the Red Crag Formation, together with the **Well Hill Gravel Formation** (Ellison et al., 2004) are also assigned to the Crag Group.

Name
Crag Group (CRAG) (after Reid, 1890; Funnell and West, 1977; Arthurton et al., 1994; McMillan, 2005 and McMillan et al., 2005).

Lithology
Sands, gravels, silts and clays. The sands are characteristically dark green from glauconite, but weather bright orange with haematite 'iron pans'. The gravels in the lower part of the group are almost entirely composed of flint. Those higher in the group include up to 10% of quartzite from the Midlands, igneous rocks from Wales, and chert from the Upper Greensand of south-eastern England.

Formal subdivisions and correlation table
Subdivided into Coralline Crag Formation, the Red Crag Formation, the Norwich Crag Formation and the Wroxham Crag Formation. The Stanmore Gravel Formation and the Well Hill Gravel Formation (Ellison et al., 2004) are also assigned to the Crag Group (Tables 2, 15, 18a and 18b).

Type area/Reference section
Type area: East Anglia (Hamblin et al., 1997) and deposited on the south-west flank of the North Sea Basin.

Lower and upper boundaries
A sharp, planar unconformity upon strata extending from the Chalk Group (Cretaceous) in the west to the London Clay Formation (Palaeogene) of the Thames Group in the east. Usually there is a glauconitic conglomerate of rounded flints at the base of the Crag Group.

Overlain by deposits of the Dunwich Group, Albion Glacigenic Group, Britannia Catchments Group or British Coastal Deposits Group. Also interdigitates with the Dunwich Group, from which it can be distinguished by the marine origin of the sediments (all Dunwich Group formations are fluvial). May be distinguished from the Albion Glacigenic Group by the absence of northern British erratic clasts in the Crag Group.

Landform description and genetic interpretation
A suite of shallow-water marine and estuarine deposits.

Thickness
Up to 70 m onshore.

Distribution and extent
East Anglia, and extending south-westwards into Hertfordshire.

Age
Pliocene to Pleistocene (MIS pre-103–?17).

3.2.3 Dunwich Group

A new palaeo-catchment Dunwich Group (Tables 1b, 3, 15–18) is established for mainly fluvial sands and gravels of the Ancaster, Bytham and ancestral pre-diversionary Thames rivers, which formed in pre-Anglian time and were overridden by ice of the Anglian glaciation (Figure 2). These deposits lie to the south of the Devensian ice-sheet limit and their distribution is unrelated to the present day catchment physiography. The Dunwich Group also includes some deposits of interfluvial areas such as the 'high level' gravels formerly referred to the 'Pebble Gravel Group' (Pebble Gravel Formation of Gibbard, p. 48 in Bowen, 1999) of southern England (Section 12.3, Tables 18-19). Most of these deposits, being of uncertain origin and age, are currently classified as lithogenetic units although some have formation status. Most of the deposits of the ancestral Thames and Bytham rivers are placed within two subgroups (Section 3.2.3.1), the **Kesgrave Catchment Subgroup** (Kesgrave Group of Whiteman and Rose, 1992; Moorlock et al., 2000a; Northern Drift Formation of Gibbard and Sumbler, p. 47 in Bowen, 1999) and the **Bytham Catchments Subgroup** (Tables 3 and 15–18). The **Kesgrave Catchment Subgroup** includes the **Sudbury** and **Colchester** formations of Whiteman and Rose (1992). The Bytham Catchments Subgroup includes the **Ingham** and **Shouldham** formations of Lewis (1993), the **Bytham Sand and Gravel Formation** of Rose (1994) and the **Baginton Sand and Gravel Formation** of the Proto-Soar (Shotton, 1953). The Dunwich Group also includes the Nettlebed Formation (Rose et al., 2001), the **Caesar's Camp Gravel Formation**, the **Milton Formation**, pedogenic units of Suffolk (Hey, 1965; Rose and Allen, 1977) which overlie the deposits of the two subgroups, the **Letchworth Gravels Formation** of Hertfordshire (Smith and Rose, 1997) and part of the **Cromer Forest-bed Formation** of Funnell and West (1977). The latter is redefined to include only the non-marine members exposed on the Weybourne to Kessingland coast of Suffolk and Norfolk.

Name
Dunwich Group (DUNW) (after Rose et al., 2002, McMillan and Hamblin, 2000, McMillan, 2005, and McMillan et al., 2005)

Lithology
Gravels with subsidiary sands, clays and silts.

Formal subdivisions and correlation table
Subdivided into the Kesgrave Catchment Subgroup and the Bytham Catchments Subgroup. The Nettlebed Formation, Caesar's Camp Gravel Formation, Milton Formation,

Letchworth Gravels Formation and Cromer Forest-bed Formation are also assigned to the Dunwich Group (Tables 1b, 3, 15–18).

Type area/Reference section
Type area: East Anglia (Rose et al., 2001).

Lower and upper boundaries
A sharp planar unconformity, resting on strata on bedrock of Triassic–Palaeogene age or the Crag Group (Pliocene–Pleistocene). Deposits of the Dunwich Group also interdigitate with those of the Crag Group.

Most commonly overlain by deposits of the Albion Glacigenic Group, from which it can be distinguished by the presence of northern-British derived erratics in the Albion Glacigenic Group. It is less commonly overlain by deposits of the Britannia Catchments Group or British Coastal Deposits Group.

Landform description and genetic interpretation
The Group comprises the interpreted fluvial terrace sequences of those rivers that were either destroyed by or, in the case of the Proto-Thames, significantly modified by, the overriding ice-sheets that deposited the Albion Glacigenic Group. The pebble contents of these various gravels can be used to demonstrate the denudation history of the source areas of the sediments. The group can be distinguished from the Crag Group which shows shallow marine to estuarine characteristics.

Thickness
Up to 15 m.

Distribution and extent
The southern limit is taken as the course of the River Thames above its point of diversion, and below that, the southern limit of the Kesgrave Catchment Subgroup; i.e. a line from [SU 770 830] near Marlow to [TM 120 160] near Clacton-on-Sea. There is no northern limit but no deposits are currently identified north of East Anglia and the Midlands. Farther north all such deposits could have been destroyed by the advancing ice responsible for deposition of the Albion Glacigenic Group.

Age
Pliocene to Pleistocene (MIS ?61–13)

3.2.3.1 PALAEO-CATCHMENT SUBGROUPS

The term subgroup was recognised by Salvador (1994) as a formal subdivision of a group, although Rawson et al. (2002), whilst acknowledging its usage, considered it was not in the formal hierarchy. For Quaternary deposits the BGS framework adopts the term subgroup as a useful subdivision enabling geographically sourced sediments to be identified within the overall group hierarchy. The Dunwich Group has been subdivided into two subgroups for fluvial formations of palaeo-catchments of the Early–Middle Pleistocene Bytham and Proto-Soar rivers (Bytham Catchments Subgroup) and the ancestral pre-diversionary River Thames (Kesgrave Catchment Subgroup).

Name
Bytham Catchments Subgroup (BYCA) (after Lewis, 1993 and Rose, 1994).

Lithology
Sands, gravels, clays and organic deposits. Gravels of all contain a high proportion of rounded pebbles of grey and purple 'Bunter' quartzite of Triassic derivation, and pebbles of vein quartz, Jurassic and Cretaceous rocks are locally important constituents.

Formal subdivisions and correlation table
Component formations include the Baginton Sand and Gravel Formation (Proto-Soar, Leicestershire), Bytham Sand and Gravel Formation (pre-Glacial Bytham River, Lincolnshire), Ingham Sand and Gravel Formation (pre-Glacial Bytham River, Central East Anglia) and Shouldham Sand and Gravel Formation (pre-Glacial Bytham River, Norfolk) (Tables 3 and 15–16).

Type area/Reference section
Partial type section: Bytham Sand and Gravel Formation, Thunderbolt Pit, 800 m east of Castle Bytham [SK 998 184] (Lewis, 1993; Rose, 1994).

Lower and upper boundaries
Unconformable on older superficial deposits or on bedrock of Carboniferous to Palaeogene age.

Commonly overlain by Middle Pleistocene glacigenic deposits. Upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of angular clasts, chalk, and poorer sorting in the latter is generally helpful.

Landform description and genetic interpretation
Fluvial, lacustrine and organic deposits. Sedimentary structures indicate that the fluvial deposits were laid down in braided rivers.

Thickness
About 18 m.

Distribution and extent
Deposits of the subgroup follow the courses of the pre-Glacial Proto-Soar and Bytham rivers, from Snitterfield near Stratford-upon-Avon in the west, to Croft and Huncote, Leicester, Castle Bytham and Witham-on-the-Hill, towards the Fen edge south of Bourne, through Shouldham Thorpe, south along the eastern margin of Fens to High Lodge, Mildenhall, along the valleys of the Lark, Little Ouse, and Waveney, to the North Sea coast at Pakefield and Kessingland.

Age
Pleistocene (MIS ?61–13).

Name
Kesgrave Catchment Subgroup (KGCA) (after Kesgrave Group of Whiteman and Rose, 1992 and Moorlock et al., 2000a; Northern Drift Formation of Gibbard and Sumbler, p. 47 in Bowen, 1999).

Lithology
Mainly gravels characterised by quartz and quartzite from the Triassic, Carboniferous and Devonian rocks of the West Midlands, Welsh Borderland and possibly south-western Pennines, and by felsic volcanic rocks from northern Wales. The members comprise bodies of cross-bedded and massive, moderately sorted sand and gravel. The upper part of the gravels that dominate the subgroup are commonly affected by pedogenesis. The Valley Farm Soil is a rubified and clay-enriched horizon affecting the top 1.0–1.5 m and indicating warm interglacial conditions. The Barham Arctic Structure Soil is a complex pedogenic horizon affecting

the topmost 1.0 to 1.5 m of the subgroup and of the Valley Farm Soil (Rose and Allen, 1977; Rose et al., 1985).

Formal subdivisions and correlation table
Subdivided into the Colchester Formation and Sudbury Formation (Tables 3, 15, 17, 18a and 18b).

Type area/Reference section
Type section: Gravel pit at Kesgrave [TM 228 465] (Rose and Allen, 1977)

Lower and upper boundaries
Unconformable on bedrock (Cretaceous–Palaeogene) and Crag Group. The deposits are generally entrenched into bedrock with a difference in surface elevation of at least 5 m. Differentiation from the Crag Group can be difficult where the latter is reworked, and the distinction must be made on the basis of sedimentological structures: the Crag Group is of shallow marine to estuarine origin, the Kesgrave Catchment Subgroup is fluvial.

Commonly overlain by mid-Pleistocene glacigenic deposits. The upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of more angular clasts, chalk, and poorer sorting in the overlying beds is usually helpful. The uppermost 1.0–1.5 m of the subgroup is commonly marked by the pedogenic Valley Farm Soil and/or the Barham Arctic Structure Soil.

Landform description and genetic interpretation
Encompasses fluvial, lacustrine and organic deposits of the pre-diversionary River Thames, and the pre-glacial soils developed on such deposits. Most of the surviving deposits are fluvial gravels, with sedimentary structures indicating deposition by braided rivers. The presence of mega-erratics and glacially-fractured sand grains indicate glacial erosion in the headwater regions of the river. The fluvial gravels occupy terrace levels, and formations and members are defined on the basis of altitude and pebble clast content. Rare lacustrine silts and clays and organic peats are present.

Thickness
About 21.3 m aggregate thickness with individual terrace aggradations typically 5–12 m thick.

Distribution and extent
The subgroup is restricted to the Thames Valley, Essex and Suffolk. BGS 1:50 000 Sheets E206–208, 221–225, 239–242, 255–257.

Age
Pleistocene (MIS ?61–13).

3.2.4 British Coastal Deposits Group

Excluding the deposits of the Crag Group of East Anglia (Section 3.2.2), the British Coastal Deposits Group (Tables 1b, 5, 9–15, 18a and 19) is established for Pliocene and younger gravels, sands and silts of estuarine, marine and beach origin (including beach dune deposits). Peat is also included where it forms a part of coastal sequences. Thin, interbedded fluvial strata may also be included within dominantly marine and estuarine sequences. The defining formations occur at or near the present day coast and within estuaries and also as raised marine and beach units.

The group is defined with reference to established stratotypes of constituent formations. The earliest deposits include remnants of Pliocene marine deposits, not associated with the Crag Group, such as the **St Erth Formation** of Cornwall (Table 19) (Edmonds et al., 1975). Other deposits of marine origin that have been subjected to dissolution and disturbance are assigned to the Residual Deposits Group (Section 3.2.1).

Formations of mid-Pleistocene age and younger include the **Ayre Formation** (Thomas, p. 94 in Bowen, 1999), **Fenland Formation** (after Ventris, 1985), **Nar Clay Formation** (Nar Member of Lewis, p.18 in Bowen, 1999) and, although not yet formalised in the BGS Lexicon, the **West Sussex Coast Formation** (modified after Gibbard and Preece, pp. 61–62 in Bowen, 1999). Late Pleistocene to Holocene formations include the **St Fergus Silt** and **Kessock Bridge Silt formations** of north-east Scotland (Merritt et al., 2003), **Errol Clay, Forth Clay,** and **Carse Clay** formations of east Scotland (modified after Paterson et al., 1981), the **Clyde Clay Formation** of west–central Scotland (modified from Browne and McMillan, 1989), **Glannoventia** and **Hall Carleton** formations of Cumbria (Merritt and Auton, 2000), **Grange-over-Sands, Seacombe Sand** and **Shirdley Hill** Sand formations of Lancashire (after Thomas, pp. 95–96 in Bowen, 1999), **Morston Formation** of East Anglia (Morston Member of Lewis, p. 18 in Bowen, 1999), and **Burtle Formation** of Somerset (Campbell et al., pp. 77–78 in Bowen, 1999). Formal units of solely Holocene age include the **Clydebank Clay** (modified from Browne and McMillan, 1989), **Point of Ayre** (Thomas, p. 94 in Bowen, 1999), **Drigg Point Sand** (Merritt and Auton, 2000), **Lytham** (after Thomas, p. 95 in Bowen, 1999), **Kenfig** (after Bowen, p. 83 in Bowen, 1999), **Ynyslas** (after Bowen, p. 90 in Bowen, 1999), **Breydon** and **North Denes** (Arthurton et al., 1994), **Gwent Levels** (after Bowen, p. 90 in Bowen, 1999), **Oldbury and Avonmouth Levels** (after Welch and Trotter, 1961), and **Somerset Levels** (Campbell et al., pp. 77–78 in Bowen, 1999) formations.

Name
British Coastal Deposits Group (COAS) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Sands, gravels, silts and clays that contain clasts derived from rocks cropping out throughout Great Britain and the Isle of Man. Peat is also included where it forms a part of coastal sequences. The group includes glacio-isostatically uplifted (raised) deposits lying to the north of a hinge-line crossing northern England between the Ribble and Tyne rivers, and isostatically uplifted interglacial shoreline deposits around the coast of southern Britain. Excludes deposits of the Crag Group of East Anglia.

Formal subdivisions and correlation table
The British Coastal Deposits Group is divided into formations (Tables 5, 9–15, 18a and 19).

Type area/Reference section
Type area: The coastline and estuaries of Great Britain and the Isle of Man. See also the stratotypes of constituent formations.

Lower and upper boundaries
Unconformable contact with units of the Britannia Catchments Group, the Caledonia Glacigenic Group, the Albion Glacigenic Group, the Dunwich and/or Crag groups, and bedrock.
Generally the ground surface, but units of this Group commonly interfinger with units of the Britannia Catchments

Group. Raised beaches of Late Devensian age commonly interdigitate with units of the Caledonia Glacigenic Group.

Landform description and genetic interpretation
A suite of near-shore shallow marine, coastal and estuarine deposits including Blown Sand and sediments deposited in deltaic and beach environments. Raised marine and raised beach deposits are included.

Thickness
Up to 80 m.

Distribution and extent
Great Britain (England, Scotland, Wales and the Isle of Man).

Age
Pliocene to Holocene.

3.2.5 Britannia Catchments Group

Excluding the deposits of the Dunwich Group (Section 3.2.3), the Britannia Catchments Group (Tables 1b, 6, 9–19; Figure 4) is established for mid-Pleistocene and younger gravels, sands and silts of fluvial and lacustrine deposits. Aeolian (cover sands and loess) and organic beds (including peat and soils) and mass movement (head) deposits are also included within the group. The term 'Britannia' was referred to by Pliny as an alternative name for 'Albion', i.e. Scotland, England and Wales.

Constituent subgroups (Section 3.2.5.1) are defined with reference to the stratotypes of terrace deposits of principal river valley formations. Separate formations may be established within the Britannia Catchments Group for non-fluvial deposits (e.g. lacustrine deposits, blanket peat) that do not form part of a river valley formation and may extend across catchment boundaries. The Britannia Catchments Group also includes lithogenetic units such as head and other mass movement deposits, which cannot be assigned formal lithostratigraphical status.

Name
Britannia Catchments Group (BCAT) (after McMillan, 2005, and McMillan et al., 2005; includes the catchment groups proposed by McMillan and Hamblin, 2000).

Lithology
Clays, silt, sands, gravels and peat. Gravels are composed of clasts derived from rocks cropping out throughout Great Britain and the Isle of Man.

Formal subdivisions and correlation table
Fluvial deposits and related interbedded organic and lacustrine deposits are assigned formational status within subgroups defined geographically by drainage systems. Other organic, lacustrine and mass movement deposits (e.g. those representing interglacials) are assigned formational status or are defined as lithogenetic units of the Britannia Catchments Group (Tables 1b, 6, 9–19).

Type area/Reference section
Type area: Great Britain and the Isle of Man.

Lower and upper boundaries
Unconformable contact with units of the Albion Glacigenic Group, the Caledonia Glacigenic Group, the Dunwich Group, the Crag Group or bedrock.

Generally the ground surface, but locally units of this group interfinger with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of fluvial, lacustrine, organic, mass movement, periglacial and aeolian deposits. Includes alluvium and river terrace deposits, head, and cover sands.

Thickness
Up to 100 m.

Distribution and extent
Great Britain and the Isle of Man.

Age
Mid-Pleistocene–Holocene (MIS 13–1).

3.2.5.1 Catchment subgroups

Pre-Anglian fluvial deposits of the Ancaster, Bytham and ancestral pre-diversionary Thames rivers are referred to the Dunwich Group and its subgroups (Section 3.2.3).

Catchments subgroups (groups of McMillan and Hamblin, 2000) of the Britannia Catchments Group have been identified geographically and are generally related either to present-day river systems draining to a major estuary (e.g. **Forth Catchments Subgroup**) or to a broad physiographic region drained by several rivers (e.g. **Cumbria–Lancashire Catchments Subgroup, Sussex Catchments Subgroup**) (Tables 6, 9–19; Figure 4; McMillan, 2005; McMillan et al., 2005). Normally each subgroup is defined by Anglian to Holocene fluvial (terrace and alluvial) deposits of one or more river valley formations (Section 2.1.5.3), named after the principal rivers or river valleys within the subgroup area. However where there is evidence to link the successions of earlier palaeo-catchments with those of the present day, the catchment subgroup is so defined. In southern Britain examples include the **Thames Catchments Subgroup**, defined by the **Upper Thames Valley** and **Maidenhead** formations (after Gibbard, pp. 45–58 in Bowen, 1999), the **Trent–Witham Catchments Subgroup**, defined by the **Trent Valley, Bain Valley** and **Soar Valley** formations (after Brandon, p. 41 in Bowen, 1999) and the **Severn and Avon Catchments Subgroup**, defined by the **Severn Valley, Warwickshire Avon Valley** and **Bristol Avon Valley** formations (after Sumbler and Maddy, pp. 34–36 in Bowen, 1999). In northern Britain river valley formations include the **Clyde Valley Formation** (modified from Sutherland, pp. 109–110 in Bowen, 1999, with members originally defined as formations by Browne and McMillan, 1989) of the **Clyde Catchments Subgroup**.

In total, twenty-four subgroups of the Britannia Catchments Group have been defined (Figure 4; Tables 6, 9–19). Detailed descriptions of the subgroups are presented in the regional chapters 4–14. Of these subgroups, the deposits of eleven lie fully to the north of the Devensian ice-sheet limit (Figure 4) and are defined by formations of generally Late Devensian to Holocene age. Six subgroups straddle the Devensian limit, three straddle the Anglian ice-sheet limit, and four lie to the south of this line. In the proximity of, and to the south of Devensian ice-sheet limit, the catchment subgroups comprise formations that range from Anglian to Holocene age. Also included are the earliest, possibly pre-Anglian, terrace deposits of southern England catchments.

3.2.6 Albion Glacigenic Group

The Albion Glacigenic Group comprises all formations and lithogenetic units of pre-Ipswichian age (Tables 1b, 7a–c, 9, 10, 12–18a and 19; Figures 1, 2, 8, 12–13). The term glacigenic is taken to include deposits of glacial, glaciofluvial, glaciolacustrine and proximal glaciomarine origin together with associated periglacial and paraglacial units. The name is derived from the Old English (via Latin) from the Celtic name for Great Britain. The group comprises mainly, *but not exclusively*, the glacigenic deposits between the Anglian and Devensian ice-sheet limits of southern Britain (Figure 2). Deposits of this group are also present locally, both at the surface and as concealed sequences, in Britain within the main Devensian ice-sheet limit (Section 3.2.7.1). In southern Britain, the surface, having been subjected to denudation and weathering over varying lengths of time and under a range of extreme climatic regimes, exhibits a generally subdued morphology. The group may be considered the equivalent of the 'Older Drift' of previous classifications (Wright, 1937). The group is defined with reference to stratotypes of several component formations. These include the **Happisburgh Glacigenic** and **Lowestoft** formations of East Anglia (after Lewis, pp. 11, 15–16 in Bowen, 1999) and, in the English Midlands, the **Wolston** (after Sumbler, p. 37 in Bowen, 1999), **Nurseries Glacigenic** (after Maddy, p. 34 in Bowen, 1999), **Oakwood Glacigenic** (after Worsley, pp. 32–34 in Bowen, 1999) and **Ridgacre** formations (after Maddy and Sumbler, p. 34 in Bowen, 1999).

Name
Albion Glacigenic Group (ALBI) (after McMillan, 2005, and McMillan et al., 2005; includes deposits of the Southern British Glacigenic Group proposed by McMillan and Hamblin, 2000).

Lithology
Tills (diamictons), sands, gravels, silts and clays. Sands and gravels contain clasts derived from rocks cropping out throughout northern, central and eastern England, Scotland and Wales, and offshore.

Formal subdivisions and correlation table
Subdivided into formations south of the Devensian ice-sheet limit and into subgroups north of this limit (Tables 1b, 7a–c, 9, 10, 12–18a and 19).

Type area/Reference section
Type area: The deposits occur mainly between the glacial limits of the Devensian and Anglian ice-sheets. Isolated remnants are present to north of the Devensian glacial limit. See the stratotypes of the constituent formations.

Lower and upper boundaries
Sharp, planar unconformable contact with units of the Dunwich and/or Crag groups, or bedrock.

Ground surface or unconformable contact with units of the Caledonia Glacigenic Group, the Britannia Catchments Group or the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of glacial, glaciofluvial, glaciolacustrine and glaciomarine deposits.

Thickness
Up to 120 m.

Distribution and extent
The whole of Great Britain lying to the north of the Anglian glacial limit crossing southern England, but mainly occurring between the Anglian and Devensian glacial limits.

Age
Cromerian–pre-Ipswichian (MIS 16–6).

3.2.7 Caledonia Glacigenic Group

The Caledonia Glacigenic Group comprises all formations and lithogenetic units of Devensian glacigenic deposits (Tables 1b, 8–15, 17, 18a and 19; Figures 1, 2, 3, 5–18). The name is derived from the Latin name for the Highlands of Scotland, where the principal British ice-sheets originated. The group comprises the glacigenic deposits of Scotland, most of Wales, northern England and parts of the English Midlands. Component formations are mainly distributed across land lying within the main Devensian ice-sheet limit (Figures 2 and 3). Some deposits assigned to the group (e.g. glaciofluvial gravels) may extend beyond the limit. Being the products of the latest glaciations, the deposits commonly have distinct morphological expression and this morphology is commonly an important part of the definition of component formations and their subdivisions. In terms of age, distribution and morphology, the group comprises deposits of the 'Newer Drift' of earlier workers (Wright, 1937).

The group and constituent subgroups (Section 3.2.7.1) are defined with reference to stratotypes of regionally significant till formations and associated formations of glaciofluvial, glaciolacustrine and glaciomarine origin. Defining formations are described from Lincolnshire and from the Cheshire and the Severn Valley in the English Midlands. In Lincolnshire, the **Holderness Formation** (North Sea Coast Glacigenic Subgroup) is a succession of diamicton, gravel, sand, silt and clay with three till members, the *Bridlington* (Basement Till of Catt and Penny, 1966; Catt, 1991), *Skipsea Till* and the *Withernsea* members, all interpreted to be of Devensian age (McCabe and Bowen, pp. 13–14 in Bowen, 1999; Bowen et al., 2002). In Norfolk, two members are recognised, the *Holkham Till* and the *Ringstead Sand and Gravel* members (after Lewis, pp. 18–19 in Bowen, 1999).

In Cheshire, the **Four Ashes Sand and Gravel Formation** (partly Ipswichian and partly Early–Middle Devensian and correlated with MIS 5d–3), of the Britannia Catchments Group, is overlain by the **Stockport Glacigenic Formation** (after Worsley, 1991; Worsley in Bowen, 1999) of the Irish Sea Coast Glacigenic Subgroup. In West Cumbria, regionally important units include the **Maudsyke Till** and **Blengdale Glacigenic** formations (Central Cumbria Glacigenic Subgroup) and **Seascale Glacigenic, Gosforth Glacigenic** and **Aikbank Farm Glacigenic** formations (Merritt and Auton, 2000).

In central Scotland, regionally significant till formations of the Midland Valley Glacigenic Subgroup include the pre-Late Devensian **Baillieston Till Formation** and the **Littlestone Till Formation**, and the Dimlington Stadial (Late Devensian) **Wilderness Till Formation** (Rose et al., 1988; Browne and McMillan, 1989; Jardine et al., 1988). In north-east Scotland, Merritt et al. (2003) have defined the **Whitehills Glacigenic Formation** (here assigned to the Banffshire Coast and Caithness Glacigenic Subgroup), the **Banchory Till Formation** (here assigned to the East Grampian Glacigenic Subgroup) and the **Hatton Till Formation** (here assigned to the Logie-Buchan Glacigenic Subgroup).

Name
Caledonia Glacigenic Group (CALI) (after McMillan, 2005, and McMillan et al., 2005; includes deposits of the Northern British Glacigenic Group proposed by McMillan and Hamblin, 2000).

Lithology
Tills (diamictons), sands, gravels, silts and clays. Sands and gravels contain clasts derived from rocks cropping out

throughout northern England, Scotland and Wales, and offshore.

Formal subdivisions and correlation table
Subdivided into subgroups defined by formations north of the Devensian ice-sheet limit (Tables 1b, 8–15, 17, 18a and 19).

Type area/Reference section
Type area: Great Britain lying to the north and west of the Devensian glacial limit. See also the stratotypes of the constituent subgroups and formations.

Lower and upper boundaries
Sharp, unconformable contact with bedrock or units of the Albion Glacigenic Group.

At the ground surface or at unconformable contact with various units of the Britannia Catchments Group or the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of glacial, glaciofluvial, glaciolacustrine and glaciomarine deposits.

Thickness
Up to 120 m.

Distribution and extent
At the ground surface or at unconformable contact with various units of the Britannia Catchments Group or the British Coastal Deposits Group.

Age
Devensian (MIS 5d–1).

3.2.7.1 Glacigenic subgroups

The term subgroup is not in the formal lithostratigraphical hierarchy (Salvador, 1994) but is here used to distinguish formations of glacigenic origin with broadly similar lithological characteristics and common geographical distribution.

In Scotland, northern England and Wales, north of the Devensian limit, the lithology, and inferred provenance, of glacigenic deposits is strongly influenced by the build-up and decay of regionally distinct sectors of former ice-sheets (e.g. Central Grampians–Rannoch Moor) or ice domes (e.g. Central Cumbria–Lake District). In these areas, it is possible, and potentially useful, to demonstrate lithological similarities of Quaternary sediments of varying age. The Caledonia Glacigenic Group is divided into a series of subgroups that are defined primarily geographically (Figure 2) on the basis of the distribution of mappable formations of till (Figure 3). The till formations are related geographically to the principal areas of ice accumulation and dispersal, but their gross lithological characteristics and provenance is determined by lithologies of the regional bedrock. Each subgroup embraces associated formations of glaciofluvial, glaciolacustrine and glaciomarine deposits. All deposits are placed in the Caledonia Glacigenic Group unless they are known to be older, as has been demonstrated locally in north-east Scotland (Auton et al., 2000; Merritt et al., 2003; Tables 8–10; Figures 6–8).

To maintain a strict hierarchy, within the main Devensian ice-sheet limit known pre-Devensian units are assigned to a set of glacigenic subgroups that mirror those of the Caledonia Glacigenic Group and are identified by the addition of the word 'Albion', e.g. Irish Sea Coast (Albion) Glacigenic Subgroup. It is not presently intended to propose subgroups of the Albion Glacigenic Group south of the Devensian ice-sheet limit because the origin and lithological variation is less clear. However, lithological and palynomorph provenance analysis of Middle Pleistocene tills in East Anglia, reported by Lee et al. (2004) and Hamblin et al. (2005), may offer the potential to extend the subgroup concept into this area. Detailed descriptions of the currently defined subgroups are presented in the regional chapters 4 to 13.

As indicated above, glacigenic subgroups are defined on the basis of lithological characteristics and properties common to two or more till formations. Subgroups assume parental status for formations in areas where they are adopted. There are examples where it is possible to demonstrate interdigitation of formations belonging to different subgroups that are the product of different ice streams during several glaciations (e.g. in north-east Scotland, Figure 5; Auton et al., 2000; Merritt et al., 2003). The complexity of glacigenic sequences may depend on preservation potential associated with the location of a site with respect to the ice-dispersal centre (McMillan et al., 2005, fig. 12; Andrews, 1979; Lowe and Walker, 1997). The thickest and most complex sequences may be preserved at sites that were glaciated for the shortest time.

4 Highlands and Islands of Scotland

The oldest superficial deposits of this district are of residual origin (Residual Deposits Group) and probably date back to the Miocene. Representatives of the two glacigenic groups (Albion Glacigenic Group and Caledonia Glacigenic Group) are present: the most extensive deposits being of Devensian age. Deposits of the Britannia Catchments Group and British Coastal Deposits Group in the region range in age from Devensian to Holocene.

4.1 RESIDUAL DEPOSITS GROUP

4.1.1 Formations of the Residual Deposits Group

Deeply weathered residual deposits of flint and quartzite gravels occur in the Buchan district of Aberdeenshire. They were assigned to two members of the **Buchan Gravels Formation** by Merritt et al. (2003), having been previously named the Pliocene Gravels by Flett and Read (1921), the Buchan Ridge Gravels and Windyhills Gravels by McMillan and Merritt (1980) and Hall (1982, 1984), and the Cruden Flint Gravels and Windyhills Gravels by Kesel and Gemmell (1981). The deposits, which are of probable Miocene to Early Quaternary age, were first described by Christie (1831). Ferguson (1850, 1855) and Jamieson (1865, 1874) deduced that they were beach gravels although Jamieson (1906) subsequently considered them to have been deposited by ice moving south from the Moray Firth. Kesel and Gemmell (1981) and Gemmell and Kesel (1982) favoured a fluvial and glaciofluvial origin for the Cruden Flint Gravels (Buchan Ridge Gravel Member of Merritt et al., 2003) and fluvial origin for Windyhills Gravels; McMillan and Merritt (1980) and Merritt and McMillan (1982) considered the former deposits to be marine (beach) gravels and the latter to be fluvial.

4.1.1.1 Buchan Gravels Formation

Name
Buchan Gravels Formation (BUG) (after McMillan and Merritt, 1980, and Merritt et al., 2003).

Lithology
Well-rounded gravel and cobble gravel comprising white quartzite, vein quartz and flint, in white, micaceous, silty sand matrix or in a white, sandy, kaolinitic clay matrix.

Formal subdivisions and correlation table
Subdivided into the Windy Hills Gravel Member and the Buchan Ridge Gravel Member (Table 10).

Type area/Reference section
Type section (Windy Hills Gravel Member)

Sand and gravel pit section [NJ 7999 3997] near Cottown of Fetterletter, 6.5 km west-north-west of Methlick, and borehole NJ73NE2.

Reference sections (Buchan Ridge Gravel Member): Borehole NK04SW3 [NK 0288 4020] and Borehole NK04SE6 [NK 0594 4144].

Type area: Buchan Ridge [NK 010 390–NK 070 410], 11 km south-west of Peterhead, comprising Moss of Auquharney, Moss of Cruden, Corse of Balloch, Hill of Aldie and Windy Hills, Fyvie.

Lower and upper boundaries
Unconformable on Neoproterozoic rocks, or on the Moreseat Sandstone Formation.

Overlain unconformably by till or head, or at the surface.

Landform description and genetic interpretation
Residual beach and river gravels forming broad ridges and plateaux up to 140 m above OD (McMillan and Merritt, 1980; Merritt et al., 2003).

Thickness
Up to 25 m or more.

Distribution and extent
North-east Scotland.

Age
Miocene–Quaternary
Buchan Ridge Gravel Member (BURG).

The Buchan Ridge Gravel Member comprises at least 25 m of well-rounded cobble gravel composed of flint and white quartzite in a white, sandy, kaolinitic clay matrix. It rests unconformably on bedrock of Devonian or Cretaceous age or on deeply weathered crystalline basement. It is present at ground surface or lies unconformably beneath till or head.

Windy Hills Gravel Member (WING)

The Windy Hills Gravel Member comprises at least 10 m of well-rounded gravel composed of white quartzite and vein quartz in white micaceous, silty sand matrix. It rests unconformably on bedrock of deeply weathered crystalline basement. It is present at ground surface or lies unconformably beneath till or head.

4.2 GLACIGENIC GROUPS AND SUBGROUPS OF THE SCOTTISH HIGHLANDS AND ISLANDS

The most intensive stratigraphical studies of superficial deposits in the Highlands and Islands have been focused in north-east Scotland for which a regional memoir was published (Merritt et al., 2003). The stratigraphical framework for the Inverness area is based on Fletcher et al. (1996), Merritt et al. (1995) and Bowen (1999). Several recently published BGS 1:50 000 sheets adopt elements of the framework for north-east Scotland and Inverness (BGS Sheets S64W, 66E, 67, 76E, 77, 87W, 96W, and 96E). Recent research has extended the application of lithostratigraphy to Caithness and the north-west Highlands. The formal lithostratigraphical units for Caithness are those adopted for the geological mapping that is being currently undertaken, and have been adapted from those proposed by Omand (1973) and Hall and Whittington (1989). The stratigraphical framework for the north-west Highlands is based on Bradwell (2003). Bowen (1999) documents the many lithostratigraphical units for the Northern Highlands and Islands that have been described in the extensive literature.

It has been the practice to relate the glacigenic deposits of north-east Scotland to one of three distinct bodies of ice that existed in the region during past glaciations (Figure 5). Each ice mass gave rise to a distinctive 'series' of deposits and the names are entrenched in the literature (Sutherland, 1984; Hall and Connell, 1991). Ice moving north-eastwards along the east coast led to the deposition of the 'Red Series' (Jamieson, 1906; Synge, 1956), which includes a variety of materials of a typically vivid reddish brown colour. Ice moving eastwards along the Moray Firth impinged on the coastal lowlands and was responsible for laying down a suite of typically dark grey deposits assigned to the 'Blue-grey Series' (Synge, 1956). The typically sandy, yellowish brown diamictons laid down in the interior by ice flowing from the eastern Grampian Highlands were assigned to an 'Inland Series' (Hall, 1984).

The tripartite division was modified by Merritt et al. (2003) who subdivided the 'series' into five 'Drift Groups', with deposits of the 'Red Series' being divided into two groups and the addition of a group for deposits whose provenance is in the Central Highlands. In the present framework the groups are divided into subgroups of either the **Albion Glacigenic Group** for pre-Devensian deposits or the **Caledonia Glacigenic Group** for Devensian deposits (Tables 1b, 7c, 8–10).

Most of the deposits are of Devensian age **(Caledonia Glacigenic Group)**. Pockets of pre-Devensian deposits **(Albion Glacigenic Group)** are preserved at type sections in north-east Scotland, and representatives of this group are also present in the Shetland Islands and possibly in the Western Isles. Precise dating of these deposits is commonly not possible. However, weathering characteristics and the presence of palaeosols aid the interpretation of relative age and some deposits can be tentatively referred to marine isotope stages. Most non-glacigenic materials such as palaeosols and organic beds, which may relate to interglacial stages, are assigned to the Britannia Catchments Group. These units represent important events in the Quaternary geological record in the district. However some periglacial deposits are retained as beds within formations of glacigenic origin, as these units are closely associated with the glacigenic sequence.

The subgroups are defined mainly by the lithology of the constituent formations. Clast composition is the most important attribute in deciding from which ice stream a deposit was derived. Colour remains a useful parameter for general classification of a unit, but it can be misleading locally. The distribution of the glacigenic subgroups in north-east Scotland is shown in Figure 5. The relative positions of the ice streams and lobes changed with time. More than one glaciation may have affected the region. Earlier glaciations probably did not affect exactly the same ground as the more recent. There is consequently local interdigitation of formations belonging to the different subgroups (Tables 9, 10, Figures 5–9).

In north-east Scotland, the 'Blue-grey Series' (Jamieson, 1906; Bremner, 1934; Synge, 1956; Sutherland, 1984; Hall and Connell, 1991; Sutherland and Gordon, 1993) or 'Banffshire Coast Drift Group' (Merritt et al., 2003) is redefined as the **Banffshire Coast and Caithness (Albion) Glacigenic Subgroup** (Section 4.3.3) and the **Banffshire Coast and Caithness Glacigenic Subgroup** (Section 4.4.5). Deposits of these subgroups contain clasts derived from the Moray Firth basin in addition to more locally-occurring rock types. Deposits occur from Inverness eastwards towards Peterhead (Tables 9, 10, Figures 5, 7, 8), within the eastern part of Caithness and Sutherland and across Orkney (Table 9, Figure 9). The diamictons, silts and clays are typically dark grey, calcareous and contain ice-worn Quaternary shell fragments in addition to abundant reworked Early Jurassic–Early Cretaceous microfossils and sporadic macrofossils. Permo-Triassic and Lower Jurassic–Upper Cretaceous strata crop out within the Moray Firth basin. Both clasts and large glacial rafts of these formations are common in the tills of these subgroups. Locally, both the colour and composition of the tills strongly reflect the lithology of the underlying bedrock. The glaciofluvial sands and gravels generally contain similar suites of clasts to the tills, and shell fragments are common. The silts and clays of both glaciolacustrine and glaciomarine origin typically contain abundant reworked Mesozoic and Quaternary microfossils. Information reported by Merritt et al. (2003) indicates that some units described by Bowen (1999) are in fact glacial rafts. On the Banffshire coast at Boyne Bay and Gardenstown it is considered that the Castleton Formation of Bowen (1999) is almost certainly a collection of large glacial rafts and not an *in situ* glaciomarine deposit (Peacock and Merritt, 1997, 2000a). Three members of the Clava Formation of Bowen (1999) (here defined as the Clava Shelly Formation) are also interpreted as rafts (Merritt, 1992).

The 'Inland Series' (Hall, 1984; Hall and Connell, 1991; Sutherland and Gordon, 1993) or **'East Grampian Glacigenic Group'** (Merritt et al., 2003) is redefined as the East Grampian (Albion) Glacigenic Subgroup (Section 4.3.4) and the **East Grampian Glacigenic Subgroup** (Section 4.4.7). These deposits contain clasts derived from the eastern Grampian Highlands (Table 10, Figures 5 and 6). Although erratics from farther afield do occur sporadically, the colour and clast composition of the tills closely reflect the nature of underlying bedrock, or of rocks cropping out within a few kilometres to the west. The tills are generally yellowish brown, sandy, thin (less than 2 m in thickness) and patchy, especially across central Buchan. Thicker and more widespread tills occur in the valleys of the Dee and Don, where colours range from browns to grey. The sandiness and pale colour of the deposits of the **East Grampian Glacigenic Subgroup** in central Buchan commonly give them a weathered appearance, which has suggested that they may result from either a pre-Late Devensian glaciation (Hall, 1984; Sutherland, 1984; Hall and Connell, 1991) or a pre-Devensian one (Synge, 1956). These characteristics are more likely to result from the incorporation of significant proportions of deeply weathered bedrock, which is very common in the area. Furthermore, there is now robust evidence that most of the deposits of the subgroup are of Late Devensian age (Clapperton and Sugden, 1977; Hall and Bent, 1990; Whittington et al., 1998; Merritt et al., 2003).

Part of the 'Red Series' (of Jamieson, 1906), the 'red drift' (Merritt, 1981), the 'Red Series' (Hall, 1984; Hall and Connell, 1991) or 'Logie-Buchan Drift Group' (Merritt et al., 2003), is redefined as the **Logie-Buchan (Albion) Glacigenic Subgroup** (Section 4.3.5) and the **Logie-Buchan Glacigenic Subgroup** (Section 4.4.8). These deposits comprise interbedded clayey diamictons, clays, silts, muds, sands and gravels laid down by ice that moved onshore from the North Sea basin (Tables 7c, 8, 10). Most deposits are typically vivid reddish brown in colour and calcareous. The sands are typically fine- to medium-grained, silty and micaceous, and contain shell fragments. In addition to locally-occurring rock types such as amphibolite, feldspathic psammite, quartzite and meta-wacke, the deposits contain appreciable proportions of rocks derived from the sea bed to the east, including limestone, calcareous siltstone, white and red sandstone of Devonian, Permo-

Triassic, Jurassic, Cretaceous and Palaeocene age. Most of the deposits are restricted to the coastal lowlands north of Aberdeen, east of Ellon and south of Peterhead (Figure 5), where they form distinctive, fresh-looking, hummocky topography comprising kettleholes, mounds, plateaux, esker ridges and narrow, winding, steep-sided valleys.

Reddish brown tills derived entirely from Scottish ice flowing within Strathmore, the north-eastern part of the Midland Valley of Scotland, are referred to the **Mearns Glacigenic Subgroup** (Mearns Drift Group of Merritt et al., 2003) (Section 5.1.1).

Deposits of the **Central Grampian (Albion) Glacigenic Subgroup** (Section 4.3.6) and the **Central Grampian Glacigenic Subgroup** (Section 4.4.6) ('Central Grampian Drift Group' of Merritt et al., 2003) were laid down by ice that radiated from a centre over Rannoch Moor in the western Highlands, carrying rock fragments from the Central Highland Migmatite Complex and Caledonian igneous rocks as well as from more local bedrock. The ice entered north-east Scotland via the Great Glen and the lower reaches of the Nairn, Findhorn and Spey valleys. It merged with the Cairngorm–East Grampians ice-sheet and the more powerful Moray Firth ice stream (Figure 5). The relative power of the merging ice streams varied through time, resulting in the local interdigitation of deposits (Figures 7 and 8).

Additional glacigenic subgroups have been established for deposits of other parts of the Northern Highlands and Islands. Pre-Devensian and Devensian glacigenic deposits around and to the east and north-east of Inverness dominated by Old Red Sandstone rock types (Devonian) are assigned to the **Inverness (Albion) Glacigenic Subgroup** (Section 4.3.2) and the **Inverness Glacigenic Subgroup** (Section 4.4.4) respectively (Table 10, Figure 7). The deposits were laid down by ice that flowed from the Great Glen and north-west Highlands, where it crossed Devonian strata (mainly red sandstones, siltstones and conglomerates). This ice was forced to flow eastwards towards the Elgin area, across high ground, by the more powerful flow of ice emanating from the north-west Highlands. As the latter ice crossed onto Devonian strata it also laid down tills dominated by these rock types.

Ice that flowed outward from the mountains of the Northern Highlands laid down tills and outwash characterised by clasts of crystalline basement rocks (Table 9) (Auton, 2003; Bradwell, 2003). These sediments, assigned here to the **Northwest Highlands Glacigenic Subgroup** (Section 4.4.3), are typically thin (less than 5 m thick), gravelly and pale grey to light brown in colour. Apart from where they occur in western Caithness (Figure 9), much of their outcrop is poorly known and awaits modern re-survey.

Although Devensian glacigenic deposits of local source underlain by organic deposits occur at Sel Ayre [HU 176 540], Walls Peninsula, Shetland Mainland (Mykura and Phemister, 1976; Hall et al., 1993b; Bowen, 1999) formal units have yet to be defined within the **Shetland (Albion) Glacigenic Subgroup** (Section 4.3.1) or the **Shetland Glacigenic Subgroup** (Section 4.4.1) (Table 9). Evidence of easterly-derived Scandinavian ice (Golledge et al., 2008) may also indicate the presence of deposits of the Banffshire Coast and Caithness Glacigenic Subgroup (Section 4.4.5).

Glacigenic and associated marine and organic deposits of the Outer Hebrides and St Kilda are all provisionally assigned to the **Western Isles Glacigenic Subgroup** (Section 4.4.2, Table 9). An Early Devensian age is considered likely for the oldest deposits (Bowen, 1999), although it is possible that some of the earliest deposits could be pre-Ipswichian in age. Glacigenic and organic sediments in cliff sections [NB 448 600] at Sgarbh Sgeir and Toa Galson (Tobha Ghabhsainn) are described by Sutherland and Walker (1984) and Peacock (1984, 1991). Glacigenic and organic deposits of Devensian age are described from Tolsta Head [NB 5572 4682], north-west Lewis, Western Isles (Weymarn and Edwards, 1973; Weymarn 1979; Sutherland et al., 1984, Bowen, 1999). Sutherland (p.106 in Bowen, 1999) refers all the deposits of the Western Isles and St Kilda to the Lewis Formation. Only the **Lewis Till Formation** (Section 4.4.2.1) (Dun Member of Bowen, 1999) has been defined in the BGS Lexicon.

4.3 ALBION GLACIGENIC GROUP

4.3.1 Shetland (Albion) Glacigenic Subgroup

Name
Shetland (Albion) Glacigenic Subgroup (SDAG) (after McMillan et al., 2005)

Lithology
Sandy diamicton (till), sand, gravel, silt and clay. Clasts are derived predominantly from rocks cropping out on the Shetland archipelago.

Formal subdivisions and correlation table
South Wick Till Formation (currently undefined in the BGS Lexicon): Fugla Ness Till, Lower Till of Hall et al. (1993a). See also units of Mykura and Phemister (1976) and South Wick Member (correlated with MIS 12) of the Shetland Formation of Sutherland (p. 106 in Bowen, 1999) (Tables 7c and 9).

Type area/Reference section
Type area: The Shetland archipelago, Foula and Fair Isle. See also the stratotypes of constituent informal formations documented in Bowen (1999).

Lower and upper boundaries
Sharp, unconformable contact with bedrock.

Unconformably overlain by units of the Shetland Glacigenic Subgroup or Holocene deposits, predominantly peat.

Landform description and genetic interpretation
A suite of glacial, glaciofluvial, glaciolacustrine and organic sediments deposited by ice that radiated from an ice divide positioned along the axis of the archipelago.

Thickness
Up to 10 m.

Distribution and extent
The Shetland archipelago, Foula and Fair Isle.

Age
Mid-Pleistocene (MIS 13–6).

4.3.2 Inverness (Albion) Glacigenic Subgroup

Name
Inverness (Albion) Glacigenic Subgroup (IAG) (after McMillan et al., 2005).

Lithology
Sandy diamictons (till), sand, gravel, silt and clay. Clasts are derived predominantly from the comminution of Devonian (Old Red Sandstone) sandstone, siltstone and conglomerate.

Formal subdivisions and correlation table
Sections 4.3.2.1–4.3.2.4 and Tables 7c and 10.

Type area/Reference section
Type area: See the stratotypes of constituent formations, including the Cassie Till, Drummore Gravel, Craig an Daimh Gravel and Suidheig Till.

Lower and upper boundaries
Sharp, unconformable, uneven contact with bedrock.

Ground surface or unconformably overlain by various units of the Inverness Glacigenic Subgroup or other subgroups.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial, glaciolacustrine and glaciomarine deposits.

Thickness
Up to 10 m.

Distribution and extent
The hinterland of the Moray Firth, including the north-eastern end of the Great Glen, the southern shores of the Moray Firth as far east as Buckie, the Black Isle and the land surrounding the Cromarty and Dornoch firths.

Age
Mid-Pleistocene (MIS 13–6).

4.3.2.1 Cassie Till Formation

Name
Cassie Till Formation (CASS) (after Horne et al., 1894; Cassie Till of Merritt, 1992; Cassie Member of Clava Formation of Sutherland, p. 103 in Bowen, 1999).

Lithology
Yellowish brown, sandy clayey diamicton.

Formal subdivisions and correlation table
No subdivisions (Table 9).

Type area/Reference section
Type section: Boreholes 1 and 3 of Horne et al. (1894), drilled in the vicinity of the type section of the Clava Shelly Clay Formation. Boreholes at site of the 'Main Pit' of Horne et al. (1894). Section NH74SE E5 [NH 7656 4411] of BGS Standard map NH74SE.

Lower and upper boundaries
Unconformable on bedrock.

Sharp contact with overlying Drummore Gravel Formation.

Landform description and genetic interpretation
Glacigenic deposit presumed to be a lodgement till.

Thickness
6.6 m.

Distribution and extent
Drummore of Clava, Strath Nairn (BGS 1:50 000 Sheet S84W, Fortrose).

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.2.2 Drummore Gravel Formation

Name
Drummore Gravel Formation (DRGR) (after Horne et al., 1894; Peacock, 1975a; Merritt, 1990, 1992; Drummore Member of Clava Formation of Sutherland, p. 103 in Bowen, 1999).

Lithology
Clayey, sandy, gravelly diamicton containing abundant clasts of sandstone. Distinctly weathered.

Formal subdivisions and correlation table
No subdivisions (Table 9).

Type area/Reference section
Partial type section: 'Main Pit' composite section of Horne et al. (1894), including their Boreholes 1 and 3. Section in former clay pit by Cassie Burn, excavated by Horne et al. (1894). Section NH74SE E5 [NH 7656 4411] on BGS Standard map NH74SE.

Partial type section: River cliff of Finglack Burn. Section NH74SE E1 on BGS Standard map NH74SE. 'Finglack Section' [NH 7688 7422] of Merritt (1990).

Lower and upper boundaries
Sharp, with Cassie Till Formation.

Unconformable, glaciotectonic, with Clava Lodge Clay Member of the Clava Shelly Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
4.6 m.

Distribution and extent
Drummore of Clava, Strath Nairn (BGS 1:50 000 Sheet S84W, Fortrose).

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.2.3 Suidheig Till Formation

Name
Suidheig Till Formation (SUTI) (Dearg Till Formation of Walker et al., 1992; Dearg Member of Dalcharn Formation of Sutherland, p.103 in Bowen, 1999).

Lithology
Stony sandy clayey diamicton, matrix-supported, moderate yellowish brown, extremely compact, containing clasts of Devonian sandstone and siltstone with some psammite, granite and schist. Many clasts are decomposed, especially pelitic rocks and granite, with orange weathering rinds.

Formal subdivisions and correlation table
No subdivisions (Table 10).

Type area/Reference section
Type section: Exposed at the base of a river cliff of the Allt Odhar, immediately upstream of its confluence with the Caochan nan Suidheig, Moy Estate, 16 km south-east of Inverness [NH 7980 3680].

Reference section: River cliff sections of the Allt Dearg, 6 km south-west of Cawdor, Nairnshire. Basal unit of the Dalchard East section of Walker et al. (1992) at the Dalcharn Interglacial site [NH 815 452–NH 816 454].

Lower and upper boundaries
Uneven, unconformable contact with bedrock.

Erosional, undulating, unconformable contact with the Odhar Gravel Bed at the Allt Odhar Interstadial site, the Craig an Daimh Gravel Formation at the Dalcharn Interglacial site, or unconformable planar contact with Athais Till Formation elsewhere.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
2 m.

Distribution and extent
Allt Odhar and Dalcharn, south-east of Inverness (BGS 1:50 000 Sheet S84W, Fortrose).

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.2.4 Craig An Daimh Gravel Formation

Name
Craig an Daimh Gravel Formation (CDGR) (Dalcharn Gravel Formation of Walker et al., 1992; Craig an Daimh Member of Dalcharn Formation of Sutherland, p.103 in Bowen, 1999).

Lithology
Cobble gravel with a sandy, silty, clayey matrix, clast-supported, very dense, containing clasts mainly of Devonian sandstones and siltstones, with some granite and psammite. Strong weathering profile developed with pelitic schist clasts decomposed.

Formal subdivisions and correlation table
No subdivisions (Table 10).

Type area/Reference section
Type section: Exposed near the base of river cliff sections of the Allt Dearg, 6 km south-west of Cawdor, Nairnshire, at the Dalcharn Interglacial site (west) [NH 815 452–NH 816 454].

Lower and upper boundaries
Sharp, undulating, erosional, unconformable contact with stony sandy clayey diamicton of the Suidheig Till Formation.

Gradational contact with white clayey gravel of the Rehiran Cryoturbate Member of the Dalcharn Palaeosol Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
3 m.

Distribution and extent
Allt Odhar and Dalcharn, south-east of Inverness (BGS 1:50 000 Sheet S84W, Fortrose).

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.3 Banffshire Coast and Caithness (Albion) Glacigenic Subgroup

Name
Banffshire Coast and Caithness (Albion) Glacigenic Subgroup (BCAG) (after McMillan et al., 2005; pre-Devensian formations of the Banffshire Coast Drift Group of Merritt et al., 2003).

Lithology
Reddish to dark blue-grey clayey diamictons containing clasts and rafts of Mesozoic rocks derived from the bed of the Moray Firth; also pre-Late Devensian glaciomarine shelly muds.

Formal subdivisions and correlation table
Camp Fauld Till Formation (Merritt et al., 2003) (Tables 7c and 10); Red Burn Till Formation (possibly MIS 8; Red Burn Member of Teindland Formation of Sutherland, p.102 in Bowen, 1999).

Type area/Reference section
Type area: The hinterland of the Moray Firth, including the north-eastern end of the Great Glen, the southern shores of the Moray Firth as far east as Buckie, the Black Isle, the land surrounding the Cromarty and Dornoch firths, Caithness and Orkney.

Lower and upper boundaries
Unconformable on bedrock.

Ground surface or unconformably overlain by deposits of the Caledonia Glacigenic Group.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial, glaciolacustrine and glaciomarine deposits.

Thickness
Up to 10 m.

Distribution and extent
The hinterland of the Moray Firth, Buchan, Caithness and Orkney.

Age
Mid-Pleistocene (MIS 13–6).

4.3.3.1 Camp Fauld Till Formation

Name
Camp Fauld Till Formation (CFTI) (after Merritt et al., 2003, p. 125); Corse of Balloch Member of Camp Fauld Formation of Sutherland, p. 102 in Bowen (1999).

Lithology
Sandy, silty diamicton (till), very stiff, grey to very dark grey, massive to crudely horizontally-bedded, with sparse pebbles. Clast lithologies comprise mainly rounded quartzite and flint, with lesser amounts of subangular grey granite, mafic igneous rocks, red sandstone and soft grey siltstone. The matrix is a micaceous sandy silt and clay; clay mineralogy is largely kaolinite, illite-smectite and minor glauconite.

Formal subdivisions and correlation table
No formal subdivisions but includes the Hardslacks Gelifluctate Bed of Merritt et al., (2003), Tables 7c and 10.

Type area/Reference section
Partial type section: The Camp Fauld site lies on the southern slope of the Moss of Cruden, about 900 m north-west of Moreseat, Buchan [NK 049 410] (Whittington et al., 1993).

Lower and upper boundaries
Sharp, unconformable contact with compressed humified peat and organic sand of the Berryley Peat Bed, where the upper part of the till is mottled (weathered).

The diamicton rests on, locally passes down into, and incorporates rafts of glauconitic Moreseat Sandstone (Lower Cretaceous). The upper part of the till is mottled (weathered) and unconformably overlain by compressed humified peat and organic sand of the Berryley Peat Bed and Moreseat Farm Sand Bed (Moy Burn Palaeosol Formation), which is in sheared glaciotectonic contact with either the Aldie Till Member (Whitehills Glacigenic Formation) or with sand and gravel with stringers of peat passing up into a head deposit named informally as the Hardslacks Gelifluctate Bed, in turn overlain by Aldie Till Member.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
At least 2 m.

Distribution and extent
Moss of Cruden, Buchan.

Age
Mid-Pleistocene (possibly MIS 6).

4.3.3.2 Red Burn Till Formation

Name
Red Burn Till Formation (RDBRN) (after Merritt et al., 2003, p.126).

Lithology
Stiff, reddish brown, massive, matrix-supported sandy, silty, clayey diamicton. Quartzite and psammite clasts are dominant, but the presence of Devonian sandstone and Mesozoic siltstone and sandstone suggests ice movement from the north-west.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: Pipeline trench, since reinstated, located 700 m south-west of Teindland Quarry [NJ 294 568] (Hall et al., 1995a).

Partial type section: Teindland Quarry [NJ 297 570], a small sand and gravel pit, located in Teindland Forest, 5 km south-west of Fochabers, Morayshire (Merritt et al., 2003).

Lower and upper boundaries
Sharp, uneven, unconformable contact with bedrock, locally a gradational unconformable contact with weathered Devonian conglomerate.

At the Red Burn site, the Red Burn Till is overlain unconformably by a unit of sand with sporadic clasts that appears to correlate with the Deanshillock Gravel Formation at the base of the known sequence at Teindland Quarry.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
At least 1.5 m.

Distribution and extent
Morayshire.

Age
Mid-Pleistocene (possibly MIS 6).

4.3.4 East Grampian (Albion) Glacigenic Subgroup

Name
East Grampian (Albion) Glacigenic Subgroup (EGAG) (after McMillan et al., 2005; pre-Devensian formations of the East Grampian Drift Group of Merritt et al., 2003).

Lithology
Sandy diamictons (till), sands, gravels, silts and clays. Clasts are derived predominantly from weathered Neoproterozoic metamorphic rocks (psammite, meta-wacke sandstone, slate) and Caledonian igneous rocks (granite, granodiorite, gabbro).

Formal subdivisions and correlation table
Subdivided into nine formations: Sections 4.3.4.1–4.3.4.9 and Tables 7c and 10.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Sharp, unconformable contact with bedrock.

Unconformably overlain by deposits of the Caledonia Glacigenic Group.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial and glaciolacustrine deposits. Deposited from ice that radiated from the eastern Grampian mountains.

Thickness
Up to 10 m.

Distribution and extent
The east Grampian Highlands, Cairngorm Mountains and Gaick Plateau.

Age
Mid Pleistocene (MIS 13–6).

4.3.4.1 Leys Till Formation

Name
Leys Till Formation (LEYST) (after Merritt et al., 2000, and Merritt et al., 2003, p. 135; Leys Till of Hall and Jarvis, 1993; Leys Member of Kirkhill Formation of Sutherland, p. 99 in Bowen, 1999).

Lithology
Non-calcareous, matrix-supported, gravelly, slightly clayey, silty sand diamicton. Dominantly pale olive-brown and olive-brown (upper interval shows extensive yellowish brown and strong brown mottling). Non-calcareous, matrix-supported, gravelly, slightly clayey, silty sand. Clast types include quartzites, psammitic and pelitic meta-

sedimentary rocks, felsite, mafic igneous rocks and grey granite. The lower intervals contain lenses and small rafts of kaolinised metasedimentary rocks and grussified mafic igneous rocks.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Partial Type section: BGS Trial Pit NK05SW44 in the floor of Leys Quarry (disused) (NK 0047 5234), 6.5 km south-east of Strichen, Buchan, 1–3.5 m depth. Base of unit seen in pit (Hall et al., 1989).

Partial Type section: BGS Trial Pit NK05SW47 in the floor of Leys Quarry (disused) (NK 0037 5230), 6.5 km south-east of Strichen, Buchan, 1.6–3.6 m depth. Top of unit seen in pit (Hall et al., 1989).

Lower and upper boundaries
Trial pits show either sharply unconformable, planar boundary on weathered bedrock or gradational, glaciotectonised boundary (over about 0.4 m) showing incorporation of lenses and small rafts of weathered metasedimentary or mafic igneous rock types.

Trial pits show sharp, planar, erosive upper boundary with overlying felsite-rich gravels of the Leys Gravel Formation (Denend Gravel of Merritt et al., 2003).

Landform description and genetic interpretation
Interpreted as a sub-glacial till.

Thickness
Up to 2.5 m.

Distribution and extent
Buchan, north-east Scotland. This formation is currently known only from within the confines of Leys Quarry (disused) (centred on NK 0040 5250), Sheet Scotland 87W (Ellon). The unit might be regionally significant and present locally across north-east Scotland.

Age
Mid-Pleistocene (possibly MIS 8 or older).

4.3.4.2 Leys Gravel Formation

Name
Leys Gravel Formation (LEY) (Leys Lower Gravel of Kirkhill sequence described by Hall and Connell, 1986; includes the Denend Gravel Formation of Merritt et al., 2003).

Lithology
Gravel, subrounded–rounded, up to boulder-sized clasts, over 90% felsite.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: sections in Leys Sand and Gravel Pit [NK 0029 5228].

Lower and upper boundaries
Unconformable on diamicton of the Leys Till Formation.

Unconformably overlain by rubbly felsitic ‘head’ deposit, named as the ‘Kirkhill Gelifluctate I’ by Hall and Connell (1986).

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
About 5 m.

Distribution and extent
Buchan, north-east Scotland. Sheet Scotland 87W (Ellon).

Age
Mid-Pleistocene (possibly MIS 8 or older).

4.3.4.3 Pitscow Sand and Gravel Formation

Name
Pitscow Sand and Gravel Formation (POWSG) (after Merritt et al., 2000, and Merritt et al., 2003, p. 136; Kirkhill Lower Sand and Gravel of Hall and Connell, 1991; Pitscow Member of Kirkhill Formation of Sutherland, p. 99 in Bowen, 1999).

Lithology
Sand with subsidiary beds of gravel. Dominantly pale olive-brown and pale pinkish brown quartzose and felsitic medium- to coarse-grained sand. Typically horizontally stratified with some planar and trough cross-beds indicating transport towards the west. The gravel component diminishes upwards and is typically of pebble–cobble grade. Angularity varies significantly from rounded–angular. Clast lithologies are dominated by felsite, with smaller quantities of quartzite, psammite, hornfels and red and grey granites.

Formal subdivisions and correlation table
Kirkhill Palaeosol Bed, Kirkton Gelifractate Bed. Tables 7c and 10.

Type area/Reference section
Partial Type Section: East face, Kirkhill Quarry (infilled) [NK 0130 5290], 7 km south-east of Strichen, Buchan, north-east Scotland (Connell et al., 1984).

Partial Type Section: North-east face, Leys Quarry (disused) [NK 0045 5257], 6.5 km south-east of Strichen, Buchan, north-east Scotland (Hall and Jarvis, 1993).

Lower and upper boundaries
In Kirkhill Quarry south-east face A and east face, the base of the unit rests unconformably on unweathered felsite bedrock. In south-east face B the formation in part both overlies and interdigitates with felsitic rubble of the Kirkton Gelifractate Bed. To the south-west at Leys Quarry, north-east face, a sand and gravel body interpreted to be the Pitscow Sand and Gravel Formation unconformably overlies the Leys Gravel Formation. Here the Pitscow Formation rests in a 2 m-deep erosive channel feature.

At both Kirkhill Quarry south-east face A and east face, and Leys Quarry, north-east face, the upper boundary of the unit is a gradational, undulatory boundary with the overlying bleached, podzolic Kirkhill Palaeosol Bed.

Landform description and genetic interpretation
Interpreted as a periglacial fluvial deposit (possibly glaciofluvial in part).

Thickness
Up to 4 m.

Distribution and extent
Buchan, north-east Scotland. The formation is currently

known only within the immediate vicinity of Kirkhill Quarry (infilled) and Leys Quarry (disused) on Sheet Scotland 87W (Ellon). The unit may be regionally significant and present locally across north-east Scotland.

Age
Mid-Pleistocene (MIS 8 or older).

4.3.4.4 West Leys Sand And Gravel Formation

Name
West Leys Sand and Gravel Formation (WLSG) (after Merritt et al., 2000 and Merritt et al., 2003, p. 135).

Lithology
Sandy gravel and gravelly sand, very pale brown–pale brown, pebble–cobble grade, clast-supported with quartzose medium- to coarse-grained sand matrix; locally sand with dispersed pebbles. Clasts are subangular to rounded. Clast lithologies are dominated by psammitic and quartzite metasedimentary rock, with subsidiary felsite, mafic igneous rocks, pelites, red and grey granites and red sandstone. The sediments display tabular cross-beds showing palaeocurrents from the north-west, and crude horizontal bedding.

Formal subdivisions and correlation table
Camphill Gelifluctate Bed, Swineden Sand Bed. Tables 7c and 10.

Type area/Reference section
Type section: North-east face of Leys Quarry (disused) [NK 0045 5257], 6.5 km south-east of Strichen, Buchan, north-east Scotland (Hall and Jarvis, 1993).

Lower and upper boundaries
The lower boundary of this unit is a sharp erosional unconformity on angular gravel of the Camphill Gelifluctate Bed. It represents a discontinuous channel, (up to 1 m in depth) eroded into the underlying deposit.

The upper boundary of the unit is unconformable: a subhorizontal, planar erosion surface at the base of the yellowish brown diamicton of the Rottenhill Till Formation.

Landform description and genetic interpretation
Interpreted as either a proglacial or sub-glacial glaciofluvial sediment.

Thickness
Up to 1 m.

Distribution and extent
Buchan, north-east Scotland. The formation is currently shown only from Leys Quarry (disused) (centred on NK 0040 5250) on Sheet 87W (Ellon). The unit might be regionally significant and present locally across north-east Scotland.

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.4.5 Rottenhill Till Formation

Name
Rottenhill Till Formation (ROTIL) (after Merritt et al., 2000, and Merritt et al., 2003, p. 135; Kirkhill Lower Till of Hall and Connell, 1991; Rottenhill Member of Kirkhill Formation of Sutherland, p. 100 in Bowen, 1999).

Lithology
Diamicton, dominantly yellowish brown, very stiff, non-calcareous, matrix-supported, gravelly, slightly clayey, silty sand. Clast types include pebbles and cobbles of quartzitic, psammitic and pelitic metasedimentary rocks, phyllite/slate, felsite, grey and red granites, basic igneous rocks, red sandstone and red-stained quartzite. Clast fabric indicates glacial transport from the north-west. In the north-west and north-east faces of Leys Quarry (disused) thin beds of deformed and attenuated silty fine–medium-grained sand are present. Interpreted as a sub-glacial till.

Formal subdivisions and correlation table
Includes the Corsend Gelifluctate Bed. Tables 7c and 10.

Type area/Reference section
Type section: East face, Kirkhill Quarry (infilled), 7 km south-east of Strichen, Buchan [NK 0130 5290] (Connell et al., 1984).

Reference section: North-east face of Leys Quarry (disused), 6.5 km south-east of Strichen, Buchan [NK 0045 5257] (Hall and Jarvis, 1993).

Lower and upper boundaries
In Kirkhill Quarry (infilled) the basal boundary of the unit is a sharp, planar, subhorizontal unconformity. The till rests on units from the Camphill Gelifluctate Bed (CHLGE), the Swineden Sand Bed (SWDEN) and the Kirkhill Palaeosol Bed (KHLPS) down to the Pitscow Sand and Gravel Formation. It is also seen to unconformably overlie unweathered felsite bedrock close to the margins of channels/basins. In Leys Quarry (disused) the till has been observed to have a sharp, planar, subhorizontal, unconformable basal boundary on the West Leys Sand and Gravel Formation and the Camphill Gelifluctate Bed.

In Kirkhill Quarry (infilled) the upper boundary of the unit is a sharp, planar, subhorizontal unconformity overlain by gravelly, sandy, silty diamicton of the Corsend Gelifluctate Bed (CSEND). The uppermost part has undergone pedogenesis to form the Fernieslack Palaeosol Bed (FSLCK). In Leys Quarry (disused) the upper boundary of the unit is a sharp, undulatory unconformity overlain by the Corse Diamicton Member (Whitehills Glacigenic Formation).

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 2.5 m.

Distribution and extent
Buchan, north-east Scotland. The formation is currently known only within the immediate vicinity of Kirkhill Quarry (infilled) and Leys Quarry (disused) on Sheet Scotland 87W (Ellon). The unit may be regionally significant and present locally across north-east Scotland.

Age
Mid-Pleistocene (possibly MIS 6).

4.3.4.6 Bellscamphie Till Formation

Name
Bellscamphie Till Formation (BLTI) (Bellscamphie Lower Till of Hall and Jarvis, 1995 and Merritt et al., 2003; Inland Series Till of Hall, 1984; Elton Member of Bellscamphie Formation of Sutherland, p. 102 in Bowen, 1999).

Lithology
Diamicton, stony, sandy, strong brown or yellowish brown.

Mostly rock types derived a short distance to the north-west. Locally containing flint and quartzite from the Buchan Gravels Formation.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: Railway cutting at Bellscamphie (abandoned) [NK 0184 3368]. Trial pits 7 km east-north-east of Ellon (Hall and Jarvis, 1995).

Reference section: Tillybrex gravel pit (now infilled) [NK 0005 3489], 6 km north-east of Ellon, BGS Section NK03SW1 (Merritt, 1981).

Lower and upper boundaries
Unconformable on bedrock.

Unconformably overlain by the Pitlurg Farm Till Member of the Whitehills Glacigenic Formation or other, younger glacial or glaciofluvial deposits.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
2 m or more.

Distribution and extent
Probably widespread over central Buchan and as pockets to the south and east (beneath Hatton Till Formation).

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.4.7 Tillybrex Sand and Gravel Formation

Name
Tillybrex Sand and Gravel Formation (TBSXG) (after Merritt et al., 2003).

Lithology
A clayey gravel and yellowish brown sand, with subrounded to well-rounded pebbles of psammite, meta-wacke and quartzite, with some gneiss and slate, the latter two rock types being strongly weathered.

Formal subdivisions and correlation table
No subdivisions (see Tables 7c and 10).

Type area/Reference section
Type section: Former Tillybrex gravel pit section [NK 001 347] and BGS-registered borehole NK03SW1 drilled on the quarry floor (Merritt, 1981, Merritt et al., 2003).

Lower and upper boundaries
A sharp, erosional, undulating contact with very compact, yellowish brown sandy clayey diamicton of the Bellscamphie Till Formation, containing clasts of psammite, meta-wacke and quartzite derived from the west.

A sharp, planar, unconformable contact with an unnamed brown till, containing clasts of psammite, meta-wacke and quartzite derived from the west, or with dark grey pebbly clayey diamicton of the Pitlurg Farm Till Member (Whitehills Glacigenic Formation), with sparse erratics and fossils derived from Jurassic strata beneath the Moray Firth to the north-west.

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
12 m.

Distribution and extent
Eastern Aberdeenshire. Sheet Scotland 87W (Ellon).

Age
Mid Pleistocene (possibly MIS 6).

4.3.4.8 Birnie Gravel Formation

Name
Birnie Gravel Formation (BEGR) (after Campbell, 1934, and Auton et al., 2000).

Lithology
Matrix-rich, red-brown, clayey gravel containing cobbles of schistose semipelite, quartzite, psammite and sandstone.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: Stream section of Burn of Benholm [NO 7955 6915], locality B of Campbell (1934).

Reference section: Burn of Benholm stream section (BBS4) [NO 7923 6914]. BGS Section NO76NE8 (Auton et al., 2000).

Lower and upper boundaries
Unconformable on bedrock.

Tectonic or unconformable contact with Mill of Forest Till Formation or Benholm Clay Formation.

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
Up to 3 m.

Distribution and extent
Burn of Benholm and local developments on the Kincardine coast between Inverbervie and Gourdon.

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.4.9 Pishlinn Burn Gravel Formation

Name
Pishlinn Burn Gravel Formation (PIGB) (after Read, 1923; Merritt et al., 2003).

Lithology
Clast- or matrix-supported cobbly gravel with a matrix of silty sand. Clasts are angular to subrounded.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: North side of Castle Hill [NJ 794 640], Gardenstown (Merritt et al., 2003).

Lower and upper boundaries
Overlies bedrock.

Upper limit defined by base of Whitehills Glacigenic Formation or Crovie Till Formation.

Landform description and genetic interpretation
Mass movement or water-lain deposit.

Thickness
Up to 15 m.

Distribution and extent
Portnockie to Troup Head (BGS 1:50 000 Sheet S96E, Ellon).

Age
Mid Pleistocene (possibly MIS 6 or earlier).

4.3.4.10 CROSSBRAE TILL FORMATION

Name
Crossbrae Till Formation (CBTIL) (after Merritt et al., 2000, and Merritt et al., 2003, p. 135; Lower Diamicton of Whittington et al. 1998; Crossbrae Member of Kirkhill Formation of Sutherland, p. 101 in Bowen, 1999).

Lithology
Dominantly brown/dark brown, very stiff, weakly calcareous, matrix-supported, gravelly, slightly clayey, silty sand diamicton. Clast lithologies are dominated by quartzite/psammite and red-brown Devonian sandstones, with less common pelitic/semipelitic metasediments, felsite, grey granite and mafic igneous rocks. Clasts are typically subangular to subrounded (with the pelitic metasedimentary rocks commonly striated). Clast fabrics indicate glacial transport from the north-west.

Formal subdivisions and correlation table
Includes Crossbrae Gelifluctate Bed. Tables 7c and 10.

Type area/Reference section
Partial Type section: Temporary drainage pipe excavation (Site A, pit 1) [NJ 7529 5119], near Crossbrae Farm, 3 km north-east of Turriff, Buchan, north-east Scotland (Whittington et al., 1998).

Partial Type section: Temporary drainage pipe excavation (Site A, pit 2) [NJ 7531 5122], near Crossbrae Farm, 3 km north-east of Turriff, Buchan, north-east Scotland (Whittington et al., 1998).

Lower and upper boundaries
A sharp, planar unconformity on Devonian red-brown pebbly sandstones.

A sharp, planar, subhorizontal surface overlain by periglacial diamicton of the Crossbrae Gelifluctate Bed (CBGEL). The Crossbrae Till Formation is believed to be locally overlain by the Crossbrae Farm Peat Bed (CBFMP).

Landform description and genetic interpretation
Interpreted as a sub-glacial till.

Thickness
Up to 0.7 m observed.

Distribution and extent
Buchan, north-east Scotland. The formation is currently known only from the vicinity of Crossbrae Farm, Turriff (BGS 1:50 000 Sheet S86E). The unit may be regionally significant and present locally across north-east Scotland.

Age
Mid-Pleistocene (possibly MIS 6).

4.3.5 Logie-Buchan (Albion) Glacigenic Subgroup

Name
Logie-Buchan (Albion) Glacigenic Subgroup (LBAG) (after McMillan et al., 2005; pre-Devensian formations of the Logie-Buchan Drift Group of Merritt et al., 2003).

Lithology
Clayey diamictons (till), sand, gravel, silt and clay. Clasts were derived predominantly from off the Aberdeenshire coast (calcareous siltstone, limestone, red sandstone, shell fragments).

Formal subdivisions and correlation table
Comprises one formation: Section 4.3.5.1 and Tables 7c and 10.

Type area/Reference section
Type area: Slains, north-east of Aberdeen [NK 030 310] (Merritt et al., 2003). See also the stratotypes of constituent formations, including Benholm Clay and Auchleuchries Sand and Gravel.

Lower and upper boundaries
Sharp, unconformable contact with bedrock.

Unconformably overlain by units of the Logie-Buchan and East Grampian Glacigenic subgroups.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial and glaciolacustrine deposits. Deposited from ice that pushed onshore from the North Sea Basin.

Thickness
Up to 10 m.

Distribution and extent
Coastal lowland north of Montrose, east of Ellon and south of Peterhead.

Age
Mid-Pleistocene (MIS 13–6).

4.3.5.1 BENHOLM CLAY FORMATION

Unlike the majority of younger units assigned to the Logie-Buchan Glacigenic Subgroup in the Aberdeen area, the **Benholm Clay Formation** of the Stonehaven and Montrose districts (Auton et al., 2000) is grey rather than red in colour (Figure 6). It is calcareous and contains fossils and clasts derived from the North Sea basin.

Name
Benholm Clay Formation (BECL) (after Auton et al., 2000 and Merritt et al., 2003, p. 134; Black Shelly Boulder Clay of Campbell, 1934; High Level Marine Shell Bed of Sutherland, 1981).

Lithology
Dark grey, shelly, silty clay with broken marine bivalve shells and sparse clasts of sandstone, andesite, siltstone and limestone.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: BGS Trial Pit (BBP4); Registered number NO76NE4 [NO 7943 6914].

Reference section: BGS measured section (BBS1), NO76NE5, Burn of Benholm area [NO 7943 6916].

Reference section: Horse Crook stream section [NO 8310 7124].

Lower and upper boundaries
Unconformable on bedrock and conformable or glaciotectonic contact on Birnie Gravel Formation.

Tectonic contacts with Burn of Benholm Peat Bed (BBP) and Mill of Forest Till Formation.

Landform description and genetic interpretation
Glacigenic deposit; a deformation till derived from and including glacially transported rafts of marine sediment (Auton et al., 2000).

Thickness
Greater than 4.6 m.

Distribution and extent
Burn of Benholm area and coastal exposures on Kincardine coast between Inverbervie and St Cyrus.

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.6 Central Grampian (Albion) Glacigenic Subgroup

Name
Central Grampian (Albion) Glacigenic Subgroup (CGAG) (after McMillan et al., 2005; pre-Devensian formations of the Central Grampian Drift Group of Merritt et al., 2003).

Lithology
Sandy diamictons (till), sand, gravel, silt and clay. Clasts are predominantly of micaceous psammite, mica schist, granite and granodiorite.

Formal subdivisions and correlation table
Subdivided into Boyne Craig Till, Ailleag Diamicton, Pattack Till, and Deanshillock Gravel formations; Sections 4.3.6.1–4.3.6.4 and Tables 7c and 10.

Type area/Reference section
Type area: BGS 1:50 000 Sheet S63E (Dalwhinnie). See also the stratotypes of constituent formations, including the Boyne Craig Till and Ailleag Diamicton.

Lower and upper boundaries
Unconformable contact with bedrock.

Unconformably overlain by units of the Central Grampian Glacigenic Subgroup.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial and glaciolacustrine deposits mainly deposited from ice that radiated away from an ice-divide centred over Rannoch Moor.

Thickness
Up to 10 m.

Distribution and extent
The Grampian Highlands bounded by the Great Glen and Moray Firth to the north, the Cairngorms and Gaick Plateau to the east, Strathmore to the south, and including the Inner Hebrides lying to the south of Mull.

Age
Mid-Pleistocene (MIS 13–6).

4.3.6.1 Boyne Craig Till Formation

Name
Boyne Craig Till Formation (BCTI) (after Peacock and Merritt, 2000b; Craig of Boyne Till Formation of Merritt et al., 2003, p. 137).

Lithology
Diamicton: clayey, sandy, gravelly, dark yellowish brown to orangey brown. Containing much decomposed calcsilicate-rock and clasts of quartzite, psammite, gabbro and probable Triassic sandstone.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: Sections in western side of the Boyne Limestone Quarry [NJ 6114 6581–NJ 6135 6604].

Lower and upper boundaries
Unconformable on bedrock.

Conformably overlain by the Whitehills Glacigenic Formation (Banffshire Coast and Caithness Glacigenic Subgroup).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
4.6 m or more.

Distribution and extent
Known only in Boyne Limestone Quarry, Portsoy district.

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.6.2 Ailleag Diamicton Formation

Name
Ailleag Diamicton Formation (AILL) (Ailleag Diamicton Member of Merritt, p.142–143 in Lucas et al., 2004).

Lithology
Compact, very poorly sorted, clast-supported, matrix-rich diamicton formed of angular fragments of weathered psammite (locally granite or porphyry) to boulder size in a yellow-brown or orange, commonly ferruginous, matrix of silty sand.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: River cliff of the Feith Ghorm Ailleag [NN 8029 7984], Gaick Plateau, exposing the full thickness of the unit.

Partial reference section: River cliff of the Feith Ghorm Ailleag [NN 7990 7953], exposing the upper contact and overlying unit.

Lower and upper boundaries
Unconformable, on bedrock.

Sharp, unconformable with the Gaick Plateau Moraine Formation (Central Grampian Glacigenic Subgroup).

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 5 m.

Distribution and extent
Central Grampian Mountains (BGS 1:50 000 Sheet S63E, Dalwhinnie).

Age
Mid-Pleistocene (possibly MIS 6 or 12).

4.3.6.3 Pattack Till Formation

Name
Pattack Till Formation (PATT) (after Merritt, 1999).

Lithology
Gravelly sandy clayey diamicton with angular to rounded clasts of micaceous psammite, grey granite, porphyry and quartzite. Pale olive-brown and slightly weathered.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 10).

Type area/Reference section
Type section: River cliff section 350 m downstream of the confluence of the River Pattack and the Allt Coire nam Plaidean [NN 5478 8273].

Reference section: River cliff section 250–350 m upstream of the confluence of the River Pattack and the Allt Coire nam Plaidean [NN 5475 8221–NN 5478 8206].

Reference section: River cliff section at the confluence of the River Pattack and the Allt Beinn Eilde [NN 5493 8368].

Lower and upper boundaries
Unconformable, on bedrock.

Generally unconformable with the Ardverikie Till Formation, but locally conformable with overlying Linn of Pattack Silt Formation (Central Grampian Glacigenic Subgroup).

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Less than 4 m.

Distribution and extent
Valley of the River Pattack and around the Gaick Plateau (BGS 1:50 000 Sheets S63E, S64E and S64W).

Age
Mid-Pleistocene (possibly MIS 6).

4.3.6.4 Deanshillock Gravel Formation

Name
Deanshillock Gravel Formation (DHKG) (after Merritt et al., 2003, p. 119; Teindland Gravel and Teindland Lower Sand of Hall et al., 1995a; Orbliston and Deanshillock members of the Teindland Formation of Sutherland, p.102 in Bowen, 1999).

Lithology
At Teindland Quarry the Deanshillock Gravel comprises coarse cobble gravel with clasts of quartzite and psammite. It passes upwards into very pale brown sand, the Orbliston Sand Bed. At the Red Burn site, the Deanshillock Gravel Formation comprises a unit of sand with sporadic clasts.

Formal subdivisions and correlation table
Informal Orbliston Sand Bed (Table 10).

Type area/Reference section
Type section: Teindland Quarry, a small sand and gravel pit, is located in Teindland Forest, 5 km south-west of Fochabers, Morayshire. [NJ 297 570] (Merritt et al., 2003).

Partial reference section: Pipeline trench, since reinstated, located 700 m south-west of Teindland Quarry [NJ 294 568] (Hall et al., 1995a).

Lower and upper boundaries
Unconformable on diamicton of the Red Burn Till Formation At Teindland Quarry, the pale brown sand of the Orbliston Sand Bed is overlain unconformably by bleached sand at the base of the Teindland Palaeosol Formation. At the Red Burn site, the upper contact of the Deanshillock Gravel Formation is gradational with overlying bleached, silty, sandy gravel at the base of the Teindland Palaeosol Formation.

Landform description and genetic interpretation
The Deanshillock Gravel and Orbliston Sand Bed are of probable glaciofluvial origin.

Thickness
6.5 m or more.

Distribution and extent
Morayshire.

Age
Mid-Pleistocene. The Deanshillock Gravel and Orbliston Sand Bed, together with the underlying Red Burn Till Formation, probably date from MIS 6.

4.4 CALEDONIA GLACIGENIC GROUP

4.4.1 Shetland Glacigenic Subgroup

Name
Shetland Glacigenic Subgroup (SHETG) (after McMillan et al., 2005).

Lithology
Sandy diamicton (till), sand, gravel, silt and clay. Clasts are derived predominantly from rocks cropping out on the Shetland archipelago.

Formal subdivisions and correlation table
Informal Burrier Wick Till (BWTI) and Sandness Till formations (currently undefined in the BGS Lexicon): see units of Mykura and Phemister (1976), and Burrier Wick and Sandness members of the Shetland Formation of Sutherland (pp. 106–107 in Bowen, 1999) (Tables 8 and 9).

Type area/Reference section
Type area: Shetland archipelago, Foula and Fair Isle.

Lower and upper boundaries
Sharp, unconformable contact with bedrock or with units of the Shetland (Albion) Glacigenic Subgroup.

Ground surface or unconformable contact with various Holocene deposits, predominantly peat.

Landform description and genetic interpretation
A suite of glacial, glaciofluvial and glaciolacustrine sediments deposited by ice that radiated from an ice divide positioned along the axis of the archipelago.

Thickness
Up to 20 m.

Distribution and extent
The Shetland archipelago, Foula and Fair Isle.

Age
Devensian (MIS 5d–2).

4.4.2 Western Isles Glacigenic Subgroup

Name
Western Isles Glacigenic Subgroup (WISG) (after McMillan et al., 2005).

Lithology
Sandy diamicton (till), sand, gravel, silt and clay. Clasts are derived predominantly from Lewisian rocks of the Western Isles.

Formal subdivisions and correlation table
Subdivided into two formations (Tables 8 and 9): Lewis Till Formation (Dun Member of Lewis Formation of Sutherland, p. 106 in Bowen, 1999, and previously Ruaival Drift of Sutherland et al., 1984); and Port Beag Till Formation (Port Beag Member of Lewis Formation of Sutherland, p. 106 in Bowen, 1999).

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Sharp, unconformable contact with bedrock or planar unconformity with units of the Western Isles (Albion) Glacigenic Subgroup.

Ground surface or unconformable contact with various Holocene deposits, predominantly peat.

Landform description and genetic interpretation
A suite of glacial, glaciofluvial and glaciolacustrine sediments deposited by ice that mainly radiated outwards from an ice divide positioned along the western seaboard of the Western Isles archipelago.

Thickness
Up to 20 m.

Distribution and extent
The Western Isles archipelago (Western Isles and St Kilda).

Age
Devensian (MIS 5d–2).

4.4.2.1 Lewis Till Formation

Name
Lewis Till Formation (LEWTI) (Includes, on St Kilda, the Dun Member of Lewis Formation of Sutherland, p. 106 in Bowen, 1999, and previously Ruaival Drift of Sutherland et al., 1984).

Lithology
Compact greyish brown, matrix-supported diamicton with cobble to boulder-sized subangular clasts mainly of Lewisian gneiss lithologies in a silty sand matrix. Generally becomes more gravelly towards the base, with angular clasts, and interstratified with sand in the uppermost metre or so, where boulders up to 2 m in diameter are common. Forms gently undulating sheets.

Formal subdivisions and correlation table
Currently no subdivisions (Tables 8 and 9).

Type area/Reference section
Type section: Sea cliff section at the head of Holm Bay, Holm [NB 453 307], 4 km south-east of Stornoway, Isle of Lewis (Peacock, 1991).

Lower and upper boundaries
Rests on broken or striated rock surface.

Generally capped by peat or alluvial deposits. Unconformably overlain by brown, matrix-supported, clast-rich diamicton of the Ruaival Diamicton Formation (Head) on St Kilda (Sutherland et al., 1984).

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 6 m.

Distribution and extent
The Western Isles archipelago (Western Isles and St Kilda).

Age
Devensian (possibly MIS 4).

4.4.2.2 Port Beag Till Formation

Name
Port Beag Till Formation (PBTI) (after Weymarn and Edwards, 1973; Port Beag Member of Lewis Formation of Sutherland, p. 106 in Bowen, 1999).

Lithology
Reddish brown, matrix-supported diamicton with a notable proportion of clasts of Torridonian sandstone and, at the type section, blocks of the underlying organic sand and silt. Generally occurs as an interbedded and locally glaciotectonically deformed sequence of shelly diamicton, silt, sand and gravel.

Formal subdivisions and correlation table
Currently no subdivisions (Tables 8 and 9).

Type area/Reference section
Type section: Cliff top section at Port Beag on the southern side of the Tolsta Head peninsula [NB 557 468], Isle of Lewis (Gordon and Sutherland, 1993b).

Lower and upper boundaries
Irregular, unconformable contact with underlying deposits

of organic sand and silt belonging to the mid-Devensian Tolsta Head Member of the Lewis Formation of Sutherland (p. 106 in Bowen, 1999).

Ground surface or unconformably overlain by glaciofluvial sand and gravel.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 25 m.

Distribution and extent
Northern Lewis, north-east of a prominent lateral moraine.

Age
Devensian (MIS 2).

4.4.3 Northwest Highlands Glacigenic Subgroup

Name
Northwest Highlands Glacigenic Subgroup (NWHG) (after McMillan et al., 2005).

Lithology
Sandy diamictons (till), sand, gravel, silt and clay. Clasts are derived predominantly from Lewisian, Torridonian, Cambrian, Caledonian igneous and Moine psammitic rocks of the Northern Highlands.

Formal subdivisions and correlation table
Subdivided into Dunbeath Till, Reay Burn Till, Loch Broom Till, Assynt Glacigenic and Ullapool Gravel formations: see Sections 4.4.3.1–4.4.3.5 and Tables 8 and 9.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Sharp, unconformable contact with bedrock.

Ground surface or unconformable contact with various Holocene deposits, predominantly peat.

Landform description and genetic interpretation
A suite of glacial, glaciofluvial and glaciolacustrine deposits deposited by ice that radiated outwards from an ice divide positioned inland of the western seaboard of the Northern Highlands.

Thickness
Up to 20 m.

Distribution and extent
The north-west Highlands north of the Great Glen, and the Inner Hebrides from Mull northwards, but excluding Caithness, the hinterland of Inverness and the Western Isles.

Age
Devensian (MIS 5d–2).

4.4.3.1 Dunbeath Till Formation

Name
Dunbeath Till Formation (DUTI) (after Omand, 1973 and Hall and Whittington, 1989).

Lithology
Sandy, silty and commonly gritty diamicton, typically pale to dark brown in colour; clasts include Devonian mudstones, sandstones and flagstones, some Caledonian igneous and Moine metamorphic rocks.

Formal subdivisions and correlation table
No subdivisions (Figure 9, Tables 8 and 9).

Type area/Reference section
Type section: Dunbeath Water, about 200 m upstream of the A9T road bridge [ND 158 300].

Reference section: River cliff at Balantrath on Dunbeath Water [ND 146 303].

Lower and upper boundaries
Unconformable on bedrock.

Overlain by the Reisgill Burn Till Formation (Banffshire Coast and Caithness Glacigenic Subgroup), typically the base of the Forse Till Member.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 12 m thick.

Distribution and extent
Caithness and Sutherland north-east of a line between Reay and Berridale (BGS 1:50 000 Sheets S110, 115E and W, 116E and W).

Age
Early Devensian (possibly MIS 4).

4.4.3.2 Reay Burn Till Formation

Name
Reay Burn Till Formation (REBU) (after Reay Till of Omand, 1973; reddish brown ground moraine of Peach and Horne, 1881).

Lithology
Diamicton, clayey and sandy, typically reddish brown to pale yellowish brown, with clasts mainly of Caledonian igneous and Moine metamorphic rocks (Thormaid Till Member) when overlying or near basement outcrops. Where overlying Devonian strata the diamicton contains boulder-sized clasts mainly of Orcadian Devonian sandstones, conglomerates, siltstones and mudstones (Broubster Till Member).

Formal subdivisions and correlation table
Subdivided into the Broubster Till Member and Thormaid Till Member (Figure 9, Tables 8 and 9).

Type area/Reference section
Type section: River cliff on the western side of Reay Burn [NC 960 652], about 50 m upstream of the mouth at Mean High Water Springs, Sandside Beach.

Reference section: Cliff section on the eastern side of Sandside Bay [NC 9686 6576], about 200 m north of the mouth of the Burn of Isauld, BGS Registered Field Locality CA 1409.

Lower and upper boundaries
Unconformable on bedrock.

Unconformably overlain by Holocene strata of Britannia Catchments Group.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 10 m thick.

Distribution and extent
Caithness and Sutherland mainly east of a line between Reay and Berridale (BGS 1: 50 000 Sheets S100, 115E and W).

Age
Late Devensian, Dimlington Stadial (MIS 2).

THORMAID TILL MEMBER (THTI)

The Thormaid Till Member (Figure 9) is a gravelly and sandy diamicton, typically light brown with clasts of predominantly Caledonian igneous and Moine metamorphic rocks (Hall and Whittington, 1989). The unit is up to 5 m thick and rests unconformably on bedrock.

BROUBSTER TILL MEMBER (BRBU)

The Broubster Till Member (Figure 9) is a clayey and sandy diamicton, typically reddish brown to moderate brown, with clasts of Orcadian Devonian sandstones, conglomerates, siltstones and mudstones, some Caledonian igneous and Moine metamorphic rocks. The unit is up to 10 m thick and rests unconformably on bedrock.

4.4.3.3 LOCH BROOM TILL FORMATION

Name
Loch Broom Till Formation (LBTI) (after Stoker et al., 2009).

Lithology
Matrix-supported clay/silt-rich diamicton with strong east-west clast fabric and pervasive shear planes. Clast lithologies include Moine psammite, Eriboll quartzite and Torridon Group sandstone. Becomes increasingly sandstone-dominated with distance west.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 9).

Type area/Reference section
Allt an t-Srathain [NH 1085 9673] (Bradwell and Stoker, 2010).

Lower and upper boundaries
Unconformably overlies bedrock.

Unconformably overlain by members of the Assynt Glacigenic Formation and/or Ullapool Gravel Formation.

Landform description and genetic interpretation
Glacigenic deposit: sub-glacial lodgement till of the Minch palaeo-ice stream.

Thickness
Up to 20 m.

Distribution and extent
Loch Broom and Gruinard Bay, North-west Highlands. Extends offshore.

Age
Mid to Late Devensian, Dimlington Stadial (MIS 3-2).

4.4.3.4 ASSYNT GLACIGENIC FORMATION

Name
Assynt Glacigenic Formation (ASGL) (after Bradwell, 2003; Stoker et al., 2009).

Lithology
Heterogeneous, poor to well-consolidated, red-brown to grey, clast-rich to clast-supported sandy diamicton and interbedded sands and gravels with wide ranging sedimentological properties. Contains a diverse suite of clast lithologies including Lewisian gneiss, Torridon Group sandstone, Eriboll Formation sandstone (quartzite), Moine Supergroup psammite, Durness Group limestone, Canisp porphyry, Borralan syenite and other minor igneous rocks. Deposits range in texture from poorly consolidated, clast-supported (even openwork) gravels to well-consolidated, matrix-rich diamictons with shear planes and aligned macrofabric.

Formal subdivisions and correlation table
Composed of the following geographically distinct members, each representing late-stage glacier oscillations: Allt na h-Airbhe Member (ANHA) (almost exclusively offshore), Allt an t-Srathain Till Member (STTI), Rhiroy Member (RHIR) (after Stoker et al., 2009) and Glen Douchary Member (Bradwell and Stoker 2010) (Tables 8 and 9).

Type area/Reference section
Reference section: (Assynt Glacigenic Formation) Road cutting (gravel pit) on unclassified Achiltibuie road [NC 0470 0412], 400 m north-west of Achduart, Coigach, Wester Ross.

Reference section: (Allt an t-Srathain Till Member) Allt an t-Srathain river bank [NH 1070 9678], 300 m from A835, 2.5 km north-west of Ullapool, Wester Ross.

Reference section: (Rhiroy Member) cutting in moraine, north side of Allt Ardcharnich gorge [NH 1772 8988], 100 m above A835 on east side of Loch Broom.

Reference section: (Glen Douchary Member) cutting in mound [NH 2465 8930], part of hummocky moraine suite, between Alltan Ban and River Douchary, Wester Ross.

Lower and upper boundaries
Unconformable on the Loch Broom Till Formation or bedrock.

Interdigitates with glaciofluvial gravel of the Ullapool Gravel Formation and locally overlain by Holocene deposits, typically peat or fluvial gravel.

Landform description and genetic interpretation
Glacigenic deposit composed mainly of till. The till is typically autochthonous, being largely derived from the underlying bedrock, however it may also contain reworked glaciofluvial and/or morainic deposits of Devensian age or older.

Thickness
Variable, ranges from 0.5–7.8 m (maximum observed thickness).

Distribution and extent
Patchy, discontinuous extent across Wester Ross and western Sutherland, west of the main Highland watershed. Extends offshore.

Age
Late Devensian (MIS 2).

4.4.3.5 Ullapool Gravel Formation

Name
Ullapool Gravel Formation (ULGR) (after Stoker et al., 2009).

Lithology
Clast-supported cobble-grade gravel and sand.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 9).

Type area/Reference section
Type section: Ullapool fan-delta at Ullapool [NH 1284 9461].

Lower and upper boundaries
Interdigitates with members of the Assynt Glacigenic Formation.

Ground surface.

Landform description and genetic interpretation
Glaciofluvial fan, deltaic and outwash deposits relating to former higher sea-levels (+10–20 m above OD).

Thickness
Ullapool fan-delta is up to 45 m thick.

Distribution and extent
Well-developed in the Ullapool district, including the margins of Loch Broom, Loch Kanaird and Little Loch Broom, Ross and Cromarty. Distributed locally along the seaboard of north-west Highlands.

Age
Late Devensian, Windermere Interstadial (MIS 2).

4.4.4 Inverness Glacigenic Subgroup

Name
Inverness Glacigenic Subgroup (INVG) (after McMillan et al., 2005).

Lithology
Sandy diamictons (till), sand, gravel, silt and clay. Clasts are derived predominantly from the comminution of Devonian (Old Red Sandstone) sandstone, siltstone and conglomerate.

Formal subdivisions and correlation table
Subdivided into four formations: Sections 4.4.4.1–4.4.4.4 and Tables 8–10.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Sharp, unconformable, uneven contact with bedrock.

Ground surface or unconformable contact with various Holocene deposits.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial, glaciolacustrine and glaciomarine deposits.

Thickness
Up to 40 m.

Distribution and extent
The hinterland of the Moray Firth, including the north-eastern end of the Great Glen, the southern shores of the Moray Firth as far east as Buckie, the Black Isle, and the land surrounding the Cromarty and Dornoch firths.

Age
Devensian (MIS 5d–2).

4.4.4.1 Red Craig Gravels Formation

Name
Red Craig Gravels Formation (RCGR) (after Fletcher et al., 1996).

Lithology
Gravel, clast-supported but locally matrix-supported with matrix of reddish brown sandy mud. Angular clasts of sandstone and psammite.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 9).

Type area/Reference section
Type section: Cliff immediately to north of Rosemarkie Village (forming base of cliff), Ross and Cromarty [NH 7361 5783].

Type area
Rosemarkie Glen, a deep glacial meltwater channel extending north-westwards from Rosemarkie [NH 7200 5900–NH 7370 5780].

Lower and upper boundaries
Not seen, but probably rests directly on bedrock.

Sharp, gently undulating erosion surface. Overlain by Kincurdy Silts Formation.

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
12 m or more.

Distribution and extent
Confined to Rosemarkie Glen, Rosemarkie, Black Isle.

Age
Early Devensian (MIS 4).

4.4.4.2 Kincurdy Silts Formation

Name
Kincurdy Silts Formation (KSI) (after Fletcher et al., 1996).

Lithology
Thinly interlaminated silt, sandy silt and plastic clay with drop-stones and lenses of diamicton; becoming coarser-grained upwards.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 9).

Type area/Reference section
Type section: Cliff immediately to the north of Rosemarkie Village [NH 7361 5783].

Type area: Rosemarkie Glen, a deep glacial meltwater channel extending north-westwards from Rosemarkie [NH 7200 5900–NH 7370 5780].

Lower and upper boundaries
Sharp, gently undulating erosion surface on Red Craig Gravels Formation below.

Sharp, planar, associated with glaciotectonic shearing at base of overlying (unnamed) till.

Landform description and genetic interpretation
Glaciolacustrine deposits.

Thickness
6.5 m.

Distribution and extent
Confined to Rosemarkie Glen, Rosemarkie, Black Isle.

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.4.3 Finglack Till Formation

Name
Finglack Till Formation (FINT) (after Fletcher et al., 1996).

Lithology
Stiff stony sandy clayey diamicton with predominantly sandstone clasts.

Formal subdivisions and correlation table
Subdivided into the Baddock Till Member in the Ardersier district and the Balmakeith Till Member in the Nairn–Forres district (see Figures 7 and 8 and Tables 8 and 9).

Type area/Reference section
Type section: 'Main Pit' composite section of Horne et al. (1894). River cliff section of Cassie Burn exposure NH74SE E5 [NH 7656 4411] on BGS Standard map NH74SE.

Type section: River cliff of Finglack Burn. Section NH74SE E1 [NH 7688 7422] on Standard map NH74SE. 'Finglack section' of Merritt (1990).

Lower and upper boundaries
Sharp, unconformable, glaciotectonic contact with Clava Shelly Formation or with bedrock.

Sharp contact with glaciofluvial sheet deposits, ice-contact deposits or moundy glacial deposits.

Landform description and genetic interpretation
Glacigenic deposit, lodgement till.

Thickness
8 m or more.

Distribution and extent
Cromarty and Beauly Firths, BGS 1:50 000 Sheet S84W.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Baddock Till Member (BTI)

The Baddock Till Member (Figure 8) is a stony, sandy, stratified clay-rich diamicton, yellowish brown, containing clasts mainly of sandstone. The formation is up to 2 m thick on the Ardersier Peninsula where it rests unconformably on glaciotectonised sands and silts of the Ardersier Silts Formation (Banffshire Coast and Caithness Glacigenic Subgroup, Section 4.4.5.9).

Balamakeith Till Member (BALT)

The Balamakeith Till Member is a firm, sandy and silty diamicton, moderate reddish brown to reddish yellow, with abundant rounded clasts of red-brown Upper Devonian (Nairn Sandstone Formation) sandstone. The formation is up to 3.2 m thick in the Nairn district where it rests unconformably on glaciotectonised pebbly sands of the Ardersier Silts Formation (Banffshire Coast and Caithness Glacigenic Subgroup, Section 4.4.5.9) or on bedrock.

4.4.4.4 Athais Till Formation

Name
Athais Till Formation (ATTI) (Dalcharn Lower Till of Auton et al., 1990; Paraglacial Member and Moy Lower Till Member of Walker et al, 1992, and Fletcher et al., 1996; Kincraig Member and Beinn Bhreac Member of the Allt Odhar Formation of Sutherland, p. 105 in Bowen, 1999).

Lithology
Stony, clayey sand diamicton, matrix-supported, moderate brown to yellowish brown, extremely compact, containing clasts of Devonian sandstone and siltstone, with some psammite, granite and schist. Many clasts are weathered, with orange weathering rinds. Mainly massive lodgement till, but contains lenses of stratified gravelly, sandy diamicton and bedded sandy gravel. Locally includes a bed of glaciotectonite at the base (Allt Odhar site).

Formal subdivisions and correlation table
No formal subdivisions; includes the Kincraig Paraglacial Bed (Tables 8 and 10).

Type area/Reference section
Principal reference section: Exposed towards the top of a river cliff of the Allt Odhar, immediately upstream of its confluence with the Caochan nan Suidheig, Moy Estate, 16 km south-east of Inverness. The Allt Odhar Interstadial site [NH 798 368].

Reference section: 30 m-high river cliff sections of the Allt Dearg, 6 km south-west of Cawdor, Nairnshire. The Dalcharn Interglacial site [NH 815 452–NH 816 454].

Lower and upper boundaries
Sharp, undulating or planar, glaciotectonic, unconformable contact with white, sandy, organic deposits of the Dalcharn Palaeosol Formation, compressed peat of the Moy Burn Palaeosol Formation, or bedrock.

Either a gradational contact with dark yellowish brown to olive-grey stony sandy clayey diamicton of the overlying Beinn an Uain Till Formation (Central Grampian Glacigenic Subgroup) or a sharp, glaciotectonic boundary with some wedge structures filled by that till.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
10 m.

Distribution and extent
Strath Nairn, south-east of Inverness (BGS 1:50 000 Sheet S84W).

Age
Early Devensian (possibly MIS 4).

4.4.5 Banffshire Coast and Caithness Glacigenic Subgroup

Name
Banffshire Coast and Caithness Glacigenic Subgroup (BCD) (after McMillan et al., 2005; Devensian formations of the Banffshire Coast Drift Group of Merritt et al., 2003).

Lithology
Suite of reddish to dark blue-grey, clayey diamictons containing clasts and rafts of Mesozoic rocks derived from the bed of the Moray Firth, also pre-Late Devensian glaciomarine shelly muds.

Formal subdivisions and correlation table
Subdivided into ten formations: Sections 4.4.5.1–4.4.5.10 and Tables 8–10.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock or units of the Banffshire Coast and Caithness (Albion) Glacigenic Subgroup.

Extends to the surface or buried by Late-glacial–postglacial deposits.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
30 m or more.

Distribution and extent
Southern coast of Moray Firth from Elgin to Peterhead, Caithness and Orkney.

Age
Devensian (MIS 5d–2).

4.4.5.1 Clava Shelly Formation

Name
Clava Shelly Formation (CLSH) (after Horne et al., 1894; Peacock, 1975a; Merritt, 1992).

Lithology
Diamicton, olive-grey, very stiff, fissile, with sparse shell material and silty sand.

Formal subdivisions and correlation table
Subdivided into the Dalroy Sand, Clava Lodge Clay and Culdoich Till members (after members of the Clava Formation of Sutherland, p. 103 in Bowen, 1999) (Tables 8 and 9).

Type area/Reference section
Type section: Section in former clay pit by Cassie Burn; boreholes 1 and 3 of Horne et al. (1894). Section NH74SE E5 [NH 7656 4411] on BGS Standard map NH74SE.

Reference section: River cliff section of Cassie Burn. Section NH74SE E9 [NH 7638 4371] on BGS Standard map NH74SE (Peacock, 1975a).

Lower and upper boundaries
Unconformable, glaciotectonic boundary of the Clava Lodge Clay Member of the Clava Shelly Formation with the Drummore Gravel Formation of the Inverness (Albion) Glacigenic Subgroup.

Unconformable, glaciotectonic boundary with Finglack Till Formation (Inverness Glacigenic Subgroup).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
11 m at type section.

Distribution and extent
Drummore of Clava, Strath Nairn (BGS 1:50 000 Sheet S84W).

Age
Middle Devensian (MIS 3).

Dalroy Sand Member (DROY)

The Dalroy Sand Member comprises up to 6 m of silty fine- to medium-grained, micaceous sand, containing graded beds and sparse drop-stones. Typically the unit is glaciotectonised.

Culdoich Till Member (CUTI)

The Culdoich Till Member comprises 2.5 m of pebbly silty clayey diamicton containing shell fragments of high-boreal to low-arctic aspect. Clasts are typically well-rounded and of high sphericity. The formation has a sharp, unconformable or glaciotectonic boundary with either the Cassie Till Formation or bedrock.

Clava Lodge Clay Member (CLOCL)

The Clava Lodge Clay Member comprises up to 5 m of silty clay with sparse well-rounded, high sphericity pebbles of psammite and quartzite, containing in situ high-boreal shells/microfauna. It rests with a sharp, unconformable contact on the Drummore Gravel Formation.

4.4.5.2 Howe Of Byth Gravel Formation

Name
Howe of Byth Gravel Formation (HOBGR) (after Merritt et al., 2000, and Merritt et al., 2003; Byth Gravel of Hall et al., 1995a; Howe Member of Kirkhill Formation of Sutherland, p. 101 in Bowen, 1999).

Lithology
Gravel with subsidiary beds of diamicton and sand. Typically brown to dark brown and olive-grey. Dominantly clast-supported with a medium- to coarse-grained quartzose sand matrix. Clasts are subrounded or rounded and composed mainly of quartzite (probably reworked from Devonian conglomerates) with sparse metasedimentary rock, granites and grey and black mudstones of possible Mesozoic age. Red sandstone clasts are present in the lowest part of the formation where it directly overlies Devonian red sandstone bedrock. The gravels are crudely horizontally-bedded and interbeds of sand show both horizontal stratification and local planar cross-bedding. Both gravels and sands display locally strong staining and cementation by Fe and Mn. Palaeocurrent measurements from cross-beds and imbricate clasts is towards the south. Common medium beds of yellowish brown gravelly, silty, sandy diamicton are present and are interpreted as debris flow deposits. The upper 1–2 m of the deposit display crude involutions and erected clast fabric indicating disruption by periglacial soil processes.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: North face (as at May 2002) of Howe of Byth Quarry [NJ 8381 5768], 18 km south-west of Fraserburgh, Buchan, north-east Scotland (Hall et al., 1995a).

Lower and upper boundaries
In the most recent exposures in Howe of Byth Quarry the lower boundary of the unit was a sharp, locally channelled, unconformity on weathered Devonian red sandstone.

The upper boundary of the formation is a sharp, planar, sub-horizontal, unconformity overlain by reddish brown diamicton of the Byth Till Formation (East Grampian Glacigenic Subgroup).

Landform description and genetic interpretation
Interpreted as glaciofluvial outwash and debris flow deposits.

Thickness
Up to 13 m.

Distribution and extent
The formation is currently known only from the vicinity of the Howe of Byth Quarry, Buchan, on Sheet Scotland 97 (Fraserburgh). The unit might be of regional significance and present locally across north-east Scotland.

Age
Late Devensian, possibly mid-Devensian (MIS 3).

4.4.5.3 Reisgill Burn Till Formation

Name
Reisgill Burn Till Formation (REDR) (after Lybster Formation (in part) of Hall and Whittington, 1989; Shelly Boulder Clay of Crampton and Carruthers, 1914; Caithness Shelly Drift of Sissons, 1967; Lybster Till of Omand, 1973; Shelly Till of Johnstone and Mykura, 1989). Note that the partially synonymous term Lybster Formation (Hall and Whittington, 1989) was previously used by the BGS for Middle Devonian strata (Lybster Flagstone Formation).

Lithology
Dominantly calcareous glacial diamicton containing clasts of Orcadian Devonian rocks, Mesozoic erratics and Quaternary shells.

Formal subdivisions and correlation table
To date only one member, the Forse Till Member, has been recognised (Hall and Whittington, 1989) (Tables 8 and 9).

Type area/Reference section
Type area: Sections in the Reisgill Burn, inland of Lybster, Caithness.
Type Section: Stream section at Ellanmore, Reisgill Burn (Hall and Whittington, 1989).

Lower and upper boundaries
Unconformable on bedrock or on the Dunbeath Till Formation.

Taken at the base of overlying Holocene strata.

Landform description and genetic interpretation
Glacigenic deposits. Hall and Whittington (1989) included late-glacial peats and gelifluctates, but here only glacial sediments are included in the Reisgill Burn Till Formation.

Thickness
Up to 25 m.

Distribution and extent
Caithness and Sutherland north-east of a line between Reay and Berridale (BGS 1:50 000 Sheets S110, 115E and W, 116 E and W).

Age
Late Devensian, Dimlington Stadial (MIS 2).

Forse Till Member (FOTI)

The Forse Till Member comprises up to 25 m of sandy, silty and clayey diamicton, typically dark grey to olive-grey and grey-brown, often weathered and mottled in the upper parts to orange, brown and yellow. Cobble- and boulder-sized clasts include Devonian flagstones, Jurassic and Lower Cretaceous mudstones, siltstones, sandstones and shell fragments together with Moine metamorphic and Caledonian igneous rocks.

4.4.5.4 Whitehills Glacigenic Formation

Name
Whitehills Glacigenic Formation (WHGL) (after Peacock, 1966, 1971, Peacock and Merritt, 1997, and Merritt et al., 2003).

Lithology
Dark blue-grey clayey till with erratics and rafts of Mesozoic strata, pre-Late Devensian glaciomarine shelly mud, shell fragments and rafts of sand and clay.

Formal subdivisions and correlation table
Subdivided into the Corse Diamicton Member, Pitlurg Farm Till Member, Aldie Till Member and informal Bearnie Till and Anderson Drive Diamicton members (Tables 8 and 10).

Type area/Reference section
Type section: Boyne Limestone Quarry [NJ 614 660].
Reference section: Cliff sections at Castle Hill, Gardenstown [NJ 795 642].

Lower and upper boundaries
On bedrock or overlying the Pishlinn Burn Gravel Bed.

At the surface or, in the Banff–Gardenstown district, overlain by the Kirk Burn Silt Formation or by the Byth Till Formation (East Grampian Glacigenic Subgroup); in Buchan overlain by the Hatton Till Formation (East Grampian Glacigenic Subgroup).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
20 m.

Distribution and extent
Elgin to Ellon.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Corse Diamicton Member (CORSE)

The Corse Diamicton Member (after Merritt et al., 2003; East Leys Till of Hall and Jarvis, 1993; East Leys Member of the Kirkhill Formation of Sutherland, p. 101 in Bowen, 1999) comprises up to 4.7 m of pebbly, clayey, sandy silt diamicton known only from its partial type sections at Kirkhill Quarry [NK 0120 5285], and Leys Quarry [NK 0045 5257], Buchan. Typically the unit is black and dark grey, weakly calcareous, and matrix-supported. The matrix contains a rich Mesozoic (principally Jurassic and Lower Cretaceous) palynoflora. Clasts are of pebble grade, typically subangular to rounded and composed of quartzitic and psammitic metasedimentary rocks, with sparse felsite, chalk and shell fragments. Deformed and attenuated beds and rafts of pinkish yellow, fine-grained, slightly pebbly sand are locally common. Interpreted as having been initially deposited as sub-glacial till but subsequently, at least in part, glaciotectonically deformed and rafted into position during a later glacial event.

PITLURG FARM TILL MEMBER (PGTI)

The Pitlurg Farm Till Member (after Hall and Jarvis, 1995; Indigo Boulder Clay of Jamieson, 1906) comprises at least 7 m of very dark to dark grey, clayey, silty, pebbly, slightly calcareous diamicton. Besides local rock types, it includes red (Devonian) sandstone, white (probably Mesozoic) sandstone, and shell fragments. The unit is generally unconformable on bedrock or on older tills, such as the Bellscamphie Till Formation. It is generally unconformably overlain by the Hatton Till Formation (Logie–Buchan Glacigenic Subgroup).

ALDIE TILL MEMBER (ALDTI)

The Aldie Till Member (after Merritt et al., 2003) comprises up to 10 m of gravelly, clayey sand and diamicton (till), greenish grey (5GY 6/1), stiff, massive to crudely horizontally-bedded, with broken rounded pebbles and cobbles of flint and quartzite reworked from the Buchan Ridge Gravels Formation (Residual Deposits Group), together with sparse mica schist, granite, mafic igneous and red sandstone clasts. The matrix is kaolinitic quartz sand. The lithology of the till varies laterally with the underlying bedrock. The deposit thickens to the south and east of the Moss of Cruden, near Peterhead, where it includes red granite and has a weak north-west–south-east orientated clast fabric. The till locally incorporates large masses of weathered brown sand with sparse quartzite clasts of unknown derivation and origin.

BEARNIE TILL MEMBER

The Bearnie Till Member was assigned as an informal member of the Banchory Till Formation (East Grampian Glacigenic Subgroup) by Merritt et al. (2003). In the present framework it is reassigned to the Whitehills Glacigenic Formation. It contains clasts of local provenance but is typically dark grey and contains a rich Jurassic palynoflora. The last two attributes are probably the result of glacial reworking of the older Pitlurg Farm Till Member.

ANDERSON DRIVE DIAMICTON MEMBER

The 'dark shelly boulder clay' observed by Bremner (1934, 1943) at South Anderson Drive, Aberdeen, was named the Anderson Drive Diamicton Formation of the Banffshire Coast Drift Group by Merritt et al. (2003). In this framework the deposits are named the Anderson Drive Diamicton Member of the Whitehills Glacigenic Formation (Banffshire Coast and Caithness Glacigenic Subgroup).

4.4.5.5 BLACKHILLS SAND AND GRAVEL FORMATION

Name
Blackhills Sand and Gravel Formation (BLSG) (after Merritt et al., 2003).

Lithology
Sand and gravel, locally with shell fragments. Silt and clay in local pockets.

Formal subdivisions and correlation table
Kirkhill Church Sand Member and Auchmeddon Gravel Member (Tables 8 and 10).

Type area/Reference section
Type section: Blackhills Quarry [NJ 926 609–NJ 926 615].
Reference section: Brandon Howe Quarry, Hills of Boyndie [NJ 667 637].
Partial reference section: Broomhead Quarry [NJ 983 640].

Lower and upper boundaries
Lies (in part) on the Essie Till Formation, the Whitehills Glacigenic Formation, and on bedrock.

Normally the ground surface. Locally overlain by the Arnhash Till Member of the Essie Till Formation.

Landform description and genetic interpretation
Glaciofluvial outwash and ice-contact deposits with local pockets of glaciolacustrine deposits.

Thickness
30 m.

Distribution and extent
From Elgin to Fraserburgh, southwards to New Pitsligo [NJ 880 560]. Members of the formation are also identified at Kirkhill Quarry [NK 0120 5285], Ellon.

Age
Late Devensian, Dimlington Stadial (MIS 2).

KIRKHILL CHURCH SAND MEMBER (KHLCH)

The Kirkhill Church Sand Member (formation of Merritt et al., 2000, and Merritt et al., 2003), known only in the vicinity of Kirkhill Quarry [NK 0120 5285], Ellon, comprises up to 1.5 m of pale yellow-brown, slightly gravelly, fine- and medium-grained quartzose sand. It contains sparse, rounded quartzite and psammite metasedimentary pebbles. The basal boundary of the deposit is an unconformable, sharp, channelled surface cut into underlying dark grey to black diamicton of the Corse Diamicton Member (Whitehills Glacigenic Formation). The upper boundary of the formation is generally the present ground surface.

AUCHMEDDON GRAVEL MEMBER (AMNGR)

The Auchmeddon Gravel Member (formation of Merritt et al., 2000, and Merritt et al., 2003; Auchmeddon Member of the Kirkhill Formation of Sutherland, p. 101 in Bowen, 1999) comprises up to 3 m of clast-supported, pebble to boulder grade gravel with medium- to coarse-grained quartzose sand matrix. Clasts are subrounded to rounded and composed mainly of quartzite (probably reworked from underlying gravel deposits and Devonian conglomerates). Other lithologies are rare. The gravels are crudely horizontally-bedded with local sand interbeds displaying horizontal stratification. Clast imbrication measurements indicate palaeocurrents flowing towards the south. The deposit is interpreted as glaciofluvial outwash (Hall et al., 1995a).

4.4.5.6 Essie Till Formation

Name
Essie Till Formation (ESTI) (after Merritt et al., 2003 pp. 124–125; 'Blue-grey Series' of Hall and Connell, 1991).

Lithology
Pebbly sandy silty clayey diamicton, calcareous, dark bluish grey but mottled orange-brown near top, containing well-dispersed clasts of red granite, quartzite and schistose meta-sediments, and sparse fragments of shell, red marl, red sand-stone and chalk. The unit locally includes rafts of red clayey diamicton and black fossiliferous mudstone. Commonly including a lower unit that is dark reddish brown.

Formal subdivisions and correlation table
Arnhash Till Member (Tables 8 and 10).

Type area/Reference section
Partial type section: Pipeline trenches logged by M. Munro (Aberdeen University) at South Essie Farm, near St Fergus, 7 km north-west of Peterhead [NK 083 523].

Partial type section: BGS-registered borehole NK05SE9, 0.6–9.2 m depth, drilled at Kinloch Farm, 4 km north-west of Peterhead [NK 0989 5093] (McMillan and Aitken, 1981).

Lower and upper boundaries
Sharply unconformable, undulating contact with Hatton Till Formation or bedrock, or gradational, planar, glaciotec-tonic contact with laminated silt and clay of the Ugie Clay Formation.

Generally sharp, erosional with overlying glaciofluvial or alluvial sand and gravel, or ground surface.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 10 m.

Distribution and extent
Buchan, north-east Scotland, between Peterhead and Fraserburgh (BGS 1:50 000 Sheets S87E and 97.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Arnhash Till Member (ARTI)

The Arnhash Till Member (after Peacock and Merritt, 1997, and Merritt et al., 2003) comprises up to 2 m of reddish brown to brownish grey till or diamicton, depos-ited by local re-advances of the Moray Ice Stream in the Elgin to Fraserburgh district. It unconformably overlies the Blackhills Sand and Gravel Formation.

4.4.5.7 Kirk Burn Silt Formation

Name
Kirk Burn Silt Formation (KBSI) (after Peacock, 1971, and Merritt et al., 2003).

Lithology
Interbedded silt, clay and fine-grained sand, yellowish brown to dark grey. Local ferruginous nodules. Very locally interbedded with, or overlain by, thin diamicton (Arnhash Till Member).

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: Castle Hill, Gardenstown [NJ 795 642].

Lower and upper boundaries
Overlies bedrock (Middle Old Red Sandstone) or older Quaternary deposits of the Byth Till Formation (East Grampian Glacigenic Subgroup) or Whitehills Glacigenic Formation (Banffshire Coast and Caithness Glacigenic Subgroup).

Surface, or overlain by younger deposits of Holocene age (peat, alluvium, etc.).

Landform description and genetic interpretation
Glaciolacustrine deposits.

Thickness
30 m.

Distribution and extent
Portknockie to New Aberdour.

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.5.8 Grange Hill Sand Formation

Name
Grange Hill Sand Formation (GRHS) (after Peacock et al., 1968).

Lithology
Sand with diamicton and sandy silt.

Formal subdivisions and correlation table
Subdivided into the East Grange Till, Hempriggs Sand, and Milton Hill Silt members (Tables 8 and 10).

Type area/Reference section
Type section of the East Grange Till Member: Disused clay pit, 560 m north of East Grange farm. Red-brown sandy diamicton, at least 2.5 m thick, containing drop-stone cob-bles deforming laminated lenses of silty fine white sand.

Lower and upper boundaries
Not seen; mapping indicates erosional contact on till of the Finglack Till Formation (Inverness Glacigenic Subgroup), glaciofluvial outwash of the Main Late Devensian Glaciation or Old Red Sandstone bedrock.

Generally the ground surface, but locally unconform-ably overlain by Late Devensian raised beach deposits or Holocene raised marine deposits.

Landform description and genetic interpretation
Glaciomarine ice-contact deltaic deposits forming a dis-sected curvilinear ridge that generally rises up to 25 m above the surrounding land surface.

Thickness
At least 20 m.

Distribution and extent
Discontinuous curvilinear ridge that extends north-west-wards from 2.6 km east of the centre of Forres, a distance of 8.5 km to Easter Coltfield [NJ 1202 6440]. Isolated undulat-

ing ridges rising to between 45 m and 55 m above OD are also present east of Forres. All known exposures lie within the south-west corner of BGS 1:50 000 Sheet S95 (Peacock et al., 1968).

Age
Late Devensian, Dimlington Stadial (MIS 2).

EAST GRANGE TILL MEMBER (EGTI)

The East Grange Till Member is composed of at least 2.5 m of red-brown sandy, silty, matrix-supported diamicton with isolated drop-stone cobbles of Moine psammite. It generally underlies the Hempriggs Sand Member and rests with erosional contact on glaciofluvial outwash of the Main Late Devensian Glaciation.

HEMPRIGGS SAND MEMBER (HRGS)

The Hempriggs Sand Member is composed of 5 to 10 m of sand with subsidiary silt and diamicton interpreted as glaciomarine ice-contact deltaic deposits. Locally there are thin discontinuous beds (typically 5 to 10 cm thick) of sandy, pale brown diamicton. The sands display soft-sediment deformation and glaciotectonic deformation structures.

MILTON HILL SILT MEMBER (MHSI)

The Milton Hill Silt Member is composed of up to 5 m of red-brown micaceous sandy silt with sparse scattered cobbles and boulders on the ground surface. The member is generally conformable on the Hempriggs Sand Member. The deposits are interpreted to be topset beds of glaciomarine ice-contact delta sequences.

4.4.5.9 ARDERSIER SILTS FORMATION

Name
Ardersier Silts Formation (ARDS) (after Merritt et al., 1995, and Fletcher et al., 1996; Ardsier Member of Clava Formation of Sutherland, p. 103 in Bowen, 1999).

Lithology
Rhythmically-bedded sequence of silty clays, silts and silty sands, typically graded, with soft-sediment deformation structures. Subordinate diamicton and gravel.

Formal subdivisions and correlation table
Kirkton Clay Member (Kirkton Member of Clava Formation of Sutherland, p. 103 in Bowen, 1999) (Tables 8 and 9).

Type area/Reference section
Partial type section: 'Contorted silts of Ardersier'. Cliff section in Main Late-glacial cliffline (trimmed in Mid-Holocene times) [NH 7800 5595].

Partial type section: 'Kirkton Pit', an old clay pit (re-excavated Sept 1990) in Main Late-glacial cliffline (trimmed in mid-Holocene times) [NH 7849 5647].

Lower and upper boundaries
Lower boundary not seen but likely to be lodgement till or bedrock.

Gradational contact with Alturlie Gravels Formation above, or unconformable boundary with younger deposits.

Landform description and genetic interpretation
The deposits are locally glaciotectonised and of mainly glaciomarine origin (Merritt et al., 1995).

Thickness
At least 20 m.

Distribution and extent
Southern shores of the inner Moray Firth, between Inverness and Elgin.

Age
Late Devensian, Dimlington Stadial (MIS 2).

KIRKTON CLAY MEMBER (KICL)

The Kirkton Clay Member comprises up to 12 m of stiff, thinly horizontally interbedded and rhythmically interlaminated clay, silt and silty sand, pale yellowish brown to orange in colour. Individual beds are generally graded. Convolute bedding is common in silt beds. The beds are stacked into packages, probably glaciomarine cyclopels, 0.3–0.8 m thick.

4.4.5.10 ALTURLIE GRAVELS FORMATION

Name
Alturlie Gravels Formation (ALGR) (after Merritt et al., 1995; Fletcher et al., 1996).

Lithology
Sand and gravel.

Formal subdivisions and correlation table
Bothyhill Gravels Member (Bothyhill Member of Clava Formation of Sutherland, p. 103 in Bowen, 1999), Braicklaich Sand Member (Tables 8 and 9).

Type area/Reference section
Partial type section: Bothyhill Gravel Pit, Alturlie Point [NH 7150 4910].

Partial type section: Mid Coul Gravel Pit, Tornagrain, 12 km east-north-east of Inverness [NH 776 502].

Lower and upper boundaries
Gradational contact with the Ardersier Silts Formation, or unconformably overlies lodgement till or bedrock.

Unconformable with Late Devensian raised marine deposits above, or the present ground surface.

Landform description and genetic interpretation
Typically deltaic coarsening-upwards sequences. Undulating spreads with kettleholes, locally glaciotectonised, of mainly glaciomarine origin (Merritt et al., 1995).

Thickness
At least 20 m.

Distribution and extent
The area surrounding the southern shore of the inner Moray Firth, between Inverness and Elgin.

Age
Late Devensian, Dimlington Stadial (MIS 2).

BOTHYHILL GRAVELS MEMBER (BOGR)

The Bothyhill Gravels Member comprises up to 20 m of a coarsening-upwards deltaic sequence of sand and gravel, containing sparse cobbles of Inchbae granite-gneiss.

BRAICKLAICH SAND MEMBER (BRSA)

The Braicklaich Sand Member comprises up to 7 m of rhythmically-bedded, pale yellowish brown sand, silty sand and silt, capped by sand and gravel. Individual beds are generally graded sand/silt couplets, 0.2 to 0.4 m thick, exhibiting planar or ripple-drift cross-lamination. The beds are stacked into packages and are probably glaciomarine cyclopsams.

4.4.6 Central Grampian Glacigenic Subgroup

Name
Central Grampian Glacigenic Subgroup (CGDR) (after McMillan et al., 2005; Devensian formations of the Central Grampian Drift Group of Merritt et al., 2003).

Lithology
Diamicton, sands, gravels and silts. Clasts mainly derived from Central Highland Migmatite Complex and Caledonian igneous rocks.

Formal subdivisions and correlation table
Subdivided into seven formations in the Highlands of Scotland: Sections 4.4.6.1–4.4.6.7 and Tables 8–10, and three formations in the Midland Valley of Scotland: Sections 5.1.3.1–5.1.3.3 and Tables 8 and 11.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock.

Generally the ground surface.

Landform description and genetic interpretation
Glacial, glaciofluvial and glaciolacustrine sediments deposited by ice that mainly radiated from a centre over Rannoch Moor.

Thickness
Generally 5–10 m, but locally 30 m or more.

Distribution and extent
The Grampian Highlands as far as Strath Spey, the Cairngorm Mountains and Gaick Plateau to the east, Strathmore, Menteith and Loch Lomond to the south, including the Inner Hebrides to the south of Mull.

Age
Devensian (MIS 2–5e).

4.4.6.1 Linn Of Pattack Silt Formation

Name
Linn of Pattack Silt Formation (LPSI) (after Merritt, 1999).

Lithology
Silty clay and clayey silt, thinly laminated, pale olive-grey. Some drop-stones. Coarsening upwards into ripple cross-laminated sand.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Partial type section: River cliff section 250–350 m upstream of the confluence of the River Pattack and the Allt Coire nam Plaidean [NN 5475 8221–NN 5478 8206].

Partial type section: River cliff section 350 m downstream of the confluence of the River Pattack and the Allt Coire nam Plaidean [NN 5478 8273].

Partial type section: River cliff of the Allt Coire na Ceardaich at its confluence with the River Mashie [NN 5746 5441].

Lower and upper boundaries
Conformable on the Pattack Till Formation.

Unconformable with the Ardverikie Till Formation.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
10 m or more.

Distribution and extent
Catchments of the rivers Pattack and Mashie and around the Gaick Plateau.

Age
Devensian (MIS ?3)

4.4.6.2 Ceardaich Sand and Gravel Formation

Name
Ceardaich Sand and Gravel Formation (CEAR) (after Merritt, 1999).

Lithology
Sand and gravel; clasts mainly psammite, with granodiorite, granite and porphyry; large scale deltaic cross-bedding common.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: River cliff of Allt Coire na Ceardaich [NN 5746 8441].

Lower and upper boundaries
Unconformable on bedrock; erosional on the Pattack Till Formation; gradational on the Linn of Pattack Silt Formation.

Unconformable or glaciotectonic contact with Ardverikie Till Formation.

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
5 m.

Distribution and extent
Central Grampian Mountains of Scotland.

Age
Early Devensian–Late Devensian (MIS ?3).

4.4.6.3 Ardverikie Till Formation

Name
Ardverikie Till Formation (ARDT)

Lithology
Stony sandy clayey diamicton with angular–subrounded clasts up to boulder size; a typical lodgement till. Locally overlying a unit of deformation till derived from the destruction of underlying Linn of Pattack Silt Formation.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Reference section: River cliff of the Allt Coire na Ceardaich at its confluence with the River Mashie [NN 5746 8441].

Partial type section: River cliff section 250–350 m upstream of the confluence of the River Pattack and the Allt Coire nam Plaidean [NN 5475 8221–NN 5478 8206].

Partial type section: River cliff of River Pattack at its confluence with the Allt Beinn Eilde [NN 5493 8368].

Lower and upper boundaries
Unconformable on the Linn of Pattack Silt Formation, or the Pattack Till Formation, or bedrock.

Conformable with units of outwash sand and gravel, morainic deposits or peat, etc.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 12 m.

Distribution and extent
Central highlands west of the Cairngorms and Gaick Plateau.

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.6.4 Gaick Plateau Moraine Formation

Name
Gaick Plateau Moraine Formation (GPM) (after Lucas et al., 2004).

Lithology
Diamicton, mainly clast-supported, gravelly, sandy, silty, and matrix-rich gravel. Poorly consolidated, formed of angular–subangular fragments of weathered psammite and porphyry mainly less than 64 mm in diameter with some cobbles and boulders; yellowish brown.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type area: Drumochter to Glen Dee [NN 630 730–NN 990 870] including the Gaick Plateau in central Grampian Highlands [NN 720 780–NN 980 810].

Type locality: valley of Tarf Water upstream of Falls of Tarf [NN 983 797].

Lower and upper boundaries
Bedrock or unconformable contact on Ailleag Diamicton Formation of the Central Grampian (Albion) Glacigenic Subgroup.

Generally ground surface or peat.

Landform description and genetic interpretation
Glacigenic deposits that form a distinct suite of low, recessional moraine ridges, possibly formed annually, typically 2–5 m high, that are predominantly composed of comminuted deeply weathered rock. They are closely associated with ice-marginal glacial drainage channels and occur across the Gaick Plateau in the central Grampian Highlands of Scotland.

Thickness
Up to 8 m.

Distribution and extent
The deposits occur across the Gaick Plateau in the central Grampian Highlands (BGS 1:50 000 Sheet S64E (Ben Macdui).

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.6.5 Beinn an Uain Till Formation

Name
Beinn an Uain Till Formation (BUTI) (after Walker et al., 1982 and Fletcher et al., 1996).

Lithology
Stony sandy clayey diamicton, matrix-supported, dark yellowish brown to olive-grey, fissile, massive, extremely compact, containing angular–subrounded clasts of gneissose psammite and semipelite, granite and some Devonian sandstone and siltstone. Typical lodgement till with well-developed north-easterly fabric and containing concavo-convex discontinuities that are commonly sand-filled.

Formal subdivisions and correlation table
Ruallan Till Member and Cantray Till Member (Tables 8 and 10).

Type area/Reference section
Partial type section: Exposed at the top of river cliffs of the Allt Odhar, immediately upstream of its confluence with the Caochan nan Suidheig [NH 798 368], Moy Estate, 16 km south-east of Inverness.

Partial type section: River cliff sections of the Allt Dearg, 6 km south-west of Cawdor, Nairnshire. The Dalcharn Interglacial site [NH 815 452–NH 816 454].

Lower and upper boundaries
Generally a gradational contact over 10–20 cm, or locally a sharp, planar one, with stony, sandy diamictons of the underlying Athais Till Formation, or on bedrock.

Erosional contact with gravel of the Carn Monadh Gravel Formation at the Allt Odhar Interstadial site, various younger deposits or the ground surface.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
10 m.

Distribution and extent
BGS Sheet Scotland 84W (Fortrose), south-east of Inverness.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Ruallan Till Member (RNTI)

The Ruallan Till Member comprises up to 3.5 m of dark yellowish brown, compact, matrix-supported, stony sandy clayey diamicton, containing angular to subrounded clasts of gneissose psammite and semipelite, pink and grey granite and some Devonian sandstone and siltstone. It is interpreted as a lodgement till.

Cantray Till Member (CYTI)

The Cantray Till Member comprises up to 6.5 m of strong brown to dark yellowish brown, compact, matrix-supported, stony sandy clayey diamicton, containing angular to subrounded clasts of gneissose psammite and semipelite, granite and Devonian sandstone and siltstone. It is interpreted as a lodgement till. The diamicton has a well-developed north-easterly orientated fabric and commonly includes rip-up masses of the underlying till unit of the Athais Till Formation. The Cantray Till has a generally gradational contact, but with a sharp change in colour, with the overlying Ruallan Till Member.

4.4.6.6 Carn Monadh Gravel Formation

Name
Carn Monadh Gravel Formation (CMOGR) (after Walker et al., 1992, and Fletcher et al., 1996).

Lithology
Silty, sandy gravel, horizontally stratified, thin-bedded, pale olive-grey, with subsidiary beds of sand, clast-supported gravel and silty sandy gravel diamicton. Pebbles consist of red and grey granites, semipelitic gneiss, psammite and brown flaggy sandstone.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: Exposed at the tops of river cliff sections of the Allt Odhar, immediately upstream of its confluence with the Caochan nan Suidheig, Moy Estate, 16 km south-east of Inverness, in the vicinity of the Allt Odhar Interstadial site [NH 798 368].

Lower and upper boundaries
Sharp, undulating, erosional, unconformable contact with stony, sandy, clayey diamictons of the underlying Beinn an Uain Till Formation.

Ground surface.

Landform description and genetic interpretation
Forming ice-marginal fans.

Thickness
10 m.

Distribution and extent
Moy Estate, south-east of Inverness (BGS 1:50 000 Sheet S84W).

Age
Devensian (MIS 2 Dimlington Stadial).

4.4.6.7 Old Hythe Till Formation

Name
Old Hythe Till Formation (OHT) (after Peacock, 1966, and Peacock and Merritt, 2000b).

Lithology
Diamicton, silty, clayey, stony, dark yellowish brown to dark grey, angular to well-rounded clasts of psammite, quartzite, pink granite, Devonian and Triassic sandstone, amphibolite and (importantly) fresh gabbro and troctolite.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: Sections in the western side of Boyne Limestone Quarry [NJ 6114 6581–NJ 6135 6604].

Lower and upper boundaries
Gradational contact with underlying diamictons (including rafts) of the Whitehills Glacigenic Formation, or unconformable contact with Boyne Craig Till Formation, or on bedrock.

Generally the land surface or overlain conformably by glaciofluvial or glaciolacustrine deposits.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Over 10 m.

Distribution and extent
BGS 1:50 000 Sheets S95 (Elgin) and 96W (Portsoy).

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.6.8 Informal Till Formations of the Elgin District

In the Elgin district, the Late Devensian Altonside Till, Waterworks Till and Tofthead Tills were named by Hall et al. (1995b) and Hall (2000). These units are treated in the current framework as informal formations. The **Altonside Till Formation** (Altonside Member of the Teindland Formation of Sutherland, p. 102 in Bowen 1999) is a dark grey to grey-brown compact diamicton containing shell fragments and Mesozoic erratics from the bed of the Moray Firth to the north-west (Peacock et al., 1968, Aitken et al., 1979). It is assigned to the Banffshire Coast and Caithness Glacigenic Subgroup (Banffshire Coast Drift Group of Merritt, 2003). The Altonside Till Formation is overlain by younger tills of the **Waterworks Till** and **Tofthead Till** formations. These are brown sandy tills derived from Old Red Sandstone conglomerates to the west, and are assigned to the Central Grampian Glacigenic Subgroup (Central Grampian Drift Group of Merritt et al., 2003).

At Teindland Quarry [NJ 297 570], organic sediments (Badentinan Sand Bed of the Moy Burn Palaeosol Formation, and underlying sediments of the Teindland Palaeosol Formation, Sections 4.6.1.2–4.6.1.3) are overlain by up to 2.2 m of bedded sandy diamicton, the **Woodside Diamicton Formation** (currently informal; after Merritt et al., 2003, p. 121; Woodside Member of Sutherland, p. 102 in Bowen, 1999; Teindland Till of Hall et al., 1995b). It is considered to be Early Devensian (MIS 4) in age by Hall et al. (1995b).

4.4.6.9 Informal Formations of the Central Grampian Glacigenic Subgroup in Argyll and Southern Grampian Highlands

Devensian glacigenic deposits of Argyll are referred to informal formations of the Central Grampian Glacigenic Subgroup. Moundy and flat-terraced sand and gravel of the Achnacree-Achnaba area [NM 930 360], north of Connel are referred by Sutherland (pp.110–111 in Bowen, 1999) to the Etive Formation. This name is pre-occupied by a unit of the Jurassic Brent Group and in this framework the unit is provisionally named the informal **Achnacree Sand and Gravel Formation**. These deposits are considered to be of glaciofluvial and ice-marginal origin (McCann, 1966; Gray, 1975, 1993). The **Roy Formation** (Sutherland, p. 111 in Bowen, 1999) (type area: Glen Roy, NN 300 880) comprises two facies the first of laminated fine sand and silt, and the second of laminated silt and clay, both glaciolacustrine in origin (Miller, 1987).

In the Southern Grampian Highlands between Rannoch Moor and Loch Lomond, Golledge (2007) presented a detailed sedimentological and stratigraphical analysis of the glacial deposits of the district enabling them to be related to pre-Main Late Devensian, Late Devensian and Loch Lomond Stadial glacial events. Although, the deposits remain un-named, all of the units (comprising eight lithofacies) can be initially assigned to the Central Grampian Glacigenic Subgroup.

4.4.7 East Grampian Glacigenic Subgroup

Name
East Grampian Glacigenic Subgroup (EGD) (after McMillan et al., 2005; Devensian formations of the East Grampian Drift Group of Merritt et al., 2003).

Lithology
Sandy diamicton (till), sand, gravel, silt and clay. Clasts are derived predominantly from weathered Neoproterozoic metamorphic rocks (psammite, meta-wacke sandstone, slate) and Caledonian igneous rocks (granite, granodiorite, gabbro).

Formal subdivisions and correlation table
Subdivided into six formations: Sections 4.4.7.1—4.4.7.6 and Tables 8 and 10.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on units of the Albion Glacigenic Group or bedrock.

Surface or unconformable contact with units of the Britannia Catchments Group.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial and glaciolacustrine deposits laid down from ice that radiated from the Eastern Grampian mountains.

Thickness
Very variable, generally 5–10 m; more than 40 m proved in some sections.

Distribution and extent
The East Grampian Highlands, Cairngorm Mountains and Gaick Plateau.

Age
Devensian (MIS 5d–2).

4.4.7.1 Banchory Till Formation

Name
Banchory Till Formation (BATI) (after Merritt et al., 2003).

Lithology
Gravelly and sandy diamicton composed principally of decomposed Neoproterozoic metamorphic rocks and Caledonian igneous rocks.

Formal subdivisions and correlation table
Divided into informal members: Tables 8 and 10.

Type area/Reference section
Type area: Banchory-Strachan area, Kincardineshire.

Reference section: River cliff section of the Burn of Granney, 400 m west of the Mill of Clinter.

Reference Section: Small working, 400 m west-south-west of Finzean House. BGS section and pit reference number NO69SW2, 0.3–4.9 m depth.

Lower and upper boundaries
Unconformable: On pre-Late Devensian superficial deposits or bedrock.

Conformably overlain by Glen Dye Silts Formation or Lochton Sand and Gravel Formation; otherwise unconformably overlain by Holocene deposits, or at the ground surface. Locally overlain unconformably by the Blairdaff Moraine Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Very variable, generally 2–5 m, over 8 m proved in some sections.

Distribution and extent
East Grampian Highlands.

Age
Late Devensian, Dimlington Stadial (MIS 2).

The informal *Nigg Till Member* of the Banchory Till Formation is dark greyish brown, contains clasts derived from the west to the west-south-west and is typical of surficial tills in the lower Dee valley and to the south (Merritt et al., 2003). The brown *Kingswell Till Member* is probably a local variant, having a west-south-west to east-north-east fabric and containing much 'Hill of Fare' granite (Merritt et al., 2003). It is equivalent to Till B of Murdoch (1977) and its type area is the Kingswell-Culter-Aberdeen city area. A third unit, the dark grey *Den Burn Till Member* with locally-derived clasts, underlies the above-mentioned till in the vicinity of the Kingswell Roundabout [NJ 878 061] (Merritt et al., 2003). It has a north-west to south-east fabric and is equivalent to Till A of Murdoch (1977). It is possibly equivalent to the 'grey boulder clay' with clasts derived from the north-west, which Bremner (1934, 1943) recorded as overlying 'dark shelly boulder clay' (the *Anderson Drive Diamicton Member* of the Whitehills Glacigenic Group) in excavations for the Anderson Drive Ring Road.

4.4.7.2 Blairdaff Moraine Formation

Name
Blairdaff Moraine Formation (BDMO) (after Merritt et al., 2003).

Lithology
Typically yellowish brown, crudely-bedded, with extremely variable sorting of both matrix- and clast-supported clayey gravel, with boulders and sandy diamicton, containing angular to well-rounded clasts composed of psammite, meta-wacke sandstone, granite and quartzite, with some gneiss, slate and dolerite, elsewhere locally formed of mainly granite or gabbroic rocks, forming hummocky ground and cross-valley moraine ridges.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: Sand and gravel pit section at Blairdaff [NJ 7001 1797], 4 km north-west of Kemnay, Aberdeenshire (Merritt et al., 2003).

Reference section: Exposure in bank in forestry track 300 m north of Toll Farm [NJ 8495 1168], 11 km north-west of Aberdeen.

Reference Section: Small working, 400 m west-south-west of Finzean House (BGS section and pit reference number NO69SW2, 0.3–4.9 m depth).

Lower and upper boundaries
Generally a sharp, undulating, unconformable contact with a yellowish brown, gravelly, clayey sand diamicton of the Banchory Till Formation and other sandy tills of the East Grampian Glacigenic Subgroup.

Generally the present ground surface.

Landform description and genetic interpretation
Glacigenic deposits, forming hummocky ground and cross-valley moraine ridges.

Thickness
Up to 10 m.

Distribution and extent
East Aberdeenshire (BGS 1:50 000 Sheets S76E, S77, S66E, S67).

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.7.3 Glen Dye Silts Formation

Name
Glen Dye Silts Formation (GDSI) (after Merritt et al., 2003).

Lithology
Laminated brown to olive-grey silt and clay.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: River cliff sections on the southern bank of Miller Burn 600–800 m upstream of its confluence with the Water of Dye, Glen Dye.

Reference section: BGS borehole NO69SE8, 400 m north-east of Bogarn, 14.3–18.8 m in borehole.

Reference section: BGS section and pit reference number NO68NW2 at Miller's Bog, Glen Dye, 9.3–11.3 m depth in pit.

Lower and upper boundaries
Generally conformable on the Banchory Till Formation.

Generally overlain conformably by the Lochton Sand and Gravel Formation.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
Generally 2–3 m; 5 m proved in boreholes.

Distribution and extent
The East Grampian Highlands.

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.7.4 Lochton Sand and Gravel Formation

Name
Lochton Sand and Gravel Formation (LOSG) (after Merritt et al., 2003).

Lithology
Sand and gravel composed predominantly of clasts of Neoproterozoic metamorphic rocks and Caledonian igneous rocks.

Formal subdivisions and correlation table
Informal Ness Sand and Gravel Member (Merritt et al., 2003) Tables 8 and 10.

Type area/Reference section
Reference Section: BGS borehole NO69SE15 at Heughhead, about 3 km south-west of Banchory, 0.4–5.2 m depth in borehole.

Reference section: BGS section and pit reference number NO69SW6, 300 m south-west of Easter Clune Farm, 0.3–5.0 m depth.

Partial type section: Lochton Gravel Pit, 6 km south-east of Banchory, BGS section and pit reference number NO79SE1, 0–5.4 m depth.

Reference section (Ness Sand and Gravel Member): Nigg Bay [NJ 965 045], south of Aberdeen (Jamieson, 1882; Bremner, 1928; Simpson, 1948; Synge, 1963; Merritt et al., 2003).

Lower and upper boundaries
Unconformable on bedrock or conformable on Banchory Till Formation or Glen Dye Silts Formation.

At ground surface or unconformably overlain by Holocene deposits.

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
Very variable, generally 3–5 m; 14 m proved in boreholes.

Distribution and extent
The East Grampian Highlands.

Age
Late Devensian, Dimlington Stadial (MIS 2).

The *Ness Sand and Gravel Member* (Unit 1 of the Nigg Bay section, Merritt et al., 2003) comprises up to 9 m of coarse gravel, locally bouldery, passing upwards into sand and minor gravel beds. The deposit contains clasts predominantly derived from the Dee valley to the west (Synge, 1963) with sparse erratics of flint and of Scandinavian provenance (Bremner, 1928; Read et al., 1923; Merritt et al., 2003). It is overlain unconformably by grey sandy diamicton of the Nigg Till Member (Banchory Till Formation, Section 4.4.7.1).

4.4.7.5 Hythie Till Formation

Name
Hythie Till Formation (HYTIL) (after Merritt et al., 2003).

Lithology
Gravelly, clayey, silty sand diamicton, typically brown/dark brown, with greyish brown/grey ped faces, very stiff,

non-calcareous, matrix-supported. Clast angularity ranges from angular to subrounded. Clast lithologies are varied and include psammitic, pelitic and quartzitic metasedimentary rock, felsite, mafic igneous rocks, slate, grey granite and sparse red sandstone, flint and a single piece of Norwegian rhomb porphyry.

Formal subdivisions and correlation table
Sandford Bay Till Member, Manse Gelifluctate Bed (Merritt et al., 2003) (Tables 8 and 10).

Type area/Reference section
Partial Type Section: East face, Kirkhill Quarry (infilled) [NK 0130 5290], 7.0 km south-east of Strichen, Buchan, north-east Scotland (Connell et al., 1984).

Partial Type Section: North-east face of Leys Quarry (disused) [NK 0045 5257], 6.5 km south-east of Strichen, Buchan, north-east Scotland (Connell, unpublished work, 1990).

Lower and upper boundaries
Typically the formation has a sharp, planar, subhorizontal, erosional basal boundary on sediments of the Corsend Gelifluctate Bed (e.g. east and south faces, Kirkhill Quarry). In other situations the basal boundary can be more complex — e.g. north-east face, Leys Quarry (disused). Here the formation displays either a sharp, undulating, unconformable, basal boundary on brown diamicton of the Rottenhill Till Formation; or a sharp to gradational basal/ lateral, glaciotectonic, boundary with sheets and rafts of black clayey diamicton of the Corse Diamicton Member (Whitehills Glacigenic Formation).

Typically the upper boundary is the present ground surface. Within the valleys of the North and South Ugie Waters the upper boundary can be sharp, erosional with overlying glaciofluvial or alluvial sands and gravels. The Manse Gelifluctate Bed is a mass movement deposit of felsite rubble, crudely bedded sand and pebbly diamicton resting on the Hythie Till Formation (Connell and Hall, 1987, Merritt et al., 2000, 2003).

Landform description and genetic interpretation
Glacigenic deposit. Interpreted as a sub-glacial till (Merritt et al., 2003). Clast fabrics indicate glacial transport from the west and west-south-west.

Thickness
Up to 3 m.

Distribution and extent
Buchan, north-east Scotland. The formation is known in the vicinity of Kirkhill Quarry (infilled) [centred on NK 0120 5285] and Leys Quarry (disused) [centred on NK 0040 5250], and more widely as a surface, or subsurface deposit in the area of the North and South Ugie Water valleys on Sheet Scotland 87W (Ellon). The unit may be regionally significant and present locally across north-east Scotland.

Age
Devensian, Dimlington Stadial (MIS ?2).

SANDFORD BAY TILL MEMBER

The informal Sandford Bay Till Member is a granite-rich till assigned to the Hythie Till Formation by Merritt et al. (2003). It occurs at the base of the glacial sequence in cliff sections near Sandford Lodge [NK 125 434], Sandford Bay, south of Peterhead.

4.4.7.6 BYTH TILL FORMATION

Name
Byth Till Formation (BYTIL) (after Merritt et al., 2003).

Lithology
Gravelly, slightly clayey, silty sand diamicton. Dark reddish brown, weakly calcareous, matrix-supported. Clast lithologies are dominated by quartzite, psammitic metasedimentary rocks and red Devonian sandstones and shale. Clasts are typically subangular to subrounded and Devonian shale lithologies are striated. Clast lithologies are dominated by quartzite, psammitic metasediments and red Devonian sandstones and shale.

Formal subdivisions and correlation table
Includes the Crovie Till Member (Tables 8 and 10).

Type area/Reference section
Type section: North face (as at May 2002) of Howe of Byth Quarry, 18.0 km south-west of Fraserburgh, Buchan, north-east Scotland (Hall et al., 1995a).

Lower and upper boundaries
The lower boundary of the unit is a sharp, planar, sub-horizontal unconformity on gravels of the Howe of Byth Gravel Formation. To the west of the Howe of Byth quarry the Byth Till has been observed sharply unconformable on Devonian red sandstones.

The upper boundary of the formation is a sharp, undulatory (relief of up to 1.0 m) erosional unconformity overlain by the Auchmeddon Gravel Formation.

Landform description and genetic interpretation
Glacigenic deposit. Interpreted as a sub-glacial till. Clast fabrics indicate glacial transport from the west.

Thickness
Up to 5 m.

Distribution and extent
Buchan, north-east Scotland. The formation is known from the vicinity of the Howe of Byth Quarry on BGS 1:50 000 Sheet S97 (Fraserburgh) inland to New Pitsligo [NJ 880 560], but may be regionally significant and present locally across north-east Scotland.

Age
Late Devensian, Dimlington Stadial (MIS 2).

CROVIE TILL MEMBER (CRTI)

The Crovie Till Member comprises up to 5 m of commonly reddish brown till with predominantly local psammitic rocks together with erratics from the west or north-west (Read, 1923).

4.4.8 Logie–Buchan Glacigenic Subgroup

Name
Logie–Buchan Glacigenic Subgroup (LBD) (after McMillan et al., 2005; Devensian formations of the Logie–Buchan Drift Group of Merritt et al., 2003).

Lithology
Red clayey diamictons and gravels with a distinctive suite of

clasts derived from the floor of the North Sea Basin, including calcareous siltstone, red sandstone and shell fragments.

Formal subdivisions and correlation table
Subdivided into four formations: Sections 4.4.8.1–4.4.8.4 and Tables 8 and 10.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock or older superficial deposits.

Ground surface or beneath postglacial deposits.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 20 m.

Distribution and extent
Coastal lowland north of Aberdeen, east of Ellon and south of Peterhead.

Age
Devensian (MIS 5d–2).

4.4.8.1 Auchleuchries Sand and Gravel Formation

Name
Auchleuchries Sand and Gravel Formation (ALSSG) (after Merritt et al., 2003, p. 132).

Lithology
A mostly pale yellowish brown pebbly sand, containing a relatively large proportion of pink granite and seams of chocolate brown or dark grey clay, which is interpreted as having been derived from the underlying till.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: BGS registered borehole NK03NW01 [NK 0057 3649], sited on the hill of Auchleuchries, 8 km north-east of Ellon, Aberdeenshire (Merritt, 1981).

Reference section: Trial pits dug in the vicinity of Bellscamphie railway cutting [NK 018 337], 8 km east-north-east of Ellon, Aberdeenshire.

Lower and upper boundaries
A sharp, undulating, erosional, unconformable contact with a dark grey, pebbly clayey diamicton (currently un-named, originally the lower unit of the Pitlurg Till Formation of Merritt et al., 2003).

Sharp, planar or gradational glaciotectonic, unconformable contact with a reddish brown, gravelly sandy clayey diamicton of the Hatton Till Formation, and elsewhere overlain by yellowish brown, gravelly clayey sand diamictons of the East Grampian Glacigenic Subgroup, which contain psammite, meta-wacke sandstone and granite clasts.

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
Up to 12 m.

Distribution and extent
Ellon district, Eastern Aberdeenshire.

Age
Late Devensian, Dimlington Stadial (MIS2).

4.4.8.2 Hatton Till Formation

Name
Hatton Till Formation (HATT) (after Hall and Jarvis, 1995, and Merritt et al., 2003).

Lithology
Diamicton, clayey, pebbly, calcareous, red, crudely stratified. Besides local rock types it contains red (Devonian) sandstone, Mesozoic mudstone and limestone, shell fragments.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Type section: Abandoned railway cutting of Bellscamphie [NK 0184 3368], trial pits (Hall and Jarvis, 1995) and boreholes (Merritt, 1981), 7 km east-north-east of Ellon.

Lower and upper boundaries
Unconformable on bedrock, on Kippet Hills Gravels Formation or older tills, e.g. Pitlurg Farm Till Member of the Whitehills Glacigenic Formation.

Ground surface or beneath post-glacial deposits.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
10 m or more.

Distribution and extent
Coastal lowland north of Aberdeen, east of Ellon and south of Peterhead.

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.8.3 Kippet Hills Gravels Formation

Name
Kippet Hills Gravels Formation (KHG) (after Hall and Jarvis, 1995, and Merritt et al., 2003).

Lithology
Gravels and sands. Besides local rock types (e.g. psammite) clasts include distinctive Mesozoic limestones and mudstone and shell fragments of Red Crag affinity from the Aberdeen Ground Formation.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 10).

Type area/Reference section
Partial type section: Bellscamphie railway cutting (abandoned) [NK 0184 3368], 7 km east-north-east of Ellon. Trial pits described in Hall and Jarvis (1995).

Partial type section: Whitefields Pit (Section NK03SW12 of Merritt, 1981) [NK 0327 3206] 7.5 km east-north-east of Ellon.

Lower and upper boundaries
Generally unconformable on bedrock or older tills (e.g.

Pitlurg Farm Till Member of the Whitehills Glacigenic Formation). Locally interbedded with Hatton Till Formation.

Occurs to surface or capped unconformably by the Hatton Till Formation or postglacial deposits.

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
15 m or more locally.

Distribution and extent
Coastal lowland north of Aberdeen, east of Ellon and south of Peterhead.

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.4.8.4 Ugie Clay Formation

Name
Ugie Clay Formation (UGCL) (after Merritt et al., 2003; 'Red Series' clays of Connell et al., 1985, and Hall and Connell, 1991).

Lithology
A typically reddish brown, but locally dark grey, black, brown and yellowish brown, laminated clay, silt and fine-grained sand, with localised black organic laminae formed of reworked Jurassic material.

Formal subdivisions and correlation table
Tullos Clay Member (Tables 8 and 10).

Type area/Reference section
Partial type section: Stream section [NK 0050 4732], 400 m north-north-west of Balluss Bridge, Mintlaw.
Partial type section: Abandoned clay-pit at Errolston [NK 088 368], Cruden Bay (Connell et al., 1985).

Lower and upper boundaries
Generally a sharp, undulating, draped, unconformable contact with the gravelly, clayey, sand diamictons (tills) of the East Grampian Glacigenic Subgroup, but locally a sharp, undulating, draped, unconformable contact with deposits of glaciofluvial gravel with erect pebbles at the top, a fabric probably formed in a periglacial environment.

Generally a sharp, undulating, draped, erosional and unconformable contact with glaciofluvial or alluvial sand and gravel. Locally the boundary is seen as a sharp, planar, unconformable glaciotectonic contact with red clayey diamictons (deformation tills, glaciotectonites) of the Logie-Buchan Glacigenic Subgroup towards the North Sea coast.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
Up to 20 m.

Distribution and extent
Buchan, north-east Scotland, between Peterhead, Ellon and Aberdeen.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Tullos Clay Member (TSCL)

The Tullos Clay Member comprises up to 30 m of reddish brown and olive-brown silt and clay, mainly massive, but with some laminae of sand (Merritt et al., 2003). It is distributed along the coast between Newburgh and Aberdeen. The deposits have a sharp, draped, undulating, unconformable contact with underlying massive, gravelly, silty, sandy, clayey diamicton of the Hatton Till Formation.

4.5 BRITISH COASTAL DEPOSITS GROUP

4.5.1 Formations of the British Coastal Deposits Group

Pre-Devensian shell-bearing clays from Cleongart Glen [NR 668 347], Kintyre, initially identified by Horne et al. (1897), have been assigned to the Tangy Glen Member of the Cleongart Formation by Sutherland (p. 110 in Bowen, 1999; Table 9). Referred to by Sutherland (1981, 1993) as the Tangy Glen High Level Shell Bed, the deposits comprise up to 8 m of blue-grey shelly clay resting on unfossiliferous sand and gravel (Barr Member of Sutherland, p. 109 in Bowen, 1999) and overlain by up to 22.5 m of reddish brown diamicton (Corputechan Member) interpreted as a till. The shell-bearing deposits were considered by Synge and Stephens (1966) to be a till and by Horne et al. (1897), Jessen (1905) and Sutherland (1981) to be marine or glaciomarine. None of the units is currently defined in the BGS Lexicon. This report refers the shelly clays informally to the Tangy Glen Shelly Clay Bed (TGSC) of the British Coastal Deposits Group. Mean D-alle/L-alle ratios on Arctica islandica of 0.249 indicate a MIS 8 age for the fauna (Bowen and Sykes, 1988).

Late Devensian and Holocene raised marine, estuarine, tsunami and beach deposits and blown sand of the Highlands and Islands are included within the British Coastal Deposits Group (Tables 5, 9 and 10). Around the Beauly, Cromarty and Moray firths coastal and marine deposits described by Peacock et al. (1980), Firth and Haggart (1989), Auton et al. (1990), and Fletcher et al. (1996) were assigned as members of the Clava Formation and of the Cromarty Formation of Sutherland (p. 103–106 in Bowen, 1999). Most units remain informal and are currently not described in the BGS Lexicon. The group also includes the sequence of raised marine deposits in the Fraserburgh area (Merritt et al., 2003, p. 115).

The earliest marine deposits of the Late Devensian are assigned to the **Errol Clay Formation**, which is distributed along the east coast and firths of Scotland (Peacock, 1999) (see also Chapter 5) and the **St Fergus Silt Formation** confined to the Peterhead area (McMillan and Aitken, 1981; Peacock, 1999; Merritt et al., 2003).

4.5.1.1 Errol Clay Formation

Name
Errol Clay Formation (ERRCL) (after Peacock, 1999; Errol Beds of Paterson et al., 1981; Errol Member of Sutherland, p. 114 in Bowen, 1999, and correlated offshore with St Abbs Formation by Stoker et al., 1985, and Cameron and Holmes, p. 130 in Bowen, 1999).

Lithology
Massive to thinly-bedded and coarsely laminated, calcareous, silty and sandy clay interbedded with sand, commonly forming a fining-upwards sequence. Generally reddish brown, but locally brownish and yellowish grey or pale

to dark grey. Streaks and mottling of dark grey to black sulphide are common and calcareous concretions occur towards the base locally.

Formal subdivisions and correlation table
Subdivided into the Spynie Clay Member (Tables 5 and 10); and Lunan Clay Member of the Midland Valley of Scotland (Section 5.2.1.2; Tables 5 and 11).

Type area/Reference section
Type section: Auger holes A and B sited in the vicinity of the former Inchcoonan Brick and Tile Works clay-pit, near Errol [NO 241 233] (Peacock, 1999).

Type section: Spynie Clay Member, Spynie clay-pit [NJ 232 672] (Spynie Clay Formation of Peacock, 1999).

Lower and upper boundaries
Unconformable, draped contact with underlying glaciofluvial sand and gravel or till.

Overlain conformably at the type section by dark grey clay of the Powgavie Clay Member (Forth Clay Formation).

Landform description and genetic interpretation
The sparse fauna indicate distal glaciomarine to high Arctic marine depositional conditions (Peacock, 1999).

Thickness
Up to at least 20 m.

Distribution and extent
East coast and firths of Scotland from Berwick-upon-Tweed to Inverness.

Age
Late Devensian, Dimlington Stadial (MIS 2). Laid down diachronously at the retreating ice-sheet of the Main Late Devensian Glaciation between 14C 15 000–13 000 cal. years BP.

SPYNIE CLAY MEMBER (SPYCL)

In the Elgin area, the Errol Clay Formation is represented by the Spynie Clay Member (Spynie Clay Formation of Peacock, 1999), a dark bluish grey to yellowish red, commonly laminated clay, up to 20 m thick, containing well-dispersed clasts and lenses of sand, gravel and diamicton, and low diversity, high-Arctic microfossils, indicative of a glaciomarine environment (Peacock, 1999).

4.5.1.2 ST FERGUS SILT FORMATION

In the Peterhead–Cruden area, a separate formation, the St Fergus Silt Formation, is established (Peacock, 1999; Merritt et al., 2003), which may be a correlative of the Errol Formation but which is probably older.

Name
St Fergus Silt Formation (SFSI) (after Peacock, 1999 and Merritt et al., 2003).

Lithology
A dark grey, silty clay with laminae of sand and well-dispersed gravel drop-stone clasts, containing boreal to boreal arctic marine microfossils.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 10).

Type area/Reference section
Type section: BGS registered borehole NK15SW1 [NK 1030 5344], 1.9–17.9 m depth (McMillan and Aitken, 1981).

Lower and upper boundaries
A sharp, undulating, unconformable contact with underlying till, comprising grey, pebbly clayey diamicton, yellowish brown, gravelly, clayey sand diamicton, and reddish brown gravelly silty sandy clayey diamicton.

A gradational contact with overlying organic silts and clays, interpreted as lacustrine alluvium.

Landform description and genetic interpretation
Glaciomarine to glaciolacustrine depositional environment.

Thickness
Up to 16 m.

Distribution and extent
Buchan, north-east Scotland (BGS 1:50 000 Sheets S87E and 97).

Age
Late Devensian, Dimlington Stadial (MIS 2).

4.5.1.3 KESSOCK BRIDGE SILT FORMATION

The Kessock Bridge Silt Formation of the Windermere Interstadial (MIS 2) of the Inner Moray Firth and Beauly Firth is here formally defined (Figure 8).

Name
Kessock Bridge Silt Formation (KEBR) (after Merritt et al., 1995; Kessock Bridge Member of Clava Formation of Sutherland, p. 103 in Bowen, 1999).

Lithology
Clayey silt and fine-grained sand with well-dispersed, angular lithic pebbles, chiefly of psammite and sandstone. Shell fragments particularly common towards the top of the unit. Contains a mid-boreal, shallow-water fossil assemblage of Windermere Interstadial age.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 9).

Type area/Reference section
Type section: Commercial boreholes drilled along the line of the Kessock Bridge, Inverness [NH 687 455–NH 662 478] (Peacock and Wilkinson, 1995).

Lower and upper boundaries
Conformable contact with Ardersier Silt Formation.

Erosional contact with Longman Gravel Formation.

Landform description and genetic interpretation
Marine deposit.

Thickness
Up to 30 m.

Distribution and extent
Area around the Inner Moray Firth and Beauly Firth, Inverness. BGS 1:50 000 Sheet S84W.

Age
Late Devensian, Windermere Interstadial (MIS 2).

4.5.1.4 Informal Formations of Late Devensian to Holocene Age

Around the Cromarty Firth and Beauly Firth several other Late Devensian to Holocene units of marine and coastal origin are currently informally-defined formations of the British Coastal Deposits Group (Figure 8; Table 5; Auton et al., 1990; Fletcher et al., 1996).

Peacock et al. (1980) established from boreholes in the Cromarty Firth [NH 51 61] the following units: *Lower Findhorn Beds* (Culbokie Member of the Clava Formation of Sutherland, p. 103 in Bowen, 1999; **Culbokie Silt Formation**, MIS 2); *Upper Findhorn Beds* (Balmeanach Member of the Clava Formation of Sutherland, p. 103 in Bowen, 1999, **Balmeanach Silt Formation**, Loch Lomond Stadial, MIS 2–1); Ardullie Silt (Ardullie Member of the Cromarty Formation of Sutherland, p. 105 in Bowen, 1999, **Ardullie Silt Formation**, Holocene MIS 1); *Lower Cromarty Beds* (Lemlair Member of the Cromarty Formation of Sutherland, p. 106 in Bowen, 1999, **Lemlair Sand Formation**, Holocene, MIS 1) and *Upper Cromarty Beds* (Foulis Member of the Cromarty Formation of Sutherland, p. 106 in Bowen, 1999, **Foulis Silt Formation**, Holocene, MIS 1).

In the Moniack district [NH 540 440], south-east of Beauly, Firth and Haggart (1989) established the *Moniack Member* (Moniack Member of the Cromarty Formation of Sutherland, p. 105 in Bowen, 1999, named here informally the **Moniack Peat Formation**, Holocene, MIS 1) up to 15 m of dark brown to black peat, the *Barnyards Beds* (Barnyards Member of the Cromarty Formation of Sutherland, pp. 105–106 in Bowen, 1999, named here informally the **Barnyards Silt Formation**, Loch Lomond Stadial, MIS 2–1) 3 m of pink to grey laminated clayey silt; and the *Beauly Beds* (Beauly Member of the Cromarty Formation of Sutherland, p.106 in Bowen, 1999, named here informally the **Beauly Silt Formation**, Holocene, MIS 1), 4 m of grey silt and clay with shells. All may be provisionally correlated with units of the **Carse Clay Formation** of the Midland Valley of Scotland (Section 5.2.1.6).

In the south-west Highlands Late Devensian marine sediments (Windermere Interstadial to Loch Lomond Stadial, MIS 2–1) were described by Peacock et al. (1978) at Ardyne Point [NS 007 684]. Sutherland (p. 110 in Bowen, 1999), based on Peacock et al. (1978), established the Killellan, Toward and Ardyne Point members (currently not defined in the BGS Lexicon) of his Ardyne Formation which may be correlatives of the Paisley Clay and Linwood Clay Members of the Clyde Clay Formation (Section 5.2.1.3).

4.5.1.5 Holocene Beach-Dune-Machair Deposits

Beach-dune-machair systems of Holocene age occupy coastal areas in parts of the Highlands and Islands (Ritchie, 1975; Ritchie and Mather, 1974). The machair comprises mainly deposits of sand rich in shell debris, which in Orkney are locally underlain by aeolianite (cemented dune sand) (Nature Conservancy Council, 1978). These coastal deposits have not been formally defined lithostratigraphically, although there is potential for a framework to be developed. For example, the informal **Northton Formation** (Table 9) of Late Holocene age (stratotype at Northton, NF 980 911, South Harris) was recognised by Sutherland (p. 106 in Bowen, 1999) to include aeolian sands interstratified with thin palaeosols and lacustrine units.

4.6 BRITANNIA CATCHMENTS GROUP

4.6.1 Formations of the Britannia Catchments Group

Several organic and soils units ascribed to the Ipswichian Interglacial Stage (MIS 5e) or earliest Devensian (MIS 5a–d) have been recognised in the Grampian Highlands. Although most palaeosols are assigned as beds related to an underlying parent unit, the **Dalcharn Palaeosol** is elevated to formational status in the Britannia Catchments Group owing to its regional significance as a representative of the Ipswichian Stage (MIS 5e) or possibly the Hoxnian (MIS 11) (Tables 6 and 10). The **Teindland Palaeosol Formation** (MIS 5e) and the **Moy Burn Palaeosol Formation** (MIS 5a–d) are also formally defined (Tables 6 and 10). The organic units of Fugla Ness and Sel Ayre in Shetland (Hall et al., 1993a, 1993b; Sutherland, p.106–107 in Bowen, 1999) await definition in the BGS Lexicon (Table 9).

4.6.1.1 Dalcharn Palaeosol Formation

Name
Dalcharn Palaeosol Formation (DNPS) (after Walker et al., 1992, and Fletcher et al., 1996).

Lithology
Sandy, pebbly, clayey silt (diamicton), very dense, crudely laminated, fissile, olive-grey, with wisps of white, silty, pebbly sand, disseminated peaty material and charcoal. Pebbles are bleached white. Containing pollen of Interglacial aspect. Passing down into clayey, sandy, silty gravel (diamicton), matrix-supported, very dense, very pale grey to white, with disseminated black charcoal and peaty material. Gravel similar in composition to that occurring in Craig an Daimh Gravel Formation of the Inverness (Albion) Glacigenic Subgroup, but bleached white or pale yellow.

Formal subdivisions and correlation table
Subdivided into the Drummournie Biogenic Member (DMBG) and Rehiran Cryoturbate Member (RECR). (Tables 6 and 10).

Type area/Reference section
Type section: Exposed towards the base of river cliff section of the Allt Dearg [NH 815 452–NH 816 454], 6 km south-west of Cawdor, Nairnshire, at the Dalcharn Interglacial site (west).

Lower and upper boundaries
Gradational contact over 20–50 cm with weathered, clayey cobble gravel of the Craig an Daimh Gravel Formation of the Inverness (Albion) Glacigenic Subgroup.

Sharp, gently undulating, unconformable contact with stony sandy clayey diamicton of the Athais Till Formation (Inverness Glacigenic Group).

Landform description and genetic interpretation
Biogenic, organic and soil.

Thickness
1.6 m.

Distribution and extent
BGS Sheet S84W (Fortrose), south-east of Inverness.

Age
Ipswichian (MIS 5e) or possibly Hoxnian (MIS 11).

4.6.1.2 Teindland Palaeosol Formation

Name
Teindland Palaeosol Formation (TELND) (Teindland Buried Soil of Hall et al., 1995a; Teindland Palaeosol Bed of Sutherland, p. 102 in Bowen, 1999, and Merritt et al., 2003).

Lithology
The Teindland Palaeosol Formation is developed on the surface of the Orbliston Sand Bed and is podzolic in character. It comprises a thin redeposited humic 'H' horizon, a bleached 'Ea' horizon up to 15 cm thick, an intermittently developed iron pan and a lower 'strong brown' 'Bs' horizon, 5–15 cm thick. Overlying the humic horizon are thin layers of organic sand with charcoal fragments. At Teindland Quarry, the Badentinan Sand Bed (Moy Burn Palaeosol Formation), up to 1.5 m thick, overlies the organic sands. The lower 80–100 cm comprises parallel thin beds of brown polleniferous sand. This pollen was partly derived from reworking of soils around the site and partly from contemporaneous sparse grassland. The upper 50–70 cm of the sand is non-polleniferous. The presence of small gravel clusters, silt balls, an isoclinal fold and of shear zones suggest a glacial or glaciotectonic influence on, or more likely following, deposition in a small pond. The formation is less well-developed at Red Burn, where the parent material is a greenish grey sandy diamicton and where the overlying organic sediments are thin and disturbed by cryoturbation.

Formal subdivisions and correlation table
Includes the Fernieslack Palaeosol Bed (FSLCK) (Kirkhill Quarry) (Tables 6 and 10).

Type area/Reference section
Type section: Teindland Quarry [NJ 297 570], a small sand and gravel pit, which is located in Teindland Forest, 5 km south-west of Fochabers, Morayshire.

Partial reference section: Pipeline trench, since reinstated, located 700 m south-west of Teindland Quarry [NJ 294 568] (Hall et al., 1995a).

Lower and upper boundaries
At Teindland Quarry, the formation rests unconformably on up to 3 m of very pale brown sand (Orbliston Sand Bed of the Deanshillock Gravel Formation). At the Red Burn site, the formation rests unconformably on a unit of sand with sporadic clasts, that appears to correlate with the Deanshillock Gravel Formation at the base of the known sequence at Teindland Quarry.

At Teindland Quarry, the organic sediments of the formation are overlain by up to 2.2 m of bedded sandy diamicton, the Woodside Diamicton Formation (currently informal, after Merritt et al., 2003, p. 121; Woodside Member of Sutherland, p. 102 in Bowen, 1999), with crude parallel bedding and localised wash horizons.

Landform description and genetic interpretation
Pollen analysis of the formation and the overlying organic sands shows that the earliest vegetation recorded at the site was woodland of 'interglacial' character with grassland openings. Pine and alder are represented at Teindland, and alder and hazel at Red Burn. Podzolisation of the palaeosol ended with an influx of sands derived from erosion of the surrounding slopes, perhaps in response to burning during a grassland phase. The combined evidence of environmental deterioration from pollen and sediments suggests events characteristic of the end of an interglacial episode.

Thickness
Less than 4 m.

Distribution and extent
Morayshire.

Age
Ipswichian (MIS 5e). Luminescence dates of 79 and 67 ka BP for the sands (Badentinan Sand Bed) overlying the soil suggest that the soil developed towards the close of the Ipswichian Stage.

4.6.1.3 Moy Burn Palaeosol Formation

Name
Moy Burn Palaeosol Formation (MBP) (after Walker et al., 1992, and Fletcher et al., 1996; Allt Odhar Formation of Sutherland, p. 105 in Bowen, 1999).

Lithology
Peat: highly compressed, black, with lenses of pebbly, peaty sand and bleached white sand conformably overlying cobble gravel with lenses of finer gravel and sand.

Formal subdivisions and correlation table
At the Allt Odhar type section subdivided into the Allt Odhar Peat Member (AOPT) and Odhar Gravel Member (ODGR). Other units referred to the formation include the Badentinan Sand Bed (Teindland Quarry), Crossbrae Farm Peat Bed (CBFMP) (Crossbrae), Berryley Peat Bed (BLYP) (Moss of Cruden, Buchan), Moreseat Farm Sand Bed and Burn of Benholm Peat Bed (BBP) (Stonehaven) (Tables 6 and 10).

Type area/Reference section
Type section: Exposed midway up a river cliff of the Allt Odhar, immediately upstream of its confluence with the Caochan nan Suidheig [NH 798 368], Moy Estate, 16 km south-east of Inverness. Till occurs both lower and higher in this section.

Reference section: Camp Fauld [NK 049 410], Moss of Cruden, west of Peterhead. The Berryley Peat Bed and underlying Moreseat Farm Sand Bed rest unconformably on the Camp Fauld Till Formation (Section 4.3.3.1). The Moreseat Farm Sand Bed is considered to be Ipswichian (MIS 5e) in age (Whittington et al., 1993; Merritt et al., 2003). The Berryley Peat Bed lies below the Aldie Till Member (Whitehills Glacigenic Formation).

Lower and upper boundaries
The Odhar Gravel Member has a sharp, erosional, undulating contact with underlying sandy, clayey diamicton of the Suidheig Till Formation.

The Allt Odhar Peat Member is unconformably overlain by or has a glaciotectonic contact with stiff, stony sand and clayey diamicton of the overlying Athais Till Formation.

Landform description and genetic interpretation
Organic and fluvial deposits.

Thickness
2.6 m, of which the Allt Odhar Peat Member is 0.6 m.

Distribution and extent
South-east of Inverness (BGS 1:50 000 Sheet S84W).

Age
Ipswichian to Early Devensian (MIS 5e–a).

Odhar Gravel Member (ODGR)

The Odhar Gravel Member comprises 2 m of cobble gravel with lenses of finer gravel and sand. The deposit is dense, mainly clast-supported, containing subangular to rounded clasts of pink granite with psammites, gneiss and schist. All but the psammite clasts are commonly weathered. An iron-pan is commonly developed.

Allt Odhar Peat Member (AOPT)

The Allt Odhar Peat Member comprises 0.6 m of highly compressed, black peat, with lenses of pebbly, peaty sand and bleached white sand. The deposit contains beetle remains and pollen indicative of (early Devensian) interstadial conditions. At the Allt Odhar type section (see above) the contact between Allt Odhar Peat and the overlying Kincraig Paraglacial Bed (Athais Till Formation, Section 4.4.4.4), is gradational.

In the Cromarty Firth and Beauly Firth areas, sequences of organic and lacustrine deposits of Late Devensian to Holocene age, described by Auton et al. (1990) and Fletcher et al. (1996), are referred to the Britannia Catchments Group. The informal **Moniack Peat Formation** (MIS 1) (Section 4.5.1.4; Tables 5 and 9) together with other named gelifluctate, gravel and peat beds of similar age in the Eastern Grampian Highlands (Table 10) remain to be defined in the BGS Lexicon.

In Argyll, formal units for the organic and fluvial deposits of Holocene age (MIS 1) (cf. the Argyle Formation of Sutherland, p. 111 in Bowen, 1999; Table 9) remain to be defined in the BGS Lexicon.

Fluvial deposits (alluvium and river terrace deposits) of the Highlands mainland are currently assigned to two subgroups, the **Grampian Catchments** and the **Northern Highlands and Argyll Catchments** subgroups.

4.6.2 Grampian Catchments Subgroup

The Grampian Catchments Subgroup of the Britannia Catchments Group (Table 10, Figure 8) encompasses the mainly late-Devensian and Holocene alluvial and river terrace deposits that occur in the Grampian Highlands. Formally named units are presently restricted to the deposits occurring around the Beauly, Cromarty and Moray firths. Fluvial, lacustrine and organic deposits of each substantial river system, defined by river catchment, are placed in a separate formation. Currently one formation is defined, the **Strath Spey Formation**. Organic (peat), aeolian (blown sand) and mass movement (head) deposits are retained as lithogenetic units of the Britannia Catchments Group.

Name
Grampian Catchments Subgroup (GRCA) (after McMillan et al., 2005).

Lithology
Sand, gravel, clay and organic deposits. Sand, gravel, and boulders include clasts derived from rocks cropping out in the eastern Grampian Mountains and Buchan.

Formal subdivisions and correlation table
Strath Spey Formation (Tables 6 and 10).

Type area/Reference section
Type area: The Eastern Grampian Highlands and Aberdeenshire and Moray Firth lowlands.

Lower and upper boundaries
Unconformable contact with units of the Central Grampian, East Grampian, Inverness, Banffshire Coast and Caithness, and Logie-Buchan Glacigenic subgroups, and with bedrock.

Generally the ground surface, but units of this subgroup locally interfinger with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
Alluvium and river terrace deposits, and associated organic and lacustrine deposits.

Thickness
Up to 25 m.

Distribution and extent
The Eastern Grampian Highlands and Buchan.

Age
Devensian to Holocene (MIS 2–1).

4.6.2.1 Strath Spey Formation

Name
Strath Spey Formation (SPEY) (after McMillan et al., 2005).

Lithology
Mainly sand and gravel forming river terraces and silty, clayey sand forming floodplains and concealing sand and gravel. Includes units of silty sand, silt, clay and peat.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 10).

Type area/Reference section
Type area: the valley of the River Spey and its tributaries, Grampian Highlands [NN 400 900–NJ 400 650].

Lower and upper boundaries
Sharp, undulating, erosional contact, mainly on yellowish brown tills (diamicton) of the Central Grampian, East Grampian or Banffshire Coast and Caithness Glacigenic subgroups, or on bedrock.

Ground surface, locally covered by peat.

Landform description and genetic interpretation
River terrace floodplain deposits.

Thickness
Up to 25 m.

Distribution and extent
The valley of the River Spey and its tributaries, Grampian Highlands.

Age
Devensian to Holocene (MIS 2–1).

4.6.2.2 Late-Glacial Organic Deposits

Peat, organic muds and organic-rich sand occur at numerous sites in north-east Scotland buried by later sediments (Merritt et al., 2003). Most commonly found are Late Glacial organic deposits (Gunson, 1975), chiefly lake or pond muds and thin peat beds, organic muds and sands. The pollen record from these sites reveals that in the Windermere Interstadial, from about 13 000 BP, an initial phase of open habitat vegetation was succeeded by closed heath and scrub vegetation, with local growth of tree birch and pine. After about 11 500 BP, the temperature began to decline and tundra vegetation had become established by the start of the Loch Lomond Stadial at 11 000 BP. Beds named by Merritt et al. (2003) and assigned to the Grampian Catchments Subgroup include the *Garral Hill Peat Bed* (11 888 ± 225–10 808 ± 230 BP, Godwin and Willis, 1959), under the *Garral Hill Gelifluctate Bed* (remobilised till) at Garral Hill [NJ 444 551], Keith; the *Woodhead Peat Bed* (10 780 ± 50 BP, Connell and Hall, 1987) under the *Woodhead Gelifluctate Bed* (remobilised till) at Woodhead [NJ 788 384], Fyvie; the *Loch of Park Gytta Bed* (11 900 ± 260–0 280 ± 220, Vasari and Vasari, 1968), kettlehole infill at Loch of Park [NO 72 988]; the *Mill of Dyce Peat Bed* (11 640 ± 70–11 550 ± 80, Harkness and Wilson, 1979), kettlehole infill at Mill of Dyce [NJ 8713 1496]; and the *Glenbervie Peat Bed* (12 460 ± 130–12 305 ± 50), peat under remobilised till at Glenbervie [NO 767 801].

At Howe of Byth [NJ 822 471] the *Thinfolds Peat Bed*, up to 1 m thick, lies within a shallow basin on the surface of the Byth Till Formation. Pollen analysis shows typical Late Glacial (Windermere) Interstadial pollen assemblages, supported by a radiocarbon age determination of about 11.3 ka BP (SRR-4830) (Hall et al., 1995a; Merritt et al., 2003). The peat is overlain by about 1 m of cryoturbated gravel, the *Todholes Gravel Bed*.

4.6.3 Northern Highlands and Argyll Catchments Subgroup

The Northern Highlands and Argyll Catchments Subgroup of the Britannia Catchments Group includes all of the late-glacial and post-glacial deposits within river catchments of the Northern Highlands and Argyll (Figures 4 and 9, Tables 6 and 9). The subgroup contains a similar suite of deposits to those of the Grampian Catchments Subgroup, but the drainage basins of the rivers are much less extensive than those of the Cromarty area. Few of the Northern Highland sequences have been surveyed in detail, but it is recommended that typical fluvial-lacustrine-organic sequences of each the major river systems (such as those within the Helmsdale and Halladale river catchments) are assigned formation status (Figure 9). Late Devensian and Holocene deposits in smaller adjacent catchments may also be assigned to these formations. Currently one formal unit has been established. Organic (peat), aeolian (blown sand) and mass movement (head) deposits are retained as lithogenetic units of the Britannia Catchments Group.

Name
Northern Highlands and Argyll Catchments Subgroup (NHC) (after McMillan et al., 2005).

Lithology
Sand, gravel, silt, and clay. Clasts are derived from sedimentary, metamorphic and igneous rocks cropping out in the northern and western Highlands and Argyll.

Formal subdivisions and correlation table
Longman Gravel Formation; currently mainly lithogenetic units (Tables 6 and 9).

Type area/Reference section
Type area: Valleys of the northern and western Highlands, western Grampians and Argyll.

Lower and upper boundaries
Unconformable contact with units of the Northwest Highlands Glacigenic Subgroup, the Central Grampian Glacigenic Subgroup, the Banffshire Coast and Caithness Glacigenic Subgroup, and with bedrock.

Generally the ground surface, but units of this Subgroup locally interfinger with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of fluvial (alluvium, river terrace) and associated organic and lacustrine deposits.

Thickness
Up to 25 m.

Distribution and extent
The northern and western Highlands, western Grampians and Argyll.

Age
Devensian to Holocene (MIS 2–1).

4.6.3.1 Longman Gravel Formation

Name
Longman Gravel Formation (LNGR) (after Peacock, 1977, Merritt et al., 1995, and Fletcher et al., 1996).

Lithology
Cobble gravel with sand and clay, and sparse shell fragments.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 9).

Type area/Reference section
Type section: Site investigation boreholes (570 L3–11 and M1–6) (BGS Registered Nos. NH64SW16839 and NH64NW17718 suffixes 1–7 [NH 687 455–NH 662 478] drilled along the line of the Kessock Bridge, Inverness (Merritt et al., 1995).

Lower and upper boundaries
An undulating, channelled and erosional unconformable contact with the underlying clayey silt and fine-grained sand of the Kessock Bridge Silt Formation.

The present ground surface or a sharp, generally planar, erosional and unconformable contact with the overlying Holocene raised beach deposits.

Landform description and genetic interpretation
Deltaic deposit.

Thickness
About 30 m.

Distribution and extent
The area around the Inner Moray Firth and Beauly Firth, Inverness. BGS Sheet Scotland 87W (Fortrose).

Age
Late Devensian, Loch Lomond Stadial (MIS 2–1).

4.6.4 Catchments of the Scottish islands

Fluvial, organic, lacustrine and mass movement sediments of the Scottish islands are currently informally defined within the Britannia Catchments Group. A possible Early Devensian peat bed, the *Toa Galson Bed* (Table 9), overlain by interbedded succession of sand, diamicton and sand and gravel, is described from a cliff section [NB 448 600] on the west coast of the Isle of Lewis (Sutherland and Walker, 1984; Sutherland, p.106, in Bowen, 1999). Mid Devensian organic deposits (the *Tolsta Head Member* of the Lewis Formation of Sutherland, p. 106 in Bowen, 1999) at Tolsta Head [NB 5572 4682] on the east coast of Lewis are unconformably overlain by diamicton of the Port Beag Till Formation (Section 4.4.2.2) (Gordon and Sutherland, 1993b).

5 Midland Valley of Scotland

The oldest superficial deposits of this district are of glacigenic origin and of pre-Late Devensian age (Caledonia Glacigenic Group): the most extensive deposits relate to the Late Devensian including the Loch Lomond Stadial. Deposits of the Britannia Catchments Group and British Coastal Deposits Group range in age from Late Devensian to Holocene.

The stratigraphical framework is based on the research of Rolfe (1966), Dickson et al. (1976), Rose (1981), Rose et al. (1988), Browne and McMillan (1989), and Hall et al. (1998) in west–central Scotland, Jardine et al. (1988) in Ayrshire, Kirby (1968, 1969a,b), Francis et al. (1970), Browne et al. (1984) and Barras and Paul (1999) in the Forth valley and Paterson et al. (1981) and Armstrong et al. (1985) in the Tay–Earn area. One of the difficulties with the Geological Society's Revised Correlation report for the region (Sutherland, pp. 107–114 in Bowen 1999) is that some all-embracing formations (e.g. the Clyde Valley Formation of Sutherland, p. 109 in Bowen, 1999 — redefined in the present report to include only fluvial and related organic deposits: Section 5.3.2.1) are not useful for mapping purposes. This account favours a systematic modification of previously proposed formations, which it is considered will be of use for correlation.

5.1 CALEDONIA GLACIGENIC GROUP

Most of the glacigenic and meltwater deposits relate to the Main Late Devensian Glaciation, sourced predominantly from the Grampian Highlands, Rannoch Moor in the west and, to a lesser extent the Cairngorms in the east. A subsidiary southerly source from the Southern Uplands is recognised in parts of Midlothian and Lanarkshire (McCall and Goodlet, 1952; McMillan et al., 1981). Formations of four glacigenic subgroups are established.

5.1.1 Mearns Glacigenic Subgroup

The Mearns Glacigenic Subgroup (Tables 8, 10 and 11; Figures 5 and 6) (Mearns Drift Group of Merritt et al., 2003) is restricted to Strathmore and Angus and comprises interbedded diamictons, glaciolacustrine silts and clays, and glaciofluvial sands and gravels that are all typically vivid reddish brown in colour. Sutherland (p. 114 in Bowen, 1999) referred all of the deposits to members of the Mill of Forest Formation. The clasts are mostly derived from the Devonian conglomerates and andesitic volcanic rocks of Strathmore, whereas till matrices and fine-grained deposits are derived mainly from Devonian sandstones and mudstones. The subgroup broadly equates with the southern outcrop of the 'Red Series' of Bremner (1916), Sutherland (1984), Hall and Connell (1991) and Sutherland and Gordon (1993). The deposits were laid down by, or at the margins of, Late Devensian ice that flowed north-eastwards into the North Sea basin from Strathmore.

Name
Mearns Glacigenic Subgroup (MDR) (after McMillan et al., 2005; Devensian formations of the Mearns Drift Group of Merritt et al., 2003).

Lithology
Till, sand and gravel and laminated silt composed principally of decomposed Silurian and Devonian rocks and associated with deposition from glacial ice of the Strathmore ice-stream.

Formal subdivisions and correlation table
Subdivided into three formations: Sections 5.1.1.1–5.1.1.3 and Tables 8, 10 and 11.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock.

Ground surface or unconformably overlain by Holocene deposits.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Very variable, generally 5–10 m, but in excess of 24 m proved in boreholes.

Distribution and extent
Strathmore, east of Perth, and as isolated spreads along the coast between Stonehaven and the mouth of the River Dee.

Age
Devensian (MIS 5d–2).

5.1.1.1 Mill Of Forest Till Formation

Name
Mill of Forest Till Formation (MFT) (after Merritt et al., 2003, p. 129).

Lithology
Sandy diamicton, red-brown with clasts predominantly of Devonian rocks.

Formal subdivisions and correlation table
Arbikie Diamicton Member (ARBI) (Tables 8, 10 and 11).

Type area/Reference section
Type section: River cliff on the north side of the Carron Water [NO 8617 8545–NO 8624 8532], 200 m downstream (east) of Mill of Forest Farm, Stonehaven.

Reference section: BGS trial pit, reference number NO77NW1 [NO 7110 7897], about 320 m south-west of Drumelzie Farm, near Auchenblae, 0.3–3.8 m depth.

Reference section: BGS trial pit, reference number NO77NE11 [NO 7805 7966], 250 m north-east of East Mondynes, 0.3–3.2 m depth.

Lower and upper boundaries
Unconformable on pre-Late Devensian deposits or bedrock. The Burn of Benholm Peat Bed (BBP) is in tectonic contact with the overlying diamicton of the Mill of Forest Till

Formation and rests with tectonic contact on the Benholm Clay Formation (Figure 6).

Generally conformably overlain by Ury Silts Formation and Drumlithie Sand and Gravel Formation (Figure 6).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Very variable, generally 5–8 m, up to 7 m exposed at type section.

Distribution and extent
Howe of Mearns area and flanking the coastline between Stonehaven and the mouth of the River Dee.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Arbikie Diamicton Member (ARBI)

The Arbikie Diamicton Member comprises up to 1.3 m of red-brown, silty clayey, stony sand diamicton. It overlies reddish brown, pebbly sand (un-named) or rests unconformably on bedrock.

5.1.1.2 Ury Silts Formation

Name
Ury Silts Formation (USI) (after Merritt et al., 2003, p. 129).

Lithology
Laminated silt and clay, generally red-brown.

Formal subdivisions and correlation table
No subdivisions (Tables 8, 10 and 11).

Type area/Reference section
Reference section: Cliff exposure [NO 8300 7350], 550 m south of Pitcorry Farmhouse, Inverbervie.
Reference section: BGS borehole Registered No. NO88NW13 [NO 8389 8514] at Craigie's Wood, Stonehaven, from 6.5–12.8 m depth in borehole.
Partial type section: BGS borehole Registered No. NO88NE4 [NO 8557 8897], 20 m west of the Houff of Ury, Stonehaven, from 14.5–18.5 m depth in borehole.

Lower and upper boundaries
Generally conformable on Mill of Forest Till Formation.

Generally overlain conformably by the Drumlithie Sand and Gravel Formation.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
Very variable, generally 3–4 m; 7.7 m proved in boreholes.

Distribution and extent
Howe of Mearns area and flanking the coastline between Stonehaven and the mouth of the River Dee.

Age
Late Devensian, Dimlington Stadial (MIS 2).

5.1.1.3 Drumlithie Sand and Gravel Formation

Name
Drumlithie Sand and Gravel Formation (DSG) (after Merritt et al., 2003, p. 129).

Lithology
Sand and gravel, red-brown, with clasts predominantly of Devonian sandstone, mudstone and andesite. Locally with lenses of silt and clay.

Formal subdivisions and correlation table
No subdivisions (Tables 8, 10 and 11).

Type area/Reference section
Reference section: British Geological Survey borehole Registered No. NO78SE4 [NO 7848 8066], at Orchard Hill, Drumlithie, from 0.3–3.4 m depth in borehole.
Reference section: British Geological Survey borehole Registered No. NO77NE1 [NO 7526 7888] at Causeywell Brae, about 2.2 km east of Auchenblae, from 0.1–23.5 m depth in borehole.
Partial type section: Kaim of Clearymuir Gravel Pit [NO 7983 8149], 1.3 km east-north-east of Drumlithie Crossroads.

Lower and upper boundaries
Unconformable on bedrock or the Lunan Clay Member of the Errol Clay Formation. Elsewhere the unit is conformable on Mill of Forest Till Formation or Ury Silts Formation.

Either at the ground surface or unconformably overlain by Holocene deposits.

Landform description and genetic interpretation
Glaciofluvial sand and gravel.

Thickness
Very variable, generally 5–10 m; more than 23 m proved in boreholes.

Distribution and extent
Howe of Mearns area and flanking the coastline between Stonehaven and the mouth of the River Dee.

Age
Late Devensian, Dimlington Stadial (MIS 2).

5.1.2 Midland Valley Glacigenic Subgroup

The Midland Valley Glacigenic Subgroup (Tables 8 and 11; Figures 10a and 10b) extends over most of the Midland Valley of Scotland. It comprises glacial, glaciofluvial and glaciolacustrine formations of mainly Late Devensian age. Deposits associated with the Loch Lomond Stadial glaciers emanating from the southern Grampian Highlands are referred to the Central Grampian Glacigenic Group (Section 5.1.3). The deposits of west-central Scotland including the Clyde Valley and Loch Lomond district have been the subject of detailed research over the past forty years (e.g. Rolfe, 1966; Rose and Letzer, 1977; Jardine, 1980; Rose, 1981; Jardine et al., 1988; Browne and McMillan, 1989; Finlayson et al., 2010).

Name
Midland Valley Glacigenic Subgroup (MVG) (after McMillan et al., 2005).

Lithology
Till (diamicton), sand, gravel, silt and clay. The deposits contain clasts derived predominantly from Carboniferous

to Permian sedimentary rocks (sandstone, siltstone, and mudstone) and volcanic and intrusive rocks (basalt, microdiorite) of the Midland Valley of Scotland with varying but minor proportions of Dalradian metasedimentary rocks (metasandstone, metapelite) and Caledonian igneous rocks (granite, granodiorite, and gabbro). In contrast to the Mearns Glacigenic Subgroup of the Strathmore Basin, with red tills dominated by clasts and matrix of Devonian origin, the Midland Valley Glacigenic Subgroup tills have characteristically grey and brownish grey matrices. However, locally they can be red where the diamictons are derived from red sandstone or reddened measures (e.g. Upper Coal Measures, Permian strata and small outcrops of Devonian rocks).

Formal subdivisions and correlation table
Subdivided into seven formations: Sections 5.1.2.1–5.1.2.7 and Tables 8 and 11.

Type area/Reference section
Type area: the Midland Valley of Scotland.

Lower and upper boundaries
Sharp, unconformable contact with bedrock. Pre-Ipswichian Quaternary deposits are not proven within the Midland Valley of Scotland.

Unconformable contact with units of the Britannia Catchments Group (Forth Catchments Subgroup, Tay Catchments Subgroup, Clyde Catchments Subgroup) and the British Coastal Deposits Group.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial and glaciolacustrine deposits. The sediments were deposited by or are the deglaciation products of ice that emanated from the western Grampian Highlands and streamed generally eastwards across the Midland Valley of Scotland.

Thickness
Up to 100 m.

Distribution and extent
The Midland Valley of Scotland (most of Strathclyde, Stirlingshire, the Lothians and Fife) excluding Arran. Approximately bounded to the south by the line of the Southern Upland Fault. Units of the subgroup may occur locally beyond these geographical boundaries and beyond the approximate surface boundaries with adjacent glacigenic subgroups. Units may also extend offshore.

Age
Devensian (MIS 5d–2).

5.1.2.1 Baillieston Till Formation

On the eastern fringes of Glasgow at Baillieston subsurface data and temporary sections reveal deposits of the pre-Late Devensian Baillieston Till Formation (Baillieston Formation of Browne and McMillan, 1989; Baillieston Member of the Clyde Valley Formation of Sutherland, p. 109 in Bowen, 1999). In temporary sections at the Baillieston M8 Motorway Interchange it consists of up to 14 m of stiff to hard, reddish brown till.

Name
Baillieston Till Formation (BNTI) (after Browne and McMillan, 1989).

Lithology
The typical lithology is a till (diamicton), composed of isolated boulders, gravel and pebbles in a matrix of sandy silty clay. The more elongated clasts are preferentially orientated and the deposit usually has systematic sets of joints. The deposit is of a stiff to hard consistency and low plasticity. In general the colour of the till reflects that of the local bedrock so may be totally different from one area to the next and can be reddish brown (Devonian and Upper Coal Measures) or brownish grey or black (Carboniferous).

Formal subdivisions and correlation table
No subdivisions (Table 11).

Type area/Reference section
Type area: Clyde valley between Erskine Bridge [NS 450 730] and Baillieston Interchange [NS 700 640].

Lower and upper boundaries
Unconformity or glacial deformation boundary on bedrock or on assumed older (usually unclassified) Quaternary strata.

Unconformity or glacial deformation boundary below younger Quaternary strata. Where data are available the Baillieston Till Formation is seen to be overlain by the Broomhill Clay Formation and/or the Cadder Sand and Gravel Formation or the Wilderness Till Formation.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
From a veneer to over 20 m.

Distribution and extent
Glasgow area.

Age
Early Devensian (MIS ?4).

5.1.2.2 Broomhill Clay Formation

Glaciolacustrine sediments of the Broomhill Clay Formation (Broomhill Formation of Browne and McMillan, 1989; Broomhill Member of the Clyde Valley Formation of Sutherland, p. 109 in Bowen, 1999) have been proved in several boreholes and in temporary sections for the Baillieston M8 Motorway Interchange.

Name
Broomhill Clay Formation (BRLL) (after Browne and McMillan, 1989).

Lithology
The typical lithology is thinly-bedded silty clay with wisps, laminae and bands of silt and, locally, sand. The deposit is reddish brown in colour with grey or buff silt and sand. Isolated clasts up to 14 cm mean diameter are present and are considered to be drop-stones. The deposit is of a hard to stiff consistency and medium to high plasticity. Thin diamicton bands and patches occur locally, with some graded bedding (turbidity flows) and microfaulting. Laminations are probably varves, and, if so, together represent 600–1000 years of sedimentation.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 11).

Type area/Reference section
Type section: The Erskine Bridge Borehole [NS 4634 7251], BGS Registered No. NS47SE 18 (Browne and McMillan, 1989, fig. 11) contains the standard section for the Broomhill Clay Formation (from 16.31–32.75 m depth). Its stratigraphical position between the Baillieston and Wilderness till formations is clearly established here (see also Browne and McMillan, 1989, figs. 3B and D).

Type section: Broomhill Park Borehole No.2 [NS 5985 6650] (Browne and McMillan, 1989; Forsyth et al., 1996).

Lower and upper boundaries
Unconformity on older Quaternary strata such as the Baillieston Till Formation or bedrock, or a glacial deformation boundary.

Unconformably overlain by younger Quaternary strata or most commonly a glacial deformation boundary with the overlying glacial diamicton of the Wilderness Till Formation.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
From a veneer to over 15 m.

Distribution and extent
Glasgow area.

Age
Early Devensian (?MIS 4).

5.1.2.3 Cadder Sand and Gravel Formation

In the Kelvin valley and under western Glasgow thick deposits of sand and gravel referred to the Cadder Sand and Gravel Formation (Cadder Formation of Browne and McMillan, 1989; Cadder Member of the Clyde Valley Formation of Sutherland, p.109 in Bowen, 1999) occur under the Wilderness Till Formation formed during the Main Late Devensian Glaciation. An age of 27 550 + 1370/-1680 14C BP on a humerus of woolly rhinoceros *(Coelodonta antiquitatis)* was obtained from a fine-grained sand bed within the formation at Wilderness Pit [NS 60060 72297], Bishopbriggs (Rolfe, 1966). This age was questioned by Sutherland (1984). A new AMS radiocarbon determination of 35 864–34 675 cal BP on the humerus from Wilderness Pit, following ultrafiltration pre-treatment, indicates that western central Scotland was ice-free at this time (Jacobi et al., 2009).

Name
Cadder Sand and Gravel Formation (CADR) (after Browne and McMillan, 1989).

Lithology
The typical lithological assemblages consist of mainly framework-supported bouldery gravel and sand, and coarse to fine-grained, locally pebbly, sand with silt. In a geotechnical sense, the deposits are usually dense to very dense. Much of the gravel is thickly-bedded and trough cross-bedded in sets up to 3 m thick. These interfinger with sands. The sands are trough cross-bedded, ripple-laminated and horizontally laminated.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 11).

Type area/Reference section
Type section: Temporary sections at Wilderness Plantation north of Bishopbriggs [NS 6050 7200–NS 3410 7768].

Lower and upper boundaries
Unconformity on bedrock or on older unnamed Quaternary strata or the Baillieston Till Formation.

Unconformity or glacial deformation boundary below younger Devensian till deposits, mainly the Wilderness Till Formation.

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
From a veneer to more than 45 m.

Distribution and extent
Central Scotland, related to ice streams sourced in the Highlands (in contrast to the Southern Uplands); currently identified in the Glasgow area.

Age
Possible Early Devensian (MIS 4).

5.1.2.4 Wilderness Till Formation

The till sheet of the Wilderness Till Formation (Wilderness Till of Rose, 1981 and Rose et al., 1988; Wilderness Formation of Browne and McMillan, 1989; Wilderness Member of the Clyde Valley Formation of Sutherland, p. 109 in Bowen, 1999) may be correlated across much of west–central Scotland. Following the classification of Rose et al. (1988), the Wilderness Till Formation is named after the Wilderness Plantation, north of Bishopbriggs [NS 605 720] (Browne and McMillan, 1989; Hall et al., 1998). In this area the formation comprises a hard, reddish brown, sandy, silty diamicton which rests with stepped but low-angle disconformity on a thick series of cross-bedded sands and gravels of the Cadder Sand and Gravel Formation (Section 5.1.2.3).

Name
Wilderness Till Formation (WITI) (after Rose, 1981, Rose et al., 1988, and Browne and McMillan, 1989).

Lithology
The typical lithology is a till (diamicton) composed of isolated boulders, cobbles, gravel and pebbles in a matrix of sandy silty clay. The more elongate clasts are preferentially oriented and the deposits usually have systematic sets of joints. It is of a hard to stiff consistency and low plasticity. The colour varies, depending upon that of the local bedrock, and can be reddish brown (Devonian and Upper Coal Measures), brownish grey or black (Carboniferous) and also greenish grey (Highland metamorphic rocks). Minor features include pockets and bands of medium-grained sand and laminated clay bands up to 10 cm thick. In the Cadder area, temporary sections revealed that the diamicton is locally graded, displaying both upward and downward coarsening of the dispersed pebble to boulder-sized clasts. At Baillieston, the till includes slices (one of considerable size, estimated to be tens of metres long and up to 10 m thick) of laminated clay sandwiched between two discordant planes (low angle thrusts) near the base of the formation.

Formal subdivisions and correlation table
Auchenwinsey Till Member and Eglinton Shelly Till Member. Tables 8 and 11.

Type area/Reference section
Type section: Temporary sections at Wilderness Plantation [NS 6050 7200–NS 3410 7768], north of Bishopbriggs.

Reference section: BGS Bellshill Borehole [NS 7304 6161], BGS Registered No. NS76SW 451.

Lower and upper boundaries
Unconformity or glacial deformation boundary on bedrock or on older Quaternary strata, e.g. the Cadder Sand and Gravel Formation.

Unconformity below younger Quaternary strata, or a glacial deformation boundary that is partly represented by the upper surface of drumlinoid landforms. These landforms are commonly seen at surface but may also form buried features in the Glasgow conurbation.

Landform description and genetic interpretation
Commonly drumlinoid landforms.

Thickness
Up to over 30 m.

Distribution and extent
Onshore, Central Scotland, related to ice streams sourced in the Highlands (in contrast to the Southern Uplands) during the Dimlington Stadial; Glasgow area, Ayrshire, Stirling, Clackmannan, Tayside, north and south Lanarkshire, Lothians and Edinburgh, Fife.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Two members of the Wilderness Till Formation are defined in Central Ayrshire (see also Section 5.1.2.7)..

EGLINTON SHELLY TILL MEMBER (ESHTI)

The organic deposits of the Sourlie Organic Silt Formation (Section 5.3.1.1) are overlain by up to 3.5 m of pinkish brown, very stiff, pebbly sandy silty clayey diamicton containing clasts of local sandstone, mudstone, coal and dolerite, 'far-travelled sedimentary, igneous and metamorphic rocks' and shell fragments, including sparse paired valves of marine molluscs yielding Late Devensian amino acid ratios (Jardine et al., 1988). This unit (Eglinton Member of the Sourlie Formation of Sutherland, p. 109 in Bowen, 1999), is here named the Eglinton Shelly Till Member of the Wilderness Till Formation. It is similar to the shelly lodgement tills of Ayrshire. It is probably a deformation till, which elsewhere contains rafts of cold-water marine silts and clays, notably at Afton Lodge.

AUCHENWINSEY TILL MEMBER (AWTI)

The uppermost glacigenic unit at Sourlie comprises up to 12 m of stiff, dark grey 'lodgement till' of similar composition to the Littlestone Till Formation, but containing relatively more basic igneous rock types. This unit (Upper grey diamicton of Jardine et al., 1988; Auchenwinsey Member of the Sourlie Formation of Sutherland, p. 109 in Bowen, 1999) is named here as the Auchenwinsey Till Member of the Wilderness Till Formation. It forms most of the drumlin into which the opencast site was excavated and its base is defined by a 'convex-upwards erosion surface' (Jardine et al., 1988) that crosses both the Eglinton Shelly Till Member and Littlestone Till Formation to lie directly on bedrock.

5.1.2.5 BROOMHOUSE SAND AND GRAVEL FORMATION

In the valleys of the Kelvin Water and River Clyde glaciofluvial sand and gravel and glaciolacustrine deposits associated with deglaciation during the Late Devensian are referred to the Broomhouse Sand and Gravel Formation (Broomhouse Formation of Browne and McMillan, 1989; Broomhouse Member of the Clyde Valley Formation of Sutherland, pp. 109–110 in Bowen, 1999), named after the Broomhouse area of eastern Glasgow where it usually overlies the Wilderness Till Formation.

Name
Broomhouse Sand and Gravel Formation (BHSE) (after Browne and McMillan, 1989).

Lithology
Three members are identified, the Greenoakhill Sand and Gravel, Ross Sand and Bellshill Clay. Lithological associations of the Greenoakhill Sand and Gravel Member are of rare matrix-supported bouldery gravel with sand, common framework-supported bouldery gravel with sand and pebbly coarse- to fine-grained sand, silt and clay. The most abundant is sand. The unit varies from loose to very dense. Much of the gravel is massive to crudely bedded but planar beds and trough cross-bedded units are present. Sands are planar and trough cross-bedded, and ripple and horizontally laminated. Deformed bedding (including reverse faults and folds) probably marks the former contacts with dead ice. The Bellshill Clay Member comprises silty clay with wisps, laminae and bands of silt, and the Ross Sand Member is predominantly flat- and ripple-laminated, medium- to fine-grained sand with bands of silt.

Formal subdivisions and correlation table
Subdivided into the Greenoakhill Sand and Gravel Member, Ross Sand Member, and Bellshill Clay Member (Tables 8 and 11).

Type area/Reference section
Type area: Broomhouse, eastern Glasgow [NS 650 630–NS 690 610].

Type section: Greenoakhill [NS 675 625] in the Broomhouse–Tollcross area of Glasgow.

Lower and upper boundaries
Unconformable boundary on bedrock or most commonly on older Quaternary strata particularly the Wilderness Till Formation.

Unconformable boundary below younger Quaternary strata such as the Clyde Clay Formation but also exposed at surface.

Landform description and genetic interpretation
Surface morphologies of the Greenoakhill Sand and Gravel Member are of ice-contact origin (esker ridges, mounds and closed hollows). The Bellshill Clay Member occurs as drapes on the sides of drumlins and in drumlin hollows, and the Ross Sand Member as alluvial fans; both members having formed in ice-dammed lakes.

Thickness
Up to about 25 m.

Geographical limits
Central Scotland; Glasgow area, Stirling, Clackmannan, Tayside, north and south Lanarkshire, Lothians and Edinburgh, Fife and probably also Ayrshire.

Age
Late Devensian, Dimlington Stadial–Windermere Interstadial (MIS 2).

Deltaic sands and glaciolacustrine laminated clays of the Clyde Valley ('Lake Clydesdale' of Browne and McMillan, 1989) are referred respectively to the Bellshill Clay Member and Ross Sand Member of the Broomhouse Sand and Gravel Formation. The lake clays are extensive and occur in tributary valleys such as that of the Avon Water (Nickless et al., 1978).

GREENOAKHILL SAND AND GRAVEL MEMBER (GOHL)

The Greenoakhill Sand and Gravel Member (after the Broomhouse Formation of Browne and McMillan, 1989; Broomhouse Formation of the Clyde Valley Formation of Sutherland, p. 110 in Bowen, 1999) comprises up to 25 m of glaciofluvial ice-contact sand and gravel in the form of eskers, mounds and flat-topped kames in the Clyde valley.

BELLSHILL CLAY MEMBER (BILL)

The Bellshill Clay Member (after the Bellshill Formation of Browne and McMillan, 1989; Bellshill Member of the Clyde Valley Formation of Sutherland, p. 110 in Bowen, 1999) comprises up to 10 m silty clay with wisps, laminae and bands of silt and locally sand. The member usually rests unconformably on the Wilderness Till Formation.

ROSS SAND MEMBER (RSSA)

The Ross Sand Member (Ross Formation of Browne and McMillan, 1989; Ross Member of the Clyde Valley Formation of Sutherland, p. 110 in Bowen, 1999) comprises up to 20 m of flat and ripple-laminated medium- to fine-grained sand with laminae and thin bands of silt. The member interdigitates with the Bellshill Clay Member.

In central Ayrshire, deposits of the Midland Valley Glacigenic Subgroup are defined on the basis of the succession formerly exposed in an opencast coal site at Sourlie [NS 3380 4139], 3.5 km north-east of Irvine (Jardine et al., 1988). The lithostratigraphy established in this report (Sections 5.1.2.4, 5.1.2.6, 5.1.2.7 and 5.3.1.1) is based on units A–F described by Jardine et al. (1988) and named by Bowen (1999) as members of his Sourlie Formation. The site was excavated into the drumlinised north-western side of Sourlie Hill. Thin lenses of organic material occurring between two units of till yielded a rich flora and fauna deposited within a shallow pond in a treeless, low-shrub to sedge-moss tundra environment, and included bones of woolly rhinoceros and reindeer. Radiocarbon dates on antler fragments, plant debris and bulk organic matter range between 33.5 and 29.0 ka 14C BP, confirming a mid-Devensian age (Bos et al., 2004). Sourlie is one of very few reliably described and sampled localities in Scotland where ice-free conditions can be proven immediately before the Main Late Devensian Glaciation; others notably include Balglass Burn (glaciotectonised organic deposits referred to MIS 3), in the Campsie Fells (Brown et al., 2006), and Tolsta Head, on the Isle of Lewis (Whittington and Hall, 2002). Sourlie is also important because the succession includes a unit of shelly diamicton above the organic deposits that is correlated with other shelly tills in Ayrshire, placing them in a firm stratigraphical context.

5.1.2.6 LITTLESTONE TILL FORMATION

The basal unit (basal grey diamicton of Jardine et al., 1988) comprises up to 7.5 m of very stiff, dark grey, silty sandy stony clayey diamicton ('lodgement till'), containing clasts of mainly local Westphalian lithologies (sandstone, mudstone, limestone, coal), and dolerite. This unit, the Littlestone Till Formation (Littlestone Member of the Sourlie Formation of Sutherland, p.107 in Bowen, 1999), locally encloses deformed sheets (possible glacial rafts) of sand up to 7.5 m thick.

Name
Littlestone Till Formation (LSTI) (Basal grey diamicton of Jardine et al., 1988).

Lithology
Silty sandy stony clayey diamicton, very stiff, dark grey, containing clasts of mainly local Westphalian lithologies (sandstone, mudstone, limestone, coal), and dolerite. Locally enclosing deformed sheets of sand up to 7.5 m thick.

Formal subdivisions and correlation table
Lawthorn Diamicton Member (Tables 8 and 11).

Type area/Reference section
Type section: Former Sourlie opencast coal site [NS 33803 41395], excavated into the north-west side of Sourlie Hill, 3.5 km north-east of Irvine, Ayrshire (Jardine et al., 1988).

Lower and upper boundaries
Sharp, irregular contact with bedrock, with relief amplitude of 7.5 m, part controlled by faults in the bedrock.

The upper unit of the formation is a clay-rich gravel or clayey sand of the Lawthorn Diamicton Member. The Lawthorn Member has a sharp, irregular, erosional contact with overlying sand and gravel of the Armsheugh Sand and Gravel Formation with relief amplitude of about 3.5 m.

Landform description and genetic interpretation
Interpreted as a lodgement till. Moundy landforms (morainic deposits) are commonly associated, exposures in which also reveal closely related sand and gravel deposits. Small drumlins have locally been sculpted into the till sheet.

Thickness
Up to 7.5 m.

Distribution and extent
Probably widespread in west Central Scotland.

Age
Early Devensian (MIS 4) or mid-Pleistocene (possibly MIS 6 or earlier).

LAWTHORN DIAMICTON MEMBER (LTND)

The Littlestone Till Formation is overlain by up to 3.5 m of unstratified, clay-rich gravel and clayey sand interpreted as an 'ablation deposit' by Jardine et al. (1988), now considered to be debris flow deposits. This unit is named as the Lawthorn Diamicton Member (Lawthorn Member of the Sourlie Formation of Sutherland, pp. 107–109 in Bowen, 1999) of the Littlestone Till Formation. The age of these two units is not known. They are assumed to have been deposited during an Early Devensian glaciation, but they could be older.

5.1.2.7 Armsheugh Sand And Gravel Formation

The Lawthorn Diamicton Member is overlain by up to 5.5 m of partially cross-stratified sand and gravel, the Armsheugh Sand and Gravel Formation (Armsheugh Member of the Sourlie Formation of Sutherland, p. 109 in Bowen, 1999), which is interpreted by Jardine et al. (1988) to have formed as glaciofluvial outwash. It could, however, have formed in a periglacial environment by reworking of glacial material.

Name
Armsheugh Sand and Gravel Formation (AHSG) (after Jardine et al., 1988).

Lithology
Sand and gravel, horizontal and cross-stratified.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 11).

Type area/Reference section
Type section: Former Sourlie opencast coal site [NS 33803 41395], excavated into the north-west side of Sourlie Hill, 3.5 km north-east of Irvine, Ayrshire (Jardine et al., 1988).

Lower and upper boundaries
Sharp, irregular, erosional contact with underlying clay-rich gravel or clayey sand of the Lawthorn Diamicton Member, with relief amplitude of about 3.5 m.

Sharp, conformable contact with laminated sand and organic-rich clay and silt of the Sourlie Organic Silt Formation.

Landform description and genetic interpretation
Glaciofluvial outwash deposit interpreted to represent longitudinal bars of proximal to medial reaches of a glaciofluvial outwash fan (Jardine et al., 1988).

Thickness
Up to 5.5 m.

Distribution and extent
Probably local to west Ayrshire.

Age
Early Devensian (MIS 4) or possibly mid-Pleistocene (MIS 6 or earlier).

Mid-Devensian organic deposits, named here as the **Sourlie Organic Silt Formation** (Redburn Member of the Sourlie Formation of Sutherland, p. 109 in Bowen, 1999) of the Britannia Catchments Group (Section 5.3.1.1), occupy shallow depressions within the surface of the sand and gravel. The Sourlie Organic Silt Formation is locally capped by laminated sand.

Two members of the Wilderness Till Formation are defined in Central Ayrshire, where they occur in the topmost part of the succession at Sourlie (Section 5.1.2.4).

5.1.3 Central Grampian Glacigenic Subgroup

Glacigenic deposits associated with the Loch Lomond Stadial glaciers of Loch Lomond, Menteith and Callander are referred to the Central Grampian Glacigenic Subgroup (Section 4.4.6). Formal units defined after Browne and McMillan (1989) include the **Gartocharn Till Formation** (Gartocharn Member of the Clyde Valley Formation of Sutherland, p. 111 in Bowen, 1999), glaciolacustrine clays and silts of the **Blane Water Silt Formation** (Blane Valley laminated silts and clays of Rose, 1981; Blane Member of the Clyde Valley Formation of Sutherland, p. 111 in Bowen, 1999), and outwash sand and gravel of the **Drumbeg Sand and Gravel Formation** (Drumbeg Member of the Clyde Valley Formation of Sutherland, p. 111 in Bowen, 1999).

These deposits occur within the type area of the Loch Lomond Stadial. The BGS borehole at Mains of Kilmaronock (Section 5.1.3.1) is a possible type locality for this stadial although Gordon (chapter 13 in Gordon and Sutherland, 1993a) notes that three localities on the south shore of Loch Lomond about 6 km north-east of Balloch, at Portnellan [NS 404 873], Ross Priory [NS 413 876] and Claddochside [NS 427 878], illustrate important aspects of the Late Glacial and Holocene history of the Loch Lomond area.

5.1.3.1 Gartocharn Till Formation

Name
Gartocharn Till Formation (GATI) (after Browne and McMillan, 1989).

Lithology
The Gartocharn Till Formation is of variable lithology reflecting the extremes of deposition by terminal ice front deformation to sub-glacial lodgement processes. At the reference section the deposit is a brown to dark brownish grey silty clayey diamicton with dark sulphide patches and marine shells. The clay is massive and contains isolated pebbles, gravel and boulders, and knots of sand. It is stiff–hard and of medium–high plasticity and is characterised by joints and low angle thrust surfaces. The combined characteristics reflect the nature of the Linwood Clay Member (Clyde Clay Formation) that has been glacially reworked by advancing ice.

Elsewhere, inboard from the terminal moraine, the till is a more typical, glacial lodgement diamicton composed of boulders, gravel and pebbles in a sandy silty clay matrix. The constituent clasts are of two general types: a) locally derived rocks of Devonian and Carboniferous ages from the Midland Valley, and b) more generally in the Highlands, Dalradian metamorphic rocks. Quaternary marine shells are locally incorporated.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 11).

Type area/Reference section
Type area: Loch Lomond Basin within the limits of the Loch Lomond Stadial ice-sheet [NS 448 883–NS 389 800].

Reference section: The BGS Mains of Kilmaronock Borehole (BGS Registered No. NS48NW3) [NS 4483 8829] (28.07–32.99 m depth) (Browne and McMillan, 1989).

Lower and upper boundaries
Unconformity or glacial deformation boundary on older Quaternary strata such as the Linwood Clay Member and the Wilderness Till Formation, also on bedrock. Complex relationships laterally with the lacustrine sediments of Blane Water Silt Formation and deltaic/lacustrine sediments of the Drumbeg Sand and Gravel Formation (forming part of the Loch Lomond Stadial Terminal Moraine Complex in the Leven and Endrick valleys in the Loch Lomond basin).

Unconformity below younger Quaternary strata or glacial deformation boundary. Where data are available the till of the Gartocharn Till Formation is overlain by the Drumbeg Sand and Gravel Formation and by the Buchanan Clay Member (Clyde Clay Formation) in the Loch Lomond area.

Landform description and genetic interpretation
Moundy landforms (morainic deposits) are commonly associated landforms, exposures in which also reveal closely related sand and gravel deposits. Small drumlins have locally been sculpted into the till sheet.

Thickness
Up to over 6 m.

Distribution and extent
Loch Lomond and the Trossachs.

Age
Late Devensian, Loch Lomond Stadial (MIS 2–1).

5.1.3.2 Blane Water Silt Formation

Name
Blane Water Silt Formation (BLAW) (after Rose, 1981, and Browne and McMillan, 1989).

Lithology
The typical lithology is of regular interbedded clay and silt forming varves with dark coloured tops. The clays are silty, reddish brown and brownish grey, with grey silt, some sand layers and wisps, and thin beds of diamicton up to 7 cm thick. The clay is firm–stiff and of medium–high plasticity. Isolated stones up to 2 cm are interpreted as drop-stones.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 11).

Type area/Reference section
Type area: Loch Lomond Basin within the limits of the Loch Lomond Stadial ice-sheet [NS 448 883–NS 389 800].

Reference section: BGS Gartness Borehole [NS 4973 8672] BGS Registered No. NS48NE2, 10.17–23.55 m (Browne and McMillan, 1989).

Reference section: BGS Killearn Borehole [NS 5100 8467] BGS Registered No. NS58SW3, 0.5–15.61 m (Browne and McMillan, 1989).

Lower and upper boundaries
The formation rests with angular unconformity on older Quaternary sediments including the Gartocharn Till Formation inside the Loch Lomond Stadial ice limit and outside on the Wilderness Till Formation (Midland Valley Glacigenic Subgroup). In Strathblane the formation rests on members of the Clyde Clay Formation (British Coastal Deposits Group).

The formation is overlain conformably and by glaciotectonically emplaced younger sediments of the Drumbeg Sand and Gravel Formation and Gartocharn Till Formation in the Endrick valley outside and at the Loch Lomond Stadial ice limit. In Strathblane it is exposed at the surface.

Landform description and genetic interpretation
Lithological associations of the formation are consistent with deposition of muds on a lake bottom in contact and near to glacier ice.

Thickness
From a veneer to over 15 m.

Distribution and extent
Recognised in the lower Endrick valley near its confluence with Loch Lomond and in the Blane Water valley above Strathblane.

Age
Late Devensian, Loch Lomond Stadial (MIS 2–1).

5.1.3.3 Drumbeg Sand and Gravel Formation

Name
Drumbeg Sand and Gravel Formation (DRBG) (after Rose, 1981 and Browne and McMillan, 1989).

Lithology
Sand, reddish-brown or orange, fine- to medium-grained, with silt or sand and clay layers, and abundant shelly layers derived from older units; pebbly, and with diamicton layers near the top.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 11).

Type area/Reference section
Reference section: BGS Gartness Borehole [NS 4973 8672] BGS Registered No. NS48NE2, 0.5–10.17 m depth (Browne and McMillan, 1989).

Partial type section: Drumbeg Gravel Pit [NS 484 882] (Rose, 1981; Browne and McMillan, 1989; Phillips et al., 2002).

Lower and upper boundaries
The formation interdigitates with clays and silts of the Blane Water Silt Member (Gartocharn Till Formation).

Ground surface.

Landform description and genetic interpretation
Deltaic deposits in contact with active and decaying glacier ice.

Thickness
About 10 m.

Distribution and extent
Stirlingshire near, at and within the limits of the Loch Lomond Stadial ice-sheet in the Endrick, Blane and Leven valleys.

Age
Late Devensian, Loch Lomond Stadial (MIS 2–1).

5.1.4 Southern Uplands Glacigenic Subgroup

The Southern Uplands Glacigenic Subgroup (after McMillan et al., 2005; Section 6.1.1) includes deposits of Southern Uplands provenance on the southern margin of the Midland Valley in south Lanarkshire and parts of Midlothian. In the Lothians the Wilderness Till Formation (Midland Valley Glacigenic Subgroup) of west–central Scotland may be correlated with the lower till unit (the Park Burn Member of the Forth–Teith Formation of Sutherland, p. 113 in Bowen, 1999) of the Roslin multiple till–sand succession (Kirby, 1968, 1969a,b) of the North Esk valley, Midlothian. Some authors (e.g. McCall and Goodlet, 1952) consider the upper till unit (Roslin Till of Kirby, 1968, 1969a; Roslin Upper Boulder Clay of Mitchell and Mykura, 1962; Roslin Member of the Forth–Teith Formation of Sutherland p. 113 in Bowen, 1999; Table 11) to have been deposited by re-advancing ice from the Southern Uplands. This might establish it as a formation in the Southern Uplands Glacigenic Subgroup. Others (Martin, 1981) modelled the entire sequence as a product of a single easterly-moving

Late Devensian ice-sheet which incorporated an element of Southern Uplands-derived material.

Southerly derived glacigenic deposits, which potentially could also be ascribed to the Southern Uplands Glacigenic Subgroup, occur in the Dolphinton and Biggar areas (McCall and Goodlet, 1952; McMillan et al., 1981; Shaw and Merritt, 1982) and also in parts of the successions exposed in the valley of the Keith Water, East Lothian (Gordon, 1993b) and River Nith, Ayrshire (Holden, 1977a,b; Holden and Jardine, 1980; Sutherland, 1993). The extensive deposits of kamiform sand and gravel and associated diamictons of the Carstairs area of south Lanarkshire have variously been ascribed as the products of ice-sheets originating from the Grampians (Charlesworth, 1926a, b) and the Southern Uplands (Gregory, 1915; Goodlet, 1964). However, although Carstairs deposits contain a component of Southern Uplands-derived material (Laxton and Nickless, 1980) lithologies are dominated by locally-derived rock types more appropriately correlated with formations within the Midland Valley Glacigenic Subgroup.

5.2 BRITISH COASTAL DEPOSITS GROUP

5.2.1 Formations of the British Coastal Deposits Group

Formations of the British Coastal Deposits Group are established for marine and raised marine deposits of Devensian–Holocene age for the Midland Valley of Scotland (including the Tay and Forth estuaries) and west–central Scotland (including the Glasgow district, the Firth of Clyde and Ayrshire).

5.2.1.1 Afton Lodge Clay Formation

Name
Afton Lodge Clay Formation (AFTL) (after Gordon, 1993a; see also Smith, 2002 and Smith et al., in prep. 2009).

Lithology
Stiff, calcareous, grey, silty clay with well-dispersed small pebbles, shells, foraminiferids, ostracods and inclusions of diamicton, sand and gravel. The clay is generally massive, although locally laminated with concentrations of dark minerals and/or organic material. The lenses of diamicton, sand and gravel are sparse and disrupted in deformation zones within a metre or so of the upper boundary.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 11).

Type area/Reference section
Partial type section: Trial pit (No. 2) [NS 4158 2586] excavated 200 m south-south-east of Shawwood Farm, Ayrshire (Smith et al., in prep. 2009).

Partial type section: Auger hole sunk into the bed of the Ladykirk Burn at the confluence with an un-named minor tributary joining the main stream from the south [NS 4156 2584], of 200 m north-north-east of Afton Lodge, Ayrshire (Smith et al., in prep. 2009).

Lower and upper boundaries
Not observed, probably unconformable directly on bedrock, but possibly a gradational glaciotectonic contact with underlying till.

Either a sharp, concavo-convex to planar boundary with overlying reddish brown, sandy, silty clay with scattered cobbles (Auchenwinsey Till Member of the Wilderness Till Formation; Section 5.1.2.4), or a gradational, glaciotectonic boundary involving intercalation and intermixing with the overlying till.

Landform description and genetic interpretation
Marine deposits. The foraminiferal and dinoflagellate cyst associations present in the clay both indicate a cold, but not fully glacial estuarine environment. The deposit is very likely to have been ice-rafted from an original position nearer to the coast to the west or from the Firth of Clyde.

Thickness
Greater than 5 m.

Distribution and extent
South Ayrshire.

Age
Mid-Devensian (MIS 3). Two samples of benthonic foraminiferids from near the top of the sequence have yielded a Conventional Radiocarbon age of 41 002 ± 803 years BP. The calculated Calendar age is 45 605 ± 731 years BP (a minimum mid-Devensian age) (Smith et al., in prep. 2009).

5.2.1.2 Errol Clay Formation

In the eastern Midland Valley (Stirlingshire, east coast and Tay and Forth estuaries), Late Devensian (Dimlington Stadial) glaciomarine deposits are represented by the Errol Clay Formation (Peacock, 1999) (Section 4.5.1.1) of which the Lunan Clay Member crops out in the Lunan and Brothock valleys, Angus. The Loanhead Clay Member (Loanhead Beds of Browne et al., 1984; Loanhead Member of the Forth–Teith Formation of Sutherland p. 113 in Bowen, 1999), currently undefined in the BGS Lexicon (Table 11), may also represent early marine sedimentation during deglaciation.

Lunan Clay Member (LCL)

The Lunan Clay Member comprises up to 11 m of red, laminated plastic clay with laminae of very fine-grained sand. AMS radiocarbon dates of 17 065 and 17 720 years BP on marine fauna were reported by McCabe et al. (2007). The Lunan Clay rests with a sharp conformable contact on gravel (un-named) and is unconformably overlain by the Drumlithie Sand and Gravel Formation (Mearns Glacigenic Subgroup) (Section 5.1.1.3).

5.2.1.3 Clyde Clay Formation

In the west–central part of the Midland Valley, glaciomarine deposits of Windermere–Loch Lomond Stadial age are assigned to the Clyde Clay Formation (Tables 5 and 11). In the Glasgow, Paisley and Loch Lomond districts the formation is subdivided into six members defined after formations of Browne and McMillan (1989), namely the *Bridgeton Sand, Paisley Clay, Linwood Clay, Killearn Sand and Gravel, Inverleven Gravel*, and *Balloch Clay* members. A seventh member, the *Portavadie Sand and Silt Member* is established from sections described by Peacock et al. (1978) and Peacock (1997) at Ardyne [NS 100 681] and Portavadie [NR 926 692] in the south-west Highlands. Sutherland (p. 110 in Bowen, 1999), based on Peacock et al. (1978), defined the Ardyne Formation with Killellan, Toward and Ardyne Point members. These units are correlatives of the Paisley Clay, Linwood Clay and Portavadie Sand and Silt members of the Clyde Clay Formation and are not included in the current framework.

Name
Clyde Clay Formation (CLYD) (after Peacock, 1997, Peacock et al., 1978, and Browne and McMillan, 1989; Clyde Beds of Peacock, 1975b, and Sutherland, 1984; parts of Clyde Valley and Ardyne formations of Sutherland, pp. 110–111 in Bowen, 1999).

Lithology
Laminated and massive clay and silt with sand and gravel.

Formal subdivisions and correlation table
Subdivided into seven members. The stratigraphical relationships and geographical distribution of the Bridgeton Sand, Paisley Clay, Linwood Clay, Killearn Sand and Gravel, Inverleven Gravel, and Balloch Clay members are summarised in Browne and McMillan (1989, figs. 2, 3 and 4). The Portavadie Sand and Silt Member (Firth of Clyde and Loch Fyne) is established after Peacock et al. (1978) and Peacock (1997). See Figures 10a and 10b, and Tables 5 and 11.

Type area/Reference section
Type section: Geilston Burn, valley side exposures [NS 3410 7783–NS 3410 7768], by Cardross, Clyde estuary.

Lower and upper boundaries
The Clyde Clay Formation rests with angular unconformity on older Quaternary sediments or bedrock. It normally rests on the Wilderness Till Formation.

The Clyde Clay Formation is overlain unconformably by younger Quaternary sediments, normally either the Clydebank Clay Formation or the Clippens Peat Formation or Clyde Valley Formation. It is also extensively exposed at surface in the lower Clyde valley.

Landform description and genetic interpretation
Marine deposits.

Thickness
Up to over 50 m.

Distribution and extent
The Clyde Clay Formation is recognised in the lower Clyde valley north of Lanark, in and around the estuary of the Clyde and Firth of Clyde and linked sea lochs, and in Loch Lomond. It is also present under the coastal plain of Ayrshire.

Age
Late Devensian, Windermere Interstadial–Loch Lomond Stadial (MIS 2–1).

BRIDGETON SAND MEMBER (BRON)

The Bridgeton Sand Member (Bridgeton Formation of Browne and McMillan, 1989; Bridgeton Member of the Clyde Valley Formation of Sutherland p. 110 in Bowen, 1999) comprises up to over 20 m of beds of fine– to medium–grained sand, and sandy, fine- to coarse-grained gravel in an upward–fining succession. The member rests with angular unconformity on bedrock or older Quaternary sediments. It commonly rests on the Wilderness Till Formation. It is overlain unconformably or disconformably by younger Quaternary sediments, normally the Paisley Clay Member (British Coastal Deposits Group) or the Clyde Valley Formation of the Clyde Catchments Subgroup (Britannia Catchments Group).

PAISLEY CLAY MEMBER (PAIS)

The Paisley Clay Member (Paisley Formation of Browne and McMillan, 1989; Paisley Member of the Clyde Valley Formation and correlative of the Killellan Member of the Ardyne Formation of Sutherland p. 110 in Bowen, 1999) comprises up to 25 m or more of beds of clay and silt that are finely colour-banded in shades of greyish brown, grey and reddish brown. The member normally rests on the Wilderness Till Formation but adjacent to the River Clyde it is underlain by the Bridgeton Sand Member.

LINWOOD CLAY MEMBER (LIWD)

The Linwood Clay Member (Linwood Formation of Browne and McMillan, 1989; Linwood Member of the Clyde Valley Formation and correlative of the Toward and Ardyne Point members of the Ardyne Formation of Sutherland p. 110 in Bowen, 1999) consists of thickly-bedded to massive silts, clayey silts and silty clays, medium to dark grey becoming brownish grey downwards, with sand layers, black sulphide bands and many marine shells. A rich boreal fauna includes *Arctica islandica* (Linné) and *Modiolus modiolus* (Linné). The member rests with angular unconformity and conformity on older Quaternary sediments or bedrock. It normally rests conformably on the Paisley Clay Member of the Clyde Clay Formation or unconformably on the Wilderness Till Formation. It is overlain unconformably by younger Quaternary sediments, normally either the Clydebank Clay Formation (British Coastal Deposits Group) or the Clippens Peat Formation or Clyde Valley Formation (Britannia Catchments Group).

PORTAVADIE SAND AND SILT MEMBER (PRTS)

The Portavadie Sand and Silt Member (Portavadie Formation of Peacock, 1997: Unit 2 at Portavadie; Units 3 and 4 at Ardyne) comprises up to 3 m or more of poorly sorted, grey to dark grey, silty sand and sandy silt with angular to subangular clasts up to 200 mm across. The deposit contains seaweed, plant fragments and intact marine shells of arctic aspect, and normally rests unconformably on either the Linwood Clay or Paisley Clay members. It is overlain unconformably by younger Quaternary sediments, normally either the Gourock Sand Member of the Clydebank Clay Formation (British Coastal Deposits Group).

KILLEARN SAND AND GRAVEL MEMBER (KARN)

The Killearn Sand and Gravel Member (Killearn Formation of Browne and McMillan, 1989; Killearn Member of the Clyde Valley Formation of Sutherland p. 111 in Bowen, 1999) is composed of up to 15 m or more of commonly reddish brown and yellow, fine– to medium–grained sand with clay layers and beds of gravel. The member rests with angular unconformity on older Quaternary sediments or bedrock. It normally rests either unconformably or with interdigitation on the Paisley Clay and Linwood Clay members of the Clyde Clay Formation or on the Wilderness Till Formation.

INVERLEVEN GRAVEL MEMBER (INVN)

The Inverleven Gravel Member (Inverleven Formation of Browne and McMillan, 1989; Inverleven Member of the Clyde Valley Formation of Sutherland p. 111 in Bowen, 1999) is typically composed of up to 3 m or more of angular–subrounded boulders, cobbles and gravel in a clayey sand matrix with barnacles. The member rests with angular unconformity on older Quaternary sediments or on bedrock. Most commonly it rests on the Paisley Clay Member of the Clyde Clay Formation or on the Wilderness Till Formation. It is overlain conformably or disconformably by younger Quaternary sediments, commonly either the Balloch Clay Member of the Clyde Clay Formation or the Clydebank Clay Formation.

Balloch Clay Member (BOCH)

The Balloch Clay Member (Balloch Formation of Browne and McMillan, 1989; Balloch Member of the Clyde Valley Formation of Sutherland p. 111 in Bowen, 1999) consists of up to 40 m or more of clayey silt, silt, clay and sand, mid to dark grey, brownish grey and locally reddish brown, bedded and thinly laminated, normal and reverse graded units, with dark sulphide patches and rare marine shells. The member rests with angular unconformity on older Quaternary sediments or bedrock. It normally rests on the Inverleven Gravel Member of the Clyde Clay Formation or possibly on the Wilderness Till Formation. It is overlain unconformably by younger Quaternary sediments, normally the Clydebank Clay Formation (British Coastal Deposits Group) but is expected to include buried deposits belonging to the deglacial phase at the end of the Loch Lomond Stadial.

5.2.1.4 Clydebank Clay Formation

Marine deposits of Holocene age in the Clyde valley are represented by the Clydebank Clay Formation. The Girvan Formation established by Sutherland (p. 109 in Bowen, 1999) is recommended for the Holocene deposits of marine and organic origin of the Ayrshire coast. This unit has yet to be included in the BGS Lexicon (Table 11).

Name
Clydebank Clay Formation (CBCL) (after Browne and McMillan, 1989).

Lithology
Clay and silt, with subsidiary sand and gravel deposits.

Formal subdivisions and correlation table
Subdivided into four members, the Buchanan Clay, Longhaugh Sand and Gravel, Erskine Clay, and Gourock Sand members (Figures 10a and 10b, and Tables 5 and 11).

Type area/Reference section
Type area: Lower Clyde valley, Clyde Estuary and Loch Lomond [NS 160 580–NN 520 160].

Lower and upper boundaries
Rests with angular unconformity on older Quaternary sediments or bedrock. It most commonly rests on the Wilderness Till Formation (Midland Valley Glacigenic Subgroup).

Overlain unconformably by younger Quaternary sediments, normally either the Clippens Peat Formation or Clyde Valley Formation of the Clyde Catchment Subgroup (Britannia Catchments Group). It is also extensively exposed at surface in the lower Clyde valley.

Landform description and genetic interpretation
Marine and coastal deposits.

Thickness
Up to more than 15 m.

Distribution and extent
The Clydebank Clay Formation is recognised in the lower Clyde valley north of Lanark, in the estuary of the Clyde, and in Loch Lomond.

Age
Holocene (MIS 1).

Buchanan Clay Member (BCHN)

The Buchanan Clay Member (Buchanan Formation of Browne and McMillan, 1989; Buchanan Member of the Clyde Valley Formation of Sutherland p. 111 in Bowen, 1999) is typically composed of up to 7 m or more of thinly-bedded, silty clay with many laminae and thin beds of silt and locally of sand. The member rests with angular conformity on older Quaternary sediments including the Gartocharn Till Formation (Central Grampian Glacigenic Subgroup). It is overlain conformably by younger Quaternary sediments of the Kilmaronock Silt Member (Strathendrick Formation).

Longhaugh Sand and Gravel Member (LUGH)

The Longhaugh Sand and Gravel Member (Longhaugh Formation of Browne and McMillan, 1989) consists of up to 15 m or more of mainly grey, loose, fine– to medium–grained, locally silty sand containing some comminuted shell debris. Gravel with shells is recorded below the sand units in the Longhaugh No. 20 Borehole [NS 4291 7319]. The member rests with angular unconformity on older Quaternary sediments, commonly the Wilderness Till Formation, or on bedrock. It is overlain by younger Quaternary sediments of the Clydebank Clay Formation.

Erskine Clay Member (ERSK)

The Erskine Clay Member (Erskine Formation of Browne and McMillan, 1989; Erskine Member of the Clyde Valley Formation of Sutherland p. 110 in Bowen, 1999) comprises up to more than 4 m of very silty clay with sand and silt laminae and beds. The member rests with angular unconformity on older Quaternary sediments or on bedrock. It is known to rest unconformably on the Inverleven Gravel Member of the Clyde Clay Formation and possibly disconformably on the Endrick Sand Member of the Strathendrick Formation. It is overlain by younger Quaternary sediments, normally the Gourock Sand Member. It is also exposed at the surface in the lower Clyde valley.

Gourock Sand Member (GOSA)

The Gourock Sand Member (Gourock Formation of Browne and McMillan, 1989; Gourock Member of the Clyde Valley Formation of Sutherland p. 110 in Bowen, 1999) is typically composed of up to 5 m or more of grey, fine– to coarse–grained sand. The member rests, possibly by passage, on the underlying Erskine Clay Member where developed, and with angular unconformity on older Quaternary sediments or bedrock. It is exposed at surface in the lower Clyde valley and in lower Strathendrick.

5.2.1.5 Forth Clay Formation

Post–Dimlington Stadial estuarine and marine deposits of the principal estuaries of the Forth and Tay have been described in detail by Sissons and Smith (1965), Sissons (1966, 1969, 1972, 1974, 1983), Francis et al. (1970), Paterson et al. (1981), Browne et al. (1984), Armstrong et al. (1985), Peacock (1998), Barras and Paul (1999), and Sutherland (p. 113–114 in Bowen, 1999). The present framework establishes two formations, the **Forth Clay Formation** with six members (Early Windermere Interstadial, MIS 2 to Early Holocene, MIS 1) and the **Carse Clay Formation** (Sections 5.2.1.6 and 6.2.1.1) with nine members (Loch Lomond Stadial to Holocene, MIS 2–1).

Name
Forth Clay Formation (FOCL) (after Paterson et al., 1981).

Lithology
The Forth Clay Formation comprises in the Tay–Earn (and by association the Eden–Montrose) basins: Marine clay and silt of the Powgavie Clay Member containing subangular ice-rafted clasts (drop-stones), characterised by graded units from 2–10 cm thick consisting of a thin basal layer of pale-coloured silt or sand passing up into dark brownish grey clay. The Culfargie Sand Member is more arenaceous but generally laminated with varying proportions of clay, silt and sand. The formation is considered to be prodeltaic to estuarine in origin but with a significant unit of gravel, the Tay–Earn Gravels Member that is supposedly fluvial in origin. In the Forth area, the formation is represented by the Kinneil Kerse Silt Member, Abbotsgrange Silt Member with the unconformable Bothkennar Gravel Member at the top of the formation.

Formal subdivisions and correlation table
Subdivided into six members: the Powgavie Clay, Culfargie Sand, and the Tay–Earn Gravels members in the Tay–Earn area and the Kinneil Kerse Silt, Abbotsgrange Silt, and Bothkennar Gravel members in Forth area: Tables 5 and 11.

Type area/Reference section
Partial Type Section: Powgavie B Borehole, BGS Registered No. NO22NE31 [NO 2912 2532] from 6.15–35.10 m depth, Carse of Gowrie west of Perth (Paterson et al., 1981).

Partial Type Section: Culfargie Borehole, BGS Registered No. NO11NE2 [NO 1675 1749], from 7.8–46.2 m depth; lower River Earn valley (Paterson et al., 1981).

Lower and upper boundaries
In the Tay–Earn (and by association the Eden–Montrose) basins: the relationship of the Powgavie Clay Member to the (supposedly) underlying Errol Clay Formation is not clearly demonstrable at any known locality. At the type section this member rests unconformably on glaciofluvial sand and gravel. This relationship is assumed to have come about by mass movement on the sea floor causing removal of the Errol Clay before deposition of this member. However the Errol Clay Formation passes up into the Culfargie Sand Member in the deltaic setting of the lower Earn and Tay valleys. In the Forth area, the Errol Clay Formation passes up into the Kinneil Kerse Silt Member which in turn passes up and into the Abbotsgrange Silt Member, where developed. The Bothkennar Gravel Member rests unconformably on a wide range of units and also on bedrock. This unit, the 'buried gravel layer' of the scientific literature from the 1960s onwards, is widely recognised in the Forth valley and under the Firth of Forth.

Unconformable top related to marine transgression and regression and associated erosion, overlain by members of the Carse Clay Formation including the Carey Silt and Carse of Gowrie members (Tay area), and the Letham Silt, Carse of Stirling and Claret Clay members (Forth area), and the sub-Carse Peat of the Flanders Moss Peat Formation (Forth, Tay and Earn).

Landform description and genetic interpretation
Marine and coastal deposits.

Thickness
Ranges from a veneer to more than 38 m.

Distribution and extent
River Tay from just north-west of Perth and the Earn from Forgandenny eastwards and adjacent to the Tay/Earn estuaries; some of the units may occur in the Eden and Montrose basins. River Forth east of Aberfoyle, Forth estuary and Firth of Forth.

Age
Late Devensian, Early Windermere Interstadial (MIS 2)–Early Holocene (MIS 1).

In the Tay–Earn area the members are:

POWGAVIE CLAY MEMBER (PGCL)

The Powgavie Clay Member (Powgavie Member of the Tay Formation of Sutherland, p. 114 in Bowen, 1999) comprises up to 20 m of marine clay containing subangular ice-rafted clasts (drop-stones) characterised by graded units from 2–10 cm thick consisting of a thin basal layer of pale-coloured silt or sand passing up into dark brownish grey clay (Paterson et al., 1981). Sporadic laminae and thicker beds are stained black by sulphide. The deposit is considered to be prodeltaic in origin. The member has a reasonably abundant and diverse fauna resembling that of the Clyde Clay Formation on the west coast of Scotland. The relationship of the Powgavie Clay to the (supposedly) underlying Errol Clay Formation is not clearly demonstrable at any known locality. At the type section the member rests unconformably on glaciofluvial sand and gravel. This relationship is assumed to have come about by mass movement on the sea floor causing removal of the Errol Clay before deposition of this member. The member has a diachronous transitional top with and passes laterally into the Culfargie Sand Member.

CULFARGIE SAND MEMBER (CUSA)

The Culfargie Sand Member (Culfargie Beds of Armstrong et al., 1985; Culfargie Member of the Tay Formation of Sutherland, p. 114 in Bowen, 1999) comprises up to 35 m of deltaic and estuarine deposits. Typically these are composed of very fine- to medium-grained, finely micaceous, mainly flat laminated grey sand with silt and some clay laminae. Scattered pebbles occur up to 2 cm size along with rare pebble beds, and there are black sulphidic patches. The member has a limited fauna resembling that of the Powgavie Clay Member and also the Clyde Clay Formation on the west coast of Scotland. Coarser deposits including much higher proportions of coarse sand and gravel beds are known in the western areas of occurrence. The member has a diachronous transitional base with and passes laterally into the Powgavie Clay and also the Errol Clay Formation.

TAY–EARN GRAVELS MEMBER (TEGR)

The Tay–Earn Gravels Member (Friarton Gravel and Earn Gravel of Armstrong et al., 1985; Friarton Member of the Tay Formation of Sutherland, p. 114 in Bowen, 1999) comprises up to 25 m of rounded–subangular, coarse gravel, and fine- to coarse-grained sand. The gravel is recorded by Armstrong et al. (1985) as composed of vein quartz, quartzite and other metamorphic rocks, Lower Devonian lavas and dolerite. This fluvial unit is mostly found in a deep channel cut into pre-existing deposits but is recognised on the flanks too. The member has a markedly erosive base cut into the Errol Clay Formation and the Culfargie Sand Member of the Forth Clay Formation. It is overlain unconformably by the transgressive estuarine sand, silt and clay of the Carey Silt Member (Carse Clay Formation) and also younger units including the sub-Carse Peat of the Flanders Moss Peat Formation and Carse of Gowrie Member (Carse Clay Formation). It is also exposed at the surface locally.

In the Forth area members are:

KINNEIL KERSE SILT MEMBER (KKSI)

The Kinneil Kerse Silt Member (Kinneil Kerse Beds of Browne et al., 1984; Kinneil Kerse Member of the Forth–Teith Formation of Sutherland, p. 113 in Bowen, 1999) comprises up to 12 m of grey, soft to firm, interlaminated clayey silt and dusky yellowish brown silty clay of marine origin (Browne et al., 1984). It contains subangular ice-rafted clasts (drop-stones) of coal, basalt, mudstone and sandstone. It is characterised by laminations and, in some cases, many thin beds of pale-coloured silt and sand that are ripple bedded in places. The silt exhibits sporadic black mottling and banding caused by the concentration of oxidised sulphide minerals. The deposit is considered to be prodeltaic in origin. The member has a reasonably abundant and diverse fauna resembling that of the Clyde Clay Formation on the west coast of Scotland. The relationship of the Kinneil Kerse Silt Member (Forth Clay Formation) to the underlying Errol Clay Formation is transitional. The member has a diachronous transitional top. It may pass laterally into the Abbotsgrange Silt Member but this is speculative. It is known only to be overlain unconformably by younger deposits such as the Claret Clay Member (Carse Clay Formation) and Bothkennar Gravel Member.

ABBOTSGRANGE SILT MEMBER (AGSI)

The Abbotsgrange Silt Member (Abbotsgrange Beds of Browne et al., 1984; Abbotsgrange Member of the Forth–Teith Formation of Sutherland, p. 113 in Bowen, 1999) comprises up to 37 m of well-bedded, very micaceous, black, grey and brownish grey, loose silts, with many laminae and thin beds of fine-grained sand and dark grey silty clay. It is of marine origin (Browne et al., 1984). The unit has clasts up to 8 cm mean diameter, in sandy silt, of coal, basalt, mudstone and quartzite near its base suggestive of local erosion of underlying strata. The deposit is considered to be prodeltaic in origin. The member has a reasonably abundant and diverse fauna resembling that of the Clyde Clay Formation on the west coast of Scotland. The relationship of the Abbotsgrange Silt Member (Forth Clay Formation) to the underlying Errol Clay Formation is probably unconformable. It is not known to be in contact with the slightly older Kinneil Kerse Silt Member. The member is overlain unconformably by younger deposits such as the Letham Silt and Claret Clay members of the Carse Clay Formation and Bothkennar Gravel Member.

BOTHKENNAR GRAVEL MEMBER (BKGR)

The Bothkennar Gravel Member (Buried Gravel Layer of Sissons, 1969; Bothkennar Gravel Formation of Peacock, 1998; Bothkennar Member of the Forth–Teith Formation of Sutherland, p. 113 in Bowen, 1999) comprises up to 3.5 m or more of fine- to coarse-grained gravel, subangular to rounded cobbles and boulders (one was recorded to be at least 1.8 m across in an old excavation at Bo'ness) in a matrix where present or recorded that varies from loose sand to firm clayey sandy silt (Browne et al., 1984). Some cobbles and boulders are striated. Clasts are of mainly locally-derived Carboniferous and Devonian lithologies. The deposit is poorly sorted. It is considered to have been deposited by ice-rafting of materials from the shore during the Loch Lomond Stadial (MIS 2–1) (Sissons, 1974). The member has a markedly erosive base cut into the various local members of the Forth Clay Formation, Wilderness Till Formation (Main Late Devensian Glaciation) and bedrock (Browne et al., 1984; Paul et al., 1995). It is overlain unconformably by the early Holocene transgressive estuarine sand, silt and clay of the Letham Silt Member and also younger units including the Carse of Stirling Clay Member and the later Claret Clay Member (all members of the Carse Clay Formation).

5.2.1.6 CARSE CLAY FORMATION

Name
Carse Clay Formation (CARCL) (after Francis et al., 1970, Paterson et al., 1981, Browne et al., 1984, and Armstrong et al., 1985).

Lithology
The Carse Clay Formation comprises clayey silt and clay, often rooty and structureless; also highly laminated with silt and very fine- to medium-, sometimes coarse-grained sand with pebbles up to 5 mm and fragments of vivianite; grey and brownish grey, finely micaceous, dark sulphidic patches. In sand-dominated successions in outer estuary situations, coarse gravel also occurs at the base of the local member.

Formal subdivisions and correlation table
Subdivided into nine members: the Gowrie, Carse of Gowrie, Carey Silt and Kingston Sand members in the Tay–Earn area; the Letham Silt, Carse of Stirling Clay, Claret Clay and Grangemouth Silt members in Forth area: Tables 5 and 11, and the Newbie Silt Member in the Solway lowlands (Section 6.2.1.1).

Type area/Reference section
Partial Type Section: Culfargie Borehole, BGS Registered No. NO11NE2, from surface to 7.34 m depth; lower Earn estuary (Paterson et al., 1981).

Reference Section: Burnside Borehole, BGS Registered No. NO32NW11, from surface to 7.97 m depth; lower Tay estuary (Paterson et al., 1981).

Lower and upper boundaries
Internally unconformable on the sub-Carse Peat (Flanders Moss Peat Formation); unconformable on the Forth Clay and Errol Clay formations and older deposits including the Wilderness Till Formation and bedrock.

Upper boundary unconformable with modern alluvium, and commonly at surface.

Landform description and genetic interpretation
Marine and coastal deposits.

Thickness
Ranges from a veneer to more than 27 m.

Distribution and extent
The Carse Clay Formation is recognised in the Lower Tay valley from north-west of Perth, Tay estuary and Firth of

Tay; lower Earn valley east of Forteviot, and estuary (Carse of Gowrie); lower Eden valley east of Cupar and estuary; Montrose Basin area; and Forth valley from Aberfoyle eastwards (Carse of Stirling) and Forth estuary.

Age
Late Devensian, Loch Lomond Stadial–Holocene (MIS 2–1).

In the Tay–Earn area the members are:

Gowrie Member (GWR)

The Gowrie Member comprises up to 10 m of clayey silt and clay of estuarine origin (Paterson et al., 1981). It may be rooty and structureless but otherwise is highly laminated with silt and very fine- to medium-grained sand. It is grey and brownish grey, and finely micaceous, with dark sulphidic patches. In more open marine situations, it is composed of brown and grey, fine-grained shelly sand. The member is unconformable on terraced estuarine deposits, often on the Tay–Earn Gravels Member, and other Holocene and late Devensian units. Its upper boundary is most commonly at the surface. It is thought to be younger than about 4500 BP.

Carse of Gowrie Member (COGW)

The Carse of Gowrie Member comprises up to 10 m of clayey silt and clay, which is often rooty and structureless but otherwise highly laminated with silt and very fine- to medium-, sometimes coarse-grained sand with pebbles up to 5 mm in diameter and fragments of vivianite. It is grey and brownish grey, and finely micaceous, with dark sulphidic patches (Paterson et al., 1981). The member is unconformable on the sub-Carse Peat of the Flanders Moss Peat Formation, and older Holocene and late Devensian units including the Carey Silt Member. Its upper boundary is possibly overlain unconformably by the transgressing Gowrie Member, but is commonly at surface. However, it tends to lie at a higher level than the Gowrie Member, being somewhat older (about 8500 BP to about 6000 BP).

Carey Silt Member (CYSI)

The Carey Silt Member (Carey Member of the Tay Formation of Sutherland, p. 114 in Bowen, 1999) comprises up to 8 m of grey and brownish grey, well-laminated to thin-bedded, very fine- to coarse-grained sand, silt and clay (Paterson et al., 1981). The deposit contains some pebbles up to 4 cm and is finely micaceous. It is rooty near the top below the sub-Carse Peat of the Flanders Moss Peat Formation. Depending on location within the palaeo-estuary, the dominant material varies from sand to clay. The deposit forms a series of raised beaches and terraces related to transgressive and regressive cycles of sea-level change. The member has an unconformable and transgressive base on older units including the Tay–Earn Gravels and Culfargie Sand members of the Forth Clay Formation, and the Errol Clay Formation. It is overlain unconformably by the sub-Carse Peat of the Flanders Moss Peat Formation, and transgressive estuarine clay, silt and sand of the Carse of Gowrie Member (Carse Clay Formation).

Kingston Sand Member (KNSA)

The Kingston Sand Member (formerly Kingston Beds and Buddon Sands of Paterson et al., 1981; Kingston and Buddon members of the Tay Formation of Sutherland, p. 114 in Bowen, 1999) comprises up to 20 m of very fine- to medium-grained sand with silt and clay laminae. It is grey and brownish grey, and finely micaceous, with some shells and comminuted shell debris and dark sulphidic patches (Paterson et al., 1981). The sediments contain marine microfauna of temperate estuarine type. At Barry Buddon, the unit has a gravelly base with clasts to 20 cm of schist and quartzite. The member has an unconformable, assumed deep channelised base upon the Errol Clay Formation at Kingston but no cores of the basal boundary have been recovered. The member is possibly overlain unconformably by the transgressing Carse of Gowrie Member but may pass laterally into the Carey Silt Member. At Barry Buddon, the unit is difficult to distinguish from overlying sands of the Main Post-Glacial Raised Beach.

In the Forth area the members are:

Letham Silt Member (LESI)

The Letham Silt Member (Letham Beds of Browne et al., 1984; Letham Member of the Forth–Teith Formation of Sutherland, p. 113 in Bowen, 1999) comprises up to 9 m of very fine- to coarse-grained sand, silt and clay, which is grey and brownish grey, and well-laminated to thin-bedded, with some pebbles up to 4 cm. It is finely micaceous, and rooty near its top below the sub-Carse Peat (where developed) of the Flanders Moss Peat Formation (Browne et al., 1984). Depending on location within the palaeo-estuary, the dominant material varies from sand to clay. The deposit forms a series of buried raised beaches/terraces related to transgressive and regressive cycles of sea-level change from the latest part of the Loch Lomond Stadial to the Holocene (MIS 2–1). The member has an unconformable and transgressive base on older units including the Bothkennar Gravel, Abbotsgrange Silt and Kinneil Kerse Silt members of the Forth Clay Formation, and the Errol Clay Formation. It is overlain unconformably by the sub-Carse Peat (where present) of the Flanders Moss Peat Formation, and by transgressive estuarine clay, silt and sand of the Carse of Stirling Clay Member.

Carse of Stirling Clay Member (COSCL)

The Carse of Stirling Clay Member (Carse Clay of Francis et al., 1970) comprises up to 15 m of clayey silt and clay, often rooty and structureless but otherwise highly laminated with silt and very fine- to medium-, sometimes coarse-grained sand. It is grey, black and brownish grey, and finely micaceous, with dark sulphidic patches, shells and shell fragments, and vivianite grains (Francis et al., 1970). These are deposits of an estuarine tidal flat complex formed just before and at the time of highest Holocene sea-level (Main Post-Glacial Shoreline). The member is unconformable on the sub-Carse Peat of the Flanders Moss Peat Formation, and older Holocene and late Devensian units including the Letham Silt Member (deposits of the High, Main and Low Buried Beaches). Its upper boundary is partly unconformably overlain by the transgressing Claret Clay Member and is also unconformably overlain by surface peats. The member is commonly exposed at the surface, partly because of peat clearances from the 18th century onwards. It also passes laterally into the peat bodies of the Flanders Moss Peat Formation on East and West Flanders Mosses.

Claret Clay Member (CTCL)

The Claret Clay Member (Claret Beds of Browne et al., 1984; Claret Formation of Paul et al., 1995; Claret Member of the Grangemouth Formation of Sutherland, p. 113 in Bowen, 1999) comprises up to 18 m of clayey silt and silty clay, which is typically finely laminated and crudely stratified with silt and very fine- to medium-, sometimes coarse-grained sand. It is grey, black and brownish grey, finely micaceous, and sulphide-rich, with shells and shell fragments, and vivianite grains (Francis et al., 1970). The sediments are massive where the lamination has been disturbed by burrowing organisms and, sometimes, by roots. These are deposits of an estuarine tidal flat complex formed after the time of highest Holocene sea-level (Main Post-Glacial Shoreline). The member is unconformable on older Holocene and late Devensian units including the Bothkennar Gravel Member and also on the Wilderness Till Formation. Locally in the Alloa–Grangemouth area of the Forth estuary the Carse of Stirling Clay Member passes upwards into this member. The upper boundary of the Claret Clay Member is mainly at the surface or it is overlain unconformably by modern alluvial deposits, e.g. the Grangemouth Silt Member.

GRANGEMOUTH SILT MEMBER (GMSI)

The Grangemouth Silt Member (Grangemouth Beds of Browne et al., 1984; Grangemouth Docks Member of the Grangemouth Formation of Sutherland, p. 113 in Bowen, 1999) comprises up to 18 m of clayey silt and silty clay, which is finely laminated and crudely stratified with silt and very fine- to medium-, sometimes coarse-grained sand. The base of the member is gravelly. It is grey, black and brownish grey, finely micaceous, and sulphide-rich, with shells and shell fragments (Browne et al., 1984). The sediments are massive where lamination has been frequently disturbed by burrowing organisms. Decaying vegetable matter is present locally as thin peat beds (maximum 9 cm). Cross-bedded sands, which represent tidal channel deposits, are also developed. These strata are deposits of an estuarine tidal flat complex formed after the time of highest Holocene sea-level (Main Post-Glacial Shoreline), up to modern times. The member is generally unconformable on Claret Clay Member, and on older Holocene and late Devensian units including the Wilderness Till Formation. Its upper boundary is mainly at the surface or the sea bed.

5.3 BRITANNIA CATCHMENTS GROUP

5.3.1 Formations of the Britannia Catchments Group

5.3.1.1 SOURLIE ORGANIC SILT FORMATION

Middle Devensian organic silts of the Sourlie Organic Silt Formation (Redburn Member of the Sourlie Formation of Sutherland, p. 109 in Bowen, 1999) were reported from sections at an opencast coal site at Sourlie [NS 3380 4139], 3.5 km north-east of Irvine, by Jardine et al. (1988) (Section 5.1.2.4).

Name
Sourlie Organic Silt Formation (SOSI) (after Jardine et al., 1988).

Lithology
Mainly dark brown, laminated organic silt and clay containing fragments of bone, antler and plant debris, with lenses of pebbly sand, pale and dark brown silt, black silty clay and about 30 cm of pale grey to white clay at base. Containing a rich fauna and flora indicative of a shallow pond within a treeless low-shrub to sedge-moss tundra of Middle Devensian age, including bone of woolly rhinoceros and reindeer. Radiocarbon dates on antler fragments range between 33.5–29.0 ka BP.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 11).

Type area/Reference section
Type section: Former Sourlie opencast coal site [NS 3380 4139], excavated into the NW side of Sourlie Hill, 3.5 km north-east of Irvine, Ayrshire (Jardine et al., 1988).

Lower and upper boundaries
Sharp, conformable contact with sand and gravel of the Armsheugh Sand and Gravel Formation at 10.8 m above OD.

Sharp unconformable, planar to gently undulating contact with pinkish brown shelly clayey diamicton of the Eglinton Shelly Till Member (Wilderness Till Formation) at 11.10 m above OD.

Landform description and genetic interpretation
Lacustrine deposits.

Thickness
Up to 1.5 m.

Distribution and extent
West Central Scotland.

Age
Middle Devensian (MIS 3).

5.3.1.2 CLIPPENS PEAT FORMATION

Late Devensian to Holocene peat of the Glasgow area is assigned to the Clippens Peat Formation (Clippens Formation of Browne and McMillan, 1989; Clippens Member of the Clyde Valley Formation of Sutherland, p. 110 in Bowen, 1999) (Figure 10a).

Name
Clippens Peat Formation (CLPT) (after Browne and McMillan, 1989).

Lithology
Peat.

Formal subdivisions and correlation table
No subdivisions (Table 11).

Type area/Reference section
Type area: Linwood Moss, near Paisley [NS 446 659].

Reference section: BGS Linwood Borehole [NS 4459 6588] BGS Registered No. NS46NW62 (Browne and McMillan, 1989, fig. 17) records 45 cm of very peaty stony soil overlying 1.3 m of peat, resting on 5 cm of grey rooty clay, followed by 84 cm of peat to the base of the formation at 2.64 m depth. The base of the upper bed of peat was at 8.43 m above OD and the base of the lower at 7.54 m above OD.

Lower and upper boundaries
Rests possibly by transitional passage on underlying members and formations or with angular unconformity on older Quaternary sediments or bedrock.

Ground surface in the Clyde valley catchment and also locally overlain by younger sediments.

Landform description and genetic interpretation
Organic deposits.

Thickness
Up to more than 5 m.

Distribution and extent
The Clippens Peat Formation is recognised discontinuously throughout the Clyde valley catchment.

Age
Late Devensian to Holocene (MIS 2–1). The basal 3 cm of each peat bed from the BGS Linwood Borehole (see Reference Section) have been radiocarbon dated to 7110 ± 50 years BP for the base of the upper peat and 9540 ± 50years BP for the base of the lower. A single specimen of the marine gastropod Onoba semicostata was found in the clay bed, tentatively indicating a marine origin, the transgression ending earlier than 7100 years BP.

5.3.1.3 FLANDERS MOSS PEAT FORMATION

Peat of Holocene age in the Forth, Earn, Tay, and Eden catchments and the Montrose Basin (for details see Francis et al., 1970, Paterson et al., 1981 and Browne et al., 1984) is assigned to the Flanders Moss Peat Formation.

Name
Flanders Moss Peat Formation (FLMP) (after Paterson et al., 1981).

Lithology
Peat with subordinate silt, clay and sand. Peat, fine and coarse textured, dark to pale brown and sometimes orange, with wood fragments and a wide variety of other organic remains including Sphagnum; in some areas wedges laterally into laminated minerogenic sediments.

Formal subdivisions and correlation table
No subdivisions currently in BGS Lexicon (Tables 6 and 11); includes the sub-Carse Peat of Francis et al. (1970) or Flanders Moss Member of the Grangemouth Formation of Sutherland (p. 113 in Bowen, 1999); see also Jamieson (1865), Sissons (1966, 1969, 1972, 1983); Sissons and Smith (1965) and Robinson (1993). The formation also includes the Hole of Clein Bed of the Tay Formation of Sutherland (p. 114 in Bowen, 1999).

Type area/Reference section
Type area: East and West Flanders Mosses [NS 6300 9800], western Forth valley (Smith and Holloway, 2000).

Lower and upper boundaries
Unconformable base on various local members of the Forth Clay Formation, Wilderness Till Formation and bedrock; also transitional base on clay gyttja and laterally passing into laminated minerogenic sediments (wedging into the Carse Clay Formation).

Overlain partly unconformably by Holocene transgressive estuarine sand, silt and clay of the Carse Clay Formation including the Letham Silt Member and also younger units including the Carse of Stirling Clay Member; and at surface.

Landform description and genetic interpretation
Organic deposits.

Thickness
From a veneer to over 7 m.

Distribution and extent
Surface and buried peats in the Forth (from east of Aberfoyle), Earn (from Dalreoch Bridge eastwards) and Tay (eastwards from just north of Perth) valleys and Forth, Eden and Tay estuaries, Montrose basin areas.

Age
Holocene (MIS 1).

Mass movement (lithogenetically defined units including head) and periglacial deposits are also referred to the Britannia Catchments Group.

Fluvial deposits (alluvium and river terrace deposits) of the Midland Valley are assigned to three subgroups, the **Clyde Catchments**, the **Forth Catchments** and the **Tay Catchments** subgroups (Sections 5.3.2–5.3.4).

5.3.2 Clyde Catchments Subgroup

The Clyde Catchments Subgroup (Tables 6 and 11; Figures 10a and 10b) includes the fluvial deposits of the River Clyde and its tributaries. Formations are based on the definitions of Browne and McMillan (1989). Fluvial deposits of the Leven, Ayr and Irvine valleys have yet to be defined in the BGS Lexicon.

Name
Clyde Catchments Subgroup (CLYCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
The deposits include alluvium and river terrace deposits of the Clyde Valley Formation and fluvial deposits of the Strathendrick Formation and other units defined simply by lithogenetic categories. The deposits of the subgroup comprise gravel, sand, silt, peat and head. Rock types found in clasts are principally of Carboniferous and Devonian strata (sandstone, siltstone) with volcanic (basalt) and intrusive igneous rocks (microdiorite) of Midland Valley provenance. Variable but generally minor components of Dalradian metasedimentary and Caledonian igneous rocks derived from the Grampian Highlands are present. Wacke sandstone and siltstone sourced in the Southern Uplands and Caledonian igneous rocks form a component of clastic fluvial deposits in parts of catchments close to the Southern Uplands.

Formal subdivisions and correlation table
Subdivided into the Clyde Valley Formation and Strathendrick Formation (Table 11).

Type area/Reference section
Type area: Catchments of the rivers Clyde, Kelvin, Endrick and the rivers of Ayrshire.

Lower and upper boundaries
Unconformable contacts with units of the Midland Valley, Mearns, central Grampian and Southern Uplands Glacigenic subgroups, and bedrock.

Generally the ground surface, but units of this subgroup interfinger locally with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of fluvial (alluvium and river terrace deposits) and associated organic and lacustrine sediments that contain clasts derived from Palaeozoic rocks and glacigenic depos-

its cropping out in the catchment of the River Clyde and other rivers flowing directly to the Firth of Clyde, including the River Leven, and Waters of Girvan, Ayr and Irvine.

Thickness
Up to 25 m.

Distribution and extent
The present physical catchments of the rivers Clyde, Kelvin, Endrick and the rivers of Ayrshire. The catchments extend across Strathclyde, (Ayrshire, Lanarkshire and Dumbartonshire).

Age
Devensian to Holocene (MIS 2–1).

5.3.2.1 Clyde Valley Formation

Name
Clyde Valley Formation (CLVY) (after Browne and McMillan, 1989).

Lithology
In the Clyde valley catchment, especially the Clyde and its major tributaries, the formation consists of a wide range of lithologies encompassing pebbles, fine to coarse gravel, cobbles and boulders in a sandy matrix and coarse- to fine-grained sand, silt and clay. Beds rich in organic remains occur as well as peat (in the floodplain deposits). The stratigraphical relationships and geographical distribution of the Clyde Valley Formation (formerly the Law Formation of Browne and McMillan, 1989) are illustrated in Browne and McMillan (1989, figs. 2e and 3).

Formal subdivisions and correlation table
Subdivided into the Lochwinnoch Clay, Law Sand and Gravel, and Strathkelvin Clay and Silt members (Tables 6 and 11).

Type area/Reference section
Type area: Clyde Catchment [NS 577 649–NS 963 159].

Reference section: BGS Law Borehole (BGS Registered No. NS85SW436) [NS 8357 5247], Castlehill Ridge, Law (Browne and McMillan, 1989).

Reference section: BGS Lochwinnoch Borehole (BGS Registered No. NS35NE26) [NS 3518 5812] (Browne and McMillan, 1989).

Lower and upper boundaries
Unconformably overlies older Quaternary deposits and bedrock.

Upper boundary normally the land surface.

Landform description and genetic interpretation
Fluvial (alluvium and river terrace deposits) and associated organic and lacustrine sediments.

Thickness
From a veneer to several metres.

Distribution and extent
Onshore, recognised in the Clyde catchment area as the alluvial deposits of the Clyde and all its tributaries, from highest to lowest order.

Age
Late Devensian to Holocene (MIS 2–1).

Lochwinnoch Clay Member (LNCH)

The Lochwinnoch Clay Member (Lochwinnoch Formation of Browne and McMillan, 1989; Lochwinnoch Member of Clyde Valley Formation of Sutherland, p. 110 in Bowen, 1999) comprises up to at least 4 m of silty clay with many layers of silt and locally of sand. Bands relatively rich in organic detritus also occur, typically about 20 units per metre. Grains and flecks of vivianite are common except in the lowest metre of the unit. In the basal 50 cm or so the deposit is almost all minerogenic and thinly colour-laminated in shades of orange, brown and grey. In general the clays are dark brown, of a firm consistency and medium plasticity, locally displaying folded slumped bedding. The base of the unit is a 10 cm-thick ripple-laminated sand. The lithofacies association is typical of lake-bottom muds, the presence of vivianite supporting this interpretation. The presence of dark organic-rich bands suggests seasonal banding. The deposits are interpreted to have formed as an alluvial fan laterally infilling the basin in the Lochwinnoch Gap, Lochwinnoch, Ayrshire, during the Windermere Interstadial (MIS 2).

Law Sand and Gravel Member (LAWSG)

The Law Sand and Gravel Member (formerly the Law Formation of Browne and McMillan, 1989; Law Member of Clyde Valley Formation of Sutherland, p. 110 in Bowen, 1999) comprises up to 7.6 m of massive, flat-laminated and also cross-bedded grey, fine- to coarse-grained sand with silt and traces of fine gravel, locally loose to dense, dark brownish grey, framework-supported, subangular to rounded fine to medium gravel with sand. Bedded silt with thin peat units and organic layers are intercalated. In places the member may encompass an even wider range of grain sizes including coarse gravel, cobbles and boulders. The deposits are interpreted to have formed in a minor meandering stream during the Holocene (MIS 1).

Strathkelvin Clay and Silt Member (KELV)

The Strathkelvin Clay and Silt Member of the Kelvin valley (Kelvin Formation of Browne and McMillan, 1989) comprises up to at least 9 m of silty clay with many layers of silt and locally of sand. Interbedded peat is also found. Bands relatively rich in organic detritus also occur. In general the clays are dark brown. The deposits are of either floodplain or lacustrine origin.

5.3.2.2 Strathendrick Formation

Name
Strathendrick Formation (SRCK) (after Browne and McMillan, 1989).

Lithology
In addition to alluvium of the present day floodplain and river terrace deposits, the Strathendrick Formation includes a wide range of lithologies encompassing pebbles, fine to coarse gravel, cobbles and boulders in a sandy matrix and coarse- to fine-grained sand, silt and clay. Beds rich in organic remains occur as well as peat (in the floodplain deposits).

Formal subdivisions and correlation table
Subdivided into the Kilmaronock Silt Member and Endrick Sand Member (Tables 6 and 11).

Type area/Reference section
Type area: The valley of the Endrick Water, in the Clyde catchment [NS 426 896–NS634 863].

Partial type section: BGS Mains of Kilmaronock Borehole, near Drymen (BGS Registered No. NS 48NW3) [NS 4483 8829] (Endrick Formation of Browne and McMillan, 1989).

Lower and upper boundaries
Unconformably overlies older Quaternary deposits and bedrock.

Upper boundary normally the land surface.

Landform description and genetic interpretation
Fluvial (alluvium and river terrace deposits) and associated organic and lacustrine sediments.

Thickness
From a veneer to several metres.

Distribution and extent
Recognised in the Clyde catchment area as the fluvial and lacustrine deposits of the valley of the Endrick Water.

Age
Late Devensian to Holocene (MIS 2–1).

KILMARONOCK SILT MEMBER (KILK)

The Kilmaronock Silt Member (after Kilmaronock Formation of Browne and McMillan, 1989; Kilmaronock Member of Clyde Valley Formation of Sutherland, p. 111 in Bowen, 1999) comprises up to at least 6 m of very thinly-bedded lacustrine silt with many clayey silt and silty clay layers. Sand layers are also common. The deposits are brown, dark brown, brownish grey and grey, with plant remains and locally with dark organic-rich bands. Grains and flecks of vivianite are present throughout. The deposit is of a firm and locally stiff consistency and medium to low plasticity. The Mains of Kilmaronock Borehole (Browne and McMillan, 1989, fig. 6) contains the standard (and only) section in the Kilmaronock Silt Member (13.6–19.95 m in depth).

ENDRICK SAND MEMBER (ENDR)

The Endrick Sand Member (Endrick Formation of Browne and McMillan, 1989; Endrick Member of Clyde Valley Formation of Sutherland, pp. 111–113 in Bowen, 1999) comprises up to at least 7.5 m of loose, fine- to medium-grained sand with some silt layers. The deposit is reddish brown and contains abundant plant remains and some dark organic clay bands. The sand usually appears to be flat-bedded but traces of cross-bedding are also present. Overall the deposit becomes coarser-grained upwards. The sediment at Mains of Kilmaronock might have been deposited by a meandering river in similar environments to those of the present River Endrick. They could also be partly deltaic in origin. The Mains of Kilmaronock Borehole (Browne and McMillan, 1989, fig. 6) contains the standard section in the Endrick Sand Member (5.99–13.6 m depth).

5.3.3 Forth Catchments Subgroup

The Forth Catchments Subgroup (Tables 6 and 11) is defined in this framework to include the fluvial and related organic deposits of the catchments surrounding the Forth Estuary. The alluvium and river terrace deposits of the river valleys of the Forth, Avon, Carron, Almond and Tyne (East Lothian), Water of Leith, Devon and Teith are assigned to the Forth Valley Formation.

Name
Forth Catchments Subgroup (FORCA) (after McMillan et al., 2005).

Lithology
The deposits include alluvium and river terrace deposits comprising gravel, sand, silt and peat. Rock types are principally of Carboniferous and Devonian strata (sandstone, siltstone) with volcanic (basalt and andesite) and intrusive igneous rocks (microdiorite) of Midland Valley provenance. Variable but generally minor components of Dalradian metasedimentary and Caledonian igneous rocks derived from the Grampian Highlands are present.

Formal subdivisions and correlation table
Forth Valley Formation (FOVA) (Tables 6 and 11).

Type area/Reference section
Type area: Catchment of the River Forth and Firth of Forth.

Lower and upper boundaries
Unconformable contacts with units of the Midland Valley, Mearns and Central Grampian Glacigenic subgroups and bedrock.

Generally the ground surface, but units of this subgroup interfinger locally with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of fluvial (alluvium and river terrace deposits) and associated organic and lacustrine sediments that contain clasts derived from Palaeozoic rocks and glacigenic deposits cropping out in the catchment of the River Forth and other rivers flowing directly to the Firth of Forth, including the rivers Teith, Almond, Carron, Allan Water, and the rivers Esk and Tyne of the Lothians.

Thickness
Up to 25 m.

Distribution and extent
The present physical catchment of the River Forth and the Firth of Forth. The catchments extend across Stirlingshire, Clackmannanshire, south Fife and the Lothians.

Age
Late Devensian to Holocene (MIS 2–1).

5.3.3.1 FORTH VALLEY FORMATION

Name
Forth Valley Formation (FOVA) (after Francis et al., 1970).

Lithology
In the Forth valley catchment, especially the Forth and its major tributaries, the formation consists of a wide range of lithologies encompassing pebbles, fine to coarse gravel, cobbles and boulders in a sandy matrix and coarse- to fine-grained sand, silt and clay. Beds rich in organic remains occur as well as peat (in the floodplain deposits).

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 11).

Type area/Reference section
Type area: Forth valley upstream of the tidal limit at Stirling [NS 5300 9900–NS 800 9450].

Lower and upper boundaries
Unconformably overlies older Quaternary deposits and bedrock.

Upper boundary normally the land surface.

Landform description and genetic interpretation
Fluvial (alluvium and river terrace deposits) and associated organic and lacustrine sediments.

Thickness
From a veneer to several metres.

Distribution and extent
Onshore, recognised in the Forth catchment area as the alluvial deposits of the River Forth and all of its tributaries, from highest to lowest order. Includes the valleys of the Water of Leith, Almond, Avon, Carron, Devon and Teith.

Age
Late Devensian to Holocene (MIS 2–1).

5.3.4 Tay Catchments Subgroup

The Tay Catchments Subgroup (Tables 6 and 11) is defined in this framework to include the fluvial and related organic deposits of the catchments surrounding the Tay Estuary. The alluvium and river terrace deposits of the river valleys of the Tay, Earn, Eden, Almond, Isla, Tummel and Garry are assigned to the **Strathtay Formation**. Formal status for deposits of the North Esk and South Esk has not yet been established.

Name
Tay Catchments Subgroup (TAYCA) (after McMillan et al., 2005).

Lithology
The deposits include alluvium and river terrace deposits comprising gravel, sand, silt, peat and head. Rock types are principally of Carboniferous and Devonian strata (sandstone, siltstone) with volcanic (basalt) and intrusive igneous rocks (microdiorite) of Midland Valley provenance. North of the Highland Boundary Fault the deposits are dominantly derived from Dalradian metasedimentary and Caledonian igneous rocks of the Grampian Highlands. South of the fault variable but generally minor components of Dalradian metasedimentary and Caledonian igneous rocks are present.

Formal subdivisions and correlation table
Strathtay Formation (Tables 6 and 11).

Type area/Reference section
Type area: Catchments of the River Tay and Firth of Tay.

Lower and upper boundaries
Unconformable contacts with units of the Midland Valley, Mearns and Central Grampian Glacigenic subgroups and bedrock.

Generally the ground surface, but units of this subgroup interfinger locally with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of fluvial (alluvium and river terrace deposits) and associated organic and lacustrine sediments that contain clasts derived from Palaeozoic rocks and glacigenic deposits cropping out in the catchment of the River Tay and other rivers flowing directly to the Firth of Tay, including the rivers Earn, Almond, Tummel, Isla, and the rivers North Esk and South Esk of Angus.

Thickness
Up to 25 m.

Distribution and extent
The present physical catchments of the River Tay and the Firth of Tay and the Montrose Basin. The catchments extend across Perthshire and Angus (Strathmore).

Age
Late Devensian to Holocene (MIS 2–1).

5.3.4.1 Strathtay Formation

Name
Strathtay Formation (STAY) (after Armstrong et al., 1985).

Lithology
In the Tay valley catchment, especially the Tay and its major tributaries, the formation consists of a wide range of lithologies encompassing pebbles, fine to coarse gravel, cobbles and boulders in a sandy matrix and coarse- to fine-grained sand, silt and clay. Beds rich in organic remains occur as well as peat (in the floodplain deposits).

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 11).

Type area/Reference section
Type area: Tay valley upstream from the tidal limit at Perth to the outlet of Loch Tay at Kenmore [NO 1300 2150–NN 7700 4500].

Lower and upper boundaries
Unconformably overlies older Quaternary deposits and bedrock.

Upper boundary normally the land surface.

Landform description and genetic interpretation
Fluvial (alluvium and river terrace deposits) and associated organic and lacustrine sediments.

Thickness
From a veneer to several metres.

Distribution and extent
Onshore, recognised in the Tay catchment area as the alluvial deposits of the River Tay and all of its tributaries, from highest to lowest order. Includes valleys of the Earn, Eden, Almond, Isla, Tummel and Garry.

Age
Late Devensian to Holocene (MIS 2–1).

6 Southern Scotland and the Solway

The oldest superficial deposits of this district are of glacigenic origin and of Devensian age including the period of the Loch Lomond Stadial (Caledonia Glacigenic Group). Pre-Devensian deposits are not known from southern Scotland although pockets may be preserved beneath parts of deep valley-fill. Deposits of the Britannia Catchments Group and British Coastal Deposits Group range in age from Late Devensian to Holocene.

6.1 CALEDONIA GLACIGENIC GROUP

6.1.1 Southern Uplands Glacigenic Subgroup

The Southern Uplands Glacigenic Subgroup comprises lithogenetically-defined glacigenic deposits with a significant proportion of locally-derived early Palaeozoic wacke sandstone, siltstone and mudstone components. These deposits are distributed widely over the Southern Uplands of Scotland but a formal lithostratigraphy has yet to be applied over much of the area. Within the Midland Valley, it is likely that formations of the Southern Uplands Glacigenic Subgroup and Midland Valley Glacigenic Subgroup interdigitate (e.g. to the south-east of the Pentland Hills). The principal centres of ice build-up were the Galloway Hills, the Moffat Hills, and the Cheviot Hills, all of which may have nourished small ice caps during the Loch Lomond Stadial and at earlier times during the Devensian. New lithostratigraphical glacigenic formations have been established in the Dumfries–Carlisle area (BGS 1:50 000 Special Sheets Solway East and Solway West; McMillan et al., in prep.).

Name
Southern Uplands Glacigenic Subgroup (SUDR) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Diamicton, gravel, sand, silt and clay containing clasts predominantly of wacke sandstone and siltstone with some granite, granodiorite, porphyry and dolerite. Deposits locally dominated by granite or granodiorite. Typically yellowish brown but locally reddish brown.

Formal subdivisions and correlation table
Subdivided into four formations: Sections 6.1.1.1–6.1.1.4 and Tables 8 and 12.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock.

Ground surface or unconformable contact with units of the Britannia Catchments Group (Solway Catchments Subgroup, Tweed Catchments Subgroup) and the British Coastal Deposits Group.

Landform description and genetic interpretation
See landforms associated with component formations.

Thickness
Up to 30 m.

Distribution and extent
Southern Uplands of Scotland.

Age
Devensian (MIS 2–5e).

6.1.1.1 LANGHOLM TILL FORMATION

The Langholm Till Formation, first described in the Langholm district (Lumsden et al., 1967; McMillan et al., in prep.), is widespread across the Southern Uplands.

Name
Langholm Till Formation (LHTI) (after Lumsden et al., 1967, Phillips and Auton, 2007, and McMillan et al., in prep.)

Lithology
Stiff, pale yellowish brown to pale grey, stony, sandy, silty clayey diamicton containing subangular to subrounded clasts of wacke sandstone and siltstone, and other rocks cropping out in the Southern Uplands.

Formal subdivisions and correlation table
New Abbey Till Member (NATI); Hoghill Gravel Bed (HGGR) Tables 8 and 12.

Type area/Reference section
Type section: River cliff on the southern side of the Hoghill Burn, 1 km upstream of Hoghill Farm [NY 3820 8905]. Here, the base of the Langholm Till Formation is represented by a 2.5 m-thick unit of dense clast-supported diamicton with angular–subangular wacke sandstone and siltstone clasts in a pale yellowish brown, silty sand that is referred to the Hoghill Gravel Bed (HGGR) (possibly MIS 3). This unit, interpreted as a gelifractate (scree), may rest on reddish brown, stony clayey diamicton (seen in nearby exposures) that possibly correlates with the Chapelknowe Till Formation (Irish Sea Coast Glacigenic Subgroup).

Lower and upper boundaries
Unconformable on bedrock or older Quaternary deposits.

Ground surface or conformable with younger Quaternary deposits.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 15 m.

Distribution and extent
Southern Uplands of Scotland.

Age
Late Devensian, Dimlington Stadial (MIS 2).

NEW ABBEY TILL MEMBER (NATI)

The New Abbey Till Member (NATI) comprises a pale grey to yellow-brown sandy and gravelly diamicton with a predominance of clasts of granodiorite derived from the Criffel Pluton.

6.1.1.2 DALSWINTON MORAINE FORMATION

Morainic deposits around Dumfries are assigned to the Dalswinton Moraine Formation and in the valley of the Esk north of Langholm to the Mouldy Hills Gravel Formation.

Name
Dalswinton Moraine Formation (DSMO) (after McMillan et al., in prep).

Lithology
Diamicton, bouldery, silty and sandy; very poorly exposed.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section
Type area: North-western flank of the valley of the River Nith in the vicinity of the village of Dalswinton [NX 935 856–NX 960 840], about 8 km north-west of Dumfries.

Lower and upper boundaries
Not seen; probably unconformable on Lower Palaeozoic wacke sandstone or Permian sandstone bedrock.

Present ground surface.

Landform description and genetic interpretation
Glacigenic deposit; large lateral moraine ridges rising 10–20 m above the level of the floodplain of the River Nith.

Thickness
Up to 15 m.

Distribution and extent
Valley of the River Nith, Dalswinton, Dumfries and Galloway (BGS 1:50 000 Special Sheet Solway West).

Age
Late Devensian, Dimlington Stadial (MIS 2).

6.1.1.3 MOULDY HILLS GRAVEL FORMATION

Name
Mouldy Hills Gravel Formation (MOHI) (after McMillan et al., in prep).

Lithology
Very poorly-sorted, matrix-rich gravel with boulders comprising angular–subrounded clasts mostly of wacke sandstone and siltstone with a matrix of yellowish brown, clayey sand. Subordinate beds of both clast- and matrix-supported, stratified diamicton, and lenses of silty sand.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section
Type section: Road cutting section on the western side of the A7(T), 1 km south of Langholm, Dumfries and Galloway [NY 3695 8313].

Lower and upper boundaries
Generally conformable boundary with the underlying Langholm Till Formation; otherwise unconformable contact with bedrock.

Generally at the ground surface, locally a conformable upper boundary with overlying Holocene deposits.

Landform description and genetic interpretation
Morainic deposits forming valley-side spreads.

Thickness
20 m.

Distribution and extent
Langholm district, Southern Uplands of Scotland (BGS 1:50 000 Special Sheet Solway East).

Age
Devensian.

6.1.1.4 KIRKBEAN SAND AND GRAVEL FORMATION

Name
Kirkbean Sand and Gravel Formation (KN) (after McMillan et al., in prep.)

Lithology
Sand and gravel, with cobbles and pebbles of Ordovician, Silurian, Devonian and Carboniferous rocks in a matrix of medium- to coarse-grained sand; typically pale yellow to pale brown. Granitic clasts are commonly a major component. Esker deposits are typically poorly sorted, being cobbly and bouldery, and well-bedded with high-angle cross-bedding, involutions and slumps. There are some interbeds of coarse sand. Kame and kettle deposits are poorly exposed, but appear to be typically moderately sorted, silty, sandy, clast-supported gravel with rounded–subrounded cobbles and pebbles. Glaciofluvial sheet deposits are poorly exposed but appear typically to be well-sorted sandy gravel, with interbeds of coarse- to medium-grained sand.

Formal subdivisions and correlation table
Subdivided on maps into three morpho-litho-genetic classes (Table 12).

Type area/Reference section
Type section: Kirkbean Quarry [NX 9793 5892], Kirkbean .

Lower and upper boundaries
Unconformable on older glacigenic sediments, such as till of the Gretna Till Formation; locally rests directly on bedrock.

Locally overlain by Holocene alluvium and peat, and by Holocene and Late-glacial raised marine deposits. Some exposures are capped by gravelly, friable, pale brown to reddish brown diamicton (supraglacial flow till typically 0.3–0.7 m in thickness).

Landform description and genetic interpretation
Esker ridges (glaciofluvial sub-glacial deposits), kame and kettle mounds and ridges (glaciofluvial ice-contact deposits) and fans and terraces (glaciofluvial sheet deposits).

Thickness
Variable, typically 4–10 m; esker deposits may be greater than 12 m thick; moundy ice-contact deposits and sheet deposits are typically 2–8 m thick.

Distribution and extent
Dumfries and Galloway (BGS 1:50 000 Special Sheets Solway West and Solway East).

Age
Late Devensian, Dimlington Stadial (MIS 2).

6.1.2 Irish Sea Coast Glacigenic Subgroup

In the Solway lowlands the Devensian glacigenic deposits of the Irish Sea Coast Glacigenic Subgroup are typically reddish brown and are derived predominantly from Permo-Triassic 'red-beds'. The subgroup subsumes the 'West Cumbria Drift Group' defined by Akhurst et al. (1997) and Merritt and Auton (2000) (Sections 7.1 and 7.3.2). The deposits include material derived from south-west Scotland and the Solway lowlands together with predominantly glaciomarine sediments from the Irish Sea Basin. The deposits were laid down from ice that flowed from southern Scotland across the Solway lowlands and around the north-western side of the Lake District southwards across the Irish Sea Basin.

Name
Irish Sea Coast Glacigenic Subgroup (ISCG) (after McMillan et al., 2005; Devensian formations of the West Cumbria Drift Group of Akhurst et al., 1997 and Merritt and Auton, 2000).

Lithology
Diamictons, gravel, sand, silt and clay, typically reddish brown and containing clasts of red and yellow sandstone, wacke sandstone and siltstone, granite and granodiorite. Welded tuff (Borrowdale Volcanic Group), mudstone, coal, shell fragments and reworked marine microfossils are common to the south of the Solway Firth.

Formal subdivisions and correlation table
Subdivided into Gretna Till, Chapelknowe Till, Plumpe Sand and Gravel, Kerr Moraine, Kilbane Sand and Gravel, and Cullivait Silt formations of the Solway district; the Gillcambon Till and Great Easby Clay formations of the Vale of Eden and north Cumbria; the Carleton Silt, Seascale Glacigenic, Aikbank Farm Glacigenic, and Gosforth Glacigenic formations of west Cumbria; the Shellag, Orrisdale and Jurby formations in the Isle of Man; the Kirkham Till Member (Stockport Glacigenic Formation) of Lancashire, the Stockport Glacigenic Formation of Cheshire, Staffordshire and North Wales, and the St Asaph Glacigenic and Teifi Clay formations of west Wales. Offshore units include the Cardigan Bay and Morecambe Bay formations. See Tables 8, 12, 13 and 17.

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock.

Ground surface or unconformable contact with units of the Britannia Catchments Group and the British Coastal Deposits Group.

Landform description and genetic interpretation
Glacigenic deposits. See landforms associated with component formations.

Thickness
Up to 50 m.

Distribution and extent
Solway lowlands, Vale of Eden, west Cumbria, Isle of Man, Lancashire, Cheshire, north and west Wales.

Age
Devensian (MIS 5d–2).

The 'tripartite' sequence of the Solway region has been the subject of debate over many years. A recurrent conclusion in the older literature is that several glacial re-advances occurred across the Solway lowlands during the Main Late Devensian Glaciation. However, although Pennington (1970), Evans and Arthurton (1973) and Thomas (1985a) concluded that the proposed major re-advance episodes were largely illusory and devoid of stratigraphical and chronological foundation, the re-advance concept has gained renewed support in the past thirty years (Huddart, 1970, 1971a, b, 1991, 1994; Huddart and Tooley, 1972; Huddart et al., 1977; Huddart and Clark, 1994; Merritt and Auton, 2000).

Re-advances of the last ice-sheet were first recognised within the Carlisle district by Trotter (1922, 1923, 1929). The 'tripartite' re-advance model was developed by Trotter and Hollingworth (1932a, b), who concluded that at least one major expansion of Scottish ice occurred that laid down a suite of deposits quite distinct from those formed during the main glaciation. Glaciofluvial and glaciolacustrine sediments were laid down in the coastal lowlands of west Cumbria during the initial deglaciation, later to be over-ridden during glacial re-advances. Each re-advance is considered to have caused minimal recognisable sub-glacial erosion, and laid down a thin, widespread mantle of diamicton ('upper till').

The 'tripartite' sequence identified by Trotter in the Gretna area has been confirmed (McMillan et al., in prep). It appears to be confined to a buried valley lying to the east of Gretna and Gretna Green. Here crumbly red sandy till overlies a thick sequence of red fine-grained sands and silts resting on gravel, which in turn rests on stiff red clayey till. The upper till is patchy and very variable in lithology. The underlying sequence has been glaciotectonised to a varying degree. Two type sections have been identified. At Plumpe Farm, Gretna [NY 3344 6813] the upper till has been assigned to the Plumpe Bridge Till Member (PLBT) of the **Gretna Till Formation**. The underlying sands have been named as the **Plumpe Farm Sand Member** (PFS) of the **Plumpe Sand and Gravel Formatio**n (Figure 11).

In the valley of the Logan Burn [NY 3110 7181], south of Chapelknowe, two red tills are separated by 5 m of dense gravel. The lower till is referred to the **Chapelknowe Till Formation**. The gravel, probably glaciofluvial, has been named as the Loganhouse Gravel Member (LOGG) of the **Plumpe Sand and Gravel Formation**.

6.1.2.1 Gretna Till Formation

At Plumpe Farm and elsewhere in the Solway district the surficial tills of the Irish Sea Coast Glacigenic Subgroup are assigned to the Gretna Till Formation. The tills are predominantly reddish brown with matrices composed of variable proportions of clay, silt and fine-grained sand. Gravel content is also variable. The tills are generally very compact, poorly stratified, matrix-supported diamictons containing angular–rounded clasts up to boulder-size. The most abundant clasts are generally wacke sandstones and siltstones from the Southern Uplands, with smaller proportions of red sandstone and vivid red to purple siltstone from the local Permo-Triassic outcrops. Sparser lithologies include granodiorites and granites from Criffel and the

Galloway Hills respectively, more locally-derived Permian and Carboniferous andesites and basalts (mainly from the Birrenswark Volcanic Formation), and dolerite from dykes. Tills overlying outcrops of Carboniferous sedimentary rocks are commonly yellowish brown in colour and contain much yellow and white sandstone. Large angular blocks of underlying strata are common towards the base of tills.

The tills vary up to about 25 m in thickness, but probably average about 5 m. In general they become increasing compact and more homogeneous downwards. The uppermost few metres are commonly crudely stratified and vary considerably in lithology and compactness over distances of a few metres (both horizontally and vertically). Lenses of sand, gravel, silt and clay are common towards the surface, but locally there are thicker and more laterally-persistent beds that represent mappable units within the local glacigenic sequence (see below).

Name
Gretna Till Formation (GRET) (after Trotter, 1929, Trotter and Hollingworth, 1932a, and McMillan et al., in prep.)

Lithology
Reddish brown, sandy, silty, clayey diamicton with clasts of wacke sandstone, red sandstone, siltstone and grey granodiorite. Uppermost 3 m generally variable in lithology and compactness, with lenses of sand, gravel, silt and clay. Commonly becoming more compact and stony with depth.

Formal subdivisions and correlation table
Plump Bridge Till Member (PLBT) (Tables 8 and 12).

Type area/Reference section
Partial type section: River cliff of the Logan Burn [NY 3110 7181], 1.5 km south of Chapelknowe, Dumfries and Galloway.

Partial type section: Plumpe Farm [NY 3344 6813], 1 km east of Gretna, Dumfries and Galloway. Note, however, that the unit is named for the nearby 'Plump Bridge'(sic).

Lower and upper boundaries
Unconformable on bedrock.

Ground surface or overlain conformably by glaciofluvial/ glaciolacustrine or Holocene sediments.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 20 m.

Distribution/extent
Solway lowlands.

Age
Late Devensian, Dimlington Stadial (MIS 2).

PLUMP BRIDGE TILL MEMBER (PLBT)

The Plump Bridge Till Member comprises up to 10 m of reddish brown, sandy, silty, clayey diamicton with clasts of wacke sandstone, red sandstone, siltstone and grey granodiorite. The uppermost 3 m is generally variable in lithology and compactness, with lenses of sand, gravel, silt and clay. The member commonly has a gradational, glaciotectonic contact with the underlying Plumpe Sand and Gravel Formation, or Chapelknowe Till Formation. Otherwise it is unconformable on bedrock. The upper boundary of the member is at surface or it is overlain conformably by glaciofluvial, glaciolacustrine or Holocene sediments.

6.1.2.2 CHAPELKNOWE TILL FORMATION

The Chapelknowe Till Formation can be distinguished from the Gretna Till Formation only where it is separated from it by members of the Plumpe Sand and Gravel Formation.

Name
Chapelknowe Till Formation (CHAK) (after Lower Boulder Clay of Trotter and Hollingworth, 1932a; McMillan et al., in prep.)

Lithology
Reddish brown, sandy, silty, clayey, stony diamicton with clasts of wacke sandstone and siltstone, red sandstone, and grey granodiorite. Generally very compact.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12, Figure 11).

Type area/Reference section
Type section: river cliff of the Logan Burn [NY 3110 7181], 1.5 km south of Chapelknowe, Dumfries and Galloway.

Lower and upper boundaries
Lower boundary unconformable on bedrock.

Upper boundary sharp, erosional contact with deposits of the overlying Plumpe Sand and Gravel Formation.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
20 m.

Distribution and extent
Solway lowlands.

Age
Early Devensian (MIS ?4) or younger.

6.1.2.3 PLUMPE SAND AND GRAVEL FORMATION

Name
Plumpe Sand and Gravel Formation (PLSG) (Middle Sands of Trotter and Hollingworth, 1932a).

Lithology
Sand and gravel, typically reddish brown and silty, containing clasts of red sandstone, wacke sandstone and siltstone, and grey granodiorite.

Formal subdivisions and correlation table
Subdivided into the Plumpe Farm Sand Member and Loganhouse Gravel Member (Tables 8 and 12, Figure 11).

Type area/Reference section
Partial type section: River cliff of the Logan Burn, 1.5 km south of Chapelknowe, Dumfries and Galloway.

Partial type section: Plumpe Farm [NY 3344 6813], 1 km east of Gretna, Dumfries and Galloway.

Lower and upper boundaries
Erosional contact with the underlying Chapelknowe Till Formation.

Commonly a gradational, glaciotectonic contact with the overlying Plump Bridge Till Member of the Gretna Till Formation.

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
15 m.

Distribution/extent
Solway lowlands.

Age
Late Devensian, Dimlington Stadial (MIS 2).

PLUMPE FARM SAND MEMBER (PFS)

The Plumpe Farm Sand Member comprises up to 15 m of reddish brown, silty sand with subordinate beds of silt, clay and gravel. Locally the unit is composed dominantly of silt and clay. It has a conformable contact with the underlying Chapelknowe Till Member (Gretna Till Formation) or with the Loganhouse Gravel Member (Plumpe Sand and Gravel Formation). Commonly there is a gradational, glaciotectonic contact with the overlying Plump Bridge Till Member (Gretna Till Formation). Otherwise the member is unconformable on bedrock.

LOGANHOUSE GRAVEL MEMBER (LOGG)

The Loganhouse Gravel Member comprises up to 5 m of dense, reddish brown, silty gravel with clasts of red sandstone, wacke sandstone and siltstone. The member has an erosional contact with the underlying Chapelknowe Till Member Formation. It has either a conformable contact with the overlying Plumpe Farm Sand Member (Plumpe Sand and Gravel Formation) or a sharp, glaciotectonic contact with the overlying Plump Bridge Till Member (Gretna Till Formation).

6.1.2.4 KERR MORAINE FORMATION

These hummocky deposits are highly variable in lithology and include complex interdigitating beds of diamicton, boulder gravel, sand, silt and clay. Most deposits are 'constructional' moraines that formed at the ice-sheet margin during 'active' glacial retreat. They were deposited by several processes, including 'dumping' of debris from the glacier surface, and 'bulldozing' of loose debris at the ice front during forward movement of the ice.

Many morainic ridges are closely associated with ice-marginal glacial drainage channels. Good examples of such channels are found in the vicinity of Kerr Height [NY 338 800], 5 km south-west of Langholm, where southward-flowing meltwater at the westward retreating ice margin cut a series of interconnecting channels down the valleyside. The channels abut ridges, one of which includes a kettle-hole. This is the type area of the Kerr Moraine Formation, which includes most of the morainic deposits of the Irish Sea Coast Glacigenic Subgroup.

Name
Kerr Moraine Formation (KEMO) (after McMillan et al., in prep.)

Lithology
Interbedded diamicton, boulder gravel, sand, silt and clay. Typically reddish brown with clasts of red sandstone dominant, but locally yellowish brown with clasts of yellow sandstone dominant.

Formal subdivisions and correlation table
Marchfield Moraine Member (MMO) (Tables 8 and 12).

Type area/Reference section
Type area: mounds and ridges found in the vicinity of Kerr Height, 5 km south-west of Langholm, Dumfries and Galloway [NY 338 800]. The ridges are generally closely associated with ice-marginal glacial drainage channels and formed at the ice margin during glacial retreat.

Lower and upper boundaries
Lower boundary generally conformable with the Gretna Till Formation, or rests unconformably on bedrock.

Upper boundary generally the ground surface.

Landform description and genetic interpretation
Large recessional moraine forming discontinuous mounds and ridges typically rising 10–15 m above the level of the surrounding glaciofluvial sand and gravel deposits; a large mound at Cargenbridge rises up to 22 m above the glaciofluvial deposits on the western bank of the River Nith.

Thickness
Generally up to 5 m and locally at least 12 m.

Distribution and extent
Solway lowlands.

Age
Late Devensian, Dimlington Stadial (MIS 2).

MARCHFIELD MORAINE MEMBER (MMO)

The Marchfield Moraine Member comprises a lithologically heterogeneous sequence, at least 12 m thick, of interstratified sand and gravel, reddish brown glacial diamicton (till), silt and clay. Surface exposures show extensive small-scale normal faulting and some low-angle glaciotectonic thrusting. The lower boundary is not exposed, but is probably a gradational contact on till of the Gretna Till Formation. The upper boundary is normally the ground surface but locally the deposit is overlain by Holocene peat in hollows in the moraine surface.

6.1.2.5 KILBLANE SAND AND GRAVEL FORMATION

The glaciofluvial deposits of the Irish Sea Coast Glacigenic Subgroup are composed of a similar range of rock types to the tills, except that clasts of Permo-Triassic red sandstone are relatively more abundant. The glaciofluvial deposits that extend to the present land surface have been assigned to the Kilblane Sand and Gravel Formation. The three morphogenetic categories of deposit may be regarded as informal members of the formation. Most of the deposits were laid down during the final deglaciation, either sub-glacially as eskers, or proglacially as glacial outwash fans and deltas (sandar).

Name
Kilblane Sand and Gravel Formation (KBSG) (after Huddart, 1999, and McMillan et al., in prep.)

Lithology
Sand and gravel, with cobbles and pebbles predominantly of Permo-Triassic sandstone and Lower Palaeozoic

sedimentary and volcanic rocks in a matrix of medium- to coarse-grained sand; typically pale yellow to reddish brown. Wacke sandstone and granitic clasts are common in subordinate amounts. Esker deposits are typically poorly sorted, cobbly and bouldery, well-bedded with high-angle cross-bedding. Some interbeds of coarse sand. Fluted kame and kettle deposits are typically moderately sorted, thickly-bedded, cobbly, commonly in upward-fining, steeply tabular cross-bedded or trough cross-bedded units. Glaciofluvial sheet deposits are typically thickly-bedded well-sorted gravels, with interbeds of coarse- to medium-grained sand. Commonly horizontally-bedded, but tabular high-angle cross-bedded units are common. The upper surface is commonly involuted and beds of laminated and rippled sandy silt and clay with drop-stone cobbles are present locally, indicating the presence of temporary glacial lakes.

Formal subdivisions and correlation table
Subdivided into three types of morpho-litho-genetic category (Tables 8 and 12).

Type area/Reference section
Partial Type Section: Kilblane Quarry [NX 9846 8212].

Reference Section: Locharbriggs Sand and Gravel Pit [NX 9937 8156].

Lower and upper boundaries
Unconformable on older glacigenic sediments, such as till of the Gretna Till or Langholm Till formations, or sandy and silty glaciolacustrine deposits of the Cullivait Silts Formation; locally rests directly on bedrock.

Locally overlain by Holocene alluvial and raised marine deposits, and peat. Some exposures in sheet deposits are capped by gravelly friable pale brown to reddish brown diamicton (supraglacial flow till), typically 0.3–0.6 m in thickness. Involutions and possible frost-wedge casts are present in the upper parts of terraced and kame-terrace deposits.

Landform description and genetic interpretation
Esker ridges (glaciofluvial sub-glacial deposits), fluted kame and kettle mounds and ridges (glaciofluvial ice-contact deposits), kame terraces, sandar plains, fans and terraces (glaciofluvial sheet deposits).

Thickness
Variable, typically 3–10 m, esker deposits may be greater than 15 m thick, the worked spreads of ice-contact deposits may exceed 10 m in thickness locally; kame terrace deposits and sandar are typically 2–8 m thick.

Distribution and extent
Northern margin of the Solway Firth, principally between Dumfries and Gretna, but extending inland to beyond Dalswinton, Lochmaben, Lockerbie and Canonbie.

Age
Late Devensian, Dimlington Stadial (MIS 2).

6.1.2.6 Cullivait Silts Formation

The glaciolacustrine deposits within the Irish Sea Coast Glacigenic Subgroup are assigned to the Cullivait Silts Formation. Fine-grained sand, silt and clay laid down in standing water form part of many glaciofluvial sequences in the district, but only those deposits that are sufficiently extensive have been identified separately as being 'glaciolacustrine'. These are commonly laminated and contain drop-stones. They were mainly deposited in ice-marginal, proglacial lakes that formed in the upper reaches of valleys during ice-sheet deglaciation whilst the lower reaches were blocked by ice. Extensive deposits of laminated silt and clay occur to the east of the Solway.

Name
Cullivait Silts Formation (CUS) (after McMillan et al., in prep.)

Lithology
Interbedded silty clay, sandy silt, and silty sand, forming upwards coarsening flat-lying units; generally moderate reddish brown to brown or greyish brown. Sandy silts and silty clays are typically thinly-bedded in finely-laminated to massive beds; silty sands display planar lamination, ripple lamination and small-scale tabular cross-bedding. Rounded wacke sandstone drop-stone cobbles disrupt the lamination in silt and clay units at the Partial Type Section.

Formal subdivisions and correlation table
No subdivisions (Table 12).

Type area/Reference section
Reference Section: BGS Registered Borehole NY 37NE1 [NY 3934 7538], about 1 km south-south-east of Canonbie, Dumfries and Galloway (A7 Improvement-Canonbie Site Investigation Record SE 1054, Borehole 4).

Partial Type Section: Locharbriggs Sand and Gravel Pit. BGS Registered Section CA1320 [NX 9956 8138] about 250 m south-east of Cullivait House, Dumfries and Galloway.

Lower and upper boundaries
Either overlies bedrock or red-brown diamicton of the Gretna Till Formation. Base of unit is not exposed at the Partial Type Section.

Taken at the base of the Kilblane Sand and Gravel Formation at the Partial Type Section; overlain by red-brown diamicton of the Gretna Till Formation in the Reference Section.

Landform description and genetic interpretation
Glaciolacustrine deposits infilling basins and hollows associated with glaciofluvial outwash deposited during Late Devensian deglaciation.

Thickness
Typically 3–5 m, but greater than 10 m proved in boreholes south of Canonbie.

Distribution and extent
Northern margin of the Solway Firth, principally between Dumfries and Gretna, but extending inland to Dalswinton and Canonbie. These deposits also occur concealed beneath the alluvial sediments of the River Esk between Gretna and Carlisle.

Age
Late Devensian, Dimlington Stadial (MIS 2).

6.1.3 Borders Glacigenic Subgroup

The Borders Glacigenic Subgroup comprises a suite of glacial, glaciofluvial and glaciolacustrine deposits including sandy diamictons (till), sand, gravel, silt and clay. The sediments were deposited by or are the deglaciation products of ice that emanated from the Southern Uplands and streamed eastwards around the northern margins of the Cheviot Hills across the Merse of Berwickshire.

Name
Borders Glacigenic Subgroup (BDRGL) (after McMillan et al., 2005).

Lithology
Sandy diamictons (till), sand, gravel, silt and clay. The deposits contain clasts derived from predominantly Devonian to Carboniferous sedimentary rocks (sandstone, siltstone and mudstone) with Carboniferous volcanic rocks of the Kelso District. Varying proportions of Devonian volcanic and intrusive rocks (basalt, andesite) of the Cheviot Hills and Lower Palaeozoic wacke sandstone and siltstone are also present. Tills are generally matrix-supported diamictons with characteristically brownish grey or yellowish grey matrices. However, locally they can be reddish brown either where the diamictons are weathered or are derived from red strata (e.g. Devonian outcrops).

Formal subdivisions and correlation table
Norham Till Formation and informal Greenlaw Gravel Formation (Tables 8 and 12); other units (e.g. glaciofluvial sand and gravel) yet to be formalised.

Type area/Reference section
Type area: The glacigenic deposits of the Borders Glacigenic Subgroup are distributed across the Merse of Berwickshire and around the northern margins of the Cheviot Hills. They are dominated by tills but also include glaciofluvial sheet sand and gravels and sub-glacial (esker) deposits such as the Bedshiels Kames between Greenlaw and Duns. Minor outcrops of glaciolacustrine silty clays are present in small basins, notably between Swinton and Coldstream.

Lower and upper boundaries
Sharp, unconformable contact with bedrock. Pre-Ipswichian Quaternary deposits are not proved within the Scottish Borders.

Unconformable contact with units of the Britannia Catchments Group (Tweed Catchments Subgroup) and the British Coastal Deposits Group.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial and glaciolacustrine deposits. Tills are drumlinised. Glaciofluvial deposits occur as mounds (kames) and eskers. Terrace deposits are also present.

Thickness
Up to 30 m.

Distribution and extent
Distributed across the Merse of Berwickshire from the Lammermuir Hills in the north to the margins of the Cheviot Hills in the south. Units of the subgroup may occur locally beyond these geographical boundaries and beyond the approximate surface boundaries with adjacent glacigenic subgroups (e.g. the North Sea Coast Glacigenic Subgroup). Units may also extend offshore.

Age
Late Devensian, Dimlington Stadial (MIS 2).

6.1.3.1 Norham Till Formation

Name
Norham Till Formation (NMTI) (after Carruthers et al., 1932).

Lithology
Dark red sandy, silty clayey diamicton containing clasts of gravel to cobble grade (1–10 cm). Semi-consolidated, matrix-supported. Clasts are subrounded to subangular consisting of sandstone, quartz and a hard, red mudstone, and have no apparent preferred orientation

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section
Type section: Top of bank on the north side of the River Tweed [NT 0054 7821], north of the village of Norham, Berwickshire.

Reference section: Pressen Farm [NT 836 359], Northumberland.

Lower and upper boundaries
Base of till not seen at type section, but probably rests on bedrock.

At surface.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 4 m.

Distribution and extent
Merse of Berwickshire (BGS 1:50 000 Sheet S26W, Coldstream, in prep.)

Age
Late Devensian, Dimlington Stadial (MIS 2).

The informal **Greenlaw Gravel Formation** (proposed by McMillan et al., 2005) comprises sand and gravel of glaciofluvial origin and Late Devensian age. The deposits are best exposed in sections of the esker system of Bedshiel Kaims [NT 3707 6512], on Greenlaw Moor, 4 km north of Greenlaw, Berwickshire (Evans et al., 2006). The esker varies in height between 6 and 12 m above the flattish surface of till on which it rests. The gravel is dominated by locally-derived wacke sandstone.

6.1.4 Cheviot Glacigenic Subgroup

Name
Cheviot Glacigenic Subgroup (CHVG) (after Carruthers et al., 1932, Clapperton, 1970, Douglas and Harrison, 1985, 1987, and Mitchell, 2005, 2008; includes Linhope Spout Formation of Thomas, p.98 in Bowen, 1999).

Lithology
Suite of sandy diamictons (till, morainic and solifluction deposits), sand, gravel, silt and clay originating from the Cheviot Hills. The deposits contain clasts derived predominantly from volcanic and intrusive rocks (basalt, andesite and granite) of the Cheviot Hills. Varying proportions of Lower Palaeozoic wacke sandstone and siltstone are also present near the western limits of the subgroup. Tills are generally matrix-supported diamictons with characteristically brownish grey or yellowish grey matrices. However, locally they can be reddish brown either where the diamictons are weathered or are derived from red strata (e.g. Devonian outcrops).

Formal subdivisions and correlation table
Kale Water Till Formation (after Mitchell, 2005, 2008) (Tables 8 and 12).

Type area/Reference section
Type area: Uplands of the Cheviot Hills between Carter Bar and Harehope, south-east of Wooler [NT 693 071–NT 101 184].

Lower and upper boundaries
Unconformable contact with bedrock. Bedrock is commonly weathered to depths of several metres.

Unconformable contact with peat or fluvial deposits of the Britannia Catchments Group (Tweed Catchments or Northumbria Catchments subgroup).

Landform description and genetic interpretation
Glacigenic sediments deposited by ice which emanated from the Cheviot Hills.

Thickness
Up to 10 m.

Distribution and extent
Distributed over the Cheviot Hills massif.

Age
Late Devensian, Dimlington Stadial (MIS 2).

6.1.4.1 Kale Water Till Formation

Name
Kale Water Till Formation (KWTI) (after Mitchell, 2005, 2008).

Lithology
Compact matrix-supported diamicton with numerous subrounded, striated boulder-sized clasts. Clast lithology is dominated by the local andesite but there are also striated clasts of sandstones and other sedimentary rocks which have been brought from the south and west of the Kale Water (Mitchell, 2005, 2008).

Formal subdivisions and correlation table
Linhope Spout Member (after Douglas and Harrison, 1985, 1987, and Douglas, 1991; Linhope Spout Formation of Thomas, p.98 in Bowen, 1999) (Tables 8 and 12).

Type area/Reference section
Type section: East bank of the Kale Water [NT 7694 1561], south of Swanlaws: at least 3 m of highly compact diamicton with large subangular to subrounded erratic clasts of sandstone and fine-grained igneous rock (Mitchell, 2005, 2008).

Lower and upper boundaries
Unconformable on bedrock.

This diamicton is at surface or is overlain either by resedimented diamicton which can be defined as a solifluctate (head) or by gravel.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
At least 3 m.

Distribution and extent
Valley of the Kale Water, Cheviot Hills.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Linhope Spout Member

The Linhope Spout Member (Linhope Spout Formation of Thomas, p. 98 in Bowen, 1999) comprises locally-derived basal till overlain by 4 m of bedded solifluction deposits composed of coarse-grained granite debris (Tables 8 and 12). The stratotype is Linhope Spout [NT 958 171] in the Breamish valley, south of the Cheviot.

6.2 BRITISH COASTAL DEPOSITS GROUP

6.2.1 Formations of the British Coastal Deposits Group

The British Coastal Deposits Group includes estuarine, beach and marine deposits of the Solway lowlands. Sutherland (p. 107 in Bowen, 1999) defines seven members of one formation, the Redkirk Formation, comprising late Devensian to Holocene marine, estuarine, organic, lacustrine and fluvial sediments. In the present framework the non-marine units are referred to the **Blelham Peat Formation** of the Britannia Catchments Group (Section 6.3.1.1) and the Holocene estuarine deposits are assigned to the informal Newbie Silt Member of the **Carse Clay Formation** (Sections 5.2.1.6 and 6.2.1.1). Beach and raised beach deposits of the Solway have yet to be defined formally in the BGS Lexicon.

6.2.1.1 Carse Clay Formation

See Section 5.2.1.6 for a description of this formation.

Newbie Silt Member

The Newbie Silt Member comprises 6 m or more of silt and fine sand with lenses of peat. It rests unconformably on the Redkirk Point Peat Bed (Blelham Peat Formation) or till or bedrock. It is overlain by or interdigitates with the Racks Moss Peat Member (Blelham Peat Formation). The type section is Newbie shore [NY 165 651] (Gordon, 1993c).

6.3 BRITANNIA CATCHMENTS GROUP

6.3.1 Formations of the Britannia Catchments Group

Late Devensian to Holocene organic (blanket peat) and lacustrine beds are known from many parts of the South of Scotland (for a summary see Nichols, 1967; Moar, 1969). Blanket peat is extensive on the Cumbrian side of the Border (Dixon et al., 1926). In the Solway, such deposits have been described from sections at Bigholms Burn [NY 316 812], south-west of Langholm, Redkirk Point [NY 301 652] and Racks Moss [NY 030 730], part of Lochar Moss, Dumfries (Nichols, 1967; Moar, 1969; Bishop and Coope, 1977; Gordon, 1993d; Sutherland, p. 107 in Bowen, 1999).

6.3.1.1 Blelham Peat Formation

The fluvial, lacustrine and organic deposits of Bigholms Burn, [NY 3141 8131], 6 km south-west of Langholm (Moar, 1969; Bishop and Coope, 1977; Gordon, 1993d) are considered to be of Windermere Interstadial–Holocene age (MIS 2–1). Informal members and beds (members of the

Redkirk Formation of Sutherland, p.107 in Bowen, 1999) are here referred to the Blelham Peat Formation (BHBT) (Section 7.5.1.3). Informal units include the *Redkirk Point Peat Bed, Bigholms Burn Peat Bed, Bigholms Burn Gravel Member, Healy Hill Organic Mud Member* and *Racks Moss Peat Member* (modified after Sutherland, p.107 in Bowen, 1999) (Tables 6 and 12).

Fluvial deposits (alluvium and river terrace deposits) of the South of Scotland are assigned to two subgroups, the **Solway Catchments** and the **Tweed Catchments** subgroups.

6.3.2 Solway Catchments Subgroup

The Solway Catchments Subgroup includes fluvial deposits (alluvium and river terrace deposits) of the entire catchment of the Solway Firth bordering the coast between Stranraer and St Bees Head (McMillan and Hamblin, 2000). The subgroup partially subsumes the Solway Formation of Thomas (p.96 in Bowen, 1999) and the Solway Drift Group defined in the Sellafield area of the west Cumbrian coast by Merritt and Auton (2000). The deposits range from Late Glacial–Holocene (MIS 2-1) in age.

Formations are assigned to the fluvial deposits of the principal river valleys (Table 12). These include in Dumfries and Galloway, the formally defined **Solway Esk Valley Formation** (BGS 1:50 000 Special Sheet Solway East; McMillan et al. In prep.) and the informal **Cree Valley, Fleet Valley, Kirkcudbright Dee Valley, Nithsdale, Annan Valley** formations. In north Cumbria informal units include the **Eden Valley, Wampool Valley, Waver Valley, Ellen Valley** and **Derwent Valley** formations. The informal formations have yet to be defined in the BGS Lexicon.

Name
Solway Catchments Subgroup (SYDR) (after McMillan, 2005, and McMillan et al., 2005; partially subsumes Solway Drift Group of Merritt and Auton, 2000).

Lithology
A suite of fluvial and associated organic deposits that contain clasts derived from Palaeozoic rocks and glacigenic deposits cropping out in the catchment of the Solway Firth, including the Rivers Cree, Dee (Kirkcudbright), Nith, Annan, Esk, Eden.

Formal subdivisions and correlation table
Includes the Solway Esk Valley Formation and informal Cree Valley, Fleet Valley, Kirkcudbright Dee Valley, Nithsdale, Annan Valley, Eden Valley, Wampool Valley, Waver Valley, Ellen Valley and Derwent Valley formations. Section 6.3.2.1 and Tables 6 and 12.

Type area/Reference section
Type area: The catchment of the Solway Firth.

Lower and upper boundaries
Generally an unconformable boundary with units of the Caledonia Glacigenic Group.

Generally the ground surface, but units of this Subgroup interfinger locally with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
River terraces and floodplains.

Thickness
Up to 30 m.

Distribution and extent
The catchment of the Solway Firth.

Age
Late Devensian to Holocene (MIS 2–1).

6.3.2.1 Solway Esk Valley Formation

Name
Solway Esk Valley Formation (SESKV) (after Dixon et al., 1926, and McMillan et al., in prep.)

Lithology
Mainly comprises sand and gravel and silty, clayey sand. Includes units of sand, silt and clay, which are typically reddish brown.

Formal subdivisions and correlation table
Subdivided into terrace deposit members; formation only shown in Tables 6 and 12.

Type area/Reference section
Type area: the valley of the River Esk and its tributaries [NY 205 965–NY 340 640], Dumfries and Galloway.

Lower and upper boundaries
A sharp, undulating, erosional contact, mainly on reddish brown, clayey, sandstone-rich diamictons of the Gretna Till Formation, or yellowish brown, wacke-rich diamictons of the Langholm Till Formation.

At the present ground surface or, locally, covered by peat.

Landform description and genetic interpretation
River terraces and floodplain.

Thickness
Up to 15 m.

Distribution and extent
The valley of the River Esk and its tributaries, Dumfries and Galloway.

Age
Late Devensian to Holocene (MIS 2–1).

6.3.3 Tweed Catchments Subgroup

The Tweed Catchments Subgroup comprises a suite of fluvial, lacustrine, mass movement (head), periglacial and organic (peat) deposits. The subgroup includes the alluvium and river terrace deposits of the River Tweed and tributaries (Tweed Valley Formation). The fluvial deposits contain clasts derived from rocks cropping out within the catchment of the River Tweed in northern Northumberland and the Scottish Borders (mainly Devonian–Carboniferous sandstone, siltstone with limestone, Lower Palaeozoic wacke sandstone and siltstone and varying proportions of volcanic rocks including Devonian andesites of the Cheviot Hills and Carboniferous basalts of the Kelso district). No formal units have been established. The Tweed Valley Formation will be defined during the course of ongoing Survey revision mapping.

Name
Tweed Catchments Subgroup (TWEED) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Gravel, sand, silt and clay.

Formal subdivisions and correlation table
Tweed Valley Formation (TWVA) Tables 6 and 12.

Type area/Reference section
Type area: The Tweed catchment of the Scottish Borders and Northumberland.

Lower and upper boundaries
Unconformable contact with units of the Caledonia Glacigenic Group.

Generally the ground surface, but units of this subgroup interfinger locally with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of fluvial and lacustrine deposits that contain clasts derived from Palaeozoic rocks and glacigenic deposits cropping out in the catchment of the River Tweed.

Thickness
Up to 25 m.

Distribution and extent
The Tweed catchment of the Scottish Borders and Northumberland.

Age
Late Devensian–Holocene (MIS 2–1).

7 The Vale of Eden, Lake District, west Cumbria and the Isle of Man

The oldest superficial deposits of west Cumbria and the Isle of Man are of glacigenic origin and of pre-Devensian age (Albion Glacigenic Group). The most extensive deposits are assigned to the Caledonia Glacigenic Group and are of Late Devensian age including the Loch Lomond Stadial. Deposits of the Britannia Catchments Group and British Coastal Deposits Group range in age from Late Devensian to Holocene.

The onshore lithostratigraphy of the region (Table 12) is based mainly on type sections in west Cumbria described by Huddart et al. (1977), Huddart (1991), Nirex (1997a, 1997b) and Merritt and Auton (2000). A summary appears in Akhurst et al. (1997). Table 12 also shows the stratigraphical equivalence with formations defined by Thomas in Chadwick et al. (2001) for the Isle of Man and for certain offshore units. However, only broad regional correlation is possible with the generally seismically determined stratigraphy of the Irish Sea Basin (Nirex, 1997a; Jackson et al., 1995).

7.1 GLACIGENIC GROUPS AND SUBGROUPS

Pre-Devensian glacigenic deposits of the Albion Glacigenic Group are preserved locally in the Lake District and are known from borehole evidence in west Cumbria and the Isle of Man. These deposits are referred to the **Central Cumbria (Albion) Glacigenic Subgroup** (Section 7.2.1) and the **Irish Sea Coast (Albion) Glacigenic Subgroup** (Section 7.2.2). The effect of re-advances of Scottish ice during the Devensian complicates the stratigraphical framework for the widely distributed glacigenic deposits of the Caledonia Glacigenic Group. The deposits are referred to formations of the **Central Cumbria Glacigenic Subgroup** (Section 7.3.1), the **Irish Sea Coast Glacigenic Subgroup** (Sections 6.1.2, 7.3.2), and the **Manx Glacigenic Group** (Section 7.3.3).

The **Central Cumbria (Albion) Glacigenic Subgroup** and the **Central Cumbria Glacigenic Subgroup** (formerly defined as the Central Cumbria Drift Group by Merritt and Auton, 2000) (Table 12) include deposits that principally occur within the Lake District and over Shap Fell but also in parts of the Vale of Eden and along the west Cumbrian coast. The deposits contain material locally derived from the Lake District, Shap Fell and the Howgill Fells predominantly from Devonian, Silurian and Ordovician rocks, together with clasts of igneous intrusive rocks of various ages (Nirex, 1997b). The deposits were mostly laid down directly from, or were derived from, the melting of glaciers and isolated ice caps that existed in the Lake District at various times.

The **Irish Sea Coast (Albion) Glacigenic Subgroup** and **Irish Sea Coast Glacigenic Subgroup** (formerly West Cumbria Drift Group of Nirex, 1997b; Merritt and Auton, 2000) comprise predominantly glacigenic (glacial, glaciofluvial, glaciolacustrine) deposits that occur in the Solway lowlands (Chapter 6), the Vale of Eden and in west Cumbria (this chapter), and Lancashire, Cheshire and North Wales (Chapter 8, Table 13). The subgroups include pre-Holocene (mainly Late Devensian) formations of Bowen (1999), together with others proposed by Merritt and Auton (2000). Constituent formations (and informally named members) are defined from relatively thin, laterally variable sequences of sediments. Pre-Late Devensian deposits are recognised from boreholes. Lithologies are defined by locally-occurring rocks of Carboniferous, Permian and Triassic age. The deposits were laid down mainly directly from, or were derived from, the melting of ice that streamed around the north-western side of the Lake District to merge with ice moving directly down the Irish Sea basin from southern Scotland (Merritt and Auton, 2000). This pattern of ice movement probably occurred during several glaciations.

There is a recurrent conclusion in the older literature that one or more major glacial re-advances of Scottish ice occurred across the Solway lowlands and the coast of west Cumbria during the latter stages of the last glaciation. Several limits have been postulated for the main event, the 'Scottish Re-advance', that extend across the Irish Sea, link with the Bride Moraine in the north of the Isle of Man and continue into Ireland, but they since have been generally dismissed as being largely illusory and devoid of stratigraphical or chronological foundation. However, the re-advance concept has gained renewed support from new evidence in the Solway lowlands, west Cumbria, the Isle of Man and Ireland.

Evidence for a re-advance of Scottish ice was first reported from the Carlisle district and subsequently two re-advances, the 'Gosforth Oscillation' and the subsequent 'Scottish Re-advance' *sensu stricto* were established in west Cumbria and farther south. Evidence for another, earlier, re-advance of the Irish Sea ice stream has been reported from near Barrow-in-Furness. It has since been confirmed from extensive investigations in west Cumbria (Merritt and Auton, 2000) that the 'Gosforth Oscillation' event, in particular, caused large ice-dammed proglacial lakes to form in the lower reaches of the Ehen Valley and in Lower Wasdale, accompanied by deposition of glaciofluvial and glaciolacustrine members of the **Seascale Glacigenic Formation** and the **Aikbank Farm Glacigenic Formation** of the **Irish Sea Coast Glacigenic Subgroup**. Deposits were extensively over-ridden and locally glaciotectonically-disturbed during several glacial re-advances that caused minimal sub-glacial erosion, yet laid down thin, widespread units of sandy or clayey diamicton containing well-dispersed pebbles and shell fragments (deformation till). This thinly-bedded and heterogeneous package of sediments constitutes the **Gosforth Glacigenic Formation (Irish Sea Coast Glacigenic Subgroup)**. There are minority views that tills of the Gosforth Glacigenic Formation are either solely the products of proglacial, cohesive debris flows (flow till) or, most contentiously, are glaciomarine mud drapes. The stratigraphical relationship of constituent members of the three formations is presented in Figure 12.

The type area for the Scottish Re-advance is at St Bees Head, where there are splendid cliff sections through proglacially tectonised deposits in the St Bees Moraine. However, the regional significance of the Scottish Re-advance at St Bees remains problematic. It generally has been correlated with the creation of the Bride Moraine on the Isle of Man, which recently has been linked with the Killard Point Stadial. The Gosforth Oscillation and other earlier re-advances probably occurred during the post-18 ka BP phase of the Main Late Devensian Glaciation, in response to expansions of the Irish Sea ice stream, causing it to encroach inland repeatedly, overriding ground glaciated earlier by ice sourced inland.

7.2 ALBION GLACIGENIC GROUP

7.2.1 Central Cumbria (Albion) Glacigenic Subgroup

Name
Central Cumbria (Albion) Glacigenic Subgroup (CCAG) (after McMillan et al., 2005; pre-Devensian formations of the Central Cumbria Drift Group of Nirex, 1997b, and Merritt and Auton, 2000).

Lithology
A suite of mappable units of diamicton, gravel, sand, silt and clay, typically yellowish or greyish brown and containing clasts derived from the Lake District, Shap Fell and the Howgill Fells, including welded tuff (Borrowdale Volcanic Formation), slate, granite, granophyre, limestone and sandstone.

Formal subdivisions and correlation table
Thornsgill Till Formation (Section 7.2.1.1 and Tables 7c and 12).

Type area/Reference section
Type area: the central Lake District, Shap Fell and the Howgill Fells.

Lower and upper boundaries
Unconformable on bedrock.

Locally the ground surface, but generally overlain unconformably by deposits of gravel, sand, silt, clay and peat of the Central Cumbria Glacigenic Subgroup.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 10 m.

Distribution and extent
The central Lake District, Shap Fell and the Howgill Fells.

Age
Mid-Pleistocene (MIS 13–6).

7.2.1.1 THORNSGILL TILL FORMATION

The Thornsgill Formation is the oldest of three formations of glacigenic deposits established in the north-eastern Lake District by Boardman (1981, 1991) and formalised by Thomas (p. 95 in Bowen, 1999). The deposits are all derived mainly from Borrowdale Volcanic Group lithologies, slate and Threlkeld microgranite. The type localities of the Thornsgill Formation occur in the valleys of Thornsgill [NH 3814 2427] and Mosedale [NH 3556 2388], between Keswick and Penrith, where the Thornsgill Till Member is the main component. The latter is renamed here as the Thornsgill Till Formation. It is severely weathered and glaciotectonised. The weathering profile of the till, which is known as the **Troutbeck Palaeosol** (Britannia Catchments Group) (Section 7.5.1.1), is considered to have taken at least 150 000 years to form in a temperate climate, suggesting that the till may be Anglian in age. It is given bed status here. A deposit of compressed peat overlying the till in Mosedale has been assigned tentatively to an early Devensian interstadial or the end of the Ipswichian Interglacial (Boardman and Walden, 1994; Boardman, 2002); the unit is named here as the **Mosedale Beck Peat Bed**.

Name
Thornsgill Till Formation (THGTI) (after Boardman, 1991).

Lithology
Extremely compact, silty sandy gravelly diamicton containing clasts mainly of slate, 'Borrowdale Volcanic Group' lithologies and Threlkeld microgranite. Dark grey at base becoming increasingly weathered upwards to yellowish brown with olive brown, orange and white mottling where it has been cryoturbated. Most clasts are decomposed towards the top and are commonly bleached. The deeply weathered zone above the unit is named the Troutbeck Palaeosol.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 12).

Type area/Reference section
Partial type section: River sections in the banks of Mosedale Beck [NY 3556 2388], 3 km south of Wallthwaite, Cumbria.
Partial type section: River cliff sections in the banks of Thornsgill Beck [NY 3814 2427], 1 km south of Troutbeck Head, Cumbria.

Lower and upper boundaries
Generally an uneven, unconformable boundary with slate bedrock (Skiddaw Group), but locally a thin unit of weathered sand and gravel intervenes. Bedrock commonly decomposed.

Generally a sharp, planar, or gradational glaciotectonic boundary with greyish brown stony clayey diamicton (Threlkeld Till Formation).

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 15 m.

Distribution and extent
Vale of Threlkeld, Cumbria.

Age
Mid-Pleistocene (possibly MIS 10 or 12).

7.2.2 Irish Sea Coast (Albion) Glacigenic Subgroup

Name
Irish Sea Coast (Albion) Glacigenic Subgroup (ISCAG) (after McMillan et al., 2005; pre-Devensian formations of the West Cumbria Drift Group of Nirex, 1997b, and Merritt and Auton, 2000).

Lithology
Diamicton, gravel, sand, silt and clay, typically reddish brown and containing clasts of red and yellow sandstone, wacke sandstone and siltstone, granite and granodiorite. Welded tuff (Borrowdale Volcanic Group), mudstone, coal, shell fragments and reworked marine microfossils are common to the south of the Solway Firth.

Formal subdivisions and correlation table
Drigg Till Formation, Ayre Lighthouse Formation, Kiondroughad Formation (Tables 7c and 12); Seisdon Sand and Gravel Formation and Oakwood Glacigenic Formation (Sections 8.1.2.1 and 8.1.2.2, Table 7c and 13).

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock.

Ground surface or unconformable contact with units of the Caledonia Glacigenic Group.

Landform description and genetic interpretation
See landform associated with component formations.

Thickness
Up to tens of metres.

Distribution and extent
Cheshire, Lancashire, North Wales, western Cumbria and the Solway lowlands.

Age
Mid-Pleistocene (MIS 13–6).

7.2.2.1 DRIGG TILL FORMATION

The oldest till in Cumbria, the Drigg Till Formation has been found only in a few deep boreholes in Lower Wasdale and around Drigg. It comprises a weathered, stony diamicton that contains clasts of both Lake District and northern provenance (rocks derived from north-west Cumbria, Southern Scotland and the Irish Sea basin).

Name
Drigg Till Formation (DGTI) (after Merritt and Auton, 2000).

Lithology
Stony sandy silty clayey diamicton, reddish brown, extremely compact, with clasts mainly of welded tuff, wacke sandstone, slate and granite derived from the western Lake District, together with red (Permian) and yellow (Carboniferous) sandstone and coal from West Cumbria, and sparse granodiorite from Scotland.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 12).

Type area/Reference section
Type section: commercial borehole drilled at the Drigg landfill site [SD 0504 9855], BNFL Off-site Borehole D, 43.2–37.6 m depth.
Reference section: Nirex Borehole 10C [SD 0434 0309], 20.4–17.3 m depth.

Lower and upper boundaries
Sharp, irregular, unconformable contact with bedrock (mostly sandstone of the Sherwood Sandstone Group).

Sharp, gently undulating, unconformable contact with laminated silt and clay of the Stubble Green Silt Member of the Glannoventia Formation, or sharp, planar, unconformable contact with sandy clayey diamicton of the Holmrook Till Member of the Blengdale Glacigenic Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
5 m.

Distribution and extent
Drigg area and Lower Wasdale, West Cumbria.

Age
Mid-Pleistocene (possibly MIS 6).

Based on borehole evidence two formations, the **Ayre Lighthouse Formation** and **Kiondroughad Formation**, were established for pre-Devensian (possibly as early as Anglian) glacigenic deposits of the Isle of Man (Chadwick et al., 2001).

7.2.2.2 AYRE LIGHTHOUSE FORMATION

Name
Ayre Lighthouse Formation (AYRL) (after Lamplugh, 1903, and Chadwick et al., 2001).

Lithology
Sand, gravel and diamicton of northern origin that rests on Permo-Triassic bedrock (known only from boreholes).

Formal subdivisions and correlation table
No subdivisions (Table 7c and 12).

Type area/Reference section
Type Section: Borehole IV, Point of Ayre [NX 440 035] (Lamplugh, 1903; Smith, 1930).

Lower and upper boundaries
Unconformably overlies Permo-Triassic bedrock.

Base of the shelly silts and sands of the overlying Ayre Formation (British Coastal Deposits Group).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
About 70 m at borehole type section. Base on bedrock at 140 m below OD.

Distribution and extent
Northern part of the Isle of Man (BGS 1:50 000 Sheets E36 and possibly 46).

Age
Mid-Pleistocene (possibly MIS 8, 10 or 12).

7.2.2.3 KIONDROUGHAD FORMATION

Name
Kiondroughad Formation (KDRD) (after Lamplugh, 1903, and Chadwick et al., 2001).

Lithology
Sand, gravel and diamicton (till) of lithologies derived from the north of the Isle of Man (Chadwick et al., 2001).

Formal subdivisions and correlation table
No subdivisions (Table 12).

Type area/Reference section
Reference section: Borehole 16, Kiondroughad [NX 395 015] (Lamplugh, 1903).

Lower and upper boundaries
Overlain unconformably by the Shellag Formation (Irish Sea Coast Glacigenic Subgroup).

Rests on an extensive bedrock platform between 41 and 53 m below OD and partly on the Ayre Formation (British Coastal Deposits Group).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
About 60 m.

Distribution and extent
The Isle of Man (BGS 1:50 000 Sheets E36, 45, 46 and 56).

Age
Mid-Pleistocene (possibly MIS 6 or 8) or Early Devensian (MIS 4).

7.3 CALEDONIA GLACIGENIC GROUP

7.3.1 Central Cumbria Glacigenic Subgroup

Name
Central Cumbria Glacigenic Subgroup (CCGL) (after McMillan et al., 2005; Devensian formations of the Central Cumbria Drift Group of Nirex, 1997b, and Merritt and Auton, 2000).

Lithology
Diamicton, gravel, sand, silt and clay, typically yellowish or greyish brown and containing clasts derived from the Lake District, Shap Fell and the Howgill Fells, including welded tuff (Borrowdale Volcanic Group), slate, granite, granophyre, limestone and sandstone.

Formal subdivisions and correlation table
Subdivided into the Maudsyke Till, Threlkeld Till, Lobbs Sand and Gravel, Greystoke Till, Baronwood Sand and Gravel, Blengdale Glacigenic, and Wolf Crags formations (Table 8 and 12).

Type area/Reference section
Type area: The central Lake District, Shap Fell and the Howgill Fells [SD 100 600–NY 700 400].

Lower and upper boundaries
Generally unconformable on bedrock, but locally unconformable on older deposits of diamicton, gravel, sand, silt and clay assigned to the Central Cumbria (Albion) Glacigenic Subgroup.

Generally the ground surface, but commonly overlain unconformably by deposits of gravel, sand, silt, clay and peat of the Solway or Cumbria–Lancashire Catchments subgroups (Britannia Catchments Group).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 40 m.

Distribution and extent
The central Lake District, Shap Fell and the Howgill Fells.

Age
Devensian (MIS 5d–2).

7.3.1.1 Maudsyke Till Formation

In West Cumbria, pre-Late Devensian diamictons of the Maudsyke Till Formation have been proved at depth in boreholes. These deposits were previously regarded Merritt and Auton (2000) as the oldest member of the Blengdale Glacigenic Formation (Section 7.3.1.6).

Name
Maudsyke Till Formation (MSYT) (after Merritt and Auton, 2000).

Lithology
Extremely dense, moderate to pale reddish brown, cobbly sandy clayey diamicton, mainly matrix-supported, with clasts predominantly of Borrowdale Volcanic Group lithologies (rhyolite, welded tuff, slate).

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section
Type section: BNFL 'off-site' borehole C [SD 0547 9805], from 50.3–60.2 m depth (Nirex, 1997b).

Lower and upper boundaries
Generally a sharp, undulating to uneven, unconformable contact with bedrock, but locally a sharp, probably planar contact with extremely stiff, reddish brown, gravelly sandy clayey diamicton of the Drigg Till Formation.

Sharp, draped, unconformable contact with overlying thinly laminated (varved) silt and clay of the Stubble Green Silt Member of the Carleton Silt Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 10 m.

Distribution and extent
At depth beneath Lower Wasdale, western side of the Lake District.

Age
Early Devensian (MIS 4).

7.3.1.2 Threlkeld Till Formation

The Thornsgill Till is overlain by unweathered till of probable Late Devensian age and following Boardman (1991, 2002), it is named here the Threlkeld Till Formation. This till unit forms the topmost till sheet in the area (north-east Lake District) and passes laterally into the Greystoke Till Formation (Section 7.3.1.4) in Edenside.

Name
Threlkeld Till Formation (TKTI) (after Boardman, 1991).

Lithology
Very compact, olive-grey, sandy, silty, clayey, stony diamicton containing clasts mainly of 'Borrowdale Volcanic Group' lithologies, slate and Threlkeld microgranite. Locally includes masses of weathered diamicton (Thornsgill Till) at base. Commonly weathered to yellowish grey.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section:
Type area: North-east Lake District, Cumbria.

Lower and upper boundaries
Generally an unconformable boundary on bedrock. Locally a sharp, planar, or gradational glaciotectonic boundary with yellowish brown sandy gravelly clayey diamicton (Thornsgill Till Formation).

Mostly ground surface or overlain unconformably by glaciofluvial sand and gravel.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 25 m.

Distribution and extent
North-east Lake District, Cumbria.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.3.1.3 Lobbs Sand and Gravel Formation

Glaciofluvial sand and gravel associated with the Threlkeld Till Formation was named the Lobbs Sand and Gravel Member by Boardman (1991). This unit has here been raised to formation status to include all superficial glaciofluvial deposits occurring the north-east Lake District.

Name
Lobbs Sand and Gravel Formation (LOBSG) (after Boardman, 1991).

Lithology
Mainly sand and gravel with subordinate beds of silt and clay, containing clasts mainly of Borrowdale Volcanic Group rocks, slate and Threlkeld microgranite. Forming both moundy and terraced spreads of glaciofluvial sand and gravel in the northern Lake District.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section
Type area: Keswick [NY 250 200–NH 360 320], Vale of St. Johns and Naddle, Cumbria.

Lower and upper boundaries
Generally an erosional, unconformable boundary on olive grey, sandy, silty, clayey, stony diamicton (Threlkeld Till Formation).

Mostly ground surface or overlain unconformably by Holocene deposits.

Landform description and genetic interpretation
Forms both moundy and terraced spreads of glaciofluvial sand and gravel in the northern Lake District.

Thickness
Up to 15 m.

Distribution and extent
North-east Lake District, Cumbria.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.3.1.4 Greystoke Till Formation

The shape and distribution of elongate drumlins in the Vale of Eden and around the north of the Lake District, together with the composition of glacial erratics, indicate unambiguously that during the Last Glacial Maximum (LGM) ice flowed northwards, down the Vale of Eden, swinging around to the west around the Lake District and into the Irish Sea basin. There is northward progression from spindle-shaped drumlins, through elongate drumlins and transverse asymmetrical forms, to rogen moraines that indicate diminishing rates of flow northwards towards Carlisle. The glacial reorganisation possibly followed partial deglaciation and is recorded between Appleby and Brough, where the 'Stainmore suite' of drumlins is overprinted by the younger Howgill Suite, created by ice flowing northwards from an important ice divide crossing the Howgill Fells from west to east.

The till deposited in the Vale of Eden following the reorganisation is named here the Greystoke Till Formation. Although most clasts are derived from the Lake District and Edenside, the till also contains some Scottish erratics, especially towards the north, which have probably been reworked from the products of the Early Scottish Advance (Huddart, 1971b). The Ravenglass Till and Lowca Till members of the Seascale Glacigenic Formation were probably formed at this time in west Cumbria, by ice swinging around the north of the Lake District, picking up clasts from the Cumberland Coalfield. The tills are generally red, extremely compact and stony. They are up to 10 m thick, but locally infill buried valleys 70 m deep. The Greystoke Till Formation covers a substantial part of northern Cumbria. Its type section is the same as for the older Gillcambon Till, where clasts of the latter are enclosed within the base of the overlying Greystoke Till, a grey-brown diamicton containing clasts of only Lake District volcaniclastic rocks and local Carboniferous limestone (Eastwood et al., 1968, p. 231). Till fabric analysis on the till indicated that ice flowed from the south-west (Huddart, 1971b). The Greystoke Till is equivalent to the Eden and Lanerstock members of Thomas (pp. 95–96 in Bowen, 1999), which represent tills in the Penrith and Brampton areas respectively.

The flaw in many published glacial reconstructions is that Scottish ice is envisaged to funnel through the Tyne Gap from the Solway lowlands contemporaneously with ice flowing from the Vale of Eden, either adjacently in the opposite direction, or at different levels in the ice-sheet. It is more likely that ice ceased to flow through the Tyne Gap following either a major glacial readjustment resulting from changing mass balances of ice accumulation areas, or a significant partial deglaciation.

Name
Greystoke Till Formation (GYTI) (after Eastwood et al., 1968, Trotter, 1929, and Trotter and Hollingworth, 1932a; Eden Member of Penrith Formation of Thomas, p. 96 in Bowen, 1999).

Lithology
Grey stony sandy clayey diamicton with clasts of Lake District volcaniclastic rocks and Carboniferous limestone. Contains rip-up clasts of underlying Gillcambon Till at type section. Elsewhere in Edenside the unit contains relatively more Permo-Triassic red sandstone and Carboniferous sandstones.

Formal subdivisions and correlation table
Edenside Till Member (Tables 8 and 12).

Type area/Reference section
Type section: West Bank of Gillcambon Beck [NY 3888 3474], 275 m above the road bridge.

Lower and upper boundaries
Planar or uneven unconformable boundary with red diamicton of the Gillcambon Till Formation below, or unconformable on bedrock.

At land surface or overlain unconformably by glaciofluvial, glaciolacustrine or Holocene sediments.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
10 m.

Distribution and extent
The Vale of Eden and southern Solway lowlands north of the 'Scottish Re-advance' limit.

Age
Late Devensian, Dimlington Stadial (MIS 2).

EDENSIDE TILL MEMBER (EDTI)

The Edenside Till Member (Eden Member of Penrith Formation of Thomas, p. 96 in Bowen, 1999) comprises up to 20 m of stiff, reddish brown, very sandy, silty clayey diamicton with clasts mainly derived from the Vale of Eden (mostly brown 'Penrith' and red 'St Bees' sandstones, but including Carboniferous limestone and yellow sandstones), the Lake District (including andesitic lavas and welded tuffs), and the Alston Block (sandstone and grit), but also with sparse granodiorite, granite and wacke sandstones from the Galloway Hills of Scotland.

7.3.1.5 BARONWOOD SAND AND GRAVEL FORMATION

All deposits of glaciofluvial sand and gravel laid down during ice-sheet deglaciation and lying to the south and east of the 'Scottish Re-advance' limit of Trotter (1929) in Edenside and around the north of the Lake District are placed here in the Baronwood Sand and Gravel Formation. These deposits contain clasts mainly derived from the Edenside (including brown 'Penrith' and red 'St Bees' sandstones, Carboniferous limestone and yellow sandstones), the Lake District (including andesitic lavas and welded tuffs) and the Alston Block (sandstone and grit), but also with some granodiorite, granite and other rocks from the Galloway Hills. Deposits occur as ice-marginal fans, flat-topped plateaux, mounds, ridge systems and terraces. Fans and plateaux commonly include deltaic sequences that coarsen upwards from laminated silt and clay, through fine- and coarse-grained sand to cobble gravel. Ridge systems commonly include cores of cobble gravel partially overlain and surrounded by sand and gravel that fine upwards. Terraces are commonly underlain by dense gravel. All deposits include lenses of, and are locally capped by, red gravelly diamicton (flow till). The 'Brampton Moraine Belt' east of Brampton exemplifies this suite of landforms. It is an ice-marginal, glaciofluvial complex bounded by ice-contact slopes that face west or north-west. It includes the Hallbankgate Esker, which extends towards a major subglacial drainage channel within the Tyne Gap.

The formation subsumes the Baronwood Member of the Penrith Formation of Thomas (p. 96 in Bowen, 1999). Partial type sections in former gravel pits at Baronwood [NY 516 433] and at Low Plains [NY 502 417] are described by Huddart (1970, 1981) and Huddart and Glasser (2002). The formation also subsumes the Brampton Member of the Irthing Formation of Thomas (p. 95 in Bowen, 1999), which represented the extensive spreads of sand and gravel forming the Brampton Kame Belt described by Huddart (1970, 1981) and Huddart and Glasser (2002).

Name
Baronwood Sand and Gravel Formation (BWSG) (after Huddart, 1981; Baronwood Member of the Penrith Formation and Brampton Member of the Irthing Formation of Thomas (pp. 95–96 in Bowen, 1999).

Lithology
Sand and gravel with clasts mainly derived from the Vale of Eden (including brown 'Penrith' and red 'St Bees' sandstones, Carboniferous limestone and yellow sandstones), the Lake District (including andesitic lavas and welded tuffs) and the Alston Block (sandstones and grit), but also with some granodiorite, granite and other rocks from the Galloway Hills. Deposits occur as fans, flat-topped plateaux, mounds, ridge systems and terraces. Fans and plateaux commonly include deltaic sequences that coarsen upwards from laminated silt and clay, through fine- and coarse-grained sand to cobble gravel. Ridge systems commonly include cores of cobble gravel partially overlain and surrounded by sand and gravel that fine upwards. Terraces are commonly underlain by dense gravel. All deposits include lenses of, and are locally capped by, red gravelly diamicton (flow till).

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section
Partial type section: Sections in former sand and gravel pit at Low Plains Farm [NY 502 417], 6 km west of Kirkoswald, Cumbria.

Partial type section: Sections in former sand and gravel pit at Baronwood Farm [NY 516 433], 4 km north-west of Kirkoswald, Cumbria.

Lower and upper boundaries
Unconformable boundary on red diamicton of the Greystoke Till Formation or on bedrock.

Ground surface or overlain unconformably by Holocene sediments.

Landform description and genetic interpretation
Deposits occur as fans, flat-topped plateaux, mounds, ridge systems and terraces.

Thickness
Up to 30 m.

Distribution and extent
The Vale of Eden and the southern Solway lowlands north of the 'Scottish Re-advance' limit.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.3.1.6 BLENGDALE GLACIGENIC FORMATION

In Lower Wasdale, West Cumbria, the Blengdale Glacigenic Formation crops out inland of the eastern extent of the

Aikbank Farm Glacigenic Formation (Section 7.3.2.6). It also extends to the present coastline, and probably beyond, at depth. It includes lodgement tills and other types of diamicton in addition to sands, gravels, silts and clays. All contain clasts that have been derived predominantly from the Lake District. The glacigenic deposits in this formation would have been deposited mostly during the Main Late Devensian Glaciation, but probably also during the subsequent Gosforth Oscillation/Scottish Re-advance event if local glaciers existed at that time.

Name
Blengdale Glacigenic Formation (BLGL) (after Merritt and Auton, 2000).

Lithology
Interbedded units of gravelly sandy clayey diamicton, sand, gravel, silt and clay, typically reddish brown, with clasts mainly of Borrowdale Volcanic Group rocks (rhyolite, welded tuff, slate), granite and granophyre from the Lake District.

Formal subdivisions and correlation table
In West Cumbria the formation is subdivided into the Holmrook Till, Scale Beck Till, Bark Butts Silt, and Whin Garth Gravel members (Merritt and Auton, 2000); in the southern Lake District the Kendal Till Member is identified (Tables 8 and 12).

Type area/Reference section
Partial type section: Waterfall in deep gulley on eastern side of Blengdale, Lake District [NY 0860 0543], 120 m downstream of Bleng Bridge (exposing Holmrook Till Member only).

Partial type section: BGS registered borehole SD19NW11 (Aikbank Farm Borehole 1) [SD 1008 9988], from 49.2–55.1 m depth.

Partial type section: 40 m high natural section cut in the side of a drumlin on the west bank of the River Belah [SD 4945 8080], south of Milnthorpe centre (Kendal Till Member).

Lower and upper boundaries
Sharp, irregular, unconformable contact of diamicton on bedrock, or undulating to planar, unconformable contact of diamicton on laminated silt and clay of the Stubble Green Silt or Carleton Hall Clay members of the Glannoventia Formation.

Ground surface or sharp, undulating, unconformable contact of diamicton with overlying dark brown laminated clay of the Whinneyhill Coppice Clay Member of the Aikbank Farm Glacigenic Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 40 m.

Distribution and extent
Western side of the Lake District and at depth beneath Lower Wasdale.

Age
Late Devensian, Dimlington Stadial (MIS 2).

HOLMROOK TILL MEMBER (HRTI)

The Holmrook Till Member comprises up to 11 m of very dense, pale reddish grey to red, very gravelly sandy clayey diamicton with many cobbles and boulders, with clasts of Borrowdale Volcanic Group rocks (rhyolite, welded tuff and slate), granite and granophyre. The unit is generally matrix-supported and massive, but contains some interbeds of cobble and boulder gravel, and of pebbly clay.

SCALE BECK TILL MEMBER (SBTI)

The Scale Beck Till Member comprises up to 6 m of reddish brown cobbly sandy clayey diamicton, very compact, generally massive and matrix-supported, containing clasts mainly of Borrowdale Volcanic Group rocks (rhyolite, welded tuff, slate), granite and granophyre from the Lake District. The unit has a tightly clustered clast fabric typical of a lodgement till.

BARK BUTTS SILT MEMBER (BBSI)

The Bark Butts Silt Member comprises up to 1.9 m of interbedded clayey silt, sandy silt and silty sand with thin horizontal lamination and upward-fining varved interlamination towards its base.

WHIN GARTH GRAVEL MEMBER (WGGV)

The Whin Garth Gravel Member comprises up to 1.4 m of poorly-sorted boulder and cobble gravel, matrix-rich, with poorly-developed sub-horizontal stratification and thin interbeds of brown silt and red silty diamicton present in some exposures. Clasts are generally angular–subrounded and comprise locally-derived igneous rocks from the Borrowdale Volcanic Group and metamorphic rocks. The gravel forms narrow kame terraces within the Bleng Valley area.

KENDAL TILL MEMBER (KLTI)

The Kendal Till Member is distributed over the southern Lake District, east of the Duddon, including the Lancashire coast north of Carnforth and stretching eastwards to the foot of the Pennines. It comprises generally less than 5 m of stiff, yellowish brown, reddish brown or dark grey, silty, sandy, clayey diamicton; thicker deposits, up to 40 m thick, are known from drumlins. The diamicton contains angular to rounded clasts up to boulder-size of rocks derived from the southern Lake District and the Howgill Fells, including Borrowdale Volcanic Group lithologies (rhyolite, welded tuff, slate), granite, wacke sandstones and siltstones of the Windermere Supergroup and, locally, Carboniferous basal conglomerate and limestone. Large erratics of wacke sandstone, Shap granite and Borrowdale Volcanic Group rocks are ubiquitous.

7.3.1.7 WOLF CRAGS FORMATION

A terminal moraine that was deposited on the Threlkeld Till Formation by a small cirque glacier of presumed Loch Lomond Stadial age (MIS 2–1) at Wolf Crags [NH 355 225] is named by Boardman (1991) as the Wolf Crags Formation.

Name
Wolf Crags Formation (WOCR) (after Boardman, 1991).

Lithology
Diamicton and gravel that form moraines, fluted hummocks and terraces laid down in the uplands of the central part of the Lake District by corrie glaciers and their associated meltwaters during the Loch Lomond Stadial. Two members

are recognised: The Wolf Crags Till Member is a yellowish brown sandy diamicton, with clasts of Borrowdale Volcanic Group and Skiddaw Group rocks, and subordinate numbers of clasts of Threlkeld microgranite. The Wolf Crags Gravel Member forms a series of terraces in the Mosedale Beck valley. It is composed of coarse gravel (with clasts up to 1 m diameter) with subordinate amounts of finer gravel and sand. It contains clasts of Borrowdale Volcanic Group rocks and Threlkeld microgranite.

Formal subdivisions and correlation table
Subdivided into two informal members, the Wolf Crags Till Member and the Wolf Crags Gravel Member (Tables 8 and 12).

Type area/Reference section
Type section: Exposure in the western side of the gap cut by the Mother Syke stream in the moraine ridge (at Mothersike Brow) of the Wolf Crags Corrie [NY 354 227], about 3 km south-east of the village of Threlkeld, central Cumbria.

Type area: The Mosedale Valley area, central Cumbria, from the vicinity of Mosedale Beck Fold to Lobbs [NY 354 229–NY 357 238], about 3 km south-east of the village of Threlkeld, central Cumbria.

Lower and upper boundaries
Unconformable on bedrock or disconformable on the Threlkeld Till Formation of the Central Cumbria Glacigenic Group.

Generally the ground surface, but locally overlain by Holocene peat.

Landform description and genetic interpretation
Morainic and fluted hummocks.

Thickness
About 15 m at the type section

Distribution and extent
Central Lake District (BGS 1:50 000 Sheet E29), but probably could also be applied to Loch Lomond Stadial deposits of the Central Cumbria Glacigenic Subgroup on BGS Sheets E30, 38 and 39, and elsewhere in Cumbria.

Age
Late Devensian, Loch Lomond Stadial (MIS 2–1).

7.3.2 Irish Sea Coast Glacigenic Subgroup

The deposits of the Irish Sea Coast Glacigenic Subgroup (Section 6.1.2; after McMillan et al., 2005) include material derived from south-west Scotland, the Solway lowlands and the west Cumbrian coast together with predominantly glaciomarine sediments from the Irish Sea Basin. They are typically reddish brown because they are derived predominantly from Permo-Triassic 'red-beds'. The subgroup subsumes the 'West Cumbria Drift Group' defined in Akhurst et al. (1997) and Merritt and Auton (2000).

7.3.2.1 Gillcambon Till Formation

Based upon evidence of glacial erratics (Goodchild, 1875) there is little doubt that ice sourced in the Galloway Hills of the Southern Uplands of Scotland flowed up Edenside, across the Stainmore Gap and towards the coast north of the Cleveland Hills at a stage prior to the Last Glacial Maximum (LGM). The Scottish ice was joined by easterly-flowing Lake District ice (Trotter, 1929; Trotter and Hollingworth, 1932a, b). Only remnants of till deposited during this episode remain in Cumbria, within bedrock depressions and the cores of some drumlins. The older 'Scottish' unit is named here as the Gillcambon Till Formation from its type locality, a river cliff on the western bank of the Gillcambon Beck [NY 3888 3474], 275 m upstream of the bridge, on the fringe of Greystoke Forest. Here the till is reddish brown and contains Scottish rocks (granodiorite, granite) in addition to Lake District volcaniclastic rocks, Carboniferous limestone and Coal Measures sandstones (Eastwood et al., 1968, p.231; Huddart, 1970). A till fabric analysis undertaken by Huddart (1971b) indicated ice flow from the north-west.

The Gillcambon Till is correlated with other units of older 'Scottish' till described by Trotter (1929) in the southern bank of the River Irthing at Willowford [NY 618 658], near Gilsland, and in till overlying St Bees Sandstone at Glassonby, in the Eden Valley. Huddart (1971b) reports that the till at Willowford contains 3.6 per cent Criffel granodiorite in addition to Carboniferous limestone and Coal Measures sandstones and has a fabric confirming easterly flow. Another correlative of the Gillcambon Till is the lowest of three units of diamicton occurring within the valley of the Wizza Beck [NY 296 449], near Wigton, which Eastwood et al. (1968, p. 228) described as including Criffel granodiorite and Silurian wacke sandstone, but including no definite Lake District lithologies. Judging from Goodchild (1875), who described many railway-cutting sections in Edenside, the Gillcambon Till is widespread within drumlins and concealed valleys.

Name
Gillcambon Till Formation (GCBTI) (after Eastwood et al., 1968, Trotter, 1929, and Trotter and Hollingworth, 1932).

Lithology
Extremely compact, reddish-brown, stony silty sandy clayey diamicton containing clasts of red sandstone and Scottish rock types (granodiorite, granite, wacke sandstone) in addition to Lake District volcaniclastic rocks and Carboniferous rocks.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12); the formation contains possible rafts of Ipswichian age, the Wigton Marine Bed and the Scandal Beck Peat Bed.

Type area/Reference section
Type section: West bank of Gillcambon Beck [NY 3888 3474], 275 m above the road bridge.

Lower and upper boundaries
Uneven, unconformable on bedrock.

Unconformable, planar or uneven. At the type section there are rip-up clasts of Gillcambon Till within the overlying grey diamicton of the Greystoke Till Formation (Central Cumbria Glacigenic Subgroup).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 5 m.

Distribution and extent
The Vale of Eden and the southern Solway lowlands.

Age
Early Devensian (MIS 4).

The Wigton Formation of Thomas (p. 95 in Bowen, 1999) refers to lenses of 'drab' clay within red clay found beneath drab till and gravel in BGS Registered Borehole NY24NE2 [NY 2532 4865] drilled 229 m south of Wigton Station [NY 2532 4866] (Eastwood et al., 1968, p. 227). Core recovery was poor, but the clays apparently rested on bedrock (Stanwix Shale Formation, Triassic) within a buried channel at about 46 m depth (21 m below OD) and contained *Turritella communis*, foraminiferids and ostracods. The fossiliferous deposits are possibly Ipswichian in age, but were probably transported as glacial rafts from the Solway Firth during the Early Scottish Glaciation, deposited and then preserved within the deep channel at Wigton. The deposits are assigned here to the *Wigton Marine Bed* (WIGM) within the Gillcambon Till Formation.

A more certain Ipswichian deposit occurs at Scandal Beck [NY 742 024] at the southern edge of the Vale of Eden drumlin field (Carter et al., 1978; Letzer, 1978). Named here as the Scandal Beck Peat Bed (SBPT) (Scandal Beck Bed of Thomas, p. 95 in Bowen, 1999), it comprises at least 4 m of organic mud, sand, gravel and compressed peat containing pollen, coleoptera and plant macrofossils indicative of the closing stages of an interglacial. The organic deposits occur in the core of a drumlin orientated south-south-east–north-north-west, but the stratigraphy at the site is not completely clear (Mitchell, 2002). Letzer (1978) concluded that the organic deposits have been glacially disturbed by ice advancing from the north-west and are overlain by two units of till, the lower one yellowish brown and sandstone-rich, the upper brownish grey and limestone-rich. Compositional and fabric analyses done by her suggest that the lower till was derived from the west whereas the upper till was derived from the south-west. She correlated the lower till with the phase of glaciation responsible for her older, 'Stainmore Suite' of drumlins, whereas she correlated the upper till with her younger, Howgill Suite (Letzer, 1987). The lower and upper tills may therefore correlate with the Gillcambon Till and Greystoke Till formations respectively.

Difficulties remain, however, because diamicton similar to the lower till also occurs beneath the organic deposits. Letzer originally interpreted this to indicate that the organics represent a glacial raft within the lower till unit, although probably not transported very far, but after revisiting the site she (1981) concluded that the lower till was stratigraphically older than the organic deposits and of possible Saalian age. Rose and Mitchell (1989) subsequently confirmed the presence of two distinct units of till above the organics. Mitchell (2002) concludes that the relatively unweathered condition of the lower till as compared with the basal till at Thornsgill suggests that it is Devensian in age and that the organics are indeed ice-rafted albeit over a short distance. The Scandal Beck Peat Bed is therefore assigned to the Gillcambon Till Formation.

7.3.2.2 Great Easby Clay Formation

Fine-grained glaciolacustrine deposits were laid down in the Carlisle area during ice-sheet deglaciation and the subsequent 'Scottish Re-advance' when ice occupied the Solway Firth and blocked drainage within the Solway lowlands (Trotter, 1929; Hollingworth, 1929, 1931; Trotter and Hollingworth, 1932a, b; Huddart, 1970, 1981, 1991; Huddart and Glasser, 2002). The levels of 'Lake Carlisle' thus formed were first determined by the heights of overflow channels within the Tyne Gap, many of which exploited previously formed sub-glacial channels, and later by ice-marginal channels to the south-west of Carlisle. A misfit valley linking the modern rivers Caldew and Wampool by way of the Dalston Gap, south-west of Carlisle, functioned as a major glacial spillway. The fine-grained glaciolacustrine deposits that accumulated in the lake are assigned to the Great Easby Clay Formation. They include dark reddish brown clays, silts and very fine-grained sands that are generally thinly laminated and locally varved. The laminated deposits contain sparse drop-stones and convolute bedding; slump and water-escape structures are common. Sands and gravels deposited in and around the lake to the north have been assigned to the Plumpe Sand and Gravel Formation. Sediments of this formation and the Great Easby Clay Formation are commonly disturbed glaciotectonically and capped by red diamicton of the Gretna Till Formation (Section 6.1.2.1), which occurs extensively to the north.

Uncertainty remains whether the 'Scottish Re-advance' at Carlisle was synchronous with the creation of the St Bees Moraine, and whether ice over-rode all deposits within the Irthing Valley, as claimed by Trotter and Hollingworth (1932a, b), or only those occurring in the lower stretches of the valley near Carlisle, as according to Huddart. Furthermore, there are reasons to believe that at least parts of the Great Easby Clay and Plumpe Sand and Gravel formations ('middle sands') (Section 6.1.2.3) formed earlier, because they occur within drumlins sculptured by ice flowing from the Vale of Eden, not Scotland. These older parts overlie an extensive landscape unconformity developed on the Chapelknowe Till Formation, described by Trotter, which contains Scottish clasts and which probably is laterally equivalent to the Gillcambon Till of Edenside. The age of the Plumpe Sand and Gravel and Great Easby Clay formations is unknown, but they possibly formed during a partial deglaciation of the ice-sheet of the Main Late Devensian Glaciation following the Last Glacial Maximum between 22 and 18 ka BP.

The Great Easby Clay Formation subsumes the Great Easby Member of the Irthing Formation of Thomas (p. 95 in Bowen, 1999). It is equivalent to the lower part of the Rose Hill Member of the Carlisle Formation of Thomas (p. 96 in Bowen, 1999), described by Huddart (1970, 1981) and Huddart and Glasser (2002). Both the Lanerstock Member of the Irthing Formation and the Brunstock Member of the Carlisle Formation of Thomas (pp. 95–96 in Bowen, 1999) are probably equivalent to the Plumpe Bridge Till Member of the Gretna Till Formation (Section 6.1.2.1).

Name
Great Easby Clay Formation (GECL) (after Huddart, 1970, 1981, and Huddart and Glasser, 2002; Great Easby Member of the Irthing Formation of Thomas, p. 95 in Bowen, 1999)

Lithology
Dark reddish brown clay, silt and very fine-grained sand, generally thinly-laminated and locally varved. Sparse drop-stones

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12)

Type area/Reference section
Type section: River cliff sections in the southern bank of the River Irthing [NY 540 633–NY 547 632], 3 km north-east of Brampton, Cumbria

Lower and upper boundaries
Unconformable boundary with red diamicton of the underlying Gillcambon Till Formation, or on bedrock.

Generally a sharp, planar, or gradational glaciotectonic boundary with red diamicton correlated with the Plumpe Bridge Till Member of the Gretna Till Formation.

Landform description and genetic interpretation
Glaciolacustrine deposits.

Thickness
10 m or more.

Distribution and extent
The Solway lowlands around Carlisle.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.3.2.3 Carleton Silt Formation

The Carleton Silt Formation has been found only in deep boreholes in Lower Wasdale and around Drigg. The formation comprises varved, fine-grained glaciolacustrine deposits.

Name
Carleton Silt Formation (CNSI) (after Merritt and Auton, 2000).

Lithology
Silt and clay, laminated, very stiff, pinkish grey, dusky red and light reddish brown. Laminae up to 10 mm thick, fining upwards.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 12).

Type area/Reference section
Type section: Nirex Borehole QBH 20 (SD09NE22) [SD 0730 9739], from 38.3–49.9 m depth.

Reference section: Nirex Borehole QBH2A (SD09NE21) [SD 0810 9904], from 56.3–59.8 m depth.

Lower and upper boundaries
Sharp, gently undulating, unconformable, draped contact with underlying stony sandy clayey diamicton of the Maudsyke Till Formation.

Gradational, conformable contact with overlying dark brown calcareous clay of the Carleton Hall Clay Member of the Glannoventia Formation.

Landform description and genetic interpretation
Glaciolacustrine deposits.

Thickness
Up to 11.6 m.

Distribution and extent
West Cumbria.

Age
Early Devensian (MIS 4).

7.3.2.4 Seascale Glacigenic Formation

The Seascale Glacigenic Formation is widespread, but its distribution is not well-defined. It includes silts, sands, diamictons and lodgement tills containing clasts derived from the north-western valleys of the Lake District in addition to north-west Cumbria and Scotland. Its relationship with the Holmrook Till Member of the Blengdale Glacigenic Formation is unclear, but the formation was probably laid down during the maximum build-up of the ice-sheet of the Main Late Devensian Glaciation.

Name
Seascale Glacigenic Formation (SEAG) (after Merritt and Auton, 2000).

Lithology
Interbedded sand, gravel, silt, clay, pebbly clayey diamicton and gravelly sandy clayey diamicton, typically reddish brown, containing clasts mostly derived from the north-western valleys of the Lake District (granophyre, red sandstone, wacke sandstone, welded tuff), the West Cumbrian Coalfield (yellow and white sandstone, coal), but with some from Scotland (wacke sandstone, granodiorite).

Formal subdivisions and correlation table
Subdivided into the Lowca Till, St Bees Silt, St Bees Sand and Gravel, Townhead Boulder Gravel members of the St Bees coast; the Meadow View Sand and Gravel, Low Wath Till, Catgill Wood Sand and Gravel, Ehen Valley Silt and Ehen Valley Sand and Gravel members of the Ehen valley; and the Barn Scar Sand and Silt, and Ravenglass Till members of the Ravenglass district (Merritt and Auton, 2000) (Tables 8 and 12).

Type area/Reference section
Partial type section: Sea cliffs at St Bees [NX 9586 1186–NX 9705 1046], Cumbria (exposing Lowca Till, St Bees Silt, St Bees Sand and Gravel members only).

Partial type section: Sea cliff section 500 m south of Ravenglass [SD 0871 9582–SD 0873 9574], Cumbria (exposing Ravenglass Till Member only).

Lower and upper boundaries
Generally a sharp, irregular, unconformable contact with bedrock, or locally a sharp, undulating, unconformable contact with stony clayey diamicton of the Holmrook Till Member of the Blengdale Glacigenic Formation.

Variable, but commonly the ground surface or a sharp, planar, unconformable contact with reddish brown pebbly sandy clayey diamicton units of the Gosforth Glacigenic Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 20 m.

Distribution and extent
West Cumbrian coast to the west of the Lake District and west of the limit of the 'Gosforth Oscillation' between Cleator and Ravenglass.

Age
Devensian (MIS 2–3).

Four members are present at the St Bees coast.

Lowca Till Member (LCTI)

The Lowca Till Member comprises up to 5 m of reddish brown, gravelly sandy silty clayey diamicton, massive, matrix-supported, very compact, containing angular–subrounded clasts up to boulder-size of red sandstone, with some granite, granophyre, yellow sandstone, mudstone, limestone, Borrowdale Volcanic Group lithologies (rhyolite, welded tuff), wacke sandstone and siltstone. The till has well-developed clast fabric and fissility typical of lodgement tills.

St Bees Silt Member (SBSI)

The St Bees Silt Member comprises at least 3.7 m of thinly-interlaminated calcareous, bluish grey, silty clay, reddish brown clay and yellowish brown silt passing upwards into ripple-drift cross-laminated sand with much finely disseminated coal. Palaeocurrents are mostly directed towards the north-west.

St Bees Sand and Gravel Member (SBSG)

The St Bees Sand and Gravel Member comprises up to 10 m of sand and gravel, coarsening upwards from dense pebbly sand–boulder gravel, composed of angular–subrounded clasts of red (Permian) sandstone, white and yellow (Carboniferous) sandstone and ganister, black (Carboniferous) mudstone and coal, with some Borrowdale Volcanic Group rocks (rhyolite, welded tuff), wacke sandstone and siltstone, limestone and grey (Criffel) granite. Commonly, the top of the unit is cemented by calcite. Palaeocurrents are directed between north-west and south-west.

Townhead Boulder Gravel Member (THBG)

The Townhead Boulder Gravel Member comprises up to 10 m of clast-supported, very poorly-sorted boulder gravel, with clasts up to 2.5 m in diameter. Clasts are generally angular–subrounded and mainly comprise red Permian sandstone, yellow and white Coal Measure sandstones, black Coal Measure mudstone, together with some coal, green Borrowdale Volcanic Group lavas, grey Criffel granite, ironstone, wacke sandstone and limestone.

Five members are present in the Ehen Valley:

Meadow View Sand and Gravel Member (MVSG)

The Meadow View Sand and Gravel Member comprises up to 5 m of sand and gravel forming part of the infill of the buried valleys of the Ehen and Calder. Clasts are generally of Borrowdale Volcanic Group rocks, granite and olive-brown sandstone possibly from the Latterbarrow Sandstone Formation.

Low Wath Till Member (LWTI)

The Low Wath Till Member comprises up to 20 m of stony sandy clayey diamicton, which is matrix-supported, massive, very stiff, and red, dark greyish brown to yellowish brown in colour, with sand (possibly as lenses) locally. It is a typical lodgement till, with angular–subrounded clasts up to boulder-size. Clasts derived from the north-west of the Lake District include olive-brown sandstone (possibly from the Latterbarrow Sandstone Formation), slate, limestone and granophyre. The till is locally dominated by clasts of the underlying red sandstone bedrock.

Catgill Wood Sand and Gravel Member (CGWD)

The Catgill Wood Sand and Gravel Member comprises up to 10 m of clast-supported, poorly-sorted gravel with lenses of sand. Clasts are mainly subangular to rounded, up to cobble-size and composed of red (Permo-Triassic) and yellow (Carboniferous) sandstones, and coal.

Ehen Valley Silt Member (EVSI)

The Ehen Valley Silt Member comprises up to 21.3 m of very fine-grained sand, silt and clay, greyish brown to dark grey, typically fines downwards and contains much finely disseminated coal debris; generally thickly-laminated. Thin diamictons present in thick silt sequences are recorded in boreholes. It forms part of the infill of the buried valleys of the Ehen, Calder and Lower Uldale and was laid down principally in a glaciolacustrine environment, probably during the deglaciation of the ice-sheet of the Main Late Devensian Glaciation.

Ehen Valley Sand and Gravel Member (EVSG)

The Ehen Valley Sand and Gravel Member comprises up to 30 m of pale yellowish brown fine- to medium-grained quartzose sand, which coarsens upwards into pebbly sand and then into gravel. Coal debris is a common component and microfaults, shears and cracks (lined with reddish brown silt and clay) are characteristic of its upper few metres. It forms part of the infill of the buried valleys of the Ehen, Calder and lower Uldale. Cross-lamination within the sand indicates that it was deposited by southward-directed braided outwash streams on sandar, probably during the deglaciation the ice-sheet of the Main Late Devensian Glaciation.

Two members are present in the Ravenglass district:

Barn Scar Sand and Silt Member (BSSS)

The Barn Scar Sand and Silt Member comprises up to 27 m of thinly-interbedded and laminated reddish brown and yellowish brown fine- to medium-grained sand, silt and clay with sparse gravel. Disseminated coal fragments are present throughout.

Ravenglass Till Member (RVTI)

The Ravenglass Till Member comprises up to 10 m of moderate brown, sandy, silty, gravelly diamicton, very compact, matrix-supported, generally massive, containing moderately well-dispersed, subangular to subrounded clasts of granophyre, granite, and Borrowdale Volcanic Group rocks (rhyolite, welded tuff, slate), with some red sandstone, ironstone and shell fragments.

7.3.2.5 Gosforth Glacigenic Formation

The Gosforth Glacigenic Formation is mapped seaward of the limit of the Gosforth Oscillation established in Nirex (1994, 1997b). It generally includes a complex, thinly-interbedded sequence of sands, gravels, silts, clays and deformation tills (pebbly clay-rich diamictons) containing relatively large proportions of Scottish, Irish Sea and other 'northern' rock types. Once formed, the deposits were commonly folded, faulted, sheared and sliced-up by glaciotectonic processes operating beneath or adjacent to the Irish Sea ice stream during the later stages of the Main Late Devensian Glaciation and the subsequent Gosforth Oscillation/Scottish Re-advance glacial events.

Name
Gosforth Glacigenic Formation (GOGL) (after Merritt and Auton, 2000).

Lithology
The formation includes a complex, commonly thinly-interbedded sequence of sands, gravels, silty clays, pebbly clayey diamictons and stony sandy clayey diamictons (tills) containing clasts from Scotland and the northern Irish Sea basin and the west Cumbrian coalfield, as well as from the western Lake District.

Formal subdivisions and correlation table
Subdivided into the St Bees Till, Rothersyke Till, Gutterfoot Sand, How Man Till, Low Mill Gravel, Peckmill Sand, and Meadow House Clay members in the northern part of West Cumbria; and the Kirkland Wood Sand and Gravel, Drigg Beach Till, Drigg Holme Sand, Fishgarth Wood Till, Drigg Moorside Silt, and Peel Place Sand and Gravel members in the southern part of West Cumbria (Merritt and Auton, 2000) (Tables 8 and 12).

Type area/Reference section
Type area: Coastal area between Seascale [NY 040 010–SD 090 965], Holmrook and Ravenglass, west Cumbria.

Reference section: BGS Registered borehole SD09NE 21 (Carleton Hall) (Nirex Borehole QBH2a) [SD 0809 99036], 0–20 m depth, on the eastern side of valley of River Irt about 1 km south of Holmrook, west Cumbria.

Lower and upper boundaries
Generally undulating erosional contact onto older sequences including the Ravenglass Till Member of the Seascale Glacigenic Formation.

Generally the land surface, but locally the base of the Hall Carleton, Drigg Point Sand and Ehen Alluvium formations (Holocene).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Typically 10 to 20 m.

Distribution and extent
Seascale, Ravenglass and Lower Wasdale areas, western Cumbria: BGS 1:50 000 Sheet E37 (Gosforth).

Age
Late Devensian, Dimlington Stadial (MIS 2).

There are seven members in the northern part of West Cumbria.

St Bees Till Member (STBT)

The St Bees Till Member comprises up to 3 m of pebbly silty clayey diamicton, which is calcareous, very stiff, massive, matrix-supported. It is dark greyish brown in colour. It contains well-dispersed subangular to rounded pebbles of red sandstone, white and yellow Coal Measure sandstones, coal, wacke sandstone, slate, limestone and Borrowdale Volcanic Group rocks. The diamicton is typically thinly-interlaminated with dark yellowish orange silt towards its base; locally a dense, thickly-interlaminated bed (less than 3 m thick) of fine-grained sand and silt (showing ripple-drift lamination) occurs at the base of the member.

Rothersyke Till member (RSTI)

The Rothersyke Till Member comprises up to 2 m of gravelly sandy clayey diamicton, which is compact and massive, matrix-supported, and generally reddish brown in colour. The diamicton contains well-dispersed angular–well-rounded clasts of red sandstone, Borrowdale Volcanic Group rocks, Skiddaw Group slates, limestone, yellow and white Coal Measure sandstones, coal, granophyre, granodiorite (possibly from Criffel) and wacke sandstone. The member also contains 'rip-up' clasts of underlying deposits and its composition can vary considerably locally (being largely determined by the nature of the underlying sequences from which it is mainly derived).

Gutterfoot Sand Member (GFSA)

The Gutterfoot Sand Member comprises up to 12 m of a coarsening-upwards sequence of yellowish brown, clayey silt and silty clay, passing upwards into silty, fine-grained sand and finally into fine- and medium-grained sand.

How Man Till Member (HMTI)

The How Man Till Member comprises up to 1.7 m of stiff, reddish brown, matrix-supported sandy clayey diamicton, with well-dispersed angular–subrounded clasts up to boulder-size. The clasts are mainly of red sandstone, Skiddaw Group slate, Borrowdale Volcanic Group rocks, Coal Measures sandstone, coal, limestone, ironstone, dolomite, grey (?Criffel) granite, granophyre, granodiorite, quartzite, vein quartz, andesite and shell fragments.

Low Mill Gravel Member (LMGV)

The Low Mill Gravel Member comprises up to 4 m of clast-supported, poorly-sorted cobble gravel forming glaciofluvial terraces. Clasts are generally rounded–well rounded and comprise Borrowdale Volcanic Group rocks, slate, red, yellow and white sandstones, granophyre and granite.

Peckmill Sand Member (PKSA)

The Peckmill Sand Member comprises up to 3 m of thinly-interbedded sand, sandy silt, pebbly silty sandy clay, diamicton and gravel, and is typically red-brown in colour. The member typically drapes older glacial and glaciofluvial deposits, and thickens into hollows and kettleholes in their surface. Synsedimentary small-scale normal faulting and collapse structures are common within the unit.

Meadow House Clay Member (MWHO)

The Meadow House Clay Member comprises up to 5.1 m of graded, finely-laminated silt-clay varves. It is soft to firm, finely colour-banded in yellowish red, reddish brown and dark greyish brown.

There are six members in the southern part of West Cumbria:

Kirkland Wood Sand and Gravel Member (KWSG)

The Kirkland Wood Sand and Gravel Member comprises up to 6.8 m of clast-supported gravel with subrounded–rounded clasts up to cobble grade of Borrowdale Volcanic Group igneous rocks, siltstone, and lithic sandstone, with some red sandstone, white sandstone, coal and granite. Sparse (reworked) shell fragments and dinoflagellate cysts are present in the sandier parts of the unit.

Drigg Beach Till Member (DBTI)

The Drigg Beach Till Member comprises over 1 m of dusky red, stiff, plastic, silty and clayey diamicton with well-dispersed sand grains and angular clasts (up to 30 mm) of Borrowdale Volcanic Group rocks, Skiddaw Group siltstones and sandstones, with some granite, red and white sandstone and sparse shell fragments. Rip-up clasts of underlying units are common.

DRIGG HOLME SAND MEMBER (DGHS)

The Drigg Holme Sand Member comprises up to 3.5 m of fine- to medium-grained sand with stringers of granule gravel and channels containing clast-supported gravel. The gravel comprises subangular to subrounded clasts of Skiddaw Group sandstones and siltstones, red and yellow sandstone, Borrowdale Volcanic Group rocks, granite, granophyre, coal and ironstone. The member is possibly equivalent to part of the 'shelly sands at 50 ft OD' of Trotter et al. (1937).

FISHGARTH WOOD TILL MEMBER (FWTI)

The Fishgarth Wood Till Member comprises up to 5 m of hard, moderate reddish brown, matrix-supported, massive, calcareous sandy silty clayey diamicton, with dispersed subangular to rounded clasts up to 15 cm in diameter. The clasts are mainly of red sandstone, Borrowdale Volcanic Group rocks, granite, granophyre, brown siltstone and sandstone, with some coal, black shale and comminuted shell fragments.

DRIGG MOORSIDE SILT MEMBER (DGMS)

The Drigg Moorside Silt Member comprises up to 8.6 m of thinly-interbedded brown silty clay, clayey silt, very fine-grained sand and yellow brown fine- to medium-grained sands. Some beds of clay contain granules and fine pebbles.

PEEL PLACE SAND AND GRAVEL MEMBER (PPSG)

The Peel Place Sand and Gravel Member comprises up to 20 m of well-bedded, cross-stratified gravel and sand that typically forms upward-coarsening sequences. Clasts are generally rounded–well rounded and comprise a mixture of Permo-Triassic and Carboniferous rocks, with igneous and metamorphic rocks derived from the Lake District. The deposit fines downwards into horizontally-bedded sand with horizontal and climbing ripple lamination.

7.3.2.6 AIKBANK FARM GLACIGENIC FORMATION

The Aikbank Farm Glacigenic Formation is mapped landward of the proposed limit of the Gosforth Oscillation (Irish Sea ice stream) in Lower Wasdale. It is composed mainly of glaciolacustrine silts and clays capped by deltaic deposits of sand and gravel. Several units of diamicton of possible northern provenance occur towards the middle of the sequence. An informal lithostratigraphical unit, the 'Snellings Sand Formation' has been identified from boreholes. It is formed mainly of decomposed red sandstone that has probably been partly redeposited by periglacial processes, and partly remoulded by sub-glacial processes.

Name
Aikbank Farm Glacigenic Formation (AIK) (after Merritt and Auton, 2000).

Lithology
Rhythmically laminated silt and clay (Whinneyhill Coppice Clay Member), overlain by pebbly silty clayey diamicton and sand (Green Croft Till Member), overlain by laminated clay and silt (Holmeside Clay Member), overlain by coarsening-upwards sequences of sand and gravel (Mainsgate Wood Sand and Gravel Member).

Formal subdivisions and correlation table
Subdivided into the Whinneyhill Coppice Clay, Green Croft Till, Holmeside Clay and Mainsgate Wood Sand and Gravel members (Merritt and Auton, 2000) (Tables 8 and 12).

Type area/Reference section
Type section: BGS registered borehole SD19NW12 (Aikbank Farm Borehole 2) [SD 1008 9988], from 1.5–57.8 m depth.

Reference section: BGS registered borehole SD19NW11 (Aikbank Farm Borehole 1) [SD 1016 9986], from 1.06–49.17 m depth.

Lower and upper boundaries
Sharp, undulating, unconformable contact with pale red stony clayey diamicton and cobble gravel of the Holmrook Till Member of the Blengdale Glacigenic Formation.

At ground surface or overlain by Holocene peat or alluvial deposits (Britannia Catchments Group).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 60 m.

Distribution and extent
Lower Wasdale, West Cumbria.

Age
Late Devensian, Dimlington Stadial (MIS 2).

WHINNEYHILL COPPICE CLAY MEMBER (WCC)

The Whinneyhill Coppice Clay Member comprises up to 24.7 m of dark brown clay with laminae of silt and fine-grained sand, and sparse drop-stone pebbles. Rhythmic graded lamination is common.

GREEN CROFT TILL MEMBER (GCTI)

The Green Croft Till Member comprises up to 10 m of mainly dark reddish brown pebbly silt diamicton with interbeds of sub-glacially sheared pebbly sand, silt and clay. The diamicton contains clasts of igneous and metamorphic rock types from the Lake District together with some red sandstone and coal.

HOLMESIDE CLAY MEMBER (HSCLY)

The Holmeside Clay Member comprises up to 17.7 m of interbedded moderate to reddish brown clay and silt with subordinate beds of gravel and silty sand. The fine-grained lithologies are typically laminated and some laminae are graded (rhythmites). Sparse shell fragments are present.

MAINSGATE WOOD SAND AND GRAVEL MEMBER (MGW)

The Mainsgate Wood Sand and Gravel Member comprises up to 9 m of sand and gravel. These deposits coarsen upwards from pale brown fine-grained sand, with low-angle cross-stratification and ripple-drift cross lamination, to pebbly sand disposed in planar deltaic foresets (dip towards the south), and capped by gravel deltaic topsets. Clasts comprise local Lake District igneous and metamorphic rock-types together with some red and yellow sandstone, and coal. The deposit forms flat-topped plateaux some 20 m above the surrounding, poorly-drained ground underlain by the Holmeside Clay Member.

7.3.2.7 Cardigan Bay Formation

Offshore glacigenic formations of the Eastern Irish Sea include the Cardigan Bay Formation (Jackson et al., 1995).

Name
Cardigan Bay Formation (CBAY) (after Chadwick et al., 2001).

Lithology
Upper and lower tabular unstratified (till) members, laterally grading to sands and gravels, separated by an intervening lenticular and tabular infill member. The Lower Till Member comprises stiff clay with abundant pebbles, and slightly pebbly sand with shell clasts, together suggestive of a sub-glacial lodgement till, and elsewhere includes sands interpreted as ice-proximal glaciomarine deposits. The lenticular component comprises sands with subordinate muds, whereas the associated overlying tabular beds consist of fine-grained silty sands and sandy clays. The Upper Till Member comprises a stiff to hard diamicton of clay with varying content of sand, gravel, shell, cobbles and boulders.

Formal subdivisions and correlation table
Tables 8, 12 and 13; currently three informal members of Chadwick et al. (2001).

Type area/Reference section
Reference section: Offshore BGS borehole No. 71/64 [NX 74353 12265] at 28–77 m depth and 54° 29.1' N, 3° 96.4' W.

Reference section: Offshore BGS borehole No. 71/62 [NX 76732 04407] at 44–77 m depth and 54° 25.4' N , 3° 53.8 ' W, (and borehole 71/41 but no depths noted), in conjunction with Nirex seismic line 89/29 shot points 2621–2630.

Partial type section: Borehole NX40SE3 [NX 46800 04900], Point of Ayre, Isle of Man, from surface to 111 m depth.

Lower and upper boundaries
An erosion surface with a gentle topographic variation of about 15 m on the underlying St George's Channel Formation. Locally on pre-Quaternary erosion surface.

Unconformity at base of overlying Upper Western Irish Sea Formation. Locally crops out at sea bed.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
28–158 m.

Distribution and extent
Offshore, Eastern Irish Sea.

Age
Early–Late Devensian (MIS 4–2 Dimlington Stadial).

For the Isle of Man, three formations of the Irish Sea Coast Glacigenic Subgroup have been established (Chadwick et al., 2001).

7.3.2.8 Shellag Formation

Name
Shellag Formation (SHLAG) (after Chadwick et al., 2001).

Lithology
Glacially tectonically deformed complex sequence of diamictons, gravels and shelly sands. It is dominated by material derived from offshore within the Irish Sea basin.

Formal subdivisions and correlation table
Tables 8 and 12; currently six informal members of Chadwick et al. (2001).

Type area/Reference section
Type section: Coastal cliff section at Shellag Point [NX 460 000], 4 km north of Ramsey, on the eastern side of the Isle of Man.

Lower and upper boundaries
The base of the Shellag Formation rests on sand, gravel and diamicton of northern origin forming the top of the Kiondroughad Formation.

Overlain unconformably by the Orrisdale Formation.

Landform description and genetic interpretation
Glacigenic deposits. The formation includes rafts of marine sediment.

Thickness
About 50 m (but glaciotectonically thickened by folding and repeated by faulting) at its type section.

Distribution and extent
Isle of Man.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.3.2.9 Orrisdale Formation

Name
Orrisdale Formation (ORRIS) (after Chadwick et al., 2001).

Lithology
Stratified, coarse-grained diamictons, sands and gravels. It is dominated by material derived from offshore within the Irish Sea basin.

Formal subdivisions and correlation table
Tables 8 and 12; currently ten informal members of Chadwick et al. (2001).

Type area/Reference section
Type section: Coastal cliff section at Orrisdale Head [SC 319 930], about 2 km north of Kirk Michael, on the western side of the Isle of Man.

Lower and upper boundaries
Unconformably overlies the glacially tectonically deformed complex of diamictons, gravels and shelly sands of the Shellag Formation.

At the base of the stratigraphically complex sequence of laminated and massive muds with drop-stones, gravel, sand and muddy diamicton comprising the Jurby Formation.

Landform description and genetic interpretation
Glacigenic deposits. The formation includes tills that

formed sub-glacially or by glaciomarine deposition, and some of sands and gravels show extensive flow folding.

Thickness
Up to at least 60 m.

Distribution and extent
Northern part of the Isle of Man.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.3.2.10 Jurby Formation

Name
Jurby Formation (JURBY) (after Chadwick et al., 2001).

Lithology
Laminated and massive muds with drop-stones, interstratified gravel sand and mud, and muddy diamicton.

Formal subdivisions and correlation table
Tables 8 and 12; currently three informal members of Chadwick et al. (2001).

Type area/Reference section
Type section: Coastal cliff section at Jurby Head [SC 343 980], about 1 km west of the village of Jurby West, on the western side of the Isle of Man.

Lower and upper boundaries
Disconformably overlies diamictons, sands and gravels (that contain exotic clasts) of the Orrisdale Formation. The unit crops out along the north-west coast of the Isle of Man.

Unconformably overlain by peat, organic mud and calcareous marl of the Glen Balleira Formation that in-fills kettlehole basins.

Landform description and genetic interpretation
Stratigraphically complex glacigenic sequence of local provenance.

Thickness
Unrecorded but probably over 10 m.

Distribution and extent
Northern part of the Isle of Man.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.3.3 Manx Glacigenic Subgroup

The **Snaefell Formation** was established by Chadwick et al. (2001) for locally derived diamictons on the Isle of Man. The formation is referred to the Manx Glacigenic Subgroup.

Name
Manx Glacigenic Subgroup (MXGL) (after McMillan et al., 2005).

Lithology
Boulder scree and redeposited gravels and diamictons.

Formal subdivisions and correlation table
Snaefell Formation (Tables 8 and 12).

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Generally unconformable on bedrock.

Generally the ground surface, locally overlain unconformably by deposits of gravel, sand, silt, clay and peat of the Britannia Catchments Group.

Landform description and genetic interpretation
Head, scree and slope wash deposits, covering upland areas.

Thickness
Unrecorded, less than 10 m.

Distribution and extent
Mainly the central uplands of the Isle of Man, but also present on low ground around the coast.

Age
Devensian (MIS 5d–2).

7.3.3.1 Snaefell Formation

Name
Snaefell Formation (SNAEF) (after Chadwick et al., 2001).

Lithology
Boulder scree and 'redeposited' gravels and diamictons.

Formal subdivisions and correlation table
Tables 8 and 12; currently three informal members of Chadwick et al. (2001).

Type area/Reference section
Type area: the valley of Druidale [SC 355 878], 3.5 km west of Snaefell, Isle of Man.

Lower and upper boundaries
Generally unconformable on bedrock, except where the head and scree deposits interdigitate with glacigenic sediments of the Orrisdale Formation.

The ground surface or overlain by Holocene fluvial and organic sediments.

Landform description and genetic interpretation
Head, scree and slope wash deposits, covering upland areas. Head and scree deposits intercalate with glacigenic sediments of the Orrisdale Formation at low elevations around the island margin.

Thickness
Unrecorded, probably less than 10 m.

Distribution and extent
Mainly the central uplands of the Isle of Man, but also present on low ground around the coast.

Age
Early–Late Devensian (MIS 4–2 Dimlington Stadial).

7.4 BRITISH COASTAL DEPOSITS GROUP

7.4.1 Formations of the British Coastal Deposits Group

Raised beach and estuarine deposits together with nearshore sequences formed by successive marine transgressions during glacio-isostatic and eustatic sea level recovery form an important component of this group. Although mostly of Holocene age, some sequences began to accumulate earlier, in Late Devensian times.

7.4.1.1 Ayre Formation

Ipswichian or pre-Ipswichian deposits referred to the Ayre Formation are recorded at depth in a borehole at the Point of Ayre, Isle of Man (Chadwick et al., 2001).

Name
Ayre Formation (AYRE) (after Lamplugh, 1903, and Chadwick et al., 2001).

Lithology
Shelly silts and sands with a marine fauna (known only from boreholes).

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 12).

Type area/Reference section
Type section: Borehole IV, Point of Ayre [NX 465 050] (Lamplugh, 1903; Smith, 1930).

Lower and upper boundaries
Overlies sand, gravel and diamicton of the Ayre Lighthouse Formation.

Base of sand and gravel of the overlying Kiondroughad Formation (Irish Sea Coast Glacigenic Subgroup).

Landform description and genetic interpretation
Marine deposits.

Thickness
8 m at borehole type section (at a depth of 65–73 m below OD).

Distribution and extent
Northern part of the Isle of Man.

Age
Ipswichian or possibly older (MIS 5e or possibly 7 or 9).

7.4.1.2 Glannoventia Formation

The oldest sediments belong to the Glannoventia Formation which overlies the **Carleton Silt Formation** (Irish Sea Coast Glacigenic Subgroup) (Section 7.3.2.3). The sediments have been found only in deep boreholes in Lower Wasdale and around Drigg.

Name
Glannoventia Formation (GVA) (after Merritt and Auton, 2000).

Lithology
Yellow and grey, laminated, shelly, silty sand passing downwards into brownish grey, shelly silt and dark brown, laminated, calcareous clay. The deposits contain cold water marine microfauna.

Formal subdivisions and correlation table
Subdivided into the Carleton Hall Clay, Stubble Green Silt and Kokoarrah Shelly Sand members (Merritt and Auton, 2000) (Tables 5 and 12).

Type area/Reference section
Type section: BGS Registered borehole SD09NE21 (Nirex Borehole QBH2A [SD 0810 9904], from 49.5–56.3 m depth

Reference section: BNFL Drigg Off-site Borehole D [SD 5166 4186], from 33.21–37.23 m depth.

Lower and upper boundaries
Gradational, conformable contact with underlying pinkish grey, dusky red and pale reddish brown laminated silt and clay of the Carleton Silt Formation.

Sharp, planar, unconformable contact with stiff stony diamicton of the Holmrook Till Member of the Blengdale Glacigenic Formation.

Landform description and genetic interpretation
Marine deposits.

Thickness
Up to 11.9 m.

Distribution and extent
West Cumbria, Wasdale basin and coastal zone immediately to the west (around Drigg and Hall Carleton).

Age
Middle Devensian (MIS 3).

Carleton Hall Clay Member (CHCL)

The Carleton Hall Clay Member comprises up to 11.9 m of calcareous, laminated, very stiff, dark brown, silty clay, with sparse drop-stone pebbles and cold water marine microflora. Laminae are stacked within graded, rhythmic units.

Stubble Green Silt Member (SGSI)

The Stubble Green Silt Member comprises up to 2.3 m of brownish grey, sandy silt with shell fragments and diverse assemblages of cold water marine dinoflagellate cysts and foraminiferids.

Kokoarrah Shelly Sand Member (KSSA)

The Kokoarrah Shelly Sand Member comprises up to 4 m of yellow to grey, thinly laminated, silty sand with laminae of silt, containing fragmentary marine bivalves of probable mid-Devensian age.

7.4.1.3 Hall Carleton Formation

The Hall Carleton Formation comprises silts, clays, sands and gravels that form raised beach and estuarine sequences of Late Glacial–Holocene age.

Name
Hall Carleton Formation (HALC) (after Merritt and Auton, 2000).

Lithology
Generally a fining-upward sequence of medium- to fine-grained pale brown sand with interlaminations of silt that passes upwards into mottled olive clay and silt with thin beds and partings of peat and peaty (humic) silt. The fine-grained sediments contain a marine and estuarine microfossil assemblage. The formation also includes sand and gravel forming raised beaches of Holocene age.

Formal subdivisions and correlation table
Subdivided into four informal members, the Fern Bank Silt, Netherholme Sand, Rabbit Cat Silt, and Nethertown Gravel members (Merritt and Auton, 2000) (Tables 5 and 12).

Type area/Reference section
Reference section: BGS Registered borehole SD09NE22 (Nirex borehole QBH 20A) [SD 0727 9727], 1.4–14 m depth (Nirex, 1997b).

Type area: Ground lying below 10 above OD on eastern side of the lower course of River Irt, immediately south-east of Hall Carleton Farm, about 1.5 km south-east of Drigg village, west Cumbria.

Lower and upper boundaries
Unconformable on all older glacial diamictons and glaciofluvial sand and gravel deposits. In its type area it overlies diamictons of the Gosforth Glacigenic Formation.

The ground surface or overlain by blown sand of the Drigg Point Sand Formation.

Landform description and genetic interpretation
Deposits of marine, estuarine and brackish water environments.

Thickness
Typically about 3–6 m, but 14 m thick in BGS/Nirex borehole QBX 20A (BGS Registered borehole SD09NE22).

Distribution and extent
Coastal zone of Gosforth district (BGS 1:50 000 Sheet E37), around western Cumbria. The formation could be applied to all Holocene–Late Glacial raised marine and estuarine deposits and raised beaches of the Cumbria and Lancashire coastal area.

Age
Devensian to Holocene (MIS 2–1).

Holocene sediments include blown sands of the **Drigg Point Sand Formation** and estuarine deposits of the **Grange-over-Sands Formation** of the Cumbrian part of Morecambe Bay.

7.4.1.4 Drigg Point Sand Formation

Name
Drigg Point Sand Formation (DGPS) (after Merritt and Auton, 2000).

Lithology
Fine- to medium-grained quartz sand.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 12).

Type area/Reference section
Type area: Drigg Point Nature Reserve, which covers 3.5 square km of ground between Drigg and mouth of the River Esk (Ravenglass Estuary) [SD 050 985–SD 090 959], west of the village of Ravenglass, west Cumbria.

Reference section: Nirex Borehole QBH 11. (BGS Registered borehole SD09NE 20) [SD 0676 9709], 0–1.1 m depth.

Lower and upper boundaries
Unconformable (blanket) on all older Quaternary deposits.

The ground surface.

Landform description and genetic interpretation
Coastal dunes.

Thickness
Typically 5–10 m, but up to 15 m in type area.

Distribution and extent
Western Cumbria (BGS 1:50 000 Sheets E37 and 38). The formation could be applied to coastal Blown Sand along the Cumbria–Lancashire coasts.

Age
Holocene (MIS 1).

7.4.1.5 Grange-Over-Sands Formation

Name
Grange-over-Sands Formation (GROS) (after Huddart et al., 1977; Grange Formation of Thomas, p. 96 in Bowen, 1999).

Lithology
Probably silt, clay and sand with gravel and peat.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 12).

Type area/Reference section
Type area: Grange-over-Sands, Morecambe Bay [SD 4100 7800] (Huddart et al., 1977).

Lower and upper boundaries
Probably bedrock or sediments of the Irish Sea Coast Glacigenic Subgroup.

The ground surface.

Landform description and genetic interpretation
Estuarine and alluvial deposits.

Thickness
At least 12 m.

Distribution and extent
Cumbrian part of Morecambe Bay.

Age
Holocene (MIS 1).

7.4.1.6 Point of Ayre Formation

Name
Point of Ayre Formation (POA) (after Thomas, p. 94 in Bowen, 1999).

Lithology
Coastal marine and brackish water deposits including: gravel (beach shingle ridges, beach deposits), and blown sand (dunes) of the Ayre Sand and Gravel Member (Ayre Member of Thomas, p. 94 in Bowen, 1999; Chadwick et al., 2001); diatomite, fen-peat, lagoonal and lake mud (brackish and fresh water deposits) of the Lough Cranstall Member (Chadwick et al., 2001; Cranstal Member of Thomas p. 94 in Bowen, 1999) and submerged forest peat, laminated silt and palaeosols (Phurt Member of Thomas p.94 in Bowen, 1999; Chadwick et al., 2001).

Formal subdivisions and correlation table
Three informal members (see above) defined by Thomas p.94 in Bowen (1999); see Tables 5 and 12.

Type area/Reference section
Type area: the Point of Ayre area [NX 450 030–NX 470 052], extending between Rue Point, Point of Ayre and Cranstal, northern tip of the Isle of Man.

Lower and upper boundaries
Generally unconformably overlying glacigenic diamicton or sand and gravel, or Late Glacial sediments (head gravels or humic sands, silts and clays), or bedrock.

Usually the ground surface.

Landform description and genetic interpretation
Coastal, marine, beach and brackish water deposits and dune sands. Some units deposited in lagoonal and lacustrine environments.

Thickness
Unrecorded but probably commonly exceeds 5 m locally.

Distribution and extent
Applies to all onshore coastal/marine deposits on the Isle of Man.

Age
Holocene (MIS 1).

Offshore, the Devensian to Holocene marine and glaciomarine sediments are subdivided into two formations (Jackson et al., 1995).

7.4.1.7 Upper Western Irish Sea Formation

Name
Upper Western Irish Sea Formation (UWIS) (after Jackson et al., 1995, and Chadwick et al., 2001).

Lithology
Glaciomarine and marine clay and silt with local concentrations of sand. Seismically well-ordered character, exhibiting drape, onlap and progradation features.

Formal subdivisions and correlation table
Informal members (facies) described by Chadwick et al. (2001); Tables 5 and 12.

Type area/Reference section
Reference section: Offshore BGS borehole No. 71/64 at 5–28 m depth and 54° 29.1' N, 3° 56.4' W[NX 74353 12265].

Reference section: Offshore BGS borehole No. 71/62 at 7–44 m depth and 54° 25.4' N, 3° 53.8' W[NX 76732 04407], (and borehole 71/41 but no depths), in conjunction with Nirex seismic line 89/29 shot points 2621–2630.

Lower and upper boundaries
Disconformity at top of underlying Cardigan Bay Formation or incised into pre-Quaternary rockhead surface.

Unconformity at base of overlying Surface Sands Formation (the 'Y' seismic unconformity surface of Akhurst et al., 1997). Locally crops out at sea bed.

Landform description and genetic interpretation
Glaciomarine and marine deposits.

Thickness
10–20 m, locally thickening to 60 m in channel in-fills.

Distribution and extent
Irish Sea.

Age
Devensian to Holocene (MIS 4–1).

7.4.1.8 Surface Sands Formation

Name
Surface Sands Formation (SURF) (after Jackson et al., 2005).

Lithology
Dominantly sands, with subordinate mud, peat and some basal lag gravel, together with a rich fossil assemblage of present day species.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 12).

Type area/Reference section
Reference section: Offshore BGS borehole no. 71/64 at 0–5 m depth and 54° 29.1' N, 3° 56.4' W[NX 74353 12265].

Reference section: Offshore BGS borehole no. 71/62 at 0–7 m depth and 54° 25.4' N, 3° 93.8' W, (and borehole 71/41 but no depths), in conjunction with Nirex seismic line 89/29 shot points 2621–2630 [NX 76732 04407].

Lower and upper boundaries
Unconformable erosion surface (the 'Y' seismic unconformity of Akhurst et al., 1997) proved by seabed cores, lying upon the Western Irish Sea Formation.

Present-day sea-bed surface.

Landform description and genetic interpretation
Marine deposits.

Thickness
Generally from 0.5–2 m, reaching 40 m in sandbanks and up to 100 m in channel in-fills.

Distribution and extent
Irish Sea.

Age
Holocene (MIS 1).

7.5 BRITANNIA CATCHMENTS GROUP

7.5.1 Formations of the Britannia Catchments Group

Early Devensian or Ipswichian organic deposits referred to the Britannia Catchments Group are present at several sites in Cumbria. The **Troutbeck Palaeosol** is of Ipswichian age (MIS 5e) or possibly older. The stratigraphical relationship of the *Scandal Beck Peat Bed* (possibly MIS 5a–e) is uncertain. As this unit may have been glacially rafted over a short distance it is referred to the Gillcambon Till Formation (Irish Sea Coast Glacigenic Subgroup) (Section 7.3.2.1).

7.5.1.1 Troutbeck Palaeosol

Name
Troutbeck Palaeosol (TBPS) (after Boardman, 1981, 1991, 1994, 2002).

Lithology
The Troutbeck Palaeosol comprises the deeply weathered zone of the extremely compact, silty, sandy, gravelly diamicton of the Thornsgill Till Formation. The latter contains clasts mainly of slate, Borrowdale Volcanic Group lithologies and Threlkeld microgranite. The weathered zone is dark grey at the base becoming increasingly weathered

upwards to yellowish brown with olive brown, orange and white mottling where it had been cryoturbated. Most clasts are decomposed towards the top and are commonly bleached.

Formal subdivisions and correlation table
Mosedale Beck Peat Bed (Tables 6 and 12).

Type area/Reference section
Type section: River cliff sections in banks of the Thornsgill Beck [NY 3814 2427], 1 km south of Troutbeck Head, Cumbria (Boardman, 1981, 1991, 1994, 2002; Boardman and Walden, 1994).

Reference section: River cliff sections in banks of the Mosedale Beck [NY 3556 2388], 3 km south of Wallthwaite, Cumbria (Boardman, 1981, 1991, 1994, 2002; Boardman and Walden, 1994).

Lower and upper boundaries
A gradational boundary with relatively unweathered dark grey diamicton of the Thornsgill Till Formation of the Central Cumbria (Albion) Glacigenic Subgroup, or decomposed slate bedrock.

Generally a sharp, planar, or gradational glaciotectonic boundary with overlying greyish brown stony clayey diamicton (Threlkeld Till Formation).

Landform description and genetic interpretation
Palaeosol.

Thickness
Up to 14 m.

Distribution and extent
Vale of Threlkeld, Cumbria.

Age
Ipswichian (MIS 5e) or possibly older, Hoxnian (MIS 11).

MOSEDALE PEAT BED (MOPT)

A deposit of compressed peat overlying till in Mosedale has been assigned tentatively to an early Devensian interstadial (MIS 5d–a) or the end of the Ipswichian Interglacial (Boardman, 2002; Boardman and Walden, 1994). The unit is named here as the Mosedale Beck Peat Bed.

7.5.1.2 WINDERMERE CLAY AND SILT FORMATION

Sediments of the Windermere Clay and Silt Formation, cored in Lake Windermere, form the type section for the Windermere Interstadial (MIS 2) (Coope and Pennington, 1977).

Name
Windermere Clay and Silt Formation (WMCS) (after Coope and Pennington, 1977; Windermere Formation of Thomas, p.96 in Bowen, 1999).

Lithology
Lacustrine and organic sediments infilling Lake Windermere, comprising upper (Upper Laminated Clay), and lower (Lower Laminated Clay) units of laminated clay separated by a sequence of silt or organic silt (non-organic and organic silt unit). Occasional rock fragments are present in the organic silt.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 12).

Type area/Reference section
Type section: Cored borehole (5 inch diameter) taken in Low Wray Bay, Lake Windermere [SD 3760 0130], Cumbria. The core represents the type section for the Windermere Interstadial of the Late Devensian.

Lower and upper boundaries
Overlies gravel and till of the Central Cumbria Glacigenic Subgroup (Caledonia Glacigenic Group).

The Upper Laminated Clay passes conformably upwards into organic muds of the Cumbria–Lancashire Catchments Subgroup (Britannia Catchments Group) of Holocene age.

Landform description and genetic interpretation
Lacustrine and organic deposits.

Thickness
Cores of up to 6 m have been taken in the lake floor in water depths of 30 m depth. Echo sounding in deeper water indicates 21–40 m of sediment (Howell, 1971).

Distribution and extent
Cumbria.

Age
Late Devensian, Dimlington Stadial and Windermere Interstadial (MIS 2).

7.5.1.3 BLELHAM PEAT FORMATION

Most of the organic deposits of the Cumbria–Lancashire catchment are of Holocene age, although some sequences began to accumulate in Late Devensian times. The Blelham Formation of Thomas (p. 96 in Bowen, 1999), here referred to the Blelham Peat Formation (Britannia Catchments Group), encompasses fine-grained inorganic and organic sediment in numerous lake basins and bogs in north-west England, including the coastal mosslands of the Duddon and Leven estuaries and the raised mosses of the Solway lowlands (Section 6.3.1.1; Sutherland, p. 107 in Bowen, 1999). Lithogenetic units of mass movement deposits (head) are also referred to the Britannia Catchments Group.

Name
Blelham Peat Formation (BHPT) (after Blelham Formation of Thomas, p. 96 in Bowen, 1999).

Lithology
Peat, organic mud and silt, and fine silty sand infilling lake basins, lowland bogs and mires, kettleholes and alluvial tracts, also blanketing upland areas. It may contain fossilised remains of trees, herbs, grasses, etc., plus pollen, leaves and insect remains. In Cumbria two informal members are recognised: Pow Beck Peat Member, which comprises compressed peat with wood fragments, twigs and seeds, interbedded with grey silt and tufa and some friable peat. It is of Holocene age and underlies alluvial deposits of the floodplain of the Pow Beck at St Bees, Cumbria; it locally underlies beach sand at St Bees beach. It overlies the Lowca Till Member of the Seascale Glacigenic Formation on St Bees beach, and overlies the Fern Bank Silt Member of the Hall Carleton Formation in the Pow Beck valley. The Seacote Peat Member comprises felted peat, thinly interbedded with humic sands in places. It contains insects and pollen of Late Glacial age (typically about 14 000–10 000 14C years BP) and forms part of the infill of kettleholes (notably within the St Bees Moraine); it also occurs beneath the Pow Beck Member in the Pow Beck valley. In the kettleholes within

the St Bees Moraine it is overlain by solifluction deposits of pebbly silty sand (of Loch Lomond Stadial age) and it overlies the glaciotectonised sequence of deposits forming the moraine.

Formal subdivisions and correlation table
In Cumbria two informal members are recognised, the Pow Beck Peat Member and the Seacote Peat Member. To the north of the Inner Solway Firth the following informal units are recognised: Redkirk Point Peat Bed, Bigholms Burn Peat Bed, Bigholms Burn Gravel Member, Healy Hill Organic Mud Member and Racks Moss Peat Member (modified after Sutherland, p. 107 in Bowen, 1999) (Tables 6 and 12).

Type area/Reference section
Type area: Peat core transects from a kettlehole in the eastern, un-wooded, portion of Blelham Bog (about 300 m south of Blelham Tarn) [NY 336 006–NY 264 005], about 3 km south of Ambleside and 1 km west of Lake Windermere, central Cumbria.

Partial type section: Dissected kettlehole at top of cliff section (Log NX91SE ME7) [NX 966 112], 400 m north of footbridge at Sea Mill, 300 m west of St Bees village, west Cumbria.

Partial type section: Borehole QBH 19 (BGS Registered borehole NX19SE 251) [NX 97237 12238], 1.2–2.8 m depth, sited on the floodplain of the Pow Beck, about 300 m north-north-west of St Bees Railway Station, west Cumbria.

Lower and upper boundaries
Varies from sharply unconformable on bedrock and all Late Devensian or older Quaternary deposits (particularly tills), to disconformable on Late Glacial marine deposits of the Fern Beck Silt Member of the Hall Carleton Formation.

The ground surface or overlain by Holocene blown sand of the Drigg Point Sand Formation or alluvium of the Ehen Alluvium Formation.

Landform description and genetic interpretation
Organic and lacustrine deposits.

Thickness
Up to 5 m thick in the Blelham Bog type area.

Distribution and extent
Cumbria and the Solway.

Age
Late Devensian (Dimlington Stadial) to Holocene (MIS 2–1).

7.5.2 Cumbria–Lancashire Catchments Subgroup

Fluvial (alluvium and river terrace deposits) sediments of south Cumbria and Lancashire are assigned to the Cumbria–Lancashire Catchments Subgroup, including most of the former Solway Drift Group (Nirex, 1997b; Merritt and Auton, 2000) and fluvial deposits of Lancashire (Bowen, 1999) (Tables 6, 12 and 13). The subgroup also includes the alluvial deposits of rivers flowing into Morecambe Bay (within the Grange Formation of Thomas, p. 96 in Bowen, 1999). The fluvial deposits of the catchments are of Late Devensian to Holocene age (MIS 2–1).

Name
Cumbria–Lancashire Catchments Subgroup (CLCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Alluvial silt, sand, clay and gravel with some peat. Associated river terraces are dominated by sand and gravel, gravelly sand or sandy gravel with rare clay and silt.

Formal subdivisions and correlation table
Subdivided into Ehen Alluvium, Cumbrian Esk Valley, Lune Valley, Wyre Valley and Ribble Valley formations (Sections 7.5.2.1–7.5.2.5 and Tables 6 and 12).

Type area/Reference section
Type area: River valleys in west and south Cumbria and Lancashire.

Lower and upper boundaries
Probably unconformable and in places strongly incised into highly variable sediments of the Caledonia or Albion Glacigenic groups, and bedrock.

Generally the ground surface, but units of this subgroup interfinger locally with units of the Great Britain Coastal Deposits Group.

Landform description and genetic interpretation
River terraces and floodplain deposits.

Thickness
Highly variable depending on the relative stratigraphical positions of each of the component units. In the major river valleys the thickness may vary from 2 to 5 m, but probably does not exceed 10 m. For deposits flanking the major river valleys, the thickness probably varies from 1 to 3 m.

Distribution and extent
West and south Cumbria (valleys of the Rivers Ehen and Esk), Lancashire (valleys of the Rivers Lune, Wyre, Ribble, and Mersey), Cheshire and North Wales (Weaver, Dee), the westerly and southerly catchments of the Lake District and Lancashire west of the Pennines between Whitehaven and Liverpool, including the catchments of the river valleys and their tributaries.

Age
Late Devensian to Holocene (MIS 2–1).

The **Ehen Alluvium Formation** (Ehen Alluvial Formation of Merritt and Auton, 2000) and **Cumbrian Esk Valley Formation**, in Cumbria, comprise silts, sands and gravels forming the floodplains and low-lying terraces of the respective rivers and other alluvial tracts.

7.5.2.1 Ehen Alluvium Formation

Name
Ehen Alluvium Formation (EHEN) (after Ehen Alluvial Formation of Merritt and Auton, 2000).

Lithology
Sands, gravels, silts and clays.

Formal subdivisions and correlation table
Two informal members, the Middlebank Silt Member and the Starling Sand and Gravel Member (Merritt and Auton, 2000) (Tables 6 and 12).

Type area/Reference section
Type area: Alluvium and river terraces within the valley of the River Ehen between Egremont and Sellafield [NY 020 030 to NY 010 110], west Cumbria.

Partial type section: Northern bank of the River Ehen 200 m south of Middlebank Farm [NY 0133 0561], south-south-west of Beckermet, west Cumbria.

Partial type section: Nirex borehole QBH9 [NY 01395 05489], 0.9 to1.5 m depth, 1 km north of Starling Castle (west of Sellafield), west Cumbria.

Lower and upper boundaries
Sharply erosional, unconformable on all older Quaternary deposits (particularly till) and bedrock.

The ground surface, or overlain by peat of the Blelhem Peat Formation, or overlain by blown sand of the Drigg Point Sand Formation.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Typically up to 12 m thick in the type area.

Distribution and extent
West Cumbria (BGS 1:50 000 Sheets E37 and 38) and applied to all alluvial deposits within the west Cumbria area, between Whitehaven and Muncaster, of the Cumbria–Lancashire Catchments Subgroup area.

Age
Mainly Holocene (MIS 1) but terraces may extend from Late Glacial (MIS 2).

7.5.2.2 Cumbrian Esk Valley Formation

Name
Cumbrian Esk Valley Formation (CEVY) (after Trotter et al., 1937).

Lithology
Sands, gravels, silts and clays.

Formal subdivisions and correlation table
Cumbrian Esk Alluvium Member (Tables 6 and 12).

Type area/Reference section
Type area: Valley of the River Esk, between Muncaster Castle and Lindbeck farm [SD 1059 6330–SD 141 983], west Cumbria.

Partial type section: BGS Registered Borehole SD19NW1 (Muncaster Bridge Borehole 1) [SD 1124 9639], from 0–11.58 m depth, southern side of River Esk, about 1 km east of Muncaster Castle, west Cumbria.

Lower and upper boundaries
Sharply erosional, unconformable on all older Quaternary deposits (particularly till) and bedrock.

The ground surface, or overlain by peat of the Blelhem Peat Formation, or overlain by blown sand of the Drigg Point Sand Formation.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
11.58 m thick at Partial Type Section, but otherwise probably typically 5–10 m thick in the type area.

Distribution and extent
BGS 1:50 000 Sheet E37, south of Muncaster Fell.

Age
Mainly Holocene (but terraces may extend from Late Glacial) (MIS 1–2).

Cumbrian Esk Alluvium Member (CEAL)

The Cumbrian Esk Alluvium Member comprises up to about 11.6 m of silts, clays, sands and gravels, underlying the floodplains of the River Esk catchment in Cumbria.

Fluvial deposits of the Rivers Lune, Ribble, and Wyre in Lancashire and their tributaries (parts of the Lytham and Swettenham formations of Thomas, p. 95 in Bowen, 1999) are treated as separate formations namely the **Lune Valley, Wyre Valley**, and **Ribble Valley formations** of the Cumbria–Lancashire Catchments Subgroup (Tables 6 and 13).

7.5.2.3 Lune Valley Formation

Name
Lune Valley Formation (LUNV) (parts of the Swettenham and Lytham formations of Thomas, p. 95 in Bowen, 1999).

Lithology
Dominantly silty and sandy alluvial sediments with gravel and sporadic cobbles and boulders. River terrace deposits are mainly sand and gravel.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: The area encompassing the three river terraces and alluvium of the River Lune (included in the Swettenham and Lytham formations of Thomas, p. 95 in Bowen, 1999), [SD 4200 5400–NY7500 0100].

Reference section: Lansil Ltd. water borehole, Lancaster. BGS Registered No. SD46SE1B [SD 4830 6360].

Lower and upper boundaries
Probably unconformable, irregular and in places strongly incised into lithologically variable sediments of the Caledonia and Albion Glacigenic groups or bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Generally less than 10 m.

Distribution and extent
Cheshire and south Lancashire within the river valley and tributaries of the River Lune west of the Peak District.

Age
Devensian to Holocene (MIS 2–1).

7.5.2.4 Wyre Valley Formation

Name
Wyre Valley Formation (WYRV).

Lithology
Dominantly silt, sand and clay with gravel and peat.

Formal subdivisions and correlation table
Two terrace deposit members (WYRE1and WYRE2) (Tables 6 and 13).

Type area/Reference section
Type area: Alluvium and river terrace deposits of the valley of the River Wyre [SD 3400 4800–SD 6000 5200], Lancashire.

Lower and upper boundaries
Unconformable, irregular and in places strongly incised into lithologically variable sediments of the Caledonia Glacigenic Group or into bedrock.

The ground surface.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Highly variable depending on the relative stratigraphical position of the component units. In the major river valleys the thickness might usually vary between 2 and 5 m, and probably does not exceed 10 m.

Distribution and extent
Catchment of the River Wyre from Forest of Bowland to Fleetwood estuary, Lancashire.

Age
Mainly Holocene but terraces may extend from Late Glacial time (MIS 1–2).

7.5.2.5 Ribble Valley Formation

Name
Ribble Valley Formation (RIBV) (parts of the Swettenham and Lytham formations of Thomas, p. 95 in Bowen, 1999).

Lithology
Silt, sand and clay in alluvium grading into gravel at base. River terraces are dominated by gravel grading upwards into silt and sand.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Valley of the River Ribble and tributaries west of the Peak District, [SD 3800 2600–SD 7900 8100].

Reference section: Whitbread Brewery Borehole, Preston, BGS Registered No. SD523NE12 [SD 5800 2900].

Lower and upper boundaries
Probably unconformable, irregular and in places strongly incised into lithologically variable sediments of the Caledonia and Albion Glacigenic groups or bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Generally less than 5 m but locally up to 12 m.

Distribution and extent
Cheshire and south Lancashire within the valley of the River Ribble and tributaries west of the Peak District.

Age
Devensian to Holocene (MIS 2–1).

7.5.3 Isle of Man Catchments Subgroup

The Isle of Man Catchments Subgroup is identified for the fluvial (alluvium, river terrace deposits and alluvial fan deposits) and associated organic sediments of the island. Constituent formations are taken from Chadwick et al. (2001).

Name
Isle of Man Catchments Subgroup (IMCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Alluvial gravel, sand, silt and clay forming floodplains, alluvial fans and river terrace deposits.

Formal subdivisions and correlation table
Subdivided into the Sulby Glen, Ballaugh, Curragh and Glen Balleira formations (Sections 7.5.3.1–7.5.3.4 and Tables 6 and 12).

Type area/Reference section
Type area: River valleys of the Isle of Man.

Lower and upper boundaries
Generally an unconformable boundary with units of the Caledonia Glacigenic Group.

Generally the ground surface, but units of this subgroup interfinger locally with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
River terrace and floodplain.

Thickness
Typically 2.5 m thick, but highly variable and greater than 20 m locally.

Distribution and extent
Isle of Man.

Age
Late Devensian–Holocene (MIS 2–1).

7.5.3.1 Sulby Glen Formation

Name
Sulby Glen Formation (SUGL) (after Chadwick et al., 2001).

Lithology
Well-sorted, stratified alluvial gravel, sand, silt and clay, forming floodplains and river terraces.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 12).

Type area/Reference section
Type area: The Sulby Glen area [NC 380 900–SC 3853 920], about 3 km north-north-west of Snaefell, north-west part of the Isle of Man.

Lower and upper boundaries
Generally unconformably overlying glacigenic diamictons and outwash debris flows and alluvial fan sediments or bedrock.

Usually the ground surface.

Landform description and genetic interpretation
River terrace and floodplain.

Thickness
Terraces up to 6 m high are recorded.

Distribution and extent
Isle of Man.

Age
Late Devensian to Holocene (MIS 2–1).

7.5.3.2 Ballaugh Formation

Name
Ballaugh Formation (BALGH) (after Chadwick et al., 2001).

Lithology
Gravel-dominated sequences forming mountain-front alluvial fans, commonly cryoturbated.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 12).

Type area/Reference section
Type area: Ballaugh area [SC 340 930–SC 360 960], north-west part of the Isle of Man.

Lower and upper boundaries
Generally alluvial fan gravels of the Ballaugh Formation unconformably overlie the mixed sequence of the Orrisdale Formation (though some fan gravels interdigitate with deposits of that formation). In other exposures the fan gravels overlie Late Glacial organic sediments of the Glen Balleira Formation.

Usually the ground surface.

Landform description and genetic interpretation
Alluvial fan deposits.

Thickness
Unrecorded but possibly up to 20 m thick locally.

Distribution and extent
Northern part of the Isle of Man.

Age
Late Devensian, Dimlington Stadial to Holocene (MIS 2–1).

Peat deposits and lacustrine and organic infill deposits of kettlehole in-fills on the Isle of Man are referred to two formations (Chadwick et al., 2001).

7.5.3.3 Glen Balleira Formation

Name
Glen Balleira Formation (GLNBA) (after Chadwick et al., 2001).

Lithology
Peat, organic mud and calcareous marl.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 12).

Type area/Reference section
Type area: Coastal cliff sections between Glen Balleira and Glen Wyllin [SC 314 915–SC 310 906], about 0.5 km west and north-west of Kirk Michael, Isle of Man.

Lower and upper boundaries
Unconformably overlies glacigenic deposits (diamictons, laminated muds, sands and gravels) of the Jurby and Orrisdale formations.

Usually the ground surface, but may be overlain by Holocene sediments (such as peat, with Holocene plant and insect remains, or brown sand).

Landform description and genetic interpretation
Organic and biogenic deposits infilling kettlehole basins.

Thickness
2 m of calcareous marl, capped by peaty clay, is recorded in a kettlehole infill at Glen Wyllin.

Distribution and extent
Northern part of the Isle of Man.

Age
Late Devensian, Dimlington Stadial (MIS 2).

7.5.3.4 Curragh Formation

Name
Curragh Formation (CAGH) (after Chadwick et al., 2001).

Lithology
Peat-dominated accumulations in lowland basins and on upland plateaux. Some mud and pebbly sand may occur in the lower parts of basinal sequences.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 12).

Type area/Reference section
Type area: The Curragh area [SC 360 940–SC 373 955], about 15 km north-west of Ballaugh, north-west part of Isle of Man.

Lower and upper boundaries
Generally unconformably overlying glacigenic or Late Glacial sediments or bedrock.

Generally the ground surface.

Landform description and genetic interpretation
Organic deposits.

Thickness
Up to 6 m recorded.

Distribution and extent
Isle of Man.

Age
Holocene (MIS 1).

8 Lancashire, Cheshire, Staffordshire and Wales

The oldest known superficial deposits of this district are of glacigenic origin and of pre-Devensian age (Albion Glacigenic Group). The most extensive deposits are assigned to the Caledonia Glacigenic Group and are of Devensian age. Deposits of the Britannia Catchments Group and British Coastal Deposits Group range in age from Late Devensian to Holocene (see also Chapter 7).

8.1 ALBION GLAGICENIC GROUP

8.1.1 Formations of the Albion Glacigenic Group

Pre-Ipswichian (MIS 5e) glacigenic deposits, lying on or beyond the maximum limit of the Devensian ice-sheet limit, are documented from south Wales and the border counties. Bowen (pp. 78–83 in Bowen, 1999) refers to two formations, the Llanddewi Formation of South and West Gower, of possible MIS 12 age (Bowen, 1989), and the Penfro Formation of Pembrokeshire and Carmarthenshire, of possible MIS 16 age (Bowen, 1970, 1994; Campbell and Bowen, 1989). The present framework adopts the **Llanddewi Glacigenic Formation** and the **Penfro Till Formation** as units of the Albion Glacigenic Group.

8.1.1.1 Llanddewi Glacigenic Formation

Name
Llanddewi Glacigenic Formation (LITI) (after Bowen, p. 79 in Bowen, 1999, and Bowen, p.148 in Lewis and Richards, 2005).

Lithology
Deeply weathered sand and gravel and red clay (till). Erratics include both Welsh sandstone boulders (Millstone Grit Group, Namurian) and clasts of Irish Sea provenance (George, 1933).

Formal subdivisions and correlation table
No subdivisions (Tables 7a and 13).

Type area/Reference section
Reference section: Hills Farm Borehole [SS 4525 8615], Port Eynon, on the crest of the Paviland Moraine (Bowen, p. 79 in Bowen, 1999; Bowen, p. 148 in Lewis and Richards, 2005).

Reference section: Hangman's Cross Borehole [SS 483 867], Oxwich (Bowen, p. 148 in Lewis and Richards, 2005).

Lower and upper boundaries
Unconformable contact with bedrock (limestone of the Pembroke Limestone Group, Dinantian).

Overlain by reworked sands and gravels or at ground surface.

Landform description and genetic interpretation
Glaciofluvial and till deposits.

Thickness
23 m at Hills Farm Borehole Reference Section.

Distribution and extent
South and West Gower.

Age
Possibly Anglian (MIS 12) (Bowen, 1989).

8.1.1.2 Penfro Till Formation

Name
Penfro Till Formation (POTI) (after Bowen, p. 147 in Lewis and Richards, 2005).

Lithology
Sand and gravel and red and purple stony clayey diamicton (till) with distinctive igneous clasts of western provenance (Bowen, p. 147 in Lewis and Richards, 2005). Erratic boulders include tuff (at Pentre), quartz felsite (at Newton and St Athan).

Formal subdivisions and correlation table
No subdivisions (Tables 7a and 13).

Type area/Reference section
Partial type section: Llandre Gravel Quarry [SN 093 203], Pembrokeshire: glacial gravels with local clasts and erratics from North Pembrokeshire (Bowen, 1999).

Partial type section: West Angle Bay [SM 853 031], Milford Haven: stiff purplish stony clay with igneous clasts (till), overlain by raised beach deposits (Dixon, 1921; West Angle Member of Bowen, 1999).

Lower and upper boundaries
Unconformable contact with bedrock of Silurian–Carboniferous age.

Ground surface or overlain by Glamorgan Glacigenic Formation, as at Pencoed (Griffiths, 1940).

Landform description and genetic interpretation
Glaciofluvial and glacial deposits.

Thickness
Generally up to 5 m (Bowen, p. 83 in Bowen, 1999); up to 9.5 m at Pencoed (Strahan and Cantrill, 1904).

Distribution and extent
Highly dissected in Pembrokeshire and western Carmarthenshire. Widespread in south Pembrokeshire.

Age
Possibly MIS 16 (Bowen, 1994; Campbell and Bowen, 1989).

8.1.2 Irish Sea Coast (Albion) Glacigenic Subgroup

In Staffordshire and Cheshire well-documented evidence from several gravel pits (Worsley, 1991) shows that the oldest glacigenic deposits of the **Seisdon Sand and Gravel Formation** and the **Oakwood Glacigenic Formation** lie within the maximum limit of the Devensian ice-sheet. These deposits comprise diamictons that contain clasts of both Lake District and northern provenance (rocks derived from north-west Cumbria, Southern Scotland and the Irish Sea basin) and consequently are referred to the Irish Sea Coast (Albion) Glacigenic Subgroup (Section 7.2.2).

8.1.2.1 Seisdon Sand and Gravel Formation

The Seisdon Sand and Gravel Formation (Tables 7c and 13) comprises glaciofluvial sediments lying beneath the **Trysull Silt Formation** (Britannia Catchments Group) of Hoxnian (MIS 5e) age (Morgan, 1973) (Section 8.4.1.1).

Name
Seisdon Sand and Gravel Formation (SDNSG) (after Morgan, 1973, Worsley, 1991, and Worsley, p. 32 in Bowen, 1999).

Lithology
Yellowish red sand or sandy gravel with occasional cobbles. Gravel and cobbles are dominated by well-rounded quartzite derived from the Sherwood Sandstone but with occasional rounded erratics of granite, felsite and Coal Measures sandstone. Fossiliferous in part.

Formal subdivisions and correlation table
No subdivisions (Tables 13 and 17).

Type area/Reference section
Type section: Former quarry at Seisdon (Lowe's Pit) [SJ 8470 9500], Staffordshire (Morgan, 1973).

Lower and upper boundaries
Sharp, erosive, unconformable contact with bedrock. Strongly channelled.

Either the ground surface or basal surface of red silt of the Trysull Silt Formation (Britannia Catchments Group) or silt, sand and gravel of the Stockport Glacigenic Formation.

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
3–34 m.

Distribution and extent
Narrow, linear belt between Seisdon and Trysull, Staffordshire.

Age
Anglian (MIS 10 or 12).

8.1.2.2 Oakwood Glacigenic Formation

Name
Oakwood Glacigenic Formation (OKWDG) (after Worsley et al., 1983, and Worsley, pp. 32–34 in Bowen, 1999).

Lithology
Till (sandy, gravelly clay with pebbles, cobbles and boulders) and silt, sand and gravel.

Formal subdivisions and correlation table
No subdivisions (Tables 7c and 13).

Type area/Reference section
Type section: Oakwood Quarry [SJ 8240 7170], Chelford, Cheshire (Worsley et al., 1983).

Lower and upper boundaries
Irregular, unconformable contact with bedrock.

Unconformably underlies sand of the Chelford Sand Formation (Britannia Catchments Group).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Unknown but probably greater than 5 m.

Distribution and extent
Cheshire.

Age
Possibly Anglian (MIS 12) (Worsley, 1991) or alternatively MIS 6 and correlated with the Ridgacre Formation of the Birmingham area (Maddy et al., 1995).

8.2 CALEDONIA GLACIGENIC GROUP

8.2.1 Irish Sea Coast Glacigenic Subgroup

The Late Devensian glacigenic tills and sands of the **Stockport Glacigenic Formation** (after Worsley, 1967, 1991; Worsley, p. 34 in Bowen, 1999; see also Thomas, 1985b) of Cheshire and Lancashire and the **Brewood Till Formation** (named here after Morgan, 1973; Mitchell et al., 1973a) are included in the Irish Sea Coast Glacigenic Subgroup, although it is recognised that these deposits contain variable proportions of both local and Lake District-derived rocks. The **Morecambe Bay Formation** was established by Knight (1977) for the offshore glaciofluvial and glaciolacustrine sediments overlying till that may be equivalent to the Kirkham Till Member (Stockport Glacigenic Formation) in Lancashire.

A generalised cross section of the subgroups and formations is presented in Figure 13. Further research on the tripartite sequence, 'Upper Boulder Clay–Middle Sands–Lower Boulder Clay' (Hull, 1864), may enable subdivision into two subgroups (see Central Cumbria Glacigenic Subgroup, Section 7.3.1).

The relationships between the Stockport Glacigenic Formation and the underlying **Chelford Sand Formation** (Britannia Catchments Group, Section 8.4.1.2) and **Oakwood Glacigenic Formation** (Section 8.1.2.2) are described by Worsley (1991) and shown in Figure 14.

8.2.1.1 Stockport Glacigenic Formation

Name
Stockport Glacigenic Formation (STPTG) (after Worsley, 1967, 1991; Stockport Formation of Worsley, p. 34 in Bowen, 1999).

Lithology
A mixed sequence of till (sandy, gravelly clayey diamicton with cobbles and boulders), sand, gravel and laminated clay and silt. Erratics are dominated by Lake District (Borrowdale Volcanic Group rocks and Eskdale Granite), and Carboniferous rock fragments but locally include material derived from the Irish Sea Basin.

Formal subdivisions and correlation table
Kirkham Till Member (Tables 8, 13 and 17).

Type area/Reference section
Type section: Northern bank of the River Mersey [SJ 908 915] (Worsley, 1967, 1991; Worsley, p. 34 in Bowen, 1999).

Lower and upper boundaries
Unconformable and in places heavily incised contact with bedrock.

Either the ground surface or various units of the Britannia Catchments Group or other formations or subgroups of the Caledonia Glacigenic Group.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Highly variable from 3 m to locally in excess of 100 m.

Distribution and extent
Cheshire, Staffordshire and south Lancashire approximately corresponding to the area between the Kirkham Moraine, near Kirkham [SD 4300 3200] in the north and the Ellesmere Moraine, Wood Lane Quarry, Ellesmere [SJ 4220 3280], in the south.

Age
Late Devensian, Dimlington Stadial (MIS 2).

KIRKHAM TILL MEMBER (KMGL)

The Kirkham Till Member comprises up to 100 m of till (sandy, gravelly clayey diamicton with cobbles and boulders) and laminated silt and clay separated by variably continuous lenses or beds of sand and gravel which form the Kirkham Moraine [SD 4300 3200] in north Lancashire (Gresswell, 1967; Thomas, p. 95 in Bowen, 1999). Erratics in the till are dominated by Carboniferous rocks and by Lake District and Irish Sea-derived bedrock.

8.2.1.2 BREWOOD TILL FORMATION

Name
Brewood Till Formation (BDTI) (after Morgan, 1973).

Lithology
Reddish brown, gravelly, sandy, silty, clayey diamicton dominated by locally-derived clasts such as of the Kidderminster Formation (Bunter Pebble Beds) conglomerates, but with a significant proportion of erratics including grey granite from the Southern Uplands, striated volcanic rocks, Eskdale Granite, Ennerdale Granophyre and slates from the Lake District, limestone, flint and marine shells. The tills are typically thinner, more eroded, more weathered and considerably more cryoturbated than those of the Stockport Glacigenic Formation lying to the north of the Wrexham–Ellesmere–Whitchurch–Barr Hill Moraine in Cheshire.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 13).

Type area/Reference section
Type section: Former sand and gravel quarry [SJ 916 082] on the north side of Saredon Brook, Four Ashes, Staffordshire (Morgan, 1973), formerly chosen as the type site for the Devensian (Mitchell et al., 1973a).

Partial reference section: Ketley Grange opencast site [SJ 690 100], Telford (Hamblin and Coppack, 1995).

Lower and upper boundaries
Sharp, unconformable contact with fluvial gravel (Four Ashes Sand and Gravel Formation) containing mainly well-rounded clasts derived from the Kidderminster Formation (Bunter Pebble Beds) conglomerates and numerous organic-rich lenses of Ipswichian–Middle Devensian age. The diamicton is heavily cryoturbated at the type section at Four Ashes where it has been loaded down into the underlying gravel.

The ground surface or unconformable contacts with glaciofluvial sand and gravel or younger Quaternary deposits.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
3 m at type section. Up to 17 m at Madeley in Telford district.

Distribution and extent
The ground lying within the generally accepted Late Devensian glacial limit in Staffordshire, but outside the Wrexham–Ellesmere–Whitchurch–Barr Hill Moraine in Cheshire.

Age
Late Devensian, Dimlington Stadial (MIS 2).

8.2.1.3 MORECAMBE BAY FORMATION

Name
Morecambe Bay Formation (MOBAY) (after Knight, 1977, and Thomas, p. 96 in Bowen, 1999).

Lithology
Glaciofluvial and glaciolacustrine sediments including sand, silt, laminated clay with gravel.

Formal subdivisions and correlation table
No subdivisions (Tables 8, 12 and 13).

Type area/Reference section
Type area: Cumbria and offshore in Morecambe Bay.

Lower and upper boundaries
Overlies extensive deposits of till (Knight, 1977) probably equivalent of the Kirkham Till Member (Stockport Glacigenic Formation).

Gradational with overlying post-glacial sequence of clay, silt and sand.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 18 m.

Distribution and extent
Cumbria and offshore in Morecambe Bay.

Age
Devensian (MIS 2).

Two formations referable to the Irish Sea Coast Glacigenic Subgroup are established for the Devensian glacigenic deposits of Wales. These are the **St Asaph Glacigenic Formation** (after McKenny-Hughes, 1887; Strahan, 1902; Bowen, 1999) of north-east Wales and the **Teifi Clay Formation** of South Ceredigion, north Pembrokeshire and north Carmarthenshire (Hambrey et al., 2001).

8.2.1.4 St Asaph Glacigenic Formation

Name
St Asaph Glacigenic Formation (SAGL) (after Bowen, p. 89 in Bowen, 1999).

Lithology
Stiff, generally calcareous, red, purple or bluish-black, ill-sorted, massive to crudely stratified, variably pebbly, sandy clay, characteristically containing exotic clasts and shell fragments. Includes other glacigenic deposits, notably stratified sand and gravel and morainic deposits (clayey gravel). Colour and dominant clast composition is variable and generally reflects the local bedrock geology: in Ceredigion and Pembrokeshire it is generally green-grey with abundant Lower Palaeozoic clasts.

Formal subdivisions and correlation table
Subdivided into the Lleyn Till Member and the Llangelynin Till Member (Tables 8 and 13).

Type area/Reference section
Type section: Coastal cliff section in Porth Neigwl (Lleyn Peninsula). Most of the section is dominated by a clay-rich diamicton, locally with some crude stratification. Layers and lenses of sand and gravel are generally uncommon but, where present, tend to occur towards the top of the section. The south-eastern end of the section is more complex and shows the Lleyn Till Member to be overlain by till of the Eryri Glacigenic Formation and to be separated from it by glaciofluvial sand and gravel and glaciolacustrine deposits. The section records the early advance of Irish Sea Ice into the area, followed by Welsh Ice, with ponding on the surface of the Irish Sea Ice during stagnation being represented by the intervening laminated deposits (Young et al., 2002).

Lower and upper boundaries
Base not seen at type locality, but could potentially overlie pre-Late Devensian deposits (Young et al., 2002); locally the formation overlies bedrock and Devensian head deposits (Gibbons and McCarroll, 1993). In Ceredigion and Pembrokeshire, the base is unconformable on bedrock, head and regolith (Hambrey et al., 2001); near Llanrhystud it rests on the Elenid Till Member of the Plynlimon Glacigenic Formation (Wales Glacigenic Subgroup) (Elenid Formation of Campbell and Bowen, 1989; Bowen, 1999; Davies et al., 1997). Along Liverpool and Conwy bays the base overlies bedrock and, locally, tills of Welsh origin (Warren et al., 1984).

Generally the ground surface or unconformable contact with fluvial, organic and mass movement deposits of the Britannia Catchments Group. However, at the eastern end of the type section the St Asaph Glacigenic Formation is overlain by till of the Eryri Glacigenic Formation (Wales Glacigenic Subgroup).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Highly variable: locally over 17 m in the Cardigan district (Maddison et al., 1994); over 60 m in the Dee Valley (Davies et al., 2004); and over 30 m on the Lleyn Peninsula (Gibbons and McCarroll, 1993).

Distribution and extent
Coastal fringe of Ceredigion and Pembrokeshire approximately between Llanrhystud and St Brides Bay; Anglesey; north coast and western tip of Lleyn Peninsula as far east as Porth Neigwl; coastal fringe of Conwy and Liverpool bays.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Lleyn Till Member (LLEYN)

The Lleyn Till Member (after Gibbons and McCarroll, 1993) of the Lleyn Peninsula comprises up to 30 m of stiff, generally ill-sorted, massive to crudely stratified, variably pebbly, sandy clay, characteristically containing exotic clasts and shell fragments. Subordinate clayey gravels and stratified sand and gravel are locally present. The type section, a coastal cliff at Porth Neigwl, exposes predominantly clay-rich diamicton, locally with some crude stratification. Layers and lenses of sand and gravel are generally uncommon but, where present, tend to occur towards the top of the section. The south-eastern end of the section shows the Lleyn Member to be overlain by the till of the Eryri Glacigenic Formation and to be separated from it by glaciofluvial sand and gravel and glaciolacustrine deposits. The section records the early advance of Irish Sea Ice into the area, followed by Welsh Ice, with ponding on the surface of the Irish Sea Ice during stagnation being represented by the intervening laminated deposits (Young et al., 2002).

Llangelynin Till Member (LNTI)

The Llangelynin Till Member (Llangelynin Member of the Eryri Formation of Bowen, 1999) comprises till with clasts of Mesozoic rocks from offshore and red clay from the Oligocene Bed of Tremadoc Bay, together with erratics from Cadair Idris and Aran Fawddwy. It occurs along part of the coast south of Barmouth Bay and north of Aberystwyth, between Llwyngwril and Tonfannau. The till overlies head (of the Pennard Formation, Bowen, 1999) and redeposited till (Bowen, 1974). North of Barmouth, 77 m of glacigenic sediments, comprising two tills and interbedded laminated sediments, were proved in the Mochras Farm Borehole [SH 5533 2594] (BGS Registered No. SH52NE1; Woodland, 1971; Allen and Jackson, 1985). The borehole lies immediately north of the line of an offshore gravel ridge (Sarn Badrig), interpreted as one of a series of medial moraines thought to delimit the confluence of Irish Sea and Welsh glacial masses (Etienne et al., p. 96 in Lewis and Richards, 2005). Of the succession referred to as the Mochras Member of the Eryri Formation by Bowen (1999) the lower till may possibly be correlated with the Llangelynin Till.

8.2.1.5 Teifi Clay Formation

Name
Teifi Clay Formation (TFICL) (after Hambrey et al., 2001).

Lithology
Brown and grey clay and silt-laminated clay, with interbeds of grey/yellow stratified silt and fine sand that locally increase in abundance towards the top. Drop-stones may be locally abundant and form thin beds of diamicton. Clasts are dominated by local bedrock lithologies but characteristically include shell fragments.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 13).

Type area/Reference section
Type section: BGS Pen-y-Bryn (Cardigan 2) borehole (SN14SE12), depth 3 to 64 m. The type section forms part

of the fill of a buried abandoned meander loop of the Afon Teifi and was deposited within a former proglacial lake system which developed in front of the advancing Irish Sea Ice as it dammed the mouth of rivers along the Ceredigion coast. The unit typically coarsens upwards, indicating advance of the ice into the lake basin(s), and contains shell material derived from the Irish Sea Basin (Hambrey et al., 2001).

Lower and upper boundaries
Unconformable on bedrock or contact with ?Late Devensian regolith, head and fluvial deposits.

Ground surface or (sheared) contact with overlying Lleyn Till Member (St Asaph Glacigenic Formation), or unconformably overlain by glaciofluvial deposits of the St Asaph Glacigenic Formation and Plynlimon Glacigenic Formation, peat or fluvial deposits of the West Wales Catchments Subgroup.

Landform description and genetic interpretation
Glaciolacustrine deposits.

Thickness
Up to 75 m in borehole at Llwynpiod (SN14NE156).

Distribution and extent
South Ceredigion, north Pembrokeshire and north Carmarthenshire. Predominantly within pre-glacial valley systems.

Age
Late Devensian, Dimlington Stadial (MIS 2).

8.2.2 Wales Glacigenic Subgroup

The Wales Glacigenic Subgroup is divided into five local formations, based on lithological characteristics of tills, the provenance of which have been influenced by local ice-sheet accumulation. These are the **Brecknockshire Glacigenic Formation** (west and south Wales), the **Eryri Glacigenic Formation** (Snowdonia), **Plynlimon Glacigenic Formation** (north, central and south-west Wales), the **Glamorgan Glacigenic Formation** (South Wales Coalfield), and the **Shrewsbury Glacigenic Formation** (the Shropshire lowlands). The composition of morainic sands and gravels is diverse, the extent of such deposits being largely associated with ice lobes and valley glaciers. No formal units have been established.

Glaciofluvial gravels in the form of valley-side terrace deposits and glaciolacustrine clays of major pro-delta lakes are not currently named or formally defined in the BGS Lexicon. There are a number of sites within Wales which are known to comprise deposits that formed during the Loch Lomond re-advance (Shakesby and Matthews, 1993; Carr, 2001). An assessment of the stratigraphical status of these deposits for BGS mapping purposes remains to be undertaken (Bowen, 1999).

Name
Wales Glacigenic Subgroup (WALES) (after McMillan et al., 2005).

Lithology
Suite of glacial, glaciofluvial and glaciolacustrine deposits including sandy diamictons (till), sand, gravel, silt and clay. The sediments were deposited by, or are the deglaciation products of, ice that emanated from the Welsh mountains and radiated across Wales and the Welsh Border. The till deposits vary in colour and clast content reflecting local bedrock. Constituent formations include the Brecknockshire Glacigenic Formation containing clasts derived predominantly from the Devonian (Black Mountain, Fforest Fawr and Brecon Beacons) and Carboniferous sources (sedimentary rocks of the South Wales Coalfield), the Plynlimon Glacigenic Formation and Shrewsbury Glacigenic Formation containing Lower Palaeozoic clasts of the Cambrian Mountains and the Eryri Till Formation with Lower Palaeozoic volcanic clasts derived from Snowdonia. The till formations contain subordinate stratified sand and gravel. The principal centres of ice build-up were in the Cambrian Mountains.

Formal subdivisions and correlation table
Brecknockshire Glacigenic Formation, Eryri Till Formation, Plynlimon Glacigenic Formation, Glamorgan Glacigenic Formation, Shrewsbury Glacigenic Formation (Tables 8 and 13).

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Generally sharp, unconformable contact with bedrock. Locally on head of Ipswichian or early Devensian age or on units of the Irish Sea Coast Glacigenic Subgroup (e.g. Stockport Glacigenic Formation).

At surface or unconformable contact with units of the Britannia Catchments Group (West Wales Catchments Subgroup and Cheshire-North Wales Catchments Subgroup) and the British Coastal Deposits Group.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 30 m.

Distribution and extent
South, south-east, mid and north-east Wales and Welsh Borderland.

Age
Devensian (MIS 2).

8.2.2.1 Brecknockshire Glacigenic Formation

Name
Brecknockshire Glacigenic Formation (BNOCK) (after Bowen, p.90 in Bowen, 1999).

Lithology
Generally stiff, structureless, stony, sandy and silty diamicton and clayey gravel, characteristically containing abundant Old Red Sandstone clasts (derived from Black Mountain, Fforest Fawr and the Brecon Beacons) and sparse (if any) Lower Palaeozoic clasts. Subordinate stratified sand and gravel are locally present. Colour and dominant clast composition are variable and generally reflect the local bedrock geology: in the Usk Valley the diamicton is red and composed exclusively of Old Red Sandstone material.

Formal subdivisions and correlation table
Hereford Till Member, Langland Till Member (Tables 8 and 13).

Type area/Reference section
Type section: Coastal section at Rotherslade in Langland Bay exposing 14 m of lodgement till, crudely stratified ablation till and well-imbricated glaciofluvial sand and gravel of the Brecknockshire Glacigenic Formation overlying 3.5 m of early Devensian head and 0.6 m of Ipswichian raised beach deposits of the Pennard Formation (of Bowen, 1999) on bedrock. Locally, colluvium and loess of possible Loch Lomond age overlie the Brecknockshire Glacigenic Formation (Campbell and Bowen, 1989, pp. 25–26).

Lower and upper boundaries
At the type locality the formation unconformably overlies Early Devensian head deposits and Ipswichian raised beach deposits of the Pennard Formation (of Bowen, 1999); elsewhere it is generally unconformable on bedrock or regolith (Barclay et al., 2005).

Generally the ground surface or overlain by Late Glacial organic deposits infilling kettleholes (see Bowen, 2005, p. 155) (Britannia Catchments Group), or Kenfig Formation or Gwent Levels Formation (British Coastal Deposits Group).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Highly variable, locally up to 25 m (Waters and Lawrence, 1987).

Distribution and extent
Usk Valley west of Talybont, Swansea Bay, Cardiff, Newport, Fforest Fawr and Brecon Beacons.

Age
Late Devensian, Dimlington Stadial (MIS 2).

HEREFORD TILL MEMBER (HDTI)

The Hereford Till Member (Newer Till of Brandon, 1989; Hereford Member of the Herefordshire Formation of Brandon, p. 31 in Bowen, 1999) comprises generally less than 4 m of stiff, structureless, stony, sandy and silty diamicton and clayey gravel, characteristically containing abundant Old Red Sandstone clasts (derived from Black Mountain, Fforest Fawr and the Brecon Beacons), nodular calcrete and relatively few Lower Palaeozoic clasts. Subordinate stratified sand and gravel are locally present. Colour and dominant clast composition are variable and generally reflect the local bedrock geology. Its distribution is confined to Herefordshire and the Brecon Beacons west of the River Lugg.

LANGLAND TILL MEMBER (LDTI)

The Langland Till Member comprises up to 25 m of stiff, structureless, stony, sandy and silty diamicton and clayey gravel, characteristically containing abundant Old Red Sandstone clasts (derived from the Black Mountains, Fforest Fawr and the Brecon Beacons) and very few Lower Palaeozoic clasts. Subordinate stratified sand and gravel are locally present. Colour and dominant clast composition are variable and generally reflect the local bedrock geology. The member extends from the Brecon Beacons to Swansea Bay (excluding the South Wales Coalfield).

8.2.2.2 ERYRI GLACIGENIC FORMATION

Name
Eryri Glacigenic Formation (ERYG) (after Bowen, pp. 86–88 in Bowen, 1999).

Lithology
Moderately stiff, dark grey to blue-grey, generally massive, pebbly, silty clay, characteristically containing Snowdonian Ordovician volcanic clasts but dominated by local Lower Palaeozoic clasts. Colour and dominant clast composition are variable and generally reflect the local bedrock geology. Also includes other glacigenic deposits of similar composition, notably glaciofluvial sand and gravel and morainic deposits.

Formal subdivisions and correlation table
No formal subdivisions (Tables 8 and 13); may include several members, as yet undefined in the BGS Lexicon e.g. Penrhos Member of Bowen (1999).

Type area/Reference section
Type section: Pen-y-bryn brickworks [SH 490 615], Caernarfon (Addison and Edge, 1992); succession of Irish Sea-derived till on Welsh-provenanced till and glaciofluvial gravels on biogenic muds, sands and gravels (Addison and Edge, 1992; Chambers et al., 1995; Bowen, 1999).

Lower and upper boundaries
Generally unconformable on bedrock, but locally may overlie Devensian head deposits (McCarroll, 2005, p. 29); Lleyn Till Member of St Asaph Glacigenic Formation (Lleyn Formation of Young et al., 2002), or post-Ipswichian preglacial peats (Addison and Edge, 1992).

Generally the ground surface or unconformable contact with overlying alluvial deposits, peat and head (Britannia Catchments Group). May locally be unconformably overlain by red diamicton of the Lleyn Till Member, St Asaph Glacigenic Formation (Lleyn Formation of Harris et al., 1997).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Highly variable, locally likely to greatly exceed 10 m (Warren et al., 1984).

Distribution and extent
Mountains of Snowdonia, Rhinogs and Cadair Idris; eastern Lleyn Peninsula.

Age
Late Devensian, Dimlington Stadial (MIS 2).

8.2.2.3 PLYNLIMON GLACIGENIC FORMATION

Name
Plynlimon Glacigenic Formation (PLYNT) (after Davies et al., 1997; includes most of the deposits of the Elenid Formation of Bowen, pp. 84–86, in Bowen, 1999).

Lithology
Generally stiff, blue-grey, stony, sandy and silty clay and clayey gravel, characteristically containing clasts of Lower Palaeozoic rocks (derived from the Cambrian Mountains). Subordinate stratified sand and gravel are locally present. Colour and dominant clast composition are variable and generally reflect the local bedrock geology; in central and

west Wales it is generally grey and the clasts are exclusively Lower Palaeozoic. In Broughton Bay the formation contains shell fragments (Bowen, 1999).

Formal subdivisions and correlation table
Subdivided into the Ruabon Till, Elenid Till and Merion Till members (Tables 8 and 13).

Type area/Reference section
Type section: Coastal section between Morfa Bychan and Mynachdy'r-graig in Cardigan Bay (Ceredigion), exposing up to 40 m of superficial deposits overlying and blanketed against a pre-Devensian 'fossil cliff'. A basal head deposit is sharply overlain by up to 30 m of Plynlimon Glacigenic Formation exhibiting evidence of solifluction, itself sharply overlain and overstepped by head and loess (Davies et al., 1997).

Lower and upper boundaries
Generally unconformable on bedrock or regolith/head (e.g. Davies et al., 1997). At Broughton Bay it unconformably overlies Ipswichian raised beach gravels and head (Campbell and Bowen, 1989, pp. 52–54) assigned to the Pennard Formation by Bowen (1999).

Generally the ground surface or contact with overlying peat, head (Severn and Avon and West Wales Catchments subgroups), Kenfig Formation or Ynyslas Formation (British Coastal Deposits Group). Near Llanrhystud it is overlain by the Lleyn Till Member of the St Asaph Glacigenic Formation (Lleyn Formation of Campbell and Bowen, 1999; Davies et al., 1997) and in the Shropshire lowlands by the Shrewsbury Glacigenic Formation (Thomas, 1989).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Highly variable, locally in excess of 30 m.

Distribution and extent
Denbighshire, mid- and west Wales, south-west Wales approximately north of Black Mountain and east of St Clears and Llandysul.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Three till members of the Plynlimon Glacigenic Formation are identified:

RUABON TILL MEMBER (RBNTI)

The Ruabon Till Member comprises 5 m or more of grey or brown, calcareous, sandy, stony diamicton containing significant proportion of locally-derived Carboniferous rocks (mainly limestone, sandstone and mudstone). It occurs in the Eastern Clwydian Hills and extends eastwards at depth to Mold and Wrexham.

ELENID TILL MEMBER (ELTI)

The Elenid Till Member (Central Wales Drift of Bowen, 1970; Elenid Formation of Bowen, 1999) is locally over 30 m thick. It comprises generally stiff, blue-grey, stony, sandy and silty clay and clayey gravel, characteristically containing Lower Palaeozoic clasts (derived from the Cambrian Mountains). Subordinate stratified sand and gravel are locally present. Colour and dominant clast composition are variable and generally reflect the local bedrock geology. In the Gower it contains shell fragments (Bowen, 1999). It is distributed over mid- and west Wales, with south-west Wales approximately west of Swansea and including the Gower.

MERION TILL MEMBER (MNTI)

The Merion Till Member (Meirion Formation of Bowen, 1999) is locally over 30 m thick. It comprises generally stiff, blue-grey, stony, sandy and silty clay and clayey gravel, characteristically containing Lower Palaeozoic clasts (derived from the Cambrian Mountains) with some erratics from Snowdon and the Harlech Dome. Subordinate stratified sand and gravel are locally present. Colour and dominant clast composition are variable and generally reflect the local bedrock geology. It occurs in mid- and north-east Wales, and the northern Welsh Borderlands. A thin head deposit, up to 1 m thick (named the Hiraethog Member by Bowen, 1999), occurs locally at the base of the till (Warren et al., 1984).

8.2.2.4 GLAMORGAN GLACIGENIC FORMATION

Name
Glamorgan Glacigenic Formation (GLGL) (after Woodland and Evans, 1964, and Bowen, p. 90 in Bowen, 1999; Glamorgan Drift of David, 1883).

Lithology
Stony clayey diamicton (till) and sand and gravel with clasts predominantly of Carboniferous rocks (sandstone, siltstone, mudstone) derived from the South Wales Coalfield. Brown and purplish red clays, silts and sands with small pebbles are developed locally.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 13).

Type area/Reference section
Type area: Valley of Rhondda Fawr [SN 900 200–ST 100 900] (Bowen, p. 90 in Bowen, 1999).

Lower and upper boundaries
Unconformable on bedrock of the South Wales Coal Measures and Warwickshire groups.

Ground surface or overlain by fluvial deposits (Severn and Avon Catchments Subgroup) or head.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 30 m (Woodland and Evans, 1964).

Distribution and extent
Rhondda Fawr, Maesteg, Pontypridd, Pencoed districts (South Wales Coalfield).

Age
Late Devensian, Dimlington Stadial (MIS 2).

8.2.2.5 SHREWSBURY GLACIGENIC FORMATION

Name
Shrewsbury Glacigenic Formation (SHREW) (after Worsley, 1991, and Worsley, p. 34 in Bowen, 1999).

Lithology
Stratified sand and gravel with interbeds of laminated clay,

silt and diamicton (till), all characteristically containing Lower Palaeozoic clasts derived from the Welsh massif.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 13).

Type area/Reference section
Type section: Mousecroft Lane Quarry (abandoned) [SJ 476 109], south-west suburbs of Shrewsbury. A complex of ice-marginal glacigenic sediments deposited by Welsh ice (Severn Glacier) during its advance and retreat in a 5–10 km wide zone of interaction with the Irish Sea ice-sheet extending from Wrexham to Shrewsbury (Worsley, 2005). The sequence coarsens upwards from laminated muds into sand and gravel, reflecting sandur progradation, and is overlain by till. Its contact with the underlying sequence of Irish Sea Ice-derived till and outwash (Stockport Glacigenic Formation, after Worsley, p.34 in Bowen, 1999) shows large scale, low amplitude wave-like deformation attributed to the melt-out of buried ice within the latter.

Lower and upper boundaries
Unconformable on elements of the Stockport Glacigenic Formation (after Bowen, 1999) at the stratotype locality, and locally on the Merion Till Member (Plynlimon Glacigenic Formation) in the Shrewsbury area (Thomas, 1989). At some locations farther north, it interdigitates with glacigenic deposits of the Irish Sea Coast Glacigenic Subgroup derived from the Irish Sea Basin in a complex manner (Worsley, 2005; Cannell, 1982). Locally, it overlies bedrock unconformably.

Irregularly overlain at the stratotype locality by Late Glacial solifluction deposits and then Windermere interstadial peat (Worsley, 1991) of the Britannia Catchments Group. Elsewhere forms the present ground surface or is overlain unconformably by fluvial deposits of the Severn and Avon Catchments Subgroup.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to about 6 m at stratotype locality.

Distribution and extent
Shropshire lowlands to the west of Shrewsbury and Dorrington, extending north of Four Crosses (see Pocock et al., 1938; Cannell, 1982) in a narrow band (5–10 km wide) as far as Wrexham (Worsley, 1991).

Age
Late Devensian, Dimlington Stadial (MIS 2).

8.3 BRITISH COASTAL DEPOSITS GROUP

8.3.1 Formations of the British Coastal Deposits Group

The **Seacombe Sand Formation** (glaciomarine sands of Reade, 1894, 1895), **Shirdley Hill Sand Formation** (coastal blown sand of de Rance, 1877, or outwash sands of Tooley, 1977) and the **Lytham Formation** (estuarine deposits of the Lower Mersey, Ribble and Lune) are established as component units of the group.

8.3.1.1 Seacombe Sand Formation

Name
Seacombe Sand Formation (SCMBS) (after Thomas, p.95 in Bowen, 1999).

Lithology
At Seacombe comprises a shell-rich sand with fine gravel, containing boulders and cobbles of till; it is developed over a foraminiferid-rich till at Crosby and Blackpool.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 13).

Type area/Reference section
Type locality: Seacombe [SJ 3200 0950] (Reade, 1894).

Lower and upper boundaries
Unknown lower boundary.

Overlain unconformably by till at type locality at Seacombe.

Landform description and genetic interpretation
The formation may be of marine origin and is a possible correlative of glaciomarine sediments of the informal Dog Mills Member, Orrisdale Formation (Chadwick et al., 2001), Isle of Man.

Thickness
Up to 45 m.

Distribution and extent
North Wirral and Liverpool Bay coast.

Age
Devensian (MIS 2).

8.3.1.2 Shirdley Hill Sand Formation

Name
Shirdley Hill Sand Formation (SSA) (after Thomas, p. 95 in Bowen, 1999).

Lithology
Moderately well-sorted, fine-grained sand with peat layers in the lower part. Sand grains are dominated by rounded–subrounded quartz grains. The formation is divisible into an upper 'white' sand and a lower 'brown' sand, which is olive-grey and brown in colour.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 13).

Type area/Reference section
Type section: Shirdley Hill [SD 3640 1340] (de Rance, 1869).

Lower and upper boundaries
Overlies various sediments of the Caledonia Glacigenic Group.

Either the ground surface or the base of overlying peat deposits.

Landform description and genetic interpretation
The sediments are interpreted as coastal blown sands, possibly a coastal facies of the Seacombe Sand Formation (Tooley, 1985).

Thickness
Up to 5 m.

Distribution and extent
Discontinuous distribution between Wigan, Liverpool and Southport in Lancashire and Merseyside.

Age
Devensian to Holocene (MIS 2–1).

8.3.1.3 LYTHAM FORMATION

Name
Lytham Formation (LTHM) (part of the Lytham Formation of Thomas, p. 95 in Bowen, 1999)

Lithology
Sand, clay, silt with gravel and peat. Gravel becomes dominant in the outer parts of the Mersey Estuary.

Formal subdivisions and correlation table
Includes informal units including the Scrobicularia and Lower Cyclas Clays, Leasowe Marine Bed, Preesall Shingle Bed and coastal peat beds (Tables 5 and 13).

Type area/Reference section
Type area: The Mersey, Ribble and Lune valleys and the low coast between these valleys.

Lower and upper boundaries
Probably underlain by bedrock or deposits of the Caledonia Glacigenic Group.

Ground surface.

Landform description and genetic interpretation
Marine and estuarine sediments.

Thickness
5–25 m.

Distribution and extent
Cumbria, Lancashire and north Cheshire. It includes all estuarine deposits of the rivers Lune, Ribble and Mersey.

Age
Holocene (MIS 1).

Marine deposits pre-dating the Late Devensian are located mostly south of the maximum limit of the Devensian ice-sheet in south Wales, but are also found in a few areas of north-east Wales and the Welsh Borderlands, and also in Somerset (Section 13.1.1). They comprise a series of marine beach gravels (south Wales) and cave deposits (south and north-east Wales), broadly equating with the Ipswichian interglacial period (MIS 5e) or earlier (e.g. Hunts Bay Member, Pennard Formation of Bowen, 1999). Allen (2000a, 2001a) records a discontinuous development of littoral shelly sands and gravels along the margins of the Gwent Levels, commonly overlain by head. Temperate-water molluscan and foraminiferal assemblages have been amino-acid dated to the Ipswichian (MIS 5e). Correlation is tentatively proposed with the Ipswichian marine deposits of south-west England that are referred to the **Burtle Formation** (Section 13.1.1.2).

There are, in addition, assemblages of gravelly deposits in Pembrokeshire and the Gower Peninsula that generally have been assigned to one or more periods predating the Ipswichian interglacial. They are usually referred to as 'pre-Ipswichian' as they fall broadly within the spectrum of MIS 7–12 (Anglian–pre-Ipswichian) (members of the Pennard Formation of Bowen, 1999), although their age and stratigraphical relationships are poorly constrained.

Extensive estuarine deposits of Holocene age occur along the Gwent Levels of south-east Wales forming the northern coastline of the inner Bristol Channel and Severn Estuary (Allen, 1987a, 2000b, 2001a) (see also Section 13.1.1). Allen (1987a) proposed four formations, the Northwick, Awre, Wentlooge and Rumney formations. These units were referred to the Gwynllwg Formation by Bowen (1999) and are here named the **Gwent Levels Formation**. Allen's (1987a, 2000b) Wentlooge Formation is assigned member status. Formal status for the deposits of the infilled estuary of the Afon Glaslyn behind the Cob in North Wales could be considered.

8.3.1.4 GWENT LEVELS FORMATION

Name
Gwent Levels Formation (GLEV) (after Welch and Trotter, 1961, and Allen, 2001a).

Lithology
The deposits are dark blue-grey silty clays and silts with subordinate sands and beds of peat, submerged forests and gravel. The deposits rest on a rockhead platform at 5–7.5 m below OD, intricately dissected by river valleys. Their upper surface is approximately level at about 4.5–7 m above OD. The river valleys are infilled with gravels and sands that become shelly upwards. Typically there are two beds of peat up to 0.6 m thick. The lower of these forms the lowest unit in the formation, except where it rests upon the valley-fill sands and gravels, and was formed about 8500–8000 years BP when a birch forest was inundated by the rising sea. The other formed about 5000–4500 years BP during a slowing down of the rising sea level, and is now found resting horizontally at OD.

Formal subdivisions and correlation table
Wentlooge Member (Tables 5 and 19).

Type area/Reference section
Type area: The Gwent Levels from Caldicot, Monmouthshire, to Cardiff.

Lower and upper boundaries
The formation rests unconformably on bedrock or locally on Devensian tills, glaciofluvial gravels and head or littoral sands.

Generally the ground surface.

Landform description and genetic interpretation
The formation encompasses marine, estuarine and terrestrial deposits that were formed in the Gwent Levels area during the Holocene transgression.

Thickness
10–15 m, increasing to 35 m in buried channels.

Distribution and extent
The Gwent Levels including the coast from Awre, Gloucestershire, to Cardiff.

Age
Holocene (MIS 1).

WENTLOOGE MEMBER (WLLEV)

The Wentlooge Member comprises up to about 15 m of soft to very soft, blue-grey clay, with scattered diffuse silt laminae and peats. A basal gravel and diachronous basal peat is present. The type area is the coastal plain between Cardiff and Newport on the Wentlooge Level [ST 1770 7275–ST 3187 8555].

Extensive Holocene dune systems occur in South Wales (e.g. Kenfig Burrows), mid-Wales (e.g. Borth/Ynyslas) and North Wales (e.g. Caernarfon/Anglesey). The BGS framework adopts the **Kenfig Formation** (Higgins, 1933; Bowen p. 90 in Bowen, 1999). The **Ynyslas Formation** is defined for the coastal dune complex of Cardigan Bay described by Cave and Hains (1986).

8.3.1.5 Kenfig Formation

Name
Kenfig Formation (KNFIG) (after Wilson et al., 1990, and Bowen, pp. 79–90, in Bowen, 1999).

Lithology
Stratified, unconsolidated, fine- to medium-grained, quartz sand with shell debris.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 13).

Type area/Reference section
Type area: Kenfig Burrows [SS 790 815]. Dune complex developed in response to exposed beach deposits being blown inland by prevailing winds (Higgins, 1973; Wilson et al., 1990).

Lower and upper boundaries
Laterally variable at type locality: conformable on Holocene deposits in the vicinity of Kenfig pool (Cheney et al., 2000) and elsewhere unconformable on bedrock or superficial deposits.

Generally the ground surface; locally contact with overlying Holocene deposits.

Landform description and genetic interpretation
Coastal dune complex.

Thickness
Exceptionally up to 10 m, but generally varies in accordance with the topographic expression of dune forms.

Distribution and extent
Coastal embayments on the north shore of the Bristol Channel, particularly in Swansea Bay, Carmarthen Bay and Freshwater Bay.

Age
Holocene (MIS 1).

8.3.1.6 Ynyslas Formation

Name
Ynyslas Formation (YNYSS) (after Cave and Hains, 1986).

Lithology
Stratified, unconsolidated, fine- to medium-grained, quartz sand with shell debris.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 13).

Type area/Reference section
Type area: Borth to Aberlerry Farm [SN 609 910], mostly an active dune complex consisting of a narrow strip behind the storm beach, widening northwards to about 1 km north of Foel-ynys [SN 607 929] and terminating at Twyni Bach. Relict, older sand hills occur at [SN 612 899]. The deposits developed in response to exposed beach deposits being blown inland by prevailing winds (Cave and Hains, 1986).

Lower and upper boundaries
Commonly unconformable on Holocene or Late Devensian superficial deposits. In the type area it overlies Holocene storm beach gravels in the west and peat in the east; locally, it overlies bedrock (Godwin, 1943).

Generally the ground surface, but locally the contact with overlying Holocene deposits. In the type area the formation is locally overlain by tidal flat deposits (British Coastal Deposits Group).

Landform description and genetic interpretation
Coastal dune complex.

Thickness
Exceptionally up to 10.5 m in the type area, but generally less, varying in accordance with the topographic expression of dune forms (Cave and Hains, 1986).

Distribution and extent
Cardigan Bay; principally at Morfa Bychan, Morfa Harlech, Morfa Dyffryn, Poppit Sands, Whitesands Bay and Freshwater West.

Age
Holocene (MIS 1).

8.4 BRITANNIA CATCHMENTS GROUP

8.4.1 Formations of the Britannia Catchments Group

The Britannia Catchments Group includes three formations referred to the Hoxnian and Ipswichian interglacials. The **Trysull Silt Formation** (Tables 6 and 13) comprises organic silts beneath the Stockport Glacigenic Formation in two pits at Trysull [SO 85 94] near Wolverhampton, yielding pollen of Hoxnian age (Morgan, 1973; Morgan and West, 1988) and thus may belong to either Stage 9 or 11 (Sumbler, 1995). It may be equivalent to the **Quinton Peat Formation** of the Birmingham area (Section 11.3.1.1, Table 17).

8.4.1.1 Trysull Silt Formation

Name
Trysull Silt Formation (TSLSI) (after Morgan, 1973; Trysull Member of Seisdon Formation of Worsley, p. 32 in Bowen, 1999).

Lithology
A heterogeneous, fossiliferous sequence of silt, clay, sand, clayey sand, gravel and organic rich horizons. Strong iron and manganese staining along some horizons.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type section: Former quarries at Lowe's Pit and Cooper's Pit [SJ 8470 9500], Staffordshire (Morgan, 1973).

Lower and upper boundaries
Unconformable on sand and gravel of Seisdon Sand and Gravel Formation.

Either the ground surface or underlying till of the Stockport Glacigenic Formation.

Landform description and genetic interpretation
Fluvial and lacustrine.

Thickness
2.8–5 m.

Distribution and extent
Linear belt between Seisdon and Trysull, Staffordshire.

Age
Hoxnian (MIS 11 or 9)

8.4.1.2 Chelford Sand Formation

Name
Chelford Sand Formation (CHFDS) (Congleton Sand of Evans et al., 1968; Chelford Formation of Worsley, p. 34 in Bowen, 1999).

Lithology
White to buff-coloured, well-sorted sand, with minor gravel, silt and peat lenses with occasional in situ tree stumps and wood clasts.

Formal subdivisions and correlation table
Subdivided by Worsley (p. 34 in Bowen, 1999) into informal units at type section comprising an organic-rich sand (Arclid Member) (Simpson and West, 1958), peat (Farm Wood Member) and organic clays and silts (Burland Member); a thin biogenic-rich, fluvio-lacustrine sequence of silt, sand and gravel (Worsley et al., 1983; Worsley, 1991; the Lapwing Bed) lies at the base of the sequence (Figure 14, Table 13).

Type area/Reference section
Type section: Farm Wood Quarry [SJ 8100 7300], Chelford.
Partial reference section: New Windsor Road Quarry [SJ 8570 6430], Congleton. Here, the white sands were named the Congleton Sand (Evans et al., 1968).

Lower and upper boundaries
Irregular contact with bedrock or deposits of the Oakwood Glacigenic Formation.

Unconformably overlain by till, sand and gravel of the Stockport Glacigenic Formation.

Landform description and genetic interpretation
Fluvio-aeolian (Boulton and Worsley, 1965; Worsley, 1966).

Thickness
Up to 20 m.

Distribution and extent
Cheshire.

Age
Ipswichian–Early Devensian (MIS 5e–5a).

8.4.1.3 Four Ashes Sand and Gravel Formation

The type locality for the Four Ashes Sand and Gravel Formation (Table 9) is Four Ashes [SJ 916 082], north of Wolverhampton, the Devensian Stratotype. It comprises fluvial sand and gravel with organic lenses beneath the Brewood Till Formation (Section 8.2.1.2). Palaeoecological data (Morgan, 1973) suggest that it spans the Ipswichian and early Devensian stages.

Name
Four Ashes Sand and Gravel Formation (FASG) (after Morgan, 1973, and Worsley, p. 34 in Bowen, 1999).

Lithology
Gravel with organic-rich horizons of peat and grey peaty clay. Gravel is dominantly well rounded; sandstone derived from the Sherwood Sandstone Group.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type section: Former sand and gravel quarry [SJ 916 082] on the north side of Saredon Brook, Four Ashes, Staffordshire (Morgan, 1973), the type site for the Devensian (Mitchell et al., 1973a).

Lower and upper boundaries
Sharply erosional and unconformable on bedrock (Sherwood Sandstone Group).

Either ground surface or sharp contact with lower surface of red, sandy gravelly clay of the Brewood Till Formation (Irish Sea Coast Glacigenic Subgroup).

Landform description and genetic interpretation
No landform details known. ? Fluvial.

Thickness
0.45–4.6 m.

Distribution and extent
Four Ashes, Staffordshire and the immediately surrounding area.

Age
Ipswichian–Devensian (MIS 5e–5a).

The Britannia Catchments Group includes peat and associated lacustrine deposits of Holocene age of the region. Currently two formal units, the **Tregaron Formation** and the **Ystog Formation** (after Bowen, 1999) have been established regionally across Mid-Wales, Powys and Shropshire for Late Glacial–Holocene organic and lake deposits.

8.4.1.4 Tregaron Formation

Name
Tregaron Formation (TREGN) (after Campbell and Bowen, 1989, and Bowen, pp.70–90 in Bowen, 1999).

Lithology
Peat with silt; the margins of the formation are more silt-rich.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Cors Garon [SN 685 635] comprises three separate areas of raised peat bog, at the head of the Afon Teifi (Campbell and Bowen, 1989).

Lower and upper boundaries
Defined by the base of bed 3 (Hibbert and Switsur, 1976)

where peats replace Late Devensian muds and lacustrine clay, Corylus is first represented continuously in the profile, and a 14C date of 9750 ± 220 (11 600 cal.) BP was obtained. Locally unconformably overlies Late Devensian head deposits (Godwin and Mitchell, 1938) and Plynlimon Glacigenic Formation.

Ground surface, locally unconformably overlain by Teifi Valley Formation.

Landform description and genetic interpretation
Organic deposits.

Thickness
5 m.

Distribution and extent
Tregaron Bog, Ceredigion.

Age
Devensian to Holocene (MIS 1).

8.4.1.5 Ystog Formation

The **Ystog Formation** is established for Late Devensian to Holocene lake deposits of Lake Camlad-Caebitra.

Name
Ystog Formation (YSTOG) (after Cave and Hains, 2001, and Bowen, pp. 70–90 in Bowen, 1999).

Lithology
Grey, laminated and massive, silty clay and silt. Gravelly shoreline deposits and sandy deltaic deposits are present locally (Cave and Hains, 2001). Likely to contain dropstones and interbedded thin diamictons at depth.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Boggy ground in the Caebitra and upper Camlad valleys, in the vicinity of Church Stoke. The deposits are of Lake Camlad-Caebitra, one of a series of interconnected lakes that developed initially in front of Welsh ice during the Late Devensian and persisted against moraines into the Holocene. Pollen analyses have failed to provide a date; persistence into the Holocene is inferred from geomorphological criteria (Cave and Hains, 2001).

Lower and upper boundaries
Unconformable on bedrock and Plynlimon Glacigenic Formation. Laterally, it may interdigitate with head deposits.

Generally the ground surface or unconformable contact with Holocene alluvial deposits of Severn and Avon Catchments Subgroup.

Landform description and genetic interpretation
Lacustrine deposits.

Thickness
Likely to be in excess of 10 m. A railway cutting at [SO 1696 9105] exposes 7 m of sand and fine gravel.

Distribution and extent
Upper Camlad Valley and Caebitra Valley, upper Mule Valley and lower Camlad Valley, Powys/Shropshire.

Age
Late Devensian to Holocene (MIS 2–1).

Devensian to Holocene fluvial (alluvium and river terrace) deposits of western England and Wales are referred to three subgroups, the **Cheshire–North Wales Catchments,** the **West Wales Catchments** and the **Severn and Avon Catchments** subgroups.

8.4.2 Cheshire–North Wales Catchments Subgroup

Fluvial deposits of the River Mersey and its tributaries (parts of the Lytham and Swettenham formations of Thomas, p. 95 in Bowen, 1999) are treated as a separate formation namely the **Mersey Valley Formation** of the Cheshire–North Wales Catchments Subgroup (Table 13). Valley formations for fluvial deposits of the principal river valleys in south Cheshire and north Wales, including the **Weaver Valley, Dee Valley, Clwyd Valley** and **Conwy Valley formations**, are also assigned to this subgroup.

Name
Cheshire–North Wales Catchments Subgroup (CNWCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Alluvial silt, sand, clay and gravel with some peat. Associated river terraces are dominated by sand and gravel, gravelly sand or sandy gravel with rare clay and silt. The subgroup also includes coastal and inland basin peat.

Formal subdivisions and correlation table
Subdivided into the Mersey Valley, Weaver Valley, Dee Valley, Clwyd Valley and Conwy Valley formations (Tables 6 and 13).

Type area/Reference section
Type area: Catchments of Cheshire and North Wales including the valleys and tributaries of the rivers Mersey, Weaver, Dee, Clwyd and Conwy.

Lower and upper boundaries
Probably unconformable and in places strongly incised into highly variable sediments of the Caledonia or Albion Glacigenic groups and bedrock.

Ground surface or unconformable below artificial deposits.

Landform description and genetic interpretation
River terrace and floodplain.

Thicknes
Highly variable depending on the relative stratigraphical positions of each of the component units. In the major river valleys the thickness may vary between 2 and 5 m, but probably does not exceed 10 m. For deposits flanking the major river valleys, the thickness probably varies between 1 and 3 m.

Distribution and extent
Catchments of Cheshire and North Wales.

Age
Devensian–Holocene (MIS 2–1).

8.4.2.1 Mersey Valley Formation

Name
Mersey Valley Formation (MSYVA) (after Johnson, 1969,

and Harvey, 1985; part of Swettenham and Lytham formations of Thomas, p. 95 in Bowen, 1999).

Lithology
Silt, sand and clay (with peat locally) alluvium, grading to gravel at base. River terraces are composed of gravel or gravelly sand.

Formal subdivisions and correlation table
No formal subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Valley and tributaries of the River Mersey west of the Peak District. Tributary valleys include the Dane, Goyt, Etherow and Irtwell.

Lower and upper boundaries
Probably unconformable, irregular and in places strongly incised into lithologically variable sediments of the Caledonia and Albion Glacigenic groups or bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Generally less than 10 m but locally in excess of 20 m.

Distribution and extent
Cheshire and south Lancashire within the river valley and tributaries of the River Mersey west of the Peak District.

Age
Devensian to Holocene (MIS 2–1).

8.4.2.2 Weaver Valley Formation

Name
Weaver Valley Formation (WVRVA) (after Johnson, 1969, Evans et al., 1968, and Earp and Taylor, 1986).

Lithology
Silt, sand and clay alluvium, grading to gravel at base. River terraces are composed of gravel or gravelly sand.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Valley and tributary valleys of the River Weaver.

Lower and upper boundaries
Probably unconformable, irregular and in places strongly incised into lithologically variable sediments of the Caledonia or Albion Glacigenic groups or bedrock.

Ground surface or unconformable below artificial deposits.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Probably does not exceed 10 m.

Distribution and extent
Cheshire within the river valley and tributaries of the River Weaver.

Age
Devensian to Holocene (MIS 2–1).

8.4.2.3 Dee Valley Formation

Name
Dee Valley Formation (DEEVA) (after Earp and Taylor, 1986).

Lithology
Alluvium of silt, sand and clay with some peat grading to gravel towards the base. River terraces are composed of silty sand or sandy gravel with rare clay.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Valley and tributaries of the River Dee, Cheshire.

Lower and upper boundaries
Probably unconformable, irregular and in places strongly incised into lithologically variable sediments of the Caledonia or Albion Glacigenic groups or bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Up to 10 m.

Distribution and extent
Cheshire, within the river valley and tributaries of the River Dee.

Age
Devensian to Holocene (MIS 2–1).

8.4.2.4 Clwyd Valley Formation

Name
Clwyd Valley Formation (CWYDV) (after Warren et al., 1984 and Davies et al., 2004; part of the Tywi Formation of Bowen, p.90 in Bowen, 1999).

Lithology
Unconsolidated, stratified gravels, sands, silts and clays forming the alluvial deposits of the River (Afon) Clwyd and its tributaries. Includes contemporaneous head, colluvium and pedogenic deposits within the catchment area. Clasts comprise variable proportions of Lower Palaeozoic turbidites, Ordovician volcanic rocks, Permian/Trias sandstone and Carboniferous Limestone and Coal Measures reflecting the underlying bedrock geology and complex local glacigenic sequence. North of approximately Denbigh, the deposits in the Clwyd and the Wheeler valleys, as well as those in the lower reaches of the Elwy valley, may contain exotic (Irish Sea ice-derived) materials reworked from the St Asaph Glacigenic Formation. Aggradational river terraces and major alluvial fans are characterised by pebble and cobble gravels and medium- to coarse-grained sand; the modern floodplain is dominated by silt and clay, and locally includes lenses of peat (Warren et al., 1984).

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Clwyd valley between Bodfari and Rhewl [SJ 0928 7020–SJ 1109 6055]. This reach contains numerous well-developed alluvial fans, abandoned peat-filled channels, staircases of terraces and a broad floodplain, mostly developed on till and glaciofluvial deposits. Rowlands (1955) has proposed that some of the terraces may relate to a moraine-dammed lake (Lake Clwyd) formed after the complete withdrawal of ice from the Vale. He also proposed that some older deposits originated in a lake confined between the retreating Irish Sea Ice and the Welsh Ice, but Warren et al. (1984) found little evidence for this.

Lower and upper boundaries
Sharp, unconformable and locally channelised, predominately on bedrock and Late Devensian head and glacigenic deposits, e.g. Ruabon Till Member (Plynlimon Glacigenic Formation) and Wheeler Member (of Bowen, 1999 p. 89) and Lleyn Till Member (St Asaph Glacigenic Formation). Interdigitates in a complex manner with tidal flat deposits of the Gwent Levels Formation (Gwynllwg Formation of Bowen, 1999) in the estuary (Warren et al., 1984).

Generally the present ground surface or, locally, overlain by peat.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Generally up to around 10 m; 8 m were recorded by Warren et al. (1984) in the Vale of Clwyd and 6 m are exposed near Plasnewydd [SH 9460 6640].

Distribution and extent
The valley of the River Clwyd and its tributaries (Clwyd).

Age
Devensian to Holocene (MIS 2–1).

8.4.2.5 CONWY VALLEY FORMATION

Name
Conwy Valley Formation (CONWY) (after Warren et al., 1984; part of the Tywi Formation of Bowen, p.90 in Bowen, 1999).

Lithology
Unconsolidated, stratified gravels, sands, silts and clays forming the alluvial deposits of the Afon Conwy (River Conway) and its tributaries. Includes contemporaneous head, colluvium and pedogenic deposits within the catchment area. Clasts principally consist of local Lower Palaeozoic turbidites admixed with Ordovician volcanic clasts derived from Snowdonia and the Harlech Dome (either primarily, or secondarily from the reworking of glacigenic deposits). Aggradational river terraces and major alluvial fans are dominated by pebble cobble gravels and medium- to coarse-grained sand, and locally by silty clay with pebble and cobble beds (Warren et al., 1984); the modern floodplain is dominated by silt and clay, and locally includes lenses of peat.

Formal subdivisions and correlation table
No subdivisions (Table 13).

Type area/Reference section
Type area: Conwy valley between Tal-y-Bont and Llanrwst [SH 7749 6895–SH8030 6108]. This reach contains numerous well-developed alluvial fans, large terraces, a broad floodplain and sections of abandoned channel filled with peat. The formation largely overlies the Eryri Glacigenic Formation and undifferentiated glaciofluvial deposits.

Lower and upper boundaries
Sharp, unconformable and locally channelised, predominately on bedrock and Late Devensian head and Welsh glacigenic deposits (e.g. Eryri Glacigenic Formation). Interdigitates in a complex manner with tidal flat deposits of the Gwent Levels Formation (Gwynllwg Formation of Bowen, 1999) in the estuary.

Generally the present ground surface or, locally, peat.

Landform description and genetic interpretation
River terrace and floodplain deposits.

Thickness
Generally up to around 10 m; up to 2 m are locally exposed (Warren et al., 1984).

Distribution and extent
The valley of the River Conwy and its tributaries (Gwynedd and Clwyd).

Age
Devensian to Holocene (MIS 2–1).

8.4.3 West Wales Catchments Subgroup

River valley formations have been established for the terrace deposits and alluvium of several major rivers in west Wales. Currently four formations have been formalised. Many small tracts of alluvium in river valleys should remain as a lithogenetic category only within a valley formation. They are lithologically highly variable, deriving from glacigenic deposits of Welsh and Irish Sea Coast provenance, as well as local bedrock. They grade into, and in places are mapped with primary glacial deposits. It is recommended that at present they remain as a single lithogenetic division within the catchment subgroup. Most other Holocene deposits (e.g. tufa, storm beaches, etc.) are too small in extent and too spatially separated to be accorded a formal status and should remain as lithogenetic units within the Britannia Catchments Group. Head deposits, as mapped, range in age from pre- to post-Devensian (see Bowen, 1999) and are also assigned to the Britannia Catchments Group.

Name
West Wales Catchments Subgroup (WWACA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Alluvial silt, sand, clay and gravel with some peat. Associated river terraces are dominated by sand and gravel, gravelly sand or sandy gravel with rare clay and silt.

Formal subdivisions and correlation table
Subdivided into the Dovey Valley, Teifi Valley, Tywi Valley and Neath Valley formations (Tables 6 and 13).

Type area/Reference section
Type area: Catchments of rivers draining West Wales to Cardigan Bay and south Wales to the Bristol Channel, including the valleys and tributaries of the Prysor, Wnion, Afon Dyfi (River Dovey), Rheidol, Ystwyth, Afon, Tywi, Afon Teifi and Afon Nedd (River Neath).

Lower and upper boundaries
Probably unconformable and in places strongly incised into lithologically highly variable sediments of the Caledonia Glacigenic Group or bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and floodplain.

Thickness
Highly variable depending on the relative stratigraphical positions of each of the component units. In the major river valleys the thickness may vary between 2 and 5 m, but probably does not exceed 10 m. For deposits flanking the major river valleys, the thickness probably varies between 1 and 3 m.

Distribution and extent
Catchments of west and south Wales.

Age
Devensian–Holocene (MIS 2–1).

8.4.3.1 Dovey Valley Formation

Name

Dovey Valley Formation (DOVEY) (after Thomas et al., 1982, Cave and Hains, 1986, and Pratt et al., 1995).

Lithology
Unconsolidated, stratified gravels, sands, silts and clays forming the alluvial deposits of the River Dovey (Afon Dyfi) and its tributaries. Includes contemporaneous head, colluvium and pedogenic deposits within the catchment area. Clasts principally consist of local, Lower Palaeozoic turbidites. Aggradational river terraces and major alluvial fans are characterised by pebble and cobble gravels and medium- to coarse-grained sand; the modern floodplain is dominated by silt and clay, and locally includes lenses of peat.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Dovey valley between Mallwyd and Cemmaes Road [SH 8615 1270–SH 8213 0445]. This reach contains numerous well-developed alluvial fans, a staircase of terraces and a broad floodplain, mostly developed on glaciofluvial deposits; the ages of several of the post-glacial alluvial deposits (surfaces) are well constrained (Sheppard and Davies, 2004; Wilby et al., 2005).

Lower and upper boundaries
Sharp, unconformable and locally channelised on bedrock and Late Devensian head deposits and Welsh glacigenic deposits (including Eryri and Plynlimon Glacigenic formations). Interdigitates in a complex manner with tidal flat deposits of the Gwent Levels Formation (Gwynllwg Formation of Bowen, 1999) in the estuary.

Generally the present ground surface or, locally, overlain by peat.

Landform description and genetic interpretation
River terrace and floodplain.

Thickness
Generally up to 10 m.

Distribution and extent
The valley of the River Dovey and its tributaries (Gwynedd, Powys and Dyfed).

Age
Devensian–Holocene (MIS 2–1).

8.4.3.2 Teifi Valley Formation

Name
Teifi Valley Formation (TEIFI) (after Waters et al., 1997, and Jones et al., 2006; included in Tywi Member of Gwynllwg Formation of Bowen, p. 86 in Bowen, 1999).

Lithology
Unconsolidated, stratified gravels, sands, silts and clays forming the alluvial deposits of the River Teifi (Afon Teifi) and its tributaries. Includes contemporaneous head, colluvium and pedogenic deposits within the catchment area. Clasts principally consist of local Lower Palaeozoic turbidites but, west of a line approximately running between Talgarreg [SN 4267 5096] and Pentrecagal [SN 3385 4030], a substantial admixture of 'Irish Sea' material derived from the Lleyn Formation may be present. Aggradational river terraces and major alluvial fans are characterised by pebble cobble gravels and medium- to coarse-grained sand; the modern floodplain is dominated by silt and clay, and locally includes lenses of peat.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Teifi valley between Lampeter and Pencarreg [SN 5771 4745–SN 5423 4584]. This reach consists of a broad floodplain, largely overlying Late Devensian glaciolacustrine deposits, and encompasses a number of well-defined terraces incised into fluvioglacial deposits. Parts of the alluvial sequence have been radiocarbon dated indicating deposition from 14C 11 170–10 740 BP (cal.) (Jones et al., 2006).

Lower and upper boundaries
Sharp, unconformable and locally channelised on bedrock, Devensian head deposits and Late Devensian glacigenic deposits (particularly the Plynlimon Glacigenic Formation and, west of Llandysul [SN 4190 4043], the Teifi Clay Formation and Lleyn Till Formation). In Tregaron Bog it overlies peat of the Tregaron Formation (Bowen, 1999, p. 86). Interdigitates in a complex manner with Tidal Flat Deposits of the Gwent Levels Formation (Gwynllwg Formation of Bowen, 1999) in the estuary.

Generally the present ground surface or, locally, peat.

Landform description and genetic interpretation
River terrace and floodplain.

Thickness
Generally 4 to5 m, possibly ranging up to 10 m.

Distribution and extent
The valley of the River Teifi and its tributaries (Dyfed).

Age
Devensian–Holocene (MIS 2–1).

8.4.3.3 Tywi Valley Formation

Name
Tywi Valley Formation (TYWI) (after Strahan et al., 1909;

included in Tywi Member of Gwynllwg Formation of Bowen, p. 86 in Bowen, 1999).

Lithology
Unconsolidated, stratified gravels, sands, silts and clays forming the alluvial deposits of the River Towy (Afon Tywi) and its tributaries. Includes contemporaneous head, colluvium and pedogenic deposits within the catchment area. Clasts principally consist of local Lower Palaeozoic turbidites, admixed to the west of Llandovery with Old Red Sandstone clasts. Aggradational river terraces and major alluvial fans are characterised by pebble and cobble gravels and medium- to coarse-grained sand; the modern floodplain is dominated by silt and clay, and locally includes lenses of peat.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Tywi valley between Pont-ar-gothi and Abergwili. This reach contains numerous well-developed alluvial fans, abandoned meander loop lakes, a staircase of terraces and a broad floodplain, mostly developed on glaciofluvial deposits (Strahan et al., 1909).

Lower and upper boundaries
Sharp, unconformable and locally channelised, predominantly on bedrock and Late Devensian head and Welsh glacigenic deposits (e.g. Brecknockshire and Plynlimon Glacigenic formations). Locally, beyond the ice limit of the Last Glacial Maximum (e.g. north and west of Cwmduad [SN 3748 3125]), it may overlie older alluvial, periglacial and glacial deposits. Interdigitates in a complex manner with tidal flat deposits of the Gwent Levels Formation (Gwynllwg Formation of Bowen, 1999) in the estuary.

Generally the present ground surface or, locally, peat.

Landform description and genetic interpretation
River terrace and floodplain.

Thickness
Generally up to around 10 m; may be locally greater in the lower reaches of the Tywi.

Distribution and extent
The valley of the River Tywi and its tributaries (Dyfed).

Age
Devensian–Holocene (MIS 2–1).

8.4.3.4 Neath Valley Formation

Name
Neath Valley Formation (NEATH) (after Anderson and Owen, 1979, and Barclay et al., 1988; included in Tywi Member of Gwynllwg Formation of Bowen, p. 86 in Bowen, 1999).

Lithology
Unconsolidated, stratified gravels, sands, silts and clays forming the alluvial deposits of the River Neath (Afon Nedd) and its tributaries. Includes contemporaneous head, colluvium and pedogenic deposits within the catchment area. Clasts consist exclusively of Old Red Sandstone and Carboniferous limestone, sandstone and coal sourced either directly from the bedrock or via the reworking of Late Devensian glacigenic deposits (e.g. Brecknockshire Glacigenic Formation). Aggradational river terraces and major alluvial fans are characterised by pebble and cobble gravels and medium- to coarse-grained sand (Strahan et al., 1932); the modern floodplain is dominated by silt and clay, or by poorly sorted gravel (Barclay et al., 1988, p. 39). Locally, the deposits include lenses of peat.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 13).

Type area/Reference section
Type area: Neath Valley between Pontneddfechan and Cwmgwrach [SN 9041 0771–SN 8618 0523]. This reach contains numerous well-developed alluvial fans, a laterally continuous terrace and a broad floodplain, mostly developed on glacigenic deposits (components of the Brecknockshire Glacigenic Formation). The thickness of the valley deposits has been documented by Anderson and Owen (1979); they considered the fans and the terrace to potentially represent late glacial to post-glacial lake terraces (Anderson and Owen, 1979).

Lower and upper boundaries
Sharp, unconformable and locally channelised, predominately on bedrock and Late Devensian head and glacigenic deposits (e.g. Brecknockshire Glacigenic Formation). Interdigitates in a complex manner with tidal flat deposits of the Gwent Levels Formation (Gwynllwg Formation of Bowen, 1999) in the estuary.

Generally the present ground surface or, locally, peat.

Landform description and genetic interpretation
River terrace and floodplain.

Thickness
Generally up to around 10 m; 6 m of (fluvial) gravel over 15 m of ?glaciofluvial sand were recorded in a borehole near Resolven at [SN 8346 0313] (Strahan et al., 1932).

Distribution and extent
The valley of the River Neath and its tributaries (West Glamorgan, mid-Glamorgan and Powys).

Age
Devensian–Holocene (MIS 2–1).

8.4.4 Severn and Avon Catchments Subgroup

Fluvial deposits (alluvium, alluvial fan and terrace deposits) of river valleys in South Wales and the Welsh Borders, including those of the Upper Severn, Teme, Lugg, Wye and Usk, are assigned to the Severn and Avon Catchments Subgroup (after McMillan, 2005 and McMillan et al., 2005; Table 6, Figure 4). The subgroup and principal formations are described in Section 11.3.4. Bowen (1999, chapter 7) assigned all Late Devensian to Holocene fluvial deposits in Wales to the Tywi Formation, the definition of which is revised in this report to include only the deposits of the valley of the River Tywi and its tributaries (Tywi Valley Formation; Section 8.4.3.3).

9 Northumberland, Durham, Yorkshire and the Pennines

The oldest superficial deposits of this district are karstic fissure-fill breccias that may extend in age from the Mesozoic to the mid Pleistocene. The earliest glacigenic sediments are of pre-Devensian age and are assigned to the Albion Glacigenic Group. The most extensive superficial deposits are assigned to the Caledonia Glacigenic Group and are of Late Devensian age. Deposits of the Britannia Catchments Group and British Coastal Deposits Group range in age from Late Devensian to Holocene.

9.1 GREAT BRITAIN SUPERFICIAL DEPOSITS SUPERGROUP

9.1.1 Castle Eden Fissure-fill Formation

Name
Castle Eden Fissure-fill Formation (CEDN) (after Smith and Francis, 1967, and Francis, 1970; Blackhall Colliery Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Breccia formed of limestone and dolostone together with sparse clasts of red mudstone filling subvertical karstic fissures in the limestone and dolostones of the Zechstein Group (formerly Magnesian Limestone) (Francis, 1970). Two distinct units occur. The lower 'unfossiliferous fissure-fills' are likely to be either Mesozoic or early Palaeogene in age as they are similar to evaporite dissolution breccias that occur elsewhere within the Permian limestones. In addition to limestone debris, the upper 'fossiliferous fissure-fills' contain clay that has yielded assemblages of partially pyritised organic material including peat, seeds, tree trunks, ostracods, mammalian bones and freshwater molluscs. The remains of over 100 species of plant have been identified from lower parts. Of this 'Castle Eden Flora', 64% of the species no longer grow in Britain, or are extinct. This flora suggests an Early Pleistocene age, which is supported by the identification of Mammuthus meridionalis, an elephant that was common in Europe during the Early Pleistocene up to the Cromerian. Sparse glacial erratics of supposed Scandinavian origin have been found in fissure-fill deposits south of Limekiln Gill [NZ 4776 3813].

Formal subdivisions and correlation table
No subdivisions (Tables 4 and 14).

Type area/Reference section
Type area: Hawthorn Hive and Crimdon Park [NZ 443 462–NZ 480 375], County Durham, a 9 km stretch of cliff sections (Smith and Francis, 1967).

Lower and upper boundaries
Unconformable contact with underlying fractured limestones and dolostones of the Zechstein Group. The fissures are generally linear, vary from 1–7 m wide and extend down 25 m vertically through the limestone cliffs from rockhead, locally along faults. Other fissure-fills are cylindrical in shape. Fissure walls commonly bear subvertical slickensides resulting from compaction and many of the fragments are striated and polished.

Channelled, erosional, unconformable contact with overlying limestone-rich gravel of the Limekiln Gill Gravel Formation or planar subhorizontal, unconformable contact with dark grey stony sandy silty clayey diamicton of the Blackhall Till Formation.

Landform description and genetic interpretation
Fissure-fill deposits.

Thickness
Up to 25 m.

Distribution and extent
Coast of County Durham.

Age
Mesozoic–Cromerian (pre-MIS 13).

9.1.2 Brassington Formation

Name
Brassington Formation (BTON) (after Boulter et al., 1971).

Lithology
White, pink and yellow siliceous sands with brightly coloured silts and clays, lying in pockets caused by karstic dissolution of Carboniferous limestones.

Formal subdivisions and correlation table
Subdivided into the informal Kirkham Member, Bees' Nest Member and Kenslow Member (KLOW); Tables 4 and 14.

Type area/Reference section
Type section: Bees' Nest Pit, about 0.7 km due east of Brassington [SK 241 545] (Boulter et al., 1971).

Lower and upper boundaries
The lower boundary is a sharp, unconformable contact on karstified limestones which form hollows, or 'pockets', for the formation.

Generally not preserved, but where present it is an unconformity upon which rests Quaternary till (boulder clay).

Landform description and genetic interpretation
Fissure-fill deposits.

Thickness
Highly variable. 1 to 45 m recorded.

Distribution and extent
Confined to scattered pockets on the Carboniferous limestone outcrop, recognised from north of Ramshorn [SK 088 463] to south of Monyash [SK 134 635] (Chisholm et al., 1988).

Age
Neogene (Tertiary).

9.2 ALBION GLACIGENIC GROUP

In Yorkshire representatives of the Albion Glacigenic Group lying outside the Late Devensian ice sheet limit include the informal **Balby Formation** (after Catt, 1991, and Thomas, p. 97 in Bowen, 1999), parts of which were referred to the **Harrogate Till Formation** (Cooper and Burgess, 1993). Deposits of pre-Devensian age have also been reported in the Selby district (Ford et al., 2008) and in the Vale of Pickering (Powell, oral communication, 2010).

In the Peak District of Derbyshire the **Bakewell Formation** was established by Thomas (p. 97 in Bowen, 1999) for basal tills and interbedded lacustrine clays and sands (after Burek, 1991; see Table 14). Currently these formations are regarded as informal and remain to be entered into the BGS Lexicon.

Formations of pre-Ipswichian age sourced from the north by ice that flowed south-eastwards along the eastern coast of England and from offshore areas are assigned to the **North Sea Coast (Albion) Glacigenic Subgroup**.

9.2.1 North Sea Coast (Albion) Glacigenic Subgroup

Name
North Sea Coast (Albion) Glacigenic Subgroup (NSCA) (after McMillan et al., 2005).

Lithology
Clayey diamictons (till), sand, gravel, silt and clay. Clasts are predominantly from north-east England (yellow, grey and white sandstones, mudstone, limestone, coal, dolerite), southern Scotland (wacke sandstone and mudstone, granite, andesite, red sandstone) and offshore (marl, gypsum, chalk and sparse Scandinavian erratics).

Formal subdivisions and correlation table
Includes the Warren House Gill Till Formation (Tables 7c and 14).

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Sharp, unconformable contact with bedrock

Unconformable, mainly planar contact with units of the North Sea Coast Glacigenic Subgroup. Possible lateral interdigitation with units of the North Pennine (Albion) Glacigenic Subgroup.

Landform description and genetic interpretation
Suite of glacial, glaciofluvial, glaciolacustrine and possibly glaciomarine deposits laid down by ice sourced mainly in the Scottish Borders and central Scotland that flowed south-eastwards along the eastern coast of England (but mainly offshore) as far as north Norfolk.

Thickness
Up to 10 m.

Distribution and extent
The North Sea coast and coastal plains of north-eastern and eastern England between Berwick-upon-Tweed and north Norfolk.

Age
Mid-Pleistocene (MIS 13–6).

The Harrogate Till Formation, a unit which does not yet appear in the BGS Lexicon, occurs to the west of the Vale of York, beyond the extent of Devensian deposits. It comprises slightly sandy clay with large, locally-derived blocks of sandstone that forms a dissected capping, typically between 4 and 8 m in thickness, over the hills in and around Harrogate and to the north-east and south-east of Leeds. This till differs from the Devensian till that occurs east of the River Nidd in Knaresborough in that the younger deposit contains abundant sub-rounded cobbles and gravel (Cooper and Burgess, 1993). The occurrences near Leeds are among the disparate patches of 'Older Drift' mentioned by Catt (1991), and included in the Balby Formation of Thomas in Bowen (1999).

9.2.1.1 Warren House Gill Till Formation

Name
Warren House Gill Till Formation (WAHG) (after Huddart, 2002; Warren House Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Dark grey, very compact, pebbly sandy clayey diamicton containing Scandinavian erratics but not rocks from the British mainland excepting local limestone and dolostone of the Zechstein Group. More than 80% of the erratics have been matched with igneous and metamorphic rocks occurring in the Oslo area of southern Norway, including larvikite and nordmarkite. Chalk, flint, red sandstone, red and green (Triassic) marl and belemnite fragments constitute about 6% of the erratics, and, together with numerous marine shell fragments, have been derived from the North Sea Basin. The overlying Warren House Gill Loess Bed (WAHL) (after Trechmann, 1919) comprises up to 4 m of pale brown, massive, very fine-grained sand and silt, typically with vertical cracks, containing rounded concretions and sparse pebbles. It grades upwards into horizontally stratified, very fine-grained sand and silt, with thin beds of coarser sand and stringers of fine pebbles.

Formal subdivisions and correlation table
Warren House Gill Loess Bed (Tables 7c and 14).

Type area/Reference section
Type section: Warren House Gill [NZ 4478 4217]. Crops out at the foot of cliffs adjacent to the coastal dene, north of County Durham.

Lower and upper boundaries
Unconformable, undulating erosional contact on limestone and dolostone of the Zechstein Group within the floor of a buried valley at the mouth of Warren House Gill. Locally overlies limestone rubble-filled fissures in the Zechstein Group.

Sharp, conformable, draped contact with overlying Warren House Gill Loess Bed.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
5 m.

Distribution and extent
County Durham.

Age
Mid-Pleistocene (possibly MIS 6).

9.3 CALEDONIA GLACIGENIC GROUP

9.3.1 North Sea Coast Glacigenic Subgroup

The complex interplay between glaciers emanating from the North Pennines and ice moving southwards along the North Sea coast is depicted in Figure 15. This figure also shows the putative terminal position of the Late Devensian ice and the distribution of glacial lakes beyond that position. Deposits of both the **North Sea Coast Glacigenic Subgroup** and the **North Pennine Glacigenic Subgroup** (see below) of the Caledonia Glacigenic Group are the product of glacial (till and morainic deposits), glaciofluvial and glaciolacustrine sedimentation during the advance and punctuated recession of ice in the Vale of York and in Teesside. Figures 16 and 17 show generalised relationships of constituent formations.

Name
North Sea Coast Glacigenic Subgroup (NSG) (after McMillan et al., 2005).

Lithology
Diamictons, sands and gravels that contain clasts derived predominantly from north-east England (yellow, grey and white sandstones, mudstone, limestone, coal and dolerite), southern Scotland (wacke sandstone and mudstone, granite, andesite, red sandstone) and offshore (marl, gypsum, chalk). Including clayey diamictons (till), sand, gravel, silt and clay. Deposited by ice sourced mainly in the Scottish Borders and central Scotland that flowed south-eastwards along the eastern coast of England (but mainly offshore) as far as north Norfolk.

Formal subdivisions and correlation table
Subdivided into the Holderness, Limekiln Gill Gravel, Blackhall Till, Horden Till, Peterlee Sand and Gravel and Teesside Clay formations (Tables 8 and 14).

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Sharp, unconformable, mainly planar contact with units of the North Sea Coast (Albion) Glacigenic Subgroup, or with bedrock.

Ground surface or unconformable contact with various units of the Britannia Catchments Group or British Coastal Deposits Group. Lateral interdigitation with units of the North Pennine Glacigenic Subgroup.

Landform description and genetic interpretation
A suite of glacial, glaciofluvial, glaciolacustrine and possibly glaciomarine deposits.

Thickness
Up to 50 m.

Distribution and extent
The North Sea coast and coastal plains of north-eastern and eastern England between Berwick-upon-Tweed and north Norfolk.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.1.1 Holderness Formation

Sections at Dimlington Cliff at Holderness on the Yorkshire coast provide the type locality for the Late Devensian Dimlington Stadial. Here Catt and Penny (1966) described in upwards succession, as re-named by McCabe and Bowen (pp. 13–14 in Bowen, 1999), the *Sewerby Member* (a beach gravel with an Ipswichian faunal assemblage), the 'Basement Till' (a glaciotectonically sheared diamicton named the *Bridlington Member*), the *Dimlington Bed* ('Dimlington Silts'; organic silts ^{14}C dated to 18 500 ± 400 and 18 240 ± 250, Penny et al., 1969), the Skipsea Member ('Drab Clay' of Bisat, 1940; here renamed the *Skipsea Till Member*), the *Mill Hill Bed*, the *Withernsea Member* ('Purple Clay' of Bisat, 1940), the *Hornsea Member* (glacial deposits forming a belt of hummocky topography over east Holderness), and the *Flamborough Member* (extensive gravel at Flamborough Head). These units are included within the Holderness Formation of Lewis (p. 13 in Bowen, 1999).

The Holderness Formation of Lincolnshire and Holderness (McCabe and Bowen, pp. 11–12 in Bowen, 1999) is extended in the BGS lithostratigraphical framework to include the Devensian tills and outwash deposits of north Norfolk (Moorlock et al., 2002a, 2008) (Section 10.4.1.1). The general distribution of the surficial till, labelled the 'Holderness Till Formation' is shown in Figure 3.

Name
Holderness Formation (HOLD) (after Catt, 1991, Catt and Penny, 1966, and Madgett and Catt, 1978; includes members of the Holderness Formation of McCabe and Bowen, pp. 13–14 in Bowen, 1999; includes the Filey Formation of Thomas, p.97 in Bowen, 1999 and discussed by Catt, 2007).

Lithology
Diamicton, sand, gravel, silt and clay.

Formal subdivisions and correlation table
Subdivided into Sewerby Member, Bridlington Member, Dimlington Bed (Dimlington Silts), Skipsea Till Member, Mill Hill Bed, Withernsea Member, Hornsea Member and Flamborough Member on the Holderness coast (Tables 8 and 14; these members are currently informal and remain undefined in the BGS Lexicon); and Ringstead Sand and Gravel, Red Lion Till and Holkham Till members in north Norfolk (Table 15).

Type area/Reference section
Type section: Dimlington Cliff [TA 376 237] (Catt and Penny, 1966; Madgett and Catt, 1978).

Lower and upper boundaries
Overlies Chalk bedrock at Holderness. Till of the Holkham Till Member overlies raised beach deposits of the Morston Formation in north Norfolk.

Overlain unconformably by Holocene marine and organic deposits.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
About 70 m thick in type area of Holderness.

Distribution and extent
Holderness, east Yorkshire extending southwards to north Norfolk.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.1.2 Limekiln Gill Gravel Formation

Name
Limekiln Gill Gravel Formation (LGGR) (after Smith and Francis, 1967).

Lithology
Partially cemented gravel typically containing a high (50–60%) proportion of locally derived limestone and dolomite pebbles of the Zechstein Group (formerly Magnesian Limestone) and a varied suite of far-travelled clasts including Carboniferous lithologies, andesite, granite, gneiss, schist, flint, quartz, quartzite and dolerite, together with unabraded shell fragments.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type section: Cliff section [NZ 4465 4250], 490 m south of Horden Point.

Lower and upper boundaries:
Unconformable, erosional, channelled contact with limestones and dolostones of the Zechstein Group (formerly Magnesian Limestone).

Generally a sharp, subhorizontal, planar to gently undulating contact with dark grey, stiff, sandy silty stony clayey diamicton of the Blackhall Till Formation.

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
Up to 6 m known.

Distribution and extent
Coast of County Durham.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.1.3 Blackhall Till Formation

Name
Blackhall Till Formation (BHTI) (after Blackhall Member of East Durham Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Dark grey to greyish brown, locally reddish brown, very stiff, stony sandy silty clayey diamicton with sparse fragments of shell. It contains clasts mostly of Carboniferous lithologies in southern Northumberland, with far-travelled rocks from the Southern Uplands and, south of Blyth, from the Lake District too; local Permian lithologies predominate south of the Tyne. Generally becomes more clayey and plastic upwards. Includes local lenses of sand and gravel.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type section: Cliff sections in the vicinity of, and south of Black Halls Rocks [NZ 4732 3858–NZ 4763 3825], Peterlee, County Durham.

Lower and upper boundaries
Either rests directly on bedrock or as a sharp, subhorizontal, planar to gently undulating contact with limestone-rich gravel of the Limekiln Gill Gravel Formation.

Generally a sharp, uneven, erosional contact with overlying red fine-grained sand of the Peterlee Sand Formation along the Durham coast.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 15 m.

Distribution and extent
Coast of County Durham and southern Northumberland.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.1.4 Horden Till Formation

Name
Horden Till Formation (HNTI) (after Francis, 1970; Horden Member of East Durham Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Typically very stiff, dark brown or purplish brown, stony silty sandy diamicton containing clasts mainly of limestone and dolostone of the Zechstein Group (formerly Magnesian Limestone; mostly Upper Division), Carboniferous lithologies, purple porphyry from the Cheviots and shell fragments. The till is invariably weathered reddish brown at the top, and locally throughout.

Formal subdivisions and correlation table
Elwick Moraine Member, Prismatic Clay Member (Tables 8 and 14).

Type area/Reference section
Type section: Cliff sections in the vicinity of Warren House Gill [NZ 4465 4250–NZ 4464 4224], 490 m south of Horden Point.

Lower and upper boundaries
Generally planar, unconformable, subhorizontal boundary with underlying gravel of the Peterlee Sand and Gravel Formation, where the contacts may be sharp or gradational with glaciotectonic intercalation. The till locally rests directly on bedrock.

Commonly a gradational contact with overlying brown pebbly clay with vertical prismatic jointing (Prismatic Clay Member). Lateral interdigitating boundary with the Tyne and Wear Glaciolacustrine Formation to the west.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 12.2 m.

Distribution and extent
Coast of County Durham and southern Northumberland.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Elwick Moraine Member (ELWK)

The Elwick Moraine Member (after Smith and Francis, 1967) comprises up to about 12 m of varied lithologies including ill-sorted gravel, red sand and red sandy diamicton with clasts of limestone and dolostone of the Zechstein Group (formerly Magnesian Limestone), Carboniferous lithologies (sandstone, limestone) and Cheviot andesite.

The deposit forms linear ridges and mounds with kettle-holes.

Prismatic Clay Member (PRIS)

The Prismatic Clay Member (after Smith and Francis, 1967) comprises up to 1.5 m of dull brown or reddish brown, sandy silty clay with well dispersed fine pebbles and sparse ironstone nodules. The Prismatic Clay derives its name from the closely-spaced, subvertical, prismatic jointing, which formed during dry periglacial conditions.

9.3.1.5 Peterlee Sand and Gravel Formation

Name
Peterlee Sand and Gravel Formation (PESG) (after Francis, 1970; Peterlee Member of East Durham Formation of Thomas, p.98 in Bowen, 1999).

Lithology
Typically comprises a unit of horizontally-bedded, red, fine-grained sand with beds of silt, clay, coarse sand and fine gravel, overlain by a more laterally extensive unit of gravel, coarsening upwards and locally cemented. Beds of red and grey diamicton may occur throughout, representing intercalation with underlying and overlying tills. Clasts are mainly limestone and dolostone from the upper divisions of the Zechstein Group (formerly Magnesian Limestone), together with Carboniferous lithologies, Cheviot andesite and sparse shell fragments.

Formal subdivisions and correlation table
Ryhope Sand Member (Tables 8 and 14).

Type area/Reference section
Type section: Warren House Gill [NZ 4465 4250–NZ 4464 4224], 250 m cliff sections 500 to750 m south of Horden Point.

Lower and upper boundaries
Generally sharp, erosional and forming broad depressions on underlying dark grey, stony silty sandy clayey diamicton of the Blackhall Till Formation. Lower unit mainly restricted to depressions whereas the upper unit commonly oversteps directly onto the Blackhall Till Formation.

Generally planar, subhorizontal contact with overlying dark brown to purplish brown, stony silty sandy clayey diamicton of the Horden Till Formation. Contacts may be sharp or gradational with glaciotectonic intercalation.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 22 m.

Distribution and extent
Coast of County Durham and southern Northumberland.

Age
Late Devensian, Dimlington Stadial (MIS 2).
The informal *Ryhope Sand Member* (Ryhope Member of Thomas, p. 98 in Bowen, 1999) comprises strongly cryoturbated, cross-bedded sand and gravel interpreted by Smith (1981) to be of deltaic and proglacial fluviatile origin.

9.3.1.6 Teesside Clay Formation

Name
Teesside Clay Formation (TSDC) (after Smith and Francis, 1967, and Horton et al., 1999).

Lithology
Red or reddish brown, pebbly, sandy, silty clay containing well-dispersed pebbles mainly of limestone and dolostone of the Zechstein Group (formerly Magnesian Limestone), with some Carboniferous lithologies (sandstone, mudstone, limestone, coal), typically overlying thinly laminated silts and clays, or locally overlying sand.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type area: Borehole T9 [NZ 515 257] (unregistered in BGS borehole database) sited west of Seal Sands in the Tees Estuary (Horton et al., 1999, fig. 30).

Lower and upper boundaries
Uneven, conformable, draped contact with underlying dark brown, stony silty sandy clayey diamicton of the Blackhall Till Formation (possibly of the Horden Till Formation).

Uneven, erosional contact with overlying alluvial or estuarine sands, silts and clays.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
Up to 9.1 m.

Distribution and extent
Widespread beneath the Teesside lowlands to an elevation of about 92 m above OD.

Age
Late Devensian, Dimlington Stadial (MIS 2). Varves in the laminated clays have been tentatively correlated with the late glacial Greenland ice core record, and dated very approximately by thermoluminescence to 18 365 cal. years BP.

9.3.2 North Pennine Glacigenic Subgroup

The North Pennine Glacigenic Subgroup includes deposits of the Devensian (MIS 5d–2) ice-sheets originating predominantly from the Pennines.

Name
North Pennine Glacigenic Subgroup (NPEG) (after McMillan et al., 2005).

Lithology
Dominantly glacial till (clay, sandy clay and clayey sand with gravel and boulders) with interbedded sand, gravel and laminated clay, plus more substantial areas of those individual lithologies incorporated in the till sheet, moraines and eskers.

Formal subdivisions and correlation table
Subdivided into the Stainmore Forest Till, Yorkshire Dales Till, Acklinton Till, Maiden's Hall Sand and Gravel, Tyne and Wear Glaciolacustrine, Wear Till, and Ebchester Sand and Gravel formations in Durham and Northumberland; and the Vale of York, Hemingbrough Glaciolacustrine, Elvington Glaciolacustrine, Alne Glaciolacustrine, and

Pocklington Gravel formations in the Vale of York (Tables 8 and 14).

Type area/Reference section
See type sections of component formations.

Lower and upper boundaries
Unconformable on bedrock or older superficial deposits of the Albion Glacigenic Group.

Ground surface or overlain by younger deposits such as blown sand.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to about 50 m.

Distribution and extent
East of the Pennines from the southern margin of the Cheviot Hills in the north to the southern edge of the Escrick Moraine in the south.

Age
Devensian (MIS 5d–2).

9.3.2.1 Stainmore Forest Till Formation

Name
Stainmore Forest Till Formation (SFTI) (after Burgess and Holliday, 1979).

Lithology
Dark bluish grey, brown or reddish brown, extremely compact, stony sandy silty clayey diamicton with clasts dominated by local Carboniferous lithologies (sandstone, granule-conglomerate, limestone, mudstone, gannister, coal), including Whin Sill dolerite and far-travelled clasts from Scotland and the Lake District (wacke sandstone and siltstone, welded tuffs and rhyolites, Shap Granite, granodiorite), and the Vale of Eden (red sandstone, Brockram). In Teesdale this till grades up into, or is overlain unconformably by yellowish brown, rubbly diamicton with clasts mainly of sandstone.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type area: The Stainmore Gap west of Barnard Castle and Teesdale [NY 800 300–NY 200 050] (Mills and Hull, 1976)

Partial type section: River cliff section in a drumlin on the northern bank of the River Tees immediately downstream of the confluence with the Harwood Beck [NY 861 296] (Burgess and Holliday, 1979).

Lower and upper boundaries
Generally a sharp uneven contact on bedrock, but locally a complex gradational glaciotectonic contact with fractured or decomposed bedrock. Overlies dolerite of the Whin Sill at the partial type section.

Generally the ground surface or overlain unconformably by glaciofluvial sand and gravel or younger superficial deposits. Overlain unconformably by a thin bed of cross-laminated silt and sand capped by loose, yellowish brown stony diamicton at the partial type section.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 50 m, thicker in some buried valleys.

Distribution and extent
Stainmore Gap to the west of Darlington, and Teesdale upstream of Barnard Castle, extending towards the Vale of York.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.2.2 Yorkshire Dales Till Formation

Name
Yorkshire Dales Till Formation (YDTI) (after Mitchell, 1991).

Lithology
Generally dark grey to greyish brown, extremely compact, stony sandy silty clayey diamicton with clasts dominated by, or exclusively, local Carboniferous lithologies (limestone, sandstone, granule-conglomerate and mudstone). Mostly mudstone and limestone at partial type section. Some clasts of wacke sandstone and siltstone from the Howgill Fells occur in tills in upper Wensleydale.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type area: The Yorkshire Dales south of the Stainmore Gap between Appleby-in-Westmoreland and Barnard Castle [NY 790 145–NY 990 130], and north of the Devensian glacial limit (Mitchell, 1991; Howard and Macklin, 1998).

Partial type section: River cliff section in a drumlin on the northern bank of the Widdale Beck at its confluence with the Snaiseholme Beck [SD 834 886], 4 km south-west of Hawes (Rose, 1991).

Lower and upper boundaries
Generally a sharp uneven contact on bedrock, but locally a complex gradational glaciotectonic contact with fractured or decomposed bedrock.

Generally the ground surface or overlain unconformably by glaciofluvial sand and gravel or younger superficial deposits.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Generally less than 10 m.

Distribution and extent
The Yorkshire Dales south of the Stainmore Gap and north of the Devensian glacial limit.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.2.3 Acklinton Till Formation

Name
Acklinton Till Formation (ANTI) (after Stone et al., 2009; Acklinton Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Typically very stiff, dark brown or purplish brown, stony silty sandy clayey diamicton with moderately- to well-dispersed clasts mainly of brown Fell Sandstone, pinkish grey calcareous siltstone (cementstone), limestone and dolerite with other Carboniferous lithologies (yellow sandstone, black mudstone, coal and white silicified sandstone seatearth), purple porphyry and andesite from the Cheviots, wacke sandstone and wacke siltstone from the Southern Uplands. The till is commonly weathered reddish brown and decalcified at the top, locally with vertical prismatic jointing. The till typically includes elongate, meandering lenses (palaeochannels) of gravel, fine- to medium-grained, cross-laminated sand and laminated silt and clay, typically in fining-upwards sequences that have been increasingly sub-glacially sheared and folded upwards. The lenses typically are up to 1.5 m thick but locally as much as 12 m, and have planar horizontal contacts with overlying till units. Up to seven cyclic sequences have been recorded.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type section: Buried valley exposed in former Maiden's Hall opencast coal site [NZ 2370 9845 to NZ 2370 9815], 13 km north-north-east of Morpeth, Northumberland.

Partial reference section: Logged sections in the former Acklinton opencast coal site [NU 230 012], 17 km north-north-east of Morpeth, Northumberland (Eyles et al., 1982).

Lower and upper boundaries
Generally a sharp uneven contact on bedrock, but locally a complex gradational glaciotectonic contact with fractured or decomposed bedrock. Locally a sharp, uneven to planar horizontal contact with orange-brown sand and gravel of the Maiden's Hall Sand and Gravel Formation.

Ground surface or unconformable contacts with younger superficial deposits. Towards the coast the formation is capped by very stiff, dark brown or purplish brown, weathering to reddish brown, stony silty sandy clayey diamicton containing clasts similar to the Acklinton Till, but including shell fragments (Horden Till Formation). The contact is either gradational or a sharp, planar, unconformable contact.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 25 m.

Distribution and extent
The coastal lowlands of Northumberland, north of the River Tyne, but excluding the coastal fringe underlain by the Horden Till Formation.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.2.4 Maiden's Hall Sand and Gravel Formation

Name
Maiden's Hall Sand and Gravel Formation (MHSG) (after Smith, 1981).

Lithology
Sandy gravel, yellowish brown with orange staining, with angular–well rounded clasts up to cobble size mainly of yellow, red and white sandstone, black fissile mudstone and coal. Sand mainly coarse-grained with shell fragments. Horizontal to trough cross-stratification with palaeocurrents towards the north. Locally passes upwards into granule gravel and sand with laminae of silt 10–15 mm thick.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type section: Superficial deposit-filled buried valley exposed in former Maiden's Hall opencast coal site [NZ 2370 9845], 13 km north-north-east of Morpeth, Northumberland.

Lower and upper boundaries
Sharp, erosional contact on bedrock or very compact, fissile, dusky yellowish brown to dark olive-grey, gravelly, sandy, silty, clayey diamicton (lodgement till) containing angular–well rounded clasts up to cobble-size of yellow and white sandstone, dolerite, porphyritic lavas, limestone, coal, wacke sandstone, pebbly wacke sandstone ('Haggis rock'), vein quartz, jasper, flint, granitic gneiss, numerous shell fragments and metamorphic rock of possible Scandinavian origin (Warren House Gill Till Formation).

Sharp, planar contact with dark olive-grey, very stiff, gravelly, sandy, silty, clayey diamicton with angular–well-rounded clasts up to boulder-size mainly of yellow and white sandstones, wacke sandstone, porphyritic lava and shell fragments (possibly the Blackhall Till Formation, North Sea Coast Glacigenic Subgroup).

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
Up to 3 m.

Distribution and extent
North-east England.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.2.5 Wear Till Formation

Name
Wear Till Formation (WETI) (after Francis, 1970; Winch Gill Member of Wear Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Dark greyish brown to dark yellowish brown, extremely compact, stony sandy silty clayey diamicton with clasts dominated by Carboniferous lithologies (sandstone, gritty sandstone, limestone, mudstone, ganister, coal), but including Whin Sill dolerite and far-travelled clasts from Scotland and the Lake District (wacke sandstone and siltstone, granite and granodiorite). Includes some large rafts of local rock types towards the base.

Formal subdivisions and correlation table
Butterby Till Member, Hutton Henry Peat (Tables 8 and 14).

Type area/Reference section
Type section: River cliff section in the valley of Winch Gill [NZ 3072 4572], a minor tributary of the River Wear, south-south-west of Leamside, Durham City.

Lower and upper boundaries
Generally a sharp uneven contact on bedrock, but locally a complex gradational glaciotectonic contact with fractured or decomposed bedrock.

Generally irregular, draped, conformable contact with overlying thinly laminated, greyish brown to brownish grey, silty clay and micaceous clayey silt, or gravel of the Tyne and Wear Glaciolacustrine Formation.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Generally 3–10 m, locally to 30 m.

Distribution and extent
Lowlands of County Durham and southern Northumberland.

Age
Late Devensian, Dimlington Stadial (MIS 2).

BUTTERBY TILL MEMBER (BUTTI)

The Butterby Till Member (after Francis, 1970; Upper Stony Clays of Smith and Francis, 1967; Butterby Member of Wear Formation of Thomas, p. 98 in Bowen, 1999) comprises up to 15 m of stiff, brown, gravelly sandy clayey diamicton, commonly with well-dispersed clasts of andesite, tuff and granite from the Lake District; wacke sandstone and granodiorite from southern Scotland, and red sandstones probably of both Triassic and Devonian age, in addition to Carboniferous lithologies (sandstone, gritty sandstone, limestone, mudstone, coal). Commonly it is thinly intercalated with dark grey, laminated silts and clays, and lenses of sand and gravel, e.g. of the Tyne and Wear Glaciolacustrine Formation. Some contacts are possibly glaciotectonic (Figure 18).

The *Hutton Henry Peat* (HUHY) is a transported glacial raft within the Wear Till Formation of very strongly compressed, sheared and folded peat. This peat contains well preserved fragments of moss and high percentages of Hornbeam palynomorphs indicative of the later temperate stages of the Ipswichian Interglacial (Beaumont et al., 1969; Hutton Henry Bed of Thomas, p. 98 in Bowen, 1999).

9.3.2.6 TYNE AND WEAR GLACIOLACUSTRINE FORMATION

The Tyne and Wear Glaciolacustrine Formation shows a complex interdigitation of laminated clay and diamicton (Figure 18).

Name
Tyne and Wear Glaciolacustrine Formation (TYWE) (after Smith, 1981, 1994, and Stone et al., 2009; Herrington Member of Sunderland Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Laminated greyish brown to brownish grey, silty clay and micaceous, clayey silt with subordinate beds and laminae of fine-grained sand, pebbly clayey diamicton and gravel. Complex interdigitation of units is common, especially towards the coast. Drop-stones are common and worm traces can be seen locally on partings. The complex sequence was deposited in several lake basins including Glacial Lake Wear and Glacial Lake Edderacres where it tends to fine upwards and southwards with fine-grained units successively overlapping coarser ones northwards.

Formal subdivisions and correlation table
Pelaw Clay Member (Tables 8 and 14).

Type area/Reference section
Type section: Herrington Colliery [NZ 335 540], Sunderland. Former sections in opencast workings.

Lower and upper boundaries
Generally in irregular, draped, conformable contact with underlying dark grey, stony sandy silty clayey diamicton of the Wear Till Formation.

Generally a planar, subhorizontal to undulating, gradational, glaciotectonic boundary.

Landform description and genetic interpretation
Glacigenic deposit.

Thickness
Up to 60 m within buried channels.

Distribution and extent
Lowlands of County Durham.

Age
Late Devensian, Dimlington Stadial (MIS 2).

PELAW CLAY MEMBER (PELC)

The Pelaw Clay Member comprises up to 9 m of blocky, brown pebbly and silty clay forming the surface deposits of Sunderland and adjacent districts (Thomas, p. 98 in Bowen, 1999). It was interpreted as a flow till by Francis (1970) and as a solifluction deposit by Smith (1981).

9.3.2.7 EBCHESTER SAND AND GRAVEL FORMATION

Name
Ebchester Sand and Gravel Formation (EBSG) (after Allen and Rose, 1986; glacial sand and gravel of the Ebchester Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Sand and gravel containing clasts of Carboniferous lithologies (sandstone, gritty sandstone, limestone, mudstone, gannister, coal), including far-travelled clasts from Scotland and the Lake District (wacke sandstone and siltstone, granite and granodiorite).

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type area: Broadoak sand and gravel pit [NZ 097 567], 1.5 km north-north-west of Ebchester, County Durham.

Lower and upper boundaries
Erosional unconformable contact with stiff, dark greyish brown, stony sandy silty clayey diamicton of the Wear Till Formation.

Generally the land surface, or erosional unconformable contact with sand and gravel forming more recent river terraces.

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
Up to 10 m.

Distribution and extent
Northern Pennines.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Five formations are defined within the Vale of York (after Ford et al., 2008).

9.3.2.8 Vale of York Formation

Name
Vale of York Formation (VYORK) (after Cooper and Burgess, 1993, and Ford et al., 2008).

Lithology
Dominantly glacial till (sandy clay, clayey sand and clay with gravel and boulders) with interbedded sand, gravel and laminated clay, plus more substantial areas of those individual lithologies incorporated in the till sheet and moraines.

Formal subdivisions and correlation table
Subdivided into the Escrick Moraine, York Moraine, Crockley Hill Esker, Newby Wiske-Aldwark Esker, Hunsingore Esker and Poppleton Glaciofluvial members (Tables 8 and 14).

Type area/Reference section
Reference section: The Park Farm borehole SE46SW52 [SE 4049 6429], 2 km south-south-east of Boroughbridge.

Partial type section: Grafton Gravel Quarry [SE 4200 6310], about 220 m south-east of Grafton village.

Lower and upper boundaries
Unconformable on bedrock or older superficial deposits such as valley deposits, outwash deposits and laminated clays formed in front of the advancing glacier.

Ground surface or overlain by younger deposits such as glacial lake deposits, outwash deposits and blown sand.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to about 50 m in moraines, generally 10–30 m.

Distribution and extent
Vale of York, northwards to Teesside, southwards to the Escrick Moraine.

Age
Late Devensian, Dimlington Stadial (MIS 2).

Escrick Moraine Member (ESKRM)

The Escrick Moraine Member (after Gaunt, 1970, and Ford et al., 2008) comprises up to 30 m of mainly greyish brown to yellowish brown, poorly sorted, gravelly, sandy clay to slightly gravelly clay matrix with a little, ranging to much, gravel and cobbles.

York Moraine Member (YORKM)

The York Moraine Member (after Ford et al., 2008) comprises up to 50 m of till composed of sandy clay, clayey sand and clay with erratic pebbles, cobbles and boulders mainly of Carboniferous sandstone and limestone. The member also includes local deposits of sand and gravel plus local deposits of clay and laminated clay incorporated into the sequence.

Crockley Hill Esker Member (CRHE)

The Crockley Hill Esker Member (after Ford et al., 2008) comprises 7 m or more of pale brown, reddish brown and brownish yellow, slightly silty, gravelly, fine- to coarse-grained sand. It is generally thinly bedded. The deposits may interdigitate laterally with interbedded glaciofluvial and glaciolacustrine sand and clay. Their distribution is restricted to a narrow north-south to north-west–south-east trending belt to the south of York from Escrick to Fulford (Ford et al., 2008).

Newby Wiske-Aldwark Esker Member

The Newby Wiske-Aldwark Esker Member (Powell et al., 1992; Cooper and Burgess, 1993) comprises up to 20 m or more of sand and gravel forming a beaded ridge that extends discontinuously for about 55 km in a north-north-west–south-south-east direction from the Thirsk area in the north to Aldwark in the south. At its southern end it terminates as a delta deposit in the Alne pro-glacial lake. South of this the Poppleton Glaciofluvial Member and the Crockey Hill Esker Member both have the same orientation and may be related as precursor deposits when the ice-front was further south.

Hunsingore Esker Member

The Hunsingore Esker Member (Cooper and Burgess, 1993) comprises up to about 16 m of sand and gravel forming a sinuous, beaded ridge that bifurcates in places that extends for 13 km from Brooms House [SE 399 633] in the north through Hunsingore to Lingcroft [SE 437 512] in the south.

Poppleton Glaciofluvial Member (POPP)

The Poppleton Glaciofluvial Member (after Ford et al., 2008) comprises up to 20 m of glaciofluvial sand and gravel in esker ridges, outwash fans and less definite spreads of sand and gravel.

9.3.2.9 Hemingbrough Glaciolacustrine Formation

Name
Hemingbrough Glaciolacustrine Formation (HEM) (after Cooper and Burgess, 1993, Gaunt, 1994, and Ford et al., 2008; Hemingbrough Formation of Thomas, p. 97 in Bowen, 1999).

Lithology
Unfossiliferous laminated clays, silts and sands with rare drop-stones (typically fine-grained pale-coloured sandstone, grey limestone and dark mudstone).

Formal subdivisions and correlation table
Subdivided into the Lawns House Farm Sand, Park Farm Clay and Thorganby Clay members (Tables 8 and 14).

Type area/Reference section
Type area: Working clay pit at Hemingbrough [SE 675 316].

Lower and upper boundaries
Unconformable, resting directly on bedrock or underlain by basal glaciofluvial deposits.

Ground surface or overlain by later superficial deposits, commonly represented by sand deposits of the Breighton Sand Formation or its constituent members.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
Up to 30 m.

Distribution and extent
Present at or near the surface in the Vale of York, from the Escrick Moraine in the north to Doncaster in the south, extending as a concealed unit beneath till deposits to the north of the Escrick Moraine beyond York to approximately 2 km east of Knaresbrough (BGS 1:50 000 Sheet E71).

Age
Late Devensian, Dimlington Stadial (MIS 2).

LAWNS HOUSE FARM SAND MEMBER (LHF)

The Lawns House Farm Sand Member (after Ford et al., 2008; Silt and Clay of the '25 Foot Drift' of the Vale of York, BGS 1:50 000 Sheet E71, 1973) comprises up to 2.5 m of reddish yellow, very silty, fine- to medium-grained sand with beds of silt or sand and very sparse fine gravel. Sparse bands of fine-grained dark detrital material are present.

PARK FARM CLAY MEMBER (PAF)

The Park Farm Clay Member (after Ford et al., 2008) comprises up to 16 m of greyish brown to dark grey, slightly fissured, laminated, soft silt and clay with rare fine sand layers. Laminations are 0.2–2 cm thick and are interpreted as varves. Horizons of fine-grained sand up to 1 m thick occur within the unit. The member rests on either a sand and gravel lag deposit or directly on bedrock, and is succeeded by the Lawns House Farm Sand Member. It is distributed in the Vale of York, south of the Escrick Moraine between the rivers Ouse, Foulness and Humber where the Lawns Farm Sand Member is present, and extends northwards beneath the Escrick Moraine, the York Moraine and the tills of the Vale of York Formation (Ford et al., 2008).

THORGANBY CLAY MEMBER (THOR)

The Thorganby Clay Member (after Ford et al., 2008; Sand, Silt and Clay of the '25 Foot Drift' of the Vale of York, BGS 1:50 000 Sheet E71, 1973) comprises up to 3.5 m of greyish brown, soft, locally fissured, laminated silt and clay. The top metre of the member commonly contains a higher percentage of silt and sand and is reddish yellow to grey colour-mottled. Its laminated structure has been destroyed by periglacial and soil processes. This unit can contain gravel drop-stones and display glaciotectonic structures, particularly near the Escrick Moraine.

9.3.2.10 ELVINGTON GLACIOLACUSTRINE FORMATION

Name
Elvington Glaciolacustrine Formation (ELV) (after Ford et al., 2008).

Lithology
Firm to stiff, rarely soft, mottled reddish brown (5YR 4/3) and grey (GLEY 2 3/1), thinly laminated clay. Sporadically interlaminated with silt and reddish brown, fine-grained sand. Commonly fissured. Gypsum, in the form of opaque, tabular selenite is found locally within the laminated clay below a depth of 2.5 m; crystal size is typically 15–35 mm along the longest axis.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Reference section: Borehole SE64NE10 [SE 6830 4620] in a clay pit.

Lower and upper boundaries
The Elvington Glaciolacustrine Formation overlies tills of the Vale of York Formation as proved in borehole SE64NE10, where 4.6 m of soft, grey-brown clay is recorded resting on 'brown boulder clay' (glacial till).

An outcrop overlain by aeolian or fluvial sand or clayey sand. The contact is sharp where proven in hand auger bores.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
Minimum thickness of 4.2 m proved in borehole SE64NE17 [SE 6838 4634] but generally exceeds 5 m in thickness.

Distribution and extent
The Elvington Glaciolacustrine Formation is constrained between the York Moraine Member to the north (between York in the west and Sand Hutton in the east) and the Escrick Moraine Member to the south (from Stillingfleet in the west to Sutton in the east (BGS 1:50 000 Sheet E71). It extends as far west as Copmanthorpe and as far east as Sutton upon Derwent.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.2.11 ALNE GLACIOLACUSTRINE FORMATION

Name
Alne Glaciolacustrine Formation (ALNE) (after Cooper and Burgess, 1993, Powell et al., 1992, and Ford et al., 2008).

Lithology
Laminated clay with silt (varved) and subordinate fine-grained sand beds, plus a little marginal sand and gravel.

Formal subdivisions and correlation table
No subdivisions (Tables 8 and 14).

Type area/Reference section
Type section: Alne Clay Pit [SE 520 663], about 3.5 km south-south-west of Easingwold, North Yorkshire.

Lower and upper boundaries
Unconformable on the Vale of York Formation and locally on bedrock.

Ground surface or overlain by the Sutton Sand Formation, or other cover sand deposits.

Landform description and genetic interpretation
Glaciolacustrine deposit.

Thickness
Up to 22 m. Type section exposed downwards soil and sandy clay, 0.9 m thick; brown to greenish grey, well-laminated, stone-free clay, 4.6 m thick; dark brown laminated, stone-free clay with thin brown silt laminae, 3.0 m thick (Cooper and Burgess, 1993).

Distribution and extent
Vale of York north of the York Moraine as far north as Thirsk, west to Littlethorpe and Hunsingore, east to Stockton on the Forest. Lake deposits generally below 30 m above OD, down to 14 m above OD near York.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.3.2.12 Pocklington Gravel Formation

Name
Pocklington Gravel Formation (POCKG) (Ford et al., 2008; Older Littoral Sand and Gravel of BGS 1:50 000 Sheet E71, 1973).

Lithology
Matrix- to clast-supported, clayey, sandy, medium to coarse gravel. Clast composition is typically polymict, dominated by chalk and flint. Average clast composition is 75% well-rounded chalk, 15% subangular flint, plus 10% accessory lithologies including ironstone and oolitic limestone. Clast composition varies to 100% chalk or 100% flint, although the increased flint content may be due in part to differential dissolution of chalk clasts. Matrix material is characterised by reddish brown, clayey sand varying to sandy clay with varying content of partially decomposed chalk.

Formal subdivisions and correlation table
No subdivisions (Table 14).

Type area/Reference section
Partial type section: Balk Field [SE 8042 4801], temporary section in foundation trench of housing development on southern edge of Pocklington, 375 m south-east of cemetery.

Lower and upper boundaries
Sandy gravel of the Pocklington Gravel Formation rests unconformably on Mesozoic bedrock with a sharp to variably disturbed (cryoturbated, soliflucted) basal contact.

The upper contact with the Breighton Sand Formation is proved in auger holes to be relatively sharp. Elsewhere, the Pocklington Gravel Formation is known to be overlain by alluvial, aeolian and artificial deposits with varying degrees of incision and disturbance.

Landform description and genetic interpretation
Glaciofluvial deposit.

Thickness
Greater than 1 m.

Distribution and extent
The Pocklington Gravel Formation exists as a blanket deposit at the eastern limit of the Vale of York. The gravel is known to extend beneath the Breighton Sand Formation to the west of Bielby. To the north and south the gravel flanks the elevated ground in the York and Beverley areas.

Age
Late Devensian, Dimlington Stadial (MIS 2).

9.4 BRITISH COASTAL DEPOSITS GROUP

9.4.1 Formations of the British Coastal Deposits Group

9.4.1.1 Easington Raised Beach Formation

Name
Easington Raised Beach Formation (EASN) (after Smith and Francis, 1967; Easington Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Partly cemented, well-sorted gravel and sand containing marine shells. The gravel is composed predominantly of limestone and dolostone of the Zechstein Group towards the base, with an increasing content upwards of Carboniferous rock types, Cheviot andesite, Borrowdale Volcanic Group rock types and dolerite. Also includes sparse felsite, rhomb-porphyry and garnet-hornblende schist of supposed Scandinavian origin. Twelve temperate genera of marine molluscs have been identified from the deposit, and borings by marine molluscs and annelid worms in the rock platform as well as in cobbles confirm that the deposit is in situ.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 14).

Type area/Reference section
Type section: Easington, a 300 m-long cliffline backing Shippersea Bay [NZ 4425 4528], north of the former Easington Colliery, County Durham, where the beach gravel crops out between 27 and 32 m above OD.

Lower and upper boundaries
The beach gravel rests on a bevelled, subhorizontal platform, bored by marine molluscs, cut into limestones and dolostones of the Zechstein Group at about 30 m above OD.

Thought to be a planar horizontal or undulating unconformable contact with dark grey diamicton of the Blackhall Till Formation, but contact is obscured and inaccessible.

Landform description and genetic interpretation
Beach deposit.

Thickness
4 m.

Distribution and extent
Coast of County Durham.

Age
MIS 7 or 9.

The informal **Raincliff Formation** was established by Thomas (p. 97 in Bowen, 1999) for the former Speeton Shell Bed or Speeton Formation, comprising some 3 m of fossiliferous sands and silts at Speeton [TA 147 758] of cool temperate estuarine origin. The deposits, which are overlain by the Filey Formation (glacigenic deposits correlated with the Holderness Formation by Thomas, p. 97 in Bowen, 1999), were regarded as Hoxnian by Catt and Penny (1966) and Catt (1991) but as Ipswichian by West (1969). Correlation with MIS 5 was shown by Knudsen and Serjup (1988) and Bowen and Sykes (1991).

9.5 BRITANNIA CATCHMENTS GROUP

9.5.1 Formations of the Britannia Catchments Group

In the valley of the River Dove at the southern margins of the Pennines in the Ashbourne district (BGS 1:50 000

Sheet E124) calcite-cemented gravels interpreted as fluvial deposits, overlain by red-brown stony till are referred to the informal **Ashbourne Gravel** (ASGR) by Chisholm et al. (1988). These gravels are considered to be pre-Devensian and could be of Hoxnian age.

Several pre-Devensian cave deposits of Yorkshire and Derbyshire (not described in this report) are assigned bed status by Thomas (p. 97 in Bowen, 1999) who also assigns the Early Pleistocene fossiliferous clay of Victoria Cave [SK 079 679], Derbyshire (Spencer and Melville, 1974; Stuart, 1982), to the **Dove Hole Formation**.

Lake alluvium and associated organic deposits of Late Glacial (Windermere to Loch Lomond Stadial) to Holocene (MIS 2–1) in kettle basins are referred to the **Bamburgh Formation** in Northumberland (Thomas, p.98 in Bowen, 1999). Similar deposits in Yorkshire and Derbyshire are divided into the **Bingley Bog Formation** (Late Glacial: Windermere to Loch Lomond Stadial) and the **Ringingslow Formation** (Holocene) by Thomas (pp. 97–98 in Bowen, 1999). The latter includes upland peat of the Pennines and North York Moors. These formations are regarded as informal in the present framework.

Fluvial (alluvium, river terrace deposits and alluvial fan deposits) of the region are assigned to two subgroups, the **Northumbria Catchments** and the **Yorkshire Catchments** subgroups.

9.5.2 Northumbria Catchments Subgroup

The **Northumbria Catchments Subgroup** comprises alluvial and terrace deposits, organic and mass movement deposits. River valley formations named after the principal rivers flowing to the North Sea have been formally established for the deposits of the rivers Coquet, Tyne and Wear.

Name
Northumbria Catchments Subgroup (NCAT) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Alluvium and river terrace deposits composed of sand, gravel, silt and clay. Clasts are derived from rocks cropping out in north-eastern England (mainly sandstone, gritstone, mudstone, limestone and coal).

Formal subdivisions and correlation table
Subdivided into the Coquet Valley, Tyne Valley, and Wear Valley formations (Tables 6 and 14).

Type area/Reference section
Type area: Catchments of the Northumbrian rivers.

Lower and upper boundaries
Unconformable contact with units of the North Pennine and North Sea Coast Glacigenic subgroups, and with bedrock.

Generally the ground surface, but units of the subgroup locally interfinger with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
A suite of fluvial (river terrace deposits and alluvium) and associated lacustrine and organic deposits.

Thickness
Up to 25 m.

Distribution and extent
Northumberland and County Durham east of the Pennine watershed.

Age
Devensian–Holocene (MIS 2–1).

9.5.2.1 Coquet Valley Formation

Name
Coquet Valley Formation (CQU) (after McMillan et al., 2005).

Lithology
Mainly sand and gravel forming river terraces and silty, clayey sand forming floodplains and concealing sand and gravel. Including units of silty sand, silt, clay and peat. Clasts mainly sandstone, gritstone, mudstone, limestone and coal.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 14).

Type area/Reference section
Type area: Valleys of the rivers Coquet, Aln and Wansbeck and their tributaries [NT 900 800–NU 250 350], northern England.

Lower and upper boundaries
Sharp, undulating, erosional contact, mainly on grey tills (diamicton) of the North Pennine or North Sea Coast Glacigenic subgroups, or on bedrock.

Ground surface, locally covered by peat.

Landform description and genetic interpretation
River terrace deposits and alluvium.

Thickness
Up to 10 m.

Distribution and extent
The valleys of the rivers Coquet, Aln and Wansbeck and their tributaries, northern England.

Age
Devensian to Holocene (MIS 2–1).

9.5.2.2 Tyne Valley Formation

Name
Tyne Valley Formation (TYNE) (after McMillan et al., 2005).

Lithology
Mainly sand and gravel forming river terraces and silty, clayey sand forming floodplains and concealing sand and gravel. Including units of silty sand, silt, clay and peat. Clasts mainly sandstone, gritstone, mudstone, limestone and coal.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 14).

Type area/Reference section
Type area: The valley of the River Tyne and its tributaries [NY 650 350–NU 350 750], northern England.

Lower and upper boundaries
Sharp, undulating, erosional contact, mainly of grey tills

(diamicton) of the North Pennine or North Sea Coast Glacigenic subgroups, or on bedrock.

Ground surface, locally covered by peat.

Landform description and genetic interpretation
River terrace deposits and alluvium.

Thickness
Up to 20 m.

Distribution and extent
The valley of the River Tyne and its tributaries, northern England.

Age
Devensian to Holocene (MIS 2–1).

9.5.2.3 Wear Valley Formation

Name
Wear Valley Formation (WEAR) (after McMillan et al., 2005).

Lithology
Mainly sand and gravel forming river terraces and silty, clayey sand forming floodplains and concealing sand and gravel, including units of silty sand, silt, clay and peat. Clasts mainly sandstone, gritstone, mudstone, limestone and coal.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 14).

Type area/Reference section
Type area: [NY 650 350–NU 800 350] The valley of the River Wear and its tributaries, northern England.

Lower and upper boundaries
Sharp, undulating, erosional contact, mainly on grey tills (diamicton) of the North Pennine or North Sea Coast Glacigenic subgroups, or on bedrock.

Ground surface, locally covered by peat.

Landform description and genetic interpretation
River terrace deposits and alluvium.

Thickness
Up to 20 m.

Distribution and extent
The valley of the River Wear and its tributaries, northern England.

Age
Devensian to Holocene (MIS 2–1).

9.5.3 Yorkshire Catchments Subgroup

The **Yorkshire Catchments Subgroup** comprises alluvial and terrace deposits and associated organic deposits. River valley formations named after the principal rivers flowing eastwards from the Pennines and Peak District have yet to be formally established. Loess and mass movement deposits of the catchments are also included.

Name
Yorkshire Catchments Subgroup (YKC) (after McMillan, 2005, McMillan et al., 2005, and Ford et al., 2008).

Lithology
The Yorkshire Catchments Subgroup includes fluvial (river terrace and alluvium) clay, silt, sand, gravel, boulders and associated peat beds, with blown sand.

Formal subdivisions and correlation table
Breighton Sand Formation and Sutton Sand Formation (Tables 6 and 14).

Type area/Reference section
Type area: River valleys of Lincolnshire and Yorkshire east of the Pennines watershed.

Lower and upper boundaries
Unconformable contact with older superficial deposits including units of the North Pennine, North Sea Coast and Central Cumbria Glacigenic subgroups, and bedrock.

Generally the ground surface, but units of this subgroup locally interfinger with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
River terrace deposits and alluvium; plus blown sand.

Thickness
Alluvial and terrace deposits may reach up to a maximum of around 25 m. The individual formations and members in the subgroup are highly variable in thickness.

Distribution and extent
Yorkshire, east of the Pennine watershed, including the valleys of the River Ouse and tributary rivers of the Swale, Ure, Nidd, Wharfe, Aire and Calder and Derwent.

Age
Devensian–Holocene (MIS 2–1).

9.5.3.1 Breighton Sand Formation

Name
Breighton Sand Formation (BREI) (after Ford et al., 2008; Sand of '25 Foot Drift', BGS 1:50 000 Sheet E71, 1973).

Lithology
Dominantly yellow to pale brown and reddish yellow, slightly clayey sand to silty sand with a variably developed very dusky red to black compressible peat to clayey sandy peat base. Typically composed of moderately well-sorted medium quartz grains with minor bands of finer, coarser or poorly sorted material, including finely comminuted flint and lithic clasts. Thin beds of clayey sandy peat and poorly developed fine- to medium-grained slightly gravelly clayey sand are noted towards the base of the formation.

Formal subdivisions and correlation table
Subdivided into the Bielby Sand, Skipwith Sand and Naburn Sand members (Tables 6 and 14).

Type area/Reference section
Partial type section: Breighton Airfield [SE 7100 3530].

Lower and upper boundaries
Sharp to gradational (over several tens of centimetres) transition to underlying clay, silt or sand of the Hemingbrough Glaciolacustrine Formation, gravels of the Pocklington Gravel Formation, or directly to bedrock. A moderate to well-developed basal dark brown peat, the Skipwith Peat Bed or the Bielby Peat Bed, is present in some localities.

The presence of sparsely disseminated fine flint gravel is noted close to the lower boundary, particularly towards the formation's eastern limits (Bielby Sand Member).

Typically the ground surface beneath a thin (0.2–0.5 m thick) sandy soil or locally overlain by alluvial and aeolian deposits.

Landform description and genetic interpretation
Loess deposit.

Thickness
Average 1–2 m but can exceed 6 m in some cases.

Distribution and extent
The Breighton Sand Formation is known to extend across the Vale of York, from the River Ouse in the west, to beyond Holme-on-Spalding-Moor in the east.

Age
Late Devensian (MIS 2–1).

BIELBY SAND MEMBER (BIES)

The Bielby Sand Member (after Ford et al., 2008) comprises up to 6 m of yellow to pale brown and reddish yellow slightly clayey to slightly silty sand with occasional fine gravels. The material is usually reddish brown and grey colour-mottled as a result of near-surface weathering processes. It is typically composed of moderately well-sorted medium-grained quartz grains with minor bands of finer, coarser or poorly-sorted material, including flint and chert. Thin beds (less than 5 cm) of clayey sandy peat can occur within the unit.

NABURN SAND MEMBER (NABS)

The Naburn Sand Member (after Ford et al., 2008) comprises up to 2.5 m of mottled brownish yellow, yellowish brown, brown and grey silty, sporadically clayey fine- to coarse-grained sand. Characteristically the sand is poorly sorted and locally laminated. Grains are dominated by quartz with sporadic plagioclase feldspar. Commonly the unit shows a fining upwards sequence from its lower boundary with underlying laminated clay.

SKIPWITH SAND MEMBER (SKIS)

The Skipwith Sand Member (after Ford et al., 2008) comprises up to 2.4 m of dominantly yellow to pale brown slightly clayey sand. The sand is typically composed of moderately well-sorted medium quartz grains with minor bands of finer, coarser or poorly sorted material, including finely comminuted flint and lithic clasts. Thin laminae of clayey sandy peat and poorly developed fine- to medium-grained slightly gravelly clayey sand are noted towards base of the member. There is a sharp to gradational transition (over several tens of centimetres) to underlying sands and clays of the Hemingbrough Glaciolacustrine Formation. A moderate to well-developed dark brown peat, the *Skipwith Peat Bed* (SKPE) is present at some localities, as is the basal *Bielby Peat Bed* (BIEP) which is underlain by the Hemingbrough Glaciolacustrine Formation.

9.5.3.2 SUTTON SAND FORMATION

Name
Sutton Sand Formation (SUTN) (after Matthews, 1970, Gaunt, 1994, and Ford et al., 2008; Sutton Formation of Thomas, p. 98 in Bowen, 1999).

Lithology
Fine-grained silty sand.

Formal subdivisions and correlation table
No subdivisions (Table 14).

Type area/Reference section
Type area: Sutton-on-the-Forest [SE 608 640], auger holes in areas where sand forms slightly elevated bodies (Matthews, 1970).

Lower and upper boundaries
Unconformable on older superficial deposits, mainly Devensian glacial lake deposits (e.g. Alne Glaciolacustrine Formation at type locality) and glacial till or underlying bedrock.

Ground surface.

Landform description and genetic interpretation
Blown sand.

Thickness
Up to about 7 m.

Distribution and extent
Vale of York from near Hutton Sessay [SE 48707 75623], to Sutton-on-the-Forest, southwards into the area east of Doncaster and in Lincolnshire to the west of Scunthorpe (Gaunt, 1994).

Age
Late Devensian (MIS 2–1).

10 East Anglia and the ancestral River Thames

The oldest superficial deposits of this district are marine deposits of the Crag Group and fluvial deposits of the Dunwich Group, which may extend in age from the Neogene (Tertiary) to Early Pleistocene. The most extensive deposits refer to the Anglian Glaciation and are assigned to the Albion Glacigenic Group. Representatives of the Caledonia Glacigenic Group of Late Devensian age are present in north Norfolk. Deposits of the Britannia Catchments Group and British Coastal Deposits Group range in age from Late Devensian to Holocene. Formal lithostratigraphy for the Pleistocene strata of East Anglia is already widely used. Most of the formal terms already in use by BGS are retained. The terminology proposed by Bowen (1999) has been accepted where it is applicable.

10.1 CRAG GROUP

During the early Neogene (Tertiary), East Anglia became submerged as part of the marine North Sea Basin, around the margins of which there developed a system of prograding deltas (Cameron et al., 1992). The area lay on the western margin of this rapidly subsiding basin, which retained a geometry similar to that of the present day (Anderton et al., 1979). The Crag formations of East Anglia represent tidal and sub-tidal sediments within that basin. In total, they nowhere exceed 70 m in thickness in East Anglia, compared to 350 m of equivalent sediments in the Southern North Sea Basin and 800 m in the Central North Sea Basin (Cameron et al., 1992). This is partly because of a thinning of the individual formations towards the margin of the basin, and partly as a result of erosion beneath unconformities within the sequence. The regional distribution of the Crag Group is shown in Figure 19.

West (1961) examined pollen from a Royal Society borehole at Ludham, Norfolk, and named four Quaternary climatic stages. From the base upwards these are: Ludhamian (warm), Thurnian (cold), Antian (warm) and Baventian (cold). He correlated these with the foraminiferal horizons of Funnell (1961), which similarly indicated alternations of temperature. Further climatic stages were later proposed: Pre-Ludhamian (cold; Beck et al., 1972) below the Ludhamian, and Bramertonian (warm; Funnell et al., 1979), Pre-Pastonian (cold; West, 1980) and Pastonian (warm; West, 1980) above the Baventian. A summary of these stages is given in Funnell (1987). However, it is now believed (Zalasiewicz et al., 1991) that the Bramertonian pre-dates rather than post-dates the Baventian. Thus the Antian and Bramertonian represent a single warm stage, and may be synonymous. Further, the Baventian and Pre-Pastonian are believed to represent the early and late parts of a single cold stage, correlated with Tiglian TC4c in the Netherlands (Gibbard et al., 1991a; Lister, 1998, 2000), whereas the Pastonian is correlated with the upper part of Tiglian TC5 and the lower part of TC6 (Lister, 1998). This is supported by a record of reversed magnetic polarity in Pastonian sediments at Sheringham, corresponding to the later part of TC5 and TC6, after the Olduvai event (Hallam and Maher, 1994).

Former BGS practice, e.g. on BGS 1:50 000 Sheet E162, has been not to distinguish the Red and Norwich Crag as formations, but to combine the two as the Crag Group, while retaining the Coralline Crag as a separate formation not within the Crag Group (Arthurton et al., 1994). More recently, Hamblin et al. (1997) have redefined the Red Crag and Norwich Crag as formations, and these appear along with the newly-named Wroxham Crag Formation (Hamblin, 2001a; Rose, et al., 2001) on BGS 1:50 000 Sheet E148. The BGS lithostratigraphical framework redefines the Crag Group to include the Coralline, Red, Norwich and Wroxham Crag formations (Tables 2 and 15, Figure 19). The group thus includes all the wholly or dominantly marine Neogene (Tertiary) and Quaternary formations that precede the Anglian glaciation in East Anglia.

10.1.1 Formations of the Crag Group

10.1.1.1 Coralline Crag Formation

The Coralline Crag Formation is characterised by carbonate-rich bioclastic sands and has an onshore outcrop restricted to south-east Suffolk. Here it rests unconformably on an undulose surface of London Clay Formation (Thames Group), reaching a maximum thickness of approximately 25 m. Offshore, seismic records show the formation to reach about 25 m in thickness and to extend some 14 km to the north-east of Thorpeness as a partially concealed elongate body (Moorlock et al., 2000a).

Name
Coralline Crag Formation (CCG) (after Balson et al., 1993).

Lithology
Carbonate-rich bioclastic sands. The siliciclastic sand fraction is moderately- to poorly-sorted medium-grained sand; the mud content is low. There is a basal lag gravel that is rich in pebbles of phosphatic mudstone largely derived from the Thames Group.

Formal subdivisions and correlation table
The formation has been subdivided on lithology and biofacies into a sequence of members (Balson et al., 1993), which, from the bottom up, constitute the Ramsholt Member, the Sudbourne Member, and the Aldeburgh Member. None of these units has yet been defined in the BGS Lexicon (Tables 2 and 15).

Type area/Reference section
Type area: Pits around Aldeburgh [TM 45 55], Suffolk (Balson et al., 1993).

Lower and upper boundaries
Rests unconformably on an undulose surface of the Thames Group.

Overlain unconformably by the Red Crag and Norwich Crag formations.

Landform description and genetic interpretation
Shallow marine deposit.

Thickness
About 25 m.

Distribution and extent
Restricted to south-east Suffolk, as far north as Thorpeness, and the adjacent offshore area.

Age
Pliocene (MIS pre-103).

10.1.1.2 RED CRAG FORMATION

The Red Crag was accorded formation status by Funnell and West (1977). According to the classification of Hamblin et al. (1997), the Red Crag Formation includes all the strata bounded by the marine transgression during the Pre-Ludhamian and the regression during the Thurnian. It thus includes all the Pre-Ludhamian, Ludhamian and Thurnian sediments known in East Anglia. Hamblin et al. (1997) correlate the Red Crag Formation onshore with the Westkapelle Ground Formation of the southern North Sea, which contains pollen spectra of Thurnian type (Cameron et al., 1984, 1992), and the transgression at the base of the Red Crag in eastern Suffolk with the seismic reflector at the base of the Westkapelle Ground Formation. The Red Crag Formation in south-eastern Suffolk comprises 10–40 m of poorly sorted, cross-bedded, medium- to coarse-grained, shelly sands (Mathers and Zalasiewicz, 1988).

Name
Red Crag Formation (RCG) (after Funnell and West, 1977, Mathers and Zalasiewicz, 1988, Zalasiewicz et al., 1988, Hamblin et al., 1997, and Lewis, p. 22 in Bowen, 1999).

Lithology
Coarse-grained, poorly sorted, cross-bedded, abundantly shelly sands (in East Anglia). Dark green and glauconitic when fresh, but typically oxidised to yellow or reddish brown with ferruginous concretions (iron pan). Basal bed of rounded flint pebbles. Offshore, fine- to medium-grained, muddy, calcareous, glauconitic sands.

Formal subdivisions and correlation table
Mathers and Zalasiewicz (1988) and Zalasiewicz et al. (1988) distinguish two members, an older Sizewell Member and a younger Thorpeness Member. Red Crag of more shallow-water facies has been proved at the Stradbroke borehole in West Suffolk (Beck et al., 1972) and the Ludham and Ormesby boreholes in Norfolk (Funnell, 1961; West, 1961; Arthurton et al., 1994). At Ludham, grey organic sands, silts and clays are termed the Ludham Member by Lewis (p.15 in Bowen, 1999). Also includes the informal Netley Heath Beds (Section 12.2.1.3) (Tables 2 and 15).

Type area/Reference section
Type area: Walton-on-the-Naze, Essex [TM 267 237]. Type samples offshore in Borehole 81/51 (Zalasiewicz et al., 1988).

Lower and upper boundaries
Rests unconformably on the Coralline Crag Formation, Palaeogene formations and Chalk Group bedrock.

Overlain unconformably by sands of the Norwich Crag Formation, which are less coarse-grained, better sorted, less shelly and generally paler in colour.

Landform description and genetic interpretation
Shallow marine deposit.

Thickness
10–40 m.

Distribution and extent
Eastern and southern East Anglia, extending south-westwards into Hertfordshire and north-east to Norfolk, at least as far as Ludham.

Age
Piacenzian (Waltonian) to Thurnian (MIS ?103–?82).

SIZEWELL MEMBER (SZWL)

The Sizewell Member comprises up to 13 m of shelly sands with clay layers. The type section is BGS registered borehole TM46SE37 [TM 471 622], Aldeburgh–Sizewell transect, from -34.3 to -47.6 m OD (Zalasiewicz et al., 1988). It rests unconformably on the Coralline Crag Formation or on bedrock.

THORPENESS MEMBER

The Thorpeness Member comprises 20 to 30 m of shelly sands with thin clay laminae. The type section is BGS registered borehole TM46SE37 [TM 471 622], Aldeburgh–Sizewell transect, from -13.3 to -34.3 m OD (Zalasiewicz et al., 1988).

10.1.1.3 NORWICH CRAG FORMATION

The Norwich Crag was formalised with formation status by Funnell and West (1977). According to the classification of Hamblin et al. (1997), the formation includes all of the Crag strata above the transgression that occurred during the Antian. Further research has shown that the strata that succeed the Baventian regression are better included in a further formation, the Wroxham Crag Formation (described below). Thus the Norwich Crag Formation is restricted to strata of Antian/Bramertonian and Baventian age. Hamblin et al. (1997) correlate this sediment package with the Smith's Knoll Formation offshore, since that formation contains dinoflagellate cyst and pollen assemblages resembling those of the Antian (Cameron et al., 1992).

The Norwich Crag comprises a widespread sheet of well-sorted, fine- to medium-grained sands, but also includes significant bodies of gravel and clay. Sedimentary structures in the sands include horizontal bedding, ripple marks, flaser bedding, thin clay drapes, trough cross-sets up to 0.3 m thick, vertical burrows, channel scours and mud cracks (Zalasiewicz and Mathers, 1985; Mathers and Zalasiewicz, 1988; Zalasiewicz et al., 1988).

Name
Norwich Crag Formation (NCG) (after Funnell and West, 1977, Zalasiewicz and Mathers, 1985, Mathers and Zalasiewicz, 1988, Zalasiewicz et al., 1988, and Hamblin et al., 1997).

Lithology
The formation comprises a widespread sheet of well-sorted, fine- to medium-grained micaceous, glauconitic, locally shelly sands (Chillesford Church Sand Member in south-east Suffolk), with localised beds of laminated silty clays (Chillesford Clay Member) and rounded flint gravels (Westleton Beds). The formation is marine, with the clay members being estuarine and the Westleton Beds representing beach-face gravels.

Formal subdivisions and correlation table
Subdivided into the Chillesford Church Sand and Chillesford Clay members. Several informal subdivisions (Tables 2 and 15).

Type area/Reference section
Type area: The area around Wickham Market and Aldeburgh [TM 30 55–TM 45 55], Suffolk (southern East Anglia) (Mathers and Zalasiewicz, 1988).

Lower and upper boundaries
Rests with discontinuity on the Red Crag Formation and oversteps onto Coralline Crag Formation, Palaeogene formations and Chalk Group bedrock.

Overlain disconformably by Wroxham Crag Formation, unconformably by Kesgrave Catchment Subgroup and mid-Pleistocene glacigenic deposits.

Landform description and genetic interpretation
Marine and estuarine deposits.

Thickness
About 70 m.

Distribution and extent
Restricted to East Anglia, the formation is well-defined throughout Suffolk and north Essex, as far as Stanstead Mountfichet. It continues north into Norfolk and the area of Ludham, but farther north it is cut out beneath the base of the Wroxham Crag Formation.

Age
Pliocene to Pleistocene (MIS ?81–?68).

CHILLESFORD CHURCH SAND MEMBER (CFB)

Prestwich (1849) introduced the term Chillesford Sand to describe these sands where they overlie the Red Crag in Suffolk, and Mathers and Zalasiewicz (1988) similarly referred to the sands in this area as the Chillesford Sand Member (CFB), but Bowen (1999) renamed it the Chillesford Church Member. The name Chillesford Church Sand Member is proposed here. Equivalent sands in the Gipping Valley have been termed Creeting Beds (Dixon, 1978) or Creeting Sand Member (Allen, P, 1984; Gibbard et al., 1996). North of the Aldeburgh area, the sand units of the Norwich Crag have not been named as members.

CHILLESFORD CLAY MEMBER (CFC)

Clay bodies within the Norwich Crag are typically silty, with lenticular bedding, plant remains and moulds of bivalves. Evidence of intermittent desiccation is recorded at Covehithe (West et al., 1980). Prestwich (1849) introduced the term Chillesford Clay to describe a particular clay body that overlies the Chillesford Church Sand Member at Chillesford in the Woodbridge district of Suffolk, although later workers applied the term to virtually any micaceous clay in the Crag of East Anglia. Ultimately it was accepted that the term should be restricted to the one particular clay body (Funnell, 1961; Dixon, 1972), and this is termed the Chillesford Clay Member (Chillesford Member of Bowen, 1999). A clay body at Easton Bavents near Covehithe has been termed the *Easton Bavents Clay Member* (EBC) (Gibbard and Zalasiewicz, 1988), or Easton Bavents Member (Lewis, p. 22 in Bowen, 1999). However, BGS surveys along the coast from Easton Bavents to north of Covehithe [TM 515 784–TM 534 836] (BGS 1:50 000 Sheet E176, Lowestoft) revealed several beds of clay, that pass laterally and vertically into sands and gravelly sands and that are interbedded with sands and gravel bodies (the Westleton Beds, see below), so Moorlock et al. (2000a) recommended dropping the member status of the Easton Bavents Clay. Both the Chillesford and Easton Bavents clays are Baventian in age. A slightly older (Antian/Bramertonian) clay, which overlies the Creeting Sand Member in the Gipping Valley, has been termed the College Farm Silty Clay Member (Allen, P, 1984; Gibbard et al., 1996) or College Farm Member (Allen, P., p. 22 in Bowen, 1999), and is here named the *College Farm Clay Member*, although this unit is currently not formally defined in the BGS Lexicon.

Over a large area around Southwold in Suffolk, the sands of the Norwich Crag are interbedded with lenticular bodies of flint gravel, that Prestwich (1871) named the *Westleton Beds*. At the time he believed them to overlie the Crag rather than to form a part of it, and later authors continued to portray them as a discrete unit, the highest in the local Crag succession, most commonly portrayed as a member of the Norwich Crag (e.g. Gibbard and Zalasiewicz, 1988). However, mapping of the Saxmundham and Lowestoft districts (BGS 1:50 000 Sheets E191 and E176; Hamblin et al., 1997; Moorlock et al., 2000a) has demonstrated that there are many bodies of gravel that are interbedded with sands and clay bodies of normal Norwich Crag type. Rather than give a member name to each gravel body, it is recommended that the term Westleton Beds (WBDS) be used in a facies sense to describe these various bodies of beach-face gravel.

10.1.1.4 WROXHAM CRAG FORMATION

The Wroxham Crag Formation was introduced (Hamblin, 2001a; Moorlock et al., 2002a; BGS 1:50 000 Sheets E132 and 148) to include Crag strata deposited following a further transgression post-dating the Norwich Crag Formation. The main feature that distinguishes the Wroxham Crag from the Norwich Crag is the presence of a significant proportion of quartz and quartzite pebbles in the gravels, whereas the Westleton Beds, high in the Norwich Crag, comprise almost wholly of flint. Following Rose et al. (2001), the Wroxham Crag includes all marine strata deposited in the area from the start of the influx of substantial quantities of quartz and quartzite, during the Pre-Pastonian, to the onset of glaciation represented by the Happisburgh Formation (Section 10.3.1.1). The Wroxham Crag Formation thus includes strata previously included in either the Norwich Crag Formation or the Cromer Forest-bed Formation (see below). Hamblin et al. (1997) suggested that the earlier part of the Wroxham Crag Formation (then considered as part of the Norwich Crag Formation) probably correlates with the Winterton Shoal Formation that succeeds the Smith's Knoll Formation offshore.

The Wroxham Crag Formation has been proved over a wide area of Norfolk and Suffolk, from the Southwold area in the south-east to Weybourne in the north-west. Eastwards from Weybourne, interbedded marine and freshwater strata of Early Pleistocene age are discontinuously exposed along the whole length of the north Norfolk coast, although the outcrop is much disrupted by land-slipping and glacial tectonics. It is believed that the freshwater deposits were formed by south-bank tributaries within the catchment of the Ancaster River (Rose et al., 2001) (see Cromer Forest-bed Formation, Section 10.2.1.3), and that the alternation between marine and freshwater strata reflects local fluctuations of relative sea levels. The lowest, marine unit of the north Norfolk coast succession is traditionally styled

Weybourne Crag (Wood and Harmer, 1872; Reid, 1882). Equivalent strata cropping out inland along the valley of the River Bure were styled Bure Valley Beds (Wood and Harmer, 1868). Wood and Harmer realised from the fossil content that these beds were marine, although because of the presence of the cold-water mollusc *Macoma balthica* they classed them as the lowest horizon of the Glacial Series rather than with the Crag.

Reid (1882) included all the strata overlying the Weybourne Crag in the coastal succession in the Cromer Forest Bed Series, while Funnell and West (1977) included all the strata in the coastal succession, including the Weybourne Crag, in the Cromer Forest Bed Series/Formation. Gibbard and Zalasiewicz (1988) and Lewis (p. 15 in Bowen, 1999) styled the Weybourne Crag as the Sidestrand Member of the Norwich Crag, and followed Funnell and West (1977) in subdividing the overlying strata of the Cromer Forest-bed Formation into the Sheringham, Paston, Runton, West Runton, Mundesley, and Bacton members. The present framework establishes all the marine units of this succession within the Wroxham Crag Formation. Thus the formation includes the *Sidestrand Member* (Weybourne Crag), the *Paston* and *Mundesley* members and the marine part of the *Runton Member*. The freshwater units (the *Sheringham*, *West Runton* and *Bacton* members and the freshwater part of the Runton Member) are included in the **Cromer Forest-bed Formation** (Section 10.2.1.3). Currently none of these members is formally defined in the BGS Lexicon.

Name
Wroxham Crag Formation (WRCG) (after Rose et al., 1996, 2001, Hamblin, 2001a, and Moorlock et al., 2002a; marine units of the Cromer Forest-bed Formation of Lewis, p. 15 in Bowen, 1999).

Lithology
The formation comprises a sheet of interbedded gravels, sands, silts and clays. The gravels are dominated by flint (up to about 80%) and by quartz and quartzite (up to about 60%), with far-travelled minor lithologies including Carboniferous chert, Rhaxella chert, Greensand chert, Spilsby Sandstone and felsic volcanic rocks from North Wales.

Formal subdivisions and correlation table
Subdivisions, not formally defined in the BGS Lexicon, include the Sidestrand Member (formerly of the Norwich Crag), the Paston and Mundesley members and the marine part of the Runton Member — see discussion below. The Dobb's Plantation, How Hill and Mundesley members were established by Rose et al. (2001) (Tables 2 and 15).

Type area/Reference section
Type area: The area between Wroxham, Weybourne and Sidestrand, Norfolk, including the North Norfolk coast [TG 30 14–TG 12 43] (Rose et al., 2001).

Lower and upper boundaries
Disconformable on the Norwich Crag, from which it can be distinguished by the generally coarser and less well-sorted nature of the sediments and by the presence of significant quantities of quartz, quartzite and far-travelled clasts in the gravels. The formation cuts down through the Norwich Crag Formation northwards and comes to rest on Chalk Group bedrock in north Norfolk.

Widely overlain by mid-Pleistocene glacial deposits, less widely by deposits of the Bytham Catchments Subgroup and the Cromer Forest-bed Formation. It is distinguished from the latter units by sedimentary and other features related to its marine origin.

Landform description and genetic interpretation
The deposits are interpreted as estuarine and near-shore marine.

Thickness
About 20 m.

Distribution and extent
Restricted to eastern Norfolk and north-eastern Suffolk, at least as far south as Halesworth.

Age
Pre-Pastonian to Cromerian (MIS ?67–17).

Rose et al. (2001) proposed a subdivision of the Wroxham Crag Formation into members based on the pebble content of the gravels, which in turn reflects varying input from the Thames, Bytham and Ancaster river systems. The three members are:

DOBB'S PLANTATION MEMBER (DOBP)

The earliest member, the Dobb's Plantation Member, is characterised by local materials (flint), with only 10 per cent of far-travelled material, comprising mainly white or colourless quartz and quartzite, with a little Carboniferous and Rhaxella (Late Jurassic) chert (Rose et al., 2001). This indicates derivation from Thames and Ancaster River sediments, showing that at this time the Bytham River was still transporting only suspended sediment into the sea.

HOW HILL MEMBER (HOWH)

From analyses so far performed, the overlying How Hill Member appears to be geographically the most extensive. The gravel fraction contains significantly more far-travelled material than in the Dobb's Plantation Member: up to around 60 per cent of white and colourless quartz and quartzite, with small quantities of Carboniferous and Rhaxella chert and traces of Spilsby Sandstone, Greensand chert and acid and basic volcanic rocks (Rose et al., 2001). Acid volcanic rocks and Rhaxella chert indicate contributions by the Thames and Ancaster rivers, which is confirmed by the dominantly pale nature of the quartz and quartzite. However a contribution from the Bytham River is indicated by the presence of Spilsby Sandstone and of a higher proportion of coloured quartz and quartzite than in the Dobbs' Plantation member.

MUNDESLEY MEMBER

The Mundesley Member of Rose et al. (2001) corresponds to that of Funnell and West (1977). It comprises tidal laminated silty clays and beach gravels and sands up to about 2.5 m thick (West, 1980) and includes the Leda Myalis Bed of Reid (1882) at West Runton and the Mundesley Clay at Mundesley and Paston (Lewis, p. 15 in Bowen, 1999). The gravel fraction of this member is characterised by a lower frequency of quartzose rocks than in the How Hill Member, indicating a reduced influx of far-travelled material, although input continued from the Thames, Ancaster and presumably Bytham rivers (Rose et al., 2001).

10.2 DUNWICH GROUP

The Dunwich Group includes all of the wholly or dominantly non-marine deposits of East Anglia and of the present-day Thames Valley that predate the Anglian glaciation (Tables 3 and 15). These deposits were formed largely by three major eastward-flowing river systems. The pre-glacial River Thames rose in the uplands of Wales, and in its lower reaches followed a more northerly course than the Thames does now, flowing to an estuary in the vicinity of Aldeburgh. It was diverted into its present course by the Anglian ice-sheet that deposited the Lowestoft Formation till in East Anglia. The Bytham River flowed from the English Midlands to an estuary in the vicinity of Lowestoft. The third river was the Ancaster River (Clayton, 2000), which is believed to have flowed from the southern Pennines eastwards along a course north of the present coast of north Norfolk (Rose et al., 1996). No deposits of this river have yet been described, but its existence is inferred from derived clasts within the Wroxham Crag. Both the Ancaster and Bytham rivers ceased to exist after their catchments were overrun by ice.

The three rivers probably existed throughout the Neogene (Tertiary), but the only part of the Dunwich Group believed to be older than the Wroxham Crag is the Nettlebed Formation. The remainder of the group is thus believed to span a period of some 1.2 Ma, from the Pre-Pastonian onwards (Whiteman and Rose, 1992). The sediments are inherently difficult to date, but in the case of the Bytham and Ancaster rivers, sedimentation clearly ceased when the courses of the rivers were overrun by the advance of the ice-sheets that deposited the Corton, Happisburgh and Lowestoft formation sediments. The Thames was never overrun by the ice. The deposits of the post-diversionary Thames (Anglian and later) are included in the Thames Catchments Subgroup (Section 12.5.1).

10.2.1 Formations of the Dunwich Group

There are currently two subgroups of the Dunwich Group, the Kesgrave Catchment Subgroup (Section 10.2.2) and the Bytham Catchments Subgroup (Section 10.2.3). Formations not attached to a subgroup include the **Nettlebed Formation, Caesar's Camp Gravel Formation** (Section 12.3.1.1), **Letchworth Gravels Formation** (Section 10.2.1.2), **Cromer Forest-bed Formation** (Section 10.2.1.3), and the **Milton Formation** (Section 10.2.1.4).

10.2.1.1 Nettlebed Formation

The Nettlebed Formation (NBED) (Tables 3 and 15) is the earliest stratigraphical unit of the Dunwich Group, and the earliest deposit which can be clearly ascribed to the River Thames. The formation has yet to be formally defined in the BGS Lexicon. It comprises gravelly sand with local occurrences of fine-grained organic material (Horton and Turner, 1983). The gravel fraction (bedload sediment) is dominated by flint of local origin, with only a trace of chert from the Weald and far-travelled quartzose rocks from west of the London basin. The Nettlebed Formation has been correlated with the Norwich Crag Formation (Rose et al., 2001), although a longer time span, allowing correlation with both the Red and Norwich crag formations, cannot be ruled out.

10.2.1.2 Letchworth Gravels Formation

The Letchworth Gravels Formation comprises a thin (about 3.5 m) deposit of sand and gravel, rich in quartzite and quartz, occurring as a gravel cap to a flat-topped hill at about 70 m OD near Hitchin, Hertfordshire. It was named the Letchworth Gravel Formation by Smith and Rose (1997).

Name
Letchworth Gravels Formation (LTH) (after Smith and Rose, 1997).

Lithology
Pebbly quartzose sand and sandy gravel with a high proportion (commonly 50% or more) of rounded quartzose pebbles (quartz, quartzite and sandstone).

Formal subdivisions and correlation table
No subdivisions (Tables 3 and 15).

Type area/Reference section
Type area: Hill top at former Fairfield Hospital [TL 2020 3550–TL 2065 3550], particularly open farmland to north.

Reference section: Hand auger hole TL23NW113 [TL 2048 3540], 100 m north-east of church at former Fairfield Hospital.

Lower and upper boundaries
Unconformable on Chalk. Mostly found at surface.

Overlain in part by (Anglian) chalky till.

Landform description and genetic interpretation
? Fluvial deposit.

Thickness
3.55 m proven in borehole TL23NW113 [TL 2048 3540]. May be up to 5 m elsewhere.

Distribution and extent
Capping hill top above about 65 m OD around Fairfield Hospital, near Letchworth, with smaller spreads along the Pix Brook and to the south-west of Lower Wilbury Farm. Possibly underlying till-covered ground, south of the Hospital.

Age
Early to mid-Pleistocene (MIS pre-13).

10.2.1.3 Cromer Forest-Bed Formation

The name Cromer Forest Bed Series was given by Reid (1882) to a series of marine, brackish and freshwater sediments deposited in the coastal region of northern and north-eastern East Anglia. West and Wilson (1966) and West (1980) extended the scope of the formation somewhat beyond that envisaged by Reid, to encompass strata of Pastonian, Beestonian and Cromerian age, while Funnell and West (1977) also included the Weybourne Crag. Funnell and West (1977) first formalised the term Cromer Forest Bed Formation, and estimated the maximum thickness as 8 m. The formation was later included in the Kesgrave Group by Arthurton et al. (1994). However, as has been explained under the Wroxham Crag Formation above, it is the recommendation of this report that the Cromer Forest Bed Formation should be restricted to non-marine strata, while the marine strata should be included in the Wroxham Crag Formation. Furthermore, it is current BGS practice to hyphenate the term 'Forest-bed', because of the unfortunate juxtaposition of the terms 'bed' and 'Formation'.

As it is traditionally understood, the Cromer Forest-bed Formation extends discontinuously throughout the coastal outcrop from Weybourne in north-west Norfolk to Kessingland in north-east Suffolk. However, the formation is not recorded between Corton at the northern end of the Suffolk coast, and Happisburgh in north-eastern Norfolk, and it is now clear that the Norfolk and Suffolk outcrops represent the deposits of two separate coastal complexes: the Norfolk deposits formed within the catchment of the Ancaster River, and the Suffolk deposits within that of the Bytham River. Thus it is proposed here that the term Cromer Forest-bed Formation be restricted to the deposits of the Ancaster River in north Norfolk, while the deposits at Kessingland are included in the Bytham Formation (see above). The Cromer Forest-bed Formation has been correlated offshore with the delta-top sediments of the Yarmouth Roads Formation (Bowen et al., 1986; Arthurton et al., 1994), which have recently been dated as Pastonian to Beestonian (Funnell, 1987) or Cromerian complex in age (Cameron et al., 1992).

Name
Cromer Forest-bed Formation (CRF) (after Funnell and West, 1977, and West, 1980).

Lithology
Four members are recognised in north Norfolk coastal sections. The oldest, the Sheringham Member, comprises freshwater organic mud, clay and sand. The Runton Member includes laminated freshwater silty clay. The West Runton Member comprises layers of alluvial clay and organic freshwater mud. The youngest, the Bacton Member, comprises clay and organic mud.

Formal subdivisions and correlation table
Subdivided into the Sheringham, Runton, West Runton and Bacton members (Tables 3 and 15).

Type area/Reference section
Type area: The coast of North Norfolk from Weybourne to Happisburgh [TG 11 43–TG 38 31] (Moorlock et al., 2002a).

Lower and upper boundaries
Rests disconformably on Chalk. Interdigitates the Wroxham Crag Formation as follows, from top down: Bacton Member (Cromer Forest-bed Formation); Mundesley Member (Wroxham Crag Formation); Runton Member (upper part, Woman Hythe Gravel of Reid, 1882; Wroxham Crag Formation); Runton Member (lower part, Woman Hythe Clay of Reid, 1882; Cromer Forest-bed Formation); Paston Member (Wroxham Crag Formation); Sheringham Member (Cromer Forest-bed Formation); Sidestrand Member (Wroxham Crag Formation).

Overlain by Middle Pleistocene glacial deposits (Happisburgh Glacigenic, Lowestoft, Sheringham Cliffs and Briton's Lane formations).

Landform description and genetic interpretation
The formation encompasses the fluvial, lacustrine and organic deposits of the catchment of the postulated 'Ancaster River', which is believed to have flowed from the Pennines to the North Sea along a line corresponding approximately to the present north coast of Norfolk.

Thickness
About 6 m.

Distribution and extent
The formation is restricted to North Norfolk. If deposits of the Ancaster River were discovered farther west, i.e. west of the Wash, they would constitute a new formation.

Age
Early to Middle Pleistocene (MIS pre-17).

The members which have been recognised on the north Norfolk coast (Funnell and West, 1977; Gibbard and Zalasiewicz, 1988), and which it is here recommended should remain in the Cromer Forest-bed Formation, as they are of non-marine origin, are as follows (currently none are formally defined in the BGS Lexicon):

Sheringham Member

Of Pre-Pastonian age (Funnell and West, 1977), the Sheringham Member comprises up to 2.5 m of freshwater organic muds, clays and sands. It includes Reid's Upper Freshwater Bed at Beeston and the Forest Bed at Happisburgh.

Runton Member

The Runton Member is considered to be of Beestonian age (Funnell and West, 1977; West 1980). These authors and West (1980) recognised the Beeston Beds (freshwater muds) and a lower bed of laminated freshwater silty clays known as the Woman Hythe Clay. The type locality at Beeston [TG 169 434] is also the stratotype for the Beestonian Stage.

West Runton Member

Of Cromerian I–II age, the West Runton Member comprises layers of alluvial clay and organic freshwater mud up to about 1.5–2 m thick, including the West Runton Freshwater Bed (Upper Freshwater Bed of Reid, 1882) at West Runton [TG 189 431], Norfolk, the type section. The beds were deposited under temperate climate conditions. The section is the stratotype for the Cromerian interglacial (Cromerian I-II).

Bacton Member

Of Cromerian IV age, the Bacton Member comprises clays and organic muds up to about 1.5 m thick, including the Arctic Freshwater Bed of Reid (1882).

10.2.1.4 Milton Formation

The Milton Formation (MLTS) (Belshaw et al., 2005; Barron et al., 2006; Sinclair and Smith, p. 43 in Bowen, 1999) comprises up to 13 m of pebbly sands with a wholly locally derived gravel fraction, which occur in a number of widely separated outcrops on the interfluves of the upper reaches of the Welland and Nene rivers. The formation has yet to be formally defined in the BGS Lexicon. Belshaw et al. (2005) considered it possible that the original drainage system pre-dates the development of the Bytham River, implying that the Milton Formation is of Early Pleistocene age.

10.2.2 Kesgrave Catchment Subgroup

The name Kesgrave Sands and Gravels was given by Rose et al. (1976) to a group of quartz- and quartzite-bearing sands, gravels and silts which chronologically precede and widely underlie the glacigenic deposits of the Lowestoft Till Formation (of Arthurton et al., 1994) over much of Essex and southern Suffolk. They were later renamed as the Kesgrave Formation (Rose and Allen, 1977; Hey, 1980; Rose et al., 1985), and were shown to be of braided fluvial origin, formed during successive periglacial periods and representing early terraces of the River Thames (Rose and Allen, 1977). More recently they have been treated as the Kesgrave Group by Whiteman (1992) and Whiteman and Rose (1992), and divided into the Sudbury and Colchester formations, but the term Kesgrave Formation was retained by Bowen (1999). The BGS framework now establishes the unit as the Kesgrave Catchment Subgroup (Section 3.2.3.1), comprising the **Sudbury** and **Colchester** formations (Tables 3, 15, 17, 18a and 18b). Most of the terrace deposits of the Northern Drift Formation and 'pre-diversionary Middle Thames' formations of Bowen (1999) are subsumed into the Sudbury Formation (see also Section 12.3.2).

10.2.2.1 Sudbury Formation

From the oldest terrace aggradation in East Anglia and the Middle and Upper Thames districts downwards, Whiteman and Rose (1992) named the first six members of the Sudbury Formation as the *Stoke Row Member*, the *Waterman's Lodge Member*, the *Westland Green Member*, the *Satwell Member*, the *Beaconsfield Member* and the *Gerrards Cross Member* (Gibbard, 1985; Hey, 1965, 1980). However, many synonyms have been used for the terraces of the ancestral Thames, as correlated by Whiteman and Rose (1992, Table 1). The members are described in Sections 11.1.1.1 and 12.3.2.1 of this report. The six members are characterised by quartz and quartzite from the Triassic, Carboniferous and Devonian rocks of the West Midlands, Welsh Borderland and possibly south-western Pennines, and acid volcanic rocks from northern Wales. The aggradations comprise bodies of cross-bedded, moderately sorted sand and gravel typically 5–10 m thick. They are usually entrenched into bedrock, with at least 10 m difference in surface elevation between members, and comprise the most extensive sediment aggradations of the ancestral river. They lie at an elevation that takes them above the lowest col of the Cotswold escarpment, and the pebble content implies that the ancestral River Thames flowed from north Wales. The large size of some of the erratics and the presence of glacially-fractured sand grains are taken to indicate glacial erosion in the headwater regions.

Name
Sudbury Formation (SBRY) (after Whiteman and Rose, 1992).

Lithology
Formation encompasses fluvial, lacustrine and organic deposits of the pre-diversionary River Thames. Most of the surviving deposits are fluvial gravels, with sedimentary structures indicating deposition by a braided river. Lacustrine silts and clays and organic peats are present but uncommon. The formation represents the first significant input of far-travelled materials into the Thames river sediments, and is characterised by quartz and quartzite from the Triassic, Carboniferous and Devonian rocks of the West Midlands, Welsh Borderland and possibly south-western Pennines, and felsic volcanic rocks from northern Wales. The presence of mega-erratics and glacially-fractured sand grains indicate glacial erosion in the headwater regions of the river. The fluvial gravels occupy terrace levels and the members are defined on the basis of altitude and pebble clast content. The members comprise bodies of cross-bedded and massive, moderately sorted sand and gravel. The aggradations are generally entrenched into bedrock with a difference in surface elevation of at least 10 m.

Formal subdivisions and correlation table
Subdivided into members: Stoke Row (informal), Waterman's Lodge Sand and Gravel, Westland Green Gravel, Satwell Gravel (informal), Beaconsfield Gravel and Gerrards Cross Gravel in East Anglia (Tables 3 and 15) and, with the Chorleywood Gravel the Middle Thames valley (Table 18a); the Waterman's Lodge Sand and Gravel, Ramsden Heath Sand and Gravel, Gordon House Sand and Gravel, North Leigh Sand and Gravel, and Combe Sand and Gravel members in the Upper Thames valley (Table 17); the Three Pigeons Sand and Gravel (informal) and Princes Risborough Sand and Gravel members in the Thame and Windrush valleys (Table 17); the Cold Ash Gravel, Bucklebury Common Gravel, and Beenham Stocks Gravel members in the Kennet valley (Table 18a); the Surrey Hill Gravel in the Blackwater–Loddon and Mole valley districts (Table 18a); and the Woodford Gravel, Dollis Hill Gravel and Gerrards Cross Gravel members in the Lower Thames valley (Table 18a).

Type area/Reference section
Type area: The course of the pre-diversionary River Thames from Stebbing, Essex to Claydon, Suffolk [TL 66 24–TM 13 49] (Whiteman and Rose, 1992).

Lower and upper boundaries
Unconformable on bedrock: Cretaceous, Palaeogene and Crag Group. Differentiation from the Crag Group can be difficult where the latter is reworked, and the distinction must be made on the basis of sedimentological structures: the Crag Group is marine, the Kesgrave Catchment Subgroup is fluvial.

Commonly overlain by mid-Pleistocene glacigenic deposits. Upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of more angular clasts, chalk, and poorer sorting in the latter is usually helpful.

Landform description and genetic interpretation
Fluvial, lacustrine and organic deposits of the pre-diversionary River Thames.

Thickness
About 18 m. Individual terrace aggradations typically 5–10 m thick.

Distribution and extent
Formation is restricted to the Thames Valley, Essex and Suffolk. It does not extend into Norfolk (Hamblin and Moorlock, 1995).

Age
Early to Middle Pleistocene (MIS 61–13).

10.2.2.2 Colchester Formation

The youngest four terrace aggradations in the Kesgrave Catchment Subgroup are placed in the Colchester Formation by Whiteman and Rose (1992, Table 1). They are named the *Waldringfield Membe*r, the *Ardleigh Member*, the *Wivenhoe Member* and the *Lower St. Osyth Member* (Allen, P, 1984; Bridgland, 1988). Of these currently only the Waldringfield Member is formally defined in the BGS Lexicon. The *Westmill Gravel Member* and the *Winter Hill Gravel Member* of the Thames have also been named within this formation (Section 12.3.2.2, Tables 18a and 18b). The deposits of the Colchester Formation are less extensive than those of the Sudbury Formation, and are characterised by lower quartz and quartzite content, although large erratics and Welsh felsic volcanic rocks occur with a greater frequency. The deposits are typically 5 to 12 m thick and comprise bodies of cross-bedded and massive, moderately-sorted sand and gravel, entrenched into bedrock, with around 5 m difference in surface elevation between members. Intraformational ice-wedge casts and pollen (West, 1980) indicate periglacial, cool temperate and warm temperate environments. The terraces follow a relatively sinuous course, at elevations below that of the lowest col of the Cotswold escarpment. Whiteman and Rose (1992) suggest that the upper part of the Thames catchment was beheaded due to glacial erosion of the soft rocks between the Welsh Borderland and the Cotswolds, by a glaciation earlier than any of those which reached East Anglia. Alternatively it may have been captured by the developing River Severn, or by the proto-Soar (Sumbler, 1996).

Name
Colchester Formation (CCHR) (after Whiteman and Rose, 1992).

Lithology
Lithologies include gravel, sand, silt, clay and peat. Most of the deposits are gravels, with sedimentary structures indicating deposition by a braided river. Lacustrine silts and clays and organic peats are uncommon. The gravels of the formation are characterised by quartz and quartzite from the Triassic, Carboniferous and Devonian rocks of the West Midlands, Welsh borderland and possibly south-western Pennines, and felsic volcanic rocks from northern Wales. These lithologies form a lower percentage than in the Sudbury Formation, and are believed to have been derived from that formation, but mega-erratics and felsic volcanic rocks from Wales and the Welsh borderland occur with a generally greater frequency than in the Sudbury Formation. The fluvial gravels occupy terrace levels and the members are defined on the basis of altitude and pebble clast content. The members comprise bodies of cross-bedded and massive, moderately-sorted sand and gravel. The aggradations are generally entrenched into bedrock with a difference in surface elevation in the order of 5 m. Intraformational ice wedge casts and pollen indicate periglacial, cool temperate and warm temperate climates.

Formal subdivisions and correlation table
Subdivided into the Westmill Gravel Member of the Colne valley and Winter Hill Gravel Member (Section 12.3.2.2 and Tables 3, 18a and 18b); includes the Waldringfield, Ardleigh, Wivenhoe, and Lower St Osyth members in East Anglia (Tables 3 and 15).

Type area/Reference section
Type area: The course of the pre-diversionary River Thames from Chelmsford to Colchester, Essex (Whiteman and Rose, 1992).

Lower and upper boundaries
Unconformable on bedrock: Cretaceous, Palaeogene and Crag Group. Differentiation from the Crag Group can be difficult where the latter is reworked, and the distinction must be made on the basis of sedimentological structures: the Crag Group is marine, the Kesgrave Catchment Subgroup is fluvial.

Commonly overlain by mid-Pleistocene glacigenic deposits. Upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of more angular clasts, chalk, and poorer sorting in the latter is usually helpful. The uppermost 1.0–1.5 m of the formation is commonly affected by the Valley Farm Soil, a rubified and clay-enriched horizon, and/or by the Barham Arctic Structure Soil, a complex pedogenic horizon (Rose et al., 1985).

Landform description and genetic interpretation
Fluvial, lacustrine and organic deposits of the pre-diversionary River Thames.

Thickness
Individual terrace aggradations are typically 5–12 m thick, but may locally reach about 21.3 m.

Distribution and extent
The formation is restricted to the Thames Valley, Essex and Suffolk. It does not extend into Norfolk (Hamblin and Moorlock, 1995).

Age
Early to mid-Pleistocene (pre-MIS 13).

WALDRINGFIELD MEMBER (WALD)

The Waldringfield Member comprises up to 5.3 m gravels composed of flint, quartz and quartzite (Rose and Allen, 1977; Allen, P., 1984). It rests on bedrock and is overlain by till of the Lowestoft Formation.

10.2.3 Bytham Catchments Subgroup

The deposits of the Bytham River comprise a series of quartz- and quartzite-rich fluvial sediments similar to those of the Kesgrave Catchment Subgroup, but generally richer in quartzite. They can be traced discontinuously from Warwickshire to eastern Suffolk (Rose, 1987), and were laid down by a single river system flowing from the West Midlands and southern Pennines, across the area now occupied by Fenland, and crossing the Chalk outcrop at Bury St. Edmunds. From Diss to Beccles they roughly follow the line of the present-day River Waveney. They are directly overlain by the Happisburgh and Lowestoft formations.

Rose (1994) and Bateman and Rose (1994) use the name Bytham Sands and Gravels to apply to the deposits throughout the length of the river, and this practice has been followed by BGS on 1:50 000 Sheets E176 and E190 in the Lowestoft and Eye districts (Moorlock et al., 2000a). Adopting this definition, the BGS framework establishes a single Bytham Catchments Subgroup (Tables 3 and 15; Section 3.2.3.1), subdivided into a series of formations and members. However, it should be noted that around Redgrave, in the Waveney Valley, deposits of the subgroup had previously been named as the Ingham Sand and Gravel (Clarke and Auton, 1982), and this name was used by Lewis (1993) for the formation throughout Suffolk. Lewis (pp. 10–19 in Bowen, 1999) used the terms Bytham Formation to describe the deposits in Lincolnshire (west of the Fens), Shouldham Formation in western Norfolk (on the east side of the Fens) and in western Suffolk, and Ingham Formation in eastern Suffolk.

10.2.3.1 BYTHAM SAND AND GRAVEL FORMATION

The formation encompasses fluvial, lacustrine and organic deposits of the pre-Glacial Bytham River from Castle Bytham east through Witham-on-the-Hill, Lincolnshire towards the Fen edge south of Bourne.

Name
Bytham Sand and Gravel Formation (BYTH) (after Rose, 1987, Rose, 1994 and Bateman and Rose, 1994).

Lithology
Commonly a basal coarse-grained gravel is overlain by red fine- to medium-grained sand. The gravels are composed of Triassic grey and purple quartzite, vein quartz, Jurassic limestone and ironstone, and Carboniferous sandstone and chert. The gravels are distinguished from the Baginton Sand and Gravel Formation to the west by their inclusion of a significant proportion of Jurassic as well as Triassic material.

Formal subdivisions and correlation table
No subdivisions (Tables 3 and 15).

Type area/Reference section
Partial type section: Gravel pit, Thunderbolt Pit [SK 998 184], 800 m east of Castle Bytham (Rose, 1989b; Lewis, 1993).

Lower and upper boundaries
Unconformably overlies Jurassic bedrock.

Commonly overlain by mid-Pleistocene glacigenic deposits. Upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of more-angular clasts, chalk, and poorer sorting in the latter is usually helpful.

Landform description and genetic interpretation
River terrace deposits. Sedimentary structures imply deposition in a braided river environment.

Thickness
Individual aggradations are usually 3–5 m thick; may total 18 m locally.

Distribution and extent
The deposits occupy the valley of the pre-glacial Bytham River from Castle Bytham east through Witham-on-the-Hill towards the Fen edge south of Bourne. West of Castle Bytham it is replaced by the Baginton Sand and Gravel Formation (Section 11.1.2.1).

Age
Early Pleistocene (pre-MIS13).

10.2.3.2 Ingham Sand and Gravel Formation

Lewis (1993) raised four members in the Ingham Formation, which represent successive sediment aggradations and associated terraces in Central East Anglia and the Waveney Valley. From the highest downwards, these are the Seven Hills Gravel Member, the Ingham Gravel Member, the Knettishall Gravel Member and the Timworth Gravel Member. Bowen (1999) dropped the descriptor gravel from the names of the members, and amended Ingham Gravel Member to Ingham Farm Member. The BGS framework proposes that the four units be called the *Seven Hills Gravel Member*, the *Ingham Farm Gravel Member*, the *Knettishall Gravel Member*, and the *Timworth Gravel Member* of the Ingham Sand and Gravel Formation. None of the members are formally defined in the BGS Lexicon. Only the lowest three are known on the Diss (175) and Lowestoft (176) sheets, and it appears that the terrace deposit referred to as Ingham Sand and Gravel in the memoir for the Diss sheet (Mathers et al., 1993) is in fact the Knettishall Gravel Member of Lewis (1993). At Kessingland in north-eastern Suffolk, strata previously included in the Cromer Forest-bed Formation (Section 10.2.3) are now believed to represent the estuarine deposits of the Bytham River, and it is proposed that these strata be included here in the Bytham Catchments Subgroup.

Name
Ingham Sand and Gravel Formation (ISAG) (after Clarke and Auton, 1982, Lewis, 1993; Ingham Formation of Lewis, p. 19 in Bowen, 1999).

Lithology
Lithologies include sand, gravel, clay and silt. Deposits of four separate terrace levels are recognised as members of the formation. Commonly a basal fine- to coarse-grained sandy gravel is overlain by fine- to coarse-grained pebbly sands, with few clay and silt beds. The gravels contain a high proportion (up to 54%) of rounded pebbles of grey and purple 'Bunter' quartzite of Triassic derivation, up to 47% vein quartz, and up to 56% flint derived from the local Chalk. There are traces of chalk and of igneous and metamorphic rocks. Sedimentary structures indicate deposition by braided rivers. The formation can be distinguished from formations of the Kesgrave Subgroup by the high ratio of quartzite to vein quartz in the gravels.

Formal subdivisions and correlation table
Subdivided into four informal members, the Seven Hills Gravel, the Ingham Farm Gravel, the Knettishall Gravel, and the Timworth Gravel members (Tables 3 and 15).

Type area/Reference section
Partial type section: Gravel pit 550 m north of Ingham [TL 855 715] (Lewis and Bridgland in Lewis et al., 1991).

Lower and upper boundaries
Unconformable on bedrock of the Chalk Group and Crag Group. Commonly overlain by Middle Pleistocene glacigenic deposits.

Upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of more angular clasts, chalk, and poorer sorting in the latter is usually helpful.

Landform description and genetic interpretation
Formation encompasses fluvial (river terrace), lacustrine and organic deposits of the pre-Glacial Bytham River in central East Anglia.

Thickness
About 13 m.

Distribution and extent
Recognised over a wide area of central East Anglia, from the Lark Valley in the west, to Knettishall in the valley of the Little Ouse, and along the valley of the Waveney to the North Sea coast at Pakefield and Kessingland.

Age
Early to mid-Pleistocene (pre-MIS 13).

10.2.3.3 Shouldham Sand and Gravel Formation

The BGS framework adopts the Shouldham Formation of Lewis (1993), here named the Shouldham Sand and Gravel Formation, which is present in Norfolk. It has four members, the *Shouldham Thorpe Gravel Member* (which remains informal), the *Fodderstone Gravel Member*, the *Lakenheath Gravel Member* and the *High Lodge Silt Member* (after Lewis, p. 19 in Bowen, 1999). They are distinguished from one another by their difference in height above sea level.

Name
Shouldham Sand and Gravel Formation (SMSG) (after

Lewis, 1991, 1993; Shouldham Formation of Lewis, p. 19 in Bowen, 1999).

Lithology
Lithologies include sand, gravel, clay and silt. At the type site, yellowish red to brownish yellow cross-stratified sands, with minor beds of pebbly sand, overlie sands and gravels. In the lower unit, massive and planar cross-stratified gravels alternate with planar cross-stratified, thick bedded, or massive pebbly and trough-bedded sands. Clast analysis of the gravels (11.2–16.0 mm fraction) found 60.1% quartz and quartzite, 19.0% flint, 12.1% chert and 7.0% ironstone. The quartzite is derived from Triassic pebble beds to the west, chert from the Carboniferous, and flint from the local Chalk.

Formal subdivisions and correlation table
Subdivided into four members, the Shouldham Thorpe Gravel, Fodderstone Gravel, Lakenheath Gravel, and the High Lodge Silt members (Tables 3 and 15).

Type area/Reference section
Partial type section: Gravel pit [TF 657 085], 800 m north-west of Shouldham Thorpe (Lewis in Lewis et al., 1991).

Lower and upper boundaries
Unconformable on Cretaceous bedrock. Commonly overlain by mid-Pleistocene glacigenic deposits.

Upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of more angular clasts, chalk, and poorer sorting in the latter is usually helpful.

Landform description and genetic interpretation
The formation encompasses fluvial, lacustrine and organic deposits of the pre-glacial Bytham River in Norfolk.

Thickness
About 6 m.

Distribution and extent
Deposits occupy the valley of the pre-glacial Bytham River from Shouldham Thorpe, Norfolk, southwards along the eastern margin of the Fens, as far south as High Lodge, Mildenhall.

Age
Early to mid-Pleistocene (pre-MIS 13).

SHOULDHAM THORPE GRAVEL MEMBER

The Shouldham Thorpe Gravel Member (Unit 1, Shouldham Sands and Gravels of Lewis, pp. 127–130 in Lewis et al., 1991) comprises 3 m of gravel composed of quartz, quartzite and flint.

FODDERSTONE GRAVEL MEMBER (FOGR)

The Fodderstone Gravel Member (Unit 2, Shouldham Sands of Lewis, pp. 127–130 in Lewis et al., 1991) comprises up to 3 m sand with gravel beds composed of quartz, quartzite and flint.

LAKENHEATH GRAVEL MEMBER (LHTH)

The Lakenheath Gravel Member comprises up to about 3 m of quartz- and quartzite-rich gravel. The stratotype is in gravel pits near the summit of Maidcross Hill, Lakenheath (Rose, 1987; Lewis, 1993).

HIGH LODGE SILT MEMBER (HLSI)

The High Lodge Silt Member (High Lodge Member of Ashton, p. 19 in Bowen, 1999) comprises up to about 5 m of brown silty clay and clayey silt with thin sand laminae (Cook et al., pp. 59–69 in Lewis et al., 1991). Pollen and coleopteran assemblages indicate cool temperate conditions and boreal forest vegetation (Hunt, 1992). There is a sparse mammalian fauna (Stuart, 1992).

10.2.3.4 PEDOSTRATIGRAPHICAL UNITS OVERLYING FORMATIONS OF THE KESGRAVE AND BYTHAM SUBGROUPS

Two fossil soils, developed upon the sands and gravels of the Kesgrave and Bytham subgroups, are important stratigraphical units representing the depositional hiatus between the pre-glacial fluvial formations and the glaciations that formed the Corton and Lowestoft formations (Kemp et al., 1993). Neither term yet appears in the BGS Lexicon.

The *Valley Farm Soil* (Kemp, 1985) is rubified and mottled, and contains substantial quantities of translocated clay. It affects the topmost 1.5 m of various formations of the Kesgrave and Bytham subgroups. Originally it was attributed solely to temperate pedogenesis during the Cromerian stage, but as the age range of the Kesgrave Subgroup has become extended, so the Valley Farm Soil has come to be regarded as a complex stratigraphical unit spanning cold and temperate intervals over more than a million years, from Pre-Pastonian to Cromerian (Kemp et al., 1993).

The *Barham Soil* (Rose et al., 1985), of early Anglian age, is developed on sediments of the Kesgrave Subgroup or superimposed on the Valley Farm Soil. It reveals a variety of large- and small-scale cryogenic features. The most widespread are periglacial involutions, disrupting sedimentary bedding to a maximum depth of 1.8 m, also frost-shattering of stones and fragmentation or deformation of the illuvial clay coatings developed in the Valley Farm Soil (Kemp et al., 1993).

10.3 ALBION GLACIGENIC GROUP

10.3.1 Formations

There are currently no subgroups for the deposits of the Albion Glacigenic Group lying to the south of the Devensian Ice limit. Most of the glacial deposits of East Anglia are assigned to the group (Table 7b). In recent times these have generally been accepted as being wholly of Anglian (MIS 12) age (Bowen, 1999), and to be derived from two distinct ice-sheets, the 'Scandinavian Ice-sheet', which entered the area from the north or just east of north and deposited what has traditionally been known as the 'North Sea Drift' and latterly the North Sea Drift Formation, and the 'British Eastern Ice-sheet', which entered the area from the west and north-west, and deposited the bulk of the Anglian deposits, which belong to the **Lowestoft Formation**.

The 'British Eastern Ice-sheet' brought erratics derived from Mesozoic outcrops to the north-west, principally the Chalk and Jurassic clay formations. In eastern Norfolk and north-eastern Suffolk, by contrast, the North Sea Drift Formation (Reid, 1882; Banham, 1988; Hart, 1987; Hart and Boulton, 1991, Lunkka, 1994) was thought to have been derived dominantly from the supposed 'Scandinavian Ice-sheet', which was considered to be characterised by a suite of igneous and metamorphic erratics from the Oslofjord region. The term Corton Formation was introduced by Arthurton et al. (1994) in the Great Yarmouth district (Table 7b), to include deposits that correlate with the lower part of the North Sea Drift Formation. However the Corton Formation is superseded in this report by the **Happisburgh Glacigenic Formation** (after Lee et al., 2004).

The stratigraphy of the North Sea Drift Formation is complicated by glacial tectonics and apparently has never been fully understood: conflicting stratigraphies have been published in recent years (Hart, 1987; Hart and Boulton, 1991; Lunkka, 1994). The traditional stratigraphy of the North Sea Drift has been rendered redundant by the BGS survey of the Cromer district, which has demonstrated that the lowest but one till in the North Sea Drift Formation (the Walcott Diamicton of Lunkka, 1994) equates with the Lowestoft Formation till elsewhere. Also the distinction between the North Sea and British Eastern ice-sheets has become less certain, since on-going research by BGS in collaboration with Royal Holloway University of London has failed to find evidence of Scandinavian erratics in any of the three North Sea Drift tills (for discussion see Hoare et al., 2006 and Lee et al., 2006), but has found microflora that originated from northern Britain. Thus in the present report the 'North Sea Drift Formation' is replaced by four new glacigenic formations (Tables 7a, 7b and 15). The **Happisburgh Glacigenic Formation** includes the lowermost tills of the North Sea Drift Formation (the Happisburgh Diamicton of Lunkka, 1994, and the till at Corton), the **Lowestoft Formation** is retained and includes the Walcott Diamicton (Table 7b). A third formation, here named the **Sheringham Cliffs Formation** (after Lee et al., 2004), is raised to incorporate the third North Sea Drift till (the Corton Till of Lunkka, 1994). A further formation, the **Briton's Lane Formation** (Lee et al., 2004), is raised to include a suite of gravels of North Sea and Scandinavian origin which overlie the Lowestoft and Sheringham Cliffs formations (Tables 7b and 15). A cross section from Lee et al. (2004) shows the stratigraphical relationships between the four formations (Figure 20). Dating of these four formations is currently uncertain: in this report it is tentatively postulated that they are correlated with MIS 16, 12, 10, and 6, respectively.

10.3.1.1 Happisburgh Glacigenic Formation

The Happisburgh Glacigenic Formation comprises diamictons (tills), sands and sandy gravels, and subsidiary laminated and massive lacustrine clays. The formation equates with the lower part of the North Sea Drift of Reid (1882) and with the Corton Formation of Arthurton et al. (1994).

The deposits of the Happisburgh Glacigenic Formation have traditionally been ascribed to the Anglian Stage and to MIS 12 age (Bowen, 1999), as has the Lowestoft Formation (see below). However, Rose et al. (1999a) record the discovery of boulders of mafic volcanic rocks, high-grade metamorphic rocks and Carboniferous limestone, many of which have angular edges, in the Second Terrace deposits of the Bytham Sand and Gravel Formation (Bytham Catchments Subgroup). These erratics are of northern British provenance and are interpreted to be of glacial origin. This interpretation is supported by the presence of clasts of sandy till, similar to that in the Happisburgh Glacigenic Formation. These discoveries led Hamblin et al. (2000) to equate the Second Terrace of the Bytham Sand and Gravel Formation with the Happisburgh Glacigenic Formation, and to postulate that if the Lowestoft Formation dates from MIS 12, then the Happisburgh Glacigenic Formation may date from MIS 16.

Name
Happisburgh Glacigenic Formation (HPGL) (after Lee et al., 2004, and Hamblin et al., 2005).

Lithology
Consists of a range of diamictons, sands and gravels, sands and laminated silts and clays. The diamictons (Happisburgh Till, Corton Till and California Till members) are typically sandy matrix-supported diamictons that contain a greater abundance of flint and quartzose lithologies relative to chalk, distinguishing them from the more chalky tills of the overlying Lowestoft Formation.

Formal subdivisions and correlation table
Subdivided into the Happisburgh Till, Ostend Clay, Happisburgh Sand, Corton Till, Starston Till, Banham, Leet Hill Sand and Gravel, Corton Sand, and California Till members (Tables 7a, 7b and 15).

Type area/Reference section
Type section: Coastal cliff sections beneath Happisburgh lighthouse, located 1 km south-east of Happisburgh village. At this locality an 8 m-thick sequence is evident, comprising Happisburgh Till Member, Ostend Clay Member, Happisburgh Sand Member, Corton Till Member and Corton Sand Member (Lee et al., 2004).

Lower and upper boundaries
The lower boundary of the Happisburgh Glacigenic Formation is commonly erosional in north-east Norfolk and the Waveney Valley and truncates shallow marine deposits of the Wroxham Crag Formation. More rarely, such as at sites like Leet Hill in southern Norfolk, coarse-grained outwash deposits (the Leet Hill Sand and Gravel Member) exhibit a gradational lower contact with river terrace deposits of the Bytham Catchments Subgroup.

The upper boundary of the Happisburgh Formation is erosional and angular, and truncated by the more chalky tills of the Lowestoft Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to about 20 m.

Distribution and extent
The southern limit of the Happisburgh Glacigenic Formation occurs within the Lowestoft district. From there it can be traced northwards across the Great Yarmouth, North Walsham and Mundesley districts, and westwards into the Norwich and Diss districts. In coastal sections, deposits of the formation can be observed discontinuously between Pakefield (near Lowestoft) to Overstrand in north-east Norfolk.

Age
Pleistocene (MIS ?16).

Happisburgh Till Member (HPTI)

The Happisburgh Diamicton of the north-east Norfolk coast sections (Hart and Boulton, 1991; Lunkka, 1994) is now known to be lower in the succession than the till at Corton (J R Lee, written communication), and is here named the Happisburgh Till Member (Lee et al., 2004). Both the Happisburgh and Corton Till members are exposed in the sea cliffs at Happisburgh [TG 389 305]. Studies of clast lithologies and allochthonous palynomorphs (Lee et al., 2002; Riding, 2002; Hamblin et al., 2005) demonstrate that the two tills of the Happisburgh Glacigenic Formation were deposited by an ice-sheet that flowed from central and southern Scotland, eroding materials from eastern England and the western margins of the North Sea Basin, and show no evidence of Scandinavian derivation.

Ostend Clay Member

The informal Ostend Clay Member is composed of stratified diamicton and of clay-silt rhythmites with occasional sand ripples. It occupies troughs between ridges on the upper surface of the Happisburgh Till Member (Lee et al., 2004), occurring in cliff sections from Ostend to Happisburgh lighthouse.

Happisburgh Sand Member (HPSA)

The Happisburgh Sand Member consists of yellowish brown and yellow-orange stratified sands. The sands exhibit a range of bedding structures including planar and trough cross-bedding, ripples, horizontal bedding, channel structures and sporadic horizons of convolute bedding. The transition from the laminated silts and clays of the Ostend Clay Member (also part of the Happisburgh Formation) to the sandy facies of the Happisburgh Sand Member is erosional and marked by a thin gravel lag. The change from the laminated silts and clays of the Ostend Clay Member (also part of the Happisburgh Formation) to the sandy facies of the Happisburgh Sand Member is erosional and marked by a thin gravel lag (Lunkka, 1994).

Corton Till (COTI) and Corton Sand (CORS) members

In the Great Yarmouth and Mundesley and North Walsham districts (BGS 1:50 000 Sheets E162 and E132/148) the Corton Formation (see above) was divided into arenaceous and argillaceous deposits. At Corton, which is near the southern limit of the Happisburgh Formation outcrop, the strata comprise till overlain by sand. The till comprises a homogeneous sheet of dark brown, very sandy clay or clayey sand, coarsely laminated with sand interbeds and containing chalk pellets, rounded flints and shell fragments. It was named the Cromer Till or Norwich Brickearth (Banham, 1971; Mitchell et al., 1973a; Bridge and Hopson, 1985), being equated with the till around Norwich that has traditionally been called Norwich Brickearth (Baden-Powell and West, 1960). However the term Norwich Brickearth is colloquially used in East Anglia to refer to any weathered till suitable for brick-making, and also for wind-blown cover silts similarly utilised, so its use is not to be recommended (Rose et al., 1999b). In this framework it is named *Corton Till Member* (COTI) (Lee et al., 2004). The sand unit at Corton has been named the Corton Sands (Baden-Powell, 1950; Bridge and Hopson, 1985), Corton Beds (Banham, 1971; Mitchell et al., 1973a), or Corton Member (Lewis, p. 20 in Bowen, 1999). Here, it is named the *Corton Sand Member* (Lee et al., 2004).

Starston Till Member (STIL)

In southern Norfolk, a till within the Happisburgh Formation has been termed the Starston Till (Lawson, 1982; Mathers et al., 1993) or Starston Member (Lewis, p. 20 in Bowen, 1999), and is here named the Starston Till Member. This can be up to 11.5 m thick and consists generally of structureless clayey sands, sandy diamictons and laminated sediments, with scattered chalk pebbles and fine flint gravel. It is most likely the lateral equivalent of the Corton Till Member. The Starston Till as proposed by Lawson (1982) was included in the Beccles Beds. In the Diss district, Auton et al. (1985) and Mathers et al. (1993) showed from borehole evidence an upward succession of sands and pebbly sands informally named the Pebbly Series, the Mendham Beds, Beccles Glacial Beds (BEC), and Starston Till. At Knettishall, Suffolk, the informal *Coney Weston Sand and Gravel Member* (CNYSG) is considered by Lewis and Rose (1991) to be outwash deposits associated with an underlying diamicton comparable with the Starston Till Member.

Banham Member (BANM)

The Banham Member (after Mathers et al., 1993) comprises up to 9 m of lithologically variable silt and clay, with subordinate diamicton, and sand and gravel characterised by abundant quartz and quartzite pebbles. Referred to as the Banham Beds (Mathers et al., 1987), and interpreted as glacial lake deposits they are confined to the Banham and East Harling areas, north-west of Diss.

Leet Hill Sand and Gravel Member (LEHI)

The Leet Hill Sands and Gravels (Hopson and Bridge, 1987) or Leet Hill Member (Lewis, p. 20 in Bowen, 1999) underlies the Corton Till Member in the lower Waveney Valley inland of Corton. It is here named the Leet Hill Sand and Gravel Member (Lee et al., 2004). It comprises cross-bedded pebbly sands and sandy gravels, and is interpreted as proximal glaciofluvial outwash.

California Till Member (CATI)

The California Till Member (Lee et al., 2004), previously the Norwich Brickearth of Lunkka (1994) and Corton Till of Arthurton et al. (1994) consists of a stratified matrix-supported diamicton that comprises beds of massive brown sandy diamicton, separated by beds of massive and horizontal-bedded chalky sand with sporadic augen-shaped lenses of fine silty sand. It is similar in lithology to the Corton Till Member. It has been logged in cliff sections between California Gap and Scratby, to the north of Great Yarmouth.

10.3.1.2 Lowestoft Formation

Baden-Powell (1948) introduced the term Lowestoft Boulder Clay, while Bridge and Hopson (1985) and Hopson and Bridge (1987) formally defined a Lowestoft Till Group. The term Lowestoft Formation (Mathers et al., 1987; Lewis, pp. 19–20 in Bowen, 1999) is accepted here, and includes associated outwash deposits as well as the tills (Lee et al., 2004).

The Lowestoft Formation is generally ascribed to MIS 12 (Bowen, 1986), principally because deep-sea data show this to be one of the coldest stages of the mid-Pleistocene. Support for a MIS 12 age for the Lowestoft Formation comes from U-series dating of Hoxnian interglacial deposits at Marks Tey, Essex (Rowe et al., 1999), which can be reliably correlated with the type site of the Hoxnian at Hoxne, both of which interglacial sites directly overlie the Lowestoft Formation.

Name
Lowestoft Formation (LOFT) (after Baden-Powell, 1948, Mathers et al., 1987, and Lewis, pp. 19–20 in Bowen, 1999; revised by Lee et al., 2004).

Lithology
Lithologies include diamictons, sands and gravels. The tills within the Lowestoft Formation typically contain a significantly higher percentage of chalk than the underlying tills. The gravels in the Dunwich Group contain a significant amount of quartzose lithologies and only very minor quantities of erratics and chalk, whereas the gravels in the Lowestoft Formation contain common erratics from Scotland and northern England, and abundant chalk where not decalcified.

Formal subdivisions and correlation table
Subdivided into mainly informal members in East Anglia (after Moorlock et al., 2000a; Lee et al., 2004). The Oulton Clay, Aldeby Sand and Gravel, High Lodge Gravel and Haddiscoe Sand and Gravel members are formally defined in the BGS Lexicon. Other units include the Lowestoft Till, Walcott Till, Pleasure Gardens Till, Woolpit Beds, Barham Sand and Gravel and Observatory members (Tables 7a, 7b and 15). In Lincolnshire the Wragby, Calcethorpe and Belmont tills of Straw (1966, 1983), members of the Lowestoft Formation of Lewis and Sumbler (pp. 10–13 in Bowen, 1999), who included the Belmont Till in their Calcethorpe Member, and the Welton le Wold Formation remain informal units (Table 15). Note that the Wragby Member has also been assigned to the Wolston Glacigenic Formation of the Bain Valley (Section 11.2.1.1 and Table 16).

Type area/Reference section
Type section: Cliff sections at Corton [TM 546 968], Norfolk (Moorlock et al., 2000a).

Lower and upper boundaries
The Lowestoft Formation unconformably overlies a range of Mesozoic and Cenozoic (Palaeogene–Neogene) bedrock formations, and in eastern East Anglia also unconformably overlies the older glacigenic deposits of the Happisburgh Formation (formerly Corton Formation) and fluvial sands and gravels of the Dunwich Group.

The Lowestoft Formation is overlain unconformably by deposits of the Britannia Catchments Group and in north-eastern East Anglia by the Sheringham Cliffs Formation. Where the uppermost part of the Lowestoft Formation comprises sand and gravel, its upper boundary is difficult to determine if overlain by younger sand and gravel, but in general the younger sand and gravel is better sorted and is chalk-free.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Extremely variable. It is thickest in buried valleys where locally as much as 60 m may be present. Thick accumulations are also more generally present beneath much of northern Essex and south Suffolk.

Distribution and extent
There is some debate as to the extent of the Lowestoft Formation. It is extensive over East Anglia having its southern limit near Romford, Essex and in north London. It is probable that most of the chalky tills in central East Anglia are also part of the Lowestoft Formation. In northern East Anglia the very chalky tills, commonly referred to informally as the 'marly drift', were generally included within the Lowestoft Formation, but recent work has indicated that these may belong to a younger glaciation. Likewise, chalky tills in the south and east Midlands have commonly been linked with the Lowestoft Formation, but these may be younger. It is also uncertain how the pre-Devensian tills in Lincolnshire relate to the Lowestoft Formation.

Age
Anglian (MIS 12).

LOWESTOFT TILL MEMBER (LTIL)

At its type site at Corton (Baden-Powell, 1948), the Lowestoft Formation is divided into three units (Banham, 1971; Arthurton et al., 1994). The lowest is referred to simply as Lowestoft Till by Banham (1971) and as Lowestoft Till Formation (undivided) by Arthurton et al. (1994). It is here named the Lowestoft Till Member (Lee et al., 2004). It comprises olive-grey, sandy, silty clay with scattered lithic clasts. The matrix is largely composed of reconstituted Kimmeridge Clay and the clasts consist of subangular to subrounded fragments of chalk, flint, older Mesozoic limestones and sandstones, and quartz and quartzite pebbles.

The type site at Corton [TM 546 968] is recognised as the stratotype for the Anglian Stage, correlated with MIS 12 (see Lewis, pp. 19–20 in Bowen, 1999).

WALCOTT TILL MEMBER (WATI)

In the north-east Norfolk, BGS survey of the Cromer sheet (Hamblin et al., 2000) has shown that the Second Cromer Till of Banham (1968) or Walcott Diamicton of Lunkka (1994) is the local representative of the Lowestoft Till Member, and this is here named the Walcott Till Member after Lee et al. (2004).

OULTON CLAY (OULT) AND PLEASURE GARDENS TILL MEMBERS

At Corton the main till of the Lowestoft Formation is overlain by the Oulton Beds (Banham, 1971). These comprise stiff grey laminated clay overlain by grey to buff sand with ripple-drift bedding. Banham believed them to have been deposited in water ahead of the retreating Lowestoft ice-sheet, over a lateral extent of a few square kilometres. They are overlain by the Pleasure Gardens Till (Banham, 1971). This unit is similar in character to the Lowestoft Till Member but has a more chalky matrix and contains smaller chalk erratics. The two members are here named the Oulton Clay Member and the Pleasure Gardens Till Member (after Lee et al., 2004). (Currently only the Oulton Clay Member is defined in the BGS Lexicon).

The name Woolpit Beds has been given to a high-level 'brickearth' in the Woolpit area of Suffolk (Bristow and Gregory, 1982) and mapped on BGS 1:50 000 Sheets E189 (Bury St Edmunds) and E190 (Eye). The deposits comprise buff laminated silt, fine-grained sand, silty clay and clayey silt, up to at least 23 m thick (Bristow, 1990). A sparse fauna of Pleistocene foraminiferids has been obtained, but the deposit is unlikely to be marine and in situ, in view of its elevation (60 m above OD) and its distance from the coast (35 km) or from the nearest known Middle Pleistocene marine deposits (45 km). More likely the sediment and its fauna have been washed out of ice surrounding a terrestrial hollow in the till (Bristow, 1990). The deposits are here named the Woolpit Beds (WPIT).

HADDISCOE SAND AND GRAVEL MEMBER (HGV)

Gravels flanking the valleys of the rivers Yare and Waveney are referred to as the Haddiscoe Sands and Gravels

(Arthurton et al., 1994; Moorlock et al., 2000a). These include black, well-rounded fine- to coarse-grained flint gravels, and large rotated blocks of sand which Bridge and Hopson (1985) consider could only have been incorporated in a frozen condition. This unit is here named the Haddiscoe Sand and Gravel Member.

Aldeby Sand and Gravel Member (ASAG)

Another gravel unit, the Aldeby Sands and Gravels (Hopson, 1991) similarly flanks the valleys of the Waveney, its tributary the Broome Beck, and the Hundred River to the south of the Waveney. This deposit comprises gravels dominated by angular flint with some quartz and quartzite, also lenses of chalky till up to more than a hundred metres in lateral extent, discrete beds of sand and clay, reconstituted chalk, and masses of sand apparently transported from the Corton Sand. This unit is here named the Aldeby Sand and Gravel Member.

Observatory Member

The informal Observatory Member (Lewis and Boreham, p.20 in Bowen, 1999) appears to be the earliest evidence of the River Cam system, but is included in the Lowestoft Formation as it may be mostly composed of glacial meltwater gravels (Marr, 1920).

Barham Sand and Gravel Member (BHSG)

Glaciofluvial deposits laid down ahead of the advancing Anglian ice in Suffolk, which contain much quartz and quartzite derived from the Kesgrave Catchment Subgroup, were named the Barham Sands and Gravels by Allen, P (1984), and are here named the Barham Sand and Gravel Member of the Lowestoft Formation.

High Lodge Gravel Member (HLOGR)

Glaciofluvial deposits within the palaeovalley of the River Bytham in the Mildenhall area of Suffolk, comprising gravel and sand that is predominantly composed of flint and chalk with quartz and quartzite and traces of other far-travelled rock-types including Rhaxella chert. These deposits were named as the Mildenhall Upper Sands and Gravels by Cook et al. (pp. 59–69 in Lewis et al., 1991). They rest unconformably, locally in channels, on the High Lodge Silt Member (Shouldham Sand and Gravel Formation).

The informal **Welton le Wold Formation** (Bowen, p. 13, in Bowen, 1999) forms part of the glacial sequence of the Lincolnshire Wolds in the vicinity of Welton le Wold [TF 282 884] where a sequence of gravels and tills was identified in quarry workings (Alabaster and Straw, 1976). The glacigenic Welton Member (Bowen, p. 13, in Bowen, 1999) was suggested to represent a glaciation intermediate between the Anglian and Devensian glaciations (Bowen et al., 1986). This continues to be its current status although it could equally be the same age as the Lowestoft Formation and thus Anglian. Thus correlation with MIS 6 is only tentative.

10.3.1.3 Sheringham Cliffs Formation

The Sheringham Cliffs Formation is introduced here (after Lee et al., 2004) to include the Third Cromer Till of the North Sea Drift Formation (Banham, 1968, 1988), the Cromer Diamicton of Lunkka (1994), and associated outwash and lacustrine members.

The age of the Sheringham Cliffs Formation is uncertain. At Trimingham, the Bacton Green Till (see below) is overlain by an interglacial deposit of proposed Hoxnian age (Hart and Peglar, 1990). This date is currently not proven, but if it is correct then the Sheringham Cliffs Formation could be correlated with MIS 12, as is the Lowestoft Formation. However, Rowe et al. (1997) recorded a peat of MIS 9 age directly overlying a chalky till at Tottenhill in north-west Norfolk, implying an age of MIS 10 for the till, and that age has been provisionally adopted for the Sheringham Cliffs Formation.

Name
Sheringham Cliffs Formation (SMCL) (after Lee et al., 2004 and Hamblin et al., 2005; includes Cromer Diamicton of Lunkka, 1994, and members of the Beeston Regis Formation of Moorlock et al., 2000b, 2002b).

Lithology
There are several distinctive lithofacies. The basal member is the Mundesley Sand Member, which consists of stratified fine-grained sands; this is overlain by the laminated silts and clays of the Ivy Farm Laminated Silt Member. Overlying these water-lain sediments are the Runton Till and Bacton Green Till members; these are matrix-supported diamictons, which in turn are overlain by thin units of clay (Trimingham Clay Member) and sand (Trimingham Sand Member). These deposits are truncated by the chalky Weybourne Town Till Member, a highly consolidated matrix-supported diamicton, and finally by the Runton Cliffs Sand and Gravel Member, which forms the highest stratigraphical unit within the Formation.

Formal subdivisions and correlation table
Subdivided into the Bacton Green Till, Hanworth Till, Runton Cliffs Sand and Gravel, Runton Till, Weybourne Town Till, Trimingham Clay, Trimingham Sand, Ivy Farm Laminated Silt, and Mundesley Sand members (Tables 7a, 7b and 15).

Type area/Reference section
Type area: The stratotype area for the Sheringham Cliffs Formation is located within the coastal section between West Runton and Sheringham. At this location, tills of the Sheringham Cliffs Formation can be seen overlying preglacial deposits of the Wroxham Crag Formation, and being overlain in turn by sand and gravel of the Briton's Lane Formation (Lee et al., 2004).

Lower and upper boundaries
Two different stratigraphical associations of the lower boundary of the formation can be observed. Firstly, where the Mundesley Sand Member rests upon the upper surface of the Walcott Till Member (Lowestoft Formation) it exhibits a slightly scoured, erosional contact, and lithological transition from till to sand. Secondly, where the Runton Till Member truncates shallow marine sediments of the Wroxham Crag Formation, the contact is commonly marked by a sharp plane of décollement.

The upper boundary is a sharp, erosional contact at the base of the overlying Briton's Lane Formation. The lithological change is from till to sand and gravel.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 40 m.

Distribution and extent
The Sheringham Cliffs Formation has been mapped extensively in northern Norfolk and crops out in the Cromer, Aylsham and Wells districts.

Age
Mid-Pleistocene (possibly MIS 10).

MUNDESLEY SAND MEMBER (MYSA)

The Mundesley Sand Member comprises up to 9 m dull yellow-orange to dull yellowish brown stratified silty sands with a high abundance of detrital chalk in the lower horizons, and opaque heavy minerals. Typical bedding structures include planar cross-bedding, horizontal bedding, massive beds, climbing ripples and convolute bedding.

BACTON GREEN TILL MEMBER (BGTI)

The Bacton Green Till Member (Lee et al., 2004) comprises up to 15 m of generally clayey, silty sand, with a small content of pebbles of apparent North Sea origin. It is interbedded with 'marly drift' formed from reconstituted chalk. The 'marly drift' varies from stringers only centimetres thick interbedded with the till, to incorporated masses hundreds of metres across. Rafts of Upper Chalk of very local derivation and even larger size are also known, for instance at West Runton. The Bacton Green Till is typically very highly tectonised, with the interbedded sandy till and marly drift commonly occurring as isoclinal folds, forming the 'Contorted Drift' of Reid (1882).

HANWORTH TILL MEMBER (HATI)

Occurring to the south of the Cromer Ridge, the Hanworth Till Member comprises up to 25 m of unbedded clayey, silty sand, incorporating masses of 'marly drift'. It differs from the Bacton Green Till in not being contorted.

Because of the traditionally assumed Scandinavian origin for the tills of both the Bacton Green Till Member and the Hanworth Hill Till Member, Moorlock et al. (2000b) included them in the Overstrand Formation (now superseded, Section 10.3.1.4) and in the Beeston Regis Formation (BERE) of the Cromer district (Moorlock et al., 2002b). However, this association has been disproved by Lee et al. (2004) who refer the tills to the Sheringham Cliffs Formation. Studies of the palynology of the Bacton Green Till (Riding, 2001a, b) reveal levels of Carboniferous and Jurassic microflora which imply derivation from northern Britain.

IVY FARM LAMINATED SILT MEMBER (IFLS)

The Ivy Farm Laminated Silt Member comprises up to 22 m of clays, silts and sands. It consists of two distinctive lithofacies: (a) rhythmically-bedded dark grey clays and pale grey silts that grade upwards into a pale yellow laminated marl; (b) horizontally bedded and rippled fine-grained pale grey sand rich in the heavy mineral zircon.

RUNTON TILL MEMBER (RUTI)

The Runton Till Member comprises up to 9 m of dark grey to greyish brown matrix-supported diamicton that contains highly attenuated lenses and laminations of sand, chalk and reworked inclusions of older and more chalk-rich till of the Walcott Till Member (Lowestoft Formation).

TRIMINGHAM CLAY MEMBER (TRIMC)

The Trimingham Clay Member (Trimingham Clays of Hart and Boulton, 1991, Hart, 1992, and Lunkka, 1994) comprises up to 2.2 m of rhythmically laminated clays and pale grey silts.

TRIMINGHAM SAND MEMBER (TRIMS)

The Trimingham Sand Member (Trimingham Sands of Hart and Boulton, 1991, Hart, 1992, and Lunkka, 1994) comprises up to 0.3 m of horizontally bedded and massive sand with sporadic ripple structures. The Trimingham Sands were previously assigned to the Beeston Regis Formation (Moorlock et al. 2002b).

WEYBOURNE TOWN TILL MEMBER (WTTI)

The Weybourne Town Till Member comprises up to 9 m of highly calcareous silt and chalk-rich matrix-supported diamicton. It is generally massive in structure, but locally, such as at the unit's stratotype locality, the diamicton is highly stratified, consisting of highly attenuated and deformed inclusions of pre-existing till (Bacton Green Till Member).

RUNTON CLIFFS SAND AND GRAVEL MEMBER (RUCSG)

The Runton Cliffs Sand and Gravel Member comprises up to 10 m of planar cross-bedded, rippled, channelised and horizontally-bedded yellow to olive brown sands with sporadic beds of massive or cross-bedded gravel. The flint gravel content (about 82%) is low compared to other outwash lithofacies in north Norfolk, but it contains a high content (about 3–4%) of far-travelled erratics including Carboniferous limestone, micaceous schist, quartz-schist, granodiorite, felsic porphyry and andesite.

10.3.1.4 BRITON'S LANE FORMATION

The Briton's Lane Formation (after Lee et al., 2004, Moorlock et al., 2008) consists of several coarse-grained sand and gravel outwash lithofacies that truncate and drape pre-existing sediments in the Cromer and Mundesley districts. No in-situ till deposits have been identified, but thrust slabs of till have been recognised at several localities. The Briton's Lane Formation subsumes the Overstrand Formation, which had been introduced by Moorlock et al. (2000b, 2002a, b) to include widespread glacial deposits of northern British, North Sea and Scandinavian origin, which succeed the Lowestoft Formation in northern Norfolk.

Name
Briton's Lane Formation (BRLA) (after Lee et al., 2004 and Hamblin et al., 2005; Overstrand Formation of Moorlock et al., 2000b, 2002a, b).

Lithology
The Briton's Lane Formation consists of several coarse-grained sand and gravel outwash lithofacies that truncate and drape pre-existing sediments in the Cromer and Mundesley districts. No in-situ till deposits have been identified to date, but thrust slabs of till have been recognised at several localities.

Formal subdivisions and correlation table
Subdivided into the Tottenhill Sand and Gravel, Stow Hill Sand and Gravel, Beacon Hill Sand and Gravel, Corton Woods Sand and Gravel, and Briton's Lane Sand and Gravel members (Tables 7a, 7b and 15).

Type area/Reference section
Partial type section: The stratotype for the Briton's Lane Formation is Briton's Lane Quarry at Beeston Regis near Sheringham in north Norfolk. At this site, up to 40 m of outwash sand and gravel can be observed. Large erratics of both British and Scandinavian outwash have been recorded. It should be noted, however, that all of the lithofacies of this formation cannot be seen in superposition in any one section (Lee et al., 2004).

Lower and upper boundaries
The lower boundary of the formation is erosional, and sands and gravels truncate earlier deposits of the Sheringham Cliffs Formation.

The Briton's Lane Formation is commonly exposed at the surface although in places it has a thick palaeosol developed within the upper 2–3 m.

Landform description and genetic interpretation
Glaciofluvial deposits.

Thickness
Maximum thickness of the formation is estimated to be in the region of 50 m.

Distribution and extent
The Briton's Lane Formation crops out across much of northern Norfolk, from Trimingham in the east to Edgefield and Holt in central north Norfolk.

Age
Mid-Pleistocene (possibly MIS 6)

TOTTENHILL SAND AND GRAVEL MEMBER (TOTL)

At Tottenhill in north-west Norfolk, flint-dominated sands and gravels (Ventris, 1985, 1986) are named the Tottenhill Sand and Gravel Member (after Lewis, p. 18 in Bowen, 1999). The sequence has been interpreted as sub-aquatic deltaic outwash from an adjacent ice-sheet, some time between MIS 11 and 5e (Gibbard et al., 1991b, 1992; Lewis and Rose, 1991). The Tottenhill Sand and Gravel Member is tentatively correlated with MIS 6 by Lewis (p. 18 in Bowen 1999).

STOW HILL SAND AND GRAVEL MEMBER (STHSG)

The Stow Hill Sand and Gravel Member (after Lee et al., 2004) comprises up to 8 m of matrix-supported gravel separated by thick beds of horizontally-bedded sand. Up to 92% of the clast content is flint, with a small (about 6%) subsidiary quartzose content. The deposits rest unconformably on the Bacton Green Till Member between Bacton Green [TG 338 345] and Mundesley [TG 319 361], and on the Weybourne Town Till Member within large, tectonically-controlled synclines, between Trimingham [TG 279 389] and Sidestrand [TG 265 397].

BEACON HILL SAND AND GRAVEL MEMBER (BHIL)

The Beacon Hill Sand and Gravel Member (Lee et al., 2004) comprises up to 12 m of shelly, cross-bedded and rippled sands with flint-rich gravel seams and sporadic intraformational ice wedge casts and drop-soil structures (periglacial involutions). The lower horizons of the deposits are intensely glaciotectonised.

CORTON WOODS SAND AND GRAVEL MEMBER (CWSG)

At Corton the Pleasure Gardens Till (Lowestoft Formation) is overlain by at least 4 m of gravels referred to as Plateau Gravels by Banham (1971) and as Corton Wood Sands and Gravels by Arthurton et al. (1994). They comprise reddish brown to orange-brown sands and medium-grained, strongly imbricated, quartz- and quartzite-bearing flint gravels. Arthurton et al. (1994) do not include them in the Lowestoft Till Formation as their mineralogy does not accord with that of the till (Bridge and Hopson, 1985), and it is tentatively suggested that they belong to the Briton's Lane Formation. They are here named the Corton Woods Sand and Gravel Member.

BRITON'S LANE SAND AND GRAVEL MEMBER (BRLSG)

The Briton's Lane Sand and Gravel Member (member of the Overstrand Formation of Moorlock et al., 2000b) comprises up to 40 m of horizontal, massive and low angle planar cross-bedded gravels and cobble gravels with thin seams of horizontal and rippled sand. A thick sequence of coarse gravels and sands which form a major topographic ridge south of Cromer are well exposed in 30 m-high sections in a gravel pit in Briton's Lane, Beeston Regis, where they are rich in Scandinavian erratics. The deposits form a part of a major sandur deposit. Elsewhere along the Cromer Ridge, the sandur deposits pass out into very gravelly till, provisionally informally named the Stody Member with a type section at a gravel pit on the Stody Estate [TG 056 345] (Hamblin, 2001b). This deposit is unbedded and demonstrates ice-contact structures, and is interpreted as a till. However, in view of the dominantly gravelly nature of this till, it was not possible to distinguish it from the Briton's Lane Sand and Gravel Member during resurvey of the Cromer district (BGS 1:50 000 Sheet E131).

10.4 CALEDONIA GLACIGENIC GROUP

10.4.1 North Sea Coast Glacigenic Subgroup

10.4.1.1 HOLDERNESS FORMATION

Till and associated outwash deposits of Devensian age extending a short distance inland from the north coast of Norfolk are correlated by Moorlock et al. (2002a, 2008) with the Holderness Formation of the Yorkshire and Lincolnshire coasts (Tables 8, 14 and 15, Figure 3; Section 9.3.1.1) (Lewis, McCabe and Bowen, p. 13–14 in Bowen, 1999). The term Hunstanton Formation (after Hunstanton Till of Gallois, 1978, 1994, Gale et al., 1988, and Gale and Hoare, 2007) was proposed by Lewis (p.18 in Bowen, 1999) for the Norfolk succession, but this name is pre-occupied as a formal term for the 'Red Chalk' at Hunstanton (Gallois, 1994; Owen, 1995).

Three members are of the Holderness Formation are recognised in Norfolk (Moorlock et al., 2008; BGS 1:50 000 Sheet E131):

HOLKHAM TILL MEMBER (HOTI)

The Holkham Till Member (Hunstanton Till of Gallois, 1978, 1994, Gale et al., 1988, and Gale and Hoare, 2007; Holkham Member of the Hunstanton Formation, Lewis, p. 18 in Bowen, 1999) comprises up to 10 m of dull reddish brown sandy clay, commonly containing chalk clasts, flint pebbles, Carboniferous and Triassic pebbles, and igneous and metamorphic rocks (Gallois, 1978, 1994).

Red Lion Till Member (RLTI)

The Red Lion Till Member, restricted to the area around Stiffkey [TF 969 434], is a chalk-rich diamicton, up to 4 m thick, overlying a heavily disturbed Chalk surface (England and Lee, 1991; Hoare and Connell, 2003).

Ringstead Sand and Gravel Member (RDSG)

The Ringstead Sand and Gravel Member (Ringstead Member of Lewis, pp. 18–19 in Bowen, 1999) comprises generally less than 3 m of glaciofluvial sands and gravels, ranging from rounded cobbles to subangular and angular clasts, mainly flint. Deposits of the Hunstanton Esker in Old Hunstanton Park [TF 694 340] (Straw, 1960) are included in this member.

10.5 BRITISH COASTAL DEPOSITS GROUP

10.5.1 Formations of the British Coastal Deposits Group

10.5.1.1 Nar Clay Formation

The Nar Member of Bowen (1999) has appeared on BGS maps as the Nar Valley Clay and is now established as the Nar Clay Formation (including both the marine Nar Clay and the underlying Nar Valley Freshwater Beds).

Name
Nar Clay Formation (NACL) (after Ventris, 1985, 1986; Nar Member of Nar Valley Formation of Lewis, p. 18 in Bowen, 1999).

Lithology
The Nar Clay Formation consists of finely laminated marine clays, silts and silty clays, and peat of the Nar Valley Freshwater Peat Beds. Brickpits have yielded a rich fauna of well preserved bivalves and gastropods, foraminiferids, ostracods and diatoms. The clay has also yielded the bones and teeth of mammals.

Formal subdivisions and correlation table
Includes the Nar Valley Freshwater Bed (Tables 5 and 15).

Type area/Reference section
Type section: BGS Nar Valley Borehole, Setch, registered No. TF61SE25 [TF 6377 1435], 5.6–17.5 m (Gallois, 1976).

Lower and upper boundaries
Clays of the Nar Clay Formation overlie freshwater peat of the Nar Valley Freshwater Beds (which are included in the formation), and oversteps onto a variety of older rocks with marked unconformity. At East Winch the base of the clays is marked by a shell bed composed almost entirely of the oyster Ostrea edulis.

The Nar Clay Formation is present at surface. It is locally overlain unconformably by the Tottenhill Sand and Gravel Formation (Briton's Lane Formation).

Landform description and genetic interpretation
Mainly marine deposits but including the organic deposits of the Nar Valley Freshwater Beds.

Thickness
Up to 10 m.

Distribution and extent
The Nar Clay Formation is restricted to the Nar Valley, Norfolk.

Age
? Hoxnian (MIS 11).

10.5.1.2 Fenland Formation

The Fenland Formation was named by McCabe and Bowen (p. 14 in Bowen, 1999) to include all the Holocene marine alluvium and peats of the Fenland Basin. Such deposits have appeared as named beds on BGS maps, including the *Nordelph Peat* (NP) (elevated in this framework to a member), the *Barroway Drove Beds* (BYD) (Neolithic) and the *Terrington Beds* (TTB) (Romano-British). The formation is also extended to include older beach face gravels preserved on the inner margins of the Fens; those that have appeared with formal names on BGS maps, and which are here elevated to member status, are the *March Gravels Member* (MRCG) (possibly pre-Ipswichian) and the *Abbey Sand and Gravel Member* (ABSG) (Devensian).

Name
Fenland Formation (FEND) (after McCabe and Bowen, p. 14 in Bowen, 1999, but includes pre-Holocene beach deposits of the inner margins of the Fens).

Lithology
The formation includes fresh and brackish water peats, salt marsh clays, fluvial silts and fine-grained sands, marine sands, and beach-face sands and gravels. In the centre of the Fen Basin, five stratigraphical units are present. In ascending order these are the basal sand and gravel, the Fen Lower Peat Bed, Barroway Drove Beds, Nordelph Peat Member and Terrington Beds (Gallois, 1979). The Barroway Drove Beds comprise intertidal soft grey clays and silty clays cut by tidal channels and creeks infilled with silt and fine-grained sand. The Terrington Beds comprise marine and brackish water silts and fine-grained sands. Older marine sands and gravels marginal to the Fen Basin (Fen Gravel, FEG, of Skertchly, 1877, Fen-margin Gravel of Prentice, 1950, and described by Castleden, 1980, Horton, 1989a, and Booth, 1982, 1983) are represented by two members of the Fenland Formation: the March Gravels Member (sandy gravel to clayey pebbly sand) and the Abbey Sand and Gravel Member (clayey, sandy gravels).

Formal subdivisions and correlation table
Subdivided into several members. Formal members are the March Gravels, Abbey Sand and Gravel, and Nordelph Peat. Informal units of member status include the Fen Lower Peat, Crowland Bed, Barroway Drove Beds, and Terrington Beds. Tables 5 and 15.

Type area/Reference section
Type area: The Fens of Cambridgeshire and Lincolnshire [TF 57 63–TL 57 86].

Lower and upper boundaries
Rests unconformably on glacial deposits or on Jurassic and Cretaceous bedrock.
Ground surface.

Landform description and genetic interpretation
The Formation encompasses the marine, estuarine and terrestrial deposits that were formed in the Fens and adjacent areas during the Holocene and previous interglacial periods.

Thickness
About 35 m.

Distribution and extent
The Fens of Cambridgeshire and Lincolnshire, and continuing along the coast of Lincolnshire as far as Humberston near Cleethorpes.

Age
Pre-Ipswichian to Holocene (MIS 7–1).

MARCH GRAVELS MEMBER (MRCG)

Boreholes indicate that the March Gravels Member (March Formation of Keen and Green, p. 44 in Bowen, 1999) can vary from sandy flint gravel to clayey, silty, pebbly sand. The deposit, which can be up to 5 m in thickness, is commonly cross-bedded and shelly. Locally the gravels contain pebbles of limestone and ironstone in addition to flint. The fauna includes marine bivalves and gastropods, and mammalian bones have also been recorded (Keen et al., 1990). The deposits are tentatively correlated with MIS 7 (Bridgland et al., 1991; Keen and Green, p. 44 in Bowen, 1999).

ABBEY SAND AND GRAVEL MEMBER (ABSG)

The Abbey Sand and Gravel Member (Devensian), formerly an undifferentiated part of the Fen Gravel, comprises up to about 5 m of sands and gravels, some with marine shells, including clayey, sandy gravels and pebbly sands. They are overlain by pebbly, silty, sandy clays and clayey sands of the *Crowland Bed* (CRWB) (Booth, 1982). In the absence of the Crowland Bed, they may not be separable from the lowest part of the Barroway Drove Beds. They pass laterally into First Terrace Deposits (e.g. of Nene and Welland rivers). The *Barroway Drove Beds* (BYD) are mainly silts and clays (Older Salt Marsh and Tidal Creek Deposits), which overstep the *Fen Lower Peat* (FLPT). In places this can be several metres thick, representing a sequence of mixed forests passing up into sphagnum bogs (Gallois, 1994).

NORDELPH PEAT MEMBER (NP)

The Nordelph Peat (Gallois, 1978) (Upper Peat of Godwin, 1940) (Holocene) contains trunks and roots of oaks and small trees, some in situ, and woody debris from alder, birch, sallow, buckthorn and pine are common. In the more seaward areas the peat is composed largely of stems and rhizomes of sedges and reeds. In southern Fenland the peat contains thin, but extensive, lenticular deposits of shell marl that formed in shallow meres within the peat fens. The peat is generally less than 1 m thick but can be up to 3 m. It is disconformably overlain by the Terrington Beds (TTB). The *Terrington Beds* result from a transgression that caused marine and brackish water silt and fine-grained sand to be deposited far inland along the major river courses and gave rise to extensive salt-marsh deposits of interlaminated dull, reddish brown clays and pale brown silts. which were sufficiently well drained by the time of the Roman occupancy for them to have been extensively colonised.

10.5.1.3 MORSTON FORMATION

Raised beach deposits at Morston, north Norfolk, are considered to be interglacial, most likely of Ipswichian age (Gale et al., 1988; Gale and Hoare, 2007). At the type section [TF 987 441], about 2.3 m of rounded flint cobbles and gravel overlie laminated mud with pollen suggesting warm climatic conditions. These deposits (named the Morston Member of the Hunstanton Formation by Lewis, p. 18 in Bowen, 1999), are here referred to the Morston Formation.

Name
Morston Formation (MORS) (after Gale et al., 1988, and Gale and Hoare, 2007).

Lithology
Interglacial raised beach deposits: gravel of rounded flint cobbles and pebbles overlying finely laminated mud.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 15).

Type area/Reference section
Type section: Raised beach at Morston [TF 987 441] (Gale et al., 1988).

Lower and upper boundaries
Rests unconformably on till of the Lowestoft Formation.

Overlain by till of the Holderness Formation (till of the north Norfolk coast).

Landform description and genetic interpretation
Beach deposits. Pollen from the finely laminated mud suggests warm climate conditions.

Thickness
About 2.3 m.

Distribution and extent
The coast of north Norfolk.

Age
Ipswichian (MIS 5e) ; uncertainty expressed by Gale et al. (1988).

10.5.1.4 BREYDON FORMATION

The Breydon Formation (Arthurton et al., 1994) is the name given to the Holocene marine and estuarine sequence underlying the marshland that occupies the floodplains of the Waveney, Yare and Bure rivers and their tributaries (Figure 21). The Formation as defined by Arthurton et al. was formed under estuarine to marine conditions, and is not intended to include fluvial deposits beyond estuarine influence, or deposits formed after the sea had been artificially excluded from the area and the marshland drained.

Name
Breydon Formation (BRYD) (after Arthurton et al., 1994).

Lithology
This formation, which underlies much of the marshland in the Great Yarmouth district, is dominated by unconsolidated silt and clay with a shelly marine fauna. Sand is generally a minor component, though locally substantial sand bodies interrupt the argillaceous succession. Peat, of freshwater and brackish origins, is a major component adjacent to much of the marshland margin and particularly in the valleys of the River Yare and tributary streams. It also occurs as three widespread though locally impersistent layers: at the base of the formation, within it, and at the top, mainly in the marshland fringe.

Formal subdivisions and correlation table
Subdivided into informal members, the Basal or Lower

Peat (BRY1), Lower Clay (BRY2), Middle Peat (BRY3), Upper Clay (BRY4) and the marginal Upper Peat (BRY5); Tables 5 and 15; Figure 21.

Type area/Reference section
Type section: North Crains Borehole TG 50NW417, sited on southern shore of the eastern end of Breydon Water (Arthurton et al., 1994).

Lower and upper boundaries
Commonly unconformably overlies tills and outwash sands and gravels of the Happisburgh and Lowestoft formations and also sands, gravels and silts of the Crag Group. Also overlies gravels of the Yare Valley Formation (as in the type section). In the west of the outcrop the base of the formation locally overlies rocks of the Chalk Group and London Clay Formation (Thames Group).

Ground surface or overlain by deposits of the North Denes Formation.

Landform description and genetic interpretation
Marine and estuarine deposits.

Thickness
Up to 22 m, but thins towards the margins of the outcrop.

Distribution and extent
Confined to the valleys of the River Bure and River Yare near Great Yarmouth.

Age
Holocene (MIS 1)

10.5.1.5 North Denes Formation

The North Denes Formation (Arthurton et al., 1994) comprises the deposits of a coastal barrier, a kilometre wide and eight kilometres long, extending from Caister-on-Sea to Gorleston-on-Sea. It consists of sand and subordinate gravel, with a little silt and clay, up to at least 25 m thick. It forms the eastern limit of the estuarine Breydon Formation, which it overlies unconformably (Figure 21), and is Holocene (MIS 1) in age.

Name
North Denes Formation (NRD) (after Arthurton et al., 1994).

Lithology
Consists of an elongate, wedge-shaped body of sand with subordinate gravel and thin layers of silty clay.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 15).

Type area/Reference section
Type section: Marine Outfall Borehole 8, TG50NW542 [TG 5325 0999] (Arthurton et al., 1994).

Lower and upper boundaries
The North Denes Formation rests unconformably mostly on the silts, clays and sands of the Breydon Formation, but also on the sands and gravels of the Crag Group, and to a lesser extent on the glacigenic deposits of the Happisburgh Formation.

Surface, or else covered by blown sand.

Landform description and genetic interpretation
Marine deposits.

Thickness
About 26 m.

Distribution and extent
The formation comprises a coastal barrier, 1 km wide by 8 km long, between Caister-on-Sea and Gorleston-on-Sea. The present coastline is taken as an arbitrary eastern limit.

Age
Holocene (MIS 1).

10.6 BRITANNIA CATCHMENTS GROUP

10.6.1 Formations of the Britannia Catchments Group

The Britannia Catchments Group includes all of the post-glacial organic and lacustrine deposits, colluvium, cover loam and cover sands and mass movement (head) deposits in East Anglia. These deposits are currently shown on BGS maps as lithogenetic units.

Deposits of head and colluvium are not as widespread throughout the region as might be expected bearing in mind the long periods of periglacial activity that have occurred since most of the region was last glaciated. This may be due to the climate being very dry during the periglacial periods. Whilst most of the head and colluvium is considered to be of Devensian age, some might be older.

Cover loam (loess) of Devensian age is widespread in north-east Norfolk, from west of Cromer to south of Lowestoft and mostly extending up to 15 km from the coast (Catt, 1977; Ballantyne and Harris, 1994, fig. 8.21). This varies in consistency from silt to sand. Cover sands are widespread around Thetford. The provenance of both the cover sands and cover loams has been postulated by Catt (1977) to be from the Devensian ice-sheet (s.l.) but these deposits are not necessarily of the same age as each other, nor was either of them necessarily formed in a single episode.

Post-Anglian fluvial deposits of the rivers of East Anglia, together with interbedded organic and lacustrine deposits, are assigned to formations of three subgroups, the **Ouse–Nene Catchments**, the **Yare Catchments**, and the **Suffolk Catchments** subgroups (Sections 10.6.2 to 10.6.4, Tables 6 and 15, Figure 4).

10.6.2 Ouse–Nene Catchments Subgroup

The Ouse–Nene Catchments Subgroup is established to encompass all the post-glacial fluvial deposits of the rivers which flow into the Wash, and includes the Holocene lacustrine and organic deposits of the Fenland Basin (Tables 6 and 15).

Name
Ouse–Nene Catchments Subgroup (ONCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium comprises soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits are largely sand and gravel, the constituents of the gravel components reflecting the source rocks in each catchment. Lacustrine deposits are dominantly soft silts and clays. Minor marine deposits are

included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Subdivided into the Nene Valley, Ouse Valley, Nar Valley, Lark Valley, Cam Valley, and Slea Valley formations (Tables 6 and 15).

Type area/Reference section
Type area: The valleys of the rivers Nene and Ouse and their tributaries in eastern England [TA 40 00–TL 55 35].

Lower and upper boundaries
Formations of the Ouse–Nene Catchments Subgroup rest with marked unconformity on Middle Pleistocene glacial deposits and on Cretaceous and Jurassic bedrock.

Surface.

Landform description and genetic interpretation
The Ouse–Nene Catchments Subgroup encompasses all the fluvial, lacustrine and organic deposits of the rivers that occupy the catchment area of the rivers Ouse (Norfolk) and Nene and their tributaries.

Thickness
Up to 14 m.

Distribution and extent
The entire catchments of the rivers Nene and Ouse and their tributaries including the Nar, Cam, Lark, and Slea.

Age
Hoxnian to Holocene (MIS 11–1).

10.6.2.1 Slea Valley Formation

Name
Slea Valley Formation (SLVY) (after Berridge et al., 1999).

Lithology
The floodplain deposits comprise soft clays, silts and fine sands, with bodies of peat, overlying sands and gravels. The terrace deposits comprise sands, gravelly sands and sandy gravels, deposited by braided rivers in a periglacial environment. The pebbles include much buff ooidal limestone from the Lincolnshire Limestone Formation, and flint, ironstone and sandstone, and are up to about 40 mm in diameter.

Formal subdivisions and correlation table
Includes the Sleaford Sand and Gravel of Berridge et al. (1999). See Tables 6 and 15.

Type area/Reference section
Type area: Valley of River Slea from Grantham to Sleaford [SK 92 34–TF 09 47], Lincolnshire (Berridge et al., 1999).

Lower and upper boundaries
Unconformable on mid-Pleistocene glacial deposits, and on Jurassic bedrock.

Surface.

Landform description and genetic interpretation
The formation encompasses the fluvial, lacustrine and organic deposits of the River Slea and its tributaries.

Thickness
Up to 7 m.

Distribution and extent
The entire catchment of the River Slea and its tributaries, Lincolnshire.

Age
Pleistocene to Holocene.

10.6.2.2 Nene Valley Formation

Name
Nene Valley Formation (NENE) (after Castleden, 1976, 1980, Horton et al., 1992, and Green and Keen, pp. 43–44 in Bowen, 1999).

Lithology
Gravel with sand, clay and locally peat.

Formal subdivisions and correlation table
Subdivided into three informal members, the Ecton Member (Floodplain Gravels of Castleden, 1976), Grendon Member (Second Terrace Gravels of Castleden, 1980) and Woodston Member (Third Terrace Gravels of Castleden, 1980) (Tables 6 and 15).

Type area/Reference section
Type area: The valley of the Nar River, Norfolk [TF 91 19–TF 62 13] (Ventris, 1986).

Lower and upper boundaries
Unconformable on mid Pleistocene glacial deposits, and on bedrock.

Ground surface.

Landform description and genetic interpretation
Fluvial.

Thickness
Up to 7.6 m (Grendon Member), up to 4.5 m (Ecton Member), up to 3 m (Woodston Member).

Distribution and extent
The catchment of the Nene Valley.

Age
Pleistocene (probably as early as Hoxnian) to Holocene (MIS ?11–1).

Woodston Member (WTB)

Formerly the Woodston Beds, the Woodston Member comprises up to 3 m of fluvial silt and sand. Pollen, plant macrofossil, coleopteran, molluscan, ostracod and mammalian evidence indicates deposition under temperate conditions. The deposits which correlate with MIS 9 (Keen and Green, p. 44 in Bowen, 1999) are recorded under the Third Terrace of the Nene from Orton Waterville [TL 157 960] eastward for about 3 km (Horton et al., 1992; BGS 1:50 000 Sheet E172 Ramsey).

Grendon Member (GREN)

The Grendon Member comprises up to 7.6 m of fluvial gravel with sand. The unit comprises the Second Terrace gravels of Castleden (1980) from Billing [SP 808 621] near Northampton to Stanground [TL 210 971] near Peterborough.

Ecton Member (ECTN)

The Ecton Member comprises up to 4.5 m of gravel with sand, clay and locally peat. The unit comprises the

Floodplain Gravels of Castleden (1976), and the type area is at Ecton [SP 826 617], Northamptonshire.

10.6.2.3 Nar Valley Formation

The Nar Valley Formation was named by Lewis (p. 18 in Bowen, 1999) to include the post-Anglian deposits of the Nar Valley of north-west Norfolk. Members raised by Bowen (1999) and accepted here in the Nar Valley Formation are the *Wormegay Member*, the *Pentney Priory Bed* (MIS 5e), the *Pentney Member* and the *Marham Member*. Currently only the Wormegay Member is formally defined in the BGS Lexicon. The Nar Member of Lewis (p. 18 in Bowen, 1999) has appeared on BGS maps as the Nar Valley Clay and is now established as the **Nar Clay Formation** (including both the marine Nar Clay and the underlying Nar Valley Freshwater Beds — Section 10.5.1.1). The Tottenhill Member of Lewis (p. 18 in Bowen, 1999) is here included as the Tottenhill Sand and Gravel Member of the Briton's Lane Formation (Section 10.3.1.4).

Name
Nar Valley Formation (NARC) (after Ventris, 1985, 1986).

Lithology
Floodplain alluvium comprising soft clay, silts and fine sands, with bodies of peat, overlying sands and gravels. River terrace deposits (Wormegay Member, Pentney Member and Marham Member of Lewis, p. 18 in Bowen, 1999) comprise sands, gravelly sands and gravels, with the pebbles dominantly of angular to subrounded flint, and Chalk.

Formal subdivisions and correlation table
Subdivided into three members, the Wormegay, Pentney, and Marham members, together with the Pentney Priory Bed (Tables 6 and 15).

Type area/Reference section
Type area: The valley of the Nar River, Norfolk [TF 91 19–TF 62 13] (Ventris, 1986).

Lower and upper boundaries
Unconformable on mid-Pleistocene glacial deposits, and on bedrock.

Surface.

Landform description and genetic interpretation
The Nar Valley Formation encompasses the fluvial, lacustrine and organic deposits of the Nar River and its tributaries.

Thickness
Up to 5 m.

Distribution and extent
The entire catchment of the Nar River and tributaries, in Norfolk.

Age
Pleistocene to Holocene (MIS ?6–1).

Wormegay Member (WGAY)

The Wormegay Member comprises up to 2.5 m of fluvial sand and gravel forming the Wormegay Terrace between Wormegay and Narborough (Ventris, 1985, 1986). It rests unconformably on the Tottenhill Sand and Gravel Member (Briton's Lane Formation).

10.6.2.4 Lark Valley Formation

The Lark Valley Formation was named by Lewis (p. 21 in Bowen, 1999) to include the post-Anglian fluvial deposits of the valley of the River Lark. Five terraces were identified by Clayton (1983). Members raised by Lewis (p. 21 in Bowen, 1999) and accepted here are the *Sicklesmere Member*, the *Eriswell Member*, the *Fornham Member,* the *Kentford Member*, the *Cavenham Member* and the *Lackford Member*.

Name
Lark Valley Formation (LKVY) (after Clayton, 1983, and Lewis, p.21 in Bowen, 1999).

Lithology
Formation encompasses the fluvial, lacustrine and organic deposits of the River Lark and its tributaries. Five terraces are identified. The terrace deposits comprise well bedded to rather poorly bedded sands and sandy gravels, deposited by braided rivers in a periglacial environment. The pebbles are dominantly angular to rounded flints up to about 10 cm across, with a few glacial erratics. The three highest terraces are cryoturbated. The floodplain alluvium comprises silts, clays and fine sands, with bodies of peat, overlying sands and gravels.

Formal subdivisions and correlation table
Subdivided into informal members, the Sicklesmere, Eriswell, Fornham, Kentford, Cavenham, and Lackford members (Tables 6 and 15).

Type area/Reference section
Type area: Valley of the River Lark from near Bury St Edmunds to near Littleport [TL 85 65–TL 56 87] (Clayton, 1983).

Lower and upper boundaries
Unconformable on mid-Pleistocene glacial deposits and on bedrock (Kimmeridge Clay to Chalk Group).

Surface.

Landform description and genetic interpretation
Fluvial, lacustrine and organic deposits.

Thickness
Up to 14 m.

Distribution and extent
The entire catchment of the River Lark and its tributaries, from near Bury St Edmunds, Suffolk to Littleport, Cambridgeshire.

Age
Pleistocene to Holocene (MIS ?11–1).

Sicklesmere Member (SKLM)

The Sicklesmere Member comprises up to 3.5 m of organic muds with plant remains and wood overlying chalky till. The pollen assemblage indicates forest vegetation correlated with the sequence at Hoxne (West, 1981).

Eriswell Member (ERIS)

The *Eriswell Member* comprises up to 1.6 m of gravelly sand forming the Fifth Terrace of the Lark valley (Clayton, 1983).

Fornham Member (FHAM)

The Fornham Member generally comprises about 4 m of sand and gravel with beds of clayey, pebbly silt forming the Fourth Terrace of the Lark valley (Clayton, 1983; Bristow, 1990; BGS 1:50 000 Sheet E189).

Kentford Member (KFRD)

The Kentford Member generally comprises about 4 m of sand and gravel forming the Third Terrace of the Lark valley (Clayton, 1983; Bristow, 1990; BGS 1:50 000 Sheet E189).

Cavenham Member (CAVM)

The Cavenham Member generally comprises about 4 m of sand and gravel but is locally up to 13 m thick. The deposits form the Second Terrace of the Lark valley (Clayton, 1983; Bristow, 1990; BGS 1:50 000 Sheet E189).

Lackford Member (LFRD)

The Lackford Member comprises between 4 and 5 m of sand and gravel with interbedded clay. Locally the deposits may be more than 9 m thick. The deposits form the First Terrace of the Lark valley (Clayton, 1983; Bristow, 1990; BGS 1:50 000 Sheet E189).

10.6.2.5 Cam Valley Formation

The Cam Valley Formation was named by Lewis (p. 21 in Bowen, 1999) to include the fluvial and lacustrine deposits associated with the River Cam and its tributaries. It is characterised by gravels and sands dominated by angular flint and quartz. Four terraces are defined on BGS maps which are referred to named members by Lewis and Boreham (pp. 21–22 in Bowen, 1999): *Little Wilbraham* and *Huntingdon Road* members (both Fourth Terrace), *Histon Road Member* (part of Third Terrace), *Barnwell Abbey Member* (Third Terrace), *Sidgwick Avenue Member* (Second Terrace), and *Barnwell Station Member* (First Terrace).

Name
Cam Valley Formation (CAMV) (after Lewis, p. 21 in Bowen, 1999).

Lithology
The terrace deposits comprise well bedded to rather poorly bedded sands and sandy gravels, deposited by a braided river in a periglacial environment. The pebbles are dominantly rounded chalk and rounded to angular flint, with a few glacial erratics. The three higher terraces are cryoturbated. Alluvial fan deposits comprise poorly sorted flinty chalky sand and gravel, with boulders of basalt and quartzite. The floodplain alluvium comprises silts, clays and fine sands, with bodies of peat, overlying sands and gravels.

Formal subdivisions and correlation table
Subdivided into nine members by Lewis and Boreham (pp. 21–22 in Bowen,1999). These are the North Hall, Bordeaux Pit, Little Wilbraham, Huntingdon Road, Histon Road, Barrington Village, Barnwell Abbey, Sidgwick Avenue, and Barnwell Station members (Table 15).

Type area/Reference section
Type area: Valley of the River Cam and its tributaries from Saffron Waldon to Little Thetford [TL 54 39–TL 53 74] (Worssam and Taylor, 1969).

Lower and upper boundaries
Unconformable on mid-Pleistocene glacial deposits and on bedrock.

Surface.

Landform description and genetic interpretation
The formation encompasses the fluvial, lacustrine and organic deposits of the River Cam and its tributaries.

Thickness
Up to 13 m.

Distribution and extent
Entire catchment of the River Cam and its tributaries, from near Saffron Waldon, Essex to near Ely, Cambridgeshire.

Age
Pleistocene to Holocene (MIS ?10–1).

North Hall Member

The North Hall Member (after Boreham, p. 21 in Bowen, 1999) comprises lacustrine sediments in the upper Cam valley. Pollen assemblages indicate correlation with the first half of the Hoxnian (Baker, 1977).

Bordeaux Pit Member (BPIT)

The Bordeaux Pit Member comprises sand and gravel in the upper Cam valley (Sparks, 1955) forming the Third Terrace of the River Cam (BGS 1:50 000 Sheet E205). The deposits may be the equivalent of the Little Wilbraham Member.

Little Wilbraham Member (LWIB)

The Little Wilbraham Member comprises at least 3 m of brown sand and gravel forming the Fourth Terrace of the River Cam, east of Cambridge (Penning and Jukes-Browne, 1881; Worssam and Taylor, 1969; BGS 1:50 000 Sheet E188).

Huntington Road Member (HURD)

The Huntington Road Member comprises about 2 m of sand and gravel forming the Fourth Terrace of the River Cam, north of Cambridge (Marr and King, 1932; BGS 1:50 000 Sheet E188).

Histon Road Member (HNRD)

The Histon Road Member comprises up to about 8 m of organic muds, shelly sand and silty marl. Pollen assemblages indicate correlation with the Ipswichian (Sparks and West, 1959). The deposits form part of the Third Terrace of the River Cam (Worssam and Taylor, 1969; BGS 1:50 000 Sheet E188).

Barrington Village Member

The Barrington Village Member comprises dominantly fluvial deposits with pollen and faunal assemblages indicative of correlation with the Ipswichian (Gibbard and Stuart, 1975).

BARNWELL ABBEY MEMBER (BABY)

The Barnwell Abbey Member (Highest terrace of Penning and Jukes-Browne, 1881) comprises up to about 7 m of sand and flint gravel forming the Third Terrace of the River Cam (Marr, 1920; Worssam and Taylor, 1969; BGS 1:50 000 Sheets E188 and E205).

SIDGWICK AVENUE MEMBER (SKAV)

The Sidgwick Avenue Member comprises up to about 6 m of sand and fine gravel forming the Second Terrace of the River Cam (Penning and Jukes-Browne, 1881; Lambert et al., 1963; Worssam and Taylor, 1969; BGS 1:50 000 Sheets E188 and E205).

BARNWELL STATION MEMBER (BSTA)

The Barnwell Station Member comprises about 4 m of fossiliferous sand and flint gravel forming the First Terrace of the River Cam (Penning and Jukes-Browne, 1881; Bell and Dickson, 1971; Worssam and Taylor, 1969; BGS 1:50 000 Sheets E188 and E205).

10.6.2.6 OUSE VALLEY FORMATION

Name
Ouse Valley Formation (OUSE) (after Rogerson et al., 1992, Green et al., 1996, and Green and Keen, p. 44 in Bowen, 1999).

Lithology
Gravel with sand.

Formal subdivisions and correlation table
Subdivided into informal units including the Biddenham Member, Stoke Goldington Member, Felmersham Member, Ravenstone Member and Woolpack Farm Bed. Tables 6 and 15.

Type area/Reference section
Type area: The valley of the River Great Ouse.

Lower and upper boundaries
Unconformable on mid Pleistocene glacial deposits, and on bedrock.

Ground surface.

Landform description and genetic interpretation
Fluvial deposits.

Thickness
Up to 8 m (Stoke Goldington Member).

Distribution and extent
The valley of the River Great Ouse in Buckinghamshire, Bedfordshire, Cambridgeshire and Norfolk.

Age
Pleistocene (possibly as early as Hoxnian) to Holocene (MIS ?11–1).

RAVENSTONE MEMBER

The informal Ravenstone Member, defined from the stratotype in the former Hartigan's Pit [SP 853 490] (Green, Keen and Coope, p. 44 in Bowen, 1999) comprises fossiliferous clays, equivalent to bed d–f of Green et al. (1996). The deposits are correlated with the Ipswichian (MIS 5e).

WOOLPACK FARM BED

The stratotype of the Woolpack Farm Bed (Woolpack Member of Green, p. 44 in Bowen, 1999) is in a pit 200 m east of Woolpack Farm [TL 299 685], Fenstanton. It comprises 3.6 m of sand and gravel with mammalian remains, mollusca and coleoptera indicative of temperate conditions. The deposits are correlated with the Ipswichian (MIS 5e).

BIDDENHAM MEMBER (BIDM)

The Biddenham Member comprises up to 4 m of fluvial gravel with sand containing thin fossiliferous clay layers with a temperate molluscan fauna. It underlies the third terrace of the River Great Ouse. The type section is the Spinney Pit [TL 023 503], Biddenham, Bedfordshire (Green and Keen, p. 44 in Bowen, 1999; BGS 1:50 000 Sheet E185 Northampton).

STOKE GOLDINGTON MEMBER (STGO)

The Stoke Goldington Member comprises up to 8 m of fluvial gravel with sand under the second terrace of the River Great Ouse. The type section is Hartigan's Pit [TL 006 586] near Stoke Goldington, Buckinghamshire (Green et al., 1996; Green and Keen, p. 44 in Bowen, 1999; BGS 1:50 000 Sheet E185 Northampton).

FELMERSHAM MEMBER (FELM)

The Felmersham Member comprises up to 3 m of fluvial gravel with sand under the first terrace of the River Great Ouse. The type section is a former pit [TL 006 586] near Radwell, Bedfordshire (Rogerson et al., 1992; Green and Keen, p. 44 in Bowen, 1999; BGS 1:50 000 Sheet E185 Northampton).

10.6.3 Yare Catchments Subgroup

The Yare Catchments Subgroup is named here to encompass all the post-glacial fluvial deposits of the valleys of the rivers Yare, Waveney and Bure, including the Norfolk Broads (Table 15).

Name
Yare Catchments Subgroup (YCAT) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium comprising soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits are largely sand and gravel. The gravels are dominantly composed of subrounded to angular flint, including large cobbles, also rounded pebbles of quartz and quartzite, northern British erratics of glacial derivation, and a little chalk. Peat is a minor component, and minor marine deposits are included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Subdivided into the Yare Valley, Blakeney Valleys, Waveney Valley, and Bure Valley formations. Tables 6 and 15.

Type area/Reference section
Type area: The valleys of the River Yare and its tributaries [TF 85 28–TG 52 07], in Norfolk.

Lower and upper boundaries
Formations of the Yare Catchments Subgroup rest unconformably on glacial and periglacial deposits and upon Crag Group, London Clay Formation and Chalk Group bedrock.

Surface, or overlain by deposits of the Breydon Formation.

Landform description and genetic interpretation
The Yare Catchments Subgroup encompasses all the fluvial, lacustrine and organic deposits of the rivers that occupy the catchment area of the River Yare and its tributaries, and also the other minor rivers that flow into the North Sea along the coast of Norfolk.

Thickness
About 18 m.

Distribution and extent
The entire catchment of the River Yare and its tributaries, and the whole of Norfolk to the north of that catchment.

Age
Hoxnian to Holocene (MIS 11–1).

10.6.3.1 Yare Valley Formation

The Yare Valley Formation, as defined by Arthurton et al. (1994), underlies the Breydon Formation (Holocene) to infill the lowest levels of the buried valley system throughout the catchment of the rivers Yare, Waveney and Bure. It is dominated by fine- to coarse-grained gravel, mostly of flint, and fine- to coarse-grained sand, with a little silt, shell debris and chalk. These deposits are mainly Devensian to early Holocene. However, the formation includes all the post-glacial fluvial deposits of the River Yare, including a range of river terrace deposits and alluvium, but not those of the Waveney and Bure.

Name
Yare Valley Formation (YV) (after Arthurton et al., 1994).

Lithology
The formation includes floodplain alluvium and a restricted development of river terrace deposits. The floodplain alluvium comprises soft clays, silts and fine-grained sands, with bodies of peat, overlying fine- to coarse-grained sands and gravels. These commonly silty but rarely shelly gravels are mostly composed of rounded flint pebbles and cobbles, with a little chalk. The gravels commonly occur in buried channels overlain by the Breydon Formation. The river terrace deposits are largely gravel and sand. The gravel is dominated by subangular to rounded flint, including large cobbles, with some pebbles of quartz and quartzite. Gravelly sediments belonging to this formation have been recorded in boreholes offshore.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 15).

Type area/Reference section
Type section: Runham/Yare Borehole 8, BGS Registered No. TG50NW480 [TG 5165 0810].

Lower and upper boundaries
Unconformable upon glacial and solifluction deposits and upon Crag Group, London Clay Formation and Chalk Group bedrock.

Surface, or overlain by deposits of the Breydon Formation.

Landform description and genetic interpretation
The formation encompasses the fluvial, lacustrine and organic deposits of the River Yare.

Thickness
About 18 m.

Distribution and extent
The valley of the River Yare and its minor tributaries, from near Shipdham to its mouth at Great Yarmouth, Norfolk, and also the offshore extensions of the buried valley of the River Yare, but not including the valleys of the rivers Bure and Waveney and their tributaries.

Age
Pleistocene to Holocene (MIS ?2–1).

10.6.3.2 Blakeney Valleys Formation

The Blakeney Valleys Formation includes all the Holocene and Ipswichian coastal deposits of the north Norfolk coast.

Name
Blakeney Valleys Formation (BLYV) (after Moorlock et al., 2002a).

Lithology
The formation includes floodplain alluvium and a restricted development of river terrace deposits. The floodplain alluvium comprises soft clays, silt and fine-grained sands, with bodies of peat, overlying fine- to coarse-grained sands and gravels. The river terrace deposits are largely gravel and sand. The gravels are dominated by subangular to rounded flint, including large cobbles, but also include rounded pebbles of quartz and quartzite, northern British erratics of glacial derivation, and a little chalk.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 15).

Type area/Reference section
Type section: The valley of the River Glaven, North Norfolk [TG 14 44–TG 16 38] (Moorlock et al., 2002a).

Lower and upper boundaries
Unconformable on glacial and solifluction deposits and on Crag Group and Chalk Group bedrock.

Surface.

Landform description and genetic interpretation
The formation encompasses the fluvial, lacustrine and organic deposits of the rivers that flow into the North Sea along the coast of north Norfolk.

Thickness
About 5 m.

Distribution and extent
North Norfolk, north of the watershed defining the catchment of the River Bure.

Age
Ipswichian to Holocene (MIS 5e–1).

10.6.3.3 Waveney Valley Formation

The Waveney Valley Formation comprises the fluvial and associated organic deposits of the River Waveney. Members raised by Lewis (p. 25 in Bowen, 1999) are the Broome, Wortwell and Shotford members. Also included as members are Bowen's Bobbitshole Formation (correlated with MIS 5e; Bowen et al., 1989; Lewis, p. 25 in Bowen, 1999) and Hoxne Formation (Wymer in Bowen, 1999; Hoxne Beds of West, 1956). The latter comprises up to 15 m of fluvial sand, silt and gravel overlying peats and lacustrine clays, which in turn rest upon the Lowestoft Formation till at Hoxne, Suffolk. The Hoxne section forms the stratotype of the Hoxnian interglacial stage, which succeeds the Anglian; support for a MIS 11 age comes from U-series dating of Hoxnian interglacial deposits at Marks Tey, Essex (Rowe et al., 1999), which can be reliably correlated with the type site at Hoxne. The Marks Tey Formation of Lewis (p. 26 in Bowen, 1999) and the Hitchin Formation, Hertfordshire (Lewis, p. 27 in Bowen, 1999) (shown in Table 15) have yet to be formalised in the BGS Lexicon.

Name
Waveney Valley Formation (WAVV) (after Waveney Valley, Athelington, St Cross, South Elmham, Hoxne, Brundon, Stutton, Stoke Tunnel and Bobbitshole formations of Lewis, pp. 23–25 in Bowen, 1999).

Lithology
The formation includes floodplain alluvium and a restricted development of river terrace deposits. The floodplain alluvium comprises soft clays, silts and fine-grained sands, with bodies of peat, overlying fine- to coarse-grained sands and gravels. River terrace deposits are largely gravel and sand. The gravels are dominated by subangular to rounded flint, including large cobbles, also rounded pebbles of quartz and quartzite and a little chalk.

Formal subdivisions and correlation table
Subdivided into members after Lewis, pp. 23–25 in Bowen (1999), including the Hoxne Member, Broome Member, Bobbitshole Member, and Shotford Member. The Wortwell Beds are included within the Bobbitshole Member (Tables 6 and 15). All but the Broome Member are currently undefined in the BGS Lexicon.

Type area/Reference section
Type area: Valley of River Waveney from Diss to near Lowestoft [TM 11 79–TG 42 02] (Coxon, 1984).

Lower and upper boundaries
Unconformable upon glacial and solifluction deposits and upon Crag Group and Chalk Group bedrock.

Surface.

Landform description and genetic interpretation
The formation encompasses the fluvial, lacustrine and organic deposits of the River Waveney and its tributaries.

Thickness
About 5 m.

Distribution and extent
Valley of River Waveney and its tributaries, from west of Diss, Suffolk, to its junction with the River Yare north-west of Lowestoft.

Age
Hoxnian to Holocene (MIS 11–1).

BROOME MEMBER (BRME)

The Broome Member comprises 2 to 4 m of fluvial sand and gravel with silty lenses, forming a bench above the present floodplain of the River Waveney between Wortham and Broome Heath (Sparks and West, 1968). The deposits rest unconformably on sands of the Happisburgh Formation.

BOBBITSHOLE MEMBER

The type locality of the currently informal Bobbitshole Member (Tables 6 and 15; Bobbitshole Formation of Lewis, p. 25 in Bowen, 1999) is Bobbitshole [TN 148 414], near Ipswich, Suffolk. The Bobbitshole Member comprises up to about 3.5 m of lacustrine silts and clay. Pollen analysis shows the deposit to represent the earlier part of an interglacial succession (West, 1957). It is correlated with MIS 5e (Bowen et al., 1989).

Bobbitshole is the type locality for the Ipswichian (Mitchell et al., 1973a).

10.6.3.4 BURE VALLEY FORMATION

The Bure Valley Formation is named here to encompass all the post-glacial fluvial deposits of the River Bure.

Name
Bure Valley Formation (BURV) (after Moorlock et al., 2002b).

Lithology
The formation includes alluvium and a restricted development of river terrace deposits. The floodplain alluvium comprises soft clays, silts and fine-grained sands, with bodies of peat, overlying fine- to coarse-grained sands and gravels. The river terrace deposits are largely gravel and sand. The gravels are dominated by subangular to rounded flint, including large cobbles, but also include rounded pebbles of quartz and quartzite, northern British erratics of glacial derivation, and a little chalk.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 15).

Type area/Reference section
Type area: Valley of the River Bure from near Cromer to near Great Yarmouth [TG 23 37–TG 49 08] (Moorlock et al., 2002b).

Lower and upper boundaries
Unconformable upon glacial and solifluction deposits and upon Crag Group and Chalk Group bedrock.

Surface.

Landform description and genetic interpretation
Formation encompasses the fluvial, lacustrine and organic deposits of the River Bure and its tributaries.

Thickness
About 5 m.

Distribution and extent
Valley of River Bure and its tributaries in North Norfolk to its junction with the River Yare near Great Yarmouth.

Age
Hoxnian to Holocene (MIS? 11–1).

10.6.4 Suffolk Catchments Subgroup

The Suffolk Catchments Subgroup (Tables 6 and 15) is named here to encompass all the fluvial and organic deposits of the valleys of the rivers which flow into the North Sea along the coast of Suffolk and Essex from the Hundred River south of Lowestoft to the River Crouch. Formations, as yet undefined, will take the names of the individual river valleys.

Name
Suffolk Catchments Subgroup (SUCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium comprising soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits largely made of sand and gravel. The gravels are dominantly composed of subrounded to angular flint, including large cobbles, also rounded pebbles of quartz and quartzite, northern British erratics of glacial derivation, and a little chalk. Marine deposits are included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
No subdivisions. Formations yet to be defined (Tables 6 and 15).

Type area/Reference section
Type area: The area covered by the valleys of the rivers of Suffolk and Essex that flow into the North Sea [TM 50 75–TQ 80 95].

Lower and upper boundaries
Units of the Suffolk Catchments Subgroup rest unconformably upon glacial and periglacial deposits, and upon Crag Group, London Clay Formation and Chalk Group bedrock.

Surface.

Landform description and genetic interpretation
Fluvial, lacustrine and organic deposits.

Thickness
About 10 m.

Distribution and extent
Restricted to that area of Suffolk and Essex that lies between the catchments of the River Thames and the River Waveney and their tributaries, on BGS 1:50 000 Sheets E176, 189–191, 205–208, 222–225, 240–242, 259.

Age
Pleistocene to Holocene (?pre MIS 5–1).

The Lexden Beds (Lexden Member of Turner, p. 26 in Bowen, 1999) are defined from their stratotype in a former brick pit at Lexden [TL 978 253], Essex. The deposits comprised peat and organic clay with mammalian remains, pollen and coleoptera indicative of an interglacial (Shotton et al., 1962). They were overlain by brickearth in the terrace deposits of the River Colne. The unit was considered by Turner to be technically a member of the Lowestoft Formation but was correlated with MIS 5e in Table 6 of Bowen (1999). Here it is assigned as standalone division of the Suffolk Catchments Subgroup.

11 The English Midlands: Trent Basin, Upper Thames and Severn valleys

This chapter describes the Quaternary deposits of much of the Midlands from the Bristol Channel into Lincolnshire, including the valleys of the Trent, proto-Trent, Upper Thames, Avon and Severn and their tributaries (Tables 3, 6, 7, 15, 16 and 17). The oldest superficial deposits of the district are Pre-Anglian (early to mid-Pleistocene age) fluvial deposits of the **Dunwich Group** (see also Section 10.2). The earliest glacigenic deposits refer to the Anglian Glaciation and are assigned to the **Albion Glacigenic Group**. Deposits of the **Britannia Catchments Group** range in age from pre-Anglian to Holocene. Formal lithostratigraphy for the terrace deposits of the rivers Trent, Thames and Severn has already become widely used. Most of the formal terms already in use by BGS are retained together with modified definitions published by Bowen (1999).

11.1 DUNWICH GROUP

11.1.1 Kesgrave Catchment Subgroup

11.1.1.1 Sudbury Formation

The Kesgrave Catchment Subgroup (see also Sections 10.2.2 and 12.3.2) includes sand and gravel deposits of Early and Middle Pleistocene age characterised by quartz and quartzite pebbles, mainly derived from the Triassic Kidderminster Formation (once known as the Bunter Pebble Beds) of the English Midlands. The subgroup includes scattered outliers adjacent to the Evenlode valley and in the Oxford–Abingdon area that were formerly thought to be glacial deposits and termed Northern Drift (the Northern Drift Formation of Bowen, 1999). They are now recognised as terrace deposits of Thames–Evenlode river (Hey, 1986) and are consequently included in an extended Sudbury Formation. Several members are identified on the basis of elevation and clast lithology. These have been equated with units of the Sudbury Formation of the Middle Thames in various different ways (e.g. Hey, 1986; Whiteman and Rose, 1992; Bridgland, 1994; Rose et al., 1999a), but long distance correlation, particularly of the oldest units, remains speculative, and even the local subdivision is somewhat dubious, given the remanié nature of most of the deposits, the inadequate maps and very few pebble counts on which it is based.

Seven terrace deposit members of the Sudbury Formation in the valley of the Upper Thames, upstream of Oxford, are identified in published accounts (e.g. Bridgland, 1994) (Tables 3 and 17). Figure 23 illustrates an idealised section through five of the terrace deposits of the Sudbury Formation in the Evenlode valley. Downstream equivalent flint-rich terrace deposits of the pre-diversionary Thames and its tributaries of the Maidenhead-Vale of St Albans area (the Middle Thames) are referred to in Section 12.3.2.1.

Waterman's Lodge Sand and Gravel Member (WMLO)

The Waterman's Lodge Sand and Gravel Member, type locality: Stag's Plain [SP 326 182], west of Waterman's Lodge, is the oldest fluvial unit yet identified in the Sudbury Formation of the Upper Thames, although scattered pebbles of Northern Drift type occur at higher elevations (over 300 m OD) in the north Cotswolds. It is characterised by a particularly high ratio of quartz to quartzite pebbles and possibly equates with the Westland Green Member downstream (Hey, 1986).

Ramsden Heath Sand and Gravel Member (RAH)

The Ramsden Heath Sand and Gravel Member, type locality: Ramsden Heath [SP 345 158], possibly equates with the Satwell Member of Hey (1986) downstream.

Gordon House Sand and Gravel Member (GOH)

The Gordon House Sand and Gravel Member, type locality: Gordon House [SP 371 192], was introduced by Whiteman and Rose (1992) to include higher parts of the Wilcote Member of Hey (1986). It possibly corresponds with the Beaconsfield Member downstream (Bridgland, 1994; Sumbler, 1995).

North Leigh Sand and Gravel Member (NLE)

The North Leigh Sand and Gravel Member, type locality: North Leigh [SP 385 130], was introduced by Whiteman and Rose (1992) to include lower parts of the Wilcote Member of Hey (1986), such as that at the latter's original type locality (Wilcote [SP 370 153]), suggested to correspond with the Gerrards Cross Member downstream (Hey, 1986; Sumbler, 1995), but see notes for the Combe Sand and Gravel Member (below).

Three Pigeons Sand and Gravel Member

The Three Pigeons Sand and Gravel Member represents the oldest fluvial deposit of the River Thame, a north bank tributary of the Thames that drains the Vale of Aylesbury. The type locality is Milton Common where it forms a plateau about 45 m above the present floodplain (the 'Three Pigeons Plateau' of Arkell, 1947a, b, named from an inn [SP 652 034]). It corresponds with the Seventh Terrace deposits of the Thame district (BGS 1:50 000 Sheet E237), and is considered to correspond with the Combe Sand and Gravel Member (Sumbler, 1995; Horton et al., 1995).

Princes Risborough Sand and Gravel Member (PRSG)

The Princes Risborough Sand and Gravel Member is a largely decalcified chalk-flint gravel which in-fills the Princes Risborough Gap [SP 805 000] in the Chilterns escarpment on the margins of the Thame basin. Similar deposits occur in analogous 'wind gaps' elsewhere, e.g. near Wendover and Tring (Sherlock, 1922). Such gravels appear to have been deposited by an early drainage system of streams flowing down the dip slope of the Chalk, and entering the Thames to the south-east. The unit probably relates to the Beaconsfield Gravel or Gerrards Cross Gravel members (Sumbler, 1995; Horton et al., 1995) (Section 12.3.2.1).

Combe Sand and Gravel Member (CMBE)

The Combe Sand and Gravel Member, type locality: Combe [SP 410 163], corresponds with the Combe Terrace deposits of Arkell (1947a, b). It is now recognised as youngest unit of the Sudbury Formation (Sumbler, 2001) of the Upper Thames and by inference is equated with the Gerrards Cross Member of the Middle Thames area (see also Whiteman and Rose, 1992; Bridgland, 1994). However, the Gerrards Cross Member is somewhat higher than would be expected for the downstream representative of the Combe and correlation with the younger Winter Hill Gravel Member (Colchester Formation), assigned to the early part of MIS 12 remains a possibility (Gibbard, 1985; Hey, 1986; Sumbler, 1995), though with ramifications that affect the deduced chronology of the Wolston Glacigenic Formation (Section 11.2.1.1).

11.1.2 Bytham Catchments Subgroup

11.1.2.1 Baginton Sand and Gravel Formation

The pre-Anglian deposits of the Warwickshire and Leicestershire areas are assigned to the Baginton Sand and Gravel Formation of the Bytham Catchments Subgroup (Tables 3, 16 and 17; Figure 22). The formation comprises mainly quartz and quartzite-bearing sand and gravel of the Proto-Soar (Shotton, 1953), which formed the upper reaches of the Bytham River (Section 10.2.3). Relationships at Stretton-on-Fosse suggest that this unit post-dates the youngest member (Combe Sand and Gravel Member) of the Sudbury Formation (Section 11.1.1.1).

Name
Baginton Sand and Gravel Formation (BGSG) (after Baginton Sand and Baginton–Lillington Gravel of Shotton, 1953; Baginton Formation of Maddy and Sumbler, p. 36 in Bowen, 1999).

Lithology
The deposits are sands and gravels, with lenses of silt and clay. In the type area around Coventry, the formation includes gravels (the Thurmaston Gravel Member) overlain by sand (the Baginton Sand Member). The gravels are up to 98% composed of grey and purple quartzite and vein quartz, largely of Triassic derivation, with a little Jurassic limestone, ironstone and robust fossils. The sands are fine- to medium-grained, clean and well-sorted. The deposits differ from the Bytham Sand and Gravel Formation by having a low proportion of Jurassic material.

Formal subdivisions and correlation table
Subdivided into four informal members, the Thurmaston Gravel, Stretton Sand, Lillington Gravel and Baginton Sand (Tables 3, 16 and 17).

Type area/Reference section
Type section: Gravel pit north-east of Baginton [SP 348 750] (Shotton, 1953).

Lower and upper boundaries
Unconformable on pre-Quaternary bedrock.

Commonly overlain by Middle Pleistocene glacigenic deposits. Upper boundary may be difficult to determine where overlain by glaciofluvial sand and gravel, but the presence of more angular clasts, flint and chalk, and poorer sorting in the latter is usually helpful.

Landform description and genetic interpretation
The formation encompasses fluvial, lacustrine and organic deposits of the Proto-Soar River. The deposits are interpreted as the deposits of low-sinuosity braided rivers dominated by longitudinal bars.

Thickness
About 16.5 m

Distribution and extent
The valley of the Proto-Soar River around Coventry, extending as far west as Stratford-on-Avon and Moreton-in-Marsh. North-eastwards it extends as far as Castle Bytham where it is replaced by the Bytham Sand and Gravel Formation.

Age
Early Pleistocene (pre-MIS12).

The formation is divisible into four informal members (Table 17):

Thurmaston Gravel Member

The type locality for the Thurmaston Gravel Member is Thurmaston Pit [SK 646 162]. The unit is the Thurmaston Sand and Gravel of Rice (1968), or Baginton Gravel of Shotton (1953). It is composed of Bunter pebble-rich gravels forming the lower part of the Baginton Sand and Gravel Formation in Coventry to Leicester area.

The Baginton Sand and Gravel Formation of the Coventry–Leicester area includes the possibly composite *Waverley Wood Beds*, organic, channel-filling silts which at their type locality (Waverley Wood, near Leamington) underlie the Thurmaston Gravel Member, but at Brandon a few kilometres to the north, presumed equivalents (based on similar flora and fauna) are intercalated within the Thurmaston Gravel Member. At Waverley Wood these strata are of Cromerian age (pre-MIS 12) based on mammal faunas amongst other evidence. Amino acid ratios suggest a MIS 15 age (Bowen et al., 1989) but may be consistent with MIS 13.

Stretton Sand Member (STSA)

The Stretton Sand Member (type locality Stretton-on-Fosse Pit [SP 218 382]; Sumbler, 2001) comprises clean pink to brown sand beneath the Paxford Gravel Member (Wolston Glacigenic Formation — Section 11.2.1.1) at Stretton and neighbouring Paxford/Ditchford Hill. It has yielded a small fauna (Shotton, 1973; Lister, 1989), including the Straight-tusked Elephant, Palaeoloxodon antiquus, as in the Thurmaston Gravel Member of Warwickshire, its presumed equivalent.

Lillington Gravel Member

The Lillington Gravel Member comprises the Lillington Gravels of Shotton (1953) and the Snitterfield Sands and Gravels of Maddy and Lewis (1991). It is composed of locally derived, Jurassic-rich gravels present at the base of the Baginton Sand and Gravel Formation in the Stratford–Hemington area, resting on bedrock.

Baginton Sand Member

The Baginton Sand Member is a sand sequence forming the upper part of the Baginton Sand and Gravel Formation in Coventry–Leicester area. Named thus by Maddy and Lewis 1991, from the Baginton Sand of Shotton (1953), it was termed the Brandon Member by Maddy (p. 36 in Bowen, 1999).

11.2 ALBION GLACIGENIC GROUP

11.2.1 Formations of the Albion Glacigenic Group

Glacigenic deposits lying to the south of the Devensian ice sheet limit are assigned to the Albion Glacigenic Group. Following Maddy and other authors (pp. 28–44 in Bowen, 1999) formally defined units include the Wolston Glacigenic, Nurseries Glacigenic, and Ridgacre formations. The Risbury Glacigenic Formation, also described in this section, remains informal.

11.2.1.1 Wolston Glacigenic Formation

The Wolston Glacigenic Formation comprises the glacial succession of much of the English Midlands (Shotton, 1953, 1983; Sumbler, 1983a, b). The possibility exists that the *Wragby Till Member* and outwash deposits of Lincolnshire were deposited during a later glaciation and consequently may have to be assigned separate formational status. However, in the present account, all of the glacial deposits of the Midlands to the west and north of the Chalk escarpment, including the Wragby Till Member, are assigned to the Wolston Glacigenic Formation (Tables 7a, 15, 16 and 17). Figure 22 shows the stratigraphical relationships of constituent members of the Wolston Glacigenic Formation.

The type locality of the Wolston Glacigenic Formation is Wolston Pit [SP 410 746]. The formation comprises the glacigenic sediments of the Wolston Series of Shotton (1953). In the type area it overlies the Baginton Sand Member of the Baginton Sand and Gravel Formation (Bytham Catchments Subgroup) and is dissected by the Avon river system and the terrace deposits of the Warwickshire Avon Valley Formation (Britannia Catchments Group). Designated the stratotype of the (post-Hoxnian) Wolstonian Stage by Mitchell et al. (1973a) it was later shown to equate with the older (Anglian) Lowestoft Formation of East Anglia (Perrin et al., 1979; Sumbler, 1983a,b; Rose, 1987). On this basis it is generally assigned to MIS 12, although it has been argued that parts (notably the Oadby Till Member and associated outwash deposits) may date from the younger MIS 10 (Sumbler, 1995, 2001).

Name
Wolston Glacigenic Formation (WOLS) (after Wolston Formation of Sumbler, p. 37 in Bowen, 1999; includes 'Moreton Drift' of Tomlinson, 1929, and Bishop, 1958, and glacigenic sediments of the Wolston Series of Shotton, 1953).

Lithology
Predominantly tills, sands, gravels and laminated clays. In the type area and elsewhere it constitutes a succession including a basal reddish brown Trias-rich till of essentially northern provenance (Thrussington Till Member; Moreton Member), glaciolacustrine muds (Wolston Clay Member and Bosworth Clay Member), an upper grey, chalky till with Jurassic and Cretaceous material, essentially of north-eastern provenance (Oadby Till Member), and flint-rich outwash gravels (Dunsmore Gravel Member). Characteristically lacks Scottish and Lake districts erratics (which characterise the Devensian Stockport Glacigenic Formation), and western (Welsh, etc.) erratics (which are found in the probably equivalent Nurseries Glacigenic and Ridgacre formations to the west of the Wolston Glacigenic Formation).

Formal subdivisions and correlation table
Subdivided into several members: Tables 7a, 15, 16 and 17 and Figure 22.

Type area/Reference section
Type section: Wolston Pit, near Coventry [SP 410 746] (Shotton, 1953; Sumbler, 1983a, b).

Type area: Area between Coventry, Rugby and Leamington Spa, Warwickshire (Shotton, 1953; Sumbler, 1983a,b; Old et al., 1987).

Lower and upper boundaries
Overlies the pre-glacial fluvial sands and gravels of the Baginton Sand and Gravel Formation or, more generally, bedrock (mainly Triassic and Jurassic).

Ground surface or various younger Quaternary deposits (head, fluvial deposits).

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
About 25 m at type locality; elsewhere may be represented by up to 80 m of deposits.

Distribution and extent
English Midlands east of Birmingham, and as far south as the Moreton-in-Marsh and Tewkesbury areas. Precise limits in east and north somewhat uncertain and contentious, but essentially lies north-west of the Chalk scarp of the Chilterns and Norfolk and west of the Fens (including lower Witham of Lincolnshire) and west of the Lincolnshire Limestone scarp of north Lincolnshire, and (mostly) south and east of the Trent.

Age
Anglian (MIS 12 and MIS 10; Sumbler, 1995, 2001).

Avon valley (Warwickshire) and Leicestershire

The following members of the Wolston Glacigenic Formation are identified (Table 7a and 17; Figure 22 shows a simplified model of some of the stratigraphical relationships):

Thrussington Till Member (THT)

The Thrussington Till Member (Thrussington Member of Maddy, p. 38 in Bowen, 1999) is the Thrussington Till of Rice (1968, 1981). It is a mainly reddish-brown Trias-rich till extending over a large part of the Midlands. Similar tills are included in the Moreton Member at Moreton-in-Marsh in the Upper Thames valley (see below).

Wolston Clay Member (WOC)

The Wolston Clay Member comprises bedded, in some cases laminated, lacustrine clay and silt, which in the type area overlies the Thrussington Till Member, and is overlain by the Dunsmore Gravel Member. The type locality is Wolston Pit [SP 410 746]. The unit is the Wolston Clay of several authors (Shotton, 1953; Sumbler, 1983a; Old et al., 1987), or the Grounds Farm Member of Maddy (p. 37 in Bowen 1999). It is generally 10–20 m thick, though probably exceeds 30 m in the Brinklow area [SP 43 79]. It contains local lenses of sand, including the widespread Knightlow Sand Member, which divides it into lower and upper leaves. Particularly in its upper part, it contains sporadic drop-stones, mainly of chalk and flint, and bodies of till. It is well-developed in the Rugby, Coventry and Leamington area, with outliers occurring further south (e.g. Snitterfield, Stretton-on-Fosse [SP 22 38]). North of Stretton under Fosse [SP 45 81], the lower leaf passes into the lithologically similar Bosworth Clay Member, and the upper leaf is replaced by the Oadby Till Member.

Snitterfield Sand Member

The Snitterfield Sand Member (Snitterfield Member of Maddy, p. 37 in Bowen, 1999) comprises lacustrine sands overlying the Baginton Sand Member of the Baginton Sand and Gravel Formation (Bytham Catchments Subgroup). It is succeeded by the Wolston Clay Member (see above) at Hutchins Brickyard, Snitterfield [SP 234 596] (Maddy and Lewis, 1991). It is probably included with the Wolston Clay on BGS 1:50 000 Sheet E183 (Redditch).

Knightlow Sand Member

The Knightlow Sand Member (Knightlow Member of Sumbler, p. 38 in Bowen, 1999) is a lenticular body of glaciofluvial sand, generally from 1–3 m in thickness, within the Wolston Clay Member. The unit is the Wolston Sand (and Gravel) of Shotton (1953), Sumbler (1983a) and Old et al. (1987). The type locality is Wolston Pit [SP 410 746], at the foot of Knightlow Hill, and the deposit is developed principally in the Rugby–Leamington area. At the type locality it lacks Cretaceous erratics and as such probably equates with the Wigston Sand and Gravel Member, although elsewhere it is likely that similar sand bodies occur at other horizons within the Wolston Clay succession (e.g. in the Stretton under Fosse [SP 45 81] area; Sumbler, 1983a; Bridge et al., 1998).

Wigston Sand and Gravel Member (WIGS)

The Wigston Sand and Gravel Member (Wigston Member of Sumbler, p.38 in Bowen, 1999) comprises glaciofluvial sands and gravels with clasts generally dominated by lithologies such as Bunter pebbles and coal, suggesting derivation from the western ice that deposited the Thrussington Till Member. The type area is Wigston, south-east Leicester, and the type locality is Cadeby Pit [SK 435 028]. The unit was variously termed the Wigston Sand and Gravel (Rice, 1968), the Cadeby Sand and Gravel (Douglas, 1980) and the Wolston Sand and Gravel (Rice, 1981; Bridge et al., 1998). It is well-developed in the area between Market Bosworth, Leicester and Monks Kirby [SP 46 83]. To the south it is probably represented by the Knightlow Sand Member (see above) at the latter's type locality. It attains a probable maximum thickness of over 25 m in the area between Leicester and Coventry.

Bosworth Clay Member (BOSW)

The Bosworth Clay Member (Bosworth Member of Sumbler and Douglas, p. 38 in Bowen, 1999) comprises lacustrine, commonly laminated clays and silts lying between the Thrussington Till Member and the Wigston Sand and Gravel Member. The type locality is Cadeby Pit [SK 435 028]. The member was formerly termed the Bosworth Clays and Silts (Shotton, 1976; Douglas, 1980; Rice, 1981; Worssam and Old, 1988), the Glen Parva/Rotherby Clays (Rice, 1968) (the informal *Glen Parva*, GPCL and *Rotherby*, RYCL members) and the Wolston Clay (Bridge et al., 1998). It reaches over 25 m in thickness in the Wolvey area [SP 43 87] and is developed between Market Bosworth and Leicester, extending to Stretton under Fosse in the south (i.e. the area where it is always overlain by Wigston Sand and Gravel or Oadby Till members, and where there is no 'Upper Wolston Clay'). Beyond Stretton it passes into the lower leaf of the Wolston Clay Member.

Hillmorton Sand Member (HISA)

The Hillmorton Sand Member (Hillmorton Member of Sumbler, p. 37 in Bowen, 1999) consists of glaciofluvial sand with some gravel lenses, which in-fills a bedrock channel (probably a modified pre-glacial valley) east of Rugby. The type locality is Hillmorton Pit [SP 542 737]. The unit is the Hillmorton Sand of Sumbler (1983a) and Old et al. (1987) and is up to 50 m thick. The Hillmorton Sand Member passes westwards and northwards into the lacustrine Wolston Clay Member. At the type locality it is overlain by the Dunsmore Gravel Member but south-eastwards passes below the Oadby Till Member. It probably represents outwash associated with the advance of the ice that deposited the Oadby Till Member.

Shawell Sand and Gravel Member (SLSG)

The Shawell Sand and Gravel Member (Shawell Member of Sumbler, p.37 in Bowen, 1999; Shawell Gravel of Sumbler, 1983a, b and Bridge et al., 1998) comprises a body of clast-supported flint and limestone-rich gravels and cross-bedded sands, intercalated within the Oadby Till Member in an area between Rugby and Lutterworth. The type locality is Gibbet Lane Quarry, Shawell [SP 540 806]. It is up to about 11 m thick and represents proximal outwash derived from the Oadby Till Member. It is probably slightly younger than the Wigston Sand and Gravel Member and the main bed of the Knightlow Sand Member.

Oadby Till Member (ODT)

The Oadby Till Member (Oadby Member of Maddy and Sumbler, pp. 38–39 in Bowen, 1999) is a diamicton with mainly Lias-derived matrix and characteristically chalk and flint erratics together with other components notably rounded quartzose sandstone cobbles (mainly Carboniferous), traceable over a wide area of the Midlands (Coventry–Grantham–Bedford area), and including the Moreton-in-Marsh area (see below) where relationships with the Upper Thames Valley Formation imply correlation with MIS 10 (Sumbler, 1995, 2001).

Dunsmore Gravel Member (DMG)

The Dunsmore Gravel Member (Dunsmore Member of Sumbler, p. 37 in Bowen, 1999) is a flint-rich, poorly sorted glaciofluvial outwash sand and gravel which caps the glacial succession of the Wolston Glacigenic Formation in the area between Hinckley in the north (where it overlies the Oadby Till Member) and Leamington Spa in the south (where it overlies the Wolston Clay Member). The type locality is Linghall Quarry [SP 449 729], Lawford Heath, Rugby (as yet undescribed), which shows the Dunsmore Gravel on Wolston Clay. It typically forms plateaux such as that of Dunsmore in the Rugby area. The member is generally 2–4 m thick, but highly variable due to the channelled base. It is considered to grade downstream into an older part of the (probably composite) Pershore Sand and Gravel Member (Avon Fifth Terrace) of the Warwickshire Avon Valley Formation (Section 11.3.4.1) and may be equated with the Spring Hill Member (Sixth Terrace) of the Severn Valley Formation (Table 17) (Sumbler, 1983a, 1995; Old et al., 1987) that is assigned to MIS 10 (Bowen, 1999).

Proto-Trent valley, west of the Lincoln Gap

The following member of the Wolston Glacigenic Formation is recognised (Table 16):

Skellingthorpe Clay Member

At Skellingthorpe, just west of Lincoln, glaciolacustrine deposits of the Skellingthorpe Clay Member (Skellingthorpe

Member of Brandon and Sumbler, p. 41 in Bowen, 1999; Skellingthorpe Clay of Howard, 1993) are generally present beneath the Eagle Moor Member (Brandon and Sumbler, 1988) (Eagle Moor Sand and Gravel Member, Trent Valley Formation, Section 11.3.2.1). BGS borehole SK96NW4 [SK 9123 6976] (Jackson, 1977, p.10) proved a maximum thickness of 6.6 m of laminated clay and silt.

Proto-Trent valley, east of the Lincoln Gap and the Bain Valley

The following members of the Wolston Glacigenic Formation are identified (Table 16):

WRAGBY TILL MEMBER

The Wragby Till Member is a chalk-bearing till with a matrix derived chiefly from Middle and Upper Jurassic mudstones (notably Oxford Clay to Kimmeridge Clay). The type locality is Wragby [TF 133 781]. The unit is the Wragby Till of Straw (1966, 1983) and its variants (notably the Heath Till), assigned by Lewis and Sumbler (pp. 10–13 in Bowen, 1999) to the Lowestoft Formation (Table 15). It passes westwards into the Lias mudstone-rich Oadby Till Member.

KIRKBY MOOR SAND MEMBER

The Kirkby Moor Sand Member (the Kirkby Moor Sands of Straw, 1958) comprises up to about 10 m of generally gravel-free, well-bedded sands forming the high ground of Kirkby Moor. The type locality is a sand pit [TF 228 627] east of Kirkby-on-Bain. The relationship to the contiguous Tattershall Airfield Sand and Gravel Member (see below) is not clear; the latter may represent the terraced basal part of the Kirby Moor Member. The Kirkby Moor Member was inferred to be distal glaciofluvial outwash (Worsley, 1991).

Lower Derwent valley downstream of Derby to the confluence with the River Trent

The following members of the Wolston Glacigenic Formation are identified (Table 16):

MILL HILL SAND AND GRAVEL MEMBER

The type area of the Mill Hill Sand and Gravel Member is Mill Hill [SK 462 345] where it comprises a sand and gravel terrace outlier, about 2 m thick at 57 m above OD. It is mapped as a glaciofluvial deposit (Brandon, 1996).

THRUSSINGTON TILL MEMBER (THT)

See above (Avon valley and Leicestershire).

OADBY TILL MEMBER (ODT)

See above (Avon valley and Leicestershire).

Lower Soar valley and Loughborough district to the confluence with the River Trent

The following members of the Wolston Glacigenic Formation are identified (Table 16):

HATHERN GRAVEL MEMBER (HNGR)

The type locality of the Hathern Gravel Member (Hathern Member of Brandon, p. 39 in Bowen, 1999) is a series of pits dug at Hathern [SK 503 214] (Brandon, 1995; Carney et al., 2001), the only known locality. The deposit comprises up to 3 m of mainly coarse gravel with its base at 53 m above OD, situated between bedrock and the Thrussington Till Member. It contains abundant Carboniferous Limestone chert and limestone clasts, the latter particularly as angular cobbles. It was probably deposited as southerly-directed glaciofluvial outwash along pre-existing Proto-Derwent valley (Brandon, 1995).

In the Loughborough, Burton and Derby district (BGS 1:50 000 Sheet E141) the informal *Findern Clay Member* (FC) (Brandon, 1997; Carney et al., 2001) represents glaciolacustrine deposits developed within deep channels or tunnel valleys (the Elvaston palaeochannel) cut into bedrock or till by sub-glacial water.

THRUSSINGTON TILL MEMBER (THT)

The Thrussington Till Member contains more Carboniferous material than in the type area (Brandon 1995) (see above — Avon valley and Leicestershire).

OADBY TILL MEMBER (ODT)

See above (Avon valley and Leicestershire).

Uppermost Evenlode valley (a Thames tributary) around Moreton-in-Marsh

The following members of the Wolston Glacigenic Formation are identified (Table 17):

PAXFORD GRAVEL MEMBER (PA)

The Paxford Gravel Member (after Sumbler, 2001) originates from the Paxford Gravel described by Dines (1928) and corresponds to the Ditchford Gravel of Tomlinson (1929). The unit comprises limestone-dominant gravels occurring at the base of the Wolston Glacigenic Formation in the area immediately north of Moreton-in-Marsh. The type locality is the former Paxford Gravel Pit [SP 188 380]. The unit includes bodies of purplish clay (cf. Moreton Member), and has an interfingering relationship with evident outwash gravels. It is probably a composite deposit of scree/head gravels partly reworked by outwash during ice advance. The gravels have yielded a molar of mammoth (Richardson and Sandford, 1960). Previous suggestions that the deposit represents the upstream equivalent of the Hanborough Sand and Gravel Member (Upper Thames Valley Formation) of the Evenlode (Arkell, 1947a; see discussion by Sumbler, 1995) are untenable. The Thames/Evenlode was truncated at a much earlier date (Sumbler, 2001).

MORETON MEMBER (MTON)

The Moreton Member (after Sumbler, 2001) comprises heterogeneous silts, sands and clays, occurring around Moreton-in-Marsh [SP 205 323]. The bulk of the member is composed of red, soft silty clays, laminated reddish or grey clays and silty fine-grained sands with a few scattered pebbles. It includes bodies of reddish brown, Trias-rich till, similar to the Thrussington Till Member, and the silts are analogous to the Wolston Clay Member (see above — Avon valley and Leicestershire). To the south-west of Moreton-in-Marsh, assorted quartz/quartzite-rich outwash gravels grade into the profile of Freeland Terrace and are consequently classified as the Freeland Sand and Gravel Member (Upper Thames Valley Formation).

Oadby Till Member (ODT)

The Oadby Till Member comprises chalky diamictons in sequences of variable thickness ranging from about 5 m up to 15 m (at Wolford Wood [SP 236 332], Sumbler, 2001). Associated bodies of flint- and chalk-rich glaciofluvial deposits occur near the base of the succession. The diamictons are essentially indistinguishable from those developed in the type area (see above — Avon valley and Leicestershire). Near Moreton-in-Marsh, it overlies the Moreton Member, or locally rests on Paxford Gravel Member.

Wolford Heath Sand and Gravel Member (WOHE)

The Wolford Heath Sand and Gravel Member is a valley sandur deposit of more-or-less flinty outwash gravels, derived from the Oadby Member (Sumbler, 2001). It grades southwards and, beyond the southern limit of the Moreton Drift, is represented by the Daylesford Member of the Upper Thames Valley Formation (on the basis of elevation and clast content).

Area east of the Cherwell and north of the Ray in the neighbourhood of Aylesbury and Buckingham

The glacial deposits of this region have not yet been formally subdivided into named units. However, in the Buckingham district (BGS 1:50 000 Sheet E219; Sumbler, 2003), they comprise a similar succession to the Wolston Glacigenic Formation of the Moreton-in-Marsh area, with older mainly locally-derived tills with quartz/quartzite erratics, local glaciolacustrine sands and silts (cf. Moreton Member), and younger chalk-flint-rich tills and mainly flint-bearing sands and gravels (Oadby Till Member). As with the Moreton Drift, it may be that these deposits correlate with both MIS 10 and 12 (Sumbler, 1995, 2001). They are consequently included in the Wolston Glacigenic Formation, and it may be appropriate to extend this term to all the 'Anglian' glacial deposits in the Midlands, to the north and west of the Chilterns.

Wellingborough and Bedford districts

The informal Bozeat Till (BOZE), assigned to the Wolston Glacigenic Formation, has been identified in the western part of the Wellingborough and Bedford districts (Barron et al., 2006; 2010) (Table 15). It comprises up to 5 m of dark bluish grey diamicton with clasts of Jurassic lithologies and rare chalk. The deposits underlie the Oadby Till Member (Wolston Glacigenic Formation).

Birmingham and Wolverhampton district

The following members of the Wolston Glacigenic Formation are identified (Table 17):

Thrussington Till Member (THT)

The Thrussington Till Member (see above — Avon valley and Leicestershire) is a red Triassic-rich till occurring beneath the Woolridge Sand and Gravel Member at Woolridge (see below), and present at several other localities in the region. It corresponds with the Eastnor Boulder Clay of Hey (1959, 1963).

Woolridge Sand and Gravel Member (WDGE)

The Woolridge Sand and Gravel Member (Woolridge Member of Maddy and Sumbler, p. 34 in Bowen, 1999) comprises generally less than 2 m of clayey sand and gravel beneath the Woolridge Terrace of Wills (1938) and is found as outliers 70–80 m above the floodplain downstream of Tewkesbury. The type locality is Woolridge [SO 806 237] (Maddy et al., 1995). The member is believed to be glaciofluvial outwash associated with the Thrussington Till, although some mapped outcrops may include younger head or fluvial gravels.

11.2.1.2 Nurseries Glacigenic Formation

The Nurseries Glacigenic Formation probably equates with the lower part of the composite Wolston Glacigenic Formation (Section 11.2.1.1).

Name
Nurseries Glacigenic Formation (NURS) (after Horton, 1974, and Maddy, p. 34 in Bowen, 1999).

Lithology
Comprises the older of the two pre-Devensian glacial successions identified in the Birmingham area. Predominantly tills, sands and gravels and laminated glaciolacustrine clays. Characteristically lacks Scottish and Lake Districts erratics (which characterise the Devensian Stockport Glacigenic Formation), and northern and eastern (e.g. Cretaceous) erratics (which are found in the Wolston Glacigenic Formation). At the type locality it comprises brown till with abundant erratics (mainly local Upper Carboniferous Coal Measures rocks (Duigan, 1956; Kelly, 1964; Powell et al., 2000) but including rocks of western derivation such as North Welsh rhyolite), together with sands and gravels and laminated clays. Represented by sand and gravel and laminated clay at Nechells (Horton, 1989b; Powell et al., 2000, fig. 25).

Formal subdivisions and correlation table
No subdivisions (Tables 7a and 17).

Type area/Reference section
Type locality: Quinton [SO 992 847] near Birmingham (Horton, 1974) where it underlies the temperate Quinton Peat Formation (Section 11.3.1.1).

Lower and upper boundaries
Rests upon Permo-Triassic and Palaeozoic bedrock.

At the type locality and at Nechells, overlain by the organic Quinton Peat Formation (Hoxnian). Elsewhere and more generally, inferred to be overlain by the Ridgacre Formation, or depending on lateral extent, younger Quaternary deposits or ground surface.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
About 20–25 m at type locality and Nechells.

Distribution and extent
Full extent highly uncertain pending further work, but likely to be fairly widespread in and to the south of the Birmingham (Redditch and Birmingham districts) (BGS 1:50 000 Sheets E168, 182 and 183) beyond the limit of the Stockport Glacigenic Formation (Devensian), both beneath the Ridgacre Formation and beyond its limits. Currently positively identified only in sections at Quinton and Nechells. Remnants may be present within the Devensian limit beneath the Stockport Glacigenic Formation.

Age
Anglian (MIS 12).

11.2.1.3 Risbury Glacigenic Formation

The 'Older Drift Deposits' of the Lugg Valley, Wye Valley and valleys west and south of the Malvern Hills were assigned by Brandon, Richards and Maddy (pp. 28–32 in Bowen, 1999) to the Risbury Formation and considered to correlate with the Anglian Stage (MIS 12). It comprises ice-contact, glaciolacustrine, glaciodeltaic and glaciofluvial deposits that occur as remnants above 80 m OD outside the Late Devensian terminal moraine from Leominster to areas south and east of Hereford (Brandon, 1989; Richards, 1994). Currently the Risbury Glacigenic Formation (as it is here known) and component members are informal units and only the *White House Silts Member* (WSI) and the *Coddington Till Member* (CODT) (White House and Coddington members of Brandon and Richards, p. 32 in Bowen, 1999) have been described in the BGS Lexicon, based on Richards (1994) and Barclay et al. (1992). At the Coddington type locality [SO 73 43] the Coddington Till Members comprises up to 10 m of reddish brown tills of northern provenance with a significant component of Triassic quartzite and quartz clasts. It corresponds with the Thrussington Till Member (Wolston Glacigenic Formation) of the areas to the north-east (Section 11.2.1.1).

Other informal units described by Brandon and Richards (pp. 28–29 in Bowen 1999) include:

The *Newton Farm Member*, stratotype: Newton Farm [SD 627 516], comprises glacitectonised, glaciodeltaic sands and gravels up to 26 m thick. The deposits were laid down at the margins of a large ice-dammed lake: Glacial Lake Bromyard (Richards, 1994). The deposits were formerly mapped as Older Fluvioglacial Gravel Deposits (Brandon, 1989).

The *Kyre Brook Member,* stratotype: Hall Farm [SO 642 624], comprises Humber Formation sands and gravels reworked by catastrophic drainage from Glacial Lake Bromyard (Richards, 1994). Cross-bedded sand units and overlying cross-bedded gravel up to 6 m thick form a low terrace from Collington [SO 645 597] to Tenbury Wells [SO 680 610], with a base at 100 m to 120 m OD.

The *Stoke Lacy Member,* stratotype: Windmill Hill [SO 606 487], comprises glacitectonised sand, gravel and till units up to 15 m in thickness (Richards, 1994). Formerly it was mapped as Older Fluvioglacial Gravel Deposits (Brandon, 1989).

The *Stoke Prior Member*, type area: Stoke Prior–Steens Bridge–Bowley Court [SO 555 524] to [SO 555 580], comprises glacigenic deposits forming hill cappings between 80 and 140 m above OD. The member includes till, glaciolacustrine, glaciofluvial and glaciodeltaic deposits representing ice-marginal deposition and the formation of Glacial Lake Humber during a recessional phase of a pre-Hoxnian glaciation (Richards, 1994). Formerly it was mapped as Older Fluvioglacial Gravel Deposits (Brandon, 1989).

The *Franklands Gate Member*, stratotype: Franklands Gate [SO 549 456], comprises channelised glaciotectonised, ice-marginal sands and gravels up to 8 m thick with a base at 80 m above OD at the type site, 98 m above OD at Norton Court [SO 539 495] to 115 m above OD at Vennwood [SO 5485 4900]. Formerly it was mapped as Older Fluvioglacial Gravel Deposits (Brandon, 1989).

The *Portway Member*, type area: Burghill [SO 488 448] (Brandon and Hains, 1981), comprises glacitectonised, glaciolacustrine and glaciofluvial deposits up to 12 m thick, which are interpreted to represent ice-marginal fluctuation and deposition during a recessional phase of a pre-Hoxnian glaciation. Gravels of this member are dominated by locally-derived Devonian clasts and the absence of northerly-derived components (Brandon, 1989; Richards, 1994). The member occurs beyond or beneath the deposits of the Late Devensian Herefordshire Formation of Brandon (p. 31 in Bowen, 1999) which includes the Hereford Till Member (HDTI) (in this framework assigned to the Brecknockshire Glacigenic Formation; Section 8.2.2.1). The Portway Member was formerly named the Portway Sand and Gravel by Brandon and Hains (1981).

11.2.1.4 Ridgacre Formation

Deposits of the Ridgacre Formation lie mainly beyond the limit of the Late Devensian glaciation, although remnants may be concealed by the Stockport Glacigenic Formation within the Devensian limit. The Ridgacre Formation overlies the temperate Quinton Peat Formation (Hoxnian) (Section 11.3.1.1).

Name
Ridgacre Formation (RIDG) (after Shotton, 1989, and Maddy, p. 34 in Bowen, 1999).

Lithology
Comprises the younger of the two pre-Devensian glacial successions identified in the Birmingham area. Predominantly sands and tills, which characteristically lack Scottish and Lake Districts erratics (which characterise the Devensian Stockport Glacigenic Formation), and northern and eastern (e.g. Cretaceous) erratics (which are found in the pre-Devensian Wolston Formation). At the type section it comprises glacigenic reddish-brown and orange sand with clay partings, overlain by reddish brown till with Trias (mainly Bunter quartz/quartzite) and Upper Carboniferous erratics; similar deposits of sand and gravel occur at Nechells.

Formal subdivisions and correlation table
No subdivisions. Tables 7a and 17.

Type area/Reference section
Type section: Quinton [SO 992 847] near Birmingham.

Lower and upper boundaries
At the type section and at Nechells, the Ridgacre Formation overlies the organic Quinton Peat Formation (Hoxnian). More generally, inferred to rest upon Nurseries Glacigenic Formation or Permo-Triassic or Palaeozoic bedrock.

Ground surface or various younger Quaternary deposits. Remnants may be present inside the Devensian limit beneath the Stockport Glacigenic Formation.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
About 8 m at type locality; elsewhere may be represented by up to 50 m of deposits.

Distribution and extent
Full extent highly uncertain pending further work, but likely to be widespread in and to the south of the Birmingham area beyond the limit of the Devensian Stockport Glacigenic Formation, and probably makes up the great bulk of the pre-Devensian glacigenic deposits there, and possibly in adjoining districts. Currently positively identified only in sections at Quinton and Nechells where it overlies the temperate (Hoxnian) Quinton Peat Formation. Possibly also represented by till at Stourport beneath the Holt Heath Sand and

Gravel Member of the Severn Valley Formation (Dawson, 1988; Maddy et al., 1995), and by gravels farther upstream in the Stour valley (Maddy et al., 1995). Remnants may be present inside the Devensian limit beneath the Stockport Glacigenic Formation.

Age
The age and correlation of the Ridgacre Formation is contentious; it is probably related to the Wolston Glacigenic Formation (e.g. Shotton, 1989), and was assigned to MIS 10 by Sumbler (1995), but Maddy et al. (1995) believed it to represent a separate and younger glaciation (MIS 6) partly from Cl36 dates.

11.3 BRITANNIA CATCHMENTS GROUP

11.3.1 Formations of the Britannia Catchments Group

11.3.1.1 Quinton Peat Formation

Within the Britannia Catchments Group the Quinton Peat Formation (Tables 6 and 17) overlies the Nurseries Glacigenic Formation (Albion Glacigenic Group) at Quinton (Horton, 1974, 1989b) and Nechells (Duigan, 1956; Kelly, 1964; Shotton and Osborne, 1965; Powell et al., 2000, fig. 26). The formation is assigned to the Hoxnian Stage on the basis of the pollen and insect content (Duigan, 1956; Kelly, 1964) and as such is assigned to MIS 11. Similar deposits were proved in boreholes at Grimstock Hill, near Gilson [SP 192 902] (Brown, 1980) and Trysull [SJ 85 95] (Morgan, 1973) where they comprise the **Trysull Silt Formation** (Section 8.4.1.1, Table 13).

Name
Quinton Peat Formation (QUIP) (after Kelly, 1964 and Horton, 1989b; Quinton Formation of Maddy and Sumbler, p. 34 in Bowen, 1999).

Lithology
Peat, organic sand, silt and humic clay with root traces and drifted wood.

Formal subdivisions and correlation table
No subdivisions (Tables 6 and 17).

Type area/Reference section
Type section: Quinton [SO 992 847] near Birmingham (Horton, 1974, 1989b).

Lower and upper boundaries
Overlies Nurseries Glacigenic Formation (Albion Glacigenic Group) at Quinton and Nechells.

Overlain by Ridgacre Formation (Albion Glacigenic Group) at Quinton and Nechells.

Landform description and genetic interpretation
Temperate organic and lacustrine deposits.

Thickness
Up to 15 m.

Distribution and extent
Quinton and Nechells districts of Birmingham.

Age
Hoxnian (MIS 11) or MIS 9.

Post-Anglian fluvial deposits of the Midlands, Upper Thames and Severn valleys are assigned to formations of three subgroups, the **Trent–Witham Catchments, Thames Catchments** and the **Severn and Avon Catchments** subgroups.

11.3.2 Trent–Witham Catchments Subgroup

All of the terrace deposits of the Trent Basin are included in the Trent–Witham Catchments Subgroup (Tables 6 and 16). The basin came into existence at the end of the Anglian glaciation, generally considered to be MIS 12. However, vertical separation of the terraces in the Trent Valley suggests that the oldest unit, the Eagle Moor Member, is the earliest representative of Trent Basin drainage and, as distal glacial outwash, is likely to date from MIS 10 (cf. the correlative Dunsmore Gravel Member of the Wolston Glacigenic Formation). Equivalents of the Eagle Moor Member include the Martin Sand and Gravel Member and the Tattershall Airfield Sand and Gravel Member of the 'Proto-Trent' and Bain Valley (see above and Table 16). In this account, all three units are placed in the Trent Valley Formation.

It seems likely that the glaciation responsible for the deposition of the Thrussington Till Member belongs to MIS 12. The drainage of the East Midlands prior to this glaciation had a very different configuration. The Proto-Soar or Bytham River was the main trunk river and the north–south Derby River was a major tributary. Their deposits are included in the Dunwich Group (Section 10.2.3). Terrace deposits are known which predate MIS 13 but the last deposition by these rivers was during MIS 12.

The present River Trent valley enters the Humber north of Scunthorpe, but in pre-Ipswichian (MIS 5e) times the 'Proto-Trent' flowed from Newark through the Lincoln Gap [SK 980 710] to the Wash. This route was abandoned by the Trent during the Late Devensian, but was taken up by the River Witham, the latter river abandoning its former course through the Ancaster Gap [SK 980 440] which, contrary to much literature, seems to be an entirely post-Anglian feature.

Other major basin tributaries whose deposits have been recently researched and for which there is a significant amount of data are the lower Dove, Derwent, Soar, Wreake and Bain. Apart from the lower Dove and Wreake, which share nomenclatures with the Trent and Soar valleys respectively, the deposits of the major tributaries are grouped into their own valley formations. This is mainly because of the enormous lithological variations in the composition of the gravels. All these valleys contain a flight of river terraces that can readily be correlated by altimetry. Discoveries at several sites each of interglacial and interstadial deposits with biota referable to MIS 2, 5a or 5c, 5e and 7 have strengthened the correlations proposed, as have comparison of details of internal terrace stratigraphy, sedimentology, presence of rubified soil, degree of cryoturbation and so forth in terrace deposits in different valleys. Head deposits have been extensively mapped in all the valleys but head terrace sequences are particularly preserved in clay vales adjacent to the Trent, notably the Vale of Belvoir. There, they have been named the *Langar Head* (LRHD), *Harby Head* (HYHD), and *Pen Hill Head* (PHHD), while in the Wreake valley (i.e. Stapleford Vale) they are the *Burton Lazars Head* (BLHD) and *Stapleford Head* (SDHD) (see BGS 1:50 000 Sheet E142, Melton Mowbray). These deposits may be referred to the appropriate valley formation but are not described herein. A summary of the nomenclature is given in Table 16.

Name
Trent–Witham Catchments Subgroup (TRWCA) (after the Trent Catchments Subgroup of McMillan, 2005, and McMillan et al., 2005).

Lithology
Sand, gravel, silt and organic deposits. The sands and gravels contain clasts derived from rocks cropping out in the Midlands of England (mainly Triassic 'Bunter', ironstone and chert, Carboniferous sandstone, Lias siltstone, limestone and ironstone).

Formal subdivisions and correlation table
Subdivided into the Trent Valley, Soar Valley and Bain Valley formations (Tables 6 and 16).

Type area/Reference section
Type area: The catchment of the valleys of the River Trent and Witham, Soar, Bain and their tributaries south and east of the Peak District including Lincolnshire. See also stratotypes of constituent formations.

Lower and upper boundaries
Unconformable contact with units of Albion Glacigenic Group and bedrock.

Generally the ground surface, but units of this group locally interfinger with units of the British Coastal Deposits Group.

Landform description and genetic interpretation
The Trent–Witham Catchments Subgroup comprises a suite of fluvial, lacustrine, mass movement (head), periglacial and organic (peat) deposits. The subgroup includes the alluvium and river terrace deposits of the Trent and Witham valleys and pre-diversionary valleys (Trent Valley Formation), the Soar valley (Soar Valley Formation) and the Bain valley (Bain Valley Formation) and their respective tributaries, including the rivers Derwent (Derbyshire), Dove and Devon.

Thickness
About 25 m at type locality; elsewhere may be represented by up to 80 m of deposits.

Distribution and extent
The catchments of the valleys of the River Trent and Witham, Soar and Bain and their tributaries south and east of the Peak District and including Lincolnshire.

Age
Anglian to Holocene (MIS 12–1).

11.3.2.1 Trent Valley Formation

The Trent Valley Formation is established to include all terrace deposits of the Trent Valley. There is difficulty in correlating terraces upriver of the Trent Trench (between Nottingham and Newark) with those developed beyond Newark in the 'Proto-Trent' route through the Lincoln Gap [SK 980 710]. Upstream of Nottingham, there is no biostratigraphical control available for deposits older than MIS 5e, and the terrace deposits are correlated by altimetry.

Name
Trent Valley Formation (TRVA) (modified after Brandon, p.41 in Bowen, 1999).

Lithology
Mainly sand, gravel and mud; divided (in type area) into six principal 'terrace' members (Eagle Moor, Etwall, Egginton Common, Beeston, Holme Pierrepont and Hemington members), plus Holocene alluvium (the Trent Member of Bowen, 1999) and with local named organic deposits. Includes contemporaneous head, colluvium and soil deposits. Gravel composition varies substantially throughout the catchment but is generally dominated by pebbles of 'Bunter' quartzite and other lithologies derived from the Triassic Sherwood Sandstone Group, together with a proportion of material from local bedrock sources and from glacial deposits of the Anglian Wolston Formation and, in the youngest terraces, from the Devensian Stockport Glacigenic Formation.

Formal subdivisions and correlation table
Subdivided into terrace deposit members: see below and Tables 6 and 16.

Type area/Reference section
Type area: Middle Trent Valley, Burton upon Trent to Nottingham [SK 43 00] (Clayton, 1953; Posnansky, 1960; Carney et al., 2001, 2002a).

Lower and upper boundaries
Unconformable, commonly channelled base on bedrock or glacial deposits (mostly Anglian Wolston Glacigenic Formation, or, in the uppermost Trent, Devensian Stockport Glacigenic Formation).

Ground surface.

Landform description and genetic interpretation
Fluvial terrace and alluvial deposits and related organic deposits of the River Trent from its source to the Humber, and those of its tributaries excluding the Soar and possibly others, pending review. The formation includes deposits of older river course via the Lincoln Gap.

Thickness
Up to 10 m.

Distribution and extent
Modern Trent catchment (excluding Derwent and Soar) and the course of the 'Proto-Trent' from Newark and through the Lincoln Gap.

Age
Anglian to Holocene (MIS 12–1).

Trent valley, upriver of Newark

The following six members of the Trent Valley Formation are identified:

Eagle Moor Sand and Gravel Member (EMSG)

The Eagle Moor Sand and Gravel Member (Brandon and Sumbler, 1991) is probably equivalent to the Upper Hilton glaciofluvial terrace gravels (Clayton, 1953; Posnansky, 1960) forming terraces about 58 m above OD (see also Martin Sand and Gravel Member).

Etwall Sand and Gravel Member (ETSG)

The Etwall Sand and Gravel Member underlies the dissected terrace remnants at 60–65 m above OD along the northern side of the lower Dove into the Trent valley. The type area is Hilton–Etwall–Willington [SK 250 315–295 298]. The main deposit consists of up to 3 m of cryoturbated sands and gravels It is the probable equivalent, in part, of the deposits of the Upper Hilton Terrace (Clayton, 1953; Posnansky, 1960). It is separated from the lower Egginton Common Sand and Gravel Member by a 3 m rock step.

The *Hykeham Soil* of the Egginton Common Sand and Gravel Member lies on the surface of the Etwall Sand and Gravel Member in its type area of Hilton–Etwall–Willington [SK 250 315–295 298].

Egginton Common Sand and Gravel Member (EGSG)

The Egginton Common Sand and Gravel Member underlies an extensive terrace on the northern side of the lower Dove into the Trent valley at 60–55 m above OD The type area is Hilton–Etwall–Willington [SK 252 307–290 286]. The main deposit (the Egginton Common Sand and Gravel) comprises up to 3 m of cryoturbated sands and gravels. It is correlated with the Lower Hilton Terrace deposits (Clayton, 1953; Posnansky, 1960). It includes the rubified temperate Hykeham Soil.

Beeston Sand and Gravel Member (BSSG)

The Beeston Sand and Gravel Member underlies a dissected terrace up to 7 m above the River Trent floodplain. The type area is Long Eaton to Beeston [SK 480 345–5309 370]. The main deposit is the Beeston Sand and Gravel, up to 5 m thick. It corresponds with that part of Beeston Terrace deposits of the Trent (not Derwent) defined by Clayton (1953) and Posnansky (1960), lying upriver of the Trent Trench.

Holme Pierrepont Sand and Gravel Member (HPSG)

The Holme Pierrepont Sand and Gravel Member was formerly termed the Floodplain Terrace (Clayton, 1953) and Floodplain Sand and Gravel (Brandon and Sumbler, 1988). The stratotype is defined at the Holme Pierrepont sand and gravel pits [SK 62 38], Nottingham (Charsley et al., 1990). The main deposit, the Holme Pierrepont Sand and Gravel comprises immature sandy gravels, up to about 10 m thick. It forms an extensive valley sandur along Trent valley downriver of the former late Devensian ice front at Uttoxeter and upriver of Burton upon Trent. It occurs beneath alluvium and Hemington Terrace Deposits and also forms low terraces about 1–2 m above the floodplain. A fauna of cold stage large mammals has been listed from the deposit (e.g. Posnansky, 1960).

Hemington Gravel Member (HETD)

The Hemington Gravel Member forms a terrace up to about 1 m above the floodplain in an area from Shardlow to Long Eaton [SK 43 30–49 31]. In contrast to the alluvium it commonly exhibits medieval ridge and furrow systems. The stratotype is the Hemington Pit [SK 464 306]. The member overlies the Holme Pierrepont Sand and Gravel Member and comprises a lower unit of laterally accreted gravels, the Hemington Gravel, and an upper unit of overbank silts totalling about 2 m. Basal silts in channels below the Hemington Gravel contain late-glacial to early Holocene pollen and are radiocarbon dated at 10 320 ± 160 years BP (Coope and Jones in Shotton, 1977). The member merges with the Ambaston Terrace deposits (Ambaston Gravel Member) of the Lower Derwent (Brandon, 1996).

Derwent Valley

The following members and beds are identified:

Eagle Moor Sand and Gravel Member (EMSG)

The Eagle Moor Sand and Gravel Member (Brandon and Sumbler, 1991) is probably equivalent to the Upper Hilton glaciofluvial gravels (Clayton, 1953; Posnansky, 1960) forming terraces about 58 m above OD.

Ockbrook Sand and Gravel Member (OKSG)

Several minor highly cryoturbated remnants of sand and gravel along the north side of valley below Derby at between 56 and about 52.5 m above OD are assigned to this unit. The maximum thickness of the unit is about 2 m (Brandon, 1996). The type area is Ockbrook [SK 425 348] where there is the largest sand and gravel terrace remnant. The deposits were included in the Upper Hilton Terrace by Clayton (1953) and Posnansky (1960).

Borrowash Sand and Gravel Member (BOSG)

The Borrowash Sand and Gravel Member forms a well-developed, dissected, highly cryoturbated gravel flat (Lower Hilton Terrace; Clayton, 1953; Posnansky, 1960) along the north side of Derwent valley below Derby, at between 53 and 44 m above OD. The type area is Borrowash [SK 4167 3425], where there is the largest sand and gravel terrace remnant. The maximum thickness of the unit is about 4.5 m (Brandon, 1996).

Allenton Sand and Gravel Member (ALSG)

The Allenton Sand and Gravel Member is composed of 2–4 m of gravels underlying a vast cryoplanation terrace feature, about 2–6.5 m above the floodplain alluvium, on both sides of Derwent below Derby. The type area is Allenton [SK 36 34–41 31]. They are evidently post-Ipswichian (post-MIS 5e) on the basis of hippopotamus remains in the underlying Crown Inn Bone Beds, and pre-late Devensian by the degree of post-depositional cryogenic disturbance (Brandon, 1996). They were previously correlated with the Beeston Terrace of the Trent (e.g. Swinnerton, 1937; Clayton, 1953; Posnansky, 1960; Jones and Stanley, 1974).

The *Crown Inn Bone Beds* comprise about 3 m of clays, silts and gravels (Bemrose and Deeley, 1896). The type locality is a well at the yard of the former Crown Inn, Allenton [SK 379 326]. Sand towards the base of the sequence contains bones of mammals including hippopotamus, considered diagnostic of the Ipswichian Interglacial (MIS 5e). The beds infill a palaeochannel below gravels of the Allenton Sand and Gravel Member (Brandon, 1996). Gravels described by Jones and Stanley (1974) (Alvaston Formation of Thomas, p. 97 in Bowen, 1999) from nearby Boulton Moor [SK 385 315] are probably from the same channel.

Holme Pierrepont Sand and Gravel Member (HPSG)

As described in the Trent Valley.

Ambaston Gravel Member (AMTD)

The Ambaston Gravel Member underlies an extensive terrace about 1–1.5 m above the Derwent floodplain. The terrace is extensively ridged and furrowed. The type area is Ambaston [SK 42 32]. The deposit (the older alluvium of Fox-Strangways, 1905, p. 43) overlies the eroded Holme Pierrepont Sand and Gravel Member. The deposit comprises gravel overlain by silt, together totalling up to 3 m in thickness. It passes into the coeval Hemington Sand and Gravel Member of the Trent valley.

Valley of the Proto-Trent River west of the Lincoln Gap

The following six members of the Trent Valley Formation are identified:

EAGLE MOOR SAND AND GRAVEL MEMBER (EMSG)

The Eagle Moor Sand and Gravel Member comprises up to 6 m of glaciofluvial sandy gravel. Between Newark and Lincoln this member forms terraced outliers from Danethorpe Hill [SK 84 57] northwards to Eagle Moor [SK 890 684], the type area, the surface falling from about 36 m (i.e. about 25 m above the Trent floodplain) to 32 m above OD.

WHISBY FARM SAND AND GRAVEL MEMBER (WFSG)

The Whisby Farm Sand and Gravel Member was formerly worked extensively from pits situated about 0.8 km to the south-west of the stratotype gravel pit [SK 925 676], near Whisby Farm, between Whisby and Hykeham, Lincoln. Up to 3 m of reddened sand and gravel form a terrace about 5 m above the Balderton Member and separated from it by a rock step (Brandon and Sumbler, 1991, p. 119, fig. 3). Bedding indicates deposition from the north-west into the Balderton course of the Trent valley. It is head gravel largely derived from the Eagle Moor Sand and Gravel Member and provisionally correlated with MIS 8.

BALDERTON SAND AND GRAVEL MEMBER (BDTN)

The Balderton Sand and Gravel Member is found between Newark [SK 79 53], Balderton [SK 82 51] and Hykeham [SK 95 69], Lincoln, and is well exposed in a series of gravel pit sections documented by Brandon and Sumbler (1991). The stratotype is a gravel pit [SK 896 663] at Whisby, near Thorpe on the Hill, Lincoln. The deposits infill a sinuous channel, 1.5 to 3 km wide, that is directed towards the Lincoln Gap. Its surface falls steadily northwards from 18 m above OD (about 7 m above the Trent floodplain) to about 11 m OD. It includes several separate units, as described below. The main deposit comprises 7–8.5 m of sand and gravel (the Balderton Sand and Gravel). This has yielded cold stage large mammals dominated by *M. primigenius* and *C. antiquitatus*, molluscs, beetles and pollen. Electron spin resonance (ESR) ages on elephant molars and amino acid ratios from molluscs indicate correlation with MIS 6 (Brandon and Sumbler, 1991). A line of outliers through Whatton [SK 745 388] (the Whatton Sand and Gravel) possibly formed in a tributary valley of the main Balderton Member river (Howard et al., 2008).

The *Thorpe on the Hill Bone Bed* comprises sandy silts with sands and basal gravel up to 1 m thick with base at about 1 m above OD. The stratotype is a pit [SK 896 663] at Whisby, near Thorpe on the Hill, Lincoln. The bed occurs in a bedrock channel beneath the Balderton Sand and Gravel Member. Its biota consists of temperate large mammals, molluscs, pollen, macroplants and beetles. Its position below the Balderton Sand and Gravel (MIS 6) and the presence of the bivalve *Corbicula fluminalis* suggests correlation with MIS 7.

Patchily preserved on the Balderton Terrace is the *Whisby Sand Bed* (Stratotype: pit [SK 930 673], Whisby, Lincoln), which comprises red sand of fluvio-aeolian origin up to 1.5 m thick that occurs in cores of ice-wedge casts and other Late Devensian cryogenic involutions on top of the Balderton Sand and Gravel Member. It was probably deposited after the Proto-Trent route to the Lincoln Gap was abandoned (Brandon and Sumbler, 1991).

The *Hykeham Soil* is developed on the surface of the Balderton Terrace. It is probably of Ipswichian age (MIS 5e), but includes ice wedge casts developed during the Late Devensian. The type locality of the *Hykeham Soil* is as for the Whisby Sand Bed. It occurs as a rubified horizon affecting the Whisby Sand Bed and the top 2 m of the Balderton Sand and Gravel. It is preserved in cores of ice wedge casts and other late Devensian cryogenic involutions and is inferred to represent MIS 5e (Brandon and Sumbler, 1991).

FULBECK SAND AND GRAVEL MEMBER (FULB)

The Fulbeck Sand and Gravel Member was deposited by an extended River Brant that flowed northwards to the Lincoln Gap from an area, west of Grantham, now occupied by the headwaters of the River Devon (a minor tributary of the Trent). Brandon and Sumbler (1988) inferred that the 'Fulbeck River' also shared headwaters with the modern River Witham, but it is now thought that most of the Fulbeck Sand and Gravel predates any input from the Witham: until late Devensian times the latter flowed eastwards through the Ancaster Gap [SK 980 440] (Berridge et al., 1999). Nevertheless the Witham may have contributed to the later phases of the Fulbeck Sand and Gravel after its initial westward diversion, before taking up its present even more westerly loop to the Lincoln Gap.

The Fulbeck Sand and Gravel comprises strongly cryogenically involuted, Lincolnshire Limestone-rich sandy gravel, up to 3 m thick, infilling a broad, shallow channel from Woolsthorpe [SK 84 35] to Hougham [SK 89 45] (where it is cut across the course of the modern River Witham), and thence northwards to Aubourn [SK 94 63] (where it rejoins the Witham). The type area is Fulbeck Airfield area [SK 89 50], Lincolnshire. The gravel is the greater part of the Fulbeck Sand and Gravel of Brandon and Sumbler (1988). The member is considered to have been deposited mostly during Early Devensian cold stages (mainly MIS 4; Berridge et al., 1999). A mammoth molar was found in the deposit [SK 8800 4198] near Marston.

The *Little Syke Bone Beds* occur at Little Syke drain [SK 896 538] and several other localities at the base and close to the western margin of the Fulbeck Sand and Gravel. The beds comprise up to about 0.5 m of strongly involuted clayey gravel which contains common mammal fossils, notably of hippopotamus (Brandon and Sumbler, 1988), and is consequently assigned an Ipswichian age (MIS 5e).

SCARLE SAND AND GRAVEL MEMBER (SCSG)

The Scarle Sand and Gravel Member forms a gravelly terrace 3–4 m above the Trent floodplain with both surface and base higher than corresponding levels of the nearby Holme Pierrepont Sand and Gravel Member. The type area lies between North Collingham [SK 830 620] and North Scarle [SK 840 670]. The main deposit is the Scarle Sand and Gravel Member. It probably aggraded when the Trent route to the Lincoln Gap was to the west and north of Eagle Moor. It is correlated with the Fulbeck Sand and Gravel of the Witham (Brandon and Sumbler, 1988, Table 1) that is probably an Early Devensian (mainly MIS 4) cold stage deposit (see above). It has yielded reindeer (*R. tarandus*) and Steppe Bison (*B. priscus*) from beds (informally named the *South Scarle Bone Beds*) in a pit [SK 8552 6400] South Scarle (A. Brandon, unpublished). The unit was unaffected by the development of the Hykeham Soil.

HOLME PIERREPONT SAND AND GRAVEL MEMBER (HPSG)

The Holme Pierrepont Sand and Gravel Member (Trent Valley Formation — see above) was probably deposited by the Trent, partly en route to the Lincoln Gap via west and north of Eagle Moor, and partly after its diversion north to the Humber (Brandon and Sumbler, 1988, p. 130). The Holme Pierrepont Sand and Gravel Member includes the *Spalford Sand* (type area: Spalford [SK 840 690], Nottinghamshire). The Spalford Sand comprises spreads of pale brown, fine-grained blown sand, up to about 3 m thick, overlying the sand and gravel. It is thought to be Late Devensian (MIS 2), possibly Late Glacial in age (Brandon and Sumbler, 1988). It was also reworked during the Holocene (MIS 1).

Valley of the Proto-Trent River east of the Lincoln Gap

Although Straw (1958, p. 37) described the following sand and gravel terrace deposits as 'Witham Terraces', the deposits are placed in the Trent Valley Formation, as for much of its history the Trent flowed through the Lincoln Gap, down what is now the lower Witham valley, to the Wash, whilst the present headwaters of the Witham flowed from the Grantham area, via the Ancaster Gap [SK 980 440] directly to the Wash, and not through Lincoln as at present (Brandon and Sumbler, 1988; Berridge et al., 1999). The following three members of the Trent Valley Formation are identified:

MARTIN SAND AND GRAVEL MEMBER (MTNSG)

The Martin Sand and Gravel Member (Martin Member of Bowen, 1999) is believed to be equivalent to the Eagle Moor Sand and Gravel Member to the west of the Lincoln Gap (Brandon and Sumbler, 1988) (see above).

SOUTHREY SAND AND GRAVEL MEMBER (SOYSG)

The Southrey Sand and Gravel Member (after Straw, 1958) is distributed along the north side of the present Witham valley from Southrey [TF 13 66] to Kirkstead [TF 19 60] (where it passes into the Thorpe Member of the Bain) as a series of much dissected remnants with a surface falling from about 8–about 5 m above OD (i.e. 6–3 m above the Witham floodplain). The type area is the Woodhall Spa–Kirkstead Bridge area [TF 18 62]. The deposits comprise quartzite-rich to flint-rich sandy gravels up to 6 m thick, correlated by altimetry with the Balderton Sand and Gravel Member (MIS 6). At two localities north of Woodhall Spa, interglacial silts have been found, apparently within narrow channels, either incised into, or overlain by the Southrey Sand and Gravel. Interpretation of the pollen and molluscs from these Coronation Farm Beds is inconclusive, but the silts are tentatively assigned to MIS 5e, although an older MIS 7 or MIS 9 age cannot be excluded.

KIRKSTEAD SAND AND GRAVEL MEMBER (KSDSG)

The Kirkstead Sand and Gravel Member is a quartzite-rich sandy gravel deposited by the Trent and penetrated by many boreholes beneath the Fen alluvium of the modern Witham valley. The type locality comprises BGS boreholes at Kirkstead [TF 1630 6114]. The deposits are considered to be coeval with the Castle Sand and Gravel Member of the Bain Valley Formation and, at least in part, with the lower part of the Holme Pierrepont Member of the Trent Valley Formation west of the Lincoln Gap. They are thought to be early to late Devensian in age (MIS 4–2).

11.3.2.2 SOAR VALLEY FORMATION

The Soar Valley Formation is established to include all the Anglian to Holocene fluvial deposits of the Soar valley.

Name
Soar Valley Formation (SOARV) (after Brandon, 1995, 1999, and Maddy, p. 39 in Bowen, 1999).

Lithology
Mainly sand, gravel and mud; includes contemporaneous head, colluvium and soil deposits. Gravel is generally dominated by 'Bunter' quartzite pebbles and flints in roughly equal proportions, plus other components including Charnian material.

Formal subdivisions and correlation table
Subdivided (in type area) into five principal 'terrace' members, the Knighton Sand and Gravel, Birstall Sand and Gravel, Wanlip Sand and Gravel, Syston Sand and Gravel, and Hemington members, together with Holocene alluvium (the Soar Member of Bowen, 1999) (Tables 6 and 16).

Type area/Reference section
Type area: Lower Soar valley, Loughborough area [SK 52 00] (Brandon, 1999; Carney et al., 2001; 2002a, b).

Lower and upper boundaries
Unconformable, commonly channelled base on Anglian glacial deposits (Wolston Glacigenic Formation) or on pre-Quaternary bedrock.

Ground surface.

Landform description and genetic interpretation
Mainly post-Anglian fluvial terrace and alluvial deposits of the River Soar of Leicestershire and those of its tributaries such as the Wreake, but excluding Anglian/pre Anglian deposits of the Proto-Soar or Bytham River.

Thickness
Up to 10 m.

Distribution and extent
Catchment of the modern Soar (including Wreake).

Age
Post-Anglian to Holocene (MIS 8–1).

The formation comprises five terrace deposit members. From oldest to youngest these are:

KNIGHTON SAND AND GRAVEL MEMBER (KNSG)

The Knighton Sand and Gravel Member comprises up to 1 m of sand and gravel of the Knighton Terrace of Rice (1968), named after the Knighton district [SK 60 01] of Leicester. It is not present in the lower Soar valley.

BIRSTALL SAND AND GRAVEL MEMBER (BISG)

The Birstall Sand and Gravel Member comprises up to 2.5 m of gravel deposits of the Birstall Terrace of Rice (1968). The base is 9–12 m above the present alluvium at Loughborough. The member is correlated with the

Balderton Member of the River Trent (MIS 6) (Brandon, 1995).

Wanlip Sand and Gravel Member (WASG)

The Wanlip Sand and Gravel Member comprises between 1.5 and 3 m of gravel of the Wanlip Terrace (Rice, 1968; Brandon, p. 39 in Bowen, 1999). The bedrock step is about 3 m above floodplain alluvium in the Loughborough area. The gravels are severely affected by post-depositional cryoturbation inferred to be of late Devensian age. A record of the elephant *Palaeoloxodon antiquus* (Plant, 1859) at Barrow upon Soar [SK 560 170] is probably from below the Wanlip Terrace and may be Ipswichian (MIS 5e) in age. The Wanlip Sand and Gravel is correlated with Allenton Member of lower Derwent (Early Devensian, possibly mainly MIS 4, Brandon, 1995).

Syston Sand and Gravel Member (SYSG)

The Syston Sand and Gravel Member comprises deposits of the Syston Terrace (Rice, 1968) together with those of the Quorndon Terrace of Rice (1968) not now recognised as a separate aggradation (Brandon, 1995; Bowen, 1999). At Syston the unit contains a flora and fauna that are indicative of a late Devensian age (e.g. Bell et al., 1972). The member includes both suballuvial and terrace deposits bordering the Soar floodplain. Trough cross-bedded gravels contain syndepositional ice wedge casts but are not affected by later cryoturbation. The unit is correlated with the Holme Pierrepont Member of the Trent.

Hemington Member (HETD)

See Trent valley, upriver of Newark (above).

11.3.2.3 Bain Valley Formation

The Bain Valley Formation includes all the Anglian to Holocene fluvial deposits of the Bain valley.

Name
Bain Valley Formation (BAINV) (after Brandon and Sumbler, p. 14–15 in Bowen, 1999).

Lithology
Mainly sand, gravel and mud; divided (in type area) into two principal 'terrace' members (Thorpe Sand and Gravel and Castle Sand and Gravel) plus alluvium (Bain Member of Bowen, 1999), and an older (late Anglian) terrace (Martin/Tattershall Airfield member of Bowen, 1999), plus local named organic deposits. Includes contemporaneous head, colluvium and soil deposits. Gravel dominated by flint and chalk pebbles, and other Jurassic/Cretaceous material derived mainly from glacial deposits of the Anglian Lowestoft Formation, plus an additional component of Upper Jurassic and Cretaceous material from bedrock of the catchment.

Formal subdivisions and correlation table
Subdivided into the Tattershall Airfield Sand and Gravel, Thorpe Sand and Gravel and Castle Sand and Gravel members (Tables 6 and 16).

Type area/Reference section
Type area: Lower Bain valley, Kirkby-on-Bain [TF 24 63] to Tattershall [TF 21 59], Lincolnshire [TF 20 60–TF 30 70] (Brandon and Sumbler, pp. 14–15 in Bowen, 1999, and unpublished data).

Lower and upper boundaries
Unconformable, commonly channelled base on Anglian glacial deposits or on pre-Quaternary bedrock.

Ground surface.

Landform description and genetic interpretation
Fluvial terrace deposits and alluvium of the River Bain.

Thickness
Up to 8 m.

Distribution and extent
Bain catchment, from headwaters near Donington on Bain [TF 23 83] to confluence with River Witham near Tattershall [TF 21 59].

Age
Post-Anglian to Holocene (MIS 7–1).

The Bain Valley Formation includes three terrace deposit members with associated organic beds:

Tattershall Airfield Sand and Gravel Member

The Tattershall Airfield Sand and Gravel Member (Tattershall Airfield Member of the Lowestoft Formation of Brandon and Sumbler, p. 14 in Bowen, 1999) forms a terrace about 3 m above the Thorpe Terrace, and its deposits pass beneath the Thorpe Sand and Gravel Member. The type locality is the Tattershall Airfield gravel pit [TF 218 617]. The unit comprises up to 7 m of sand and gravel overlying the Wragby Till Member (Wolston Glacigenic Formation — Section 11.2.1.1) between Woodhall Spa and Kirkby on Bain. From lithology and disposition the deposit is inferred to be glaciofluvial outwash and as such probably equates with the Martin Sand and Gravel Member or the Eagle Moor Sand and Gravel Member of the proto-Trent (Section 11.3.2.1).

Thorpe Sand and Gravel Member (THSG)

The Thorpe Sand and Gravel Member (Thorpe Member of Brandon and Sumbler, p. 14 in Bowen, 1999) (type locality Tattershall Thorpe gravel pit [TF 225 603]) occurs along the Bain valley from Kirkby on Bain to Tattershall Thorpe where it forms a terrace about 2 m above the Castle Terrace. Downstream it merges with the Southrey Member of the Proto-Trent. It comprises about 6 m of sand and gravel with both syn- and post-depositional ice wedge casts. It has yielded a cold stage mammal fauna originally thought to be Devensian (Rackham, 1978) but closely similar to that of the pre-Devensian Balderton Sand and Gravel Member (Section 11.3.2.1), which is now known to be correlative. Thermoluminescence dates of about 199 ka BP, obtained from the lower part of the deposit (Perkin and Rhodes, 1994), are consistent with ESR dates on mammoth molars that indicate the end of MIS 6 (Brandon and Sumbler, 2001). Radiocarbon dating giving mid-Devensian ages (Girling, 1977, 1980; Holyoak and Preece, 1985) is now thought to be unreliable. In Holyoak and Preece (1985), the deposit was not separated from the younger Castle Sand and Gravel Member.

The *Kirkby Silt Beds* (Kirkby Bed of Brandon and Sumbler, p. 14 in Bowen, 1999) comprise up to 3.3 m of mainly grey silt, exposed over many years during quarrying in adjacent pits, infilling a channel cut beneath Thorpe Sand and Gravel. The type locality is a gravel pit [TF 2246

6040]. The deposit was deduced to be Ipswichian (MIS 5e) on the basis of molluscs and pollen (Holyoak and Preece, 1985). Amino acid epimerization data suggests a MIS 5e or MIS 7 (Holyoak and Preece, 1985) or a MIS 5e (Bowen et al., 1989) age. The silt contains a temperate fauna and flora and molluscs (including *Corbicula fluminalis*), beetles, pollen and large mammals including *Palaeoloxodon antiquus.* Mapping, stratigraphy, biostratigraphy and geochronometric dating of sediments within and above the member indicate a MIS 7 age (Brandon and Sumbler, 2001).

The *Thorpe Soil* is correlated with the Hykeham Soil at the top of the Balderton Sand and Gravel Member (Trent Valley Formation). The type locality is a gravel pit [TF 225 603] near Tattershall Thorpe. Its distribution is as for the Thorpe Sand and Gravel Member. The top 2 m of that deposit is rubified and disturbed by cryogenic involutions and ice wedge casting. The Thorpe Soil is thought to be MIS 5e by relation to adjacent deposits.

Castle Sand and Gravel Member (CASSG)

The Castle Sand and Gravel Member (Castle Member of Brandon and Sumbler, p. 15 in Bowen, 1999) forms an extensive terrace along the River Bain from Kirkby on Bain downstream to Tattershall Castle beyond which it passes beneath the Witham floodplain deposits. The type locality is in the gravel pits [TF 211 571] near Tattershall Castle described by Holyoak and Preece (1985). It comprises up to about 8 m of mainly sand and gravel with syndepositional ice wedge casts. The unit is thought to be mainly of late Devensian age (MIS 2; Brandon and Sumbler, 2001), which would seem to be confirmed by thermoluminescence dates of about 29 ka BP (Perkin and Rhodes, 1994).

Associated silts are represented by the following units:

The *Tattershall Silt Beds* (Tattershall Bed of Brandon and Sumbler, p. 14–15 in Bowen, 1999) comprise about 2 m of grey silt and detrital mud in a channel cut into Wragby Till (Wolston Glacigenic Formation) and beneath the Castle Sand and Gravel at the Tattershall Castle gravel pit (Holyoak and Preece, 1985). The beds contain a temperate fauna and flora including molluscs and mammals including the elephant *Palaeoloxodon antiquus* (Holyoak and Preece, 1985; Rackham, 1981). Dates using various techniques suggest an Ipswichian age (MIS 5e) (Holyoak and Preece, 1985).

The *Castle Silt Bed* (the 'upper temperate silts') comprises grey organic silts in a channel within the Castle Sand and Gravel Member at Tattershall Castle gravel pit [TF 209 570–TF 210 570] (of Holyoak and Preece, 1985; Girling, 1974, 1977, 1980). Radiocarbon dates of about 42–43 ka BP, 'Upton Warren' temperate beetles and mammals including reindeer (*R. tarandus*) and *Bison* sp. suggest a mid-Devensian (MIS 3) age (Girling, 1974, 1977, 1980; Rackham, 1978).

11.3.3 Thames Catchments Subgroup

The Thames Catchments Subgroup comprises river terrace deposits of Anglian and younger age of the River Thames and its tributaries. Mass movement deposits and organic deposits (organic clay, tufa and peat) of the catchments are also included. The Thames river system is one of the most intensively studied in Britain. Organic fossiliferous beds interbedded with the 'cold stage' terrace sand and gravel aggradations have been correlated with interglacial 'warm stages' allowing the establishment of a detailed climate-related stratigraphical framework. Debate has continued regarding the lithostratigraphical status of the river terrace deposits with some researchers advocating member status (e.g. Gibbard, 1995) and others favouring formation status (e.g. Bridgland, 2006). This report treats the deposits as members and in the Upper Thames (i.e. upstream of Goring) the terrace deposits are currently assigned as members of the **Upper Thames Valley Formation** (see this chapter, below) with terrace deposits of the Middle and Lower Thames and most tributaries assigned as members of the **Maidenhead Formation** (redefined after Gibbard in Bowen, 1999) (Section 12.5.1.1).

Name
Thames Catchments Subgroup (THCAT) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Mainly river terrace sand and gravel, brickearth silt and alluvial floodplain silt, silty clay and sand. The subgroup includes interbedded units of locally fossiliferous silty sand, silt, together with organic clay, tufa and peat which are biostratigraphically correlated with interglacial (warm) stages. Terrace deposit gravel clasts are mainly Jurassic limestone lithologies (Upper Thames) and flint, vein quartz and local bedrock lithologies including chert (Middle and Lower Thames).

Formal subdivisions and correlation table
The subgroup is currently divided into the Upper Thames Valley Formation and the Maidenhead Formation (Middle and Lower Thames valley) for deposits of the main valley and some tributary valleys. The Kennet Valley Formation and the Medway Valley Formation is established for terrace deposits of those valleys. See Tables 6, 17, 18a and 18b.

Type area/Reference section
Type area: The Thames valley and tributaries.

Lower and upper boundaries
Unconformable on older Pleistocene strata or bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace deposits and floodplain.

Thickness
Single terrace aggradations range from 3–12 m. Interglacial units are up to 12 m thick.

Distribution and extent
The valley of the River Thames and its tributaries.

Age
Anglian to Holocene (MIS 12–1).

11.3.3.1 Upper Thames Valley Formation

The Upper Thames Valley Formation (Upper Thames Formation of Gibbard and Sumbler, pp. 47–48 in Bowen, 1999) comprises the Anglian and later fluvial deposits of the Upper Thames (i.e. upstream of Goring) and its tributaries, of which the principal ones are the Thame, Ock, Cherwell, Evenlode and Windrush. This formation has traditionally been treated as a separate entity from the terrace deposits of the Middle and Lower Thames (Maidenhead Formation) because of uncertainties of correlation (Section 12.5.1).

Name
Upper Thames Valley Formation (UTMS) (after Sandford, 1924, Briggs et al., 1985, Gibbard and Allen, 1995; Upper Thames Formation of Gibbard and Sumbler, p. 47–48 in Bowen, 1999).

Lithology
Mainly river terrace sand and gravel, brickearth silt and alluvial floodplain silt, silty clay and sand. The formation includes interbedded units (representing interglacials) of locally fossiliferous silty sand and silt, together with organic clay, tufa and peat. Terrace deposit gravel clasts are mainly Jurassic limestone lithologies.

Formal subdivisions and correlation table
Subdivided into members (Table 17).

Type area/Reference section
Type area: Valley of the River Thames and its tributaries upstream of Goring (Gibbard and Sumbler, pp. 47–48 in Bowen, 1999).

Lower and upper boundaries
Unconformable on older Pleistocene strata or bedrock.

Ground surface.

Landform description and genetic interpretation
Fluvial sand and gravel aggradations developed under mainly periglacial climates, and interbedded interglacial deposits.

Thickness
Single terrace aggradations range from 3–12 m.

Distribution and extent
The valley of the mainstream River Thames upstream of Goring and the valleys of the Thame, Ock, Cherwell, Evenlode and Windrush.

Age
Anglian to Holocene (MIS 12–1).

In the Upper Thames and tributaries including the Thame, Cherwell, Evenlode and Windrush, the formation includes sixteen members that have been described in the literature (Table 17). Figure 23 illustrates an idealised section through some of these members in the Evenlode. From oldest to youngest, the members of the Upper Thames Valley Formation are:

TIDDINGTON SAND AND GRAVEL MEMBER

The Tiddington Sand and Gravel Member is represented by outcrops of sand and gravel in the neighbourhood of Tiddington [SP 650 052], which comprise the Sixth Terrace deposits of the River Thame (BGS 1:50 000 Sheet 237). It probably corresponds with the Freeland Sand and Gravel Member of the Upper Thames and Evenlode (Sumbler, 1995; Horton et al., 1995).

FREELAND SAND AND GRAVEL MEMBER (FL)

The Freeland Sand and Gravel Member was formerly regarded as the youngest deposit of the Northern Drift Formation (Gibbard and Sumbler, p. 47 in Bowen, 1999; i.e. Sudbury Formation of this account), but is now classified as oldest unit of Upper Thames Valley Formation (Sumbler, 2001). The member, type locality Freeland [SP 414 128], corresponds with the Freeland Terrace deposits of Arkell (1947b) and is equated with the Black Park Gravel Member of the Maidenhead Formation (Section 12.5.1.1) of the Middle Thames (Gibbard, 1985; Hey, 1986; Whiteman and Rose, 1992; Bridgland, 1994; Sumbler, 1995, 2001). Relationships near Moreton-in-Marsh indicate a genetic link with Trias-rich tills in the older part (Moreton Member) of the Wolston Glacigenic Formation there (Sumbler, 2001). Near Oxford [SP 5152 0143], the *Sugworth Bed*s, channel-filling organic silts, are generally thought to underlie the Freeland Member. A 'Cromerian' age (MIS 13 or older) may be indicated by biostratigraphy of these beds (Shotton et al., 1980), but Gibbard (1985) suggested a Hoxnian age on the basis of terrace stratigraphy. A MIS 11 (Hoxnian) age is suggested by amino acid geochronometry (Bowen et al., 1989) and was supported by Sumbler (1995), but a reassessment of the age of the older Combe Sand and Gravel Member (Sudbury Formation) removes the objection to a Cromerian age (Sumbler, 2001).

CHILWORTH SAND AND GRAVEL MEMBER

The Chilworth Sand and Gravel Member is represented by small remnants of sand and gravel that comprise the Fifth Terrace deposits of the River Thame on BGS 1:50 000 Sheet E237. The type locality is at Chilworth House [SP 632 048], Great Milton. The member is thought to correspond with the Hanborough Member of the Upper Thames/Evenlode (Sumbler, 1995; Horton et al., 1995).

SPELSBURY GRAVEL MEMBER (SPBY)

The Spelsbury Gravel Member is composed of limestone-dominant gravels forming terraces along the upper Evenlode valley, between Lyneham [SP 263 212] and Spelsbury. It includes the Bledington Terrace deposits as described by Tomlinson (1929) but this term is now abandoned due to the presence of the Daylesford Member at Bledington (Sumbler, 2001). It corresponds with the Fourth Terrace deposits of BGS 1:50 000 Sheet E218 (Horton et al., 1987) and probably equates in part at least with the Hanborough Member, but may also include younger materials (Sumbler, 2001). The type locality is a gravel pit at Dean Grove, Spelsbury (or Chadlington) [SP 340 213] (Arkell, 1947a,b).

HANBOROUGH GRAVEL MEMBER (HAN)

The Hanborough Gravel Member (Hanborough Member of Gibbard and Sumbler, p. 47 in Bowen, 1999) is represented by the Han(d)borough, or 100-foot Terrace deposits (Sandford, 1924; Arkell, 1947a, b), corresponding with the Fourth Terrace of BGS maps. The unit consists of limestone-dominated gravels, up to about 6 m thick, that are well-developed in the lower Evenlode, and to a lesser extent along the Upper Thames and lower Cherwell, and is the oldest terrace deposit to occur on the Thames upstream of the confluence with the Evenlode at Eynsham. It is essentially a cold climate aggradation probably dating mainly from the early part of MIS 10, but contains temperate indicators such as straight-tusked elephant in the lower part, probably derived from earlier sediments of MIS 11 date (Briggs et al., 1985; Bridgland, 1994). The type locality is Long Hanborough Gravel Pit [SP 418 136].

BLACKDITCH SAND AND GRAVEL MEMBER

The Blackditch Sand and Gravel Member comprises the sand and gravel of the Fourth Terrace of the River Thame on BGS 1:50 000 Sheet E237. It is thought to correspond with the Wolvercote Sand and Gravel Member of the Upper Thames. Upstream, near Aylesbury, the deposits appear to grade into glaciofluvial outwash deposits associated with the Oadby Till Member (Wolston Glacigenic Formation) (Sumbler, 1995; Horton et al, 1995). The type locality is Blackditch Farm [SP 722 046], Thame.

DAYLESFORD SAND AND GRAVEL MEMBER (DAY)

The Daylesford Sand and Gravel Member (Daylesford Member of Gibbard and Sumbler, p. 48 in Bowen, 1999) was included in the Moreton Drift by Tomlinson (1929) and corresponds with the Third Terrace deposits of Horton et al. (1987). It consists of flint-bearing sands and gravels forming a terrace in the upper reaches of the Evenlode. The flint content indicates that the deposit is coeval with, or younger than, the Wolston Glacigenic Formation, and traced upstream, the terrace profile grades into that of the Wolford Heath Member (Wolston Glacigenic Formation). It probably equates with Wolvercote Sand and Gravel Member downstream. Around Bledington (e.g. at Bledington Pit [SP 248 233]) the more or less limestone-poor gravels overlie limestone-rich gravels. The latter are probably merely the lower, less decalcified parts of the deposit but may be the older Spelsbury Gravel Member (Arkell, 1947a, b; Horton et al., 1987), implying a crossing of the terrace profiles. This was thought to support the equivalence of the Paxford Gravel Member (Wolston Glacigenic Formation) and Hanborough Gravel Member (see above) but such equivalence has been shown to be untenable (Sumbler, 2001). The type locality is Daylesford Gravel Pit [SP 244 244].

WOLVERCOTE SAND AND GRAVEL MEMBER (WV)

The Wolvercote Sand and Gravel Member (Wolvercote Member of Gibbard and Sumbler, pp. 47–48 in Bowen, 1999) is represented by the Wolvercote or 50-foot Terrace deposits (Sandford, 1924; Arkell, 1947a,b), corresponding to the Third Terrace of BGS maps. It forms a weakly developed terrace chiefly in the Oxford area, but is apparently recognizable along much of the Upper Thames and to a lesser extent, the lower Evenlode and lower Cherwell. It comprises limestone-dominant gravels containing a proportion of flint and consequently said to be derived from the Wolston Glacigenic Formation (the Moreton Drift of Arkell, 1947a, b; Sumbler 1995, 2001) and thus is probably equivalent to the Daylesford Sand and Gravel Member of the Upper Evenlode that is inferred to date from the latter part of MIS 10. The type locality is Wolvercote Brick Pit [SP 498 105]. The *Wolvercote Channel Beds*, channel-filling sands, gravels and clays associated with the Wolvercote Member at the former Wolvercote Brick Pit [SP 498 105], have yielded a temperate fauna of molluscs and mammals (such as straight-tusked elephant and narrow-nosed rhinoceros) and palaeolithic artefacts (Briggs et al., 1985). The deposits are tentatively ascribed to MIS 9 (Bridgland, 1994) although it remains unclear whether they are beneath, within, or incised into the gravels of the Wolvercote Sand and Gravel.

SHABBINGTON SAND AND GRAVEL MEMBER

The Shabbington Sand and Gravel Member corresponds with the deposits of the Third Terrace of the River Thame on BGS 1:50 000 Sheet E237. The type locality is Shabbington [SP 666 070]. It is equated with the Summertown–Radley Sand and Gravel Member of the Upper Thames (Sumbler, 1995; Horton et al., 1995) and includes the *North Weston Beds*, which comprise clay, sandy clay and gravels at base of the Shabbington Member recorded by Codrington (1864) in a now disused railway cutting [SP 674 054] 0.6 km south-west of North Weston. These beds yielded freshwater and terrestrial molluscs, and a mixed cold-temperate mammal fauna including mammoth, woolly rhinoceros *(Coelodonta antiquitatis)*, narrow-nosed rhinoceros and hippopotamus. The beds probably relate to the *Eynsham* and *Stanton Harcourt Beds* (see below) (Sumbler, 1995).

SHERBORNE SAND AND GRAVEL MEMBER (SHE)

The Sherborne Sand and Gravel Member comprises limestone-rich gravels beneath the poorly-formed Second Terrace of the River Windrush in the Vale of Bourton (near Bourton-on-the-Water). It consists of more or less reworked head gravels and has yielded woolly mammoth and woolly rhinoceros *(Coelodonta antiquitatis)* (Richardson and Sandford, 1960; O'Neil and Shotton, 1974). It is probably broadly equivalent to the Summertown–Radley Sand and Gravel Member, but may conceivably include older materials.

Summertown–Radley Sand and Gravel Member (SURA) The Summertown–Radley Sand and Gravel Member (Summertown–Radley Member of Gibbard and Sumbler, p. 48 in Bowen, 1999) is defined from joint type localities at Radley [SP 525 987] and Webb's Pit, Summertown [SP 505 086] (no longer exposed). The primary reference section is the Stanton Harcourt Gravel Pit [SP 415 052] (Bridgland, 1994). It comprises terraced sand and gravel deposits that are well-developed along the Upper Thames and lower parts of some tributaries (notably the Evenlode) forming the Summertown–Radley or 20-foot terrace (Sandford, 1924), corresponding with the Second Terrace of BGS maps. It includes several fossiliferous beds. The *Stanton Harcourt Beds* are organic silts that infill channels beneath or within gravels of the Summertown–Radley Member at Stanton Harcourt Gravel Pit [SP 415 052] (Briggs et al., 1985) and elsewhere. These beds have yielded a temperate fauna of mammals and molluscs including *Corbicula fluminalis* and are assigned to MIS 7 on the basis of biostratigraphy and geochronometry. The Eynsham Beds are organic beds in the upper part of the Summertown–Radley Sand and Gravel Member. They have yielded a temperate fauna including hippopotamus, recorded form several sites in the Oxford area including the former Eynsham Station Pit [SP 430 087] (Sandford, 1924). The beds correspond with the Eynsham Gravel of Briggs et al. (1985).

ICKFORD SAND AND GRAVEL MEMBER

The Ickford Sand and Gravel Member is represented by the Second Terrace deposits of the River Thame on BGS 1:50 000 Sheet E237. The type locality is at Ickford [SP 649 073]. The deposits are generally contiguous with, and extend below those of the Quarrendon Sand and Gravel Member. They are equated with older, mid-Devensian aggradation within Northmoor Sand and Gravel Member of the Upper Thames (Sumbler, 1995; Horton et al., 1995).

QUARRENDON SAND AND GRAVEL MEMBER

The Quarrendon Sand and Gravel Member is represented by the First Terrace deposits of the River Thame (BGS 1:50 000 Sheet E237). The type locality is Quarrendon [SP 805 149], in north-west Aylesbury. It is equated with the younger, Late Devensian aggradation within Northmoor

Sand and Gravel Member of the Upper Thames (Sumbler, 1995; Horton et al., 1995).

RISSINGTON SAND AND GRAVEL MEMBER (RIN)

The Rissington Sand and Gravel Member is composed of limestone-rich gravels forming the First Terrace of the River Windrush in the Vale of Bourton. The gravels extend beneath the alluvium. Channel-filling silts beneath cryoturbated gravels have yielded molluscs and pollen indicative of cold interstadial conditions (Gilbertson in Roe, 1976; Brown et al., 1980) and woolly mammoth has been recorded from several sites (O'Neil and Shotton, 1974; Briggs in Roe, 1976; Briggs et al., 1985, p. 32; Brown et al., 1980).

NORTHMOOR SAND AND GRAVEL MEMBER (NO)

The Northmoor Sand and Gravel Member (Northmoor Member of Gibbard and Sumbler, p. 48 in Bowen, 1999) comprises deposits of the Northmoor or Floodplain Terrace (Arkell, 1947a,b; Sandford, 1924) of the Upper Thames corresponding with the First Terrace of BGS maps. The type locality is at Northmoor [SP 421 029]. Well-developed terraces of sand and gravel adjoin and extend beneath the Holocene alluvium of the floodplain of the Upper Thames (and also in some tributary valleys such as the Lower Evenlode). At least two aggradations are represented, forming separate terraces in places. Probable correlatives of these are separately named on the River Thame (see Quarrendon Sand and Gravel and Ickford Sand and Gravel members, above).

STAINES ALLUVIUM MEMBER

The Staines Alluvium Member (Staines Member of Gibbard and Sumbler, p. 48 in Bowen, 1999) comprises Holocene alluvium and contemporaneous deposits within it such as peats and calcareous tufas.

11.3.4 Severn and Avon Catchments Subgroup

The Severn and Avon Catchments Subgroup (Tables 6, 17 and 19) comprises formations, of Anglian to Holocene age, of river terrace sand and gravel, and alluvial floodplain silt, silty clay and sand within the catchments of the River Severn and its tributaries. Currently, three formations have been formally established, the **Warwickshire Avon Valley Formation**, the **Severn Valley Formation** and **Bristol Avon Valley Formation** (Section 13.4.4.1; Table 19).

Other units in Herefordshire and Worcestershire, described by Brandon and Maddy (pp. 28–32 in Bowen, 1999), include the Mathon Valley, Humber, Lugg Valley, Wye Valley, Glynch Valley, and Cradley Valley formations. These formations and constituent members currently remain informal (Section 11.3.4.3).

Name
Severn and Avon Catchments Subgroup (SACA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium comprising soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits are largely sand and gravel. The gravels include a wide range of Palaeozoic and Mesozoic rocks, and much glacial material. Peat is a minor component, and minor marine deposits are included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Subdivided into the Warwickshire Avon Valley Formation, the Severn Valley Formation and Bristol Avon Valley Formation (Sections 11.3.4.1, 11.3.4.2 and 13.4.4.1; Tables 6, 17 and 19).

Type area/Reference section
Type area: River valleys within the catchment areas of the River Severn, the Warwickshire Avon, the Bristol Avon, those rivers which flow from Wales into the Bristol Channel as far as Port Talbot, and all their tributaries.

Lower and upper boundaries
Unconformable on glacial and periglacial deposits and on Palaeozoic and Mesozoic bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and alluvium with minor, associated lacustrine organic and marine deposits.

Thickness
Up to 10 m

Distribution and extent
Catchments of the River Severn, the Warwickshire Avon, the Bristol Avon, those rivers which flow from Wales into the Bristol Channel as far west as Port Talbot, and all of their tributaries.

Age
Cromerian to Holocene (MIS 13–1)

11.3.4.1 WARWICKSHIRE AVON VALLEY FORMATION

The Warwickshire Avon Valley Formation comprises the fluvial deposits of the River Avon and its tributaries (Maddy, pp. 37–38 in Bowen, 1999). All the terrace deposits are lithologically similar with Bunter and flint pebbles present as well as other, including locally derived, lithologies.

Name
Warwickshire Avon Valley Formation (AVON) (after Avon Valley Formation of Maddy, pp. 37–38 in Bowen, 1999).

Lithology
Mainly sand, gravel and mud; includes contemporaneous head, colluvium and soil deposits. Gravels are principally composed of 'Bunter' quartz/quartzite, flint and Jurassic (mostly Lias) lithologies, derived from the Baginton Sand and Gravel Formation, Wolston Glacigenic Formation and the local bedrock of the catchment.

Formal subdivisions and correlation table
Subdivided into seven sand and gravel terrace deposit members (Frog Hall, Pershore, Strensham, Cropthorne, New Inn, Wasperton and Bretford members), the Holocene Elmore Alluvium Member (Elmore Member of Bowen, 1999) and local named organic deposits (see below and Table 17).

Type area/Reference section
Type area: Lower Avon Valley, Stratford-upon-Avon to Tewkesbury (Tomlinson, 1925).

Lower and upper boundaries
Unconformable, commonly channelled base on pre-Quaternary bedrock, or on glacial deposits (till, sands and grav-

els) of the Wolston Glacigenic Formation, or pre-glacial fluvial sands and gravels of the Baginton Sand and Gravel Formation.

Ground surface.

Landform description and genetic interpretation
Fluvial terrace and alluvial deposits of the Warwickshire River Avon and all its tributaries.

Thickness
Up to 9 m.

Distribution and extent
Avon Catchment (Warwickshire, Rugby to Tewkesbury area).

Age
Anglian to Holocene (MIS 12–1).

Eight members are identified (Table 17). From oldest to youngest they are:

Frog Hall Sand and Gravel Member (FRHA)

The Frog Hall Sand and Gravel Member (Frog Hall Member of Maddy, p. 37 in Bowen, 1999) was defined by Sumbler (1989) and described as Alluvial Fan Deposits by Old et al. (1987). The type locality is Frog Hall Quarry [SP 416 736]. The principal outcrops comprise up to 12 m of silts, sands and gravels which infill a channel incised below the level of the Dunsmore Gravel Member (youngest unit of the Wolston Glacigenic Formation), and though lithologically similar to the latter, it includes clasts of secondary iron pan derived from it. It probably relates to the Pershore Sand and Gravel Member of the downstream Avon, upon which is developed a facet of the Fifth Terrace. Its apparent relationship to the local Fourth Terrace deposits (Cropthorne Member) of the River Leam (Sumbler, 1989) may indicate that the Fourth and Fifth terraces converge in the upper Avon. It overlies the organic *Frog Hall Silt Beds* (Frog Member of Bowen, 1999) in Frog Hall Quarry that have yielded a temperate flora and fauna and amino acid ratios from molluscs suggesting MIS 9.

Pershore Sand and Gravel Member (PERT)

The Pershore Sand and Gravel Member (Pershore Member of Maddy, pp. 37–38 in Bowen, 1999) represents the Fifth Terrace Deposits of Tomlinson (1925) and of BGS Maps. Locally [SO 938 464] it overlies the *Allesborough Beds* (the Pershore Fossil Bed of Maddy et al., 1991) that yield a temperate flora and fauna probably broadly equivalent to Frog Hall Silt Beds upstream, and Hill House Beds (of the Severn), assigned to MIS 9. It probably equates with Bushley Green Member of the Severn Valley Formation (Table 17).

Strensham Sand and Gravel Member (STRSG)

The Strensham Sand and Gravel Member (Strensham Member of Maddy, p. 38 in Bowen, 1999) consists of terrace deposits of uncertain status which according to Maddy (in Bowen 1999), are intermediate in height between the Cropthorne Member and Pershore Member. The deposits were included in the Pershore Member by Barclay et al. (1997). As mapped, it locally overlies the *Strensham Court Clay Bed* of Maddy (p. 38 in Bowen, 1999; Strensham Bed of de Rouffignac et al., 1995), which may be correlated with MIS 7 on the basis of amino acid ratios (cf. the Ailstone Bed of Maddy and Keen, p. 38 in Bowen, 1999, and Bowen et al., 1989), hence Maddy's assignment of the overlying gravels to the Strensham (rather than Pershore) Member. If these beds do indeed equate with the Ailstone Bed (see below) it might suggest that the Cropthorne and Strensham members are equivalent.

Cropthorne Sand and Gravel Member (CRTD)

The Cropthorne Sand and Gravel Member (Cropthorne Member of Maddy, p. 38 in Bowen, 1999; Ailstone Member of Maddy et al., 1991) corresponds with the Fourth Terrace of BGS maps. Locally it overlies channel-filling lag gravels and fossiliferous sands of the *Ailstone Bed* (AILT) that yield the bivalve *Corbicula*, and are thus assigned to MIS 7. The Cropthorne Sand and Gravel Member probably equates with the Kidderminster Station Sand and Gravel Member of the Severn Valley Formation (Section 11.3.4.2 and Table 17).

New Inn Sand and Gravel Member (NIT)

The New Inn Sand and Gravel Member (New Inn Member of Maddy, p. 38 in Bowen, 1999) corresponds with the weakly developed Third Terrace Deposits of Tomlinson (1925) and of BGS maps. It locally overlies the channel-filling *Eckington Beds* (formerly the New Inn Fossil Bed of Maddy et al., 1991) that contain an Ipswichian (MIS 5e) fauna of molluscs and hippopotamus.

Wasperton Sand and Gravel Member (WAT)

The Wasperton Sand and Gravel Member (Wasperton Member of Maddy, p. 38 in Bowen, 1999) comprises cold-climate gravels forming the Second Terrace of BGS maps. The unit has yielded a fairly extensive, mainly cold-climate mammal fauna and it includes the *Fladbury Beds*, which are channel-filling organic silts beneath the gravels at Fladbury and Bretford. These are supposedly 'Mid-Devensian' in age and have been compared with the *Upton Warren Beds* of the Severn valley (see below) (Coope, 1968; Kelly, 1968; Shotton, 1968) but are probably older. The Wasperton Sand and Gravel Member probably equates with Holt Heath Sand and Gravel Member of the Severn Valley Formation (Section 11.3.4.2 and Table 17).

Bretford Sand and Gravel Member (BRET)

The Bretford Sand and Gravel Member (Bretford Member of Maddy, p. 38 in Bowen, 1999) comprises 3–4 m of predominantly cold phase sands and gravels that form the First Terrace deposits of BGS maps, on the upper Avon at least (Sumbler, p. 38 in Bowen, 1999). Precise correlation with members of the Severn Valley Formation is problematic.

Elmore Alluvium Member

The Elmore Alluvium Member (after Hewlett and Birnie, 1996; Elmore Member of Maddy, p. 36 in Bowen, 1999) comprises valley floor clastic alluvial sediments of Holocene age (Section 11.3.4.2).

11.3.4.2 Severn Valley Formation

The Severn Valley Formation comprises the mainly post-Anglian fluvial deposits of the River Severn and its tributaries such as the Stour (Wills, 1938: Maddy et al., 1995), but excluding the Avon (see Warwickshire Avon Valley

Formation, above) and the Teme and its tributaries.

Name
Severn Valley Formation (SEVN) (after Wills, 1938, Maddy et al., 1995, and Maddy, pp. 34–36 in Bowen, 1999).

Lithology
Mainly sand, gravel and mud; includes contemporaneous head, colluvium and soil deposits. Gravels are principally composed of Palaeozoic, Triassic and (mainly below the Avon confluence at Tewkesbury) Jurassic material from the local bedrock of the catchment, with an admixture of glacial material from the Anglian Wolston Glacigenic Formation, etc. and, in the younger terraces, a substantial admixture of Irish Sea basin glacial material from the Devensian Stockport Glacigenic Formation.

Formal subdivisions and correlation table
Subdivided into six sand and gravel terrace deposit members (Spring Hill, Bushley Green, Kidderminster Station, Holt Heath, Worcester, Power House members), the Holocene Elmore Alluvium Member (Elmore Member of Bowen, 1999), and with local named organic deposits (see below and Table 17).

Type area/Reference section
Type area: Lower Severn valley, Bridgnorth to Gloucester [SO 80 60–SO 90 70] (Wills, 1938).

Lower and upper boundaries
Unconformable, commonly channelled base on pre-Quaternary bedrock.

Surface.

Landform description and genetic interpretation
Fluvial terrace and alluvial deposits of the River Severn and tributaries excluding the Avon (see Warwickshire Avon Valley Formation) and possibly others, pending review.

Thickness
Up to 10 m.

Distribution and extent
Severn catchment (excluding Warwickshire Avon).

Age
Anglian to Holocene (MIS12–1)

The Severn Valley Formation comprises seven members (Table 17). From oldest to youngest they are:

SPRING HILL SAND AND GRAVEL MEMBER (SPHT)

The Spring Hill Sand and Gravel Member (Spring Hill Member of Maddy and Sumbler, pp. 34–36 in Bowen, 1999) comprises up to about 7 m of sand and gravel recognised in the Worcester–Tewkesbury area, at a height of about 55 m above the modern floodplain. The unit corresponds, at least in part, with the Sixth Terrace deposits of BGS maps (Barclay et al., 1997). The type locality is Spring Hill [SO 808 232] (Maddy et al., 1995).

BUSHLEY GREEN SAND AND GRAVEL MEMBER (BGT)

The Bushley Green Sand and Gravel Member (Bushley Green Member of Maddy and Sumbler, p. 36 in Bowen, 1999) comprises up to about 7 m of sand and gravel beneath the Bushley Green Terrace of Wills (1938) or the Fifth Terrace of BGS maps (Worssam et al., 1989; Barclay et al., 1997). The type locality is Bushley Green [SO 862 351] (Maddy et al., 1995). This unit can be traced within the Lower Severn valley from Worcester to the Gloucester area with an upper surface about 45 m above the present river. It includes the *Hill House Beds* (Bushley Green Beds of Maddy et al., 1995), comprising up to 1.5 m of sand and gravel at the base, containing molluscs of cool temperate aspect (Bridgland et al., 1986). Amino acid ratios suggest a MIS 9 age for these beds (Bowen et al., 1989).

KIDDERMINSTER STATION SAND AND GRAVEL MEMBER (KRT)

The Kidderminster Station Sand and Gravel Member (Kidderminster Station Member of Maddy and Sumbler, p. 36 in Bowen, 1999) comprises up to 8 m of sand and gravel beneath the Kidderminster Terrace of Wills (1938) or the Fourth Terrace of BGS maps (e.g. Worssam et al., 1989). The type locality is Yates's Pit near Kidderminster railway station [SO 839 763] (Maddy et al., 1995). It can be traced from Kidderminster in the Stour valley downstream to beyond Gloucester. It is the oldest of the Severn Valley Formation members to contain significant quantities of Permian Clent Breccia.

HOLT HEATH SAND AND GRAVEL MEMBER (HHSG)

The Holt Heath Sand and Gravel Member (Holt Heath Member of Maddy and Sumbler, p. 36 in Bowen, 1999) is probably composite and comprises up to 10 m of sand and gravel beneath the Main Terrace of Wills (1938) or the Third Terrace of BGS maps (Worssam et al., 1989; Barclay et al., 1997). It contains a significant proportion of Irish Sea basin erratics thought to be derived from the Devensian Stockport Glacigenic Formation. The type locality is Holt Heath [SO 827 627] (Dawson and Bryant, 1987; Maddy et al., 1995). The member can be traced from Bridgnorth where the deposits lie approximately 30 m above the modern floodplain to Gloucester where it passes beneath alluvium. It includes the *Upton Warren Beds*, which are channel-filling silts at Upton Warren [SO 935 673], supposedly of Mid Devensian age (Coope et al., 1961) based largely on radiocarbon dates (about 42 ka) that are, however, probably underestimates. Amino acid ratios (Bowen et al., 1989) suggested a MIS 5a age but were later revised (Bowen et al., 2002) to 57 ka (MIS 3). The member also includes the *Stourbridge Beds* at the base at Stourbridge [SO 895 855] (Boulton, 1917) that have yielded hippopotamus indicating MIS 5e.

WORCESTER SAND AND GRAVEL MEMBER (WORT)

The Worcester Sand and Gravel Member (Worcester Member of Maddy and Sumbler, p. 36 in Bowen, 1999) comprises sand and gravel underlying the Worcester Terrace of Wills (1938) which is the Second Terrace of BGS maps (Worssam et al., 1989; Barclay et al., 1997). The upper surface lies approximately 8 m below the Holt Heath Sand and Gravel Member and is traceable from Bewdley to Tewkesbury. The type locality is Grimley [SO 835 608] (Dawson, 1989).

POWER HOUSE SAND AND GRAVEL MEMBER (PSTT)

The Power House Sand and Gravel Member (Power House Member of Maddy and Sumbler, p. 36 in Bowen, 1999) corresponds to the deposits of the Power House Terrace of Wills (1938) or the First Terrace of BGS maps (Barclay et al., 1997). The type locality is Wilden [SO 824 730] (Shotton and Coope, 1983). The member is traceable downstream from Bridgnorth where the terrace is 8 m above the modern floodplain. South of Worcester it underlies the modern alluvium.

ELMORE ALLUVIUM MEMBER

As for the alluvium of the Warwickshire Avon Valley Formation (Section 11.3.4.1).

11.3.4.3 FLUVIAL AND LACUSTRINE DEPOSITS OF HEREFORDSHIRE AND WORCESTERSHIRE

Fluvial sand and gravel deposits of the Mathon and Lugg valleys (Herefordshire and Worcestershire), interpreted to pre-date the 'Older Drift Deposits' of the Risbury Glacigenic Formation (Brandon, 1989; Maddy et al., pp. 28–32 in Bowen, 1999; Section 11.2.1.3) are herein assigned to the informal **Mathon Sand and Gravel Formation** (MASG) and the **Humber Sand and Gravel Formation** (Table 17). Both formations are provisionally assigned to the Severn and Avon Catchments Subgroup.

The Mathon Sand and Gravel Formation (Mathon Valley Formation of Bowen, 1999) comprises pre-glacial fluvial sand and gravels infilling a palaeovalley west of the Malvern Hills. The type section at the Brays Pit [SO 729 441], Mathon, Herefordshire, exposed the Brays Bed (*Brays Silts Bed*, BRSI) a 1 m-thick bed of silt with fossil fauna and flora indicative of deposition within an interglacial during the mid-Pleistocene.

The Humber Sand and Gravel Formation (Humber Formation of Bowen, 1999) comprises 2–8 m of northerly-derived fluvial sand and gravel with clasts of pre-Cambrian, Lower Palaeozoic, Devonian, Carboniferous and Triassic rocks that from terrace remnants in the Lugg valley. These deposits are locally overlain or reworked by glacial deposits of the Risbury Glacigenic Formation (Section 11.2.1.3).

Post-Anglian fluvial deposits, assigned to members of the **Glynch Valley Formation** (GLVA), and the informal **Wye Valley Formation** and **Lugg Valley Formation** (after Brandon, 1989, Worssam et al., 1989, and Brandon, pp. 29–32 in Bowen, 1999) may be correlated by altimetry with members of the Severn Valley Formation (Section 11.3.4.2). Thus, the *Heath Member* (HEATH) (Fifth Terrace Deposits) of the Glynch Valley Formation, the *Holme Lacy Member* (Third Higher River Terrace of Brandon and Hains, 1981) of the Wye Valley Formation, and the *Sutton Walls Member* (Fourth Terrace Deposits) of the Lugg Valley Formation are correlated with the Bushley Green Sand and Gravel Member (MIS 8).

The *Redmarley Member* (RMLY) (Fourth Terrace Deposits) of the Glynch Valley Formation, the *Hampton Member* (Second Higher River Terrace of Brandon and Hains, 1981) of the Wye Valley Formation and the *Kingsfield Member* (Third Terrace Deposits) of the Lugg Valley Formation are correlated with the Kidderminster Station Sand and Gravel Member (MIS 6).

The *Staunton Member* (STAU) (Third Terrace Deposits) of the Glynch Valley Formation, the *Bullingham Member* (First Higher River Terrace of Brandon and Hains, 1981) of the Wye Valley Formation and the *Moreton on Lugg Member* (Second Terrace Deposits) of the Lugg Valley Formation are correlated with the Holt Heath Sand and Gravel Member (Devensian, MIS 5d–2). Inferred Late Devensian terrace sands and gravels of the *Marden Member* (Marden Deposits of Brandon, 1989) are also assigned to the Lugg Valley Formation.

The *Rudford Member* (RDFD) (Second Terrace Deposits) of the Glynch Valley Formation is correlated with the Worcester Sand and Gravel Member (MIS 2–1).

Middle to Late Devensian fluvial (river terrace) and lacustrine deposits associated with the proto-Teme drainage system between the present day valleys of the Rivers Teme and Lugg were described by Cross and Hodgson (1975). The deposits include the *Bank Farm Sand and Gravel* (BFSG), *Shakenhurst Sand and Gravel* (STSG), *Little Hereford Sand and Gravel* (LHSG), *Ashford Sand and Gravel* (ADSG), *Bromfield Sand and Gravel* (BMSG), and *Woofferton Sand and Gravel* (WNSG). McMillan et al. (2005) proposed that these informal units be assigned to the Teme Palaeovalley Formation (currently undefined in the BGS Lexicon) of the Severn and Avon Catchments Subgroup.

Late Devensian sub-alluvial sands and gravels of the *Boddenham Member* (Newer Fluvioglacial Terrace Deposits of Brandon, 1989) and other glacigenic deposits of the Herefordshire Formation of Brandon (p. 31 in Bowen, 1999) are provisionally assigned to the Brecknockshire Glacigenic Formation (Section 8.2.2.1).

In the Vale of Severn near Cheltenham the informal *Cheltenham Sand and Gravel* (CHSG) comprising the basal Fan Gravel of Worssam et al. (1989) and overlying aeolian sands, probably derived from terraces of the River Severn (Briggs, 1975), is correlated broadly with the Northmoor Sand and Gravel Member (Sumbler et al., 2000) of the Upper Thames Valley Formation, and so with the Power House, Worcester and upper part of the Holt Heath sand and gravel members of the Severn Valley Formation (Table 17).

The informal **Cradley Valley Formation** (Brandon, p. 32 in Bowen, 1999) contains the *Cradley Silts Bed* (CRSI) and the *Colwall Gelifluctate Member* (CGEL) (Cradley Bed and Colwall Member of Brandon, p. 32 in Bowen, 1999). The type section of the Cradley Silts Bed is a shallow auger hole [SO 7381 4000], near Colwall, drilled and described by the British Geological Survey. The bed, up to 1 m thick, yielded molluscs and pollen indicative of sub-arctic to temperate conditions. It is correlated with the Hoxnian Stage (MIS 11) (Barclay et al., 1992). The overlying Colwall Gelifluctate Member comprises 2–4 m of yellow-brown diamicton forming an extensive dissected solifluction terrace at Colwall. It is tentatively correlated with MIS 6 (Barclay et al., 1992).

12 Southern England and the Middle to Lower Thames catchments

This chapter describes the mainly Neogene and Quaternary deposits of the London Basin, Kent, Sussex and Hampshire together with the valley of the Middle and Lower Thames and its tributaries (Tables 18a and 18b). The oldest superficial deposits of this district, which originated in pre-Neogene time, are the Clay-with-flints of residual origin (Residual Deposits Group). Fluvial deposits of early to mid-Pleistocene age are referred to the Dunwich Group. The earliest glacigenic deposits refer to the Anglian Glaciation and are assigned to the Lowestoft Formation (Albion Glacigenic Group), as described in Section 10.3.1.2 and by Ellison et al. (2004). Deposits of the Britannia Catchments Group and British Coastal Deposits Group range in age from Anglian to Holocene. Formal lithostratigraphy for the terrace deposits of the River Thames has already become widely used but because of uncertainties of correlation, in this framework the Anglian and post-Anglian terrace deposits of the Upper, Middle and Lower Thames are currently referred to two formations, the Upper Thames Valley Formation (Section 11.3.3.1) and the Maidenhead Formation (Section 12.5.1.1).

Most of the formal terms already in use by BGS are retained. The terminology proposed by Bowen (1999) has been adopted where it is appropriate.

For deposits in each group the equivalent terms used by Bowen are given where appropriate. Allocation of deposits within the framework is based on (i) location in relation to the established geological history of the Thames valley (ii) clast composition and (iii) genesis. Un-named head deposits of the Thames Catchments Subgroup are not included in the tables.

12.1 RESIDUAL DEPOSITS GROUP

12.1.1 Formations of the Residual Deposits Group

Representatives of the Residual Deposits Group (including the **Clay-with-flints Formation**) are common in the area south of the Anglian and Devensian limits (Tables 4, 18a and 19). Their origin and development is probably more ancient and longer term than those deposits within glaciated areas and as such are generally polyphase deposits incorporating material laid down in a number of fully periglacial to temperate fluvial and possibly marine environments.

The Residual Deposits Group includes a broad range of lithologies, not generally recognised as having terrace form, that occur on the crest and dip slope of the North Downs, Chiltern Hills and elsewhere in the Chalk downlands. The majority of them rest unconformably on an irregular karstic chalk surface, and are derived from a former cover of Palaeogene sediments that consisted largely of clay, fine- to medium-grained quartz sand and flint pebble gravel. Some of those at the highest topographical level appear on BGS maps under the names Deposits of doubtful age, Older Gravel, and Lenham Beds (now the **Lenham Formation**). These may have been deposited in a Pliocene marine transgression (see Worssam, 1963, for a review). Most have been subjected to dissolution and disturbance, so are included within the Residual Deposits Group. Other deposits, of broadly similar composition, that occur at lower elevations, have been transported downslope largely by solifluction and are included in the appropriate subgroup of the Britannia Catchments Group.

12.1.1.1 Clay-with-Flints Formation

The Clay-with-flints Formation is generally considered to be derived from a former Palaeogene cover (Figures 24 and 25). Pebbly clay and sand, and Disturbed Blackheath Beds (DBLB) are regarded as lithological variants of the Clay-with-flints, mapped only locally in the North Downs (Dines and Edmunds, 1933; BGS 1:50 000 Sheet E286). The informal Headley Heath Member (HDY) occurs in the Reigate and Dorking district (Dines and Edmunds, 1933).

Name
Clay-with-flints Formation (CWF) (after Dines and Edmunds, 1933, Catt, 1986, Ellison et al., 2004, and McMillan et al., 2005).

Lithology
A residual deposit formed from the dissolution, decalcification and cryoturbation of bedrock strata of the Chalk Group and Palaeogene formations and, in the extreme west of the outcrop, the Upper Greensand Formation. It is unbedded and heterogeneous. The dominant lithology is orange-brown and red-brown sandy clay with abundant nodules and rounded pebbles of flint. Angular flints are derived from the Chalk, and rounded flints, sand and clay from Palaeogene formations. There is commonly a discontinuous basal layer up to 10 cm thick, with dark brown to black matrix, stiff, waxy and fissured, with relatively fresh flint nodules stained black or dark green with manganese or glauconite. The deposit locally includes bodies of yellow fine- to medium- grained sand, reddish brown clayey silt, and sandy clay with beds of well-rounded flint pebbles, derived from Palaeogene formations. In the extreme west of the outcrop, in Devon, the deposit locally comprises sand and clayey sand containing angular, shattered blocks of chert. This is derived wholly from the Upper Greensand Formation, in areas where the Chalk Group has been removed by erosion.

Formal subdivisions and correlation table
No formal subdivisions (Tables 4, 18a and 19).

Type area/Reference section
Type area: Coincidental with the outcrop of the Chalk Group, along the Chiltern Hills as far as Royston (Hertfordshire), the North Downs as far as Dover, the South Downs as far as Eastbourne, westwards to Sidmouth (Devon), with extension across the Upper Greensand outcrop of Devon and Somerset as far as the Blackdown Hills above Wellington, Somerset.

Lower and upper boundaries
The Clay-with-flints Formation rests upon Palaeogene formations, the Chalk Group or the Upper Greensand. Where it rests upon a Palaeogene formation or Upper Greensand, the base is taken at the base of intense cryoturbation. The base may be flat or may be highly uneven where it rests in dissolution hollows, particularly where it rests upon the Chalk. If the material is soliflucted and comes to rest on an

inclined surface on a hillside, then it is classed as head and not as a part of the Clay-with-flints Formation.

Commonly occurs at surface. Mainly overlain by Middle Quaternary glacial deposits, particularly in Hertfordshire. Locally overlain by Late Quaternary head or fluvial deposits.

Landform description and genetic interpretation
A residual deposit formed from the dissolution, decalcification and cryoturbation of bedrock strata of the Chalk Group and Palaeogene formations and, in the extreme west of the outcrop, the Upper Greensand Formation.

Thickness
Up to about 10 m, but very variable where let down into dissolution pipes in the Chalk Pipes and hollows may be 1–50 m in diameter.

Distribution and extent
Coincidental with the outcrop of the Chalk Group, along the Chiltern Hills as far as Letchworth (Hertfordshire), the North Downs as far as Dover, the South Downs as far as Eastbourne, westwards to Sidmouth (Devon), with extension across the Upper Greensand outcrop of Devon and Somerset as far as the Blackdown Hills above Wellington, Somerset.

Age
Palaeogene to Pleistocene (MIS Pre-103–?).

12.1.1.2 Chelsfield Gravel Formation

Name
Chelsfield Gravel Formation (CHGR) (after Whitaker and Davies, 1920, Berdinner, 1936, and Ellison et al., 2004).

Lithology
Well-rounded flint pebble gravels, sandy gravels, pebbly sands and sands. Lithologies similar to those in the Harwich Formation (formerly Blackheath Beds or Disturbed Blackheath Beds) from which the deposit is thought to have been mainly derived.

Formal subdivisions and correlation table
No subdivisions (Tables 4 and 18a).

Type area/Reference section
Type area: Slight positive feature on Chalk dip slope at Court Lodge Farm [TQ 476 642], Chelsfield; soil contains numerous well-rounded black flint pebbles, generally <3 cm diameter.

Lower and upper boundaries
Unconformable on the Upper Chalk or Thanet Sand, locally let down into dissolution hollows. Poorly exposed.

Ground surface.

Landform description and genetic interpretation
A head deposit or reworked Clay-with-flints (Ellison et al., 2004).

Thickness
Variable and uncertain, not exposed. Typically 2–5 m. May be 10 m where infilling hollows or pipes in Chalk.

Distribution and extent
The deposit extends for 500 m in the type area: other deposits occur in the Dartford district (BGS 1:50 000 Sheet E271) from Knockmill [TQ 57 61] to Holly Hill [TQ 66 62]. Deposits may be present also south of the Dartford district.

Age
Pliocene.

12.1.1.3 Lenham Formation

Name
Lenham Formation (LNM) (after Reid, 1890, and Worssam, 1963).

Lithology
Ferruginous sand, brightly coloured red, pink, yellow, orange and pale grey, fine-grained, micaceous and glauconitic. Beds of small, black, well-rounded, flint pebbles near base.

Formal subdivisions and correlation table
No subdivisions (Tables 4 and 19).

Type area/Reference section
Type section: Abandoned brickpit near Friningham, Kent [TQ 820 583] (Worssam et al., 1983).

Lower and upper boundaries
Unconformable on rocks of the White Chalk Subgroup, commonly preserved in dissolution hollows.

Ground surface.

Landform description and genetic interpretation
Marine origin, disturbed by dissolution of the underlying Chalk.

Thickness
Up to 3 m. Commonly occurring as in-fills of dissolution pipes in Chalk.

Distribution and extent
Restricted to the North Downs north-east of Lenham, Kent, above 180 m above OD.

Age
Pliocene.

12.2 CRAG GROUP

12.2.1 Formations of the Crag Group

The most extensive of the Early Pleistocene high-level interfluve gravels (now mainly ascribed to the Dunwich Group, Section 12.3) is the **Stanmore Gravel Formation**, which may be a marine littoral deposit coeval with the Red Crag Formation (Mathers and Zalasiewicz, 1988; Ellison et al., 2004). This unit together with the **Well Hill Gravel Formation** (Wooldridge, 1960) is assigned to the Crag Group. The informal *Netley Heath Beds* (Netley Heath Member of Gibbard, p. 53 in Bowen, 1999) is also assigned to the Red Crag Formation.

12.2.1.1 Stanmore Gravel Formation

Name
Stanmore Gravel Formation (STGR) (after Ellison et al., 2004; Plateau Gravel of Dewey et al., 1924; Warley Gravel or Pebble Gravel of Dines and Edmunds, 1925, and Bromehead, 1925; Stanmore and Warley members of Pebble Gravel Formation of Gibbard, pp. 48 and 50 in Bowen, 1999).

Lithology
Gravel and sand, clayey near base. Gravel mostly composed of flints, up to 150 mm in diameter, with a little quartz, quartzite and Lower Greensand chert in the fine fractions. Matrix of orange-brown, pale grey, red mottled clay and sandy clay, with pockets of coarse sand. Locally with layers of silt, clay or peat.

Formal subdivisions and correlation table
No subdivisions (Tables 2, 18a and 18b).

Type area/Reference section
Type area: Stanmore Common, described in BGS boreholes TQ19SE5 [TQ 1550 9394] and TQ19SE6 [TQ 1647 9360].

Lower and upper boundaries
Rests unconformably on London Clay bedrock, base of deposit at 105–128 m above OD.

Overlain in places by till of the (Anglian) Lowestoft Formation, but generally at surface.

Landform description and genetic interpretation
Plateau cappings, interpreted as offshore or beach gravels (Ellison et al., 2004), or possibly fluvial (Bridgland, 1994).

Thickness
Up to 7 m, average 3 m. A thickness of 4.80 m is recorded in BGS Stanmore Common borehole (TQ19SE102).

Distribution and extent
Thames Valley and Colne and Lea valleys region; plateau cappings from Stanmore, Middlesex to Billericay, Essex, and Shooter's Hill, Kent.

Age
Pliocene to Pleistocene (? MIS pre-82).

12.2.1.2 WELL HILL GRAVEL FORMATION

Name
Well Hill Gravel Formation (WHGR) (after Dewey et al., 1924, and Ellison et al., 2004; Plateau Gravel of Peake, 1982).

Lithology
Gravel and sandy gravel; subangular, partly water-rolled flints up to 0.3 m across. Lower Greensand cherts comprise up to 10% of the formation. Other pebbles include many decomposed brown flints; matrix of coarse sand, mostly quartzose, some flint; rare lenses of clay are present.

Formal subdivisions and correlation table
No subdivisions (Tables 2 and 18a).

Type area/Reference section
Type area: Capping hill top alongside Well Hill Road north for 700 m from main east-west road (Rock Hill) in Well Hill village [TQ 4965 6388–TQ 4977 6448] (Dewey et al., 1924).

Lower and upper boundaries
Rests unconformably on bedrock: Lambeth Group (Woolwich and Reading Beds).

Surface.

Landform description and genetic interpretation
Plateau capping possibly of marine origin.

Thickness
2–4 m.

Distribution and extent
Geographically isolated from other superficial deposits, 155–167 m above OD, capping a hill at Well Hill, Kent.

Age
Early Pleistocene (? MIS pre-82).

12.2.1.3 RED CRAG FORMATION

The Red Crag Formation includes all the strata bounded by the marine transgression during the Pre-Ludhamian and the regression during the Thurnian. It thus includes all the Pre-Ludhamian, Ludhamian and Thurnian sediments known in East Anglia (Section 10.1.1.2). It is represented locally by the informal Netley Heath Beds, as well as possibly by the Stanmore Gravel Formation.

NETLEY HEATH BEDS (NEHE)

The Netley Heath Beds (Netley Heath Member of the Red Crag Formation of Gibbard, p. 53 in Bowen, 1999) comprises sand and gravel with marine fossils (Tables 2 and 18a). The deposits lie between 150 and 223 m above OD at Netley Heath, Surrey, at the western end of the North Downs [TQ 080 495] (Dines and Edmunds, 1929; Ellison et al., 2002).

12.3 DUNWICH GROUP

12.3.1 Formations of the Dunwich Group

The earliest deposits of the Dunwich Group include the 'high level' interfluve gravels, not associated with present day valleys, of the south Chilterns, south Hertfordshire and south–central Essex areas. These deposits occur as dissected remnants and comprise local lithologies including well-rounded flints derived from Palaeogene deposits and a significant proportion of Lower Greensand chert clasts. Although the origin of the deposits is uncertain, they may be, at least in part, the remnants of fluvial deposits laid down in rivers draining northwards from the Weald. Assigned provisionally to a 'Pebble Gravel Group' (Pebble Gravel Formation of Gibbard, p. 48 in Bowen, 1999) most of the deposits are now placed in the Dunwich Group. However the Stanmore Gravel Formation (Member in Gibbard's scheme) now assigned to the Crag Group (Section 13.2 above). Other outcrops in Surrey, mapped as 'Gravel of uncertain age and origin' and the **Caesar's Camp Gravel Formation** are small isolated hill cappings lying unconformably on Palaeogene sediments. The Caesar's Camp Gravel Formation of Surrey and the **Nettlebed Formation** (Section 10.2.1.1) are assigned to the Dunwich Group.

12.3.1.1 CAESAR'S CAMP GRAVEL FORMATION

Name
Caesar's Camp Gravel Formation (CCGR) (after Dines and Edmunds, 1929, and Clarke and Fisher, 1983; Caesars Camp Formation of Gibbard, p. 53 in Bowen, 1999).

Lithology
Unbedded and thickly bedded cobble gravel with interbedded coarse sands. Gravels are dominantly nodular flint to 0.2 m diameter, with subordinate quartz and Greensand chert. The sand is subangular, dominantly quartz with

some flint, and occurs as horizontal planar-bedded units, cross-bedded lenses, and channel-fill sands and silts. Well-defined palaeosol in upper part of gravelly deposits, overlain by silty fine sand of aeolian origin.

Formal subdivisions and correlation table
No subdivisions (Tables 3, 18a and 18b).

Type area/Reference section
Type area: Plateau remnant 3 km north of Farnham [SU 831 493], at 175–187 m above OD (Clark and Fisher, 1983).

Lower and upper boundaries
Sharp, highly irregular contact with Palaeogene sands, obscured by a veneer of solifluction deposits.

Ground surface.

Landform description and genetic interpretation
Plateau cappings; the deposits are fluvial and periglacial in origin and laid down by rivers draining to the north-west.

Thickness
Up to 6 m.

Distribution and extent
Restricted to plateau remnants between Aldershot and Farnham, Surrey.

Age
Early Pleistocene.

12.3.2 Kesgrave Catchment Subgroup

Terrace deposits of the pre-diversionary ancestral River Thames in the Middle (Maidenhead–Vale of St Albans) to Lower Thames districts are assigned to the **Sudbury Formation** and the **Colchester Formation** of the Kesgrave Catchment Subgroup (after Whiteman and Rose, 1992) (Section 10.2.2). Correlation of the units is shown in Table 18a.

12.3.2.1 Sudbury Formation

The oldest terrace deposits are assigned to the Sudbury Formation (Section 10.2.2.1; Table 3; Figure 25). They differ from the equivalent terrace deposits in the Thames valley upstream (Section 11.1.1.1) in that they contain a large proportion of flint derived directly from the Chalk outcrop. The following units (oldest to youngest) appear on BGS maps:

Westland Green Gravel Member (WGGR)

The Westland Green Gravel Member (Westland Green Member of the Middle Thames Formation of Gibbard, p.48 in Bowen, 1999) comprises 1–5 m of variably sandy and clayey gravel. Its type area is the Goring district and southern East Anglia. The gravel rests unconformably on bedrock of Palaeogene–Neogene (Tertiary) to Cretaceous age. This unit previously included a high level gravel remnant at Stoke Row [SU 686 834] (Gibbard, 1985) which has subsequently been named the Stoke Row Member of the Middle Thames Formation (Gibbard, p. 48 in Bowen, 1999).

Chorleywood Gravel Member (CWGR)

The Chorleywood Gravel Member (Chorleywood Member of the Middle Thames Formation of Gibbard, p. 48 in Bowen, 1999) is named on BGS 1:50 000 Sheet E255 (Beaconsfield). Its type section is at Chorleywood [TQ 023 953] (Bridgland, 1994).

Beaconsfield Gravel Member (BDGR)

The Beaconsfield Gravel Member (Beaconsfield Member of the Middle Thames Formation of Gibbard, pp. 48–49 in Bowen, 1999) comprises 1–7 m of variably sandy and clayey gravel. Its type area is the Beaconsfield (BGS 1:50 000 Sheet E255) and type section is at Beaconsfield Station [SU 940 912] where 6 m of gravel overlie the Chalk (Gibbard, 1985). It was previously referred to as 'Plateau Gravel' and 'Higher Gravel Train'.

Gerrards Cross Gravel Member (GCGR)

The Gerrards Cross Gravel Member (Gerrards Cross Member of the Middle Thames Formation of Gibbard, p.49 in Bowen, 1999) comprises 1–10 m of sand and gravel, locally with lenses of silt, clay or peat and organic material. The unit occurs in the Colne valley near Watford up to about 90 m above OD (Ellison et al., 2004). Its type section is Gerrards Cross Quarry [SU 940 912] (Gibbard, 1985).

London area and Lower Thames

Additionally, in the London area and Lower Thames (Ellison et al., 2004; BGS 1:50 000 Sheet E256), the following units have been defined within the Sudbury Formation:

Woodford Gravel Member (WOGR)

The Woodford Gravel Member (after Strange, 1992; Woodford Green Member of the Epping Forest Formation of Gibbard, p. 50 in Bowen, 1999) comprises 1–10 m of sand and gravel, locally with lenses of silt, clay or peat and organic material. It occurs as isolated hill top gravel patches at Woodford, lying at 50–80 m above OD. The type area is based on a series of boreholes at the North Circular Road, Woodford [TQ 3973 9047]. Here the unit is 3–4 m thick. The unit is in part overlain by till of the Anglian glaciation. Dollis Hill Gravel Member (DHGR).

The Dollis Hill Gravel Member (after Gibbard, 1979, and Strange, 1992) comprises 1–15 m of gravel, sandy and clayey in part, with laminated beds of silty clay, peat and organic material. It was defined at a temporary section on Dollis Hill [TQ 2353 8825] near Hendon (BGS 1:50 000 Sheet 256; Gibbard, 1979).

In the valley of the Kennet in the Newbury district (see Aldiss et al., 2006; BGS 1:50 000 Sheet E267), remnants of high-level terrace deposits are assigned in this framework to three members of the Sudbury Formation (for the low-level terrace deposits of the Kennet Valley Formation Section 12.5.1.2). From oldest to youngest these are:

Cold Ash Gravel Member (CAGR)

The Cold Ash Gravel Member comprises 3 m of sandy gravel on bedrock at Cold Ash [SU 507 715] (Collins, p. 51 in Bowen 1999) and forms the Ninth Terrace.

Bucklebury Common Gravel Member (BYGR)

The Bucklebury Common Gravel Member (Bucklebury Member of Collins, p. 51 in Bowen 1999; Eighth Terrace) comprises 1–5 m of terraced gravel at Furze Hill [SU 426 687], Bucklebury (White, 1902; Collins, 1994). It was previously named the Plateau Gravel.

BEENHAM STOCKS GRAVEL MEMBER (BSGR)

The Beenham Stocks Gravel Member comprises up to 4 m of terraced gravel forming the Seventh Terrace in the Beenham area [SU 590 690]. The terrace surface ranges from 100–105 m above OD. It was previously named the Plateau Gravel.

Blackwater and Loddon

In the valleys of the Blackwater and Loddon in the Reading and Windsor districts (BGS 1:50 000 Sheets E268 and 269) the Seventh and Eighth Terrace deposits are not distinguished by name (cf. Gibbard pp. 52–53 in Bowen, 1999). Deposits of the Ninth Terrace are referred to the:

SURREY HILL GRAVEL MEMBER (SUHG)

The Surrey Hill Gravel Member is the equivalent of the Easthamstead, Chobham Common, Fox Hills members of the Blackwater–Loddon Formation of Gibbard (p. 53 in Bowen, 1999).

12.3.2.2 COLCHESTER FORMATION

In Berkshire, Essex and Hertfordshire two terrace deposits members of the Colchester Formation are defined:

WINTER HILL GRAVEL MEMBER (WIHG)

The Winter Hill Gravel Member (Winter Hill Member of the Middle Thames Formation of Gibbard, p. 49 in Bowen, 1999) comprises 1–8 m of variably sandy and clayey gravel. Its type section is at Winter Hill [SU 880 863] where 6 m of gravel was recorded (Gibbard, 1985). It divides into lower (fluvial) and upper (deltaic) subunits north of Slough. It was previously referred to as Plateau Gravel.

WESTMILL GRAVEL MEMBER (WLGR)

Considered by Gibbard (1977, 1985) to be the downstream continuation of the Winter Hill Gravel Member in the Vale of St Albans, the Westmill Gravel Member (Westmill Member of the Middle Thames Formation of Gibbard, p. 49 in Bowen, 1999) comprises up to 5 m of gravel and sand, locally with lenses of silt, clay or peat and organic material. The gravel is composed of 80–90 per cent flint with relatively high percentage (10–15%) of quartz and 1.5–6% Chalk. The unit occurs in the Colne valley near Watford between 60 and 70 m above OD (Ellison et al., 2004). Its type section is Westmill Quarry, St Albans, Hertfordshire. It rests unconformably on Chalk bedrock of the Chalk Group or sands and clays of the Palaeogene formations. Locally it is overlain by till of the Lowestoft Formation (Albion Glacigenic Group). Otherwise it forms the surface deposit.

12.4 BRITISH COASTAL DEPOSITS GROUP

12.4.1 Formations of the British Coastal Deposits Group

The British Coastal Deposits Group includes beach, intertidal and estuarine deposits and other raised marine deposits along the south coast of England that are described by Gibbard and Preece (pp. 59–65 in Bowen, 1999). These authors defined the Rye, Cheyne and Dungeness members of the **Romney Marsh Formation** of Kent; the **West Sussex Coast Formation** and members for raised beach and associated coastal and littoral sediments of Sussex (see also Hodgson, 1964); and the **Poole Harbour Formation** and Chesil Beach Bed of Dorset. Currently, none of these units has been assigned formal formational status in BGS publications or the Lexicon and currently all marine and coastal and deposits are shown as lithogenetic units on BGS geological maps.

12.5 BRITANNIA CATCHMENTS GROUP

12.5.1 Thames Catchments Subgroup

River terrace deposits and associated fossiliferous, organic beds laid down by the post-diversionary Thames are included within the Thames Catchments Subgroup (see also Section 11.3.3).

River terrace deposits of the Middle and Lower Thames that can be related to an individual aggradation event are given member status, being referred to the **Maidenhead Formation** (modified after Gibbard and Sumbler, pp. 46–51 in Bowen, 1999) (Tables 6 and 18a). On BGS maps the individual aggradations are either numbered with respect to their relative height above the present floodplain or assigned lithostratigraphical names (Table 18b). A separate formation, the **KENNET VALLEY FORMATION** is proposed for the deposits of the Kennet valley. It is also proposed to adopt the **Medway Valley Formation** for deposits of the Medway and its tributaries (after Bridgland, pp. 56–57 in Bowen, 1999). Bridgland's units include the Cobham Park, Lodge Hill, High Halstow, Clinch Street (all pre-MIS 13), Dagenham Farm (MIS 12), Shakespeare Farm, Newhall, Stoke (all MIS 6), Binney (MIS 3), Halling (MIS 3), Aylesford (MIS 2) and Tilbury (MIS 1) members.

The widespread head deposits are, for the most part, of limited thickness and lateral extent. Their history of formation is often difficult to determine. They may be best considered within the denudation chronology of the fluvial systems and merely become an informal 'Head Member' within each fluvial formation. Individual formal names for these deposits will depend on the level of information available.

12.5.1.1 MAIDENHEAD FORMATION

The Maidenhead Formation (here modified to include the deposits of both the Maidenhead and Lower Thames formations of Gibbard, pp. 49–51 in Bowen, 1999) is established for the terrace deposits of the post-diversionary Middle and Lower Thames downstream of Goring (Figures 25 and 26). The formation is characterised by terrace aggradations of gravels dominated by flint with minor local lithologies. Interbedded with the gravels are numerous fossiliferous beds that provide evidence of deposition in both cold and warm (interglacial) climates — only a few are referred to in this report (for detailed descriptions of type localities see Bridgland, 1994, and Gibbard, pp. 49–51 in Bowen, 1999; Ellison et al., 2004 provide a summary of interglacial sites in London).

Sand and gravel of the Maidenhead Formation overlying till of the Lowestoft Formation in the Hornchurch railway cutting, south-west Essex [TQ 547 874], was assigned to the Black Park Gravel Member by Ellison et al. (2004, p. 58) but to the Boyn Hill Gravel Member by Bridgland (his Orsett Heath Gravel; 1994, pp. 176–185, 2006).

The Maidenhead Formation also includes the deposits of the valleys of the Colne (Colne Formation of Gibbard, p. 53 in Bowen, 1999), Blackwater–Loddon (Blackwater–Loddon

Formation of Gibbard, p. 53 in Bowen, 1999), Lea (Lea Formation of Gibbard, p. 54–56 in Bowen, 1999), Wandle (Wandle Formation of Gibbard, p. 54 in Bowen, 1999), Mole and Wey (Mole–Wey Formation of Gibbard, p. 54 in Bowen, 1999), and Darent and Cray (Darent Formation of Gibbard, p.56 in Bowen, 1999). Many names have been applied to the gravels of these tributary valleys (see Gibbard, pp. 52–56 in Bowen, 1999) but much of this nomenclature is not currently employed in the BGS lithostratigraphical framework. The framework mainly adopts the published nomenclature of modern BGS 1:50 000 scale sheets (Table 18b) including E255 (Beaconsfield); E269 (Windsor); E256 (North London); E270 (South London); and E271 (Dartford). Full definitions of the terrace deposit members (Table 18a) remain to be completed for the BGS Lexicon. Lexicon codes (with generic descriptions only) defining numbered terraces have been applied for some valleys, e.g. Godalming Wey (GW1–GW3) (Sheets 300, Alresford, BGS 1999b, and 301 Haslemere, IGS, 1981); Bramley Wey (BW1–BW2) (Sheet 301 Haslemere, IGS, 1981); and Blackwater (BL2–BL4) (Sheets 285, Guildford, BGS, 2001, and 301 Haslemere, IGS, 1981).

Correlation with terrace deposits of the **Kennet Valley Formation** of the Reading and Newbury districts (Section 13.5.2) (BGS 1:50 000 Sheets E267 and E268) is given in Table 18a. Correlation with the **Upper Thames Valley Formation** is shown in Table 17.

Name
Maidenhead Formation (MNHD) (modified to include the deposits of both the Maidenhead and Lower Thames formations of Gibbard, pp. 49–51 in Bowen, 1999).

Lithology
Mainly river terrace sand and gravel, brickearth silt and alluvial floodplain silt, silty clay and sand. The formation includes interbedded units (representing interglacials) of locally fossiliferous silty sand, silt, together with organic clay, tufa and peat. River terrace deposits of the Middle and Lower Thames contain gravel clasts mainly composed of flint, vein quartz and local bedrock lithologies including chert. The terrace deposits are depicted on BGS maps using numbered terrace symbols. Modern BGS maps also show the terrace deposits as named units which are here interpreted as members of the Maidenhead Formation.

Formal subdivisions and correlation table
The main terrace deposit members are the Black Park Gravel, Boyn Hill Gravel, Lynch Hill Gravel, Hackney Gravel, Taplow Gravel, Kempton Park Gravel, Shepperton Gravel and Staines Alluvium. Brickearth silts and clays include the Enfield Silt, Roding Silt, Langley Silt, Dartford Silt, Crayford Silt and Ilford Silt members (Tables 6, 18a and 18b; Figure 26).

Type area/Reference section
Type area: Includes all of the mainstream terrace deposit members, brickearth and floodplain alluvium of the Middle and Lower Thames and tributaries downstream of Goring, except the Kennet (modified after Gibbard in Bowen, 1999).

Lower and upper boundaries
Unconformable on glacigenic deposits of the Anglian stage or on older Pleistocene strata or bedrock. Individual terrace deposit members rest unconformably on older Pleistocene strata or bedrock.

Ground surface.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates and interbedded interglacial deposits.

Thickness
Single terrace aggradations range from 3–12 m.

Distribution and extent
The valley of the mainstream River Thames and tributaries, other than the Kennet, downstream from the Goring Gap.
Age
Anglian to Holocene (MIS 12–1).

The following terrace deposit members (from oldest to youngest) are shown on modern BGS maps:

BLACK PARK GRAVEL MEMBER (BPGR)

The Black Park Gravel Member (after Hare, 1947, Gibbard, 1979, 1985, and Strange, 1992; Black Park Member of the Middle Thames Formation of Gibbard, p. 49 in Bowen, 1999) represents the deposits of the Sixth Terrace on BGS maps. It comprises up to 4 m of sand and gravel, with lenses of silt, clay or peat. The type section is in Black Park Country Park [TQ 006 832], Slough (Gibbard, 1985).

BOYN HILL GRAVEL MEMBER (BHT)

The Boyn Hill Gravel Member (after Dewey and Bromehead, 1915, Gibbard, 1985, and Strange, 1992; Boyn Hill Member of the Middle Thames Formation of Gibbard, p. 49 in Bowen, 1999; Orsett Heath Formation of the Lower Thames, Bridgland, 2006) represents the deposits of the Fifth Terrace on BGS maps. It comprises up to 6 m of sand and gravel at Boyn Hill, Maidenhead [SU 878 809].

The informal *Swanscombe Member* (Gibbard, p. 50 in Bowen, 1999), stratotype Swanscombe [TQ 595 745], comprises fossiliferous fluvial and non-fluvial deposits correlated with the Hoxnian stage (MIS 11) (Bridgland, 1994; Gibbard, 1994).

FINSBURY GRAVEL MEMBER (FIGR)

The Finsbury Gravel Member (Strange, 1992; Ellison et al., 2004) has been recognised from only a single outcrop up to 3 m in thickness, with a base at between 25 and 27 m OD at Finsbury [TQ 315 829]. Its position is intermediate in altitude between those of the Lynch Hill and the Boyn Hill gravel members nearby. Ellison et al. (2004) suggest that it is related to a phase of deposition of the Lynch Hill Gravel in the vicinity of the confluence of the rivers Lea and Thames, but recent three-dimensional modelling indicates instead that it represents a late stage of Boyn Hill Gravel deposition (Aldiss, oral communication, 2010).

LYNCH HILL GRAVEL MEMBER (LHGR)

The Lynch Hill Gravel Member (after Hare, 1947, Gibbard, 1985, and Strange, 1992; Lynch Hill Member of the Middle Thames Formation of Gibbard, p. 49 in Bowen, 1999; Corbets Tey Formation of the Lower Thames, Bridgland, 2006) represents the deposits of the Fourth Terrace on BGS maps. The type section shows up to 6 m of sand and gravel at Lynch Hill [SU 950 822], Slough (Gibbard, 1985).

Hackney Gravel Member (HAGR)

The Hackney Gravel Member (after Bromehead, 1925, and Strange, 1992) represents the deposits of the Third Terrace on BGS maps. It comprises up to 10 m of sand and gravel. The type section is taken as Hackney Downs [TQ 3446 8557] where boreholes proved 8.2 m of gravel with a base resting on London Clay at 12.8 to 13.5 m OD (Strange, 1992).

Taplow Gravel Member (TPGR)

The Taplow Gravel Member (after Bromehead, 1912, Dewey and Bromehead, 1915, Gibbard, 1985, and Strange, 1992; Taplow Member of the Middle Thames Formation of Gibbard, p. 49 in Bowen, 1999; Mucking Formation of the Lower Thames, Bridgland, 2006) represents the deposits of the Second Terrace on BGS maps. The type section shows up to 6 m of sand and gravel at Taplow Station [SU 919 816], Slough (Gibbard, 1985).

The informal *Trafalgar Square Beds* (after Gibbard, 1985, 1994; Trafalgar Square Member of the Middle Thames Formation of Gibbard, p. 49 in Bowen, 1999) comprise, at the stratotype at Canada House, Trafalgar Square [TQ 300 803], up to 12 m of fossiliferous gravel, silt, sand and mud resting on earlier Pleistocene deposits (the Spring Gardens Member of the Middle Thames Formation of Gibbard, p.49 in Bowen, 1999) or bedrock. They are correlated with the Ipswichian (MIS 5e) (Gibbard, 1985).

Kempton Park Gravel Member (KPGR)

The Kempton Park Gravel Member (after Gibbard et al., 1982, and Strange, 1992; Upper Floodplain Terrace of Dewey and Bromehead, 1921; Kempton Park Member of the Middle Thames Formation of Gibbard, p. 50 in Bowen, 1999; East Tilbury Marshes Formation of the Lower Thames, Bridgland, 2006) represents the deposits of the First Terrace on BGS maps. The type section shows up to 7 m of sand and gravel at Kempton Park [TQ 118 703], Slough (Gibbard, 1985). Discontinuous channel-fill sediments have yielded faunal and floral fossil assemblages indicative of both cold and temperate conditions.

Shepperton Gravel Member (SHGR)

The Shepperton Gravel Member (after Gibbard et al., 1985, 1989; Shepperton Member of the Middle Thames Formation of Gibbard, p. 50 in Bowen, 1999) lies beneath the Thames floodplain alluvium (the Lower Floodplain Terrace of Dewey and Bromehead, 1921). Up to 12 m of sand and gravel was observed at Shepperton [TQ 070 669] (Gibbard, 1985). It was previously referred to as Valley Gravel.

Staines Alluvium Member

The Staines Alluvium Member (Staines Member of the Middle Thames Formation of Gibbard, p. 50 in Bowen, 1999) comprises silt, clay, peat, marl and tufa with sand and gravel and was referred to the Staines Member by Gibbard (1985) based on a stratotype at Staines [TQ 042 685]. BGS has employed the term Alluvium on all of its maps.

'Brickearth' silt deposits

Several members of the Maidenhead Formation are established for the 'brickearth' silts of the Thames catchment. These clayey silts and clays are probably colluvium but may be primary loess in places (Gibbard, 1994). They cover fluvial aggradations and may be polycyclic in origin. Although shown in Table 18a to be tentatively correlated with MIS 3–4, some deposits may be older. The distribution of the silts, which are generally less than 3 m thick, is shown in Ellison et al. (2004). The members include the *Langley Silt Member* (LASI) (after Gibbard, 1995, and Strange, 1992; Langley Member of the Middle Thames Formation of Gibbard, p. 50 in Bowen, 1999); *Enfield Silt Member* (ESI) (after Strange, 1992); *Roding Silt Member* (ROSI), type section: North Circular Road [TQ 4105 9038]; *Ilford Silt Member* (ILSI) (after Bridgland, 1994), type area: old brick pits, Ilford to Seven Kings [TQ 443 866 to TQ 451 868]; *Dartford Silt Member* (DASI) (after Gibbard, 1994, and Ellison et al., 2004), silt and clay ('Wantsant Loam') overlying Boyn Hill Gravel Member (see Dartford Heath Member of Gibbard (p. 50 in Bowen, 1999), type area: Dartford Heath [TQ 518 738]; and the *Crayford Silt Member* (CFSI) (after Gibbard, 1994, and Bridgland, 1994), type area Crayford [TQ 514 767].

12.5.1.2 Kennet Valley Formation

Full definitions of the Kennet Valley Formation (KNTV) and its terrace deposit members remain to be completed for the BGS Lexicon. Reference should be made to the Kennet Valley Formation of Gibbard and Collins (pp. 51–53 in Bowen, 1999). Older Anglian and pre-Anglian terrace gravels in the Kennet valley are referred to the Sudbury Formation (Section 12.3.2.1) or the Colchester Formation (Section 12.3.2.2). All units currently shown on BGS maps are presented in Tables 18a and 18b.

The following named terrace deposit members (from oldest to youngest) in the Kennet valley are described in recently published BGS sheet explanations:

Silchester Gravel Member (SIGR)

The Silchester Gravel Member represents the deposits of the Sixth Terrace of the Kennet valley on BGS maps. The type area is the Kennet drainage basin and interfluves between Newbury (Aldiss et al., 2006; BGS 1:50 000 Sheet E267) and Reading (BGS 1:50 000 Sheet E268). Up to 8 m of gravel underlie the terrace surface around Silchester. It was previously known as Plateau Gravel.

Hamstead Marshall Gravel Member (HMGR)

The Hamstead Marshall Gravel Member represents the deposits of the Fifth Terrace of the Kennet valley on BGS maps (e.g. BGS 1:50 000 Sheet E267; Aldiss et al., 2006).

Thatcham Gravel Member (THGR)

The Thatcham Gravel Member represents the deposits of the Third Terrace of the Kennet valley on BGS maps (e.g. BGS 1:50 000 Sheet E267; Aldiss et al., 2006). It comprises 3–4 m of gravel underlying the terrace surface at Thatcham. The terrace, which is modified by erosion, is about 8–10 m about the Kennet Floodplain (Chartres, 1975).

Beenham Grange Gravel Member (BGGR)

The Beenham Grange Gravel Member represents the deposits of the Second Terrace of the Kennet valley on BGS maps (e.g. BGS 1:50 000 Sheets E267 and E268; Aldiss et al., 2006). It comprises up to 10 m of gravel underlying the terrace surface. The terrace, which is modified by erosion, lies 1–3 m above Kennet Floodplain. It was previously known as the Valley Gravel.

Heales Lock Gravel Member (HLGR)

The Heales Lock Gravel Member represents the deposits of the First Terrace of the Kennet valley in the Reading and Newbury districts (Mathers and Smith, 2000; Aldiss et al., 2006).

12.5.1.3 Medway Valley Formation

Four terrace deposit members of the Medway Valley Formation (MEVA) are shown on BGS 1:50 000 Sheets E272 (Chatham); E288 (Maidstone); and E303 (Tunbridge Wells) (Table 18b). Reference should also be made to the Medway Valley Formation and informal units of Bridgland (pp. 56–57 in Bowen, 1999) (Table 18a).

Name
Medway Valley Formation (MEVA) (after Bristow and Bazley, 1972, and Bridgland, pp. 56–57 in Bowen, 1999).

Lithology
Mainly river terrace sand and gravel, characterised by clasts of Wealden sandstone, siltstone and sporadic flints, and alluvial floodplain silt, silty clay and sand. The terrace deposits are depicted on BGS maps using numbered terrace symbols.

Formal subdivisions and correlation table
Four terrace deposit members (ME1–ME4) are shown on BGS maps (Tables 18a and 18b); for other units see Bridgland (pp. 56–57 in Bowen, 1999).

Type area/Reference section
Type area: Valley of the River Medway from Tunbridge Wells to Sheerness [TQ 500 400–TQ 910 750].

Lower and upper boundaries
Unconformable on bedrock.

Ground surface, locally overlain by head and brickearth.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates and interbedded interglacial deposits.

Thickness
Single terrace aggradations range from 3–12 m.

Distribution and extent
Valley of the River Medway and its tributaries from Tunbridge Wells to Sheerness, north Kent.

Age
Anglian to Holocene (MIS 12–1).

12.5.2 South Kent Catchments Subgroup

Alluvium, river terrace deposits and associated fossiliferous, organic and lacustrine deposits within valleys of rivers which drain to the English Channel coast of Kent are included within the South Kent Catchments Subgroup (Table 6 and 19). Head and loessic deposits are referred to the Britannia Catchments Group.

Name
South Kent Catchments Subgroup (SKCAT) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium comprises soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits are largely sand and gravel. Peat is a minor component, and minor marine deposits are included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Subdivided into the Kentish Stour, Kentish Rother, Kent Ouse and Pegwell formations (Tables 6 and 19).

Type area/Reference section
Type area: River valleys of the catchments of the Kentish Stour and Kentish Rother and other rivers together with all their tributaries which flow to the English Channel in Kent.

Lower and upper boundaries
Formations of the South Kent Catchments Subgroup rest unconformably on Lower Cretaceous bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and alluvium and associated lacustrine and organic deposits.

Thickness
Up to 10 m.

Distribution and extent
The entire area covered by the catchments of South Kent.

Age
Cromerian to Holocene (MIS 13–1).

Gibbard and Preece (pp. 59–61 in Bowen, 1999) defined several formations with members and beds for the Quaternary deposits of Kent. These include the Kentish Stour Formation (River Stour fluvial deposits), Pegwell Formation (Devensian loessic deposits of Kent and Sussex), Brook Formation (Late Devensian and Holocene slope and valley sediments flooring dry valleys) and the Romney Marsh Formation (Holocene fossiliferous silts, clays and peats together with coastal deposits). The status of some of these units for mapping purposes remains to be considered. Head deposits, for the most part, are of limited thickness and lateral extent. Their history of formation is often difficult to determine. They may be best considered within the denudation chronology of the fluvial systems.

Traditionally BGS maps have shown river terrace aggradations as staircase series of numbered upwards from youngest to oldest. The BGS Quaternary lithostratigraphical framework currently identifies three formations but they and their terrace deposit members are yet to be formally defined in the BGS Lexicon. These units are:

12.5.2.1 Kentish Stour Formation

The Kentish Stour Formation was defined by Gibbard and Preece (pp. 59–60 in Bowen, 1999) to include the fluvial and associated gravel terrace deposits of the River Stour. They defined the Chislet Member (pre-Devensian), Folkestone Battery Bed (faunal evidence suggests correlation with the Ipswichian, MIS 5e stage) and Kennington Member (Devensian). BGS maps show up to 10 aggradations above the alluvium. There are currently no formally defined units in the BGS Lexicon.

12.5.2.2 Kentish Rother Formation

The Kentish Rother has four aggradations (RO1–RO4) above the alluvium. There are currently no formally defined units in the BGS Lexicon.

12.5.2.3 Kent Ouse Formation

The River Ouse of Kent has two aggradations (OK1 and OK2) above the alluvium. There are currently no formally defined units in the BGS Lexicon.

12.5.2.4 Pegwell Formation

The informal **Pegwell Formation** (Gibbard and Preece, p. 61 in Bowen, 1999), stratotype Pegwell Bay [TR 353 644], comprises up to 3 m of loessic deposits (also termed 'head brickearth') with a cold stage molluscan fauna at some sites (Preece, 1990). It is of Mid to Late Devensian age (MIS 3-2).

12.5.3 Sussex Catchments Subgroup

Alluvium, river terrace deposits and associated fossiliferous, organic and lacustrine beds within valleys of rivers which drain southwards from the Weald are included within the Sussex Catchments Subgroup (Tables 6 and 19). Head and loessic deposits are referred to the Britannia Catchments Group.

Name
Sussex Catchments Subgroup (SXCAT) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium comprising soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits are largely sand and gravel. Peat is a minor component, and minor marine deposits are included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Subdivided into the Cuckmere, Sussex Ouse, Adur, Sussex Rother, Arun formations (Tables 6 and 19).

Type area/Reference section
Type area: River valleys of the catchments of the Ouse, Arun, Sussex Rother and Cuckmere and other rivers together with all their tributaries which flow southwards from the Weald to the English Channel.

Lower and upper boundaries
Formations of the Sussex Catchments Subgroup rest unconformably on Lower Cretaceous bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and alluvium associated lacustrine and organic deposits.

Thickness
Up to 10 m.

Distribution and extent
The entire area covered by the catchments of Sussex.

Age
Cromerian to Holocene (MIS 13–1).

The Sussex Valleys Formation and its respective members was established for the gravels, sands and associated organic sediments of the Ouse, Arun and Cuckmere rivers by Gibbard and Preece (pp. 60–62 in Bowen, 1999).

Traditionally BGS maps have shown river terrace aggradations numbered by increasing height from youngest to oldest. The BGS Quaternary lithostratigraphical framework identifies two formally defined formations and a further three formations with terrace deposit members which have yet to be formally defined in the BGS Lexicon. These units are:

12.5.3.1 Arun Formation

Name
Arun Formation (ARUN) (after Arun Member of Sussex Valleys Formation of Gibbard and Preece, p. 62 in Bowen, 1999; see also Burrin and Scaife, 1984, and Aldiss, 2002)

Lithology
River terrace gravels, sands and associated organic sediments.

Formal subdivisions and correlation table
The Arun has seven river terrace aggradations (Lexicon codes AR1–AR7) above the alluvium (e.g. Sheet 301 Haslemere BGS, 1981) (Tables 6 and 19).

Type area/Reference section
Type area: Valley of the Arun River and a tributary valley of the River Lavant, Haslemere, Horsham, Chichester district, Sussex [TQ 020 060–TQ 200 340] (Aldiss, 2002).

Lower and upper boundaries
The fluvial deposits rest unconformably on Palaeogene strata.

At surface or overlain by younger deposits including and head.

Landform description and genetic interpretation
Floodplain alluvium and river terrace deposits. Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates, with interbedded interglacial deposits. The older, higher terraces are commonly cryoturbated.

Thickness
Average 4 m, although may reach 8–10 m locally.

Distribution and extent
Valley of the Arun River, in the Haslemere, Horsham, and Chichester districts, Sussex.

Age
Pleistocene to Holocene (MIS pre-13–1).

12.5.3.2 Sussex Rother Formation

Name
Sussex Rother Formation (RSX) (after Reid, 1903, and Aldiss, 2002).

Lithology
Sands, sandy gravels, gravels, some being clayey. The gravel component is predominantly subangular flint with subordinate debris of chert, polished quartz grains and larger fragments of pebbly ferruginous sandstone derived from the Lower Cretaceous sequences to the north. Subrounded flint nodules are also present in places. Locally clayey and sandy silt and silty clay mask the sands and gravels, perhaps indicating preservation of overbank or aeolian deposits at the top of the fluvial cycle.

Formal subdivisions and correlation table
The River Rother in Sussex has five aggradations (River Terrace deposit members RS1–RS5) above the alluvium (Tables 6 and 19).

Type area/Reference section
Type area: Valley of the River Rother [SU 936 206] (Aldiss, 2002; Farrant, 2002).

Lower and upper boundaries
Incises bedrock or older superficial deposits.

At surface or overlain by younger deposits including head.

Landform description and genetic interpretation
Floodplain alluvium and river terrace deposits. Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates, with interbedded interglacial deposits. The older, higher terraces are commonly cryoturbated.

Thickness
Each terrace averages 4 m thick, reaching 8–10 m locally.

Distribution and extent
Chichester and Bognor district (BGS 1:50 000 Sheets E300, 301, 317).

Age
Pleistocene to Holocene (MIS pre-13–1).

12.5.3.3 CUCKMERE VALLEY FORMATION

The Cuckmere has two aggradations above the alluvium. There are currently no formally defined units in the BGS Lexicon.

12.5.3.4 SUSSEX OUSE VALLEY FORMATION

The Sussex Ouse has four aggradations above the alluvium. There are currently no formally defined units in the BGS Lexicon.

12.5.3.5 ADUR VALLEY FORMATION

The Adur has three aggradations (AD1–AD3) above the alluvium. There are currently no formally defined units in the BGS Lexicon.

12.5.4 Solent Catchments Subgroup

Alluvium, river terrace deposits and associated fossiliferous, organic and lacustrine beds within valleys of rivers which drain southwards from Hampshire Basin and Dorset are included within the Solent Catchments Subgroup (Table 19). Head and loessic deposits are referred to the Britannia Catchments Group. The Solent Catchments Subgroup includes the deposits of the Solent Formation and its members (Gibbard and Preece, pp. 60–63 in Bowen, 1999) that were established for the gravels, sands and associated organic sediments of the south bank tributaries of the former Solent River (Allen and Gibbard, 1994) known formerly as Plateau Gravels. Gibbard and Preece (pp. 60–63 in Bowen, 1999) also defined the Ringwood Formation for the oldest gravels (pre-MIS 13) of the south-easterly flowing Avon River and the New Forest Formation and members for the Solent River in Hampshire.

Name
Solent Catchments Subgroup (SNTCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium and river terrace deposits. The floodplain alluvium comprises soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits are largely sand and gravel. Peat is a minor component, and minor marine deposits are included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Subdivided into the Meon, Hamble, Itchen, Test (informal), Hampshire Avon, Frome–Piddle, and Dorset Stour formations (Tables 6 and 19).

Type area/Reference section
Type area: River valleys of the catchments of the 'Solent River', Meon, Hamble, Itchen, Test, Hampshire Avon, Dorset Stour and Frome–Piddle together with other rivers and all their tributaries southwards from Hampshire Basin and Dorset to the English Channel.

Lower and upper boundaries
Formations of the Solent Catchments Subgroup rest unconformably on Jurassic to Cretaceous bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and alluvium and associated lacustrine and organic deposits.

Thickness
Up to 10 m.

Distribution and extent
The entire area covered by the catchments of the Hampshire Basin and Dorset.

Age
Cromerian to Holocene (MIS 13–1).

Traditionally BGS maps have shown river terrace aggradations numbered by increasing elevation from youngest to oldest. The BGS Quaternary lithostratigraphical framework has established the following six formations (their terrace deposit members are yet to be formally defined in the BGS Lexicon).

12.5.4.1 MEON FORMATION

Name
Meon Formation (MEON) (after Hopson, 2000, and Farrant, 2002).

Lithology
Floodplain alluvium and river terrace deposits. The floodplain alluvium comprises overbank deposits of brown organic silty clay and peaty clay, together with peat, overlying sand and gravel. Terrace deposits comprise sand and gravel, commonly cross-bedded, locally overlain by overbank deposits of clayey sandy silts and silty clays. These fine-grained deposits may be partly aeolian in origin. The major gravel lithology is flint, dominantly subrounded to subangular, some of it well-rounded. The sand fraction is composed of well-rounded quartz grains and subangular flint.

Formal subdivisions and correlation table
The surviving river terrace deposits represent seven aggradations above the alluvium. Terrace deposits are currently unnamed (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the River Meon and its tributaries in the Fareham to East Meon area [SU 53 02–SU 63 23] (Hopson, 2000).

Lower and upper boundaries
The fluvial deposits rest unconformably on Palaeogene strata.

Ground surface.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates, with interbedded interglacial deposits. The older, higher terraces are commonly cryoturbated.

Thickness
Up to 12 m.

Distribution and extent
The catchment of the River Meon and its tributaries, in the Fareham to East Meon area.

Age
Pleistocene to Holocene (MIS pre-13–1).

12.5.4.2 Hamble Formation

Name
Hamble Formation (HBLE) (after Edwards and Freshney, 1987).

Lithology
Floodplain alluvium and river terrace deposits. The floodplain alluvium comprises overbank deposits of brown organic silty clay, together with peaty clay, and peat, overlying sand and gravel. Terrace deposits comprise sand and gravel, commonly cross-bedded, locally overlain by overbank deposits of clayey and sandy silts and silty clays. These fine-grained deposits may be partly aeolian in origin. The major gravel lithology is flint, dominantly subrounded to subangular, with a little that is well rounded. The sand fraction is composed of well-rounded quartz grains and subangular flint.

Formal subdivisions and correlation table
The surviving river terrace deposits represent three aggradations above the Alluvium. Terrace deposits are currently unnamed (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the Hamble River and its tributaries in the Southampton area [SU 48 06–SU 52 13] (Edwards and Freshney, 1987).

Lower and upper boundaries
The fluvial deposits rest unconformably on Palaeogene strata.

Ground surface.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates, with interbedded interglacial deposits. The older, higher terraces are commonly cryoturbated.

Thickness
Up to 12 m.

Distribution and extent
The catchment of the Hamble River and its tributaries, in the Southampton area.

Age
Pleistocene to Holocene (MIS pre-13–1).

12.5.4.3 Itchen Formation

Name
Itchen Formation (ITCH) (after Edwards and Freshney, 1987, Booth, 2002, and Farrant, 2002).

Lithology
Floodplain alluvium and river terrace deposits. The floodplain alluvium comprises overbank deposits of brown organic silty clay, together with peaty clay and peat, overlying sand and gravel. Tufa occurs as 1–2 m-high raised hummocky spreads. Terrace deposits comprise sand and gravel, planar bedded or cross-bedded, locally overlain by overbank deposits of clayey and sandy silts and silty clays. These fine-grained deposits may be partly aeolian in origin. The major gravel lithology is flint, dominantly subrounded to subangular and a little that is well rounded, and subordinate quartz, ironstone and 'sarsens'. The sand fraction is composed of fine- to coarse-grained well-rounded quartz grains, with subangular flint in the coarse fraction. The older, higher terraces are commonly cryoturbated.

Formal subdivisions and correlation table
The surviving river terrace deposits represent seven aggradations above the alluvium. The deposits are unnamed (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the River Itchen and its tributaries in the Southampton–Alresford area [SU 42 10–SU 60 33] (Edwards and Freshney, 1987).

Lower and upper boundaries
The fluvial deposits rest unconformably on Palaeogene and Cretaceous strata.

Ground surface.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates, with interbedded interglacial deposits.

Thickness
Up to 12 m.

Distribution and extent
The catchment of the River Itchen and its tributaries in the Southampton–Alresford area.

Age
Pleistocene to Holocene (MIS pre-13–1).

12.5.4.4 Hampshire Avon Formation

Name
Hampshire Avon Formation (HAAV) (after Reid, 1902, White, 1917, Clarke, 1981, and Bristow et al., 1991).

Lithology
Floodplain alluvium and river terrace deposits. The floodplain alluvium comprises overbank deposits of mottled dark grey and orange organic silt, silty clay and clayey sand,

together with peat, overlying sand and gravel. The river terrace deposits comprise very sandy gravels. The clasts are subangular to subrounded, poorly sorted up to 5 cm in diameter, dominantly flint, with a little Upper Greensand chert, 'sarsen' stone, vein quartz, Jurassic limestone, and well-rounded flints from the Palaeogene, in a matrix of clayey sand.

Formal subdivisions and correlation table
Fourteen river terraces are preserved. Terrace deposits currently unnamed (Tables 6 and 19).

Type area/Reference section
Type area: The valleys of the Hampshire Avon and its tributaries from Christchurch to Warminster and Devizes [SU 08 62–SZ 18 92] (Bristow et al., 1991).

Lower and upper boundaries
The fluvial deposits rest unconformably on Palaeogene and Cretaceous strata.

Ground surface.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates and interbedded interglacial deposits. Deposits of the higher terraces are cryoturbated.

Thickness
Up to 8 m, including up to 4 m of alluvial overbank deposits.

Distribution and extent
The catchment of the Hampshire Avon and its tributaries.

Age
Pleistocene to Holocene (MIS pre-13–1).

12.5.4.5 Frome–Piddle Formation

Preece and Gibbard (pp. 64–65 in Bowen, 1999) defined the Frome–Piddle Formation and its members for the succession of terrace deposits in the valleys of the rivers Frome and Piddle in Dorset.

Name
Frome–Piddle Formation (FRPI) (after Allen and Gibbard, 1994, and Preece and Gibbard, pp. 64–65 in Bowen, 1999)

Lithology
Floodplain alluvium and river terrace deposits. The floodplain alluvium comprises clay and silt overbank deposits, with local peat, overlying sand and gravel. The surviving river terrace deposits are largely gravel with interstitial sand. The major pebble lithologies are flint, quartz and Mesozoic chert.

Formal subdivisions and correlation table
Informal terrace deposits defined by Preece and Gibbard (pp. 64–65 in Bowen, 1999) (Tables 6 and 19).

Type area/Reference section
Type area: The valleys of rivers Frome and Piddle and their tributaries, in the Wareham–Dorchester area, Dorset [SY 63 95–SY 93 87] (Allen and Gibbard, 1994).

Lower and upper boundaries
The fluvial deposits rest unconformably on Chalk Group and Palaeogene strata.

Ground surface.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates, with interbedded interglacial deposits. The gravels were deposited by braided rivers under periglacial conditions.

Thickness
Up to 20 m.

Distribution and extent
The catchment of the rivers Frome and Piddle and their tributaries, Dorset, up to125 m above OD or higher.

Age
Pleistocene to Holocene (MIS pre-13–1).

12.5.4.6 Dorset Stour Formation

Name
Dorset Stour Formation (DOST) (after Reid, 1902, White, 1917, Clarke, 1981, and Bristow et al., 1991, 1995).

Lithology
Floodplain alluvium and river terrace deposits. The floodplain alluvium comprises overbank deposits of mottled dark grey and orange organic silt, silty clay and clayey sand, and peat, overlying sand and gravel. The river terrace deposits comprise very sandy gravels. The clasts are subangular to subrounded, poorly sorted, up to 10 cm in diameter, dominantly flint, with a little Upper Greensand chert, 'sarsen' stone, vein quartz, Jurassic limestone, Chalk, and well-rounded flints from the Palaeogene, in a matrix of clayey sand. Deposits of the higher terraces are cryoturbated.

Formal subdivisions and correlation table
Thirteen river terraces are preserved. Terrace deposits are currently unnamed (Tables 6 and 19).

Type area/Reference section
Type area: The valleys of the River Stour, River Allen, Moors River, Uddens Water and their tributaries, from Christchurch to Wincanton [ST 72 28–SZ 18 92] (Bristow et al., 1991).

Lower and upper boundaries
The fluvial deposits rest unconformably on Jurassic, Cretaceous and Palaeogene strata.

Ground surface.

Landform description and genetic interpretation
Terraces of cyclical sequence of fluvial sand and gravel aggradations developed under mainly periglacial climates, with interbedded interglacial deposits.

Thickness
Up to 11 m, including up to 4 m of alluvial overbank deposits.

Distribution and extent
The catchment of the Dorset Stour and its tributaries.

Age
Pleistocene to Holocene (MIS pre-13–1).

13 South-west England

In south-west England, the evidence for much of the Quaternary record is fragmentary, with few age determinations, and so there have been few published attempts to correlate deposits or equate disparate sequences. The earliest deposits described in this report are referred to the St Erth Formation. These marine sands and clays, which are of Pliocene age, occupy a planated surface in Cornwall. Limited evidence provided by glacigenic deposits on the northern coastline of Cornwall and Devon indicates that this part of south-west England was glaciated during the Anglian or pre-Anglian stages. These deposits are assigned to the Albion Glacigenic Group. In the ground between the Quantock and Mendip Hills known as the Somerset Levels a series of Ipswichian deposits are present. Tills and glaciofluvial deposits on the northern margin of the Bristol Channel and Severn Estuary are attributed to the Devensian ice-sheet and assigned to the Caledonia Glacigenic Group. Tills occurring in the northern Scilly Isles are also likely to be related to the Devensian glaciation. Terrace deposits of the Bristol Avon valley relate to the drainage through an extended inner Bristol Channel during the Devensian. The most complete Holocene stratigraphical record occurs in the Somerset Levels where tidal flat and freshwater sediments accumulated. The Holocene record in Devon and Cornwall is more fragmentary. Other sediments present in the region that may owe their existence indirectly to proximal ice, such as loess, cave deposits and the widespread head, are included within the Britannia Catchments Subgroup. Raised beach deposits are referred to the British Coastal Deposits Group.

13.1 BRITISH COASTAL DEPOSITS GROUP

13.1.1 Formations of the British Coastal Deposits Group

13.1.1.1 St Erth Formation

Remnants of several Pliocene to early Pleistocene marine deposits are known in south-west England. These include the St Erth Beds, which are now established as the St Erth Formation, and the deposits of St Agnes, Cornwall (Tables 5 and 19) (Mitchell, 1966; Edmonds et al., 1975; Mitchell et al. 1973b; Roe et al., 1999; Messenger et al., 2005). The much-researched beds at St Erth occur at about 25 m above OD. Here, some 4 m of fossiliferous clay overlies ferruginous and quartzose sands. The clays have yielded abundant marine mollusca and foraminiferids confirming a Late Pliocene age (Millett, 1895, 1897; Reid, 1890; Jenkins, 1982; Jenkins et al., 1986).

Name
St Erth Formation (SE) (after Mitchell, 1966, Edmonds et al., 1975, Mitchell et al., 1973b, Roe et al., 1999, and Messenger et al., 2005).

Lithology
Fossiliferous clay and sandy clay on ferruginous and quartzose sands. The clays have yielded abundant marine mollusca and foraminiferids.

Formal subdivisions and correlation table
No subdivisions.

Type area/Reference section
Type section: Vicarage Pit, St Erth, Cornwall [SW 5565 3523], based on north section of pit trenched in 1966 and reported by Mitchell et al. (1973b).

Lower and upper boundaries
Base of sands not seen but presumed to rest on Mylor Slate Formation (Late Devonian). Sections recorded by H Dewey (unpublished IGS records) in the north part of Vicarage Pit indicate shelly clay resting unconformably on bedrock.

Overlain by and in irregular contact with head.

Landform description and genetic interpretation
Marine deposits.

Thickness
Greater than 4 m.

Distribution and extent
Isolated outlier, 0.3 x 1.4 km, 1 km east of the village of St Erth, Cornwall.

Age
Late Pliocene.

13.1.1.2 Burtle Formation

In south-west England numerous post-Anglian shore platforms and raised beach deposits occur in the range up to 20 m above OD. Shell fauna associated with marine gravels from these beach deposits are undated or give ambiguous ages.

On the Lands End Peninsula, Cornwall, Campbell et al. (pp. 71–73 in Bowen, 1999) have assigned raised marine deposits to two formations, the Penlee Formation, correlated with MIS 9, and the Penwith Formation (correlated with MIS 7–2). In south Devon, Campbell et al. (p. 74 in Bowen, 1999) refer raised beach, aeolian and head deposits to the Torbay Formation (MIS 7–2). These formations are not currently described the BGS Lexicon.

In Somerset, sediments infill a former extensive drainage basin largely excavated prior to the Ipswichian (Edmonds, 1972; Gilbertson and Hawkins, 1978; Bowen, 1999) (Figure 29). Globally, sea levels were high in the Ipswichian; it has been estimated that sea level stood at between 5 and 10 m above OD in the inner Bristol Channel and Severn Estuary. Gilbertson and Hawkins (1978) suggest that a maximum wave height may have reached 10–21 m above OD. A number of shoreline features resulted including raised beaches associated with caves in the limestone rocks of the Welsh coast (Kidson, 1977; Gilbertson and Hawkins, 1977; Bowen et al., 1985; Sutcliffe et al., 1987). In Somerset about this time and within a complex of estuaries and creeks, shelly, cross-bedded sands and gravels were deposited. The remnants of these occur as isolated outcrops typically 7–15 m above OD, and were named after the nearest village as the Burtle Beds (Bullied and Jackson, 1937, 1941; Kidson et al., 1978). Here they are referred to the Burtle Formation (after Campbell et al., pp. 77–78 in Bowen, 1999). They may represent reworked glaciofluvial Kenn gravels (Gilbertson and Hawkins, 1977, 1978) of the Kenn Formation (Section 13.2.1.1). Shoals of shelly gravel and sand presumably equivalent to the Burtle Formation were also deposited inshore along the north coast of the outer Severn Estuary (Allen, 2000a, 2001a; Andrews et al., 1984). Allen (2000a) has associated these with coarse beach deposits at Goldcliff. No Ipswichian shoreline deposits have been recorded upstream of Chepstow and Aust (Allen, 2001b).

Name
Burtle Formation (BUB) (after Gilbertson and Hawkins, 1977, 1978, and Campbell et al., pp. 77–78 in Bowen, 1999).

Lithology
Sands and gravels. The sands are fine-grained and quartzose, with beds of comminuted shell. The gravels are composed of flint, quartz, sandstone, cherts, rounded lumps of red, green and grey Triassic mudstones and Liassic fossils. They contain fossilised marine, freshwater and terrestrial shells and remains of elephant, rhinoceros, horse, aurochs, red, fallow and roe deer, hyena and wolf. The marine shells indicate both cold and warm water conditions and sandy, muddy and rocky habitat, and the freshwater shell Corbicula fluminalis indicates a climate warmer than at present.

Formal subdivisions and correlation table
Subdivided into three informal members; the Kenn Church, Grey Lake and Middlezoy members (Campbell et al., pp. 77–78 in Bowen, 1999) (Tables 5 and 19).

Type area/Reference section
Type section: Greylake No. 2 Quarry [ST 385 336], about 1 km north-east of Middlezoy (Campbell et al., pp. 77–78 in Bowen, 1999).

Lower and upper boundaries
The formation rests upon Jurassic and Triassic bedrock. It commonly overlies or fringes 'reefs' or 'islands' of Lower Lias or Late Triassic rocks.

Ground surface or overlain by Holocene silts, clays and peats of the Somerset Levels Formation.

Landform description and genetic interpretation
Coastal and organic deposits. The gravels are marine in origin with a few interbedded palaeosols and freshwater sands. The deposits form low mounds protruding through the surface of the Holocene silts and clays of the Somerset Levels Formation.

Thickness
About 5 m.

Distribution and extent
Restricted to the 'Somerset Levels' of north-east Somerset. Shown on BGS 1:50 000 Sheets E279, 280, and 295.

Age
? Hoxnian to Ipswichian (MIS 11–5e).

Raised beach and solifluction deposits of Ipswichian to Devensian age occur on the Isles of Scilly (Campbell et al., p. 70 in Bowen, 1999). These deposits underlie Late Devensian till of the Scilly Till Member of the St Martin's Formation, Caledonia Glacigenic Group (Section 13.3).

The *Watermill Sand and Gravel Member* of Scourse (1991) (Watermill Member of the St Mary's Formation of Campbell et al., p. 70 in Bowen, 1999), comprises up to 1 m of clast-supported gravel (granite cobbles and boulders) overlain by structureless medium-grained sand. Sourse (1991) interpreted the deposits as a raised beach. It is correlated with the Ipswichian (MIS 5e). Its stratotype is Watermill Cove [SV 925 123] to [SV 924 123], St Mary's.

The most widespread Pleistocene deposit in the Isle of Scilly, the Porthloo Breccia Member of Scourse (1991) (Porthloo Member of the St Mary's Formation of Campbell et al., p. 70 in Bowen, 1999), comprises up to 5 m of angular granite clasts set in a matrix of granules, sand and silt. It is interpreted as a periglacial solifluction deposit (Scourse, 1987). Its stratotype is Porthloo [SV 908 115], St Mary's.

The most complete part of the Quaternary stratigraphical record in south-west England occurs within the lower part of the Severn Estuary and comprises mostly Holocene sediments (Figure 29). A number of named 'Levels' fringe the inner Bristol Channel and Severn Estuary, e.g. the Gwent Levels (Section 8.3.1.4) and the Somerset Levels; numerous authors have cited these as Holocene 'type-sites'. The depositional environments that these lithologies represent include both tidal flats with intertidal silts and freshwater supratidal peats.

At the onset of the Holocene, climatic amelioration and relative sea-level rise linked to global ice melt were the drivers of environmental change. Sea-level rise had two main effects:

- Firstly, the sea rapidly advanced eastwards into the Bristol Channel–Severn Estuary area, inundating the Late Glacial land surface (Hawkins, 1971; Austin, 1991), by then locally forested (Allen and Bell, 1991) and populated (Allen, 1998; Bell et al., 2000).
- Secondly, rising sea-level created a growing water body into which sediments emanating from the rivers could accumulate. In this way, the 'Levels' were created.

The depositional response to sea-level rise within the Inner Bristol Channel and Severn Estuary basin was determined by local factors described in detail by Allen (2000b). The general lithostratigraphical sequence consists of:

- a basal peat resting on the pre-Holocene basement and deposited prior to marine inundation
- silts and sands deposited the early Holocene phase of rapidly rising sea-level
- an interval of intercalated silts and peats approximately spanning 6000–2500 BP and reflecting the mid-Holocene slowing of sea-level rise rate
- a late-Holocene period of further deposition

The **Gwent Levels Formation** is established for deposits which accumulated along the north coast of the Severn Estuary (Section 8.3.1.4). Two formations, the **Somerset Levels Formation** and the **Oldbury and Avonmouth Levels Formation**, have been established for the Holocene estuarine deposits of Somerset and Gloucestershire.

13.1.1.3 Somerset Levels Formation

Name
Somerset Levels Formation (SLEV) (after Godwin, 1943, Kidson and Heyworth, 1976, Green and Welch, 1965, and Allen, 2000c).

Lithology
The deposits are dark blue-grey silty clays and silts with subordinate sands and beds of peat, submerged forests and gravel. River valleys cut into bedrock are infilled with gravels and sands, which become shelly upwards.

Formal subdivisions and correlation table
Informal members include the Nyland Hill Clay and Nyland Hill Peat (Haslett et al., 1998, Haslett and Davies, 2002), Tables 5 and 19.

Type area/Reference section
Type area: The Somerset Levels, from Clevedon to Langport, Somerset.

Lower and upper boundaries
The formation rests unconformably on Triassic and Jurassic bedrock. The deposits rest on a rockhead platform intricately dissected by river valleys formed when sea levels were lower.

Ground surface: the upper surface is approximately level at about 4.6–6.7 m above OD.

Landform description and genetic interpretation
The formation encompasses the marine, estuarine and terrestrial deposits that were formed in the Somerset Levels area during the Holocene transgression.

Thickness
Up to 35 m.

Distribution and extent
The Somerset Levels, from Clevedon to Langport, south-east of Bridgewater, Somerset.

Age
Holocene (MIS 1).

13.1.1.4 Oldbury and Avonmouth Levels Formation

Name
Oldbury and Avonmouth Levels Formation (OALEV) (after Welch and Trotter, 1961, and Allen, 2000c).

Lithology
The deposits are dark blue-grey silty clays and silts with subordinate sands and beds of peat, submerged forests and gravel. The deposits rest on a rockhead platform intricately dissected by river valleys, and their upper surface is approximately level at about 4.5–7 m OD. The river valleys are infilled with gravels and sands that become shelly upwards. Typically two beds of peat are included, up to 0.6 m thick; the lower of these forms the lowest unit in the formation except where it rests upon the valley-fill sands and gravels, and was formed about 8500–8000 years BP when a birch forest was inundated by the rising sea. The other formed about 5000–4500 years BP during a slowing down of the rising sea level, and is now found resting horizontally at OD.

Formal subdivisions and correlation table
No subdivisions (Tables 5 and 19).

Type area/Reference section
Type area: The Oldbury and Avonmouth Levels, from Berkeley, Gloucestershire, to Portishead, Somerset.

Lower and upper boundaries
The formation rests unconformably on Triassic bedrock.

Ground surface.

Landform description and genetic interpretation
The formation encompasses the marine, estuarine and terrestrial deposits that were formed in the Oldbury and Avonmouth Levels area during the Holocene transgression.

Thickness
About 10–13 m, increasing to about 21 m in buried channels.

Distribution and extent
The Oldbury and Avonmouth Levels, from Berkeley, Gloucestershire, to Portishead, Somerset.

Age
Holocene (MIS 1).

13.2 ALBION GLACIGENIC GROUP

13.2.1 Formations of the Albion Glacigenic Group

There are currently no subgroups assigned for deposits of the Albion Glacigenic Group lying to the south of the Devensian ice limit. Few unequivocal glacigenic sediments are known in the region, the exceptions being the isolated occurrences of tills and associated sand and gravels recorded at Kenn, Somerset (the Kennpier Till and Kenn Gravels of Gilbertson and Hawkins, 1978) and at Fremington, north Devon (Durrance and Laming, 1982) (Table 19). The deposits at Kenn, here referred to as the **Kenn Formation**, may relate to a pre-Anglian ice-sheet (possibly correlated with MIS 16 according to Campbell et al., p. 75 in Bowen, 1999) thought to have encroached across the region as far south as the northern coastline of Cornwall, Devon and Somerset (Figure 27).

Glacigenic deposits at Barnstable Bay and Lundy Island have been assigned to the Barnstable Bay Formation by Campbell et al. (pp. 74–75 in Bowen, 1999). This formation, which is not currently in the BGS Lexicon, includes the Fremington Member (Fremington Till or Fremington Clay of previous authors) and constituent beds that have been variously interpreted to have been deposited by ice of Irish Sea Basin origin during the Wolstonian Stage (Mitchell, 1960, 1972; Stephens, 1966, 1970, 1973) or in a glaciomarine environment during the Late Devensian (Eyles and McCabe, 1989).

13.2.1.1 Kenn Formation

Name
Kenn Formation (KNN) (after Campbell et al., p. 75 in Bowen, 1999; Kennpier Till and Kenn Gravels of Gilbertson and Hawkins, 1978; Kenn Gravels of Kellaway and Welch, 1993).

Lithology
The formation includes glacigenic deposits interpreted as till, outwash and glacio-marine sediments. Coarse outwash sands and gravels, poorly to well-sorted, are interbedded with reddish purple till. Both contain clasts of Carboniferous limestone, Upper Greensand chert, Jurassic limestone, and Cretaceous flint, up to cobble- and boulder-size, with small quantities of Devonian red quartzite, sandstones and conglomerates, Pennant sandstone and yellow Triassic sandrock.

Formal subdivisions and correlation table
Subdivided into five informal members (Campbell et al., p. 75 in Bowen, 1999). (Tables 7a and 19).

Type area/Reference section
Type area: Avon and north Somerset (Campbell et al., p. 75 in Bowen, 1999).

Lower and upper boundaries
Rests unconformably on Triassic bedrock.

Mostly at ground surface. At Kenn, overlain by estuarine deposits of possible Cromerian age (MIS 15) (Andrews et al., 1984; cf. Waverley Wood Beds, Warwickshire, Bowen et al., 1989; Shotton et al., 1993 — Section 11.1.2.1) and by Holocene silts and clays.

Landform description and genetic interpretation
Glacigenic deposits.

Thickness
Up to 14 m.

Distribution and extent
Restricted to Avon and north Somerset; occurrences at Kenn, Court Hill, Nightingale Valley, Failland Ridge, Bathampton Down and Bleadon Hill.

Age
? Cromerian (pre-MIS 13) or Anglian (MIS 12).

13.3 CALEDONIA GLACIGENIC GROUP

At the time of the Last Glacial Maximum, an ice-sheet lying to the north and west of the Bristol Channel and Severn Estuary extended the inner Bristol Channel and Severn Estuary drainage basin as far west as Carmarthen Bay (Figure 28).

In south-west England glacial deposits comprising tills and glaciofluvial sands and gravels with a clear Welsh provenance (Wales Glacigenic Subgroup, Caledonia Glacigenic Group) and lying on the northern margins of the Bristol Channel and Severn Estuary are attributed to this Devensian ice-sheet (Squirrell and Downing, 1969; Waters and Lawrence, 1987; Barclay, 1989; Harris and Donnelly, 1991).

Diamictons occur at various localities in the northern islands of the Scilly Isles. The Scilly Till of the St Martin's Formation (Bread and Cheese Formation of Scourse, 1991) is interpreted as till deposited by grounded ice (Scourse and Furze, 2001). An Irish Sea basin provenance is determined by the composition of the deposits. Dates from underlying beach deposits indicate that the till is of Late Devensian age although the northern Scillies may have been glaciated in pre-Devensian times (Mitchell and Orme, 1967).

Largely non-glaciated ground beyond the southern shore of the estuary lay outside the Devensian ice limit but was sufficiently close to the ice front to experience marked periglacial conditions. Granite tors considered to have formed beyond the limit of grounded ice occur in the southern Scillies (e.g. Peninnis Point, St Mary's, Scourse and Furze, 2001; Front Cover illustration). All around the Bristol Channel, ice-wedge casts and other periglacial structures are common features in exposed and intertidally exposed bedrock and superficial deposits (Allen, 1984, 1987b; Allen and Rippon, 1997), as are widespread deposits of head (Squirrell and Downing, 1969; Edmonds et al., 1979, 1985a; Gilbertson and Hawkins, 1983; Allen, 2000a). Locally, aeolian sediments of presumed Devensian age have been recorded (Greenly, 1922; ApSimon et al., 1961; Gilbertson and Hawkins, 1978). About this time, humans and a range of tundra-steppe animals intermittently occupied some of the caves in South Wales as well as in the Quantock and Mendip Hills (Sutcliffe et al., 1987; Aldhouse-Green, 1995; Aldhouse-Green and Pettitt, 1998).

13.4 BRITANNIA CATCHMENTS GROUP

13.4.1 Formations Of The Britannia Catchments Group

Non-glacigenic superficial sediments form a widespread cover over Devon and Cornwall. These deposits are largely undated. Included in the Britannia Catchments Group are the extensive spreads of mass movement deposits that comprise a continuum from landslide deposits through to mostly solifluction deposits (head) blanketing the bedrock interfluves and colluvium flanking the low valley sides and infilling low ground hollows. In Cornwall, Campbell et al. (pp. 72–74 in Bowen, 1999) describe two formations correlated with MIS 2, the Lizard Formation (formerly the Lizard Loess of Scourse, 1996), and the Camel Formation of the Camel Estuary. In north Devon between Morte Bay and Westward Ho! Head, raised beach and aeolian deposits are included within members of the Croyde Bay Formation correlated with MIS 7–2 (Campbell et al., p. 75 in Bowen, 1999). These formations are not currently defined in the BGS Lexicon.

Cave deposits occur in the Torquay (Devonian) limestone of south Devon and contain mammal faunas and Palaeolithic implements similar in age to the Mendip cave deposits. The principal deposit is at Kent's Cavern where there are several metres of breccias and sands.

Even where dates are available, it is judged here that none of these locally mappable units may be sufficiently reliably correlated to warrant formational status. Nomenclature is provisional and is based on units that form potentially mappable subdivisions.

Fluvial (river terrace and alluvial) deposits and associated lacustrine and organic deposits of Devon and Cornwall are assigned to the **Cornubian Catchments Subgroup**.

13.4.2 Cornubian Catchments Subgroup

Name
Cornubian Catchments Subgroup (CCAT) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
Floodplain alluvium comprising soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits largely composed of sand and gravel. The gravels include a wide range of Palaeozoic and Mesozoic rocks, reflecting the rock types cropping out in the various catchments. Peat is a minor component, and minor marine deposits are included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Subdivided into the Petrockstow Valley, Tamar Valley, Taw Valley, and Torridge Valley formations, and the informal Axe Valley Formation (Tables 6 and 19).

Type area/Reference section
Type area: The area covered by the catchments of the rivers of Devon and Cornwall from the River Axe westwards [ST 40–ST 32].

Lower and upper boundaries
Unconformable on bedrock of Devonian to Cretaceous age.

Ground surface.

Landform description and genetic interpretation
Fluvial (river terrace and alluvium), lacustrine and organic deposits.

Thickness
Up to 22.5 m recorded in the buried valley of the Seventh terrace of the Taw Valley Formation.

Distribution and extent
The catchments of the rivers of Devon and Cornwall from the River Axe westwards.

Age
? Cromerian to Holocene (MIS ?pre-13–1).

Traditionally BGS maps have shown river terrace aggradations numbered by increasing elevation from youngest to oldest. The BGS Quaternary lithostratigraphical framework currently formalises four formations and their terrace deposit members. These units are:

13.4.2.1 Petrockstow Valley Formation

Name
Petrockstow Valley Formation (PETRO) (after Freshney et al., 1979a).

Lithology
The formation includes the deposits of five river terraces. The deposits of the first terrace are largely gravel of Carboniferous sandstone with scattered flints, with thin seams of clayey sand and sandy clay, 1.5–7 m thick. The pebbles are up to 20 mm in diameter, increasing to 130 mm at the base. Deposits of the higher terraces are less gravelly, and dominantly comprise clay with gravel seams.

Formal subdivisions and correlation table
Subdivided into floodplain alluvium and deposits of five river terraces (PET1–PET5) (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the Petrockstow Basin [SS 485 138–SS 540 084] (Freshney et al., 1979a).

Lower and upper boundaries
Rests unconformably on Palaeogene and Late Carboniferous bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace deposits and alluvium.

Thickness
Up to about 8 m.

Distribution and extent
The Petrockstow Basin, Devon (BGS 1:50 000 Sheets 307 and 308 (part), and 309).

Age
?Cromerian to Holocene (MIS ?pre13–1).

13.4.2.2 Tamar Valley Formation

Name
Tamar Valley Formation (TAVA) (after McKeown et al., 1973, and Freshney et al., 1979a).

Lithology
The formation encompasses the fluvial, lacustrine and organic deposits of the River Tamar and its tributaries. It includes floodplain alluvium and the deposits of eight terraces. The floodplain alluvium comprises soft poorly-sorted clays, silts and fine-grained sands, with bodies of peat, overlying sands and gravels. The terrace deposits dominantly comprise silty and sandy pebbly clays but include sands and gravels, and silts. The clays are largely derived from Upper Carboniferous and Devonian mudstone bedrock. Gravels are dominantly formed of rounded pebbles up to 50 mm diameter of Upper Carboniferous sandstone but also include vein quartz and Lower Carboniferous and Devonian limestone and chert. Tin ore (cassiterite) occurs in the deposits near the Bodmin Granite.

Formal subdivisions and correlation table
Subdivided into floodplain alluvium and deposits of eight river terraces (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the River Tamar from near Holsworthy to near Plymouth, Devon [SS 28 07–SX 43 67] (McKeown et al., 1973).

Lower and upper boundaries
Unconformable on bedrock of Carboniferous and Devonian age, and on intrusive igneous rocks.

Ground surface.

Landform description and genetic interpretation
River terrace deposits and alluvium.

Thickness
Up to about 10 m.

Distribution and extent
The entire catchment of the River Tamar and its tributaries, including the rivers Ottery and Thrushel, from near Holsworthy to the sea near Plymouth, Devon (BGS 1:50 000 Sheets E307 and 308 (part), 322, 323, and 337).

Age
Anglian to Holocene (MIS 12–1).

13.4.2.3 Taw Valley Formation

Name
Taw Valley Formation (TAW) (after Freshney et al., 1979a, and Edmonds et al., 1968, 1985b).

Lithology
The formation encompasses the fluvial, lacustrine and organic deposits of the River Taw and its tributaries. It includes floodplain alluvium and the deposits of ten terraces. The floodplain alluvium comprises soft poorly-sorted clays, silts and fine-grained sands, with bodies of peat, overlying sands and gravels. The terrace deposits dominantly comprise silty and sandy pebbly clays but include sands and gravels and silts. The clays are largely derived from Upper Carboniferous mudstone bedrock. Gravels are dominantly formed of rounded pebbles up to 50 mm diameter of Upper Carboniferous sandstone but also include vein quartz and Lower Carboniferous limestone and chert. Boulders of Dartmoor Granite and quartz-feldspar-tourmaline rock are common in the upper reaches. All the terraces contain alluvial tin ore (cassiterite).

Formal subdivisions and correlation table
Subdivided into floodplain alluvium and deposits of eleven river terraces (TAW1–TAW11) (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the River Taw from Dartmoor to Barnstaple, Devon [SX 65 93–SS 56 33] (Freshney et al., 1979a).

Lower and upper boundaries
Unconformable upon bedrock of Late and Early Carboniferous and Permian age and upon the Dartmoor Granite.

Ground surface.

Landform description and genetic interpretation
River terrace deposits and alluvium.

Thickness
Up to 22.5 m recorded in the buried valley of the Seventh Terrace.

Distribution and extent
The entire catchment of the River Taw and its tributaries, including the rivers Mole and Bray, from Dartmoor and Exmoor to Barnstaple, Devon (BGS 1:50 000 Sheets E293, 309, and 324).

Age
Anglian to Holocene (MIS 12–1).

13.4.2.4 Torridge Valley Formation

Name
Torridge Valley Formation (TORR) (after McKeown, et al., 1973, Freshney et al., 1979a, b, and Edmonds et al., 1968).

Lithology
The formation encompasses the fluvial, lacustrine and organic deposits of the River Torridge and its tributaries. It includes floodplain alluvium and the deposits of eight river terraces. The floodplain alluvium comprises soft poorly-sorted clays, silts and fine-grained sands, with bodies of peat, overlying sands and subrounded gravels. The terrace deposits dominantly comprise silty and sandy pebbly clays but include sands and gravels and silts. The clays are largely derived from Upper Carboniferous mudstone bedrock. Gravels are dominantly formed of rounded pebbles up to 50mm in diameter of Upper Carboniferous sandstone but also include vein quartz and Lower Carboniferous limestone and chert. Boulders of Dartmoor Granite and quartz-feldspar-tourmaline rock are common in the upper reaches of the River Okement and its tributaries. The terraces contain alluvial tin ore (cassiterite).

Formal subdivisions and correlation table
Subdivided into floodplain alluvium and deposits of nine river terraces (TOR1–TOR9) (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the rivers Torridge and Okement from Dartmoor to Bideford, Devon [SX 58 87–SS 44 28] (Freshney et al., 1979b).

Lower and upper boundaries
Unconformable upon bedrock of Early and Late Carboniferous and Permian age and upon the Dartmoor Granite.

Ground surface.

Landform description and genetic interpretation
River terrace deposits and alluvium.

Thickness
Up to 10 m.

Distribution and extent
The entire catchment of the River Torridge and its tributaries, including the rivers Okement and Waldon, between Dartmoor and Bideford, Devon (BGS 1:50 000 Sheets E292, 307 and 308 (part), 309, 323, and 324).

Age
Anglian to Holocene (MIS 12–1).

Campbell (p. 71 in Bowen, 1999) defines five named members of terrace gravels of pre-Devensian age belonging to the **Axe Valley Formation**. The formation, together with terrace deposits of the **Exe Valley Formation**, has yet to be formally defined in the BGS Lexicon. The latter valley contains a flight of eight river terraces, as shown on BGS 1:50 000 Sheet E325.

13.4.3 Somerset Catchments Subgroup

The Somerset Catchment Subgroup encompasses all the fluvial, lacustrine and organic deposits of the rivers whose catchments fall between the Mendip, Quantock and Blackdown hills.

Name
Somerset Catchments Subgroup (SOCA) (after McMillan, 2005, and McMillan et al., 2005).

Lithology
The deposits comprise gravels, sands, silts, clays and peats. Floodplain alluvium comprises soft silts and clays, commonly with beds of peat and a basal bed of sand and gravel. River terrace deposits are largely sands and gravels. The gravels are composed of locally-derived rocks, variously Devonian sandstones, Carboniferous sandstones and limestones, Triassic sandstones, Jurassic limestones and Cretaceous chert and flint. Minor marine deposits may be included where they are intercalated in dominantly fluvial formations.

Formal subdivisions and correlation table
Parrett Valley Formation (Tables 6 and 19).

Type area/Reference section
Type area: Valley of the River Parrett and its tributaries between Martock and Westonzoyland [ST 44 20–ST 36 36].

Lower and upper boundaries
Formations of the Somerset Catchments Subgroup rest unconformably on bedrock varying in age from Devonian to Cretaceous.

Surface, or locally overlain by clays, silts and peats of the Somerset Levels Formation.

Landform description and genetic interpretation
River terrace and alluvium and organic deposits.

Thickness
About 10 m.

Distribution and extent
Somerset, constrained by the watersheds formed the Quantock Hills to the west, the Mendip Hills to the north and the Blackdown Hills to the south.

Age
Anglian to Holocene (MIS 12–1).

Traditionally BGS maps have shown river terrace aggradations numbered by increasing elevation from youngest to oldest. The BGS Quaternary lithostratigraphical framework identifies potentially at least one formation and its terrace deposit members yet to be formally defined in the BGS Lexicon:

13.4.3.1 PARRETT VALLEY FORMATION

Ten named units (fluvial gravels, sands, silts and organic deposits) are described by Campbell et al. (p. 78 in Bowen, 1999) (Sheet 295, Taunton, BGS, 1984).

13.4.4 Severn and Avon Catchments Subgroup

Terrace deposits of the Bristol Avon valley relate to the westerly drainage through an extended inner Bristol channel during the Devensian and then in Holocene time. A range of deposits formed during the Devensian glacial maxima; they include various fan gravels and cave deposits of the Mendips, and the important terraces in the valley of the Bristol Avon. The latter are included as members of the **Bristol Avon Valley Formation**.

13.4.4.1 BRISTOL AVON VALLEY FORMATION

Name
Bristol Avon Valley Formation (BAVON) (after Kellaway and Welch, 1993; Avon Formation of Campbell et al., p. 77 in Bowen, 1999).

Lithology
The floodplain alluvium comprises soft clays, silts and fine sands, with bodies of peat, all overlying sands and gravels. The terrace deposits include gravels, sands, silts and clays; the gravel clasts are dominantly local Jurassic limestones, Triassic sandstones and Carboniferous limestone, but also include some glacially-derived erratics from north-west England and the Welsh Borders.

Formal subdivisions and correlation table
Subdivided into floodplain alluvium and deposits of three river terraces: Ham Green Gravel, Stidham Gravel and Bathampton Gravel members (Tables 6 and 19).

Type area/Reference section
Type area: The valley of the Bristol Avon river from Bathampton to the mouth of the Avon [ST 78 66–ST 50 79] (Campbell, pp. 76–77 in Bowen, 1999).

Lower and upper boundaries
Rests unconformably on Jurassic, Triassic and Carboniferous bedrock.

Ground surface.

Landform description and genetic interpretation
River terrace and alluvium, lacustrine and organic deposits.

Thickness
Up to 10 m.

Distribution and extent
Catchment of the Bristol Avon river and its tributaries, from Malmesbury and Frome to the mouth of the river.

Age
Anglian to Holocene (MIS 12–1).

The important gravel terraces in the valley of the Bristol Avon, as identified by Woodward (1886) and Davies and Fry (1929) include:

HAM GREEN GRAVEL MEMBER

The Ham Green Gravel Member comprises gravels, 3–4 m thick, with a surface lying about 30 m above the present River Avon. A basal lag with the remains of large mammals was reported at Victoria Pit, Twerton by Winwood (1889) and Davies and Fry (1929). The age is unclear, possibly being correlatable with MIS 12 according to Table 18 in Bowen (1999).

STIDHAM GRAVEL MEMBER

The Stidham Gravel Member comprises gravels, 2 m thick, with a surface lying about 12 m above the present River Avon. The remains of 'mammoth' were reported by Winwood (1889) and Davies and Fry (1929). The gravels are correlated with MIS 8 (Campbell, p. 77 in Bowen, 1999).

BATHAMPTON GRAVEL MEMBER

The Bathampton Gravel Member comprises gravels, 3 m thick, with a surface of about 3–5 m above the present River Avon. It is considered to be no younger than MIS 6 (Campbell, p. 77 in Bowen, 1999).

The *Bathampton Palaeosol* is a cryoturbated, rubified clay-rich soil developed on the Bathampton Gravel Member. It is correlated probably with MIS 5e (Hunt, 1990; Campbell, p. 77 in Bowen, 1999).

BGS 1:50 000 Sheet E234 (Gloucester) shows river terrace sand and gravel deposits (FR2–FR4) of the River Frome, Gloucestershire. These informal units are currently assigned to the Severn and Avon Catchments Subgroup.

Appendix 1 Geochronological methods

Geochronology is the science of dating and determining the time sequence of events (Salvador, 1994). In recent years a wide range of geochronological techniques have been applied to British Quaternary deposits. These have shown additional events not deduced from the pollen biozone record. For brief descriptions of these methods reference should be made to Foster et al. (1999). Methods include:

- *Radiocarbon dating*. This is the principal method for determining the age of organic materials from the present to about 60 000 years ago. A non-linear relationship exists between conventional radiocarbon years before present (taken as 1950) and Calendar (sidereal) years (Stuiver and Reimer, 1993). Dates quoted in this report in the style '12.5 ka BP' or '^{14}C 11 170 to 10 740 cal. years BP' are calibrated radiocarbon years before present.
- *Amino acid dating.* This involves the analysis of proteins locked-up in the marine and non-marine bivalves and gastropods and tests of foraminiferids (Wehmiller and Miller, 2000). Upon death of these organisms, several time-dependent chemical reactions occur that provide a means of relative dating. Of these, racemisation is the most useful, involving the transformation of L-isomers of individual amino acids into D-isomers. A relative timescale may be constructed using the ratios of D-alloisoleucine to L-isoleucene (Bowen, 1999, 2001).
- *Thermoluminescence* (TL) *and optically stimulated luminescence* (OSL) dating techniques, which are based on the principle that naturally occurring minerals such as quartz and feldspar can act as dose meters, recording the amount of nuclear radiation to which they have been exposed (Miller, 1990). Although not referred to further in this report, the methods offer potential for dating loess and wind blown sand. They have proved less reliable for glaciofluvial and glaciolacustrine deposits.
- *Uranium series* 234U/230Th disequilibrium techniques on speleothems and wood, applicable up to 400 ka.
- *Electron spin resonance* (ESR) dating on fossil tooth enamel, applicable up to 600 ka.
- *Terrestrial Cosmogenic Nuclide* dating (TCN) techniques are also used for Quaternary sediments. The technique is applied in two types of study, the first and simplest is exposure age determination, and the second is landscape evolution. TCN dating seeks to determine precisely (to the precision of e x 10^{-14} or better) the number of atoms of a series of rare isotopes occurring in rocks at the Earths surface. These isotopes are produced when cosmic rays collide with atoms in certain minerals, particularly quartz, olivine and pyroxene. The mechanisms of production are complex, and it is important to note that these rare isotopes are also produced in the atmosphere, and may act as contaminants of samples.
- *Lichenometry*, which uses growth rates of lichens determined by their presence on surfaces of known age. Size measurements of other lichens may then be used to provide dates for their substrates. The method is applicable to the last few hundred years.

Appendix 2 Lithostratigraphical terms

Abbreviations

LLS	Loch Lomond Stadial
WIS	Windermere Interstadial
DS	Dimlington Stadial
MIS	Marine Isotope Stage

Supergroup

LEXICON CODE	UNIT	Parent name	Definition
GBG	Great Britain Superficial Deposits Supergroup*	None	Chapter 3, Lithostratigraphical Framework

* the supergroup includes a few residual deposits of Palaeogene age.

Groups

LEXICON CODE	UNIT	Parent name	Definition
ALBI	Albion Glacigenic Group	Great Britain Superficial Deposits Supergroup	Chapter 3, Lithostratigraphical Framework
BCAT	Britannia Catchments Group		
COAS	British Coastal Deposits Group		
CALI	Caledonia Glacigenic Group		
CRAG	Crag Group		
DUNW	Dunwich Group		
RESID	Residual Deposits Group		

Subgroups

LEXICON CODE	UNIT	Parent name	District
BCAG	Banffshire Coast and Caithness (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
BCD	Banffshire Coast and Caithness Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
BDRGL	Borders Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 6, Southern Scotland and the Solway
BYCA	Bytham Catchments Subgroup	Dunwich Group	Chapter 10, East Anglia and the ancestral River Thames
Section 3.2.3.1			
CCAG	Central Cumbria (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
CCGL	Central Cumbria Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
CGAG	Central Grampian (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland

Subgroups

LEXICON CODE	UNIT	Parent Name	District
BCAG	Banffshire Coast and Caithness (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
BCD	Banffshire Coast and Caithness Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
BDRGL	Borders Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 6, Southern Scotland and the Solway
BYCA	Bytham Catchments Subgroup	Dunwich Group	Chapter 10, East Anglia and the ancestral River Thames
Section 3.2.3.1			
CCAG	Central Cumbria (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
CCGL	Central Cumbria Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
CGAG	Central Grampian (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
CGDR	Central Grampian Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
CNWCA	Cheshire– North Wales Catchments Subgroup	Britannia Catchments Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
CHVG	Cheviot Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 6, Southern Scotland and the Solway
CLYCA	Clyde Catchments Subgroup	Britannia Catchments Group	Chapter 5, Midland Valley of Scotland
CCAT	Cornubian Catchments Subgroup	Britannia Catchments Group	Chapter 13, South-west England
CLCA	Cumbria–Lancashire Catchments Subgroup	Britannia Catchments Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
EGAG	East Grampian (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
EGD	East Grampian Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
FORCA	Forth Catchments Subgroup	Britannia Catchments Group	Chapter 5, Midland Valley of Scotland
GRCA	Grampian Catchments Subgroup	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland
IAG	Inverness (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
INVG	Inverness Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
ISCAG	Irish Sea Coast (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
ISCG	Irish Sea Coast Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 6, Southern Scotland and the Solway Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
IMCA	Isle of Man Catchments Subgroup	Britannia Catchments Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

KGCA	Kesgrave Catchment Subgroup	Dunwich Group	Chapter 10, East Anglia and the ancestral River Thames Section 3.2.3.1
LBAG	Logie–Buchan (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
LBD	Logie–Buchan Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
MXGL	Manx Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
MDR	Mearns Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 5, Midland Valley of Scotland
MVG	Midland Valley Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 5, Midland Valley of Scotland
NHC	Northern Highlands and Argyll Catchments Subgroup	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland
NPEG	North Pennine Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
NSCA	North Sea Coast (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
NSG	North Sea Coast Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
NCAT	Northumbria Catchments Subgroup	Britannia Catchments Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
NWHG	Northwest Highlands Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
ONCA	Ouse–Nene Catchments Subgroup	Britannia Catchments Group	Chapter 10, East Anglia and the ancestral River Thames
SACA	Severn and Avon Catchments Subgroup	Britannia Catchments Group	Chapter 12, West Midlands, Upper Thames and Severn valleys
SDAG	Shetland (Albion) Glacigenic Subgroup	Albion Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
SHETG	Shetland Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
SNTCA	Solent Catchments Subgroup	Britannia Catchments Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
SYDR	Solway Catchments Subgroup	Britannia Catchments Group	Chapter 6, Southern Scotland and the Solway
SOCA	Somerset Catchments Subgroup	Britannia Catchments Group	Chapter 13, South-west England
SKCAT	South Kent Catchments Subgroup	Britannia Catchments Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
SUDR	Southern Uplands Glacigenic Subgroup	Caledonia Glacigenic Group	Chapter 6, Southern Scotland and the Solway
SUCA	Suffolk Catchments Subgroup	Britannia Catchments Group	Chapter 10, East Anglia and the ancestral River Thames
SXCAT	Sussex Catchments Subgroup	Britannia Catchments Group	Chapter 12, Southern England and the Middle–Lower Thames catchments

FORMATIONS

LEXICON CODE	UNIT	Parent name	District
No code, informal	Achnacree Sand and Gravel Formation	Central Grampian Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
ANTI	Acklinton Till Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Adur Formation	Sussex Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
AFTL	Afton Lodge Clay Formation	British Coastal Deposits Group	Chapter 5, Midland Valley of Scotland
AIK	Aikbank Farm Glacigenic Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
AILL	Ailleag Diamicton Formation	Central Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
ALNE	Alne Glaciolacustrine Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Altonside Till Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
ALGR	Alturlie Gravels Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
ARDS	Ardersier Silts Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Ardullie Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
ARDT	Ardverikie Till Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
AHSG	Armsheugh Sand and Gravel Formation	Midland Valley Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
ARUN	Arun Formation	Sussex Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
ASGR, informal	Ashbourne Gravel	Britannia Catchments Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
ADSG, informal	Ashford Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
ASGL	Assynt Glacigenic Formation	Northwest Highlands Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
ATTI	Athais Till Formation	Inverness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
ALSSG	Auchleuchries Sand and Gravel Formation	Logie–Buchan Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Axe Valley Formation	Cornubian Catchments Subgroup	Chapter 13, South-west England
AYRE	Ayre Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
AYRL	Ayre Lighthouse Formation	Irish Sea Coast (Albion) Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

BGSG	Baginton Sand and Gravel Formation	Bytham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BNTI	Baillieston Till Formation	Midland Valley Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
BAINV	Bain Valley Formation	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Bakewell Formation	Albion Glacigenic Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Balby Formation	Albion Glacigenic Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BALGH	Ballaugh Formation	Isle of Man Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Balmeanach Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
No code, informal	Bamburgh Formation	Britannia Catchments Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BATI	Banchory Till Formation	East Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BFSG, informal	Bank Farm Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Barnyards Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
BWSG	Baronwood Sand and Gravel Formation	Central Cumbria Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Beauly Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
BUTI	Beinn an Uain Till Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BLTI	Bellscamphie Till Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BECL	Benholm Clay Formation	Logie–Buchan (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Bingley Bog Formation	Britannia Catchments Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BEGR	Birnie Gravel Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BHTI	Blackhall Till Formation	North Sea Coast Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BLSG	Blackhills Sand and Gravel Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BDMO	Blairdaff Moraine Formation	East Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BLYV	Blakeney Valleys Formation	British Coastal Deposits Group	Chapter 10, East Anglia and the ancestral River Thames
BLAW	Blane Water Silt Formation	Central Grampian Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland

BHPT	Blelham Peat Formation	Britannia Catchments Group	Chapter 6, Southern Scotland and the Solway Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
BLGL	Blengdale Glacigenic Formation	Central Cumbria Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
BCTI	Boyne Craig Till Formation	Central Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BTON	Brassington Formation	Great Britain Superficial Deposits Supergroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BNOCK	Brecknockshire Glacigenic Formation	Wales Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
BREI	Breighton Sand Formation	Yorkshire Catchments Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BDTI	Brewood Till Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
BRYD	Breydon Formation	British Coastal Deposits Group	Chapter 10, East Anglia and the ancestral River Thames
BAVON	Bristol Avon Valley Formation	Severn and Avon Catchments Subgroup	Chapter 13, South-west England
BRLA	Briton's Lane Formation	Albion Glacigenic Group	Chapter 10, East Anglia and the ancestral River Thames
BMSG, informal	Bromfield Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
BRLL	Broomhill Clay Formation	Midland Valley Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
BHSE	Broomhouse Sand and Gravel Formation	Midland Valley Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
BUG	Buchan Gravels Formation	Residual Deposits Group	Chapter 4, Highlands and Islands of Scotland
BURV	Bure Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
BWTI	Burrier Wick Till Formation	Shetland Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BUB	Burtle Formation	British Coastal Deposits Group	Chapter 13, South-west England
BYTIL	Byth Till Formation	East Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
BYTH	Bytham Sand and Gravel Formation	Bytham Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
CADR	Cadder Sand and Gravel Formation	Midland Valley Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
CCGR	Caesar's Camp Gravel Formation	Dunwich Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
CAMV	Cam Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
CFTI	Camp Fauld Till Formation	Banffshire Coast and Caithness (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
CBAY	Cardigan Bay Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

CNSI	Carleton Silt Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
CMOGR	Carn Monadh Gravel Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
CARCL	Carse Clay Formation	British Coastal Deposits Group	Chapter 5, Midland Valley of Scotland Chapter 6, Southern Scotland and the Solway
CASS	Cassie Till Formation	Inverness (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
CEDN	Castle Eden Fissure-fill Formation	Great Britain Superficial Deposits Supergroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
CEAR	Ceardaich Sand and Gravel Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
CHAK	Chapelknowe Till Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
CHFDS	Chelford Sand Formation	Britannia Catchments Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
CHGR	Chelsfield Gravel Formation	Residual Deposits Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
CHSG, informal	Cheltenham Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
CLSH	Clava Shelly Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
CWF	Clay-with-flints Formation	Residual Deposits Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
CLPT	Clippens Peat Formation	Britannia Catchments Group	Chapter 5, Midland Valley of Scotland
CWYDV	Clwyd Valley Formation	Cheshire–North Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
CLYD	Clyde Clay Formation	British Coastal Deposits Group	Chapter 5, Midland Valley of Scotland
CLVY	Clyde Valley Formation	Clyde Catchments Subgroup	Chapter 5, Midland Valley of Scotland
CBCL	Clydebank Clay Formation	British Coastal Deposits Group	Chapter 5, Midland Valley of Scotland
CCHR	Colchester Formation	Kesgrave Catchment Subgroup	Chapter 10, East Anglia and the ancestral River Thames
CONWY	Conwy Valley Formation	Cheshire–North Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
CQU	Coquet Valley Formation	Northumbria Catchments Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
CCG	Coralline Crag Formation	Crag Group	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Cradley Valley Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
CDGR	Craig an Daimh Gravel Formation	Inverness (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland

CRF	Cromer Forest-bed Formation	Dunwich Group	Chapter 10, East Anglia and the ancestral River Thames
CBTIL	Crossbrae Till Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Cuckmere Formation	Sussex Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Culbokie Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
CUS	Cullivait Silts Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
CEVY	Cumbrian Esk Valley Formation	Cumbria–Lancashire Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
CAGH	Curragh Formation	Isle of Man Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DNPS	Dalcharn Palaeosol Formation	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland
DSMO	Dalswinton Moraine Formation	Southern Uplands Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
DHKG	Deanshillock Gravel Formation	Central Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
DEEVA	Dee Valley Formation	Cheshire–North Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
DOST	Dorset Stour Formation	Solent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Dove Hole Formation	Britannia Catchments Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
DOVEY	Dovey Valley Formation	West Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
DGPS	Drigg Point Sand Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DGTI	Drigg Till Formation	Irish Sea Coast (Albion) Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DRBG	Drumbeg Sand and Gravel Formation	Central Grampian Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
DSG	Drumlithie Sand and Gravel Formation	Mearns Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
DRGR	Drummore Gravel Formation	Inverness (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
DUTI	Dunbeath Till Formation	Northwest Highlands Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
EASN	Easington Raised Beach Formation	British Coastal Deposits Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
EBSG	Ebchester Sand and Gravel Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
EHEN	Ehen Alluvium Formation	Cumbria–Lancashire Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

ELV	Elvington Glaciolacustrine Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
ERRCL	Errol Clay Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland Chapter 5, Midland Valley of Scotland
ERYG	Eryri Glacigenic Formation	Wales Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
ESTI	Essie Till Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Exe Valley Formation	Cornubian Catchments Subgroup	Chapter 13, South-west England
FEND	Fenland Formation	British Coastal Deposits Group	Chapter 10, East Anglia and the ancestral River Thames
FINT	Finglack Till Formation	Inverness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
FLMP	Flanders Moss Peat Formation	Britannia Catchments Group	Chapter 5, Midland Valley of Scotland
FOCL	Forth Clay Formation	British Coastal Deposits Group	Chapter 5, Midland Valley of Scotland
FOVA	Forth Valley Formation	Forth Catchments Subgroup	Chapter 5, Midland Valley of Scotland
No code, informal	Foulis Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
FASG	Four Ashes Sand and Gravel Formation	Britannia Catchments Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
FRPI	Frome–Piddle Formation	Solent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
GPM	Gaick Plateau Moraine Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
GATI	Gartocharn Till Formation	Central Grampian Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
GCBTI	Gillcambon Till Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GLGL	Glamorgan Glacigenic Formation	Wales Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
GVA	Glannoventia Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GLNBA	Glen Balleira Formation	Isle of Man Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GDSI	Glen Dye Silts Formation	East Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
GLVA	Glynch Valley Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
GOGL	Gosforth Glacigenic Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GRHS	Grange Hill Sand Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland

GROS	Grange-over-Sands Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GECL	Great Easby Clay Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GRET	Gretna Till Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
GYTI	Greystoke Till Formation	Central Cumbria Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GLEV	Gwent Levels Formation	British Coastal Deposits Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
HALC	Hall Carleton Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
HBLE	Hamble Formation	Solent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
HAAV	Hampshire Avon Formation	Solent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
HPGL	Happisburgh Glacigenic Formation	Albion Glacigenic Group	Chapter 10, East Anglia and the ancestral River Thames
No code	Harrogate Till Formation	Albion Glacigenic Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
HATT	Hatton Till Formation	Logie–Buchan Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
HEM	Hemingbrough Glaciolacustrine Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
HOLD	Holderness Formation	North Sea Coast Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines Chapter 10, East Anglia and the ancestral River Thames
HNTI	Horden Till Formation	North Sea Coast Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
HOBGR	Howe of Byth Gravel Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Humber Sand and Gravel Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
HYTIL	Hythie Till Formation	East Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
ISAG	Ingham Sand and Gravel Formation	Bytham Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
ITCH	Itchen Formation	Solent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
JURBY	Jurby Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
KWTI	Kale Water Till Formation	Cheviot Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway

KNFIG	Kenfig Formation	British Coastal Deposits Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
KNN	Kenn Formation	Albion Glacigenic Group	Chapter 13, South-west England
KNTV	Kennet Valley Formation	Thames Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Kent Ouse Formation	South Kent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Kentish Rother Formation	South Kent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Kentish Stour Formation	South Kent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
KEMO	Kerr Moraine Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
KEBR	Kessock Bridge Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
KBSG	Kilblane Sand and Gravel Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
KSI	Kincurdy Silts Formation	Inverness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
KDRD	Kiondroughad Formation	Irish Sea Coast (Albion) Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
KHG	Kippet Hills Gravels Formation	Logie–Buchan Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
KBSI	Kirk Burn Silt Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
KN	Kirkbean Sand and Gravel Formation	Southern Uplands Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
LHTI	Langholm Till Formation	Southern Uplands Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
LKVY	Lark Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Lemlair Sand Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
LNM	Lenham Formation	Residual Deposits Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
LTH	Letchworth Gravels Formation	Dunwich Group	Chapter 10, East Anglia and the ancestral River Thames
LEWTI	Lewis Till Formation	Western Isles Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
LEY	Leys Gravel Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
LEYST	Leys Till Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
LGGR	Limekiln Gill Gravel Formation	North Sea Coast Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
LPSI	Linn of Pattack Silt Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
LHSG, informal	Little Hereford Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys

LSTI	Littlestone Till Formation	Midland Valley Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
LITI	Llanddewi Glacigenic Formation	Albion Glacigenic Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
LOBSG	Lobbs Sand and Gravel Formation	Central Cumbria Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
LBTI	Loch Broom Till Formation	Northwest Highlands Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
LOSG	Lochton Sand and Gravel Formation	East Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
LNGR	Longman Gravel Formation	Northern Highlands and Argyll Catchments Subgroup	Chapter 4, Highlands and Islands of Scotland
LOFT	Lowestoft Formation	Albion Glacigenic Group	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Lugg Valley Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
LUNV	Lune Valley Formation	Cumbria–Lancashire Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
LTHM	Lytham Formation	British Coastal Deposits Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
MHSG	Maiden's Hall Sand and Gravel Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
MNHD	Maidenhead Formation	Thames Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
MASG, informal	Mathon Sand and Gravel Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
MSYT	Maudsyke Till Formation	Central Cumbria Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
MEVA	Medway Valley Formation	Thames Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
MEON	Meon Formation	Solent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
MSYVA	Mersey Valley Formation	Cheshire–North Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
MFT	Mill of Forest Till Formation	Mearns Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
MLTS	Milton Formation	Dunwich Group	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Moniack Peat Formation	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland
MOBAY	Morecambe Bay Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
MORS	Morston Formation	British Coastal Deposits Group	Chapter 10, East Anglia and the ancestral River Thames
MOHI	Mouldy Hills Gravel Formation	Southern Uplands Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
MBP	Moy Burn Palaeosol Formation	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland

NACL	Nar Clay Formation	British Coastal Deposits Group	Chapter 10, East Anglia and the ancestral River Thames
NARC	Nar Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
NEATH	Neath Valley Formation	West Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
NENE	Nene Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
NBED	Nettlebed Formation	Dunwich Group	Chapter 10, East Anglia and the ancestral River Thames
NMTI	Norham Till Formation	Borders Glacigenic Subgroup	Chapter 6, Southern Scotland and Northern Cumbria
NRD	North Denes Formation	British Coastal Deposits Group	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Northton Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
NCG	Norwich Crag Formation	Crag Group	Chapter 10, East Anglia and the ancestral River Thames
NURS	Nurseries Glacigenic Formation	Albion Glacigenic Group	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
OKWDG	Oakwood Glacigenic Formation	Irish Sea Coast (Albion) Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
OHT	Old Hythe Till Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
OALEV	Oldbury and Avonmouth Levels Formation	British Coastal Deposits Group	Chapter 13, South-west England
ORRIS	Orrisdale Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
OUSE	Ouse Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Parrett Valley Formation	Somerset Catchments Subgroup	Chapter 13, South-west England
PATT	Pattack Till Formation	Central Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Pegwell Formation	South Kent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
POTI	Penfro Till Formation	Albion Glacigenic Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
PESG	Peterlee Sand and Gravel Formation	North Sea Coast Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
PETRO	Petrockstow Valley Formation	Cornubian Catchments Subgroup	Chapter 13, South-west England
PIBG	Pishlinn Burn Gravel Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
POWSG	Pitscow Sand and Gravel Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
PLSG	Plumpe Sand and Gravel Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 6, Southern Scotland and the Solway
PLYNT	Plynlimon Glacigenic Formation	Wales Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
POCKG	Pocklington Gravel Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines

POA	Point of Ayre Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Poole Harbour Formation	British Coastal Deposits Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
PBTI	Port Beag Till Formation	Western Isles Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
QUIP	Quinton Peat Formation	Britannia Catchments Group	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Raincliff Formation	British Coastal Deposits Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
REBU	Reay Burn Till Formation	Northwest Highlands Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
RDBRN	Red Burn Till Formation	Banffshire Coast and Caithness (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
RCGR	Red Craig Gravels Formation	Inverness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
RCG	Red Crag Formation	Crag Group	Chapter 10, East Anglia and the ancestral River Thames
REDR	Reisgill Burn Till Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
RIBV	Ribble Valley Formation	Cumbria–Lancashire Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
RIDG	Ridgacre Formation	Albion Glacigenic Group	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Ringingslow Formation	Britannia Catchments Group	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Risbury Glacigenic Formation	Albion Glacigenic Group	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Romney Marsh Formation	British Coastal Deposits Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
ROTIL	Rottenhill Till Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Roy Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Sandness Till Formation	Shetland Glacigenic Group	Chapter 4, Highlands and Islands of Scotland
SCMBS	Seacombe Sand Formation	British Coastal Deposits Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
SEAG	Seascale Glacigenic Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
SDNSG	Seisdon Sand and Gravel Formation	Irish Sea Coast (Albion) Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
SEVN	Severn Valley Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
STSG, informal	Shakenhurst Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys

SHLAG	Shellag Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
SMCL	Sheringham Cliffs Formation	Albion Glacigenic Group	Chapter 10, East Anglia and the ancestral River Thames
SSA	Shirdley Hill Sand Formation	British Coastal Deposits Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
SMSG	Shouldham Sand and Gravel Formation	Bytham Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
SHREW	Shrewsbury Glacigenic Formation	Wales Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
SLVY	Slea Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
SNAEF	Snaefell Formation	Manx Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Snellings Sand Formation	Aikbank Farm Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
SOARV	Soar Valley Formation	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
SESKV	Solway Esk Valley Formation	Solway Catchments Subgroup	Chapter 6, Southern Scotland and the Solway
SLEV	Somerset Levels Formation	British Coastal Deposits Group	Chapter 13, South-west England
SOSI	Sourlie Organic Silt Formation	Britannia Catchments Group	Chapter 5, Midland Valley of Scotland
No code, informal	South Wick Till Formation	Shetland (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
SAGL	St Asaph Glacigenic Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
SE	St Erth Formation	British Coastal Deposits Group	Chapter 13, South-west England
SFSI	St Fergus Silt Formation	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
No code, informal	St Martin's Formation	Caledonia Glacigenic Group	Chapter 13, South-west England
No code, informal	St Mary's Formation	British Coastal Deposits Group	Chapter 13, South-west England
STFI	Stainmore Forest Till Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
STGR	Stanmore Gravel Formation	Crag Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
STPTG	Stockport Glacigenic Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
SPEY	Strath Spey Formation	Grampian Catchments Subgroup	Chapter 4, Highlands and Islands of Scotland
SRCK	Strathendrick Formation	Clyde Catchments Subgroup	Chapter 5, Midland Valley of Scotland
STAY	Strathtay Formation	Tay Catchments Subgroup	Chapter 5, Midland Valley of Scotland
SBRY	Sudbury Formation	Kesgrave Catchment Subgroup	Chapter 10, East Anglia and the ancestral River Thames
SUTI	Suideig Till Formation	Inverness (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland

SUGL	Sulby Glen Formation	Isle of Man Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
SURF	Surface Sands Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Sussex Ouse Formation	Sussex Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
RSX	Sussex Rother Formation	Sussex Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
SUTN	Sutton Sand Formation	Yorkshire Catchments Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
TAVA	Tamar Valley Formation	Cornubian Catchments Subgroup	Chapter 13, South-west England
TAW	Taw Valley Formation	Cornubian Catchments Subgroup	Chapter 13, South-west England
TSDC	Teesside Clay Formation	North Sea Coast Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
TFICL	Teifi Clay Formation	Irish Sea Coast Glacigenic Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
TEIFI	Teifi Valley Formation	West Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
TELND	Teindland Palaeosol Formation	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland
No code, informal	Teme Palaeovalley Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Test Formation	Solent Catchments Subgroup	Chapter 12, Southern England and the Middle–Lower Thames catchments
THGTI	Thornsgill Till Formation	Central Cumbria (Albion) Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
TKTI	Threlkeld Till Formation	Central Cumbria Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
TBXSG	Tillybrex Sand and Gravel Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	Tofthead Till Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
TORR	Torridge Valley Formation	Cornubian Catchments Subgroup	Chapter 13, South-west England
TREGN	Tregaron Formation	Britannia Catchments Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
TRVA	Trent Valley Formation	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
TBPS	Troutbeck Palaeosol	Britannia Catchments Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
TSLSI	Trysull Silt Formation	Britannia Catchments Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
TWVA	Tweed Valley Formation	Tweed Catchments Subgroup	Chapter 6, Southern Scotland and the Solway

TYWE	Tyne and Wear Glaciolacustrine Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
TYNE	Tyne Valley Formation	Northumbria Catchments Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
TYWI	Tywi Valley Formation	West Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
UGCL	Ugie Clay Formation	Logie–Buchan Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
ULGR	Ullapool Gravel Formation	Northwest Highlands Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
UTMS	Upper Thames Valley Formation	Thames Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
UWIS	Upper Western Irish Sea Formation	British Coastal Deposits Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
USI	Ury Silts Formation	Mearns Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland
VYORK	Vale of York Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
WAHG	Warren House Gill Till Formation	North Sea Coast (Albion) Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
AVON	Warwickshire Avon Valley Formation	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Waterworks Till Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
WAVV	Waveney Valley Formation	Ouse–Nene Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
WETI	Wear Till Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
WEAR	Wear Valley Formation	Northumbria Catchments Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
WVRVA	Weaver Valley Formation	Cheshire–North Wales Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
WHGR	Well Hill Gravel Formation	Crag Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Welton le Wold Formation	Albion Glacigenic Subgroup	Chapter 10, East Anglia and the ancestral River Thames
WLSG	West Leys Sand and Gravel Formation	East Grampian (Albion) Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
No code, informal	West Sussex Coast Formation	British Coastal Deposits Group	Chapter 12, Southern England and the Middle–Lower Thames catchments
WHGL	Whitehills Glacigenic Formation	Banffshire Coast and Caithness Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
WITI	Wilderness Till Formation	Midland Valley Glacigenic Subgroup	Chapter 5, Midland Valley of Scotland

WMCS	Windermere Clay and Silt Formation	Britannia Catchments Group	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
WOCR	Wolf Crags Formation	Central Cumbria Glacigenic Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
WOLS	Wolston Glacigenic Formation	Albion Glacigenic Group	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Woodside Diamicton Formation	Central Grampian Glacigenic Subgroup	Chapter 4, Highlands and Islands of Scotland
WNSG, informal	Woofferton Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WRCG	Wroxham Crag Formation	Crag Group	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Wye Valley Formation	Severn and Avon Catchments Subgroup	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
WYRV	Wyre Valley Formation	Cumbria–Lancashire Catchments Subgroup	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
YV	Yare Valley Formation	Yare Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames
YNYSS	Ynyslas Formation	British Coastal Deposits Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
YDTI	Yorkshire Dales Till Formation	North Pennine Glacigenic Subgroup	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
YSTOG	Ystog Formation	Britannia Catchments Group	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales

MEMBERS

LEXICON CODE	UNIT	Parent name	District
ABSG	Abbey Sand and Gravel Member	Fenland Formation	Chapter 10, East Anglia and the ancestral River Thames
AGSI	Abbotsgrange Silt Member	Forth Clay Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Aldeburgh Member	Coralline Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
ASAG	Aldeby Sand and Gravel Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
ALDTI	Aldie Till Member	Whitehills Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
ALSG	Allenton Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
STTI	Allt an t-Strathain Till Member	Assynt Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
ANHA	Allt na h-Airbhe Member	Assynt Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
AOPT	Allt Odhar Peat Member	Moy Burn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland

AMTD	Ambaston Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Anderson Drive Diamicton Member	Whitehills Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
ARBI	Arbikie Diamicton Member	Mill of Forest Till Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Arclid Member	Chelford Sand Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
No code, informal	Ardleigh Member	Colchester Formation	Chapter 10, East Anglia and the ancestral River Thames
ARTI	Arnhash Till Member	Essie Till Formation	Chapter 4, Highlands and Islands of Scotland
AR1, R2, AR2A,AR2B AR3 AR4 AR5 AR6 AR7	Arun Terrace Deposit Members 1,2, 2A, 2B, 3, 4, 5, 6, 7	Arun Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
ADSG	Ashford Sand and Gravel	Teme Palaeovalley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
AWTI	Auchenwinsey Till Member	Wilderness Till Formation	Chapter 5, Midland Valley of Scotland
AMNGR	Auchmeddon Gravel Member	Blackhills Sand and Gravel Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Aylesford Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Ayre Sand and Gravel Member	Point of Ayre Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
BGTI	Bacton Green Till Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Bacton Member	Cromer Forest-bed Formation	Chapter 10, East Anglia and the ancestral River Thames
BTI	Baddock Till Member	Finglack Till Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Baginton Sand Member	Baginton Sand and Gravel Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BDTN	Balderton Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BOCH	Balloch Clay Member	Clyde Clay Formation	Chapter 5, Midland Valley of Scotland
BALT	Balmakeith Till Member	Finglack Till Formation	Chapter 4, Highlands and Islands of Scotland
BANM	Banham Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
BFSG	Bank Farm Sand and Gravel	Teme Palaeovalley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BHSG	Barham Sand and Gravel Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
BBSI	Bark Butts Silts Member	Blengdale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

BSSS	Barn Scar Sand and Silt Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
BABY	Barnwell Abbey Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
BSTA	Barnwell Station Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Barrington Village Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
BYD, informal	Barroway Drove Beds	Fenland Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Bathampton Gravel Member	Bristol Avon Valley Formation	Chapter 13, South-west England
BHIL	Beacon Hill Sand and Gravel Member	Briton's Lane Formation	Chapter 10, East Anglia and the ancestral River Thames
BDGR	Beaconsfield Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Bearnie Till Member	Whitehills Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
BGGR	Beenham Grange Gravel Member	Kennet Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
BSGR	Beenham Stocks Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
BENE, informal	Bees' Nest Member	Brassington Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BSSG	Beeston Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BILL	Bellshill Clay Member	Broomhouse Sand and Gravel Formation	Chapter 5, Midland Valley of Scotland
BIDM	Biddenham Member	Ouse Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
BIES	Bielby Sand Member	Breighton Sand Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Bigholms Burn Gravel Member	Blelham Peat Formation	Chapter 6, Southern Scotland and the Solway Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Binney Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
BISG	Birstall Sand and Gravel Member	Soar Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BPGR	Black Park Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Blackditch Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys

No code, informal	Bobbitshole Member	Waveney Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Boddenham Member	Brecknockshire Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
BPIT	Bordeaux Pit Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
BOSG	Borrowash Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BOSW	Bosworth Clay Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BKGR	Bothkennar Gravel Member	Forth Clay Formation	Chapter 5, Midland Valley of Scotland
BOGR	Bothyhill Gravel Member	Alturlie Gravels Formation	Chapter 4, Highlands and Islands of Scotland
BHT	Boyn Hill Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
BOZE, informal	Bozeat Till Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BRSA	Braicklaich Sand Member	Alturlie Gravels Formation	Chapter 4, Highlands and Islands of Scotland
BRET	Bretford Sand and Gravel Member	Warwickshire Avon Valley Formation	Chapter 11, West Midlands and Upper Thames valley
BRON	Bridgeton Sand Member	Clyde Clay Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Bridlington Member	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BRLSG	Briton's Lane Sand and Gravel Member	Briton's Lane Formation	Chapter 10, East Anglia and the ancestral River Thames
BMSG	Bromfield Sand and Gravel	Teme Palaeovalley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BRME	Broome Member	Waveney Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
BRBU	Broubster Till Member	Reay Burn Till Formation	Chapter 4, Highlands and Islands of Scotland
BURG	Buchan Ridge Gravel Member	Buchan Gravels Formation	Chapter 4, Highlands and Islands of Scotland
BCHN	Buchanan Clay Member	Clydebank Clay Formation	Chapter 5, Midland Valley of Scotland
BYGR	Bucklebury Common Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Bullingham Member	Wye Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
BGT	Bushley Green Sand and Gravel Member	Severn Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
BUTTI	Butterby Till Member	Wear Till Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines

No code, informal	Calcethorpe Till Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
CATI	California Till Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
CYTI	Cantray Till Member	Beinn an Uain Till Formation	Chapter 4, Highlands and Islands of Scotland
CYSI	Carey Silt Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland
CHCL	Carleton Hall Clay Member	Glannoventia Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
COGW	Carse of Gowrie Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland
COSCL	Carse of Stirling Clay Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland
CASSG	Castle Sand and Gravel Member	Bain Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
CGWD	Catgill Wood Sand and Gravel Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
CAVM	Cavenham Member	Lark Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
CHSG	Cheltenham Sand and Gravel	Severn and Avon Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
CFB	Chillesford Church Sand Member	Norwich Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
CFC	Chillesford Clay Member	Norwich Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Chilworth Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
CWGR	Chorleywood Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
CTCL	Claret Clay Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland
CLOCL	Clava Lodge Clay Member	Clava Shelly Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Clinch Street Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Cobham Park Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
CODT, informal	Coddington Till Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
CAGR	Cold Ash Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	College Farm Clay Member	Norwich Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
CGEL, informal	Colwall Gelifluctate Member	Cradley Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys

CMBE	Combe Sand and Gravel Member	Sudbury Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
CNYSG, informal	Coney Weston Sand and Gravel Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
CORSE	Corse Diamicton Member	Whitehills Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
CORS	Corton Sand Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
COTI	Corton Till Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
CWSG	Corton Woods Sand and Gravel Member	Briton's Lane Formation	Chapter 10, East Anglia and the ancestral River Thames
CFSI	Crayford Silt Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Creeting Sand Member	Norwich Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
CRHE	Crockley Hill Esker Member	Vale of York Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
CRTD	Cropthorne Sand and Gravel Member	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
CRTI	Crovie Till Member	Byth Till Formation	Chapter 4, Highlands and Islands of Scotland
CRWB, informal	Crowland Bed	Fenland Formation	Chapter 10, East Anglia and the ancestral River Thames
CUTI	Culdoich Till Member	Clava Shelly Formation	Chapter 4, Highlands and Islands of Scotland
CUSA	Culfargie Sand Member	Forth Clay Formation	Chapter 5, Midland Valley of Scotland
CEAL	Cumbrian Esk Alluvium Member	Cumbrian Esk Valley Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DROY	Dalroy Sand Member	Clava Shelly Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Dagenham Farm Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
DASI	Dartford Silt Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
DAY	Daylesford Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Den Burn Till Member	Banchory Till Formation	Chapter 4, Highlands and Islands of Scotland
DOBP	Dobb's Plantation Member	Wroxham Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Dog Mills Member	Orrisdale Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DHGR	Dollis Hill Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments

DBTI	Drigg Beach Till Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DGHS	Drigg Holme Sand Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DGMS	Drigg Moorside Silt Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
DMBG	Drummournie Biogenic Member	Dalcharn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
DMG	Dunsmore Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
EMSG	Eagle Moor Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
EGTI	East Grange Till Member	Grange Hill Sand Formation	Chapter 4, Highlands and Islands of Scotland
ECTN	Ecton Member	Nene Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
EDTI	Edenside Till Member	Greystoke Till Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
EGSG	Egginton Common Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
ESHTI	Eglinton Shelly Till Member	Wilderness Till Formation	Chapter 5, Midland Valley of Scotland
EVSG	Ehen Valley Sand and Gravel Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
EVSI	Ehen Valley Silt Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
ELTI	Elenid Till Member	Plynlimon Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
No code, informal	Elmore Alluvium Member	Severn Valley Formation; Warwickshire Avon Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
ELWK	Elwick Moraine Member	Horden Till Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
ENDR	Endrick Sand Member	Strathendrick Formation	Chapter 5, Midland Valley of Scotland
ESI	Enfield Silt Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
ERIS	Eriswell Member	Lark Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
ERSK	Erskine Clay Member	Clydebank Clay Formation	Chapter 5, Midland Valley of Scotland
ESKRM	Escrick Moraine Member	Vale of York Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines

ETSG	Etwall Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Farm Wood Peat Member	Chelford Sand Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
FELM	Felmersham Member	Ouse Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Fern Bank Silt Member	Hall Carleton Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
FC, informal	Findern Clay Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
FIGR	Finsbury Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
FWTI	Fishgarth Wood Till Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Flamborough Member	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
FOGR	Fodderstone Gravel Member	Shouldham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
FHAM	Fornham Member	Lark Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
FOTI	Forse Till Member	Reisgill Burn Till Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Franklands Gate Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
FL	Freeland Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
FRHA	Frog Hall Sand and Gravel Member	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
FR2, FR3, FR4	Frome Terrace Deposits Members 2, 3 and 4	Severn Valley Formation	Chapter 13, South-west England
FULB	Fulbeck Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
GCGR	Gerrards Cross Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Glen Douchary Member	Assynt Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
GOH	Gordon House Sand and Gravel Member	Sudbury Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
GOSA	Gourock Sand Member	Clydebank Clay Formation	Chapter 5, Midland Valley of Scotland
GWR	Gowrie Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland
GMSI	Grangemouth Silt Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland

GCTI	Green Croft Till Member	Aikbank Farm Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
GOHL	Greenoakhill Sand and Gravel Member	Broomhouse Sand and Gravel Formation	Chapter 5, Midland Valley of Scotland
GREN	Grendon Member	Nene Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
GFSA	Gutterfoot Sand Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
HAGR	Hackney Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
HGV	Haddiscoe Sand and Gravel Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Halling Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Ham Green Gravel Member	Bristol Avon Valley Formation	Chapter 13, South-west England
No code, informal	Hampton Member	Wye Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
HMGR	Hamstead Marshall Gravel Member	Kennet Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
HAN	Hanborough Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
HATI	Hanworth Till Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
HPSA	Happisburgh Sand Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
HPTI	Happisburgh Till Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
HNGR, informal	Hathern Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
HDY	Headley Heath Member	Clay-with-flints Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
HLGR	Heales Lock Gravel Member	Kennet Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Healey Hill Organic Mud Member	Blelham Peat Formation	Chapter 6, Southern Scotland and the Solway Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
HEATH, informal	Heath Member	Glynch Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
HETD	Hemington Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
HRGS	Hempriggs Sand Member	Grange Hill Sand Formation	Chapter 4, Highlands and Islands of Scotland

HDTI	Hereford Till Member	Brecknockshire Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
No code, informal	High Halstow Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
HLOGR	High Lodge Gravel Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
HLSI	High Lodge Silt Member	Shouldham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
HISA	Hillmorton Sand Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
HNRD	Histon Road Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
HOTI	Holkham Till Member	Holderness Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Holme Lacy Member	Wye Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
HPSG	Holme Pierrepont Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
HSCLY	Holmeside Clay Member	Aikbank Farm Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
HRTI	Holmrook Till Member	Blengdale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
HHSG	Holt Heath Sand and Gravel Member	Severn Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Hornsea Member	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
HOWH	How Hill Member	Wroxham Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
HMTI	How Man Till Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Hoxne Member	Waveney Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Hunsingore Esker Member	Vale of York Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
HURD	Huntingdon Road Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Ickford Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
ILSI	Ilford Silt Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Ingham Farm Gravel Member	Ingham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
INVN	Inverleven Gravel Member	Clyde Clay Formation	Chapter 5, Midland Valley of Scotland
IFLS	Ivy Farm Laminated Silt Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames

KPGR	Kempton Park Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
KLTI	Kendal Till Member	Blengdale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
KLOW, informal	Kenslow Member	Brassington Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
OK1, OK2	Kent Ouse Terrace Deposits Members 1 and 2	Kent Ouse Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
KFRD	Kentford Member	Lark Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
RO1, RO2 RO3, RO4	Kentish Rother Terrace Deposits Members 1, 2, 3 and 4	Kentish Rother Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
KRT	Kidderminster Station Sand and Gravel Member	Severn Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
KARN	Killearn Sand and Gravel Member	Clyde Clay Formation	Chapter 5, Midland Valley of Scotland
KILK	Kilmaronock Silt Member	Strathendrick Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Kingsfield Member	Lugg Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
KNSA	Kingston Sand Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Kingswell Till Member	Banchory Till Formation	Chapter 4, Highlands and Islands of Scotland
KKSI	Kinneil Kerse Silt Member	Forth Clay Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Kirkby Moor Sand Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
KHAM, informal	Kirkham Member	Brassington Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
KMGL	Kirkham Till Member	Stockport Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
KHLCH	Kirkhill Church Sand Member	Blackhills Sand and Gravel Formation	Chapter 4, Highlands and Islands of Scotland
KWSG	Kirkland Wood Sand and Gravel Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
KSDSG	Kirkstead Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
KICL	Kirkton Clay Member	Ardersier Silts Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Knettishall Gravel Member	Ingham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Knightlow Sand Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys

KNSG	Knighton Sand and Gravel Member	Soar Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
KSSA	Kokoarrah Shelly Sand Member	Glannoventia Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Kyre Brook Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
LFRD	Lackford Member	Lark Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
LHTH	Lakenheath Gravel Member	Shouldham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
LDTI	Langland Till Member	Brecknockshire Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
LASI	Langley Silt Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
LAWSG	Law Sand and Gravel Member	Clyde Valley Formation	Chapter 5, Midland Valley of Scotland
LHF	Lawns House Farm Sand Member	Hemingbrough Glaciolacustrine Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
LTND	Lawthorn Diamicton Member	Littlestone Till Formation	Chapter 5, Midland Valley of Scotland
LEHI	Leet Hill Sand and Gravel Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
LESI	Letham Silt Member	Carse Clay Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Lillington Gravel Member	Baginton Sand and Gravel Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Linhope Spout Member	Kale Water Till Formation	Chapter 6, Southern Scotland and the Solway
LIWD	Linwood Clay Member	Clyde Clay Formation	Chapter 5, Midland Valley of Scotland
LHSG	Little Hereford Sand and Gravel	Teme Palaeovalley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
LWIB	Little Wilbraham Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
LNTI	Llangelynin Till Member	St Asaph Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
LLEYN	Lleyn Till Member	St Asaph Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
LNCH	Lochwinnoch Clay Member	Clyde Valley Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Lodge Hill Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
LOGG	Loganhouse Gravel Member	Plumpe Sand and Gravel Formation	Chapter 6, Southern Scotland and the Solway
LUGH	Longhaugh Sand and Gravel Member	Clydebank Clay Formation	Chapter 5, Midland Valley of Scotland
LMGV	Low Mill Gravel Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

LWTI	Low Wath Till Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
LCTI	Lowca Till Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
BRY2	Lower Clay Member	Breydon Formation	Chapter 10, East Anglia and the ancestral River Thames
BRY1	Lower Peat Member	Breydon Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Lower St Osyth Member	Colchester Formation	Chapter 10, East Anglia and the ancestral River Thames
LTIL	Lowestoft Till Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Ludham Member	Red Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
LCL	Lunan Clay Member	Errol Clay Formation	Chapter 5, Midland Valley of Scotland
LHGR	Lynch Hill Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
MGW	Mainsgate Sand and Gravel Member	Aikbank Farm Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
MRCG	March Gravels Member	Fenland Formation	Chapter 10, East Anglia and the ancestral River Thames
MMO	Marchfield Moraine Member	Kerr Moraine Formation	Chapter 6, Southern Scotland and the Solway
No code, informal	Marden Member	Lugg Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Marham Member	Nar Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
MTNSG	Martin Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
MWHO	Meadow House Clay Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
MVSG	Meadow View Sand and Gravel Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
MNTI	Merion Till Member	Plynlimon Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
BRY3	Middle Peat Member	Breydon Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Middlebank Silt Member	Ehen Alluvium Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Mill Hill Sand and Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
MHSI	Milton Hill Silt Member	Grange Hill Sand Formation	Chapter 4, Highlands and Islands of Scotland
MTON	Moreton Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys

No code, informal	Moreton on Lugg Member	Lugg Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Mundesley Member	Wroxham Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
MYSA	Mundesley Sand Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
NABS	Naburn Sand Member	Breighton Sand Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Ness Sand and Gravel Member	Lochton Sand and Gravel Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Netherholme Sand Member	Hall Carleton Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Nethertown Gravel Member	Hall Carleton Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
NEHE, informal	Netley Heath Beds	Red Crag Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
NATI	New Abbey Till Member	Langholm Till Formation	Chapter 6, Southern Scotland and the Solway
NIT	New Inn Sand and Gravel Member	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Newbie Silt Member	Carse Clay Formation	Chapter 6, Southern Scotland and the Solway
No code	Newby Wiske-Aldwark Esker Member	Vale of York Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Newhall Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Newton Farm Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Nigg Till Member	Banchory Till Formation	Chapter 4, Highlands and Islands of Scotland
NP	Nordelph Peat Member	Fenland Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	North Hall Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
NLE	North Leigh Sand and Gravel Member	Sudbury Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
NO	Northmoor Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Nyland Hill Clay Member	Somerset Levels Formation	Chapter 13, South-west England
No code, informal	Nyland Hill Peat Member	Somerset Levels Formation	Chapter 13, South-west England
ODT	Oadby Till Member (informal facies codes: ODTL – Lias-rich till; ODTT – Trias-rich till)	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Observatory Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames

OKSG	Ockbrook Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
ODGR	Odhar Gravel Member	Moy Burn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Ostend Clay Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
OULT	Oulton Clay Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
PAIS	Paisley Clay Member	Clyde Clay Formation	Chapter 5, Midland Valley of Scotland
PAF	Park Farm Clay Member	Hemingbrough Glaciolacustrine Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Paston Member	Wroxham Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
PA	Paxford Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
PKSA	Peckmill Sand Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
PPSG	Peel Place Sand and Gravel Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
PELC	Pelaw Clay Member	Tyne and Wear Glaciolacustrine Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Pentney Member	Nar Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
PERT	Pershore Sand and Gravel Member	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
PET1, PET2 PET3, PET4, PET5	Petrockstow River Terrace Deposits Members 1, 2,3, 4 and 5	Petrockstow Valley Formation	Chapter 13, South-west England
PGTI	Pitlurg Farm Till Member	Whitehills Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
No code, informal	Pleasure Gardens Till Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
PLBT	Plump Bridge Till Member	Gretna Till Formation	Chapter 6, Southern Scotland and the Solway
PFS	Plumpe Farm Sand Member	Plumpe Sand and Gravel Formation	Chapter 6, Southern Scotland and the Solway
POPP	Poppleton Glaciofluvial Member	Vale of York Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
PRTS	Portavadie Sand and Silt Member	Clyde Clay Formation	Chapter 5, Midland Valley of Scotland
No code, informal	Porthloo Breccia Member	St Mary's Formation	Chapter 13, South-west England
No code, informal	Portway Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Pow Beck Peat Member	Blelham Peat Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

PSTT	Power House Sand and Gravel Member	Severn Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
PGCL	Powgavie Clay Member	Forth Clay Formation	Chapter 5, Midland Valley of Scotland
PRSG	Princes Risborough Sand and Gravel Member	Sudbury Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
PRIS	Prismatic Clay Member	Horden Till Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Quarrendon Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Rabbit Cat Silt Member	Hall Carleton Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Racks Moss Peat Member	Blelham Peat Formation	Chapter 6, Southern Scotland and the Solway Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
RAH	Ramsden Heath Sand and Gravel Member	Sudbury Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Ramsholt Member	Coralline Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
RVTI	Ravenglass Till Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Ravenstone Member	Ouse Valley Fornation	Chapter 10, East Anglia and the ancestral River Thames
RLTI	Red Lion Till Member	Holderness Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Redkirk Point Peat Member	Blelham Peat Formation	Chapter 6, Southern Scotland and the Solway
RMLY, informal	Redmarley Member	Glynch Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
RECR	Rehiran Cryoturbate Member	Dalcharn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
RHIR	Rhiroy Member	Assynt Glacigenic Formation	Chapter 4, Highlands and Islands of Scotland
RDSG	Ringstead Sand and Gravel Member	Holderness Formation	Chapter 10, East Anglia and the ancestral River Thames
RIN	Rissington Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
ROSI	Roding Silt Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
RSSA	Ross Sand Member	Broomhouse Sand and Gravel Formation	Chapter 5, Midland Valley of Scotland
RSTI	Rothersyke Till Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

RBNTI	Ruabon Till Member	Plynlimon Glacigenic Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
RNTI	Ruallan Till Member	Beinn an Uain Till Formation	Chapter 4, Highlands and Islands of Scotland
RDFD, informal	Rudford Member	Glynch Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
RUCSG	Runton Cliffs Sand and Gravel Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Runton Member		
(marine deposits)	Wroxham Crag Formation	Chapter 10, East Anglia and the ancestral River Thames	
No code, informal	Runton Member		
(non-marine deposits)	Cromer Forest-bed Formation	Chapter 10, East Anglia and the ancestral River Thames	
RUTI	Runton Till Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
RHYS	Ryhope Sand Member	Peterlee Sand and Gravel Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Sandford Bay Till Member	Hythie Till Formation	Chapter 4, Highlands and Islands of Scotland
SWGR, informal	Satwell Gravel Member	Sudbury Formation	Chapter 10, East Anglia and the ancestral River Thames
SBTI	Scale Beck Till Member	Blengdale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
SCSG	Scarle Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Seacote Peat Member	Blelham Peat Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Seven Hills Gravel Member	Ingham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Sewerby Member	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Shabbington Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
STSG	Shakenhurst Sand and Gravel	Teme Palaeovalley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Shakespeare Farm Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
SLSG	Shawell Sand and Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
SHGR	Shepperton Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
SHE	Sherborne Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys

No code, informal	Sheringham Member	Cromer Forest-bed Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Shotford Member	Waveney Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Shouldham Thorpe Gravel Member	Shouldham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
SKLM	Sicklesmere Member	Lark Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Sidestrand Member		
	Wroxham Crag Formation	Chapter 10, East Anglia and the ancestral River Thames	
SKAV	Sidgwick Avenue Member	Cam Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
SIGR	Silchester Gravel Member	Kennet Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
SZWL	Sizewell Member	Red Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Skellingthorpe Clay Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
SKTI	Skipsea Till Member	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
SKIS	Skipwith Sand Member	Breighton Sand Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
SDSG	Sleaford Sand and Gravel Member	Slea Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Snitterfield Sand Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
SOYSG	Southrey Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
SPBY	Spelsbury Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
SPHT	Spring Hill Sand and Gravel Member	Severn Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
SPYCL	Spynie Clay Member	Errol Clay Formation	Chapter 4, Highlands and Islands of Scotland
SBSG	St Bees Sand and Gravel Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
SBSI	St Bees Silt Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
STBT	St Bees Till Member	Gosforth Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

No code, informal	Staines Alluvium Member	Upper Thames Valley Formation Maidenhead Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Starling Sand and Gravel Member	Ehen Alluvium Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
STIL	Starston Till Member	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
STAU, informal	Staunton Member	Glynch Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Stidham Gravel Member	Bristol Avon Valley Formation	Chapter 13, South-west England
No code, informal	Stoke Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
STGO	Stoke Goldington Member	Ouse Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Stoke Lacy Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Stoke Prior Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Stoke Row Member	Sudbury Formation	Chapter 10, East Anglia and the ancestral River Thames
KELV	Strathkelvin Clay and Silt Member	Clyde Valley Formation	Chapter 5, Midland Valley of Scotland
STRSG	Strensham Sand and Gravel Member	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
STSA	Stretton Sand Member	Baginton Sand and Gravel Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
STHSG	Stow Hill Sand and Gravel Member	Briton's Lane Formation	Chapter 10, East Anglia and the ancestral River Thames
SGSI	Stubble Green Silt Member	Glannoventia Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Sudbourne Member	Coralline Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
SURA	Summertown–Radley Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
SUHG	Surrey Hill Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
RS1 RS1A RS1B RS2 RS3 RS3A RS3B RS4 RS5	Sussex Rother Terrace Deposit Members 1, 1A, 1B, 2, 3, 3A, 3B, 4 and 5	Sussex Rother Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Sutton Walls Member	Lugg Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys

No code, informal	Swanscombe Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
SYSG	Syston Sand and Gravel Member	Soar Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
TPGR	Taplow Gravel Member	Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Tattershall Airfield Sand and Gravel Member	Bain Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
TAW1, TAW2 TAW3, TAW4, TAW5, TAW6, TAW7, TAW8, TAW9, TAW10, TAW11	Taw River Terrace Deposits Members 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11	Taw Valley Formation	Chapter 13, South-west England
TEGR	Tay-Earn Gravels Member	Forth Clay Formation	Chapter 5, Midland Valley of Scotland
TTB, informal	Terrington Beds	Fenland Formation	Chapter 10, East Anglia and the ancestral River Thames
THGR	Thatcham Gravel Member	Kennet Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
THOR	Thorganby Clay Member	Hemingbrough Glaciolacustrine Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
THTI	Thormaid Till Member	Reay Burn Till Formation	Chapter 4, Highlands and Islands of Scotland
THSG	Thorpe Sand and Gravel Member	Bain Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Thorpeness Member	Red Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Three Pigeons Sand and Gravel Member	Sudbury Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
THT	Thrussington Till Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code, informal	Thurmaston Gravel Member	Baginton Sand and Gravel Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Tiddington Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Tilbury Member	Medway Valley Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Timworth Gravel Member	Ingham Sand and Gravel Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Tolsta Head Member	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland

TOR1, TOR2 TOR3, TOR4, TOR5, TOR6, TOR7, TOR8, TOR9	Torridge River Terrace Deposits Members 1, 2, 3, 4, 5, 6, 7, 8, and 9	Torridge Valley Formation	Chapter 13, South-west England
TOTL	Tottenhill Sand and Gravel Member	Briton's Lane Formation	Chapter 10, East Anglia and the ancestral River Thames
THBG	Townhead Boulder Gravel Member	Seascale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
TRIMC	Trimingham Clay Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
TRIMS	Trimingham Sand Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
TSCL	Tullos Clay Member	Ugie Clay Formation	Chapter 4, Highlands and Islands of Scotland
BRY4	Upper Clay Member	Breydon Formation	Chapter 10, East Anglia and the ancestral River Thames
BRY5	Upper Peat Member	Breydon Formation	Chapter 10, East Anglia and the ancestral River Thames
WATI	Walcott Till Member	Lowestoft Formation	Chapter 10, East Anglia and the ancestral River Thames
WALD	Waldringfield Member	Colchester Formation	Chapter 10, East Anglia and the ancestral River Thames
WASG	Wanlip Sand and Gravel Member	Soar Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
WAT	Wasperton Sand and Gravel Member	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WMLO	Waterman's Lodge Sand and Gravel Member	Sudbury Formation	Chapter 10, East Anglia and the ancestral River Thames Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
No code, informal	Watermill Sand and Gravel Member	St Mary's Formation	Chapter 13, South-west England
WLLEV	Wentlooge Member	Gwent Levels Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
No code, informal	West Runton Member	Cromer Forest-bed Formation	Chapter 10, East Anglia and the ancestral River Thames
WGGR	Westland Green Gravel Member	Sudbury Formation	Chapter 10, East Anglia and the ancestral River Thames Chapter 12, Southern England and the Middle–Lower Thames catchments
WLGR	Westmill Gravel Member	Colchester Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
WTTI	Weybourne Town Till Member	Sheringham Cliffs Formation	Chapter 10, East Anglia and the ancestral River Thames
WGGV	Whin Garth Gravel Member	Blengdale Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man

WCC	Whinneyhill Coppice Clay Member	Aikbank Farm Glacigenic Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
WFSG	Whisby Farm Sand and Gravel Member	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
WSI, informal	White House Silts Member	Risbury Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WIGS	Wigston Sand and Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WING	Windy Hills Gravel Member	Buchan Gravels Formation	Chapter 4, Highlands and Islands of Scotland
WIHG	Winter Hill Gravel Member	Colchester Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code, informal	Withernsea Member	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code, informal	Wivenhoe Member	Colchester Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Wolf Crags Gravel Member	Wolf Crags Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
No code, informal	Wolf Crags Till Member	Wolf Crags Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
WOHE	Wolford Heath Sand and Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WOC	Wolston Clay Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WV	Wolvercote Sand and Gravel Member	Upper Thames Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WOGR	Woodford Gravel Member	Sudbury Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
WTB	Woodston Member	Nene Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
WNSG	Woofferton Sand and Gravel	Teme Palaeovalley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
WDGE	Woolridge Sand and Gravel Member	Wolston Glacigenic Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WORT	Worcester Sand and Gravel Member	Severn Valley Formation	Chapter 11, The English Midlands, Trent Basin, Upper Thames and Severn valleys
WGAY	Wormegay Member	Nar Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code, informal	Wragby Till Member	Lowestoft Formation Wolston Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys

BEDS AND GLACIAL RAFTS

All the units listed in this table are informal.

LEXICON CODE	UNIT	Parent Name	District
AILT	Ailstone Bed	Cropthorne Sand and Gravel Member; Warwickshire Avon Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Allesborough Beds	Pershore Sand and Gravel Member; Warwickshire Avon Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BNAN	Badentinan Sand Bed	Moy Burn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
No code	Bathampton Palaeosol	Bathampton Gravel Member; Bristol Avon Valley Formation	Chapter 13, South-West England
BEC	Beccles Glacial Beds	Starston Till Member; Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
BLYP	Berryley Peat Bed	Moy Burn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
BIEP	Bielby Peat Bed	Skipwith Sand Member; Breighton Sand Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
BIGP	Bigholms Burn Peat Bed	Blelham Peat Formation	Chapter 6, Southern Scotland and the Solway
BRSI	Brays Silts Bed	Mathon Sand and Gravel Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
BBP	Burn of Benholm Peat Bed	Moy Burn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
BLHD	Burton Lazars Head	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
CHLGE	Camphill Gelifluctate Bed	West Leys Sand and Gravel Formation	Chapter 4, Highlands and Islands of Scotland
No code	Castle Silt Beds	Castle Sand and Gravel Member (Bain Valley Formation)	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Coronation Farm Beds	Southrey Sand and Gravel Member; Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
CSEND	Corsend Gelifluctate Bed	Rottenhill Till Formation	Chapter 4, Highlands and Islands of Scotland
CRSI	Cradley Silts Bed	Cradley Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
CBFMP	Crossbrae Farm Peat Bed	Moy Burn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
CBGEL	Crossbrae Gelifluctate Bed	Crossbrae Till Formation	Chapter 4, Highlands and Islands of Scotland
No code	Crown Inn Bone Beds	Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
DIMS	Dimlington Bed	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines

No code	Eckington Beds	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Eynsham Beds	Summertown-Radley Sand and Gravel Member; Upper Thames Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
FLPT	Fen Lower Peat Bed	Fenland Formation	Chapter 10, East Anglia and the ancestral River Thames
FSLCK	Fernieslack Palaeosol Bed	Teindland Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
No code	Fladbury Beds	Wasperton Sand and Gravel Member; Warwickshire Avon Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Frog Hall Silt Beds	Frog Hall Sand and Gravel Member; Warwickshire Avon Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Garral Hill Gelifluctate Bed	Grampian Catchments Subgroup	Chapter 4, Highlands and Islands of Scotland
No code	Garral Hill Peat Bed	Grampian Catchments Subgroup	Chapter 4, Highlands and Islands of Scotland
No code	Glenbervie Peat Bed	Grampian Catchments Subgroup	Chapter 4, Highlands and Islands of Scotland
HYHD	Harby Head	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Hardslacks Gelifluctate Bed	Camp Fauld Till Formation	Chapter 4, Highlands and Islands of Scotland
No code	Hill House Beds	Bushley Green Sand and Gravel Member; Severn Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
HGGR	Hoghill Gravel Bed	Langholm Till Formation	Chapter 6, Southern Scotland and the Solway
HUHY	Hutton Henry Peat (glacial raft)	Wear Till Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code	Hykeham Soil	Egginton Common Sand and Gravel Member; Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Kincraig Paraglacial Bed	Athais Till Formation	Chapter 4, Highlands and Islands of Scotland
No code	Kirkby Silt Beds	Thorpe Sand and Gravel Member; Bain Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
KHLPS	Kirkhill Palaeosol Bed	Pitscow Sand and Gravel Formation	Chapter 4, Highlands and Islands of Scotland
KTNGF	Kirkton Gelifractate Bed	Pitscow Sand and Gravel Formation	Chapter 4, Highlands and Islands of Scotland
LRHD	Langar Head	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Lapwing Bed	Chelford Sand Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
No code	Leasowe Marine Bed	Lytham Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
No code	Lexden Beds	Suffolk Catchments Subgroup	Chapter 10, East Anglia and the ancestral River Thames

No code	Little Syke Bone Beds	Fulbeck Sand and Gravel Member; Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Loch of Park Gytta Bed	Grampian Catchments Subgroup	Chapter 4, Highlands and Islands of Scotland
MANSE	Manse Gelifluctate Bed	Hythie Till Formation	Chapter 4, Highlands and Islands of Scotland
No code	Mendham Beds	Happisburgh Glacigenic Formation	Chapter 10, East Anglia and the ancestral River Thames
No code	Mill Hill Bed	Holderness Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code	Mill of Dyce Peat Bed	Grampians Catchment Subgroup	Chapter 4, Highlands and Islands of Scotland
No code	Moreseat Farm Sand Bed	Moy Burn Palaeosol Formation	Chapter 4, Highlands and Islands of Scotland
MOPT	Mosedale Beck Peat Bed	Troutbeck Palaeosol	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
NVFB	Nar Valley Freshwater Beds	Nar Clay Formation	Chapter 10, East Anglia and the ancestral River Thames
No code	North Weston Beds	Shabbington Sand and Gravel Member; Upper Thames Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Orbliston Sand Bed	Deanshillock Gravel Formation	Chapter 4, Highlands and Islands of Scotland
PHHD	Pen Hill Head	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Pentney Priory Bed	Nar Valley Formation	Chapter 10, East Anglia and the ancestral River Thames
No code	Preesall Shingle Bed	Lytham Formation	Chapter 8, Lancashire, Cheshire, Staffordshire and Wales
No code	Redkirk Point Peat Bed	Blelham Peat Formation	Chapter 6, Southern Scotland and the Solway
SBPT	Scandal Beck Peat Bed (glacial raft)	Gillcambon Till Formation	Chapter 7, The Vale of Eden, Lake District, west Cumbria and the Isle of Man
SKPE	Skipwith Peat Bed	Skipwith Sand Member; Breighton Sand Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code	South Scarle Bone Beds	Scarle Sand and Gravel Member; Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Stanton Harcourt Beds	Summertown-Radley Sand and Gravel Member; Upper Thames Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
SDHD	Stapleford Head	Trent–Witham Catchments Subgroup	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Stourbridge Beds	Holt Heath Sand and Gravel Member; Severn Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Strensham Court Clay Bed	Warwickshire Avon Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys

No code	Sugworth Beds	Freeland Sand and Gravel Member; Upper Thames Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
SWDEN	Swineden Sand Bed	West Leys Sand and Gravel Formation	Chapter 4, Highlands and Islands of Scotland
TGSC	Tangy Glen Shelly Clay Bed	British Coastal Deposits Group	Chapter 4, Highlands and Islands of Scotland
No code	Tattershall Silt Beds	Castle Sand and Gravel Member; Bain Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Thinfolds Peat Bed	Grampians Catchment Subgroup	Chapter 4, Highlands and Islands of Scotland
No code	Thorpe Soil	Thorpe Sand and Gravel Member; Bain Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Thorpe on the Hill Bone Bed	Balderton Sand and Gravel Member; Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
No code	Toa Galson Bed	Britannia Catchments Group	Chapter 4, Highlands and Islands of Scotland
No code	Todholes Gravel Bed	Grampians Catchment Subgroup	Chapter 4, Highlands and Islands of Scotland
No code	Trafalgar Square Beds	Kempton Park Gravel Member; Maidenhead Formation	Chapter 12, Southern England and the Middle–Lower Thames catchments
No code	Upton Warren Beds	Holt Heath Sand and Gravel Member; Severn Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
WAHL	Warren House Gill Loess Bed	Warren House Gill Till Formation	Chapter 9, Northumberland, Durham, Yorkshire and the Pennines
No code	Waverley Wood Beds	Thurmaston Gravel Member; Baginton Sand and Gravel Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys
WBDS	Westleton Beds	Norwich Crag Formation	Chapter 10, East Anglia and the ancestral River Thames
No code	Whisby Sand Bed	Balderton Sand and Gravel Member; Trent Valley Formation	Chapter 11, The English Midlands: Trent Basin, Upper Thames and Severn valleys

Appendix 3 Superseded terms

The list is restricted mainly to units which have been referred to on BGS maps and other BGS publications.

Stratigraphical unit	Current equivalent term/terms	Lex code
Alvaston Formation	Crown Inn Bone Beds, Allenton Sand and Gravel Member	ALSG
Assynt Till Formation (ASTI) and members Allt Sgiathaig Till Member (SGTI), Loch Lurgain Till Member (LLNN), Traligill Till Member (TRTI), Unapool Till Member (UPTI)	Assynt Glacigenic Formation	ASGL
Belmont Till	Calcethorpe Till Member (informal) of Lowestoft Formation	LOFT
Beeston Regis Formation (BERE)	Members including the Bacton Green Till Member (BGTI), Hanworth Till Member (HATI), and associated outwash gravels including the Trimingham Sand Member (TRIMS), are assigned in this framework to the Sheringham Cliffs Formation (SMCL)	SMCL
Borders (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	No code
Buchan Beds (BUCB)	Buchan Gravels Formation	BUG
Clava Sand Member (CLSA)	Dalroy Sand Member	DROY
Clava Shelly Clay Member (CSCL)	Clava Lodge Clay Member	CLOCL
Clava Shelly Till Member (CLST)	Culdoich Till Member	CUTI
Congleton Sand	Chelford Sand Formation	CHFDS
Corton Formation (COLO, CORF, CRTB)	Happisburgh Glacigenic Formation	HPGL
Cromer Till (Lowest Member) (CMTL)	Happisburgh Till Member	HPTI
Cromer Till (Upper Member) (CMTU)	Walcott Till Member	WATI
Denend Gravel Formation (DNDGR)	Leys Gravel Formation	LEY
East Durham Till Formation	Referred to Blackhall Till, Horden Till, Peterlee Sand and Gravel formations of the North Sea Coast Glacigenic Subgroup	NSG
East Leys Till	Corse Diamicton Member	CORSE
Easton Bavents Clay (EBC)	Chillesford Clay Member	CFC
Edderacres Formation (EDAC)	Tyne and Wear Glaciolacustrine Formation	TYWE
Fen Gravel (FEG)	March Gravels Member and Abbey Sand and Gravel Member of the Fenland Formation	MRCG, ABSG
Filey Formation	Holderness Formation	HOLD
Gimingham Sands	Runton Cliffs Sand and Gravel Member	RUCSG
Glen Parva Member (GPCL)	Bosworth Clay Member	BOSW
Great Britain Glacigenic Supergroup	Provisional term in draft framework; all superficial deposits reassigned to the Great Britain Superficial Deposits Supergroup	GBG
Hunstanton Till	Holkham Till Member, Holderness Formation	HOTI
Kesgrave Formation (KESF, KES, KGSG)	Kesgrave Catchment Subgroup	KGCA
Manx (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	No code
Marly Drift	Weybourne Town Till Member	WTTI
Mearns (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	MEAG

Midland Valley (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	No code
Moreton Drift	Wolston Glacigenic Formation	WOLS
Nar Valley Clay (NV)	Nar Clay Formation	NACL
North Britain Glacigenic Group (BRG)	Provisional term in draft framework (equivalent of Northern Britain Glacigenic Group of McMillan and Hamblin, 2000); Devensian glacigenic deposits reassigned to the Caledonia Glacigenic Group	CALI
Northern Drift Formation (NDR)	Sudbury Formation	SBRY
North Pennine (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	No code
North Sea Drift Formation	Happisburgh Glacigenic Formation and Sheringham Cliffs Formation	HPGL and SMCL
Northwest Highlands (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	NWHAG
Norwich Diamicton (NDI)/ Norwich Brickearth (NBE)	Corton Till Member	COTI
Overstrand Formation (OVSD)	Briton's Lane Formation	BRLA
Pebble Gravel (PBGR), Plateau Gravel (PLG)	Stanmore Gravel Formation and Well Hill Gravel Formation (Crag Group)	STGR and WHGR
Rotherby Member (RYCL)	Bosworth Clay Member	BOSW
Sand of 25 Foot Drift (Vale of York)	Breighton Sand Formation	BREI
Silts and clays of 25 Foot Drift (Vale of York)	Breighton Sand Formation	BREI
South Britain Glacigenic Group (SBRG)	Provisional term in draft framework (equivalent of Southern British Glacigenic Group of McMillan and Hamblin, 2000); pre-Devensian glacigenic deposits reassigned to the Albion Glacigenic Group	ALBI
Southern Uplands (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	No code
Speeton Formation, Speeton Shell Bed	Raincliff Formation (informal), British Coastal Deposits Group. See Chapter 9, Northumberland, Durham, Yorkshire and the Pennines	No code
Trimingham Sand and Clay Member (TRIM)	Trimingham Sand Member and Trimingham Clay Member	TRIMS and TRIMC
Wales Glacigenic (Albion) Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	No code
West Cumbria Drift Group (WCDR)	Irish Sea Coast (Albion) Glacigenic Subgroup and Irish Sea Coast Glacigenic Subgroup	ISCAG and ISCG
Western Isles (Albion) Glacigenic Subgroup	Provisional term listed in McMillan et al. (2005) not required in the present framework	WIAG
Weybourne Crag (WCG)	Sidestrand Member (No code, informal) of the Wroxham Crag Formation	WRCG
Witham Valley Formation (WIVY)	Trent Valley and Bain Valley formations	BAINV, TRVA
Wolston Sand (and Gravel)	Knightlow Sand Member, Wolston Glacigenic Formation. Chapter 11 The English Midlands: Trent Basin, Upper Thames and Severn valleys	No code

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Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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List of BGS maps

BGS 1:50 000 Bedrock and Superficial deposits sheets

This report cites references to many BGS 1:50 000 sheets. Below is a complete list of sheets for England, Scotland, Wales and Isle of Man. For further details, see the BGS catalogue 2009 (available from www.bgs.ac.uk).

Bedrock & Superficial Deposits (B&Sup) – formerly 'Solid (S) & Drift (D)' – show the bedrock and superficial deposits with equal emphasis. These maps give the best picture of the surficial or 'underfoot' geology: geological boundaries and symbols for the surface outcrops of both bedrock and superficial deposits are shown, but details of bedrock geology are normally abridged. There is no new equivalent to the former 'Solid with Drift' (SwD) maps on which only abridged information is shown for the superficial deposits.

'One-inch-to-one-mile' scale maps (1:63 360) are still the current editions for some districts and are indicated in the list by the symbol '#' following the publication date. 'Provisional' editions may include substantial, but not complete, revision of the geology, and are indicated by [P]. 'Facsimile' editions are 1:50 000 scale reprints of earlier 1:63 360 scale maps, and are indicated by 'F' after the facsimile date. The availability of Geological Memoirs, Sheet Explanations or Sheet Descriptions produced to accompany geological maps is indicated by the symbol (M), (SE), or (SD) as appropriate.

England and Wales

E1, 2 Berwick on Tweed and Norham (D). 1977. (M).
E3 Ford (S&D). 1979. (M).
E4 Holy Island (S&D). 1925 #. (M).
E4 Holy Island (SwD). 1974.
E5 The Cheviot (S&D). 1976. (M).
E6 Alnwick (S&D). 1972. (M).
E6 Alnwick (SwD). 1972. (M).
E7 Kielder Castle (S&D). 1950 #.
E8 Elsdon (S&D). 1951 (1993F).
E8 Elsdon (SwD). 1951 (1993F).
E9 Rothbury (S&D). 1977. (M).
E10 Newbiggin (S&D). 1997. (M).
E11 Longtown (S&D). 1925 #. (M). See also: Solway East Special Sheet (Scotland).
E12 Bewcastle (S&D). 1969 #. (M).
E12 Bewcastle (SwD). 1969 #. (M).
E13 Bellingham (S&D). 1980. (M).
E13 Bellingham (SwD). 1980. (M).
E14 Morpeth (S&D). 2001. (SE, SD).
E15 Tynemouth (S&D). 1968 #. (M).
E15 Tynemouth (SwD). 1975. (M).
E16 See: Scotland 1:50 000 Series sheet S6W (Kirkbean); Solway West Special Sheet (Scotland). (M).
E17 Carlisle (S&D). 1925 #. (M).
E17 See also: Solway East & West Special Sheets (Scotland)
E18 Brampton (S&D). 1980. (M).
E20 Newcastle upon Tyne (S&D). 1992. (M).
E20 Newcastle upon Tyne (SwD). 1989. (M).
E21 Sunderland (D). 1978. (M).
E22 Maryport (S&D). 1995. (M).
E23 Cockermouth (S&D). 1997. (M).
E24 Penrith (S&D). 1974. (M).
E24 Penrith (SwD). Reprint of 1974 map. (M).
E25 Alston (S&D). 1973. (M).
E26 Wolsingham (S&D). 1977.
E26 Wolsingham (SwD). 1977.
E27 Durham (S&D). 1965 #. (M).
E28 Whitehaven (B&Sup). 2004. (M).
E29 Keswick (S&D). 1999. (SE, SD).
E30 Appleby (S&D). 2004. (SE).
E31 Brough under Stainmore (S&D). 1974. (M).
E31 Brough under Stainmore (SwD). 1974. (M).
E32 Barnard Castle (S&D). 1969 #. (M).
E32 Barnard Castle (SwD). 1969 #. (M).
E33 Stockton (S&D). 1987.
E34 Guisborough (S&D). [P]. 1998.
E35, pt E44 Whitby & Scalby (S&D). [P]. 1998.
E36 See: Isle of Man Special Sheet at the end of this section. (M).
E37 Gosforth (S&D). 1999. (M).
E38 Ambleside (S&D). 1998. (M).
E39 Kendal (B&Sup). Due 2009.
E40 Kirkby Stephen (S&D). [P]. 1997. (M).
E41 Richmond (S&D). [P]. 1997. (M).
E42 Northallerton (S&D). 1994. (M).
E43 Egton (S&D). [P]. 1992.
E44 See: E35 (Whitby & Scalby). (M).
E45–6 See: Isle of Man Special Sheet at the end of this section. (M).
E47 Bootle (S&D). 1997. (M).
E48 Ulverston (S&D). 1997. (M).
E50 Hawes (S&D). [P]. 1997. (M).
E51 Masham (S&D). 1985.
E51 Masham (SwD). 1985.
E52 Thirsk (S&D). 1992. (M).
E52 Thirsk (SwD). 1992. (M).
E53 Pickering (S&D). [P]. 2001.
E54 Scarborough (S&D). [P]. 1998.
E55, E65 Flamborough and Bridlington (D). 1986.
E56–7 See: Isle of Man Special Sheet at the end of this section. (M).
E58 Barrow in Furness (D). 1976. (M).
E59 Lancaster (S&D). 1995. (M).
E59 Lancaster (SwD). 1995. (M).
E60 Settle (S&D). 1991. (M).
E62 Harrogate (S&D). 1987. (M).
E62 Harrogate (SwD). 1987. (M).
E63 York (S&D). 1983.
E64 Great Driffield (S&D). [P]. 1993.
E65 See: E55 (Flamborough and Bridlington).
E66 Blackpool (D). 1975. (M).
E67 Garstang (S&D). 1991. (M).
E67 Garstang (SwD). 1990. (M).
E68 Clitheroe (S&D). 1975. (M).
E68 Clitheroe (SwD). 1960 #. (M).
E69 Bradford (S&D). 2000. (SE, SD).
E70 Leeds (S&D). 2003. (SE).
E71 Selby (B&Sup). 2008.

E72 Beverley (S&D). [P]. 1995.
E73 Hornsea (S&D). [P]. 1998.
E74 Southport (D). 1989. (M).
E75 Preston (S&D). Reprint of 1940 1-inch map. (M).
E76 Rochdale (S&D). 1974. (M).
E76 Rochdale (B&Sup). Due 2009.
E77 Huddersfield (S&D). 2003. (SE, SD).
E78 Wakefield (S&D). 1998. (M).
E78 Wakefield (SwD). 1978. (M).
E79 Goole (S&D). 1971 #. (M).
E79 Goole (SwD). 1972 #. (M).
E80 Kingston upon Hull (S&D). 1983. (M).
E80 Kingston upon Hull (SwD). 1983. (M).
E81, pts E82 & E90 Patrington (S&D). 1991.
E83 Formby (D). 1974. (M).
E83 Formby (SwD). 1976. (M).
E84 Wigan (S&D). Reprint of 1935 1-inch map. (M).
E85 Manchester (S&D). 1930 #. (M).
E86 Glossop (SwD). 1981. (M).
E87 Barnsley (B&Sup). 2008. (SE)
E88 Doncaster (S&D). 1969 #.
E88 Doncaster (SwD). 1969 #. (M).
E89 Brigg (S&D). 1982. (M).
E89 Brigg (SwD). 1982. (M).
E90 See also: E81 (Patrington).
E90, pt E91 Grimsby (S&D). 1990. (M).
E94 See also: Anglesey Special Sheet at the end of this section.
E94 Llandudno (D). 1989.
E95 Rhyl (S&D). 1970 #. (M).
E96 Liverpool (B&Sup). 2007. (SE).
E97 Runcorn (S&D). 1977.
E98 Stockport (S&D). 1962 (1993F).
E99 Chapel en le Frith (S&D). 1977. (M).
E99 Chapel en le Frith (SwD). 1975. (M).
E100 Sheffield (S&D). 1974. (M).
E101 East Retford (S&D). 1967 #. (M).
E102 Market Rasen (S&D). [P]. 1999.
E103 Louth (S&D). [P]. 1999.
E104 Mablethorpe (S&D). [P]. 1996.
E105–6 See also: Anglesey Special Sheet at the end of this section.
E107 Denbigh (S&D). 1985. (M).
E107 Denbigh (SwD). 1985. (M).
E108 Flint (S&D). 1999. (M).
E108 Flint (SwD). 1999. (M).
E109 Chester (S&D). 1965 (1990F).
E110 Macclesfield (S&D). 1968 #. (M).
E110 Macclesfield (SwD). 1968 (1990F). (M).
E111 Buxton (S&D). 1978. (M).
E112 Chesterfield (S&D). 1963 #. (M).
E113 Ollerton (S&D). 1966 #. (M).
E114 Lincoln (S&D). 1973.
E115 Horncastle (S&D). [P]. 1995.
E116 Skegness (S&D). [P]. 1996.
E119 Snowdon (S&D). 1997. (M).
E120 Corwen (S&D). [P]. 1993.
E121 Wrexham (S&D). [P]. 1993.
E122 Nantwich (S&D). 1967 #. (M).
E122 Nantwich (SwD). 1967 #. (M).
E123 Stoke on Trent (S&D). 1994. (M).
E124 Ashbourne (S&D). 1983. (M).
E125 Derby (S&D). 1972. (M).
E126 Nottingham (S&D). 1996. (M).
E127 Grantham (S&D). 1996. (M).
E128 Boston (S&D). [P]. 1995.
E129 The Wash (S&D). 1997.
E129 See also: E145 (King's Lynn & The Wash).
E130 Wells-next-the-sea (B&Sup). 2008.
E131 Cromer (S&D). 2003. (SE).
E132, pt E148 Mundesley & North Walsham (S&D). 1998. (SE).
E133 Aberdaron & Bardsey Island (D). 1994. (M).
E134 Pwllheli (S&D). 1999. (M).
E135, pt E149 Harlech (S&D). 1982. (M).
E135, pt E149 Harlech (SwD). 1982. (M).
E136 Bala (SwD). 1986.
E137 Oswestry (S&D). [P]. 1999. (M).
E138 Wem (S&D). 1967. (M).
E139 Stafford (S&D). 1974. (M).
E140 Burton upon Trent (S&D). 1982. (M).
E141 Loughborough (S&D). 2001. (SE, SD).
E142 Melton Mowbray (S&D). 2003. (SE, SD).
E143 Bourne (S&D). 1964 #.
E143 Bourne (SwD). 1964 #.
E144 Spalding (S&D). 1992.
E145, pt E129 King's Lynn & The Wash (S&D). 1978. (M).
E146 Fakenham (S&D). [P]. 1999.
E148 See also: E132 (Mundesley & North Walsham). (M).
E149 Cadair Idris (S&D). 1995. (M).
E151 Welshpool (B&Sup). 2008.
E152 Shrewsbury (S&D). 1932 #. (M).
E152 Shrewsbury (S). 1978. (M).
E153 Wolverhampton (S&D). 2001. (SE, SD).
E154 Lichfield (S&D). 1922 #. (M).
E154 Lichfield (SwD). 1926 #. (M).
E155 Coalville (SwD). 1982. (M).
E155 Coalville (B&Sup). Due 2009.
E156 Leicester (B&Sup). 2008. (SE)
E157 Stamford (S&D). 1978.
E158 Peterborough (S&D). 1984. (M).
E159 Wisbech (S&D). 1995.
E160 Swaffham (S&D). [P]. 1998.
E161 Norwich (S&D). 1975. (M).
E162 See: 1:50 000 Coastal Geology Map sheet E162 (Great Yarmouth) at the end of this section.
E163 Aberystwyth (S&D). 1989. (M).
E165 Montgomery (S&D). 1994. (M).
E165 Montgomery (SwD). 1994. (M).
E166 Church Stretton (S&D). 1967 #. (M).
E166 Church Stretton (SwD). 1974. (M).
E167 Dudley (B&Sup). 1975. (M).
E168 Birmingham (S&D). 1996. (M).
E168 Birmingham (SwD). 1924 (1992F). (M).
E169 Coventry (S&D). 1994. (M).
E169 Coventry (SwD). 1994. (M).
E170 Market Harborough (S&D). 1969 (1997F). (M).
E171 Kettering (S&D). 2002. (SE).
E172 Ramsey (S&D). [P]. 1995.
E173 Ely (S&D). 1980. (M).
E175 Diss (S&D). 1989. (M).
E176 Lowestoft (S&D). 1996. (M).
E177 Aberaeron (B&Sup). 2006.
E178 Llanilar (S&D). 1994. (M).
E178 Llanilar (SwD). 1994. (M).
E179 Rhayader (S&D). 1993. (M).
E179 Rhayader (SwD). 1993. (M).
E181 Ludlow (S&D). [P]. 2000.
E182 Droitwich (S&D). 1976. (M).
E183 Redditch (S&D). 1989. (M).
E184 Warwick (S&D). 1984. (M).
E185 Northampton (S&D). 1980.
E186 Wellingborough (B&Sup). 2006. (SE).
E187 Huntingdon (S&D). 1975. (M).
E188 Cambridge (S&D). 1981. (M).
E189 Bury St Edmunds (S&D). 1982. (M).

E190 Eye (S&D). [P]. 1995.
E191 Saxmundham (S&D). 1996. (M).
E193, pt E210 Cardigan and Dinas Island (S&D). 2003. (SE).
E194 Llangranog (B&Sup). 2006.
E195 Lampeter (B&Sup). 2006. (SE).
E196 Builth Wells (S&D). 2005. (SE).
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E198 Hereford (S&D). 1989. (M).
E199 Worcester (S&D). 1993. (M).
E200 Stratford upon Avon (S&D). 1974. (M).
E201 Banbury (S&D). 1982. (M).
E202 Towcester (S&D). 1969 #.
E203 Bedford (S&D). Reprint of 1900 1-inch map.
E204 Biggleswade (S&D). 2001. (SE).
E205 Saffron Walden (S&D). 2002. (SE).
E206 Sudbury (S&D). 1991. (M).
E207 Ipswich (B&Sup). 2006. (M, SE).
E208, pt E225 Woodbridge & Felixstowe (S&D). 2001. (SE).
E209 St Davids (S&D). [P]. 1992.
E210 See: E193 (Cardigan and Dinas Island).
E211 Newcastle Emlyn (B&Sup). 2006. (SE).
E212 Llandovery (B&Sup). 2008.
E213 Brecon (B&Sup). 2005. (SE)
E214 Talgarth (S&D). 2004. (SE).
E215 Ross on Wye (S&D). [P]. 2001. (SE).
E216 Tewkesbury (S&D). 1988.
E217 Moreton in Marsh (S&D). 2000. (SE, SD).
E218 Chipping Norton (S&D). 1968 #. (M).
E219 Buckingham (S&D). 2002. (SE).
E220 Leighton Buzzard (S&D). 1992. (M).
E221 Hitchin (S&D). 1995. (M).
E222 Great Dunmow (S&D). 1990. (M).
E223 Braintree (S&D). 1982. (M).
E225 See: E208 (Woodbridge & Felixstowe).
E226, pt E227 Milford (S&D). 1978.
E226, pt E227 Milford (SwD). 1978.
E228 Haverfordwest (S&D). 1976.
E228 Haverfordwest (SwD). 1976.
E229 Carmarthen (S&D). 1967 #. (M).
E229 Carmarthen (SwD). 1977 (1997F). (M).
E230 Ammanford (S&D). 1977. (M).
E230 Ammanford (SwD). 1977. (M).
E231 Merthyr Tydfil (S&D). 1979. (M).
E231 Merthyr Tydfil (SwD). 1979. (M).
E232 Abergavenny (S&D). 1990. (M).
E233 Monmouth (S&D). 1974. (M).
E234 Gloucester (S&D). 1972.
E235 Cirencester (S&D). 1998. (M).
E236 Witney (S&D). 1982. (M).
E237 Thame (S&D). 1994. (M).
E238 Aylesbury (S&D). 1923 (1997F). (M).
E239 Hertford (S&D). 1978. (M).
E240 Epping (S&D). 1981. (M).
E241 Chelmsford (S&D). 1975. (M).
E244, pt E245 Pembroke & Linney Head (S&D). 1983.
E246 Worms Head (S&D). [P]. 2003.
E247 Swansea (S&D). 1972 #.
E247 Swansea (SwD). 1977.
E248 Pontypridd (S&D). 1975. (M).
E248 Pontypridd (SwD). 1963 (1992F). (M).
E249 Newport (S&D). 1969 (1997F). (M).
E249 Newport (SwD). 1975. (M).
E250 Chepstow (S&D). 1972. (M).
E250-1 See also: Bristol Special Sheet at the end of this section.
E251 Malmesbury (S&D). 1970 #. (M).
E252 Swindon (S&D). 1974 (1992F).
E253 Abingdon (SwD). 1971 #.
E253 Abingdon (S&D). 1971 #.
E254 Henley on Thames (S&D). (M). 1980.
E255 Beaconsfield (S&D). 2005. (SE).
E256 North London (B&Sup). 2006. (M).
E257 Romford (S&D). 1996.
E257–9 See also: 1:50 000 Coastal Geology Map E257 Inner Thames Estuary at the end of this section.
E258, pt E259 Southend & Foulness (S&D). 1976. (M).
E261, pt E262 Bridgend (S&D). 1990. (M).
E263 Cardiff (S&D). 1988. (M).
E263 See also: 1:50 000 Coastal Geology Map E263 (Inner Bristol Channel) at the end of this section.
E264–5 See also: Bristol Special Sheet at the end of this section.
E264 Bristol (S&D). 2004. (M, SE)
E265 Bath (S&D). 1965 (1997F).
E266 Marlborough (S&D). 1974.
E267 Newbury (B&Sup). 2006.
E268 Reading (S&D). 2000. (SE).
E269 Windsor (S&D). 1999. (SE).
E270 South London (S&D). 1998. (M).
E271 Dartford (S&D). 1998. (M).
E271–3 See also: Coastal Geology Map E257 (Inner Thames Estuary) at the end of this section.
E272 Chatham (S&D). 1977. (M).
E273 Faversham (S&D). 1974. (M).
E274 Ramsgate (D). 1980. (M).
E275–6 See: E292 (Bideford & Lundy Island).
E277 Ilfracombe (S&D). 1981. (M).
E278, pt E294 Minehead (S&D). 1997. (M).
E279 Weston-super-Mare (S&D). 1980. (M).
E279 See also: 1:50 000 Coastal Geology Map E263 (Inner Bristol Channel) at the end of this section.
E280 Wells (S&D). 1984 (1997F). (M).
E280–1 See also: Bristol Special Sheet at the end of this section.
E281 Frome (S&D). 2001.
E282 Devizes (B&Sup). 2008.
E283 Andover (S&D). 1975. (M).
E284 Basingstoke (S&D). 1978 (1981F). (M).
E285 Guildford (S&D). 2001. (SE).
E286 Reigate (S&D). 1978. (M).
E287 Sevenoaks (S&D). 1971 (1990F). (M).
E288 Maidstone (S&D). 1976. (M).
E289 Canterbury (S&D). 1982. (M).
E290 Dover (S&D). 1977. (M).
E291 See: E292.
E292, pts E275–276 & E291 Bideford & Lundy Island (S&D). 1977. (M).
E293 Barnstaple (S&D). 1982. (M).
E294 See also: E278 (Minehead).
E294 Dulverton (S&D). 1974.
E295 Taunton (S&D). 1984. (M).
E295 See also: 1:50 000 Coastal Geology Map E263 (Inner Bristol Channel) at the end of this section.
E296 Glastonbury (S&D). 1973.
E297 Wincanton (S&D). 1996. (M).
E298 Salisbury (B&Sup). 2005.
E299 Winchester (S&D). 2003. (SE).
E300 Alresford (S&D). 2000. (SE).
E301 Haslemere (S&D). 1981. (M).
E302 Horsham (S&D). 1972 #. (M).
E303 Tunbridge Wells (S&D). 1971 #. (M).
E304 Tenterden (S&D). 1981. (M).
E305, pt E306 Folkestone & Dover (S&D). 1974. (M).
E307, pt E308 Bude (S&D). 1980. (M).
E309 Chulmleigh (S&D). 1980. (M).
E310 Tiverton (S&D). 1974.

E311 Wellington (S&D). 1976
E311 Wellington (B&Sup). Due 2009. (SE)
E312 Yeovil (S&D). 1958 (1997F). (M).
E313 Shaftesbury (S&D). 1994. (M).
E314 Ringwood (S&D). 2004. (SE).
E315 Southampton (S&D). 1987. (M).
E316 Fareham (S&D). 1998. (SE, SD).
E317, pt E332 Chichester & Bognor (S&D). 1996. (SE, SD).
E318, 333 Brighton & Worthing (B&Sup). 2006. (M).
E319, 334 Lewes & Eastbourne (B&Sup). 2006. (M).
E320, pt E321 Hastings & Dungeness (S&D). 1980. (M).
E322 Boscastle (S&D). 1969 #. (M).
E323 Holsworthy (S&D). 1974. (M).
E324 Okehampton (S&D). 1969 #. (M).
E325 Exeter (S&D). 1995. (M).
E326, pt E340 Sidmouth (S&D). 2004. (SE).
E327 Bridport (B&Sup). 2005. (M).
E328 Dorchester (S&D). 2001.
E329 Bournemouth (S&D). 1991. (M).
E330 Lymington (S&D). 1975 (1997F). (M).
E330–1 See also: Isle of Wight Special Sheet at the end of this section. (M).
E331 Portsmouth (S&D). 1994. (SE, SD).
E332 See: E317 (Chichester & Bognor).
E333 See: E318 (Brighton & Worthing). (M).
E334 See: E319 (Lewes & Eastbourne). (M).
E335, pt E336 Trevose Head & Camelford (S&D). 1994. (M).
E337 Tavistock (S&D). [P]. 1993. (M).
E338 Dartmoor Forest (S&D). [P]. (M). 1995.
E339 Newton Abbot (S&D). 1976 (1997F). (M).
E340 See: E326 (Sidmouth). (SE).
E341, pt E342 West Fleet & Weymouth (S&D). 2001. (M).
E343, pt E342 Swanage (S&D). 2000. (M).
E344–E345 See: Isle of Wight Special Sheet at the end of this section. (M).
E346 Newquay (S&D). 1981.
E347 Bodmin (S&D). 1982.
E348 Plymouth (S&D). 1998. (M).
E349 Ivybridge (S&D). 1974. (M).
E350 Torquay (S&D). 2004. (SE, SD).
E351, pt E358 Penzance (S&D). 1984. (M).
E352 Falmouth (S&D). 1990. (M).
E353, pt E354 Mevagissey (S&D). 2000.
E355, pt E356 Kingsbridge, Salcombe & Start Point (S&D). [P]. 2001.
E357, pt E360 Isles of Scilly (S&D). 1975.
E358 See: E351 (Penzance). (M).
E359 Lizard (S&D). 1975. (M).
E360 See: E357 (Isles of Scilly).

1:50 000 Coastal Geology (England & Wales)

These maps show the geology of selected near-shore, estuarine or offshore areas, defined as Quaternary or pre-Quaternary strata and deposits. All maps include information on the onshore geology although for some areas this may only be an outline of the geology or simplified geology which is normally published on other 1:50 000 Series Geological Maps.

E162 Great Yarmouth (S&D/Q& Pre-Q). 1990. (M).
E257, 258, 259 Inner Thames Estuary (Pre-Q/Q). (Covers parts of E257, 258, 259, 271, 272, 273). 1997. (M).
E263, pts E279, E295 Inner Bristol Channel & Severn Estuary (Pre-Q). 1996. (M).
E263, pts E279, E295 Inner Bristol Channel &Severn Estuary (Q & Pre-Q). 1996. (M).

1:50 000 Special Sheets (England and Wales)

Anglesey (S&D). Special Sheet. E92–3, & pts E94, E105–6. 1974.
Anglesey (SwD). Special Sheet. E92–3, & pts E94, E105–6. 1980.
Bristol District (S&D). Special Sheet. Pts E250–1, E264–5, E280–1. 1962 #. (M).
Isle of Wight (S&D). Special Sheet. Pts E330–1, E344–5. 1976. (M).
Isle of Man Special Sheet (S&D). Pts E36, E45–6, E56–7. 2001. (M).

Scotland

S1 See also: Rhins of Galloway Special Sheet at the end of this section.
S2 Whithorn (D). 1987. (M).
S3 Stranraer (D). 1982. (M).
S3 See also: Rhins of Galloway Special Sheet at the end of this section. (M).
S4E Wigtown (D). 1981.
S4W Kirkcowan (D). 1982.
S5E Dalbeattie (D). 1981. (M).
S5W Kirkcudbright (D). 1980. (M).
S5-6 See also: Solway West Special Sheet at the end of this section.
S6 Annan (D). 1983. Western portion largely superseded by S6W: see below.
S6E See also: Solway East Special Sheet at the end of this section.
S6W Kirkbean (S&D). 1998.
S6W See also: Solway East & West Special Sheets at the end of this section.
S7 Girvan (D). 1980. (M).
S7 See also: Rhins of Galloway Special Sheet at the end of this section. (M).
S8E Loch Doon (D). 1980. (M).
S8W Carrick (D). 1981. (M).
S9E Thornhill (D). 1980. (M).
S9E See also: Solway West Special Sheet at the end of this section.
S9W New Galloway (D). 1979. (M).
S10E Ecclefechan (D). 1982.
S10E See also: Solway East Special Sheet at the end of this section.
S10W Lochmaben (B&Sup). 2008.
S10W See also: Solway East & West Special Sheets at the end of this section.
S11 Langholm (D). 1968 #. (M).
S11 See also: Solway East Special Sheet at the end of this section.
S12 Campbeltown (S&D). [P]. 1996.
S14E Cumnock (D). 1980. (M).
S14W Ayr (D). 1978. (M).
S14W Ayr (B&Sup). Due 2009.
S15E Leadhills (S&D). 2004. (SE, SD).
S15W New Cumnock (S&D). 2000. (SE, SD).
S16E Ettrick (D). 1987.
S16W Moffat (D). 1987.
S17E Jedburgh (D). 1982.
S17W Hawick (D). 1982.
S19 South Islay (S&D). [P]. 1998.
S20, pt S21W Sound of Gigha (S&D). [P]. 1996.
S21E See: S22W (Irvine). (M).
S21W See also: S20 (Sound of Gigha) and S29W (Kilfinan).
S22E Kilmarnock (S&D). 2003. (SE, SD).
S22W Irvine (D). 1987. (M).
S23W Hamilton (D). 1993. (M).
S24E Peebles (D). 1983.
S24W Biggar (D). 1981.

S25W Galashiels (D). 1985.
S26 Berwick upon Tweed and Duns (S&D). 1969 #.
S27 North Islay (S&D). [P]. 1997.
S28E Knapdale (S&D). [P]. 1996.
S28W South Jura (S&D). [P]. 1996.
S29E See: S29 (Rothesay) & S30W (Greenock).
S29E, pt S21E Dunoon & Millport (B&Sup). 2008.
S29W, pt S21W Kilfinan (S&D). [P]. 2001.
S30E Glasgow (D). 1994. (M).
S30W, pt S29E Greenock (D). 1989. (M).
S31E Falkirk (S&D). 1997. (M).
Folded: 0751829854.
S31W Airdrie (D). 1992. (M).
S32E Edinburgh (B&Sup). 2006.
S32W Livingston (B&Sup). 2008.
S33E, pt S41 Dunbar (D). 1978. (M).
S33W, pt S41 Haddington (D). 1978. (M).
S34 Eyemouth (D). 1983. (M).
S35 Colonsay (S&D). [P]. 1996.
S36 Kilmartin (B&Sup). [P]. 2004.
S37W Furnace (B). 2008.
S38E Aberfoyle (B&Sup). 2005.
S39E Alloa (D). 1974. (M).
S39W Stirling (D). 1974. (M).
S40 Kinross (D). 1973 #. Eastern portion available as S&D sheet S40E: see below.
S40E Kirkcaldy (S&D). 1999. (SE, SD).
S41 See also: S33E (Dunbar) and 33W (Haddington).
S41 North Berwick (D). 1971 #. (M).
S42, pt S51W Tiree & Coll (S&D). [P]. 1999.
S43 Ross of Mull (S&D). [P]. 1999. (M).
S43N Staffa (S&D). [P]. 1996. (M).
S44 Mull (S&D). 1953 #. (M).
S45 Oban (S&D). 1926 #.
S48E Cupar (D). 1982. (M).
S48W Perth (D). 1985. (M).
S49 Arbroath (D). 1981. (M).
Flat: 0751809233.
S51E Caliach Point (S&D). [P]. 1976. (M).
S51W See: S42 (Tiree & Coll).
S52 Tobermory (D). 1968 #. (M).
S53 Ben Nevis (S&D). 1948 #. (M).
S54E Loch Rannoch (S&D). 1974.
S54W Blackwater (S&D). 1974.
S60 Rum (S&D). 1994. (M).
S61 Arisaig (D). 1969 #.
S62E Loch Lochy (D). 1975.
S62W Loch Quoich (D). 1975.
S63E Dalwhinnie (S&D). 2002.
S63W Glen Roy (S&D). 1995. (M).
S64 Kingussie (S&D). 1913 #.
S64E Ben Macdui (B&Sup). Due 2009.
S64W Newtonmore (B&Sup). Due 2009.
S67 Stonehaven (S&D). 1999.
S70 Minginish (S&D). 2001.
S71E Kyle of Lochalsh (S&D). 1976. (M).
S71E Kyle of Lochalsh (SwD). 1976. (M).
S71W Broadford (S&D). 2002.
S71W Broadford (SwD). 1976.
S72E Glen Affric (Sup). 2007.
S72W Kintail (D). 1985. (M).
S74 Granton on Spey (S&D). 1914 #.
S74W Tomatin (B&Sup). 2004.
S76E Inverurie (S&D). 2002. (M).
S77 Aberdeen (Sup). 2004.
S80E Portree (B&Sup). 2007. (M).
S80W Dunvegan (B&Sup). 2007. (M).
S81 See also: S80E (Portree).
S81E Loch Torridon (S&D). 1975. (M).
S81W Raasay (B&Sup). 2006. (M).
S82 Lochcarron (S&D). 1913 #.
S82 Lochcarron (SwD). 1913 #.
S82E Scardroy (S&D). [P]. 1996.
S83 Inverness (S&D). 1954 #. Western portion superseded by S83W.
S83W Strathconon (S&D). [P]. 2002.
S84E Nairn (S&D). 1978.
S84W Fortrose (S&D). 1997. (M).
S86 Huntly (S&D). 1923 #. Eastern portion superseded by S86E.
S86E Turriff (S&D). 1995. (M).
S87E Peterhead (D). 1992. (M).
S87W Ellon (S&D). 2002. (M).
S90 Staffin (B&Sup). 2006.
S91, pt S100 Gairloch (S&D). [P]. 1999.
S92 Inverbroom (S&D). 1913 #.
S93E Evanton (B&Sup). 2004.
S93W Ben Wyvis (B&Sup). 2004
S94 Cromarty (D). 1972 #.
S95 Elgin (D). 1969 #. (M).
S96E Banff (S&D). 2002. (M).
S96W Portsoy (S&D). 2002. (M).
S97 Fraserburgh (D). 1987. (M).
S100 See: S91 (Gairloch).
S101E See: Assynt Special Sheet at the end of this section.
S101W Summer Isles (S&D). [P]. 1998.
S102W See: Assynt Special Sheet at the end of this section.
S102E Lairg (S&D). [P]. 2001.
S103E Helmsdale (S&D). [P]. 1998.
S103W Golspie (S&D). [P]. 2002.
S107E See: Assynt Special Sheet at the end of this section
S107W Point of Stoer (S&D). [P]. 2002.
S108 Altnaharra (S&D). 1931 #.
S108W See: Assynt Special Sheet at the end of this section
S109 Achentoul (S&D). 1931 #.
S110 Latheron (S&D). 1931 #.
S113 Cape Wrath (S&D). [P].1998.
S115E Reay (B&Sup). 2003.
S115W Strathy Point (S&D). [P]. 1996.
S116 Wick (S&D). 1913 #.
S130 Yell (D). 1983. (M).
S131 Unst & Fetlar (D). 2002.

1:50 000 Special Sheets (Scotland)

Solway East (Sup & Simplified Bedrock). Special Sheet S10W, S10E, S11, S6W, S6E, E11, E17. 2006.
Solway West (Sup & Simplified Bedrock). Special Sheet S5E, S6W, S9E, S10W, E16, E17. 2004.
Arran (D). Special Sheet S21 & S13. 1985.
Central Shetland (D). Special Sheet. 1981 #.
Northern Shetland (S&D). Special Sheet. 1968 (1997F) #.
Southern Shetland (D). Special Sheet. 1978.
Western Shetland (D). Special Sheet. 1971 #.

Table 1a Formally ratified timescale for the Quaternary Period and Pleistocene Series with a base at 2.58 Ma.

<table>
<tr><th colspan="5">ICS proposal (Aubry et al., 2005)</th><th colspan="5">GSSC proposal (Zalasiewicz et al., 2006) and formally ratified Quaternary Period (Gibbard et al., 2010)</th></tr>
<tr><th>Era</th><th>Sub-Era</th><th>Period</th><th>Epoch</th><th>Age</th><th>Era</th><th>Period/ (Sub-Period)</th><th>Epoch</th><th>Age</th><th>Age (Ma)</th></tr>
<tr><td rowspan="8">Cenozoic</td><td rowspan="5">Quaternary</td><td rowspan="8">Neogene</td><td>Holocene</td><td rowspan="3"></td><td rowspan="8">Cenozoic (includes Quaternary, Neogene and Palaeogene)</td><td rowspan="5">Quaternary</td><td>Holocene</td><td></td><td>0.012</td></tr>
<tr><td rowspan="3">Pleistocene</td><td rowspan="4">Pleistocene</td><td>‘Tarantian’</td><td>0.126</td></tr>
<tr><td>‘Ionian’</td><td>0.781</td></tr>
<tr><td>Calabrian</td><td>‘Calabrian’</td><td>1.806</td></tr>
<tr><td rowspan="3">Pliocene</td><td>Gelasian</td><td>Gelasian</td><td>2.588</td></tr>
<tr><td rowspan="3">Tertiary (includes Neogene and Palaeogene)</td><td>Piacenzian</td><td rowspan="3">Neogene (Tertiary)</td><td rowspan="2">Pliocene</td><td>Piacenzian</td><td>3.600</td></tr>
<tr><td>Zanclean</td><td>Zanclean</td><td>5.332</td></tr>
<tr><td>Miocene</td><td>Sub-divisions not shown</td><td>Miocene</td><td>Sub-divisions not shown</td><td>23.03</td></tr>
</table>

Table 1b Summary of Quaternary and Neogene (Tertiary) lithostratigraphical framework for Great Britain and the Isle of Man with relationship of groups to Quaternary stages and suggested correlation with marine isotope stages.

ERA	PERIOD	SERIES/ EPOCH		AGE	BRITISH QUATERNARY STAGE (ONSHORE) After Gordon and Sutherland (1993a), Mitchell et al. (1973a), West (1961, 1980), Zalasiewicz et al. (1991). Equivalent Greenland Ice Core Chronology 2005 events (GS/GI) shown for the Late Devensian (after Lowe et al., 2008)		NORTH–WEST EUROPEAN QUATERNARY STAGE After Gibbard et al. (1991a), Funnell (1996), Lister (1998, 2000), Zagwijn (1992)	Marine Oxygen Isotope stage (MIS) – approx. correl- ation	SUPERGROUP	LITHO-STRATIGRAPHICAL GROUPS
	QUATERNARY	HOLOCENE 0.012Ma						1	GREAT BRITAIN SUPERFICIAL DEPOSITS SUPERGROUP	BRITANNIA CATCHMENTS GROUP; BRITISH COASTAL DEPOSITS GROUP
		PLEISTOCENE	LATE	'TARANTIAN'	DEVENSIAN	Loch Lomond Stadial (LLS) (Younger Dryas) GS-1	WEICHSELIAN	2-1		CALEDONIA GLACIGENIC GROUP
						Windermere (Late Glacial) Interstadial (WI) equivalent to Bølling/Allerød. GI-1e –GI-1a		2		
						Dimlington Stadial GS-5–GS-2a				
								3		
								4		
								5d-a		
				0.126Ma	IPSWICHIAN		EEMIAN	5e		
			MIDDLE	'IONIAN'	'WOLSTONIAN'		SAALIAN	10-6		ALBION GLACIGENIC GROUP
					HOXNIAN		HOLSTEINIAN	11		
					ANGLIAN		ELSTERIAN	12		
					'CROMERIAN COMPLEX'		'CROMERIAN COMPLEX'	21-13		
				0.781 Ma						
			EARLY	'CALABRIAN'	BEESTONIAN		BAVELIAN	64-22		CRAG GROUP; DUNWICH GROUP; RESIDUAL DEPOSITS GROUP
							MENAPIAN			
							WAALIAN			
							EBURONIAN			
				1.806 Ma	PASTONIAN		TIGLIAN C5-6			
				GELASIAN	PRE-PASTONIAN/ BAVENTIAN		TIGLIAN C4c	95-65		
					ANTIAN/BRAMERTONIAN		TIGLIAN C1–4b			
					THURNIAN		TIGLIAN B			
					LUDHAMIAN		TIGLIAN A			
				2.588 Ma	Pre-LUDHAMIAN/ WALTONIAN		PRAETIGLIAN	100-96		
							REUVERIAN C	103		
	NEOGENE	PLIOCENE	PIACENZIAN 3.6 Ma							
			ZANCLEAN 5.332 Ma							
		MIO-CENE	Sub-divisions not shown							
	PALAEO-GENE	OLIGOCENE, EOCENE, PALEOCENE Sub-divisions not shown								

Table 2 Formations and members of the Crag Group.

Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned). Emboldened codes denote that the unit has been formally defined in the Lexicon. MIS = Marine Isotope Stage (inferred correlation).

Group and Lex code	**Subgroup and Lex code**	**Defining formations**	**Lex Code**	**Approx. MIS**	**References to descriptions and subdivisions**	**Reference in Bowen, 1999**
CRAG GROUP (CRAG)	Subgroups unassigned	Stanmore Gravel Formation	STGR	? Pre-82–?	'High level' gravels formerly referred to as Plateau Gravel (Dewey et al., 1924), Warley Gravel (Dines and Edmunds, 1925), Bagshot Pebble Bed (Bristow, 1985); 'Pebble Gravel' (Gibbard in Bowen, 1999, Ellison et al., 2004)	Gibbard, p.48
		Well Hill Gravel Formation	WHGR	? Pre–82–?	Dewey et al. (1924); Peake (1982); Ellison et al. (2004)	No reference
		Wroxham Crag Formation	WRCG	? 67–? 17	Established by Hamblin (2001a) and Moorlock et al. (2002b). Dobb's Plantation DOBP, How Hill HOWH and Mundesley members of Rose et al. (2001). The Sidestrand Member of the Norwich Crag Formation (Lewis in Bowen, 1999), and the marine Paston and Mundesley members previously of the Cromer Forest-bed Formation (Lewis in Bowen, 1999) are included	Lewis, p.15
		Norwich Crag Formation	NCG	? 81–68	Established by Funnell and West (1977). Members include (Mathers and Zalasiewicz, 1988, Lewis in Bowen, 1999): the Chillesford Clay CFC, Chillesford Church Sand CFB, College Farm Clay, Creeting Sand, Easton Bavents Clay EBC	Lewis, p.22
		Red Crag Formation	RCG	? 103–? 82	Established by Funnell and West (1977). Zalasiewicz et al. (1988) defined two members in Suffolk: Sizewell SZWL and Thorpeness members. The informal Ludham Member of Norfolk (Lewis in Bowen, 1999) and the Netley Heath Beds NEHE of the western North Downs (Gibbard in Bowen, 1999) also defined	Lewis, p.22 Gibbard, p.53
		Coralline Crag Formation	CCG	Pre–103, Pliocene	Defined by Balson et al. (1993) with three members: Aldeburgh, Sudbourne and Ramsholt members	No reference

Table 3 Subgroups, formations and members of the Dunwich Group.

Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned).
MIS = Marine Isotope Stage (inferred correlation).

Group and Lex code	Subgroup and Lex code	Defining formations	Lex Code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
DUNWICH GROUP (DUNW)	Unassigned	Milton Formation	MLTS	? Pre–67	Barron et al. (2006, 2010 in press) and Belshaw et al. (2005)	Sinclair and Smith, p.43
		Letchworth Gravels Formation	LTH	Pre–13	Defined by Smith and Rose (1997)	Hopson, p.26
		Cromer Forest-bed Formation	CRF	Pre–17	Freshwater members of the Cromer Forest-bed Formation of Lewis in Bowen (1999)	Lewis, p.15
	Bytham Catchments Subgroup (BYCA)	Shouldham Sand and Gravel Formation	SMSG	Pre–12	Members include: Shouldham Thorpe Gravel, Fodderstone Gravel FOGR, Lakenheath Gravel LHTH, and High Lodge Silt HLSI members	Lewis, p.19
		Ingham Sand and Gravel Formation	ISAG		Clarke and Auton (1982). Members include: Timworth Gravel, Knettishall Gravel, Ingham Farm Gravel, Seven Hills Gravel	Lewis, p.19
		Baginton Sand and Gravel Formation	BGSG		Shotton (1953); Sumbler (1983a,b). Members include informal Thurmaston Gravel, Lillington Gravel and Stretton Sand members	Maddy and Sumbler, p.36
		Bytham Sand and Gravel Formation	BYTH		Bytham Sands and Gravels defined by Rose (1987, 1994) and Bateman and Rose (1994). Includes the Ingham Sand and Gravel as that term was previously used (Clarke and Auton, 1982, Lewis, 1993, Lewis in Bowen, 1999)	Lewis, p.19
	Kesgrave Catchment Subgroup (KGCA)	Colchester Formation	CCHR	? 61–13	Colchester Formation (Kesgrave Group) of Whiteman and Rose (1992). Includes Lower St Osyth, Wivenhoe, Ardleigh, Waldringfield WALD members. Also Winter Hill Gravel WIHG and Westmill Gravel WLGR members (Ellison et al., 2004)	Lewis, p.22 Allen, p.24 Gibbard, p.57
		Sudbury Formation	SBRY		Sudbury Formation (Kesgrave Group) of Whiteman and Rose (1992). Includes Beaconsfield Gravel BDGR, Satwell Gravel SWGR, Westland Green Gravel WGGR, Waterman's Lodge Sand and Gravel WMLO, Ramsden Heath Sand and Gravel RAH and Stoke Row members. Also included, and shown on BGS maps are the terrace deposits of the Chorleywood Gravel, Gerrards Cross Gravel GCGR, Cold Ash Gravel CAGR, Bucklebury Common Gravel BYGR, Beenham Stocks Gravel BSGR, Surrey Hill Gravel SUHG, Woodford Gravel WOGR and Dollis Hill Gravel DHGR members (e.g. Ellison et al., 2004)	Gibbard and Sumbler, pp.47–49
	Unassigned	Caesar's Camp Gravel Formation	CCGR	Pre–13	Dines and Edmunds (1929); Clarke and Fisher (1983)	Gibbard, p.53
		Nettlebed Formation	NBED	? Pre–67	Horton and Turner (1983); Nettlebed Member of Pebble Gravel Formation (Gibbard in Bowen, 1999)	Gibbard, p.48

Table 4 Subgroups, formations and members of the Dunwich Group.

Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned).
MIS = Marine Isotope Stage (inferred correlation).

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
RESIDUAL DEPOSITS GROUP (RESID)	Subgroups unassigned	Lenham Formation	LNM	Pre–65 Pliocene to Pleistocene	Ellison et al. (2004)	No reference
		Chelsfield Gravel Formation	CHGR	Pre–65 Pliocene to Pleistocene	Whitaker and Davies (1920); Berdinner (1936); Ellison et al. (2004)	No reference
		Clay-with-flints Formation	CWF	Pre–65 Palaeogene to Quaternary	Defined by Pepper (1973), Catt (1986) and Ellison et al. (2004)	No reference
		Buchan Gravels Formation	BUG	Pre-103, Pliocene	(Merritt et al., 2003) Buchan Ridge Gravel Member BURG Windy Hills Gravel Member WING	No reference

Fissure-fill formations currently assigned to Great Britain Superficial Deposits Supergroup.

Supergroup and Lex code	Group and Lex code	Defining formations	Lex code	MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
GREAT BRITAIN SUPERFICIAL DEPOSITS SUPERGROUP (GBG)	Group unassigned	Castle Eden Fissure-fill Formation	CEDN	Pre–13 Mesozoic to Cromerian	Defined by Smith and Francis (1967) and Francis (1970). Blackhall Colliery Formation of Thomas in Bowen (1999)	Thomas, p.98
		Brassington Formation	BTON	Pre–103 Neogene (Tertiary)	Defined by Boulter et al. (1971) and Chisholm et al. (1988); Bees' Nest Member BENE, Kirkham Member KHAM, Kenslow Member KLOW	No reference

Table 5 Formations and members the British Coastal Deposits Group.

Formations comprise mainly coastal and marine deposits. Locally interbedded fluvial and organic deposits may also be present.
LLS = Loch Lomond Stadial (Younger Dryas); WI = Windermere Interstadial (Bølling/Allerød).
Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned). MIS = Marine Isotope Stage (inferred correlation).

Group and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
BRITISH COASTAL DEPOSITS GROUP (COAS) *(Continued)*	Beauly Silt Formation	No code	1	Informal formations — Beauly Firth. Formerly members of the Cromarty and Clava formations (Sutherland in Bowen, 1999). Provisionally correlated with the Carse Clay Formation of the Midland Valley of Scotland	Sutherland, pp.103–106
	Moniack Peat Formation	No code			
	Foulis Silt Formation	No code			
	Lemlair Sand Formation	No code			
	Ardullie Silt Formation	No code			
	Balmeanach Silt Formation	No code	2-1 (LLS)		
	Barnyards Silt Formation	No code			
	Culbokie Silt Formation	No code	2 (WI)		
	Kessock Bridge Silt Formation	KEBR		Kessock Bridge Member of Clava Formation of Sutherland (in Bowen, 1999)	
	Errol Clay Formation	ERRCL	2	Errol Beds of Paterson et al. (1981), Errol Member of Tay Formation (Sutherland in Bowen, 1999) Correlated with St Abbs Formation (offshore) Stoker et al. (1985). Spynie Clay Member SPYCL of north-east Scotland (Merritt et al., 2003) and Lunan Clay Member LCL of the Midland Valley (McCabe et al., 2007)	Sutherland, p.114; Holmes, p.130
	St Fergus Silt Formation	SFSI		St Fergus Silt Formation of north-east Scotland (Merritt et al., 2003)	No reference
	Clydebank Clay Formation	CBCL	1	Members (after Browne and McMillan, 1989):	Sutherland, pp.110–111
				Gourock Sand Member GOSA	
				Erskine Clay Member ERSK	
				Longhaugh Sand and Gravel Member LUGH	
				Buchanan Clay Member BCHN	
	Clyde Clay Formation	CYLD	2 (WI to LLS)	Inverleven Gravel Member INVN (after Browne and McMillan, 1989)	
				Balloch Clay Member BOCH (after Browne and McMillan, 1989)	
				Portavadie Sand and Silt Member PRTS (after Peacock, 1997)	
				Linwood Clay Member LIWD (after Browne and McMillan, 1989)	
				Paisley Clay Member PAIS (after Browne and McMillan, 1989)	
				Killearn Sand and Gravel Member KARN (after Browne and McMillan, 1989)	
				Bridgeton Sand Member BRON (after Browne and McMillan, 1989)	
	Afton Lodge Clay Formation	AFTL	3	After Gordon (1993a); see also Smith (2002) and Smith et al., in prep. (2009)	No reference
	Forth Clay Formation	FOCL	2(WI) to 1	Units include Powgavie Clay PGCL, Culfargie Sand CUSA, Tay-Earn Gravels TEGR members in the Tay-Earn area; Kinneil Kerse Silt KKSI, Abbotsgrange Silt AGSI, Bothkennar Gravel BKGR members in the Forth area. Units originally established by Paterson et al. (1981), Armstrong et al. (1985) and Browne et al. (1984)	Sutherland, pp.113–114
	Carse Clay Formation	CARCL	2-1 (LLS) to 1	Units include Gowrie GWR, Carse of Gowrie COGW, Carey Silt CYSI, Kingston Sand KNSA, Letham Silt LESI, Carse of Stirling Clay COSCL, Claret Clay CTCL and Grangemouth Silt GMSI members in the Tay and Forth areas. Units originally defined originally by Paterson et al. (1981) and Armstrong et al. (1985). Claret Clay Member after Claret Formation of Barras and Paul (1999)	
			1	Informal Newbie Silt Member of the Redkirk Formation of Sutherland in Bowen, 1999) for the Solway area	Sutherland, p.107

Table 5 *Continued.*

Group and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
BRITISH COASTAL DEPOSITS GROUP (COAS) *(Continued)*	Point of Ayre Formation	POA	1	Thomas in Bowen (1999), revised by Chadwick et al. (2001)	Thomas, p.94
	Ayre Formation	AYRE	5, 7 or 9		
	Lytham Formation	LTHM	1	After formation established by Thomas in Bowen (1999)	Thomas, p.95
	Drigg Point Sand Formation	DGPS		Formation established by Merritt and Auton (2000)	No reference
	Surface Sands Formation	SURF	1	Offshore formation	Cameron, pp.137–138
	Upper Western Irish Sea Formation	UWIS	4 –1	Chadwick et al. (2001)	Cameron, pp.137–138
	Hall Carleton Formation	HALC	2 (WI)–1	Nethertown Gravel, Rabbit Cat Silt, Netherholme Sand and Fern Bank Silt members established by Merritt and Auton (2000)	No reference
	Glannoventia Formation	GVA	? 3	Formation established by Merritt and Auton (2000). Carleton Hall Clay Member CHCL Kokoarrah Shelly Sand Member KSSA Stubble Green Silt Member SGSI	No reference
	Grange-over-Sands Formation	GROS	1	Formations established by Thomas in Bowen (1999)	Thomas, pp.95–96
	Seacombe Sand Formation	SCMBS	2		
	Shirdley Hill Sand Formation	SSA	2 –1		
	Kenfig Formation	KNFIG	1	Defined by Bowen (1999)	Bowen, p.83
	Ynyslas Formation	YNYSS		After Cave and Hains (1986); included within the Kenfig Formation of Bowen (1999)	Bowen, p.90
	Easington Raised Beach Formation	EASN	7 or 9	After Smith and Francis (1967)	Thomas, p.98
	Breydon Formation	BRYD	1	Formations defined by Arthurton et al. (1994) for north-east Norfolk. Subdivided into informal members, the Basal or Lower Peat BRY1, Lower Clay BRY2, Middle Peat BRY3, Upper Clay BRY4 and the marginal Upper Peat BRY5	No reference
	North Denes Formation	NRD	1	Formations defined by Arthurton et al. (1994) for north-east Norfolk	
	Fenland Formation	FEND	7– 1	Ventris (1985), McCabe in Bowen (1999), Lewis in Bowen (1999). Formal members are the March Gravels MRCG, Abbey Sand and Gravel ABSG, and Nordelph Peat NP. Informal units of member status include the Fen Lower Peat FLPT, Crowland Bed CRWB, Barroway Drove Beds BYD, and Terrington Beds TTB	McCabe, p.14 Lewis, p.16
	Morston Formation	MORS	5e	Formerly Morston Member of Hunstanton Formation (Lewis in Bowen, 1999)	Lewis, p.18
	Nar Clay Formation	NACL	11	Nar Member of Lewis in Bowen (1999): includes Nar Valley Freshwater Bed NVFB	Lewis, p.18
	Romney Marsh Formation	No code	1	Formation established by Gibbard and Preece in Bowen (1999)	Gibbard and Preece, p.61
	West Sussex Coast Formation	No code	13–2	Component units described by Hodgson (1964)	Gibbard and Preece, pp.61–62
	Poole Harbour Formation	No code	1	Includes Poole Harbour Member of Gibbard and Preece in Bowen, 1999	Gibbard and Preece, p.64
	Gwent Levels Formation	GLEV	1	Wentlooge Member WLLEV (Gwynllwg Formation of Bowen, 1999)	Bowen, p.90
	Oldbury and Avonmouth Levels Formation	OALEV	1	After Welch and Trotter (1961) and Allen, J R L (2000c)	
	Somerset Levels Formation	SLEV	1	Defined by Campbell et al. in Bowen (1999)	Campbell et al., p.78
	Burtle Formation	BUB	11–5e	Defined as Burtle Formation with several members by Campbell et al. in Bowen (1999)	Campbell et al., pp.77–78
	St Erth Formation	SE	Pre–103	Edmonds et al. (1975); Roe et al. (1999)	No reference

Table 6 Subgroups, formations and members of the Britannia Catchments Group.

The catchment subgroups are defined principally by formations of fluvial deposits. The Britannia Catchments Group also embraces lithogenetic units including mass movement deposits (e.g. head, talus), organic deposits (e.g. peat), mountain regolith and cover sand. Where appropriate some of these units have been raised to formation status. Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned). MIS = Marine Isotope Stage (inferred correlation).

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
BRITANNIA CATCHMENTS GROUP (BCAT)	Northern Highlands and Argyll Catchments Subgroup (NHC)	Longman Gravel Formation	LNGR	2–1 (LLS)	After Fletcher et al. (1996). Longman Member of Clava Formation of Sutherland in Bowen (1999)	Sutherland, p.103
	Grampian Catchments Subgroup (GRCA)	Strath Spey Formation	SPEY	1	Alluvium and river terrace deposits of the River Spey and tributaries	No reference
	Subgroup unassigned	Moy Burn Palaeosol Formation	MBP	5d–a	Includes Odhar Gravel Member ODGR and Allt Odhar Peat Member AOPT (Allt Member and Odhar Member of the Allt Odhar Formation of Sutherland in Bowen, 1999); other units include Badentinan Sand Bed BNAN, Crossbrae Farm Peat Bed CBFMP, Berryley Peat Bed BLYP and Burn of Benholm Peat Bed BBP after Merritt et al. (2003)	Sutherland, pp.101–103, 105
		Teindland Palaeosol Formation	TELND	5e	After Merritt et al. (2003); includes Fernieslack Palaeosol Bed FSLCK	Sutherland, p.102
		Dalcharn Palaeosol Formation	DNPS	5e or possibly 11	After Fletcher et al. (1996). Rehiran Cryoturbate Member RECR Drummournie Biogenic Member DMBG	Sutherland p.103
	Tay Catchments Subgroup (TAYCA)	Strathtay Formation	STAY	2–1	Alluvium and river terrace deposits of the rivers Tay, Earn and tributaries	No reference
	Forth Catchments Subgroup (FORCA)	Forth Valley Formation	FOVA		Alluvium and river terrace deposits of the rivers Forth and other rivers flowing to the Firth of Forth	No reference
	Subgroup unassigned	Flanders Moss Peat Formation	FLMP	1	After Paterson et al. (1981) and Browne et al. (1984); Flanders Moss Member of Grangemouth Formation of Sutherland in Bowen (1999)	Sutherland, p.113
	Clyde Catchments Subgroup (CLYCA)	Clyde Valley Formation	CLVY	2–1	Defined by fluvial members (after Browne and McMillan, 1989) of the Clyde Valley Formation of Sutherland in Bowen (1999) including Law Sand and Gravel Member LAWSG (Law Borehole), Strathkelvin Clay and Silt Member KELV, and Lochwinnoch Clay Member LNCH (Lochwinnoch Borehole)	Sutherland, p.110
		Strathendrick Formation	SRCK		Fluvial members of the Clyde Valley Formation of Sutherland in Bowen (1999). Includes Kilmaronock Silt KILK and Endrick Sand ENDR members (Mains of Kilmaronock Borehole) (Browne and McMillan, 1989)	Sutherland, pp.111–112
	Subgroup unassigned	Clippens Peat Formation	CLPT		Defined from Linwood Borehole (Browne and McMillan, 1989)	Sutherland, pp.111–112
		Sourlie Organic Silt Formation	SOSI	3	Jardine et al. (1988), Sourlie, Ayrshire. Red Burn Member of Sourlie Formation of Sutherland in Bowen (1999)	Sutherland, p.109
	Tweed Catchments Subgroup (TWEED)	Tweed Valley Formation	TWVA	2–1	Alluvium and river terrace deposits of the River Tweed and tributaries	No reference
	Solway Catchments Subgroup (SYDR)	Solway Esk Valley Formation	SESKV		After McMillan et al. (in prep. 2010)	No reference

Note. Additional subgroups for the Shetland Isles, Orkney Isles, Outer and Inner Hebrides and Arran may be established.

Table 6 *Continued.*

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
BRITANNIA CATCHMENTS GROUP (BCAT) *continued*	Northumbria Catchments Subgroup (NCAT)	Coquet Valley Formation	CQU	2–1	Alluvium and river terrace deposits	No reference
		Tyne Valley Formation	TYNE			
		Wear Valley Formation	WEAR			
	Isle of Man Catchments Subgroup (IMCA)	Sulby Glen Formation	SUGL	2–1	Formations established by Thomas in Bowen (1999) and revised by Chadwick et al. (2001)	Thomas, p.94
		Curragh Formation	CAGH			
		Ballaugh Formation	BALGH			
		Glen Balleira Formation	GLNBA			
	Cumbria–Lancashire Catchments Subgroup (CLCA)	Ehen Alluvium Formation	EHEN	1	Formation established by Merritt and Auton (2000) with informal Middlebank Silt and Starling Sand and Gravel members	No reference
		Cumbrian Esk Valley Formation	CEVY	1	Alluvium and river terrace deposits, including Cumbrian Esk Alluvium Member CEAL	No reference
		Lune Valley Formation	LUNV	2–1	Formations defined for fluvial deposits of the Swettenham Formation and Lytham formations of Thomas in Bowen (1999)	Thomas, p.95
		Ribble Valley Formation	RIBV			
		Wyre Valley Formation	WYRV	2–1	Alluvium and two Wyre river terrace deposit members WYRE1, WYRE2	No reference
	Subgroup unassigned	Blelham Peat Formation	BHPT	2 (DS)–1	Blelham Formation of Thomas in Bowen (1999) and adopted by Merritt and Auton (2000); extended to include Racks Moss Peat, Healy Hill Organic Mud, Pow Beck Peat, Seacote Peat, and Bigholms Burn Gravel members and Bigholms Burn Peat and Redkirk Point Peat beds of the North Solway area (after units of the Redkirk Formation of Sutherland in Bowen, 1999)	Thomas, p.96; Sutherland, p.107
		Windermere Clay and Silt Formation	WMCS	2 (DS–WI)	After Coope and Pennington (1977), Pennington (1977, 1978)	Thomas, p.96
		Troutbeck Palaeosol	TBPS	5e or 11	After Boardman (1991). Mosedale Beck Peat Bed MOPT	Thomas, p.95
	Cheshire–North Wales Catchments Subgroup (CNWCA)	Mersey Valley Formation	MSYVA	2–1	Includes fluvial deposits of the Swettenham Formation and Lytham formations of Thomas in Bowen (1999)	Thomas, p.95
		Weaver Valley Formation	WVRVA	2–1	Alluvium and river terrace deposits	No references
		Dee Valley Formation	DEEVA			
		Conwy Valley Formation	CONWY			
		Clwyd Valley Formation	CLWYD			
	Subgroup unassigned	Four Ashes Sand and Gravel Formation	FASG	5e–5a	Defined by Worsley (1991). Four Ashes, Wolverhampton	Maddy, p.34
		Chelford Sand Formation	CHFDS		Congleton Sand of Evans et al. (1968); three members described by Worsley (1991)	Worsley, pp.32–34
		Trysull Silt Formation	TSLSI	11 or 9	Morgan (1973), Trysull, Staffordshire	
		Quinton Peat Formation	QUIP	11 or 9	Horton (1974, 1989a, b)	

Table 6 *Continued.*

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
BRITANNIA CATCHMENTS GROUP (BCAT) *continued*	Yorkshire Catchments Subgroup (YKC)	Currently lithogenetic units	Litho-genetic codes	1	Alluvium and river terrace deposits of the (Yorkshire) Ouse and its tributaries	No reference
		Sutton Sand Formation	SUTN	2	Gaunt et al. (1991)	Thomas, p.97
		Breighton Sand Formation	BREI	2	Bielby Sand BIES, Naburn Sand NABS and Skipwith Sand SKIS members; Bielby Peat Bed BIEP, Skipwith Peat Bed SKPE	No reference
	Trent–Witham Catchments Subgroup (TRWCA)	Trent Valley Formation	TRVA	12–1	Members after Brandon in Bowen (1999)	Brandon, p.41
		Bain Valley Formation	BAINV		Members after Brandon and Sumbler in Bowen (1999)	Brandon and Sumbler, pp.14–15
		Soar Valley Formation	SOARV		Members after Maddy in Bowen (1999)	Maddy, p.39
	Severn and Avon Catchments Subgroup (SACA)	Severn Valley Formation	SEVN	13–1	Members after Maddy and Sumbler in Bowen (1999)	Maddy and Sumbler, pp.34–36
		Warwickshire Avon Valley Formation	AVON		Members after Maddy et al. in Bowen (1999)	Maddy et al., pp.37–38
		Bristol Avon Valley Formation	BAVON		Members defined within the Avon Valley Formation of Campbell et al. in Bowen (1999)	Campbell et al., p.77
	West Wales Catchments Subgroup (WWACA)	Dovey Valley Formation	DOVEY	2–1	Tywi after Bowen (1999) but restricted to deposits of the Tywi valley. Other units are new terms	Bowen, pp.79–90 (Wales)
		Teifi Valley Formation	TEIFI			
		Tywi Valley Formation	TYWI			
		Neath Valley Formation	NEATH			
	Subgroup unassigned	Tregaron Formation	TREGN		Tregaron and Ystog formations after Bowen (1999).	
		Ystog Formation	YSTOG			

Table 6 *Continued.*

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
BRITANNIA CATCHMENTS GROUP (BCAT) *continued*	Ouse–Nene Catchments Subgroup (ONCA)	Nar Valley Formation	NARC	?6 –1	Marham, Pentney, and Wormegay WGAY members after Ventris (1985) and Lewis in Bowen (1999)	Lewis, p.18
		Lark Valley Formation	LKVY	?11–1	Lackford LFRD, Cavenham CAVM, Kentford KFRD, Fornham FHAM, Eriswell ERIS and Sicklesmere SKLM members after Lewis in Bowen (1999)	Lewis, p.21
		Cam Valley Formation	CAMV	?10–1	Barnwell Station BSTA, Sidgwick Avenue SKAV, Barnwell Abbey BABY, Barrington Village , Histon Road HNRD, Huntingdon Road HURD, Little Wilbraham LWIB, Bordeaux Pit BPIT and North Hall members after Lewis in Bowen (1999)	Lewis, pp.21–22
		Slea Valley Formation	SLVY	?–1	Includes Sleaford Sand and Gravel SDSG of Berridge et al. (1999)	No reference
		Nene Valley Formation	NENE	? 11–1	Woodston WTB, Grendon GREN and Ecton ECTN members	Green and Keen, pp.43–44
		Ouse Valley Formation	OUSE	?11–1	Biddenham BIDM, Felmersham FELM and Stoke Goldington STGO members	Green and Keen, p.44
	Yare Catchments Subgroup (YCAT)	Blakeney Valleys Formation	BLYV	5e –1	No subdivisions currently defined	No reference
		Bure Valley Formation	BURV	?11–1	No subdivisions currently defined	No reference
		Waveney Valley Formation	WAVV	11–1	Terrace deposits described by Moorlock et al. (2000a). Shotford, Bobbitshole and Broome BRME members, Wortwell Beds after Lewis in Bowen (1999). Hoxne Formation (Wymer in Bowen, 1999) assigned member status	Wymer, p.24, Lewis, p.25
		Yare Valley Formation	YV	? –1	Modified after Arthurton et al. (1994) and Moorlock et al. (2000a)	No reference
	Suffolk Catchments Subgroup (SUCA)	Currently lithogenetic units	Litho-genetic codes	Pre-5–1	Alluvium and river terrace and lacustrine deposits of rivers in Suffolk and Essex: see, for example Marks Tey Formation (not yet defined in BGS Lexicon)	Turner, p.26
	Thames Catchments Subgroup (THCAT)	Upper Thames Valley Formation	UTMS	12–1	River terrace deposit members of upper Thames (members of the Upper Thames Valley Formation of Gibbard and Sumbler in Bowen, 1999)	Gibbard, pp.47–48
		Maidenhead Formation	MNHD	12–1	River terrace deposit members and 'brickearth' (loessic) deposits after Ellison et al. (2004); members of the Maidenhead and Lower Thames formations of Gibbard, in Bowen, 1999)	Gibbard pp.48–51
		Kennet Valley Formation	KNTV	8–1	Members after Kennett (sic) Valley Formation (Collins in Bowen, 1999)	Collins, pp.51–52
		Medway Valley Formation	MEVA	Pre-13–1	Members after Bridgland in Bowen	Bridgland, pp.56–57

Table 6 *Continued.*

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
BRITANNIA CATCHMENTS GROUP (BCAT) *continued*	Solent Catchments Subgroup (SNTCA)	Meon Formation	MEON	Pre-13–1	Seven aggradations above alluvium (Hopson, 2000)	No reference
		Hamble Formation	HBLE		Three aggradations above alluvium (Edwards and Freshney, 1987)	No reference
		Itchen Formation	ITCH		Up to seven aggradations above alluvium (Edwards and Freshney, 1987)	No reference
		Test Formation	No code		Up to eleven aggradations above alluvium	No reference
		Hampshire Avon Formation	HAAV		Up to eleven aggradations above alluvium (Bristow et al., 1991). Includes the Ringwood Formation (formerly 'Older River Gravel Formation') and some members of the New Forest Formation of Gibbard and Preece in Bowen (1999)	Gibbard and Preece, p.63
		Dorset Stour Formation	DOST		Defined by Allen and Gibbard (1994). See also Bristow et al. (1991). Sway Member of New Forest Formation of Gibbard and Preece in Bowen (1999)	Gibbard and Preece, p.63
		Frome–Piddle Formation	FRPI		Defined by Allen and Gibbard (1994). Members described by Gibbard and Preece in Bowen (1999)	Gibbard and Preece, p.64
	Sussex Catchments Subgroup (SXCAT)	Cuckmere Formation	No code	?–1	Two aggradations above alluvium. Cuckmere Member of the Sussex Valleys Formation of Gibbard and Preece in Bowen (1999)	Gibbard and Preece, p.62
		Sussex Ouse Formation	No code		Four aggradations above alluvium. Lower Ouse Member of the Sussex Valleys Formation of Gibbard and Preece in Bowen (1999)	
		Arun Formation	ARUN		Seven aggradations AR1 to AR7 above alluvium. Arun Member of the Sussex Valleys Formation of Gibbard and Preece in Bowen (1999)	
		Adur Formation	No code		Three aggradations AD1 to AD3 above alluvium	No reference
		Sussex Rother Formation	RSX		Five aggradations RS1 to RS5 above alluvium	No reference
	South Kent Catchments Subgroup (SKCAT)	Kentish Rother Formation	No code	1	Stratotypes to be defined	No reference
		Pegwell Formation	No code	3–2	Gibbard and Preece in Bowen (1999)	Gibbard and Preece, p.61
		Kent Ouse Formation	OK	1	Terrace deposits OK1 to OK2	No reference
		Kentish Stour Formation	No code	10–3	Ten aggradations above alluvium. Possible members after Gibbard and Preece in Bowen (1999)	Gibbard and Preece, p.59
	Somerset Catchments Subgroup (SOCA)	Parrett Valley Formation	No code	9–2	Defined with several members by Campbell et al. in Bowen (1999)	Campbell et al., p.78
	Cornubian Catchments Subgroup (CCAT)	Petrockstow Valley Formation	PETRO	?pre-13–1	Five terrace deposit members above alluvium	No reference
		Tamar Valley Formation	TAMU	12–1	Eight terrace deposit members above alluvium	No reference
		Taw Valley Formation	TAW	12–1	Eleven terrace deposit members above alluvium	No reference
		Torridge Valley Formation	TORR	12–1	Nine terrace deposit members above alluvium)	No reference

Table 7a Formations and members of the Albion Glacigenic Group south of the Devensian ice sheet limit.
Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned).
MIS = Marine Isotope Stage (inferred correlation).

Group and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
ALBION GLACIGENIC GROUP (ALBI)	Briton's Lane Formation §	BRLA	?6	Lee et al. (2004). Beacon Hill Sand and Gravel Member, Briton's Lane Sand and Gravel Member, Corton Woods Sand and Gravel Member, Stow Hill Sand and Gravel Member (STHSG), Tottenhill Sand and Gravel Member	See Lewis, pp.15–20
	Ridgacre Formation	RIDG		Maddy in Bowen (1999)	Maddy, pp.34–36
	Sheringham Cliffs Formation §	SMCL	?10	Lee et al. (2004). Bacton Green Till Member, Ivy Farm Laminated Silt Member, Mundesley Sand Member, Runton Cliffs Sand and Gravel Member, Runton Till Member, Trimingham Clay Member, Trimingham Sand Member, Weybourne Town Till Member	See Lewis, pp.15–20
	Wolston Glacigenic Formation	WOLS	12 and 10	Sumbler in Bowen (1999) includes the following members: Oadby Till Member ODT, Moreton Member MTON, Thrussington Till Member THT. Numerous other informal and formal members	Sumbler, p.37
	Nurseries Glacigenic Formation	NURS	12	Horton (1974)	Maddy, pp.34–36
	Lowestoft Formation §	LOFT	12–10	Modified from Lewis in Bowen (1999). Aldeby Sand and Gravel Member, Haddiscoe Sand and Gravel Member, Lowestoft Till Member, Oulton Clay Member, Pleasure Gardens Till Member, Walcott Till Member, High Lodge Gravel Member. Informal Welton le Wold Formation might be part of this unit	Lewis, pp.19–20
	Happisburgh Glacigenic Formation §	HPTI	? 16	Member of North Sea Drift Formation after Lunkka (1994), Lewis in Bowen (1999) and Lee et al. (2004). California Till Member, Corton Sand Member, Happisburgh Sand Member, Happisburgh Till Member, Leet Hill Sand and Gravel Member, Starston Till Member	Lewis, pp.15–16
	Kenn Formation	KNN	? Pre-13 or 12	Glacigenic deposits of Avon and Somerset (Hawkins and Kellaway, 1971; Gilbertson and Hawkins, 1978); five members described by Campbell in Bowen, (1999)	Campbell, p.75
	Llanddewi Glacigenic Formation	LITI	?12	After Bowen, p.79 in Bowen, 1999, and Bowen, p.148 in Lewis and Richards, 2005	Bowen, p.79
	Penfro Till Formation	POTI	?16	After Bowen, p.147 in Lewis and Richards, 2005	Bowen, p.83

§ see below for relationship to previous stratigraphical schemes

Table 7b Subgroups, formations and members of the Albion Glacigenic Group north of the Devensian ice sheet limit.

Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned).
MIS = Marine Isotope Stage (inferred correlation).

Banham (1968, 1971)	**Lunkka (1994)**	**Bridge and Hopson (1985)**	**Previously defined formations**	**Lewis (pp.16–20 in Bowen, 1999)**	**Lee et al. (2004) and this report**	
Briton's Lane Sand and Gravel	Stow Hill Sands			Stow Hill Member	Briton's Lane Formation†	Briton's Lane, Corton Woods, Beacon Hill and Stow Hill and Tottenhill sand and gravel members
Pleasure Garden Till, Oulton Beds		Pleasure Gardens Till Oulton Beds	Lowestoft Formation after Mathers et al. (1987), Lewis (pp.15–20 in Bowen, 1999)	Pleasure Gardens, Oulton, members	Lowestoft Formation	Pleasure Gardens Till and Oulton Clay members
Marly Drift	Marly Drift Member (Lowestoft Till Formation)	Lowestoft Till (Chalky Boulder Clay of Baden-Powell, 1948)		Lowestoft Till Member	Lowestoft Formation	Lowestoft Till Member
				Weybourne Town Member of Lowestoft Fm	Sheringham Cliffs Formation	Weybourne Town Till Member
	Trimingham Sands and Clay Member		North Sea Drift Formation after Reid, (1882), Banham (1988), Hart and Boulton (1991), Lunkka (1994), Lewis (pp.15¬–20 in Bowen, 1999)	Mundesley -Trimingham Member	Sheringham Cliffs Formation	Trimingham Sand, Trimingham Clay and Ivy Farm Laminated Silt members
Gimingham Sands					Sheringham Cliffs Formation	Runton Cliffs Sand and Gravel Member
		Leet Hill Sands and Gravels*		Leet Hill Member	Happisburgh Formation*	Leet Hill Sand and Gravel Member
Corton Sands (Beds)		Corton Sands*		Corton Member		Corton Sands*
Third Cromer Till 'Contorted Drift'	Cromer Diamicton, Mundesley Diamicton members	Norwich Brickearth*		Cromer Member	Sheringham Cliffs Formation	Hanworth Till Member Bacton Green Till Member Runton Till Member
Mundesley Sands	Mundesley Sand Member (Upper Sands)				Sheringham Cliffs Formation	Mundesley Sand Member
Second Cromer Till	Walcott Diamicton Member			Walcott Member	Lowestoft Formation	Walcott Till Member
Intermediate Beds	Lower Mundesley Sands and Happisburgh Clays			Ostend Member	Happisburgh Formation*	Ostend Clay Member
First Cromer Till	Happisburgh Diamicton Member				Happisburgh Formation*	Corton Till Member
				Happisburgh Member	Happisburgh Formation*	Happisburgh Till Member

* Corton Formation of Arthurton et al. (1994), Moorlock et al. (2002a, 2002b),
† Overstrand Formation of Moorlock et al. (2000b, 2002a, 2002b)

Table 7c Subgroups, formations and members of the Albion Glacigenic Group, north of the Devensian ice-sheet limit.

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
ALBION GLACIGENIC GROUP (ALBI)	Shetland (Albion) Glacigenic Subgroup (SDAG)	South Wick Till Formation (currently undefined in BGS Lexicon)	No code	13–6	Mykura and Phemister (1976) and Hall (1993a); South Wick Member of the Shetland Formation (Sutherland in Bowen, 1999)	Sutherland pp.106–107
	Banffshire Coast and Caithness (Albion) Glacigenic Subgroup (BCAG)	Camp Fauld Till Formation	CFTI	possibly 6	Merritt et al. (2003)	Sutherland p.102
		Red Burn Till Formation	RDBRN		Merritt et al. (2003); Red Burn Member of Teindland Formation (Sutherland in Bowen, 1999)	
	East Grampian (Albion) Glacigenic Subgroup (EGAG)	Rottenhill Till Formation	ROTIL	possibly 6	Merritt et al. (2000) and Merritt et al. (2003); Rottenhill Member of Kirkhill Formation (Sutherland in Bowen, 1999). Includes the Corsend Gelifluctate Bed CSEND	Sutherland pp.100–102
		West Leys Sand and Gravel Formation	WLSG	possibly 6 or 12	Merritt et al. (2000) and Merritt et al. (2003). Includes Camphill Gelifluctate Bed CHLGE and Swineden Sand Bed SWDEN	
		Bellscamphie Till Formation	BLTI	possibly 6 or 12	Hall and Jarvis (1995), Merritt et al. (2000, 2003); Elton Member of Bellscamphie Formation of Sutherland in Bowen (1999)	
		Tillybrex Sand and Gravel Formation	TBXSG	possibly 6	After Merritt et al. (2003)	
		Pishlinn Burn Formation	PIGB	possibly 6 or earlier	After Read, 1923; Merritt et al., 2003	
		Crossbrae Till Formation	CBTIL	possibly 6	Crossbrae Member of Kirkhill Formation of Sutherland in Bowen, (1999). Includes Crossbrae Gelifluctate Bed CBGEL	
		Birnie Gravel Formation	BEGR	possibly 6 or 12	Auton et al. (2000) and Merritt et al. (2003)	
		Pitscow Sand and Gravel Formation	POWSG	possibly 8 or older	Merritt et al. (2003); members of Kirkhill Formation (Sutherland in Bowen, 1999). Includes Kirkhill Palaeosol Bed KHLPS and Kirkton Gelifractate Bed KTNGF	Sutherland p.99
		Leys Gravel Formation	LEY	possibly 8 or older		
		Leys Till Formation	LEYST	possibly 8 or older		
	Logie–Buchan (Albion) Glacigenic Subgroup (LBAG)	Benholm Clay Formation	BECL	possibly 6 or 12	Auton et al. (2000); Merritt et al. (2003)	No reference
	Central Grampian (Albion) Glacigenic Subgroup (CGAG)	Boyne Craig Till Formation	BCTI	possibly 6 or 12	Peacock and Merritt (2000b); Merritt et al. (2003)	No reference
		Pattack Till Formation	PATT	possibly 6	Keith Formation of Merritt (1999)	No reference
		Ailleag Diamicton Formation	AILL	possibly 6 or 12	After Merritt, p.143 in Lucas et al. (2004)	No reference
		Deanshillock Sand and Gravel Formation	DHKG	probably 6	After Merritt et al. (2003); includes Orbliston Sand Bed	Sutherland p.102
	Inverness (Albion) Glacigenic Subgroup (IAG)	Craig an Daimh Gravel Formation	CDGR	possibly 6 or 12	Craig an Daimh Member of Dalcharn Formation of Sutherland in Bowen (1999)	Sutherland p.103
		Drummore Gravel Formation	DRGR		Merritt (1992); members of the Clava Formation of Sutherland in Bowen (1999)	Sutherland p.103
		Cassie Till Formation	CASS			
		Suidheig Till Formation	SUTI		Dearg Till of Walker et al. (1992); Dearg Member of Allt Odhar Formation of Sutherland in Bowen (1999)	Sutherland p.105

Table 7c *Continued.*

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
ALBION GLACIGENIC GROUP (ALBI)	Irish Sea Coast (Albion) Glacigenic Subgroup (ISCAG)	Drigg Till Formation	DGTI	6	Glacigenic formation in West Cumbria established by Merritt and Auton (2000); Akhurst et al. (1997)	No reference
		Kiondroughad Formation	KDRD	4, 6 or 8	Formations revised by Chadwick et al. (2001). Ayre Lighthouse Formation formerly the Isle of Man Formation of Thomas in Bowen (1999)	Thomas, pp.91–94
		Ayre Lighthouse Formation	AYRL	8, 10 or 12		
		Oakwood Glacigenic Formation	OKWDG	?6 or ?12	Worsley in Bowen (1999)	Worsley, pp.32–34
		Seisdon Glacigenic Formation	SEIS	10 or 12	Worsley in Bowen (1999)	Worsley, p.32
	Central Cumbria (Albion) Glacigenic Subgroup (CCAG)	Thornsgill Till Formation	THGTI	possibly 10 or 12	After Thomas in Bowen (1999)	Thomas, p.95
	North Sea Coast (Albion) Glacigenic Subgroup) (NSCA)	Warren House Gill Till Formation	WAHL	?6	Thomas in Bowen (1999). Warren House Gill Loess Bed (Trenchman, 1920)	Thomas, p.98

Table 8 Subgroups, formations and members of the Caledonia Glacigenic Group mainly north of the Devensian ice sheet limit.

Lex Code = Codes from the BGS Lexicon of Named Rock Units (where assigned).
MIS = Marine Isotope Stage (inferred correlation).

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
CALEDONIA GLACIGENIC GROUP (CALI)	Shetland Glacigenic Subgroup (SHETG)	Burrier Wick Till Formation	BWTI	2	Mykura and Phemister (1976) and Hall (1993a, b); members of the Shetland Formation (Sutherland in Bowen, 1999)	Sutherland, p.107
		Sandness Till Formation	No code	2		
	Western Isles Glacigenic Subgroup (WISG)	Port Beag Till Formation	PBTI	2	von Weymarn and Edwards (1973); Port Beag Member of the Lewis Formation (Sutherland in Bowen, 1999)	Sutherland, p.106
		Lewis Till Formation	LEWTI	? 4	von Weymarn and Edwards (1973); Dun Member of the Lewis Formation, formerly Ruaival Drift (Sutherland, 1984; Sutherland in Bowen, 1999)	Sutherland, p.106
	Inverness Glacigenic Subgroup (INVG)	Finglack Till Formation	FINT	2 (DS)	Merritt et al. (1995) and Fletcher et al. (1996); Baddock Till Member BTI, Ardersier (Baddock Member of Clava Formation of Sutherland in Bowen, 1999) and Balmakeith Till Member BALT, Nairn–Forres	Sutherland, p.103
		Kincurdy Silts Formation	KSI	2 (DS)	Glaciolacustrine deposits, Black Isle	
		Red Craig Gravels Formation	RCGR	4	Fletcher et al. (1996). Sutherland in Bowen (1999). Cromarty Firth	Sutherland , p.103
		Athais Till Formation	ATTI	? 4	Allt Odhar, Inverness. Includes informal Kincraig Paraglacial Bed	
	Northwest Highlands Glacigenic Subgroup (NWHG)	Ullapool Gravel Formation	ULGR	2 (WI)	Stoker et al. (2009)	No references
		Assynt Glacigenic Formation	ASGL	2 (DS)	After Stoker et al. (2009) and Bradwell (2003): Allt an t-Strathain Till Member STTI, Allt na h-Airbhe Member ANHA (almost exclusively offshore), Glen Douchary Member and Rhiroy Member RHIR	
		Loch Broom Till Formation	LBTI	3–2 (DS)	Stoker et al. (2009)	
		Reay Burn Till Formation	REBU	2 (DS)	Caithness and Sutherland (Auton, 2003)	
		Dunbeath Till Formation	DUTI	4	Caithness and Sutherland (Auton, 2003)	No reference

Table 8 *Continued.*

Group	Subgroup	Formation	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
CALEDONIA GLACIGENIC GROUP (CALI) *continued*	Banffshire Coast and Caithness Glacigenic Subgroup (BCD)	Reisgill Burn Till Formation	REDR	2 (DS)	Forse Till Member (Auton, 2003), Caithness and Sutherland	No reference
		Alturlie Gravels Formation	ALGR	2 (DS)	Fletcher et al. (1996), Merritt et al. (2003), Moray Firth. Bothyhill Gravels Member BOGR, Braicklaich Sand Member BRSA	Sutherland, p.103
		Ardersier Silts Formation	ARDS		Fletcher et al. (1996), Merritt et al. (2003), Kirkton Clay Member KICL	
		Grange Hill Sand Formation	GRHS		After Peacock et al. (1968); East Grange Till EGTI, Hempriggs Sand HRGS, and Milton Hill Silt MHSI members	No reference
		Kirk Burn Silt Formation	KBSI		(Peacock, 1971 and Merritt et al., 2003)	Sutherland, pp.99–102
		Essie Till Formation	ESTI		Arnhash Till Member (after Peacock and Merritt, 1997, and Merritt et al., 2003)	
		Blackhills Sand and Gravel Formation	BLSG		Auchmeddon Gravel Member AMNGR (Hall et al., 1995; Merritt et al., 2000, 2003), Kirkhill Church Sand Member KHLCH (Merritt et al., 2000, 2003)	
		Whitehills Glacigenic Formation	WHGL		Corse Diamicton Member CORSE (Hall and Jarvis, 1993), Pitlurg Farm Till Member PGTI (Hall and Jarvis, 1995), Aldie Till Member ALDTI, Bearnie Till Member, Anderson Drive Diamicton Member (Merritt et al., 2003)	
		Howe of Byth Gravel Formation	HOBGR	possibly 3	Hall et al. (1995)	
		Clava Shelly Formation	CLSH	3	Merritt (1992), Moray Firth; Clava Lodge Clay Member CLOCL, Culdoich Till Member CUTI, Dalroy Sand Member DROY	
	East Grampian Glacigenic Subgroup (EGD)	Blairdaff Moraine Formation	BDMO	2 (DS)	Formations of Merritt et al. (2003)	Sutherland, p.101
		Lochton Sand and Gravel Formation	LOSG			
		Glen Dye Silts Formation	GDSI			
		Banchory Till Formation	BATI			
		Byth Till Formation	BYTIL		Formation of Merritt et al. (2003); Crovie Till Member CRTI	
		Hythie Till Formation	HYTIL		Connell et al. (1984). Sandford Bay Till Member, Manse Gelifluctate Bed (Merritt et al., 2003)	
	Logie–Buchan Glacigenic Subgroup (LBD)	Ugie Clay Formation	UGCL	2 (DS)	Tullos Clay Member TSCL (Merritt et al., 2003)	Bellscamphie Formation of Sutherland, p.102
		Hatton Till Formation	HATT		Formations of Merritt et al. (2003)	
		Kippet Hills Gravels Formation	KHG			
		Auchleuchries Sand and Gravel Formation	ALSSG			No references
	Central Grampian Glacigenic Subgroup (CGDR)	Ardverikie Till Formation	ARDT	2 (DS)	Formations of Merritt (1999)	No references
		Ceardaich Sand and Gravel Formation	CEAR	? 3		
		Linn of Pattack Silt Formation	LPSI	? 3		
		Carn Monadh Gravel Formation	CMOGR	2 (DS)		
		Beinn an Uain Till Formation	BUTI	2 (DS)	Ruallan Till Member RNTI Cantray Till Member CYTI	
		Old Hythe Till Formation	OHT	2 (DS)		
		Gaick Plateau Moraine Formation	GPM	2 (DS)		
		Drumbeg Sand and Gravel Formation	DRBG	2 (LLS)	Formations of Browne and McMillan (1989), Loch Lomond and Drymen district. Members of Clyde Valley Formation of Sutherland in Bowen (1999)	Sutherland, p.111
		Blane Water Silt Formation	BLAW			
		Gartocharn Till Formation	GATI			

Table 8 *Continued.*

Group and Lex code	Subgroup and Lex codes	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
CALEDONIA GLACIGENIC GROUP (CALI) *continued*	Mearns Glacigenic Subgroup (MDR)	Drumlithie Sand and Gravel Formation	DSG	2 (DS)	Formations of Merritt et al. (2003); members of the Mill of Forest Formation (Sutherland in Bowen, 1999), Aberdeen – Stonehaven; Arbikie Diamicton Member ARBI	Sutherland, p.114
		Ury Silts Formation	USI			
		Mill of Forest Till Formation	MFT			
	Midland Valley Glacigenic Subgroup (MVG)	Broomhouse Sand and Gravel Formation	BHSE	2 (DS - WI)	Greenoakhill Sand and Gravel Member GOHL, Ross Sand Member RSSA, Bellshill Clay Member BILL (Ross, Bellshill and Broomhouse formations of Browne and McMillan, 1989; members of Clyde Valley Formation of Sutherland in Bowen, 1999)	Sutherland, p.109
		Wilderness Till Formation	WITI	2 (DS)	In central Ayrshire two members defined after Jardine et al. (1988):	
		Cadder Sand and Gravel Formation	CADR	? 4	Formations of Browne and McMillan (1989), Glasgow district. Members of Clyde Valley Formation of Sutherland in Bowen (1999).	
		Broomhill Clay Formation	BRLL	? 4		
		Baillieston Till Formation	BNTI	? 4		
		Armsheugh Sand and Gravel Formation	AHSG	4 or earlier	Formation after Jardine et al. (1988), central Ayrshire	Sourlie Formation of Sutherland, pp.107–108 in Bowen (1999)
		Littlestone Till Formation	LSTI	4 or earlier	Formation after Jardine et al. (1988), central Ayrshire. Includes Lawthorn Diamicton Member LTND	
	Southern Uplands Glacigenic Subgroup (SUDR)	Kirkbean Sand and Gravel Formation	KN	2 (DS)	North Solway (McMillan et al., in prep. 2010)	No references
		Dalswinton Moraine Formation	DSMO			
		Mouldy Hills Gravel Formation	MOHI			
		Langholm Till Formation	LHTI		New Abbey Till Member NATI	
	Borders Glacigenic Subgroup (BDRGL)	Norham Till Formation	NMTI		Merse of Berwickshire (Coldstream, Sheet 26W in prep.)	
	Cheviot Glacigenic Subgroup (CHVG)	Kale Water Till Formation	KWTI		Cheviot Hills (after Mitchell, 2005, 2008); Linhope Spout Member (after Thomas in Bowen, 1999)	Thomas, p.98

Table 8 *Continued.*

Group and Lex code	Subgroup and Lex codes	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
CALEDONIA GLACIGENIC GROUP (CALI) *continued*	Irish Sea Coast Glacigenic Subgroup (ISCG)	Kilblane Sand and Gravel Formation	KBSG	2 (DS)	North Solway (McMillan et al., in prep. 2009)	No references
		Cullivait Silt Formation	CUS			
		Kerr Moraine Formation	KEMO		Marchfield Moraine Member MMO	
		Gretna Till Formation	GRET		North Solway (McMillan et al., in prep. 2009). Plump Bridge Till Member PLBT	
		Plumpe Sand and Gravel Formation	PLSG		Plumpe Farm Sand Member PFS and Loganhouse Gravel Member LOGG	
		Chapelknowe Till Formation	CHAK	? 2 (DS) or 4	North Solway (McMillan et al., in prep. 2009)	
		Morecambe Bay Formation	MOBAY	2 (DS)	Glacigenic formations in Cumbria. After Thomas in Bowen (1999)	Thomas, pp.95–96
		Great Easby Clay Formation	GECL		Great Easby Member of Irthing Formation of Thomas in Bowen (1999)	Thomas, pp.95–96
		Gillcambon Till Formation	GCBTI	4	Defined after Goodchild (1875), Eastwood et al. (1968) and Huddart (1971b)	No reference
		Gosforth Glacigenic Formation	GOGL	2 (DS)	West Cumbria, Merritt and Auton (2000): Drigg Beach Till DBTI, Drigg Holme Sand DGHS, Drigg Moorside Silt DGMS, Fishgarth Wood Till FWTI, Gutterfoot Sand GFSA, How Man Till HMTI, Kirkland Wood Sand and Gravel KWSG, Low Mill Gravel LMGV, Meadow House Clay MWHO, Peckmill Sand PKSA, Peel Place Sand and Gravel PPSG, Rothersyke Till RSTI, St Bees Till STBT members	No references
		Aikbank Farm Glacigenic Formation	AIK		West Cumbria, Merritt and Auton (2000): Green Croft Till GCTI, Holmeside Clay HSCLY, Mainsgate Wood Sand and Gravel MGW, Whinneyhill Coppice Clay WCC members	
		Seascale Glacigenic Formation	SEAG	3 to 2	Merritt and Auton (2000): Barn Scar Sand and Silt BSSS, Ravenglass Till RVTI,Lowca Till LCTI, St Bees Sand and Gravel SBSG, St Bees Silt SBSI, Townhead Boulder Gravel THBG, Meadow View Sand and Gravel MVSG, Low Wath Till LWTI, Catgill Wood Sand and Gravel CGWD, Ehen Valley Silt EVSI and Ehen Valley Sand and Gravel EVSG members	
		Carleton Silt Formation	CNSI	? 4	Merritt and Auton (2000)	
		Jurby Formation	JURBY	2 (DS)	Isle of Man glacigenic formations. Thomas in Bowen (1999) and Chadwick et al. (2001)	Thomas, p.94
		Orrisdale Formation	ORRIS			
		Shellag Formation	SHLAG			
		Stockport Glacigenic Formation	STPTG		Defined by Worsley (1991). Maddy in Bowen (1999). In Lancashire the Kirkham Till Member KMGL after Thomas in Bowen (1999)	Maddy, p.34; Thomas, p.95
		Brewood Till Formation	BDTI	2 (DS)	Staffordshire	No reference
		St Asaph Glacigenic Formation	SAGL	2 (DS)	North and west Wales: Lleyn Till Member LLEYN, Llangelynin Till Member LNTI	Bowen, p.84 and 89
		Cardigan Bay Formation	CBAY	4 to 2 (DS)	Offshore formation	Cameron, pp.137–138
		Teifi Clay Formation	TFICL	2 (DS)	After Hambrey et al. (2001)	No reference

Table 8 *Continued.*

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
CALEDONIA GLACIGENIC GROUP (CALI) *continued*	Central Cumbria Glacigenic Subgroup (CCDR)	Wolf Crags Formation	WOCR	2 (LLS)	Thomas in Bowen (1999). Wolf Crags Till and Wolf Crags Gravel members	Thomas, p.96
		Baronwood Sand and Gravel Formation	BWSG	2 (DS)	Baronwood Member of Penrith Formation of Thomas in Bowen (1999)	Thomas, p.96
		Greystoke Till Formation	GYTI	2 (DS)	After Eastwood et al. (1968) and Huddart (1971b); correlatives of Eden and Lanerstock tills of Thomas in Bowen (1999). Edenside Till Member (EDTI); Eden Member of Thomas in Bowen (1999)	Thomas, pp.95–96
		Blengdale Glacigenic Formation	BLGL	2	Merritt and Auton (2000): Holmrook Till (HRTI), Scale Beck Till (SBTI), Bark Butts Silt (BBSI), Whin Garth Gravel (WGGV) members; Kendal Till Member (KLTI) in southern Lake District	No reference
		Lobbs Sand and Gravel Formation	LOBSG	2 (DS)	Boardman (1982)	No reference
		Threlkeld Till Formation	TKTI	2 (DS)	After Thomas in Bowen (1999)	Thomas, p.96
		Maudsyke Till Formation	MSYT	? 4	Merritt and Auton (2000)	
	Manx Glacigenic Subgroup (MXGL)	Snaefell Formation	SNAEF	4–2	Isle of Man paraglacial formation. Thomas in Bowen (1999) and Chadwick et al. (2001)	Thomas, p.94
	North Sea Coast Glacigenic Subgroup (NSG)	Holderness Formation	HOLD	2 (DS)	Described by Catt and Penny (1966); includes Sewerby , Skipsea Till SKTI and other members, and Dimlington Bed DIMS (McCabe and Bowen in Bowen, 1999): Holkham Till HOTI, Ringstead Sand and Gravel RDSG and Red Lion Till RLTI members	McCabe and Bowen, p.13
		Teesside Clay Formation	TSDC		Horton et al. (1999)	Thomas, p.98
		Horden Till Formation	HNTI		Elwick Moraine ELWK, Prismatic Clay PRIS members, Stone et al. (2009)	
		Peterlee Sand and Gravel Formation	PESG		Ryhope Sand Member RHYS, Stone et al. (2009)	
		Blackhall Till Formation	BHTI		Durham Lower Till of Francis (1970); Stone et al. (2009)	
		Limekiln Gill Gravel Formation	LGGR		Lower Gravels of Smith and Francis (1967)	

Table 8 *Continued.*

Group and Lex code	Subgroup and Lex code	Defining formations	Lex code	Approx. MIS	References to descriptions and subdivisions	Reference in Bowen, 1999
CALEDONIA GLACIGENIC GROUP (CALI) *continued*	North Pennine Glacigenic Subgroup (NPEG)	Pocklington Gravel Formation	POCKG	2 (DS)	Sheet E71 Selby (BGS, 2008)	Thomas, p.97
		Alne Glaciolacustrine Formation	ALNE		Cooper and Burgess (1993)	
		Elvington Glaciolacustrine Formation	ELV		Sheet E71 Selby (BGS, 2008)	
		Hemingbrough Glaciolacustrine Formation	HEM		Hemingbrough Formation of Thomas in Bowen (1999): Thorganby Clay Member THOR, Park Farm Clay PAF, Lawns House Farm Sand Member LHF	
		Vale of York Formation	VYORK		Poppleton Glaciofluvial POPP, Crockley Hill Esker CRHE, Newby Wiske-Aldwark Esker, Hunsingore Esker, York Moraine YORKM, and Escrick Moraine ESKRM members	
		Ebchester Sand and Gravel Formation	EBSG		Allen and Rose (1986)	Thomas, p.98
		Wear Till Formation	WETI		Butterby Till Member BUTTI, Stone et al. (2009)	
		Tyne and Wear Glaciolacustrine Formation	TYWE		Pelaw Clay Member PELC, Stone et al. (2009)	
		Maiden's Hall Sand and Gravel Formation	MHSG		Basal Gravels of Smith (1981); Stone et al. (2009)	
		Acklinton Till Formation	ANTI		Stone et al. (2009)	
		Yorkshire Dales Till Formation	YDTI		Stone et al. (2009)	
		Stainmore Forest Till Formation	SFTI		Stone et al. (2009)	
	Wales Glacigenic Subgroup (WALES)	Shrewsbury Glacigenic Formation	SHREW	2 (DS)	Defined by Worsley (1991). Maddy in Bowen (1999)	Maddy, p.34
		Eryri Glacigenic Formation	ERYG		Bowen, p.86 in Bowen (1999)	Bowen, pp.79–90
		Plynlimon Glacigenic Formation	PLYNT		Elenid Till ELTI, Ruabon Till RBNTI, and Merion Till MNTI members	
		Brecknockshire Glacigenic Formation	BNOCK		Hereford Till HDTI, and Langland Till LDTI members	
		Glamorgan Glacigenic Formation	GLGL		After Woodland and Evans (1964)	

Table 9 Correlation chart for the Northern and Western Highlands and islands.

Epoch	Devensian/Weichselian	British/European Stage and approximate correlation with MIS	Western Isles	Shetland and Orkney	South-west Highlands	North-west Highlands
Holocene		1	BRITANNIA CATCHMENTS GROUP Subgroup for fluvial deposits undefined; currently lithogenetic units (MIS 2-1) BRITISH COASTAL DEPOSITS GROUP Mostly lithogenetic units (MIS 2-1); Northton Formation (Sutherland p.106 in Bowen, 1999) (MIS 1)	Subgroup for fluvial deposits undefined; currently lithogenetic units (MIS 2-1) BRITISH COASTAL DEPOSITS GROUP Currently lithogenetic units (MIS 2-1)	NORTHERN HIGHLANDS AND ARGYLL CATCHMENTS SUBGROUP Fluvial deposits currently defined as lithogenetic units (MIS 2–1) Argyle Formation (Sutherland p.111 in Bowen, 1999) BRITISH COASTAL DEPOSITS GROUP Currently lithogenetic units (MIS 2–1)	NORTHERN HIGHLANDS AND ARGYLL CATCHMENTS SUBGROUP Fluvial deposits currently defined as lithogenetic units (MIS 2–1) BRITISH COASTAL DEPOSITS GROUP Currently lithogenetic units (MIS 2–1)
Late Pleistocene	Devensian/Weichselian	Loch Lomond Stadial (2-1)			Fluvial, lacustrine and organic sediments of Loch Laggan East (Palmer and MacLeod, 2008) Ardyne Formation (Sutherland p.110–111 in Bowen, 1999) including Killellan, Toward and Ardyne Point members (correlatives of the Clyde Clay Formation)	NORTHWEST HIGHLANDS GLACIGENIC SUBGROUP **Assynt Glacigenic Formation:** *Glen Douchary Member*
		Windermere Interstadial (2)				**Ullapool Gravel Formation**
		Dimlington Stadial (2)	WESTERN ISLES GLACIGENIC SUBGROUP Port Beag Till Formation	SHETLAND GLACIGENIC SUBGROUP Currently lithogenetic units (MIS 5d-2) Burrier Wick Till Formation (Burrier Wick Member of Shetland Formation of Sutherland pp.106–107 in Bowen, 1999) Sandness Till Formation (Sandness Member of Shetland Formation of Sutherland pp.106–107 in Bowen, 1999)	CENTRAL GRAMPIAN GLACIGENIC SUBGROUP Currently lithogenetic units (MIS 5d–2) Roy Formation (Sutherland p.111 in Bowen, 1999) Achnacree Sand and Gravel Formation (Etive Formation of Sutherland pp.110–111 in Bowen, 1999)	**Assynt Glacigenic Formation** Allt an t-Strathain Till Member Rhiroy Member Allt na h-Airbhe Member **Loch Broom Till Formation**
		3	*Tolsta Head Member* of Lewis Formation (Sutherland p.106 in Bowen, 1999)			
		4	Lewis Till Formation (possibly MIS 4)			
		5d-a	*Goa Galson Bed* of Lewis Formation (Sutherland p.106 in Bowen, 1999)	*Dale Beds and Sel Ayre Beds* of Shetland Formation (Sutherland p.106–107 in Bowen, 1999)		
		Ipswichian/Eemian (5e)				
Mid Pleistocene		6				
		7				
		8			*Barr and Tangy Glen Members* of Cleongart Formation of Sutherland p.111 in Bowen, 1999)	
		9				
		10				
		Hoxnian/Holsteinian (11)		*Fugla Ness Beds* (member of Shetland Formation of Sutherland p.106 in Bowen, 1999)		
		Anglian/Elsterian (12)		SHETLAND (ALBION) GLACIGENIC SUBGROUP *South Wick Member* of Shetland Formation (Sutherland p.106 in Bowen, 1999) (possibly MIS 12)		

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
CALEDONIA GLACIGENIC GROUP
ALBION GLACIGENIC GROUP

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Caithness		Cromarty Firth		Beauly Firth and inner Moray Firth	
NORTHERN HIGHLANDS AND ARGYLL CATCHMENTS SUBGROUP Fluvial deposits currently defined as lithogenetic units (MIS 2–1)	**BRITISH COASTAL DEPOSITS GROUP** Currently lithogenetic units (MIS 2–1)	**NORTHERN HIGHLANDS AND ARGYLL CATCHMENTS SUBGROUP** Fluvial deposits currently defined as lithogenetic units (MIS 2–1)	**BRITISH COASTAL DEPOSITS GROUP** Foulis Silt Formation Lemlair Sand Formation Ardullie Silt Formation	Except for Longman Gravel Fm. (below) fluvial deposits currently defined as lithogenetic units (MIS 2–1) Moniack Peat Formation *Newton Burn Gravel Bed*	**BRITISH COASTAL DEPOSITS GROUP** Beauly Silt Formation
			Balmeanach Silt Formation	**NORTHERN HIGHLANDS AND ARGYLL CATCHMENTS SUBGROUP** Longman Gravel Formation	Barnyards Silt Formation
			Culbokie Silt Formation		**Kessock Bridge Silt Formation**
NORTHWEST HIGHLANDS GLACIGENIC SUBGROUP **Reay Burn Till Formation** Thormaid Till Member Broubster Till Member	**BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP** **Reisgill Burn Till Formation** Forse Till Member	**INVERNESS GLACIGENIC SUBGROUP** **Finglack Till Formation** **Kincurdy Silts Formation**		**INVERNESS GLACIGENIC SUBGROUP** **Finglack Till Formation** Baddock Till Member Balamakeith Till Member	**BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP** **Alturlie Gravels Formation** Bothyhill Gravels Member Braicklaich Sand Member **Ardersier Silts Formation** Kirkton Clay Member
					Clava Shelly Formation (glacial raft) Dalroy Sand Member Culdoich Till Member Clava Lodge Clay Member
Dunbeath Till Formation (possibly MIS 4)		Red Craig Gravels Formation			
				INVERNESS (ALBION) GLACIGENIC SUBGROUP Drummore Gravel Formation (possibly MIS 6 or 12) Cassie Till Formation (possibly MIS 6 or 12)	

Table 10 Correlation chart for the Grampian Highlands.

Epoch, British/European Stage and approximate correlation with MIS			Strath Nairn, Allt Odhar/Dalcharn	Dalwhinnie district and Gaick Plateau		Teindland/Elgin		
Holocene	1		**BRITANNIA CATCHMENTS GROUP** **GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1) **Strath Spey Formation**	**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)		**BRITISH COASTAL DEPOSITS GROUP** Currently mainly lithogenetic units (MIS 2-1)	**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)	
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)						
		Windermere Interstadial (2)						
		Dimlington Stadial (2)	**CENTRAL GRAMPIAN GLACIGENIC SUBGROUP** **Carn Monadh Gravel Formation** **Beinn an Uain Till Formation** Ruallan Till Member Cantray Till Member	**CENTRAL GRAMPIAN GLACIGENIC SUBGROUP** **Ardverikie Till Formation**	**Gaick Plateau Moraine Formation**	**Errol Clay Formation** Spynie Clay Member	**CENTRAL GRAMPIAN GLACIGENIC SUBGROUP** Waterworks Till Formation Tofthead Till Formation	**BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP** **Ardersier Silts Formation** Kirkton Clay Member **Grange Hill Sand Formation** East Grange Till Member Hempriggs Sand Member Milton Hill Silt Member Altonside Till Formation
		3		**CENTRAL GRAMPIAN GLACIGENIC SUBGROUP** **Ceardaich Sand and Gravel Formation** (possibly MIS 3) **Linn of Pattack Silt Formation** (possibly MIS 3)				
		4	**INVERNESS GLACIGENIC SUBGROUP** **Athais Till Formation** *Kincraig Paraglacial Bed*				Woodside Diamicton Formation	
		5d-a	**Moy Burn Palaeosol Formation** Allt Odhar Peat Member Odhar Gravel Member			**Moy Burn Palaeosol Formation** *Badentinan Sand Bed*		
	Ipswichian/ Eemian (5e)		**Dalcharn Palaeosol Formation (possibly MIS 11)** *Drummournie Biogenic Member* *Rehiran Cryoturbate Member*			**Teindland Palaeosol Formation**		
Mid Pleistocene	6		**INVERNESS (ALBION) GLACIGENIC SUBGROUP** **Craig an Daimh Gravel Formation** (possibly MIS 6 or 12) **Suidheig Till Formation** (possibly MIS 6 or 12)	**CENTRAL GRAMPIAN (ALBION) GLACIGENIC SUBGROUP** **Pattack Till Formation** (possibly MIS 6)	**CENTRAL GRAMPIAN (ALBION) GLACIGENIC SUBGROUP** **Ailleag Diamicton Formation** (possibly MIS 6 or 12)		**CENTRAL GRAMPIAN (ALBION) GLACIGENIC SUBGROUP** **Deanshillock Gravel Formation,** *Orbliston Sand Bed*	**BANFFSHIRE COAST & CAITHNESS (ALBION) GLACIGENIC SUBGROUP** **Red Burn Till Formation** (possibly MIS 6)
	7							
	8							
	Hoxnian/ Holsteinian (11)							
	Anglian/Elsterian (12)							
Pliocene								

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
CALEDONIA GLACIGENIC GROUP
ALBION GLACIGENIC GROUP
RESIDUAL DEPOSITS GROUP

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Boyne Limestone Quarry / Keith		Gardenstown / Banff		Byth / Crossbrae		Kirkhill/ Leys
GRAMPIAN CATCHMENTS SUBGROUP currently mainly lithogenetic units (MIS 2-1)		**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)	**BRITISH COASTAL DEPOSITS GROUP** Currently mainly lithogenetic units (MIS 2-1)	**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)		**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)
				Todholes Gravel Bed		
Garral Hill Gelifluctate Bed *Garral Hill Peat Bed*				*Thinfolds Peat Bed*		
BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP	**CENTRAL GRAMPIAN GLACIGENIC SUBGROUP**	**BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP**	**EAST GRAMPIAN GLACIGENIC SUBGROUP**	**BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP**	**EAST GRAMPIAN GLACIGENIC SUBGROUP**	**BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP**
Kirk Burn Silt Formation		**Kirk Burn Silt Formation**				Manse Gelifluctate Bed
Essie Till Formation		**Essie Till Formation**				
Arnhash Till Member		Arnhash Till Member		**Blackhills Sand and Gravel Formation**		**Blackhills Sand and Gravel Formation**
Blackhills Sand and Gravel Formation		**Blackhills Sand and Gravel Formation**		Auchmeddon Gravel Member		Kirkhill Church Sand Member
	Old Hythe Till Formation		**Byth Till Formation**		**Byth Till Formation**	**EAST GRAMPIAN GLACIGENIC SUBGROUP**
			Crovie Till Member			**Hythie Till Formation**
						BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP
Whitehills Glacigenic Formation		**Whitehills Glacigenic Formation**				**Whitehills Glacigenic Formation**
						Corse Diamicton Member
				Howe of Byth Gravel Formation	Crossbrae Gelifluctate Bed (parent unit: Crossbrae Till Formation)	Corsend Gelifluctate Bed (parent unit: Rottenhill Till Formation)
					Moy Burn Palaeosol Formation *Crossbrae Farm Peat Bed*	
Teindland Palaeosol Formation						**Teindland Palaeosol Formation** *Fernieslack Palaeosol Bed*
	CENTRAL GRAMPIAN (ALBION) GLACIGENIC SUBGROUP				**EAST GRAMPIAN (ALBION) GLACIGENIC SUBGROUP**	**EAST GRAMPIAN (ALBION) GLACIGENIC SUBGROUP**
					Crossbrae Till Formation (possibly MIS 6)	**Rottenhill Till Formation** (possibly MIS 6)
	Boyne Craig Till Formation (possibly MIS 6 or 12)				**Pishlinn Burn Formation** (possibly MIS 6 or 12)	**West Leys Sand and Gravel Formation** (possibly MIS 6 or 12)
						Camphill Gelifluctate Bed
						Swineden Palaeosol Bed
						Kirkhill Palaeosol Bed (MIS ?7)
						Pitscow Sand and Gravel Formation (possibly MIS 8 or older) *Kirkton Gelifractate Bed*
						Leys Gravel Formation (possibly MIS 8 or older) **Leys Till Formation** (possibly MIS 8 or older)

Table 10 *Continued.*

Peterhead / Cruden				Ellon / Fyvie - Aberdeen		
GRAMPIAN CATCHMENTS SUBGROUP currently mainly lithogenetic units (MIS 2-1)			**BRITISH COASTAL DEPOSITS GROUP** Currently mainly lithogenetic units (MIS 2-1)	**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)		
				Woodhead Gelifluctate Bed	*Mill of Dyce Peat Bed*	
				Woodhead Peat Bed		
BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP	**LOGIE BUCHAN GLACIGENIC SUBGROUP**	**EAST GRAMPIAN GLACIGENIC SUBGROUP**	**St Fergus Silt Formation**	**LOGIE-BUCHAN GLACIGENIC SUBGROUP**	**EAST GRAMPIAN GLACIGENIC SUBGROUP**	**MEARNS GLACIGENIC SUBGROUP**
	Ugie Clay Formation			**Ugie Clay Formation**	**Lochton Sand and Gravel Formation**	**Drumlithie Sand and Gravel Formation**
				Tullos Clay Member	*Ness Sand and Gravel Member*	
Essie Till Formation				**Kippet Hills Gravels Formation**	**Glen Dye Silts Formation**	
					Blairdaff Moraine Formation	
	Hatton Till Formation			**Hatton Till Formation**	**Banchory Till Formation**	**Mill of Forest Till Formation**
		Hythie Till Formation		**Auchleuchries Sand and Gravel Formation**		
		Sandford Bay Till Member			*Nigg/Kingswell Till Member*	
					Den Burn Till Member	
				BANFFSHIRE COAST & CAITHNESS GLACIGENIC SUBGROUP		
Whitehills Glacigenic Formation				**Whitehills Glacigenic Formation**	**Whitehills Glacigenic Formation**	
Rafts at Oldmill	Aldie Till Member			*Bearnie Till Member*	*Anderson Drive Diamicton*	
				Pitlurg Farm Till Member		
	Hardslacks Gelifluctate Bed (possible parent unit: Camp Fauld Till Formation)					
	Moy Burn Palaeosol Formation					
	Berryley Peat Bed					
	Moreseat Farm Sand Bed					
	BANFFSHIRE COAST & CAITHNESS (ALBION) GLACIGENIC SUBGROUP				**EAST GRAMPIAN (ALBION) GLACIGENIC SUBGROUP**	**BANFFSHIRE COAST & CAITHNESS (ALBION) GLACIGENIC SUBGROUP**
	Camp Fauld Till Formation (possibly MIS 6)					*Lower Till (un-named) previously ascribed to the Pitlurg Till Member*
					Tillybrex Sand and Gravel Formation (possibly MIS 6)	
					Bellscamphie Till Formation (possibly MIS 6 or 12)	
Buchan Gravels Formation				**Buchan Gravels Formation**		
Buchan Ridge Gravel Member				Buchan Ridge Gravel Member		
				Windy Hills Gravel Member		

- BRITANNIA CATCHMENTS GROUP
- BRITISH COASTAL DEPOSITS GROUP
- CALEDONIA GLACIGENIC GROUP
- ALBION GLACIGENIC GROUP
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	Banchory	Stonehaven		Epoch, British/European Stage and approximate correlation with MIS		
BRITISH COASTAL DEPOSITS GROUP Currently mainly lithogenetic units (MIS 2-1)	**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)	**GRAMPIAN CATCHMENTS SUBGROUP** currently mainly lithogenetic units (MIS 2-1)	**BRITISH COASTAL DEPOSITS GROUP** Currently mainly lithogenetic units (MIS 2-1)	**Holocene**	**1**	
				Late Pleistocene	**Devensian/ Weichselian**	**Loch Lomond Stadial (2-1)**
	Loch of Park Gytta Bed	*Glenbervie Peat Bed*				**Windermere Interstadial (2)**
Errol Clay Formation	**EAST GRAMPIAN GLACIGENIC SUBGROUP** **Lochton Sand and Gravel Formation** **Glen Dye Silts Formation** **Blairdaff Moraine Formation** **Banchory Till Formation**	**MEARNS GLACIGENIC SUBGROUP** **Drumlithie Sand and Gravel Formation** **Ury Silts Formation** **Mill of Forest Till Formation** Arbikie Diamicton Member	**Errol Clay Formation**			**Dimlington Stadial (2)**
						3
						4
		Moy Burn Palaeosol Formation *Burn of Benholm Peat Bed*				**5d-a**
					Ipswichian/ Eemian (5e)	
		EAST GRAMPIAN (ALBION) GLACIGENIC SUBGROUP **Birnie Gravel Formation** (possibly MIS 6 or 12)	**LOGIE BUCHAN (ALBION) GLACIGENIC SUBGROUP** **Benholm Clay Formation** (possibly 6 or 12)	**Mid Pleistocene**	**6**	
					7	
					8	
					Hoxnian/ Holsteinian (11)	
					Anglian/Elsterian (12)	
				Pliocene		

Table 11 Correlation chart for the Midland Valley of Scotland.

Epoch, British/European Stage and approximate correlation with MIS			Perth - Tay - Angus	Forth - East Scotland	Clyde valley
Holocene		1	**BRITANNIA CATCHMENTS GROUP** **TAY CATCHMENTS SUBGROUP** **Strathtay Formation** North Esk Formation South Esk Formation **BRITISH COASTAL DEPOSITS GROUP** **Carse Clay Formation** Gowrie Member Carse of Gowrie Member Carey Silt Member Kingston Sand Member	**Flanders Moss Peat Formation** **FORTH CATCHMENTS SUBGROUP** **Forth Valley Formation** Carse of Stirling Clay Member Grangemouth Silt Member Claret Clay Member	**Clippens Peat Formation (MIS 2-1)** **CLYDE CATCHMENTS SUBGROUP** **Clyde Valley Formation** Law Sand and Gravel Member Strathkelvin Clay and Silt Member
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)	**Forth Clay Formation** Tay-Earn Gravels Member	Letham Silt Member **Forth Clay Formation** Bothkennar Gravel Member	
		Windermere Interstadial (2)	Culfargie Sand Member Powgavie Clay Member	Abbotsgrange Silt Member Kinneil Kerse Silt Member	
		Dimlington Stadial (2)	**Errol Clay Formation** Lunan Clay Member **MEARNS GLACIGENIC SUBGROUP** **Drumlithie Sand and Gravel Formation** **Ury Silts Formation** **Mill of Forest Till Formation** Arbikie Diamicton Member	**Errol Clay Formation** *Loanhead Clay Member* **MIDLAND VALLEY GLACIGENIC SUBGROUP** **Broomhouse Sand and Gravel Formation** **? SOUTHERN UPLANDS GLACIGENIC SUBGROUP** *Roslin Member* of Sutherland (p. 113 in Bowen, 1999) **Wilderness Till Formation**	**MIDLAND VALLEY GLACIGENIC SUBGROUP** **Broomhouse Sand and Gravel Formation** Ross Sand Member Greenoakhill Sand and Gravel Member Bellshill Clay Member **Wilderness Till Formation**
		3			
		4			**Cadder Sand and Gravel Formation** **Broomhill Clay Formation** **Baillieston Till Formation**

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
CALEDONIA GLACIGENIC GROUP

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	South Renfrewshire and Ayrshire		Dumbarton - Loch Lomond	
BRITISH COASTAL DEPOSITS GROUP Clydebank Clay Formation Gourock Sand Member Erskine Clay Member Longhaugh Sand and Gravel Member	Clippens Peat Formation (MIS 2-1) CLYDE CATCHMENTS SUBGROUP Clyde Valley Formation Law Sand and Gravel Member	BRITISH COASTAL DEPOSITS GROUP Girvan Formation (Sutherland, p. 109 in Bowen, 1999)	Clippens Peat Formation (MIS 2-1) CLYDE CATCHMENTS SUBGROUP Strathendrick Formation Endrick Sand Member Kilmaronock Silt Member	BRITISH COASTAL DEPOSITS GROUP Clydebank Clay Formation Gourock Sand Member Erskine Clay Member Buchanan Clay Member
			CENTRAL GRAMPIAN GLACIGENIC SUBGROUP Drumbeg Sand and Gravel Formation Blane Water Silt Formation Gartocharn Till Formation	Clyde Clay Formation Balloch Clay Member Inverleven Gravel Member
Clyde Clay Formation Killearn Sand and Gravel Member Linwood Clay Member Paisley Clay Member Bridgeton Sand Member	Clyde Valley Formation Lochwinnoch Clay Member			Killearn Sand and Gravel Member Portavadie Sand and Silt Member Linwood Clay Member Paisley Clay Member
	MIDLAND VALLEY GLACIGENIC SUBGROUP Broomhouse Sand and Gravel Formation Wilderness Till Formation Auchenwinsey Till Member Eglinton Shelly Till Member		MIDLAND VALLEY GLACIGENIC SUBGROUP Broomhouse Sand and Gravel Formation Wilderness Till Formation	
	Sourlie Organic Silt Formation	Afton Lodge Clay Formation		
	Armsheugh Sand and Gravel Formation Littlestone Till Formation Lawthorn Diamicton Member			

Table 12 Correlation chart for the south of Scotland, Cumbria and the Isle of Man.

Epoch, British/European Stage and approximate correlation with MIS			Scottish Borders	SW Scotland and North Solway		North Cumbria
Holocene	1		**BRITANNIA CATCHMENTS GROUP** **TWEED CATCHMENTS SUBGROUP (MIS 2-1)** Tweed Valley Formation	**BRITANNIA CATCHMENTS GROUP** **SOLWAY CATCHMENTS SUBGROUP (MIS 2-1)** **Solway Esk Valley Formation** Cree Valley Formation Kirkcudbright Dee Valley Formation Fleet Valley Formation Nithsdale Formation Annan Valley Formation **BRITANNIA CATCHMENTS GROUP** **Blelham Peat Formation (MIS 2-1)** *Racks Moss Peat Member*	**BRITISH COASTAL DEPOSITS GROUP** **Carse Clay Formation** *Newbie Silt Member*	**BRITANNIA CATCHMENTS GROUP** **SOLWAY CATCHMENTS SUBGROUP (MIS 2-1)** Eden Valley Formation Wanpool Valley Formation Waver Valley Formation Ellen Valley Formation Derwent Valley Formation
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)		*Healy Hill Organic Mud Member* *Bigholms Burn Gravel Member* *Bigholms Burn Peat Bed*	*Redkirk Point Peat Bed*	
		Windermere Interstadial (2)				
		Dimlington Stadial (2)	**BORDERS GLACIGENIC SUBGROUP** *Greenlaw Gravel* **Norham Till Formation** **CHEVIOT GLACIGENIC SUBGROUP** **Kale Water Till Formation** *Linhope Spout Member*	**SOUTHERN UPLANDS GLACIGENIC SUBGROUP** **Kirkbean Sand and Gravel Formation** **Mouldy Hills Gravel Formation** **Dalswinton Moraine Formation** **Langholm Till Formation** *New Abbey Till Member*	**IRISH SEA COAST GLACIGENIC SUBGROUP** Kilblane Sand and Gravel Formation Cullivait Silts Formation **Kerr Moraine Formation** **Gretna Till Formation** Plump Bridge Till Member **Plumpe Sand and Gravel Formation** Plumpe Farm Sand Member Loganhouse Gravel Member	**CENTRAL CUMBRIA GLACIGENIC SUBGROUP** **Lobbs Sand and Gravel Formation** **Baronwood Sand and Gravel Formation** **Greystoke Till Formation** Edenside Till Member **Threlkeld Till Formation** **Blengdale Glacigenic Formation** Kendal Till Member **IRISH SEA COAST GLACIGENIC SUBGROUP** **Great Easby Clay Formation**
		3		*Hoghill Gravel Bed*		
		4			**Chapelknowe Till Formation**	**Gillcambon Till Formation**
		5d-a				*Scandal Beck Peat Bed (?glacial raft)*
	Ipswichian/ Eemian (5e)					*Wigton Marine Bed (?glacial raft)*
Mid Pleistocene	6					
	7					
	8					
	9					
	10					
	Hoxnian/ Holsteinian (11)					
	Anglian/ Elsterian (12)					

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
CALEDONIA GLACIGENIC GROUP
ALBION GLACIGENIC GROUP

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West Cumbria			Morecambe Bay - East Irish Sea	Isle of Man
BRITANNIA CATCHMENTS GROUP			**BRITISH COASTAL DEPOSITS GROUP**	**BRITANNIA CATCHMENTS GROUP**
	CUMBRIA - LANCASHIRE CATCHMENTS SUBGROUP			**ISLE OF MAN CATCHMENTS SUBGROUP**
	Ehen Alluvium Formation (MIS 2-1)	**Cumbrian Esk Valley Formation (MIS 2-1)**		**Sulby Glen Formation**
	BRITISH COASTAL DEPOSITS GROUP	Cumbrian Esk Alluvium Member		**Ballaugh Formation**
	Drigg Point Sand Formation		**Grange-Over-Sands Formation**	**Curragh Formation**
			Surface Sands Formation (offshore)	**BRITISH COASTAL DEPOSITS GROUP**
	Hall Carleton Formation (MIS 2-1)			**Point of Ayre Formation**
	Nethertown Gravel Member			
Blelham Peat Formation (MIS 2-1)	*Rabbit Cat Silt Member*		**Upper Western Irish Sea Formation (offshore, MIS 4-1)**	*Phurt Member*
Pow Beck Peat Member				*Lough Cranstall Member*
Seacote Peat Member	*Fern Bank Silt Member*			*Ayre Sand and Gravel Member*
CENTRAL CUMBRIA GLACIGENIC SUBGROUP **Wolf Crags Formation** *Wolf Crags Till Member* *Wolf Crags Gravel Member*				
Windermere Clay and Silt Formation				
IRISH SEA COAST GLACIGENIC SUBGROUP	**IRISH SEA COAST GLACIGENIC SUBGROUP**	**IRISH SEA COAST GLACIGENIC SUBGROUP**	**IRISH SEA COAST GLACIGENIC SUBGROUP**	**Glen Balleira Formation**
Gosforth Glacigenic Formation	**Gosforth Glacigenic Formation**	**Aikbank Farm Glacigenic Formation**	**Morecambe Bay Formation (offshore)**	**MANX GLACIGENIC SUBGROUP**
Meadow House Clay Member	Peel Place Sand and Gravel Member	Mainsgate Wood Sand and Gravel Member		**Snaefell Formation (MIS 4-2)**
Peckmill Sand Member	Drigg Moorside Silt Member	Holmeside Clay Member	**Cardigan Bay Formation (offshore) (MIS 4-2)**	*Three informal members (Chadwick et al., 2001)*
Low Mill Gravel Member	Fishgarth Wood Till Member	Green Croft Till Member		**IRISH SEA COAST GLACIGENIC SUBGROUP**
How Man Till Member (West Cumbria)	Drigg Holme Sand Member (West Cumbria (South))	(Lower Wasdale)		**Jurby Formation**
Gutterfoot Sand Member	Drigg Beach Till Member	Whinneyhill Coppice Clay Member		*Three informal members (Chadwick et al., 2001)*
Rothersyke Till Member	Kirkland Wood Sand and Gravel Member			**Orrisdale Formation**
St Bees Till Member	**Seascale Glacigenic Formation (MIS 3-2)**	**CENTRAL CUMBRIA GLACIGENIC SUBGROUP**		*Dog Mills Member and nine other informal members (Chadwick et al., 2001)*
Seascale Glacigenic Formation (MIS 3-2)	Ehen Valley Sand and Gravel Member	**Blengdale Glacigenic Formation**		**Shellag Formation**
Townhead Boulder Gravel Member	Ehen Valley Silt Member	Whin Garth Gravel Member		*Six informal members (Chadwick et al., 2001)*
St Bees Sand and Gravel Member (St Bees Coast)	Catgill Wood Sand and Gravel Member (Ehen Valley)	Bark Butts Silts Member		
St Bees Silt Member	Low Wath Till Member	Scale Beck Till Member		
Lowca Till Member	Meadow View Sand and Gravel Member	Holmrook Till Member		
	Ravenglass Till Member			
	Barn Scar Sand and Silt Member			
		BRITISH COASTAL DEPOSITS GROUP		
		Glannoventia Formation		
		Kokoarrah Shelly Sand Member		
		Stubble Green Silt Member		
		Carleton Hall Clay Member		
	IRISH SEA COAST GLACIGENIC SUBGROUP	**CENTRAL CUMBRIA GLACIGENIC SUBGROUP**		
	Carleton Silt Formation	**Maudsyke Till Formation**		
BRITANNIA CATCHMENTS GROUP				
Mosedale Peat Bed				
Troutbeck Palaeosol (MIS 5e or 11)				
				Ayre Formation (MIS 5e or possibly 7 or 9)
		IRISH SEA COAST (ALBION) GLACIGENIC SUBGROUP		**IRISH SEA COAST (ALBION) GLACIGENIC SUBGROUP**
		Drigg Till Formation (possibly MIS 6)		**Kiondroughad Formation (possibly MIS 6 or 8) or Early Devensian (MIS 4)**
CENTRAL CUMBRIA (ALBION) GLACIGENIC SUBGROUP				
Thornsgill Till Formation (possibly MIS 10 or 12)				**Ayre Lighthouse Formation (possibly MIS 8, 10 or 12)**

Table 13 Correlation chart for Lancashire, Cheshire, Staffordshire, Shropshire and Wales.

Epoch, British/European Stage and approximate correlation with MIS			**Lancashire**	**Cheshire**	**Staffordshire**
Holocene	**1**		**BRITANNIA CATCHMENTS GROUP** **CUMBRIA - LANCASHIRE CATCHMENTS SUBGROUP** **Wyre Valley Formation (MIS 2-1)** **Lune Valley Formation (MIS 2-1)** **Ribble Valley Formation (MIS 2-1)** **BRITISH COASTAL DEPOSITS GROUP** **Lytham Formation** *Leasowe Marine Bed* *Preesall Shingle Bed*	**CHESHIRE - NORTH WALES CATCHMENTS SUBGROUP** **Dee Valley Formation (MIS 2-1)** **Mersey Valley Formation (MIS 2-1)** **Weaver Valley Formation (MIS 2-1)** **BRITISH COASTAL DEPOSITS GROUP** **Lytham Formation** **Shirdley Hill Sand Formation (MIS 1 or 2)**	**TRENT - WITHAM CATCHMENTS SUBGROUP** **Trent Valley Formation** **SEVERN AND AVON CATCHMENTS SUBGROUP** **Severn Valley Formation**
Late Pleistocene	**Devensian/ Weichselian**	**Loch Lomond Stadial (2-1)**			
		Windermere Interstadial (2)			
		Dimlington Stadial (2)	**IRISH SEA COAST GLACIGENIC SUBGROUP** **Stockport Glacigenic Formation** Kirkham Till Member **Morecambe Bay Formation (offshore)** **Cardigan Bay Formation (offshore) (2c -4)**	**Seacombe Sand Formation** **IRISH SEA COAST GLACIGENIC SUBGROUP** **Stockport Glacigenic Formation**	**IRISH SEA COAST GLACIGENIC SUBGROUP** **Stockport Glacigenic Formation** **Brewood Till Formation**
		3			
		4			
		5d-a		**Chelford Sand Formation** *Farm Wood Member* (Worsley, p. 34 in Bowen, 1999)	**Four Ashes Sand and Gravel Formation**
	Ipswichian/ Eemian (5e)			*Arclid Member* and *Lapwing Bed* (Worsley, p. 34 in Bowen, 1999)	
Mid Pleistocene	**6**			**IRISH SEA COAST (ALBION) GLACIGENIC SUBGROUP** **Oakwood Glacigenic Formation**	
	7				
	8				
	9				
	10				
	Hoxnian/ Holsteinian (11)			**Trysull Silt Formation**	
	Anglian/ Elsterian (12)			**IRISH SEA COAST (ALBION) GLACIGENIC SUBGROUP** **Seisdon Sand and Gravel Formation**	

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
CALEDONIA GLACIGENIC GROUP
ALBION GLACIGENIC GROUP

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North and North-west Wales	Mid and west Wales and Shropshire lowlands	South-west and south Wales and Herefordshire
CHESHIRE - NORTH WALES CATCHMENTS SUBGROUP **Clwyd Valley Formation (MIS 2-1)** **Conwy Valley Formation (MIS 2-1)**	**Ystog Formation (MIS 2-1)** **SEVERN AND AVON CATCHMENTS SUBGROUP** **Severn Valley Formation**	**Tregaron Formation** **WEST WALES CATCHMENTS SUBGROUP** **Dovey Valley Formation (MIS 2-1)** **Teifi Valley Formation (MIS 2-1)** **Tywi Valley Formation (MIS 2-1)** **Neath Valley Formation (MIS 2-1)** **BRITISH COASTAL DEPOSITS GROUP** **Kenfig Formation** **Ynyslas Formation** **Gwent Levels Formation** Wentlooge Member
WALES GLACIGENIC SUBGROUP **Eryri Glacigenic Formation** **IRISH SEA COAST GLACIGENIC SUBGROUP** **St Asaph Glacigenic Formation** Lleyn Till Member	**WALES GLACIGENIC SUBGROUP** **Shrewsbury Glacigenic Formation** **Eryri Glacigenic Formation** **IRISH SEA COAST GLACIGENIC SUBGROUP** **St Asaph Glacigenic Formation** Lleyn Till Member Llangelynin Till Member **WALES GLACIGENIC SUBGROUP** **Plynlimon Glacigenic Formation** Merion Till Member Elenid Till Member Ruabon Till Member	**WALES GLACIGENIC SUBGROUP** **Brecknockshire Glacigenic Formation** Hereford Till Member Langland Till Member *Boddenham Member* **Glamorgan Glacigenic Formation** **IRISH SEA COAST GLACIGENIC SUBGROUP** **Teifi Clay Formation**
Hiraethog Member (head) of St Asaph Formation (Bowen, 1999)	*Hiraethog Member (head) of St Asaph Formation (Bowen, 1999)*	
Four Ashes Sand and Gravel Formation		
	BRITISH COASTAL DEPOSITS GROUP *Hunts Bay Member* (Pennard Formation) (Bowen, 1999)	**BRITISH COASTAL DEPOSITS GROUP** *Hunts Bay Member* (Pennard Formation) (Bowen, 1999)
		Llanddewi Glacigenic Formation (MIS 12) **Penfro Till Formation (possibly MIS 16)** **Risbury Formation (MIS 12)**
		Humber and Mathon Valley formations (Anglian to pre-Anglian) (Bowen, 1999)

Table 14 Correlation chart for North-east England.

Epoch, British/European Stage and approximate correlation with MIS			Northumberland, Durham and North Pennines	
Holocene	1		**BRITANNIA CATCHMENTS GROUP** **NORTHUMBRIA CATCHMENTS SUBGROUP** **Coquet Valley Formation (MIS 2-1)** **Tyne Valley Formation (MIS 2-1)** **Wear Valley Formation (MIS 2-1)**	**BRITISH COASTAL DEPOSITS GROUP** *Currently mainly lithogenetic units (MIS 2-1)*
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)		
		Windermere Interstadial (2)		
		Dimlington Stadial (2)	**NORTH PENNINE GLACIGENIC SUBGROUP** **Ebchester Sand and Gravel Formation** **Wear Till Formation** *Hutton Henry Peat* Butterby Till Member	**NORTH SEA COAST GLACIGENIC SUBGROUP** **Teesside Clay Formation** **Horden Till Formation** Elwick Moraine Member Prismatic Clay Member
			Tyne and Wear Glaciolacustrine Formation Pelaw Clay Member	**Peterlee Sand and Gravel Formation** Ryhope Sand Member **Blackhall Till Formation**
			Maiden's Hall Sand and Gravel Formation **Acklinton Till Formation** **Yorkshire Dales Till Formation** **Stainmore Forest Till Formation**	**Limekiln Gill Gravel Formation**
		3		
		4		
		5d-a		
	Ipswichian/ Eemian (5e)			
Mid Pleistocene	6			**NORTH SEA COAST (ALBION) GLACIGENIC SUBGROUP** **Warren House Gill Till Formation (possibly MIS 6)** *Warren House Gill Loess Bed*
	9 to 7			**BRITISH COASTAL DEPOSITS GROUP** **Easington Raised Beach Formation (MIS 7 or 9)**
Neogene			**GREAT BRITAIN SUPERFICIAL DEPOSITS SUPERGROUP** **Brassington Formation** *Bees' Nest Member* *Kirkham Member* *Kenslow Member*	
Mesozoic to Cromerian				**GREAT BRITAIN SUPERFICIAL DEPOSITS SUPERGROUP** **Castle Eden Fissure-fill Formation**

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
CALEDONIA GLACIGENIC GROUP
ALBION GLACIGENIC GROUP

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Holderness	Vale of York
BRITISH COASTAL DEPOSITS GROUP *Currently mainly lithogenetic units (MIS 2-1)*	**YORKSHIRE CATCHMENTS SUBGROUP** Alluvium and terrace deposits
	Sutton Sand Formation **Breighton Sand Formation** Naburn Sand Member Skipwith Sand Member Bielby Sand Member
NORTH SEA COAST GLACIGENIC SUBGROUP **Holderness Formation** *Flamborough Member* *Hornsea Member* *Withernsea Member ('Purple Clay 'of Bisat, 1940)* *Mill Hill Bed* *Skipsea Till Member ('Drab Clay' of Bisat, 1940)* *Dimlington Bed* *Bridlington Member ('Basement Till') (possibly Early Devensian or earlier)*	**NORTH PENNINE GLACIGENIC SUBGROUP** **Pocklington Gravel Formation** **Alne Glaciolacustrine Formation** **Elvington Glaciolacustrine Formation** **Hemingbrough Glaciolacustrine Formation** Thorganby Clay Member Lawns House Farm Sand Member Park Farm Clay Member **Vale of York Formation** Poppleton Glaciofluvial Member Crockley Hill Esker Member Newby Wiske-Aldwark Esker Member Hunsingore Esker Member York Moraine Member Escrick Moraine Member
Sewerby Member of Holderness Formation	
	Un-named till and sand and gravel (MIS 6 or older)

Table 15 Correlation chart for East Anglia and the Proto-Thames.

Epoch	British/European Stage	Substage and approximate correlation with MIS	Bucks., Beds.: Cambs.: valley of the River Great Ouse	Northants., Lincolnshire and the Fens	Central East Anglia: Cam Valley	Central East Anglia: Lark Valley	North-west Norfolk	North-east Norfolk (including Norfolk Broads)	Southern Norfolk and North Suffolk	Essex, Hertfordshire and South and East Suffolk
Holocene		1	**OUSE - NENE CATCHMENTS SUBGROUP** **Ouse Valley Formation (MIS ?10-1)** Alluvium	**OUSE - NENE CATCHMENTS SUBGROUP** **Slea Valley Formation (MIS ?-1)** *Sleaford sand and Gravel* **Nene Valley Formation (MIS ? -1)** Alluvium **Fenland Formation (MIS 7-1)** *Terrington Beds* Nordelph Peat Member *Barroway Drove Beds* *Fen Lower Peat Bed* *Crowland Bed*	**OUSE - NENE CATCHMENTS SUBGROUP** **Cam Valley Formation (MIS ?10-1)** Barnwell Station Member (1st terr.) Sidgwick Avenue Member (2nd terr.) Barnwell Abbey Member (3rd terr.) **Fenland Formation (MIS 7-1)**	**OUSE - NENE CATCHMENTS SUBGROUP** **Lark Valley Formation (MIS? 11-1)** Lackford Member Cavenham Member **Fenland Formation (MIS 7-1)**	**OUSE - NENE CATCHMENTS SUBGROUP** **Nar Valley Formation (MIS ?6 -1)** *Marham Member (MIS 2-1)* **Fenland Formation (MIS 7-1)**	**YARE CATCHMENTS SUBGROUP** **Yare Valley Formation (MIS ? 2-1)** - *no subdivisions currently defined* **Bure Valley Formation (MIS ? 11-1)** - *no subdivisions currently defined* **Blakeney Valleys Formation** - *no subdivisions currently defined* **North Denes Formation** **Breydon Formation**	**YARE CATCHMENTS SUBGROUP** **Waveney Valley Formation (MIS 11-1)** *Shotford Member* **Breydon Formation**	**SUFFOLK CATCHMENTS SUBGROUP** *(currently lithogenetic units) (MIS 2-1)*
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)								
		Windermere Interstadial (2)								
		Dimlington Stadial (2)		**Fenland Formation** Abbey Sand and Gravel Member			**NORTH SEA COAST GLACIGENIC SUBGROUP** **Holderness Formation** *Ringstead Sand and Gravel Member* *Red Lion Till Member* *Holkham Till Member* **Nar Valley Formation** *Pentney Member*			
		3		**Nene Valley Formation** Ecton Member						
		4								
		5d-a	Felmersham Member (1st terr.)							
	Ipswichian/ Eemian (5e)		**Ouse Valley Formation** Ravenstone Member of Maddy et al., p. 44 in Bowen, 1999) Woolpack Farm Bed of Maddy et al., p. 44 in Bowen, 1999)	**Fenland Formation** March Gravels Member	**Cam Valley Formation** *Barrington Village Member* Histon Road Member		**Morston Formation** **Nar Valley Formation** *Pentney Priory Bed*	**Morston Formation**	**Waveney Valley Formation** *Bobbitshole Member* *Wortwell Beds*	*Lexden Beds*
Mid Pleistocene		6	Stoke Goldington Member (2nd terr.)	Welton-le-Wold Formation of Lewis, p. 13 in Bowen, 1999) **Nene Valley Formation**	Huntingdon Road Member (4th terr.)	**Lark Valley Formation** Kentford Member Fornham Member	Wormegay Member **Briton's Lane Formation** Tottenhill Sand and Gravel Member	**Briton's Lane Formation** Briton's Lane Sand and Gravel Member Corton Woods Sand and Gravel Member Beacon Hill Sand and Gravel Member Stow Hill Sand and Gravel Member Tottenhill Sand and Gravel Member	Broome Member	
		7		Grendon Member	Little Wilbraham Member (4th terr.)	Eriswell Member				
		8			Bordeaux Pit Member					
		9	Biddenham Member (3rd terr.)	Woodston Member						
		10		**Wolston Glacigenic Formation** Oadby Till Member *Bozeat Till*	*North Hall Member*		**Sheringham Cliffs Formation**	**Sheringham Cliffs Formation** Runton Cliffs Sand and Gravel Member Weybourne Town Till Member Trimingham Sand Member Trimingham Clay Member Bacton Green Till Member Runton Till Member Ivy Farm Laminated Silt Member Hanworth Till Member Mundesley Sand Member		

					Sicklesmere Member	**Nar Clay Formation**		**Waveney Valley Formation**	Marks Tey Formation
	Hoxnian/ Holsteinian (11)		*Kirmington Beds* (Kirmington Formation of Lewis and Bowen, p. 13 in Bowen, 1999)					*Hoxne Member*	Hitchin Formation
	Anglian/ Elsterian (12)	**Lowestoft Formation**	**Lowestoft Formation** (of Lewis, p.11-13 in Bowen 1999) *Calcethorpe Member* *Wragby Member* (NB see Table 16 where the Wragby Till Member (MIS 10) is assigned to the Wolston Glacigenic Formation)	**Lowestoft Formation** *Observatory Member*	**Lowestoft Formation** High Lodge Gravel Member	**Lowestoft Formation**	**Lowestoft Formation** Aldeby Sand and Gravel Member *Pleasure Gardens Till Member* Oulton Clay Member Lowestoft Till Member Walcott Till Member	**Lowestoft Formation** *Barham Sand and Gravel Member* Woolpit Beds Haddiscoe Sand and Gravel Member	**Lowestoft Formation** see informal members of Lewis (p.23-27 in Bowen 1999) including *Barham Sand and Gravel*
Early Pleistocene	? 16						**Happisburgh Glacigenic Formation (possibly MIS 16)** California Till Member *Corton Sand Member* Leet Hill Sand and Gravel Member Corton Till Member Happisburgh Sand Member *Ostend Clay Member* Happisburgh Till Member	**Happisburgh Glacigenic Formation (?16)** Banham Member Coney Weston Sand and Gravel Member Starston Till Member	
	? 61 - 13		DUNWICH GROUP **BYTHAM CATCHMENTS SUBGROUP** **Bytham Sand and Gravel Formation**	**BYTHAM CATCHMENTS SUBGROUP** **Ingham Sand and Gravel Formation** *Timworth Gravel Member* *Knettishall Gravel Member* *Ingham Farm Gravel Member* *Seven Hills Gravel Member*	**BYTHAM CATCHMENTS SUBGROUP** **Shouldham Sand and Gravel Formation** High Lodge Silt and Sand Member Lakenheath Gravel Member Fodderstone Gravel Member *Shouldham Thorpe Gravel Member*	**Cromer Forest-Bed Formation (?17 to ?)** *Bacton Member* *West Runton Member* *Runton Member* *Sheringham Member*	**Cromer Forest-Bed Formation (?17 to ?)** *Bacton Member* *West Runton Member* *Runton Member* *Sheringham Member*	**KESGRAVE CATCHMENT SUBGROUP** **Colchester Formation** *Lower St Osyth Member* *Ardleigh Member* Waldringfield Member **Sudbury Formation** Westland Green Gravel Member **BYTHAM CATCHMENTS SUBGROUP** **Ingham Sand and Gravel Formation**	**KESGRAVE CATCHMENT SUBGROUP** **Colchester Formation** *Lower St Osyth Member* *Wivenhoe Member* *Ardleigh Member* Waldringfield Member **Sudbury Formation** Gerrards Cross Gravel Member Beaconsfield Gavel Member *Satwell Gravel Member* Westland Green Gravel Member Waterman's Lodge Sand and Gravel Member *Stoke Row Member*
	?67 - ?17		Milton Formation				**Wroxham Crag Formation** How Hill Member Dobbs Plantation Member *Mundesley Member* *Sidestrand Member* *Paston Member*		**Letchworth Gravels Formation**
	? 81- ?68						**Norwich Crag Formation** Chillesford Clay Member Chillesford Church Sand Member *College Farm Clay Member* Creeting Sand Member Easton Bavents Clay Member *Westleton Beds*		Nettlebed Formation
	?103 - ? 82						**Red Crag Formation** *Ludham Member* *Thorpeness Member* Sizewell Member		
Pliocene							**Coralline Crag Formation** *Aldeburgh Member* *Sudbourne Member* *Ramsholt Member*		

KEY TO GROUPS

- BRITANNIA CATCHMENTS GROUP
- BRITISH COASTAL DEPOSITS GROUP
- CALEDONIA GLACIGENIC GROUP
- ALBION GLACIGENIC GROUP
- DUNWICH GROUP
- CRAG GROUP

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Table 16 Correlation chart for the East Midlands.

In this table, deposits of the Wolston Glacigenic Formation are assigned variously to MIS 12 or 10 (see text) although many authors consider that the formation (and the Anglian Stage) represents MIS 12 only.

Epoch, British/European Stage and approximate correlation with MIS			Trent Valley	Derwent Valley	Soar Valley
Holocene	1		**BRITANNIA CATCHMENTS GROUP:** **Trent Valley Formation** Alluvium	**Trent Valley Formation** Alluvium	**Soar Valley Formation** Alluvium
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)	Hemington Member	Ambaston Gravel Member	Hemington Member
		Windermere Interstadial (2)	Holme Pierrepont Sand and Gravel Member	Holme Pierrepont Sand and Gravel Member	Syston Sand and Gravel Member
		Dimlington Stadial (2)			
		3			
		4	Beeston Sand and Gravel Member	Allenton Sand and Gravel Member	Wanlip Sand and Gravel Member (5-4)
		5d-a			
	Ipswichian/ Eemian (5e)		*Hykeham Soil*	*Crown Inn Bone Beds*	
Mid Pleistocene	6		Egginton Common Sand and Gravel Member	Borrowash Sand and Gravel Member	Birstall Sand and Gravel Member
	7				
	8		Etwall Sand and Gravel Member	Ockbrook Sand and Gravel Member	Knighton Sand and Gravel Member
	9				
	10		Eagle Moor Sand and Gravel Member **Wolston Glacigenic Formation (10 and 12)** *Findern Clay Member* Oadby Till Member	Eagle Moor Sand and Gravel Member Oadby Till Member	Oadby Till Member
	Hoxnian/ Holsteinian (11)				
	Anglian/ Elsterian (12)		Thrussington Till Member	Thrussington Till Member *Mill Hill Sand and Gravel Member*	Thrussington Till Member *Hathern Gravel Member*
	16 to 13				**BYTHAM CATCHMENTS SUBGROUP** **Baginton Sand and Gravel Formation** *Baginton Sand Member* *Lillington Gravel Member* *Thurmaston Gravel Member* *Waverley Wood Beds*

BRITANNIA CATCHMENTS GROUP

ALBION GLACIGENIC GROUP

DUNWICH GROUP

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Proto-Trent and Witham west of Lincoln Gap	Proto-Trent and Witham east of Lincoln Gap	Bain Valley
Trent Valley Formation Alluvium	**Trent Valley Formation**	**Bain Valley Formation** Alluvium Older Alluvium
Holme Pierrepont Sand and Gravel Member *Spalford Sand*	Kirkstead Sand and Gravel Member (upper part)	Castle Sand and Gravel Member (upper part)
		Castle Silt Bed
Scarle Sand and Gravel Member and Fulbeck Sand and Gravel Member	Kirkstead Sand and Gravel Member (lower part)	Castle Sand and Gravel Member (lower part) *Tattershall Silt Beds*
Little Syke and South Scarle bone beds *Hykeham Soil*	*Hykeham Soil* *?Coronation Farm Beds*	*Thorpe Soil*
Whisby Sand Bed Balderton Sand and Gravel Member	Southrey Sand and Gravel Member	Thorpe Sand and Gravel Member
Thorpe on the Hill Bone Bed		*Kirkby Silt Beds*
Whisby Farm Sand and Gravel Member		
Eagle Moor Sand and Gravel Member	Martin Sand and Gravel Member	*Tattershall Airfield Sand and Gravel Member*
Skellingthorpe Clay Member Oadby Till Member	*Wragby Till Member*	*Wragby Till Member (see also Lowestoft Formation, Table 15)* *Kirkby Moor Sand Member*

Table 17 Correlation chart for the West Midlands and Upper Thames.

Epoch, British/European Stage and approximate correlation with MIS			Severn Valley, Birmingham, Lugg, Wye valley and Malvern Hills		Warwickshire Avon Valley and south Leicestershire	
Holocene	1		BRITANNIA CATCHMENTS GROUP SEVERN AND AVON CATCHMENTS SUBGROUP **Severn Valley Formation** Elmore Alluvium Member		SEVERN AND AVON CATCHMENTS SUBGROUP **Warwickshire Avon Valley Formation** Elmore Alluvium Member	
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)	Power House Sand and Gravel Member (1st terrace) Worcester Sand and Gravel Member (2nd terrace): correlated with informal members of Brandon (pp.29-32 in Bowen, 1999); *Rudford Member* (Glynch Valley Formation)	Teme Palaeovalley Formation *Bank Farm Sand and Gravel* *Shakenhurst Sand and Gravel* *Little Hereford Sand and Gravel* *Ashford Sand and Gravel* *Bromfield Sand and Gravel* *Woofferton Sand and Gravel*	Bretford Sand and Gravel Member (1st terrace)	
Late Pleistocene	Devensian/ Weichselian	Windermere Interstadial (2)				
Late Pleistocene	Devensian/ Weichselian	Dimlington Stadial (2)	Holt Heath Sand and Gravel Member (3rd terrace) (= Main Terrace): correlated with informal members of **Stockport Glacigenic Formation (Irish Sea Coast Glacigenic Subgroup)**		Wasperton Sand and Gravel Member (2nd terrace)	
Late Pleistocene	Devensian/ Weichselian	3	*Upton Warren Beds (MIS 3 or 5a)*		*Fladbury Bed (MIS 3 or 5a)*	
Late Pleistocene	Devensian/ Weichselian	4	Holt Heath Sand and Gravel Member (3rd terrace) (part): correlated with informal members of Brandon (pp.29-32 in Bowen, 1999); *Staunton Member* (Glynch Valley Formation), *Bullingham Member* (Wye Valley Formation), *Marden Member* and *Moreton on Lugg Member* (Lugg Valley Formation)		Wasperton Sand and Gravel Member (2nd terrace) (part)	
Late Pleistocene	Devensian/ Weichselian	5d-a			*Fladbury Bed (MIS 5a or 3)* New Inn Sand and Gravel Member (3rd terrace) (5d-b)	
Late Pleistocene	Ipswichian/ Eemian (5e)		*Stourbridge Beds*		*Eckington Beds*	
Mid Pleistocene	6		Kidderminster Station Sand and Gravel Member (4th terrace): correlated with informal members of Brandon (pp.29-32 in Bowen, 1999); *Redmarley Member* (Glynch Valley Formation), *Hampton Member* (Wye Valley Formation), and *Kingsfield Member* (Lugg Valley Formation). Broad correlatives include the *Colwall Gelifluctate Member* (Colwall Member of Brandon, p.32 in Bowen, 1999) **Ridgacre Formation (MIS 10 or 6)**		Cropthorne Sand and Gravel Member (4th terrace) (?= Strensham Sand and Gravel Member)	
Mid Pleistocene	7				*Ailstone Bed* *Strensham Court Clay Bed*	
Mid Pleistocene	8		Bushley Green Sand and Gravel Member (5th terrace): correlated with informal members of Brandon (pp.29-32 in Bowen, 1999); *Heath Member* (Glynch Valley Formation), *Holme Lacy Member* (Wye Valley Formation) and *Sutton Walls Member* (Lugg Valley Formation)		Froghall Sand and Gravel Member and Pershore Sand and Gravel Member (5th terrace)	
Mid Pleistocene	9		*Hill House Beds*		*Frog Hall Silt Beds* *Allesborough Beds*	
Mid Pleistocene	10		Spring Hill Sand and Gravel Member (6th terrace) **Ridgacre Formation (MIS 10 or 6)**	**Wolston Glacigenic Formation (10 and 12)**	**Wolston Glacigenic Formation (10 and 12)** Dunsmore Gravel Member Oadby Till Member; Shawell Sand and Gravel Member; Wolston Clay Member (upper leaf) Hillmorton Sand Member	
Mid Pleistocene	Hoxnian/ Holsteinian (11)		**Quinton Peat Formation**. Broad correlatives include the *Cradley Silts Bed* (Cradley Bed of Cradley Valley Formation of Brandon, p.32 in Bowen, 1999)			
Mid Pleistocene	Anglian/ Elsterian (12)		**Nurseries Glacigenic Formation** Risbury Glacigenic Formation *Coddington Till Member* *Newton Farm Member* *Kyre Brook Member* *Stoke Lacy Member* *Stoke Prior Member* *Franklands Gate Member* *Portway Member* *White House Silts Member* Humber Sand and Gravel Formation	Woolridge Sand and Gravel Member Thrussington Till Member	Wigston Sand and Gravel Member; Knightlow Sand Member Bosworth Clay Member; Wolston Clay Member (lower leaf) Thrussington Till Member Snitterfield Sand Member	
Mid Pleistocene / Early Pleistocene	? 61 to 13		Mathon Valley Sand and Gravel Formation		BYTHAM CATCHMENTS SUBGROUP **Baginton Sand and Gravel Formation** *Baginton Sand Member* *Lillington Gravel Member* *Thurmaston Gravel Member* *Waverley Wood Beds*	*Stretton Sand Member*

BRITANNIA CATCHMENTS GROUP
CALEDONIA GLACIGENIC GROUP
ALBION GLACIGENIC GROUP
DUNWICH GROUP

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Upper Thames/ Evenlode valley		Thame and Windrush
THAMES CATCHMENTS SUBGROUP **Upper Thames Valley Formation** Staines Alluvium Member		**Upper Thames Valley Formation** Alluvium
Northmoor Sand and Gravel Member (?terrace 1a)		Quarrendon Sand and Gravel Member (Thame 1st terrace) (2-1); Rissington Sand and Gravel Member (Windrush) (1st terrace)
Northmoor Sand and Gravel Member (?terrace 1b)		Ickford sand and Gravel Member (Thame 2nd terrace)
Summertown-Radley Sand and Gravel Member (2nd terrace)		Shabbington Sand and Gravel Member (Thame 3rd terrace) and Sherbourne Sand and Gravel Member (Windrush 2nd terrace)
Eynsham Beds		*North Weston Beds*
Summertown-Radley Sand and Gravel Member (part)		Shabbington Sand and Gravel Member (Thame 3rd terrace) (part)
Stanton Harcourt Bed		*? North Weston Beds*
Summertown-Radley Sand and Gravel Member (part)		
Wolvercote Channel Beds		
Wolston Glacigenic Formation (10 and 12) Wolford Heath Sand and Gravel Member Oadby Till Member	Daylesford Sand and Gravel Member, Wolvercote Sand and Gravel Member (3rd Hanborough Gravel Member (4th terrace) and Spelsbury Gravel Member (in part)	Blackditch Sand and Gravel Member (Thame 4th terrace) Chilworth Sand and Gravel Member (Thame 5th terrace)
Moreton Member Paxford Gravel Member	Freeland Sand and Gravel Member	Tiddington Sand and Gravel Member (Thame 6th terrace)
KESGRAVE CATCHMENT SUBGROUP **Sudbury Formation** *Combe Sand and Gravel Member* *North Leigh Sand and Gravel Member* *Gordon House Sand and Gravel Member* Ramsden Heath Sand and Gravel Member Waterman's Lodge Sand and Gravel Member	*Sugworth Beds*	**KESGRAVE CATCHMENT SUBGROUP** **Sudbury Formation** *Princes Risborough Sand and Gravel member* *Three Pigeons Sand and Gravel Member (Thame 7th terrace)*

Table 18a Correlation chart for the Middle and Lower Thames.

Epoch, British/European Stage and approximate correlation with MIS			Middle Thames - Thames valley Beaconsfield (BGS 1:50k Sheets E255, E267, E268)	Kennet valley (BGS 1:50k Sheets E267, E268)	Blackwater - Loddon valley (BGS 1:50k Sheets E268, E269)	Lea valley
			THAMES CATCHMENTS SUBGROUP			
Holocene	1		**Maidenhead Formation** Alluvium	**Kennet Valley Formation** Alluvium	**Maidenhead Formation** Alluvium	**Maidenhead Formation** Alluvium *Floodplain Gravel Bed*
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)	Shepperton Gravel Member	Heales Lock Gravel Member (1st terrace)	Shepperton Gravel Member	Lea Valley Member (Gibbard, p.56 in Bowen, 1999)
Late Pleistocene	Devensian/ Weichselian	Windermere Interstadial (2)				
Late Pleistocene	Devensian/ Weichselian	Dimlington Stadial (2)	Kempton Park Gravel Member (terrace 1)	Beenham Grange Gravel Member (terrace 2)	Kempton Park Gravel Member (terrace 1)	*Lea Valley Arctic Bed* (Gibbard, 1994) Langley Silt Member (Brickearth) Enfield Silt Member (Brickearth)
Late Pleistocene	Devensian/ Weichselian	3				
Late Pleistocene	Devensian/ Weichselian	4				
Late Pleistocene	Devensian/ Weichselian	5d-a				
Late Pleistocene	Ipswichian/ Eemian (5e)					*Highbury Member (Gibbard, 1994)* *Waterhall Farm Member (Gibbard, 1974)*
Mid Pleistocene	6		Kempton Park Gravel Member (part) Taplow Gravel Member (terrace 2)	Thatcham Gravel Member (terrace 3)	Kempton Park Gravel Member (part) Taplow Gravel Member (terrace 2)	*Leytonstone Member (Gibbard, 1974)* *Stamford Hill Member* (*Gibbard, 1974)*
Mid Pleistocene	7					
Mid Pleistocene	8		Taplow Gravel Member (part) Lynch Hill Gravel Member (terrace 4)		Taplow Gravel Member (part) Lynch Hill Gravel Member (terrace 4)	
Mid Pleistocene	9					
Mid Pleistocene	10		Lynch Hill Gravel Member (part) Boyn Hill Gravel Member (terrace 5)	Hampstead Marshall Gravel Member (terrace 5)	Lynch Hill Gravel Member (part) Boyn Hill Gravel Member (terrace 5)	
Mid Pleistocene	Hoxnian/ Holsteinian (11)					
Mid Pleistocene	Anglian/ Elsterian (12)		Boyn Hill Gravel Member (part.) Black Park Gravel Member (terrace 6) **KESGRAVE CATCHMENT SUBGROUP** **Colchester Formation** Winter Hill Gravel Member	Silchester Gravel Member (terrace 6) **KESGRAVE CATCHMENT SUBGROUP** **Sudbury Formation** Beenham Stocks Gravel Member (terrace 7)	Boyn Hill Gravel Member (part.) *Callow Hill/ Heckford Heath Members (terrace 6) (Gibbard, 1999)* **KESGRAVE CATCHMENT SUBGROUP** **Sudbury Formation** terrace 7 deposits	**Lowestoft Formation** *Hoddeston Member (Gibbard, 1977)*
Early Pleistocene	? 61 to 13		**Sudbury Formation** Gerrards Cross Gravel Member Beaconsfield Gravel Member Chorleywood Gravel Member Westland Green Gravel Member *Satwell Gravel Member* *Stoke Row Member*	Bucklebury Common Gravel Member (terrace 8) Cold Ash Gravel Member (terrace 9)	terrace 8 deposits Surrey Hill Gravel Member (terrace 9)	
Early Pleistocene	103 to ? 82		**Stanmore Gravel Formation**			
Miocene to Early Pleistocene						

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
ALBION GLACIGENIC GROUP
DUNWICH GROUP
CRAG GROUP
RESIDUAL DEPOSITS GROUP

NB. Formations shown in **bold type** have been formally defined in the BGS Lexicon. Formations in underlined plain type are currently not formally defined in the BGS Lexicon. Members in plain type have been formally defined in the BGS Lexicon. Members and beds in *italic type* are currently informal units. MIS = Marine Isotope Stage.

Wandle valley	Mole - Wey valley (BGS 1:50k Sheet E285)	Lower Thames, London (BGS Sheet 256 North London)	Lower Thames valley, Darent - Cray (BGS 1:50k Sheet E271)	North Kent (BGS 1:50k Sheet E272)
Maidenhead Formation Alluvium	**Maidenhead Formation** Alluvium	**Maidenhead Formation** Alluvium	**Maidenhead Formation** Staines Alluvium	**Medway Valley Formation** (units of Bridgland, p.56-57 in Bowen, 1999) Tilbury Member
			BRITISH COASTAL DEPOSITS GROUP (MIS 2-1) *Currently lithogenetic units*	**BRITISH COASTAL DEPOSITS GROUP (MIS 2-1)** *Currently lithogenetic units*
		Shepperton Gravel Member		
Kempton Park Gravel Member (terrace 1)	Kempton Park Gravel Member (terrace 1)	Kempton Park Gravel Member (terrace 1) Langley Silt Member (Brickearth) Roding Silt Member (Brickearth) Kempton Park Gravel Member	Kempton Park Gravel Member (terrace 1) Ilford Silt Member (Brickearth) Crayford Silt Member (Brickearth) Dartford Silt Member Kempton Park Gravel Member	*Aylesford Member* *Halling Member* *Binney Member*
		Trafalgar Square Beds (Gibbard, 1985) *Aveley Member* (Gibbard, 1994; Bridgland, 1994)		
Kempton Park Gravel Member (part) Taplow Gravel Member (terrace 2) Hackney Gravel Member (terrace 3)	Kempton Park Gravel Member (part) Taplow Gravel Member (terrace 2) Hackney Gravel Member (terrace 3)	Kempton Park Gravel Member (part) Taplow Gravel Member (terrace 2) Hackney Gravel Member (terrace 3)	Kempton Park Gravel Member (part) Taplow Gravel Member (terrace 2) Hackney Gravel Member (terrace 3)	*Stoke Member* *Newhall Member* *Shakespeare Member*
Taplow Gravel Member (part) Lynch Hill Gravel Member (terrace 4)	Taplow Gravel Member (part) Lynch Hill Gravel Member (terrace 4)	Taplow Gravel Member (part) Lynch Hill Gravel Member (terrace 4) Finsbury Gravel Member	Taplow Gravel Member (part) Lynch Hill Gravel Member (terrace 4) = Corbets Tey Member (Bridgland, 2006)	
Lynch Hill Gravel Member (part)	Lynch Hill Gravel Member (part)	Lynch Hill Gravel Member (part) Boyn Hill Gravel Member (terrace 5)	Lynch Hill Gravel Member (part) Boyn Hill Gravel Member (terrace 5) = ?Dartford Heath Member (Gibbard, 1999)	
		Swanscombe Member		
Effra Member (Gibbard, 1995)	**KESGRAVE CATCHMENT SUBGROUP** **Sudbury Formation** terrace 7 deposits	Boyn Hill Gravel Member (part.) Black Park Gravel Member (terrace 6) **Lowestoft Formation** *Ware Till Member (Gibbard, 1977)* **KESGRAVE CATCHMENT SUBGROUP** **Colchester Formation** Westmill Gravel Member	Boyn Hill Gravel Member (part.) Black Park Gravel Member (terrace 6)	*Dagenham Farm Member*
Norwood Member (Gibbard, 1994) *Shooter's Hill Member (Gibbard, 1994)*	terrace 8 deposits Surrey Hill Gravel Member (terrace 9) **Caesar's Camp Gravel Formation**	**Sudbury Formation** Gerrards Cross Gravel Member Dollis Hill Gravel Member Woodford Gravel Member		*Clinch Street Member* *High Halstow Member* *Lodge Hill Member* *Cobham Park Member*
	Red Crag Formation *Netley Heath Beds*		**Stanmore Gravel Formation** **Well Hill Gravel Formation**	
			Clay-with-flints Formation **Chelsfield Gravel Formation**	

Table 18b Thames terrace deposit nomenclature on published BGS maps.

Sheet number	Sheet name	Date of publication	Symbols	Terrace No.	Names (members) as shown on BGS sheet	River valley	Parent formation
E 201	Banbury	1982	Terraces	1 to 4	Unnamed		
E 218	Chipping Norton	1968	Terraces	1 to 4	Unnamed		
E 235	Cirencester	1998			Cheltenham Sand and Gravel ?		
			Peat				
			Tufa				
			Alluvium / Older Alluvium				
			Terraces	1	Rissington	River Windrush	
				2	Sherbourne		
				1	First Terrace Deposits	Churn, Coln and Upper River Leach	
				1	Northmoor	Thames	
				2	Summertown-Radley		
				3	Wolvercote		Upper Thames Valley Formation
				4	Hanborough		
E 236	Witney	1938	Terraces 1-4	1 to 4	Floodplain		
					Summertown-Radley		
					Wolvercote		
					Hanborough		
E 237	Thame	1994	Terraces	1 to 7	Unnamed		
E 238	Aylesbury						
E 239	Hertford						
E 252	Swindon	1974	Alluvium	1 to 4	Unnamed		
			Terraces				
E 253	Abingdon						
E 254	Henley on Thames	1998	Alluvium			Thames	
			Valley Gravel				
E 255	Beaconsfield				Alluvium		
					Langley Silt (Brickearth)		
			River terrace deposits		Shepperton Gravel		
					Kempton Park Gravel		Maidenhead Formation
					Taplow Gravel		
					Lynch Hill Gravel		
					Boyn Hill Gravel		
					Black Park Gravel		
					Winter Hill Gravel	Pre-diversionary Thames Terrace deposits	Colchester Formation, Kesgrave Catchment Subgroup
					Gerrards Cross Gravel		
					Beaconsfield Gravel		Sudbury Formation, Kesgrave Catchment Subgroup
					Chorleywood Gravel		
					Westland Green Gravel		
					Stanmore Gravel	Pre-Anglian marine deposit	Formation of the Crag Group
E 256	North London	2006	Symbols assigned		Alluvium	River Thames	
					Enfield Silt (Brickearth)		
					Langley Silt (Brickearth)		
					Shepperton Gravel		
				1	Kempton Park Gravel		
				2	Taplow Gravel		Maidenhead Formation
				3	Hackney Gravel		
				4	Lynch Hill		
					Finsbury Gravel		
				5	Boyn Hill Gravel		
				6	Black Park Gravel		
					Dollis Hill Gravel	Pre-diversionary Thames Terrace deposits	Sudbury Formation, Kesgrave Catchment Subgroup
					Woodford Gravel		
					Gerrards Cross Gravel		
					Westmill Gravel		Colchester Formation, Kesgrave Catchment Subgroup
E 257	Romford	1976	Alluvium				
			Brickearth				
			Floodplain Alluvium				
					Taplow Gravel		
					Boyn Hill Gravel		Maidenhead Formation
E 258 and parts E 257, 259, 271, 272,273	Inner Thames	1997	River terrace deposits		Unnamed		
E 266	Marlborough	1964					
E 267	Newbury	2006	Alluvium		Alluvium	Kennet	
			River terrace deposits	1,2	Beenham Grange Gravel		
				3	Thatcham Gravel		Kennet Valley Formation
				5	Hampstead Marshall Gravel		
				6	Silchester Gravel		
				7	Beenham Stocks Gravel	Pre-Anglian Kennet Terrace deposits	Sudbury Formation,

Table 18b *Continued.*

				8	Bucklebury Common Gravel		Kesgrave Catchment Subgroup
				9	Cold Ash Gravel Member		
E 268	Reading	2000			Alluvium	River Thames	Maidenhead Formation
			River terraces	2	Kempton Park Gravel		
				3	Taplow Gravel		
				4	Lynch Hill Gravel		
				5	Boyn Hill Gravel		
				6	Black Park Gravel		
				7	Winter Hill Gravel	Pre-Anglian Thames Terrace deposits	Colchester Formation, Kesgrave Catchment Subgroup
				8	Gerrards Cross Gravel		Sudbury Formation, Kesgrave Catchment Subgroup
				9	Beaconsfield Gravel		
				10	Westland Green Gravel		
					Alluvium	Kennet	Kennet Valley Formation
				2	Beenham Grange Gravel		
				3	Thatcham Gravel		
				6	Silchester Gravel		
				7	Beenham Stocks Gravel	Pre-Anglian Kennet Terrace deposits	Sudbury Formation, Kesgrave Catchment Subgroup
				8	Bucklebury Common Gravel		
				9	Cold Ash Gravel Member		
				1- 8 and 1-2 undiff	Unnamed	Loddon and Blackwater	Maidenhead Formation
E 269	Windsor	1999	Alluvium		Alluvium	River Thames, River Wey, River Colne	
			Brickearth		Langley Silt (Brickearth)		
			River Terrace Deposits	1	Shepperton Gravel		
				2	Kempton Park Gravel		
				3	Taplow Gravel		
				4	Lynch Hill Gravel		
				5	Boyn Hill Gravel		
				6	Unnamed	Pre-diversionary Thames Terrace deposits	Sudbury Formation, Kesgrave Catchment Subgroup
				7	Unnamed		
				8	Unnamed		
				8	Surrey Hill Gravel		
E 270	South London	1981	Terrace Deposits	1 to 4	Unnamed		Maidenhead Formation
E 271	Dartford	1995	River Terrace Deposits	No nos.	Ilford Silt	Thames	
					Crayford Silt		
					Dartford Silt		
					Kempton Park Gravel		
					Taplow Gravel		
					Hackney Gravel		
					Lynch Hill Gravel		
					Boyn Hill Gravel		
					Black Park Gravel		
					Stanmore Gravel	Pre-Anglian marine deposits	Formations of the Crag Group
					Well Hill Gravel		
					Chelsfield Gravel	Pre-Anglian residual deposit	Clay-with-flints Formation
E 272	Chatham	1977	River terrace deposits	1 to 4		Medway	Medway Valley Formation
E 285	Guildford	2001	River Terrace Deposits		Kempton Park Gravel	Wey, Blackwater (2nd 3rd, 4th terraces un-named)	Maidenhead Formation
					Taplow Gravel		
					Hackney Gravel		
					Lynch Hill Gravel		
					Seventh terrace	Pre-diversionary Thames Terrace deposits	Sudbury Formation, Kesgrave Catchment Subgroup
					Eighth Terrace		
					Surrey Hill Gravel		
					Caesar's Camp Gravel		Formation of the Dunwich Group
E301	Haslemere	1981	River terrace deposits	1 to 2		Blackwater	Maidenhead Formation
				1 to 2		Bramley Wey	
				1 to 3		Godalming Wey	

Table 19 Correlation chart for southern England.

Epoch, British/European Stage and approximate correlation with MIS			Kent	Sussex	Solent and Dorset
Holocene	1		**SOUTH KENT CATCHMENTS SUBGROUP**	**SUSSEX CATCHMENTS SUBGROUP**	**SOLENT CATCHMENTS SUBGROUP**
			Kentish Rother Formation (MIS 1)	Cuckmere Formation (MIS 1)	**Dorset Stour Formation (MIS pre 13-1)**
			Kentish Stour Formation (MIS 10-1) (Gibbard and Preece, pp.59-60 in Bowen, 1999)	Adur Formation (MIS ?3-1)	**Hamble Formation (MIS pre 13-1)**
			Kent Ouse Formation (MIS 1)	Sussex Ouse Formation (MIS pre 5e-1)	**Hampshire Avon Formation (MIS pre 13-1)**
				Sussex Rother Formation (MIS pre 13-1)	**Itchen Formation (MIS pre 13 -1)**
				Arun Formation (MIS pre 13-1)	**Meon Formation (MIS pre 13-1)**
					Test Formation (MIS ? pre 13-1)
					Frome-Piddle Formation (MIS pre 13-1)
			Romney Marsh Formation (Gibbard and Preece, p. 61 in Bowen, 1999)		Poole Harbour Formation(Gibbard and Preece, p. 64 in Bowen, 1999)
Late Pleistocene	Devensian/ Weichselian	Loch Lomond Stadial (2-1)			
		Windermere Interstadial (2)			
		Dimlington Stadial (2)	Pegwell Formation (Gibbard and Preece, p.61 in Bowen, 1999	Pegwell Formation (Gibbard and Preece, p.61 in Bowen, 1999	
				West Sussex Coast Formation (MIS ?13-2) (Gibbard and Preece, pp.61-62 in Bowen, 1999)	
		3			
		4			
		5d-a			
	Ipswichian/ Eemian (5e)				
Mid Pleistocene	6				
	7				
	8				
	9				
	10				
	Hoxnian/ Holsteinian (11)				
	Anglian/ Elsterian (12)				
Early Pleistocene			**Lenham Formation**		
Pliocene					

BRITANNIA CATCHMENTS GROUP
BRITISH COASTAL DEPOSITS GROUP
CALEDONIA GLACIGENIC GROUP
ALBION GLACIGENIC GROUP
RESIDUAL DEPOSITS GROUP

NB. Formations shown in **bold type** have been formally defined in the BGS Lexicon. Formations in underlined plain type are currently not formally defined in the BGS Lexicon. Members in plain type have been formally defined in the BGS Lexicon. Members and beds in *italic type* are currently informal units. MIS = Marine Isotope Stage.

Somerset, Devon & Cornwall	Bristol	Scilly Isles
CORNUBIAN CATCHMENTS SUBGROUP **Petrockstow Valley Formation (MIS ?pre 13-1)** **Torridge Valley Formation (MIS 12-1)** **Taw Valley Formation (MIS 12-1)** **Tamar Valley Formation (MIS 12-1)** Axe Valley Formation (Campbell et al., p.71 in Bowen, 1999) Exe Valley Formation	**SEVERN AND AVON CATCHMENTS SUBGROUP** **Bristol Avon Valley Formation (MIS 12-1)** Alluvium **Gwent Levels Formation** **Oldbury and Avonmouth Levels Formation** **Somerset Levels Formation**	
Lizard Formation and Camel Formation (Campbell et al., pp.72-74 in Bowen, 1999) Croyde Bay Formation (MIS 7-2) (Campbell et al., p.75 in Bowen, 1999) **SOMERSET CATCHMENTS SUBGROUP** Parrett Valley Formation (MIS9-2) (Campbell et al., p.78 in Bowen, 1999)		**IRISH SEA COAST GLACIGENIC SUBGROUP** St Martin's Formation (Bread and Cheese Formation of Scourse, 1991) *Scilly Till Member* St Mary's Formation (Campbell et al., p.70 in Bowen, 1999) *Porthloo Breccia Member*
Burtle Formation (MIS ?11-5e)	*Bathampton Palaeosol* (Campbell et al., p.77 in Bowen, 1999)	*Watermill Sand and Gravel Member* of St Mary's Formation (Campbell et al., p.70 in Bowen,1999)
Fremington Clay (MIS 6 or 2) (Fremington Member of Barnstable Bay Formation of Campbell et al., pp. 74-75 in Bowen, 1999)	*Bathampton Gravel Member* (MIS 6 or older) (Campbell et al., p.77 in Bowen, 1999)	
Penwith Formation (MIS 7-2) (Campbell et al., pp. 71-73 in Bowen, 1999); Torbay Formation (MIS 7-2) (Campbell et al., p.74 in Bowen, 1999		
	Stidham Gravel Member (Campbell et al., p.77 in Bowen, 1999)	
Penlee Formation (Campbell et al., pp. 71-73 in Bowen, 1999)		
Kenn Formation (MIS12 or pre-13)	*Ham Green Gravel Member* (possibly MIS 12) (Campbell	
	Clay-with-flints Formation	
St Erth Formation		

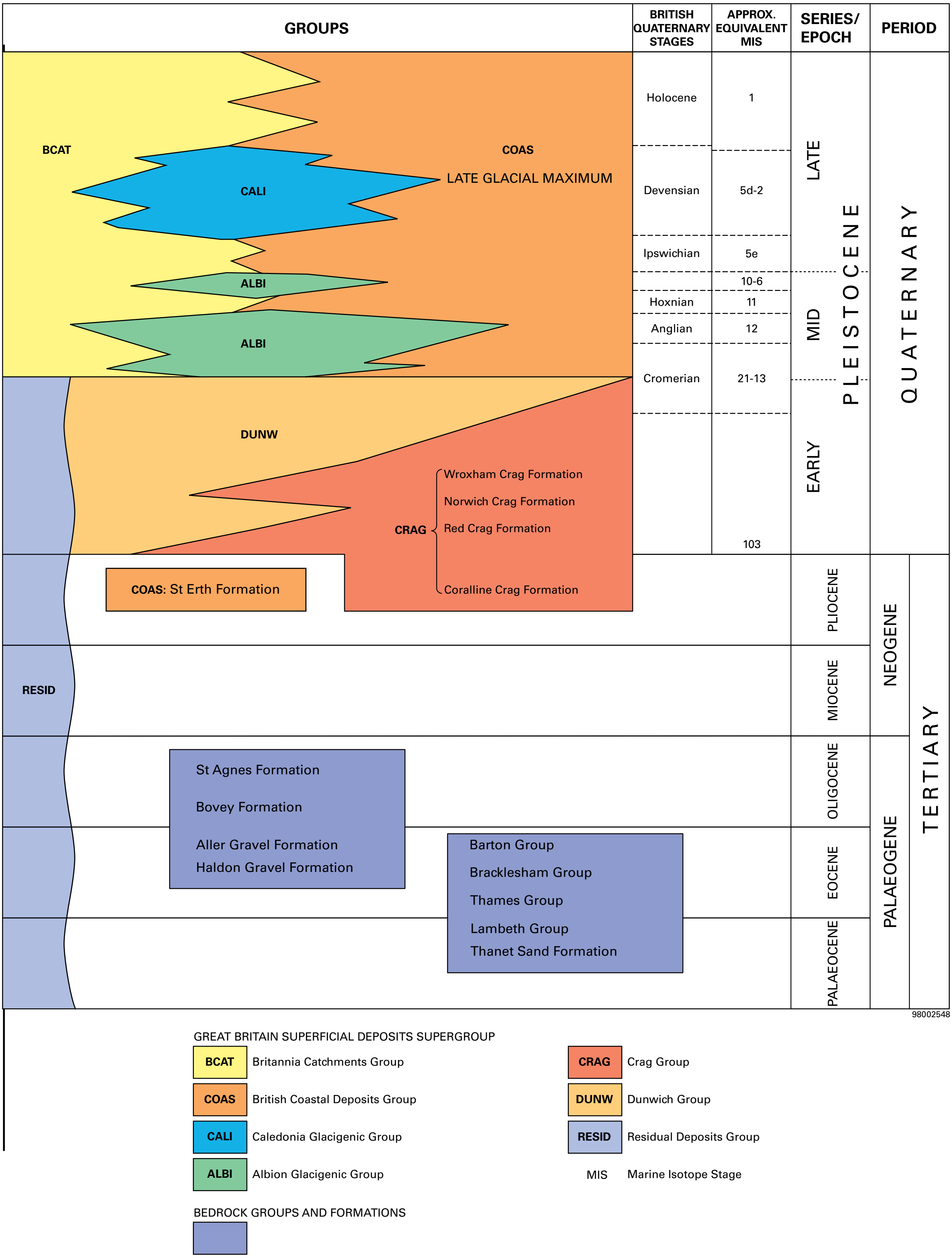


Figure 1 Generalised relationship of the seven groups belonging to the Great Britain Superficial Deposits Supergroup. Bedrock groups and formations of Palaeogene age (not described in this report) are also shown.

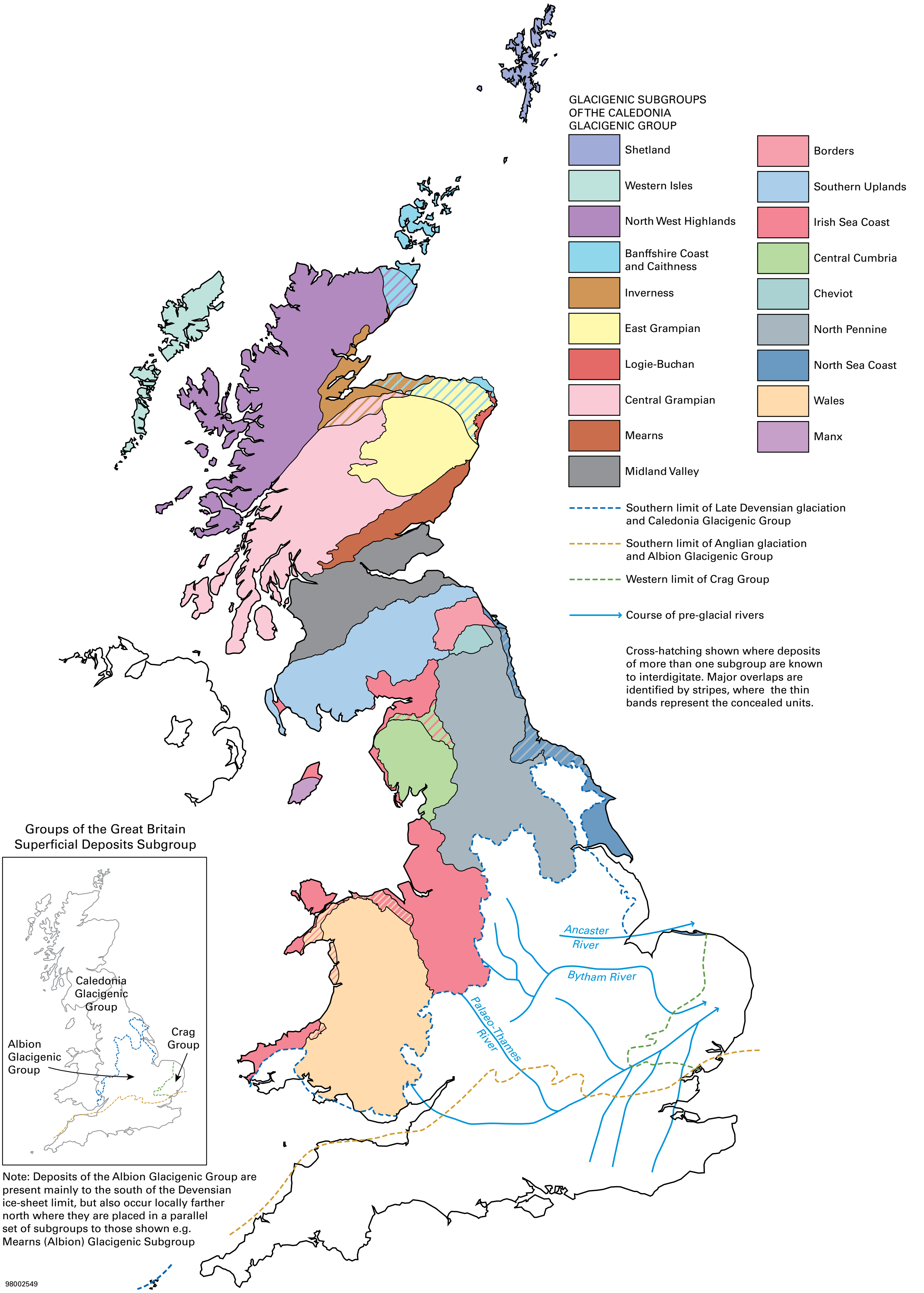


Figure 2 Surface distribution of glacigenic groups and subgroups, the Crag Group and the courses of the ancestral Thames and Bytham rivers.

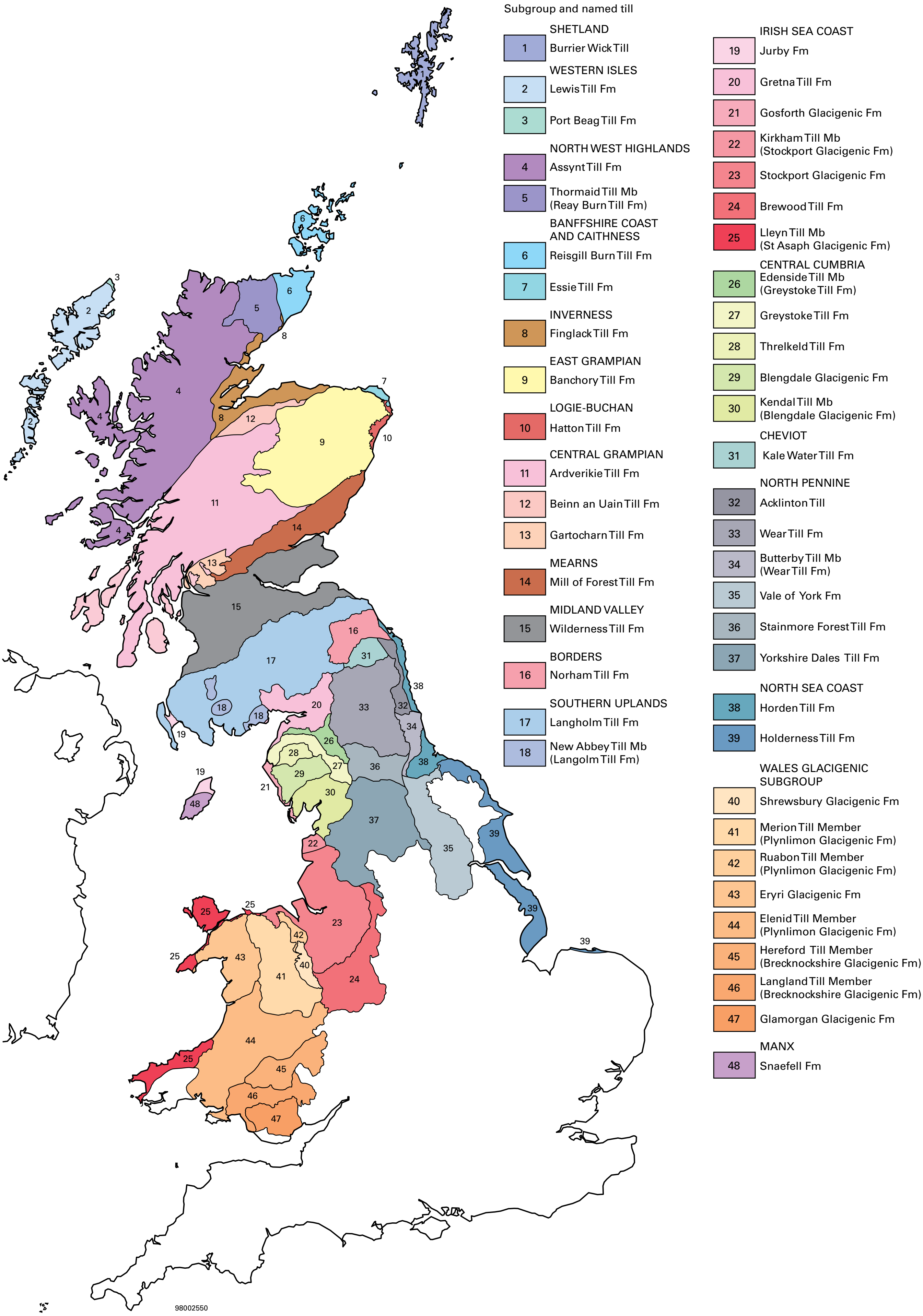


Figure 3 Distribution of surficial till formations of the Caledonia Glacigenic Group.

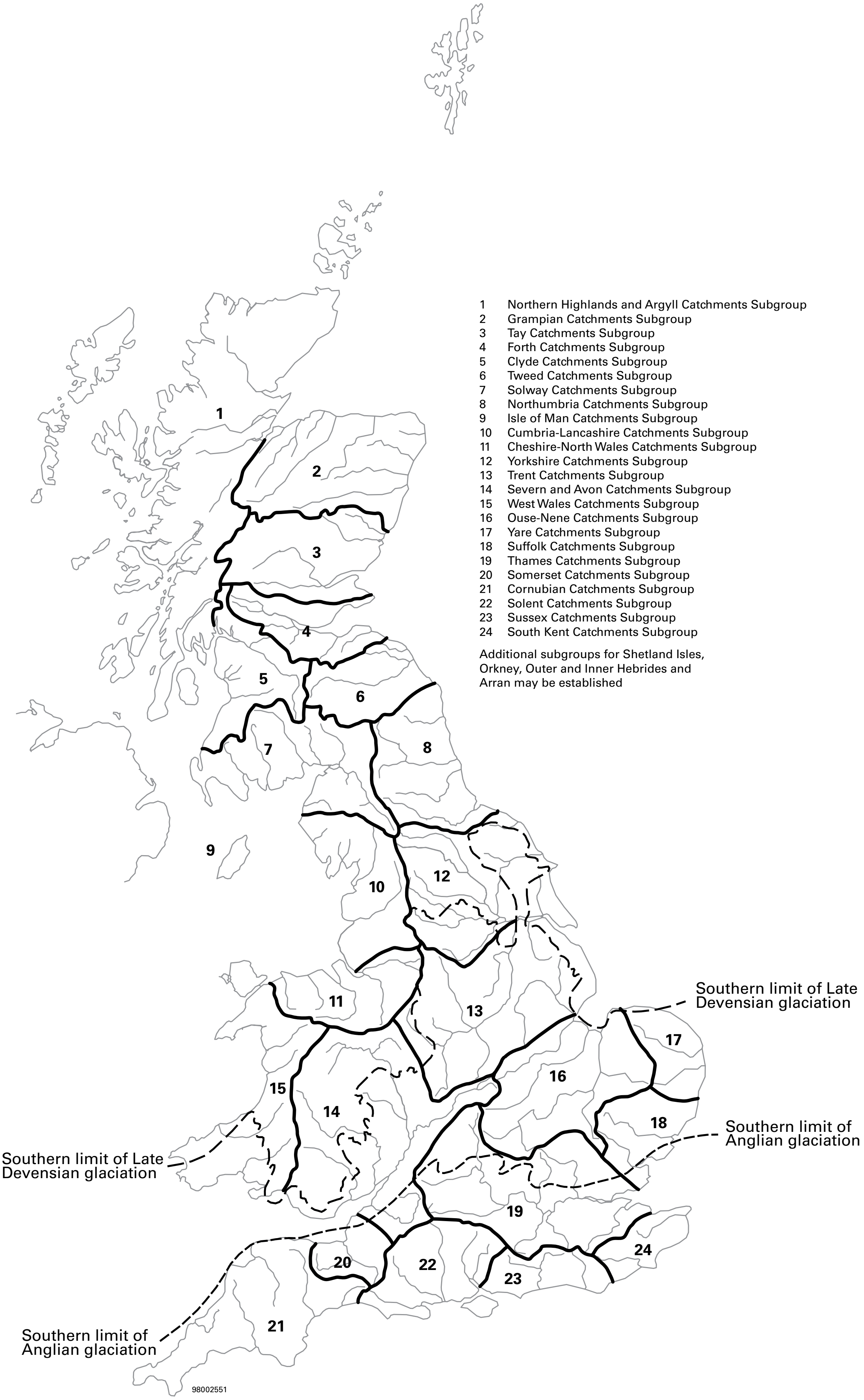


Figure 4 Distribution of catchment subgroups of the Britannia Catchments Group.

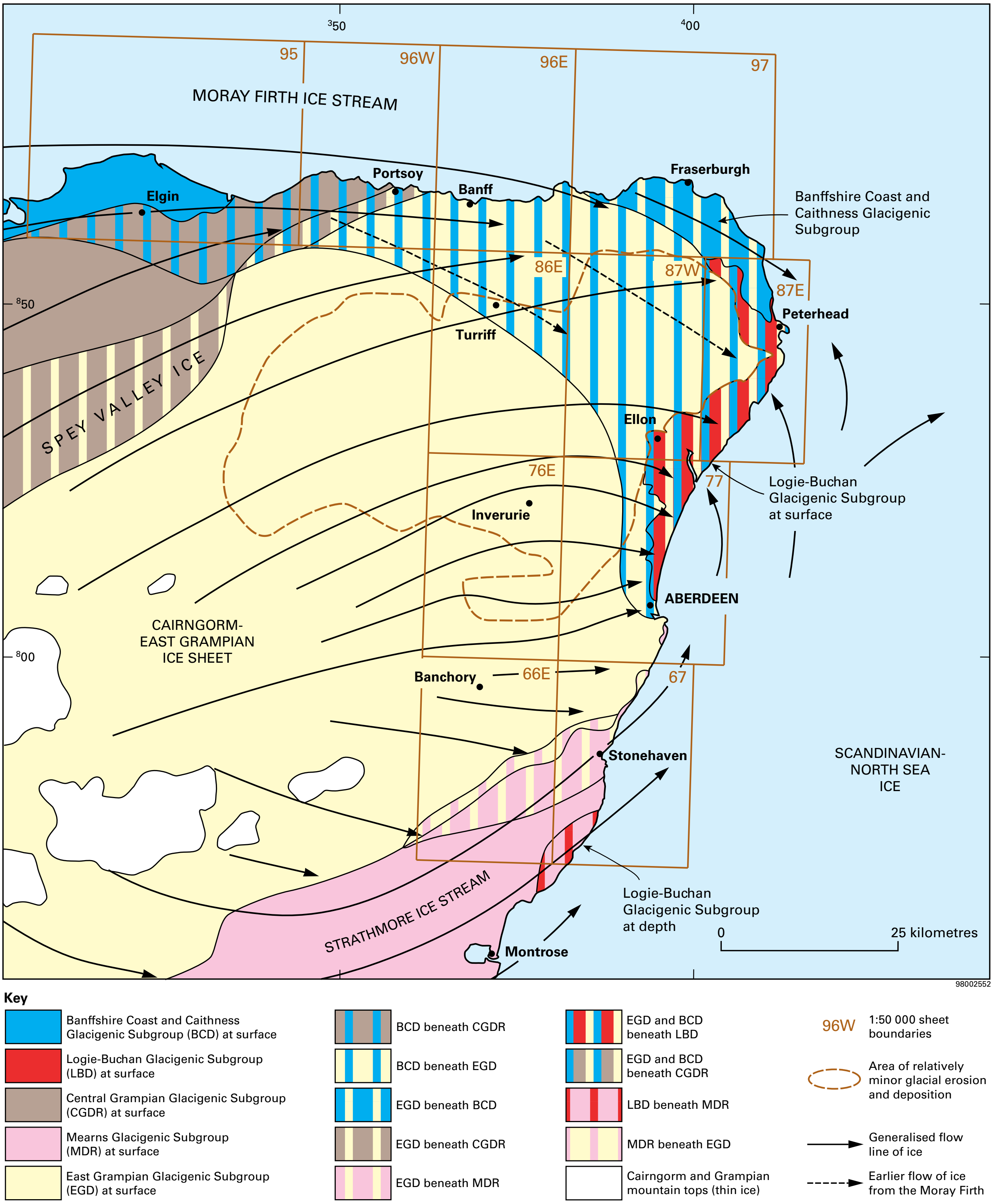
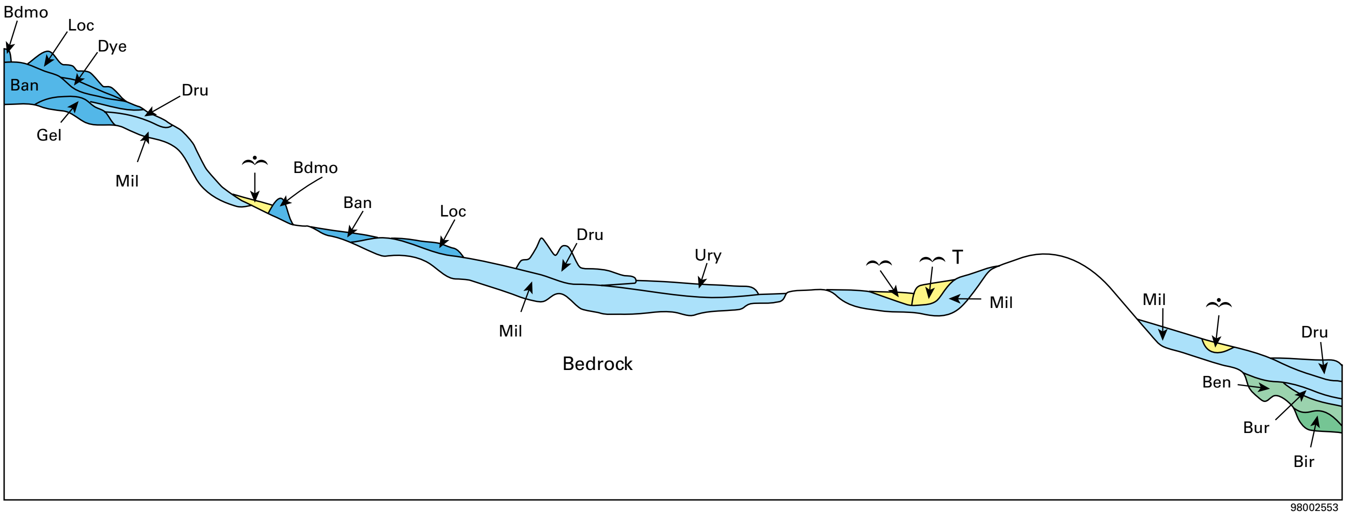


Figure 5 Generalised flow-lines of ice during the Main Late Devensian Glaciation and profile map of the five glacigenic subgroups of the Caledonia Glacigenic Group cropping out in north-east Scotland (Merritt et al., 2003).



BRITANNIA CATCHMENTS GROUP

Tay Catchments Subgroup
- Alluvium
- River terrace deposits, undifferentiated T
- Peat

ALBION GLACIGENIC GROUP

East Grampian (Albion) Glacigenic Subgroup
- Birnie Gravel Formation (Bir)

Logie-Buchan (Albion) Glacigenic Subgroup
- Benholm Clay Formation (Ben)

CALEDONIA GLACIGENIC GROUP

East Grampian Glacigenic Subgroup
- Blairdaff Moraine Formation (Bdmo)
- Lochton Sand and Gravel Formation (Loc)
- Glen Dye Silts Formation (Dye)
- Banchory Till Formation (Ban)
  - Pre-Late Devensian gelifluctate, undifferentiated (Gel)

Mearns Glacigenic Subgroup
- Drumlithie Sand and Gravel Formation (Dru)
- Ury Silts Formation (Ury)
- Mill of Forest Till Formation (Mil)
  - Burn of Benholm Peat Bed (Bur)

Figure 6 Schematic cross-section across the Highland boundary and Strathmore, north-east Scotland, showing the stratigraphical relationships between formalised glacigenic lithostratigraphical units and informal lithogenetic units.

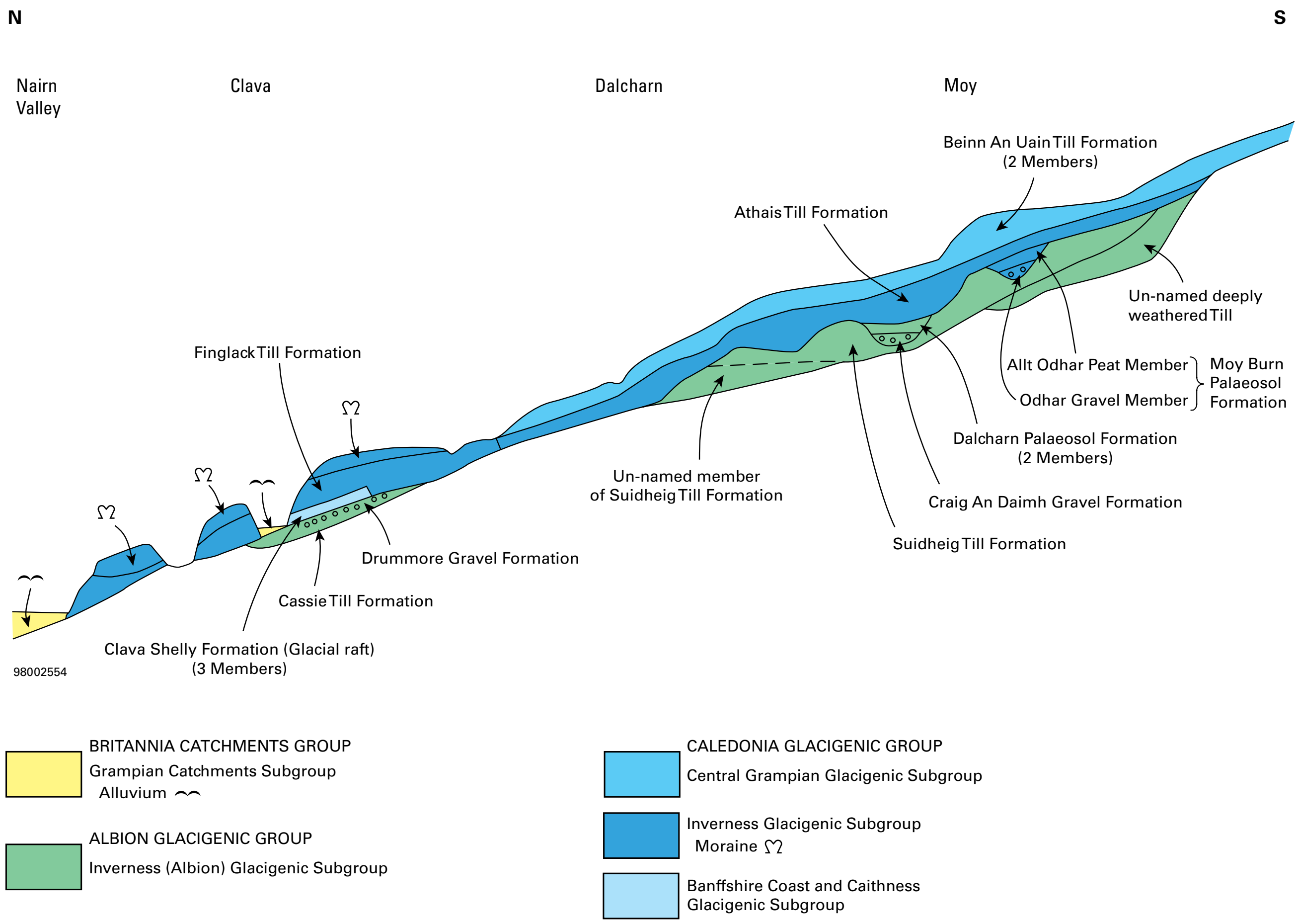


Figure 7 Schematic cross-section south-east of Inverness, showing inter-relationships between lithostratigraphical units named in Tables 9 and 10.

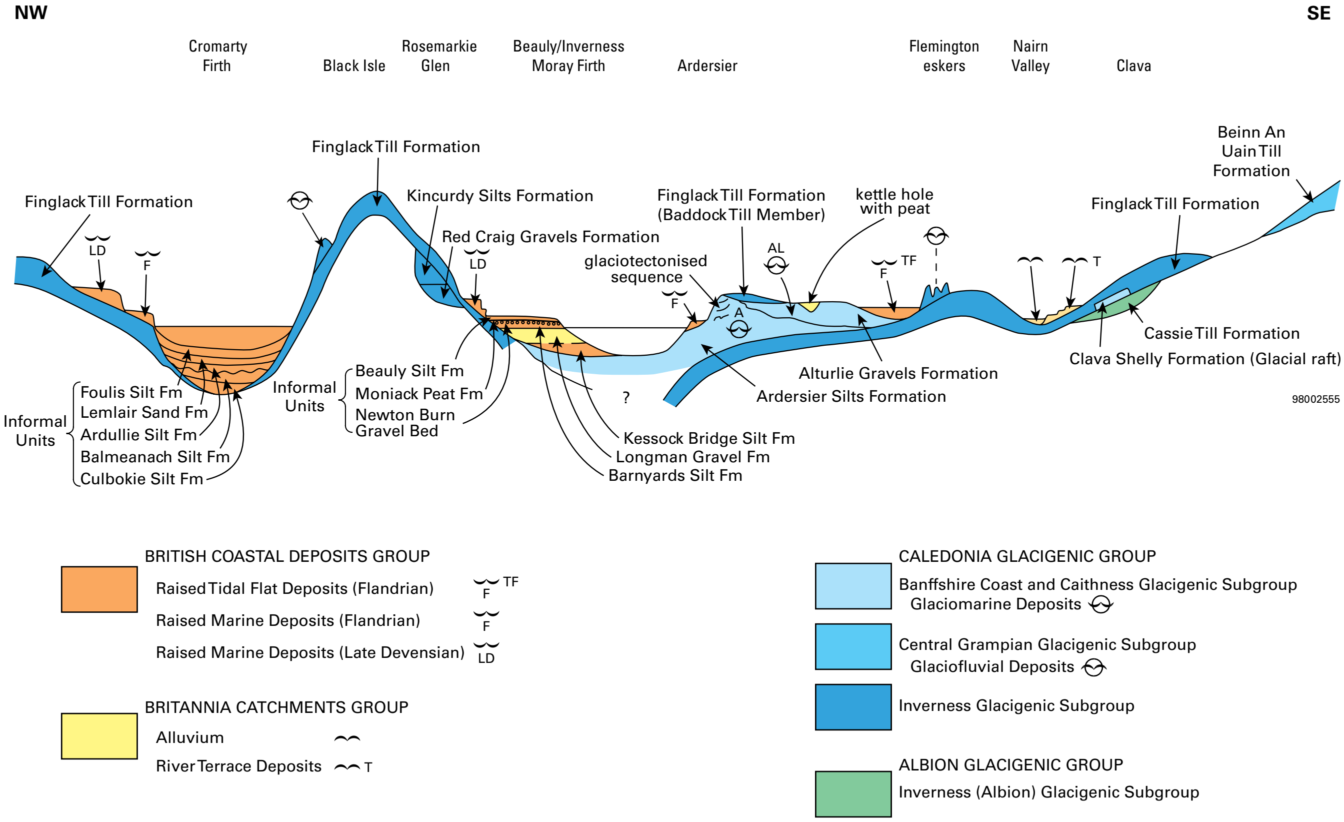


Figure 8 Schematic cross-section from the Cromarty Firth to Clava, showing inter-relationships between lithostratigraphical units named in Tables 9 and 10.

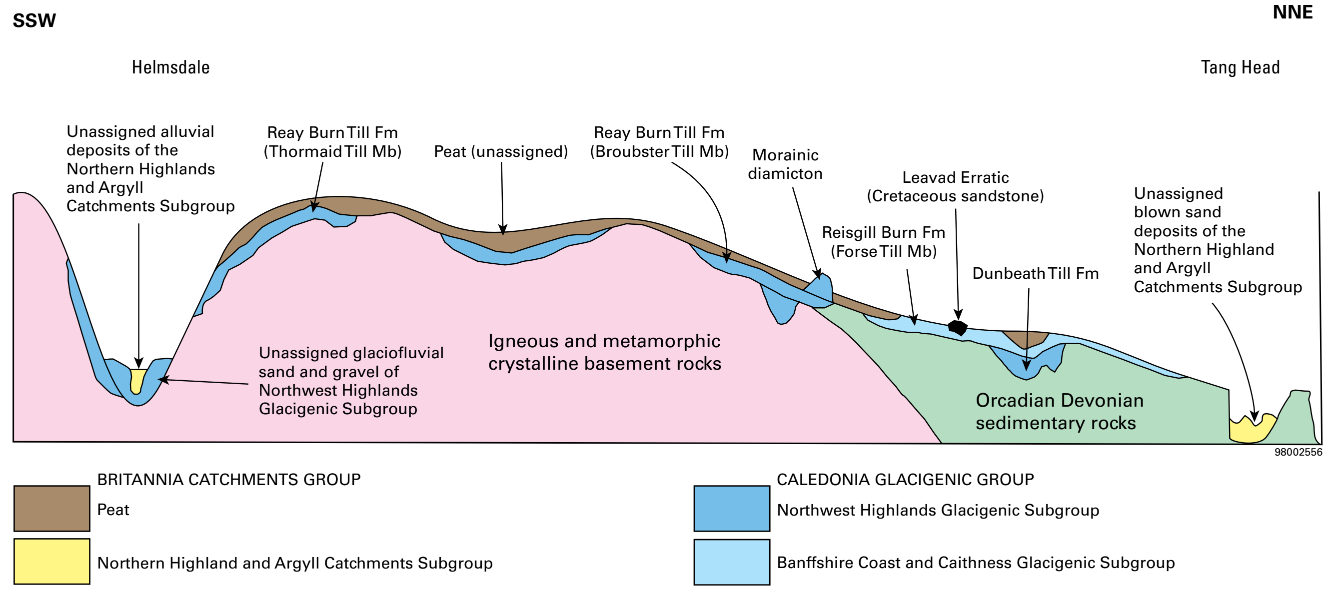


Figure 9 Schematic cross-section across Caithness and Sutherland, showing inter-relationships between lithostratigraphical units named in Table 9.

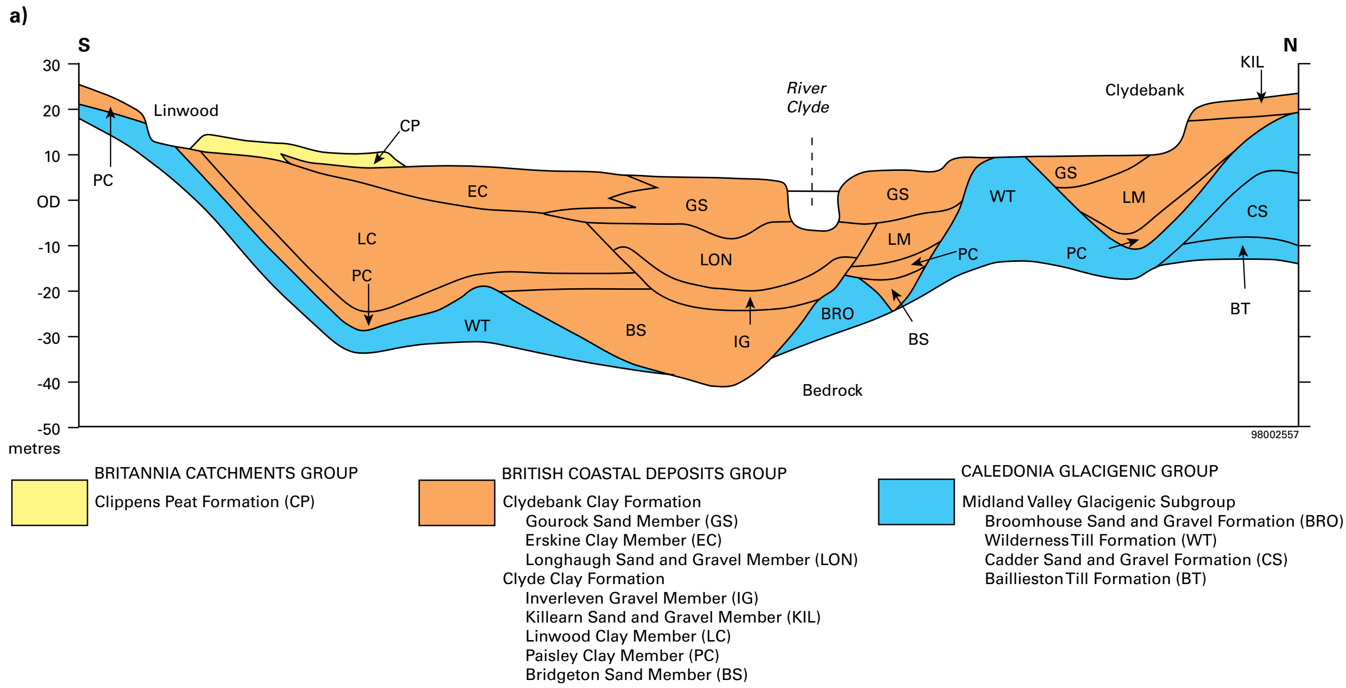


Figure 10a Schematic cross-section across the Clyde Valley in west Glasgow, showing inter-relationships between lithostratigraphical units named in Table 11 (after Browne and McMillan, 1989).

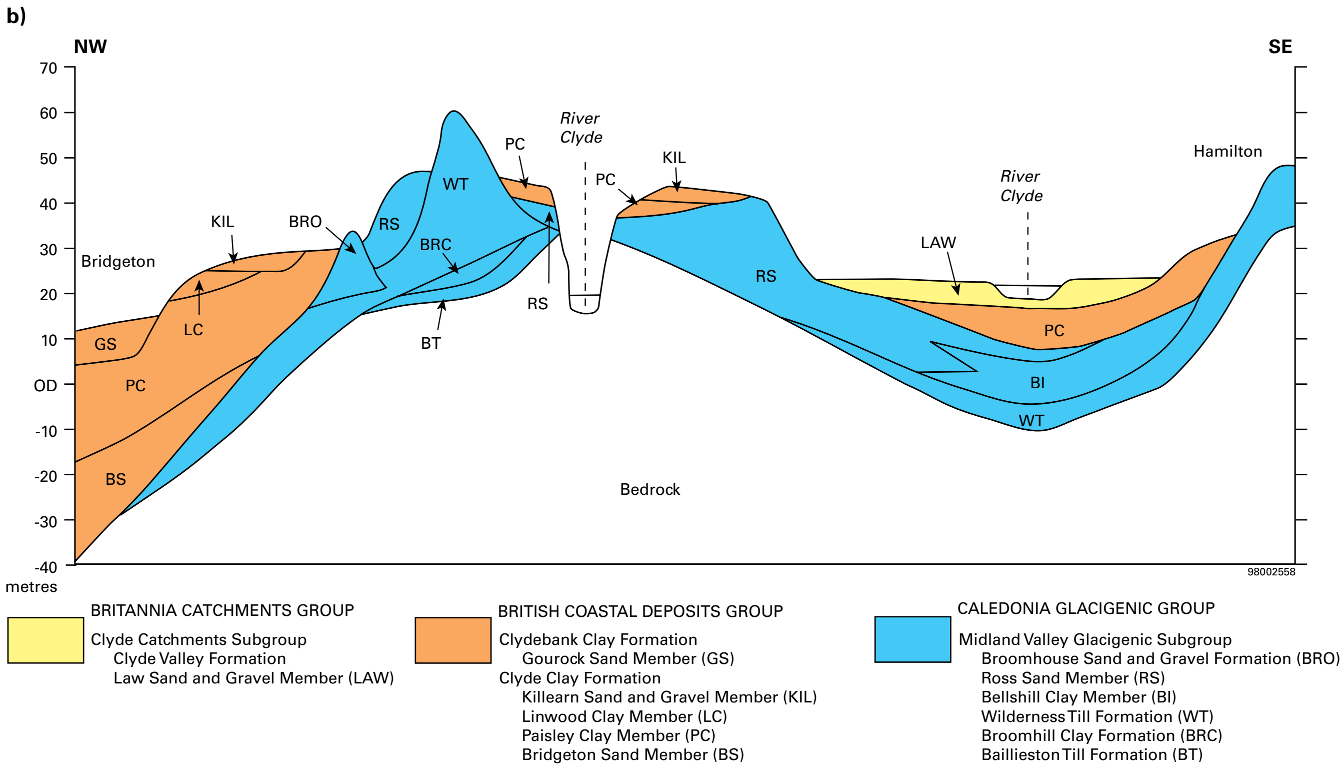


Figure 10b Schematic cross-section from Loch Lomond to Strathblane, showing inter-relationships between lithostratigraphical units named in Table 11 (after Browne and McMillan, 1989).

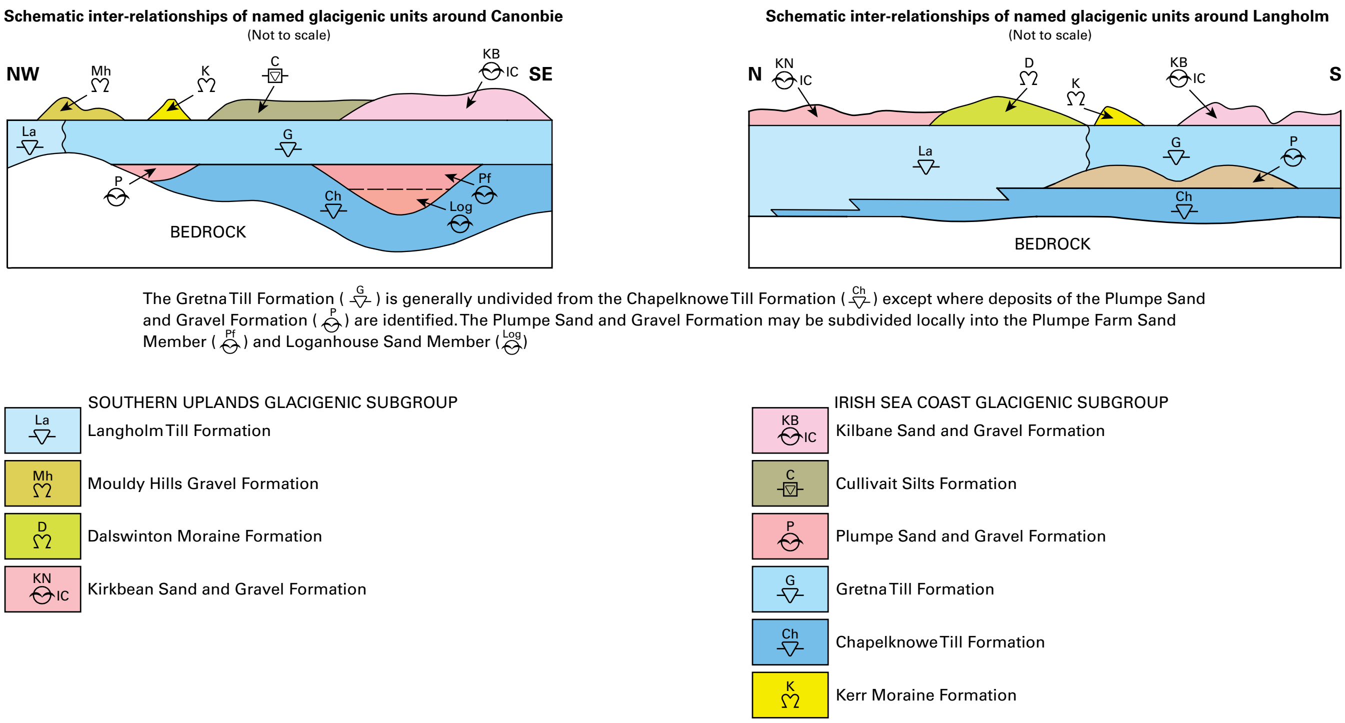


Figure 11 Schematic cross-section across the Solway, showing inter-relationships between lithostratigraphical units named in Table 12 (BGS 1:50 000 Special Sheet Solway East).

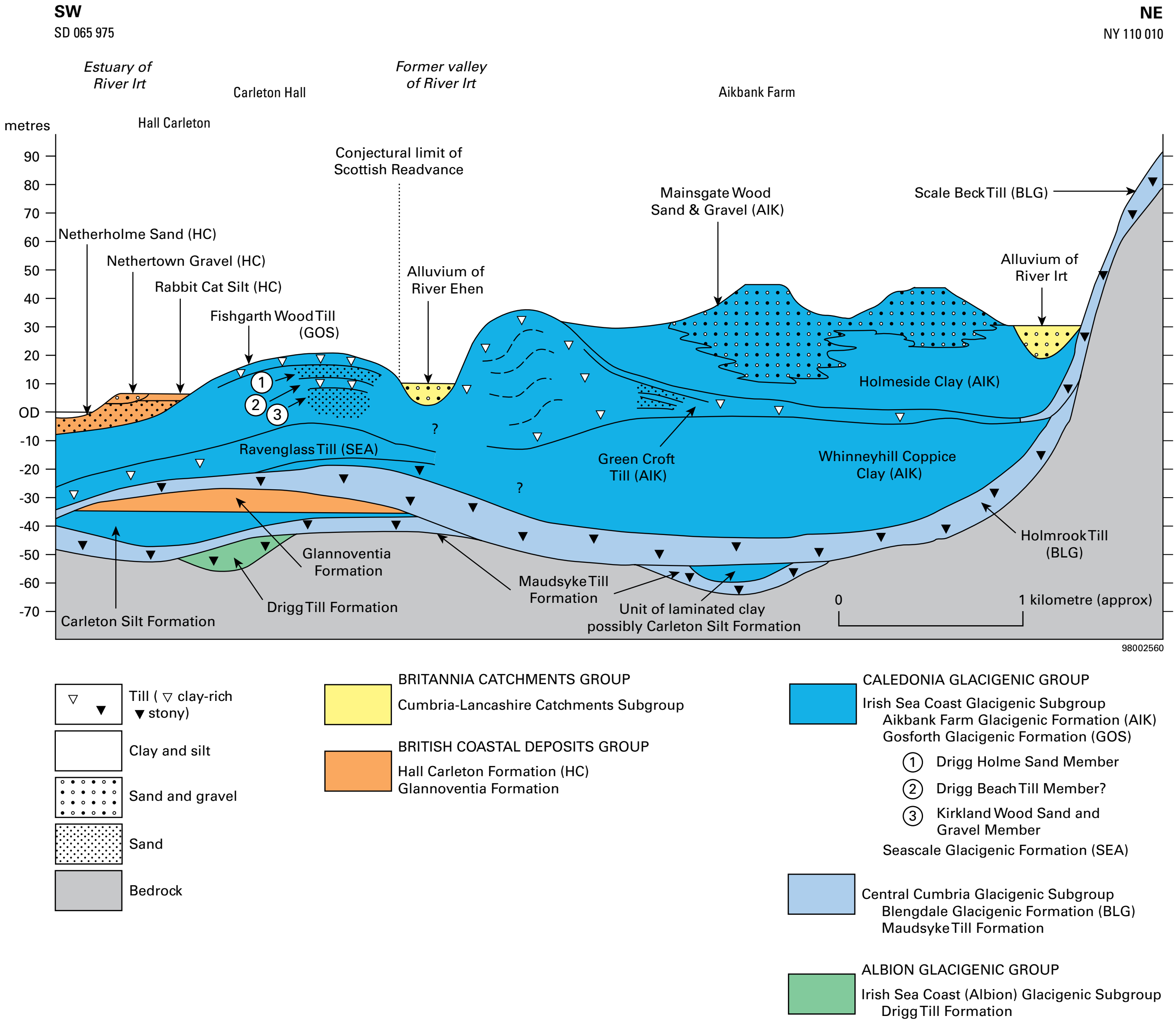


Figure 12 Schematic cross-section across West Cumbria, showing inter-relationships between lithostratigraphical units named in Table 12 (after Merritt and Auton, 2000, and Stone et al., 2009).

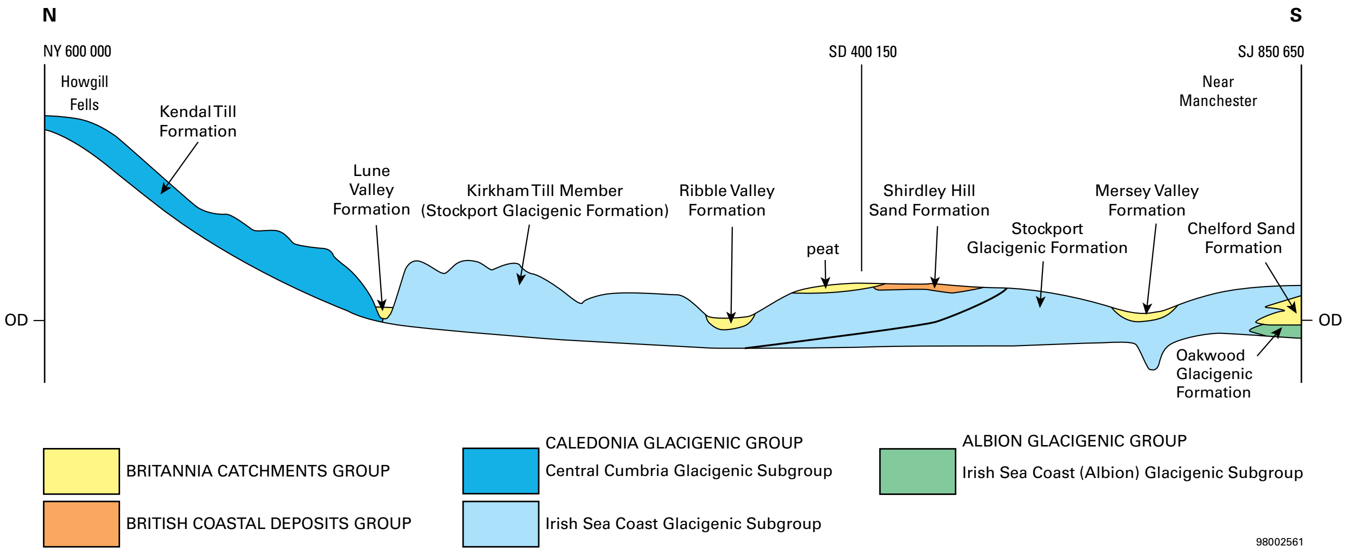


Figure 13 Schematic cross-section from the Howgill Fells to the Mersey Valley, showing the stratigraphical relationships between formalised glacigenic lithostratigraphical formations.

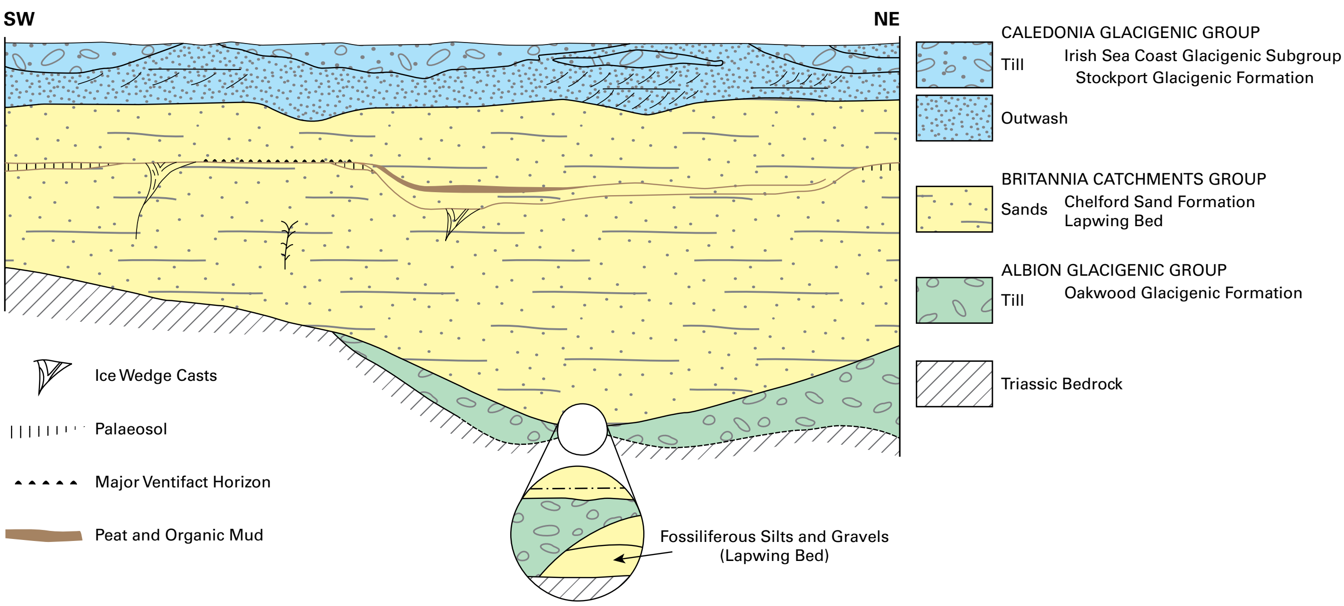


Figure 14 Schematic cross-section of the Pleistocene succession at Oakwood, Chelford (after Worsley, 1991).

Figure 15 Late Devensian glacial features in East Yorkshire (after Catt, 1991).

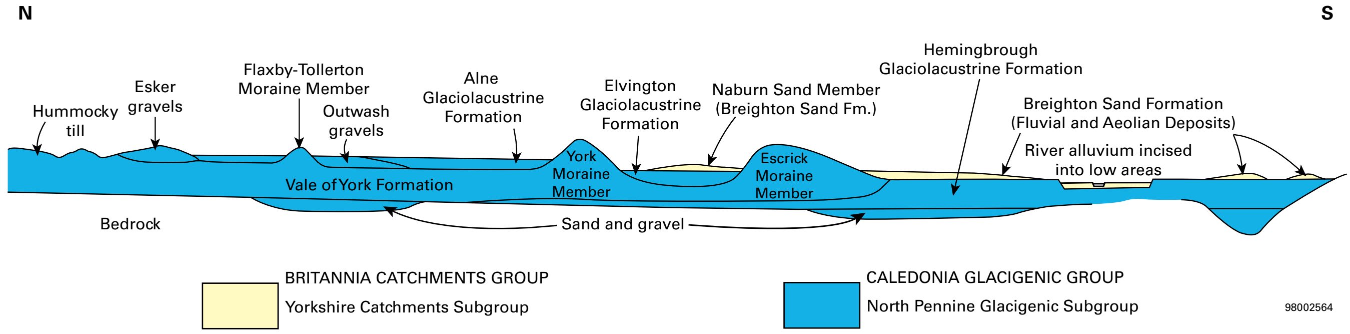


Figure 16 Schematic cross-section from Teesside to Thirsk, showing the stratigraphical relationships between formalised glacigenic lithostratigraphical formations.

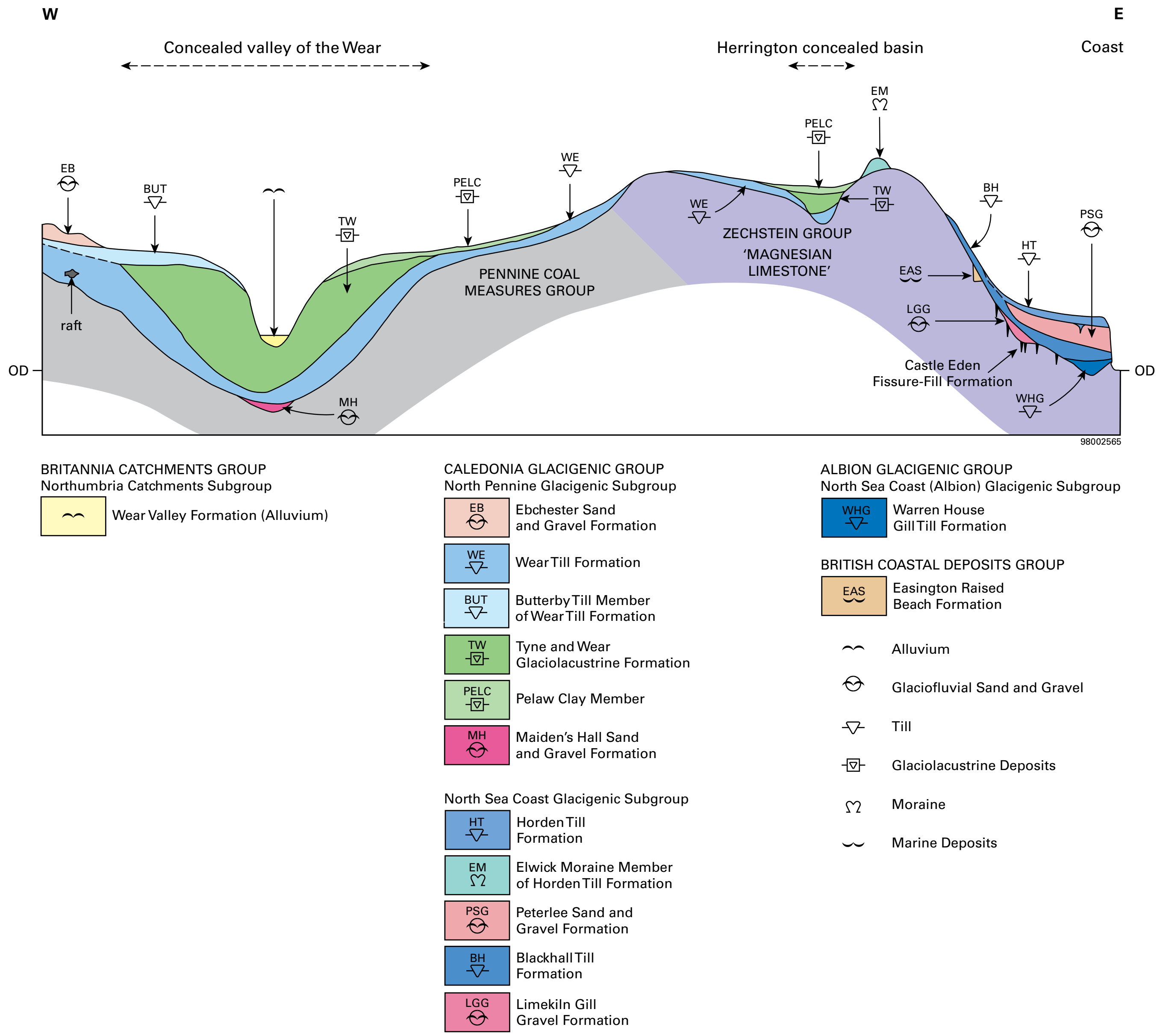
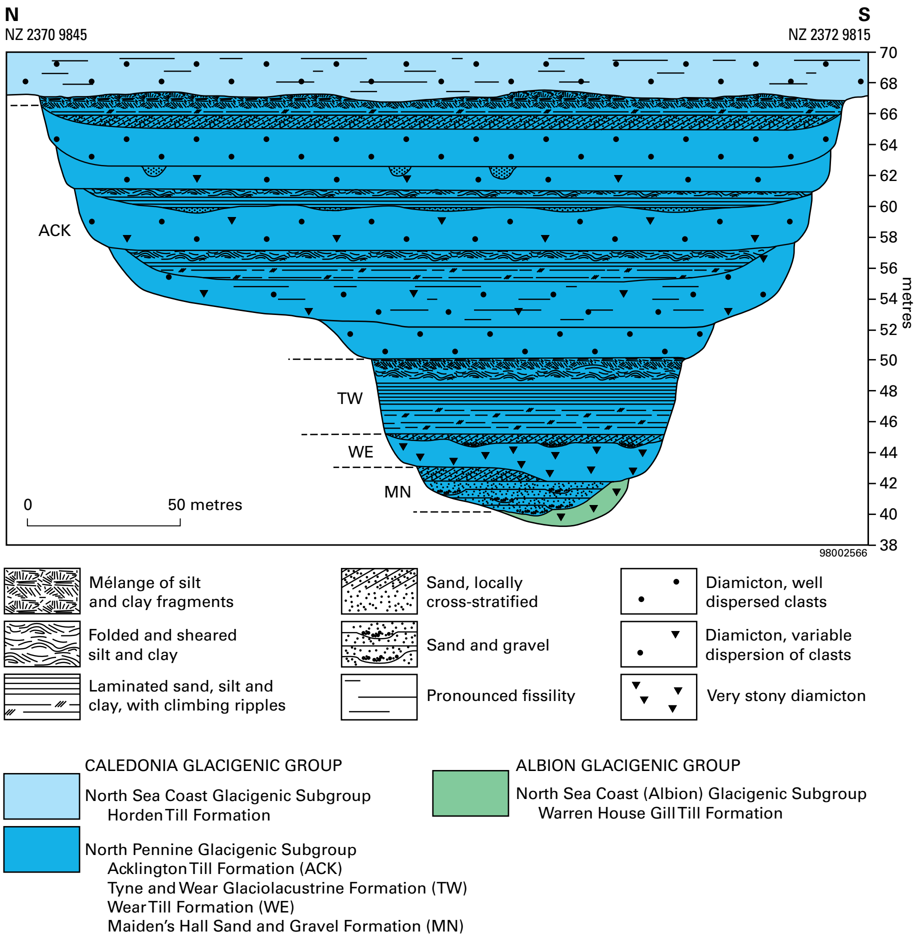


Figure 17 Schematic cross-section of the Wear valley, showing the stratigraphical relationships between formalised glacigenic lithostratigraphical units of the North Pennine and North Sea Coast glacigenic subgroups.

Figure 18 Detailed section of the interbedded diamictons and laminated clays of the Tyne and Wear Glaciolacustrine Formation (North Pennine Glacigenic Subgroup) (after Stone et al., 2009).



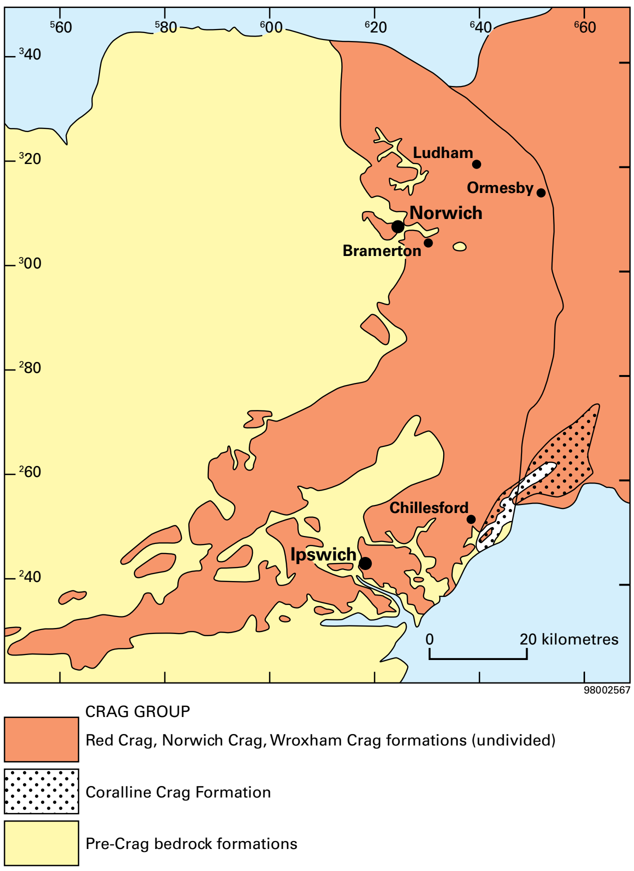


Figure 19 Regional distribution of the Crag Group (after Arthurton et al., 1994).

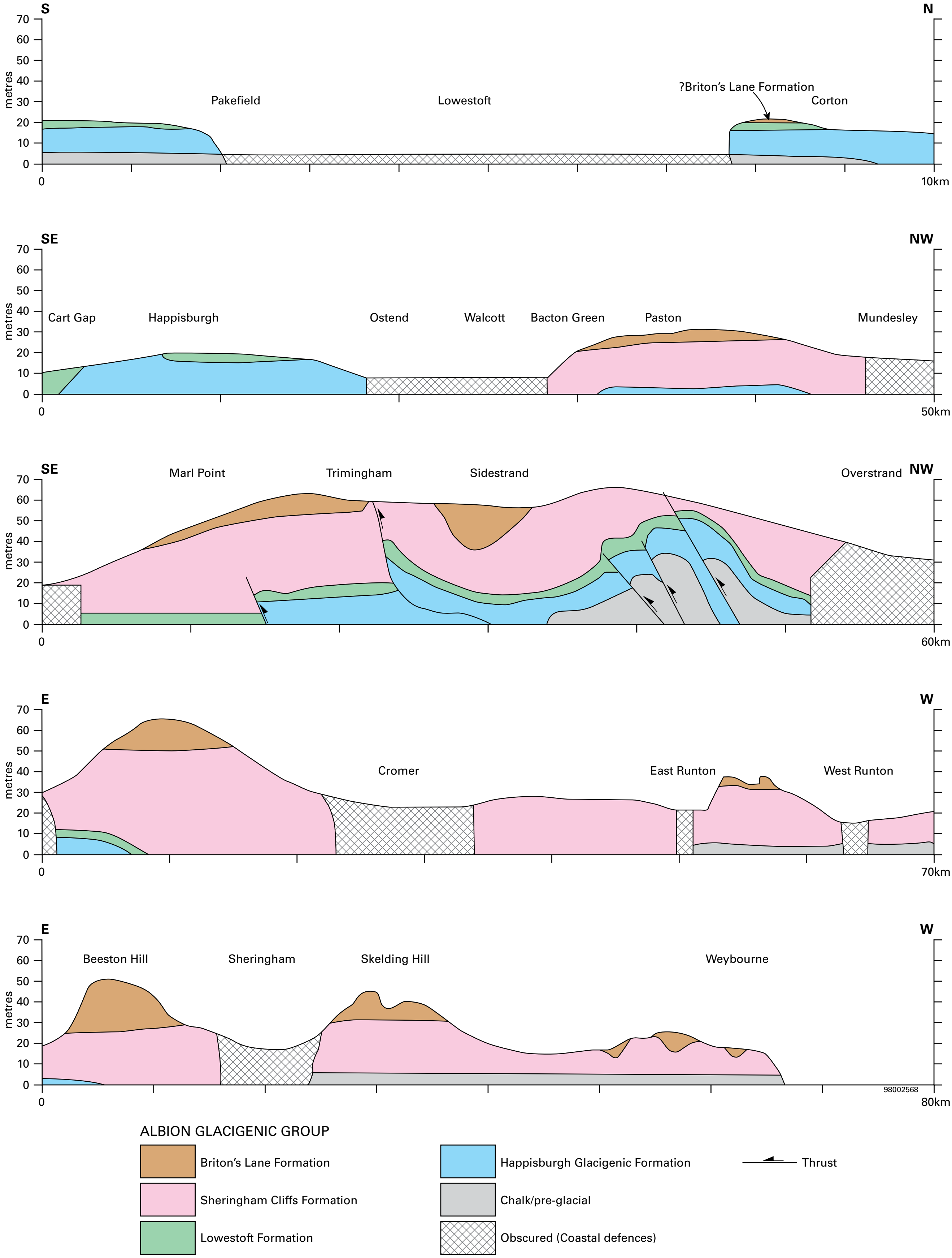


Figure 20 Schematic cross-section of the coastal sections between Pakefield and Corton in the Waveney Valley, showing the stratigraphical relationships between formalised glacigenic lithostratigraphical units of Albion Glacigenic Group (after Lee et al., 2004).

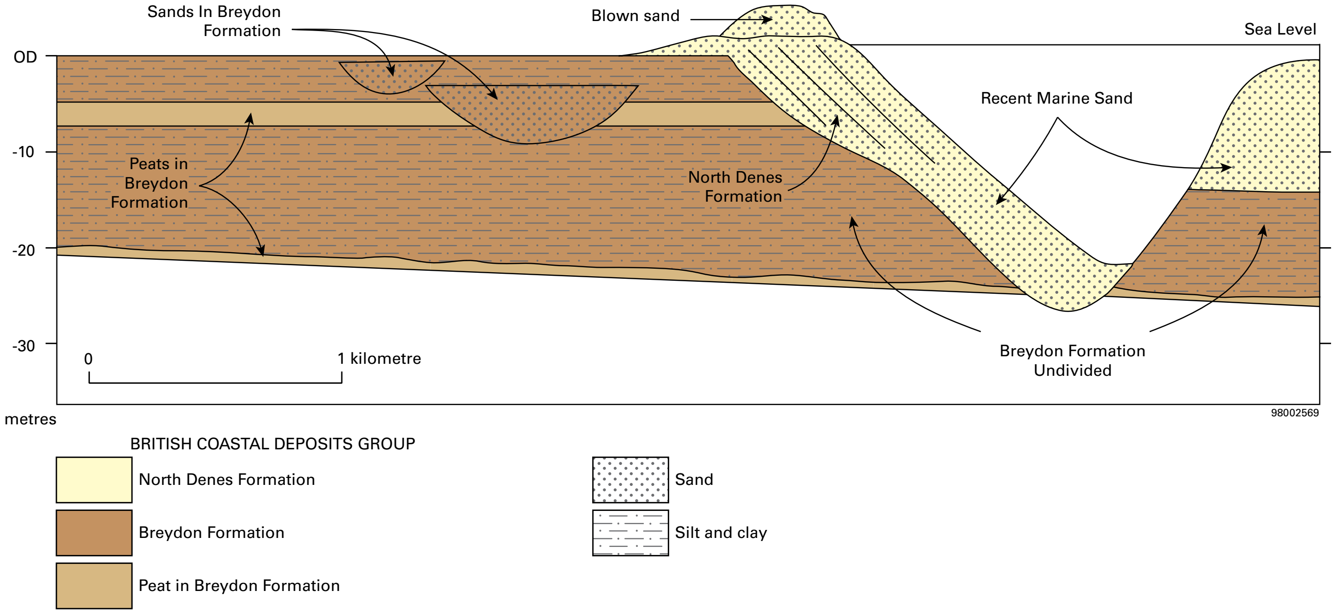


Figure 21 Schematic cross-section at Breydon, East Anglia, showing the stratigraphical relationships between formalised lithostratigraphical units of the British Coastal Deposits Group (after Arthurton et al., 1994).

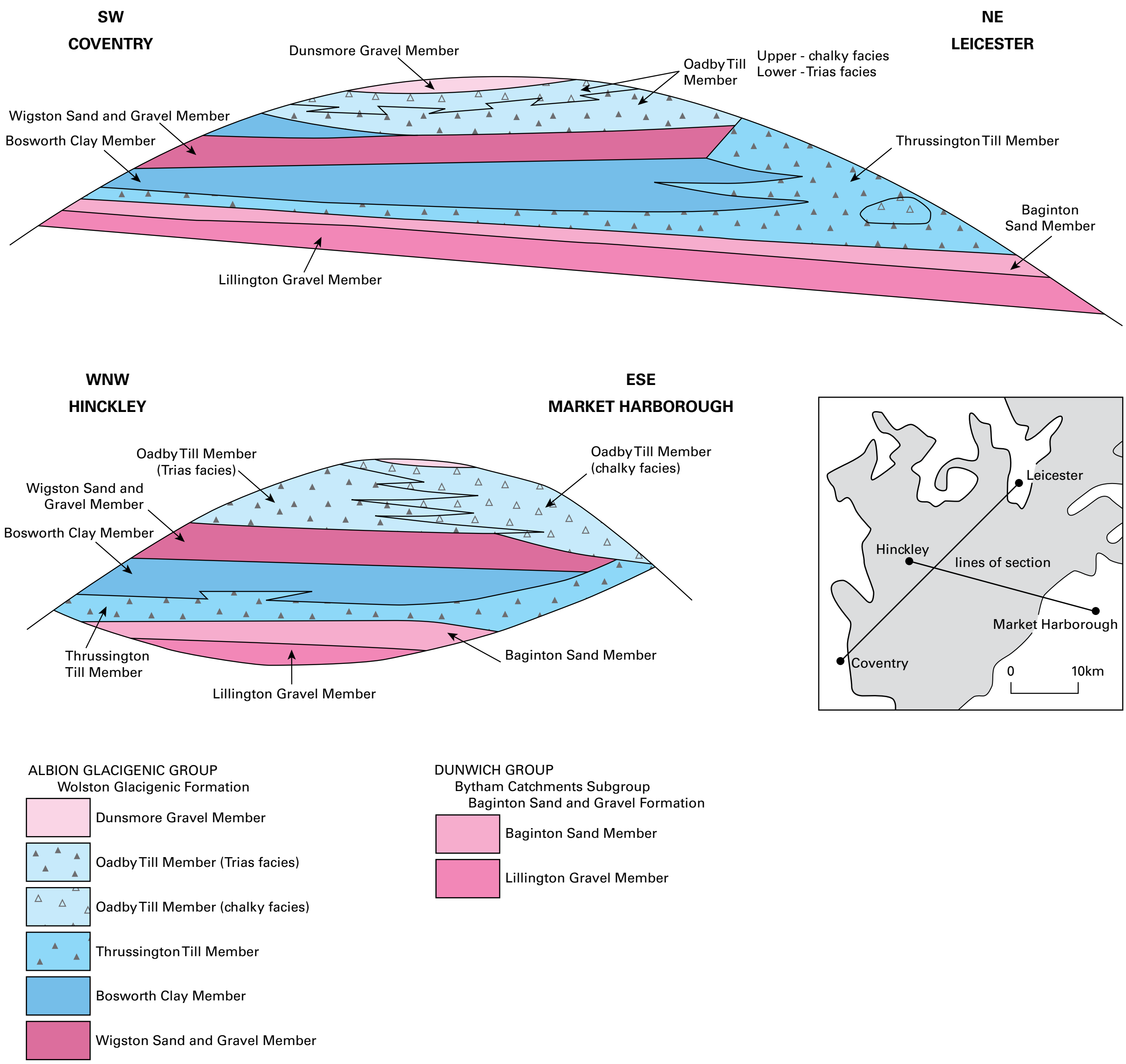


Figure 22 Model of stratigraphical relationships of members of the Wolston Glacigenic Formation (Albion Glacigenic Group) and the Baginton Sand and Gravel Formation (Bytham Catchments Subgroup) (after Rice and Douglas, 1991).

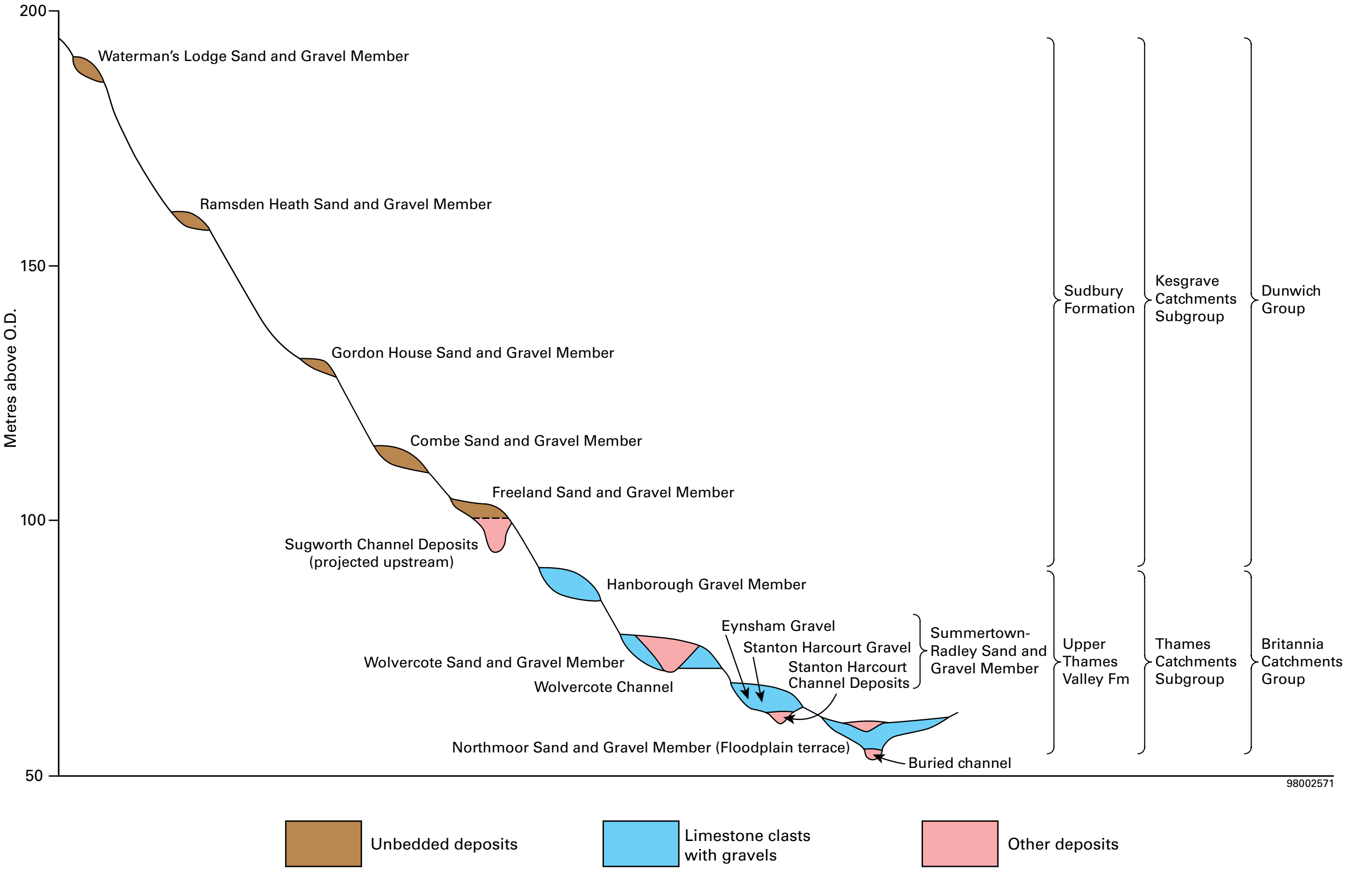


Figure 23 Terrace deposits of the Sudbury Formation (Kesgrave Catchment Subgroup) and Upper Thames Valley Formation (after Bridgland, 1994).

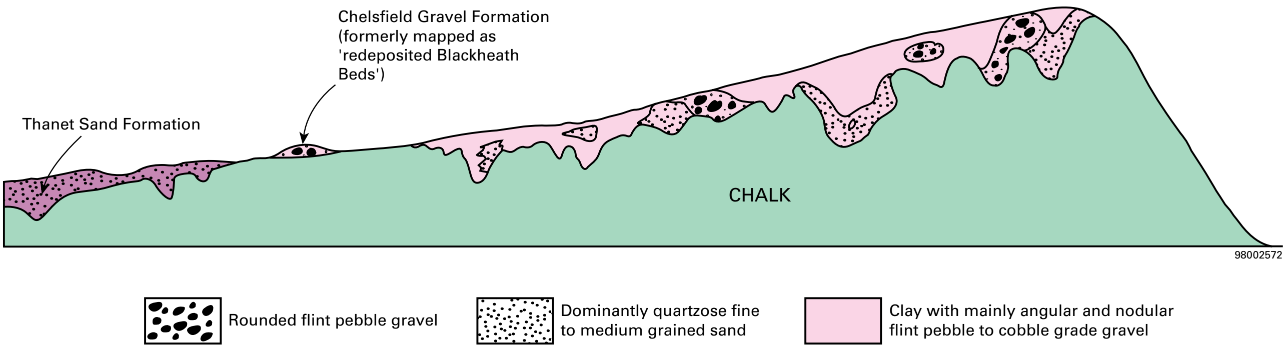


Figure 24 Schematic cross section to show the lateral variation in the Clay-with-flints Formation (after Ellison et al., 2004).

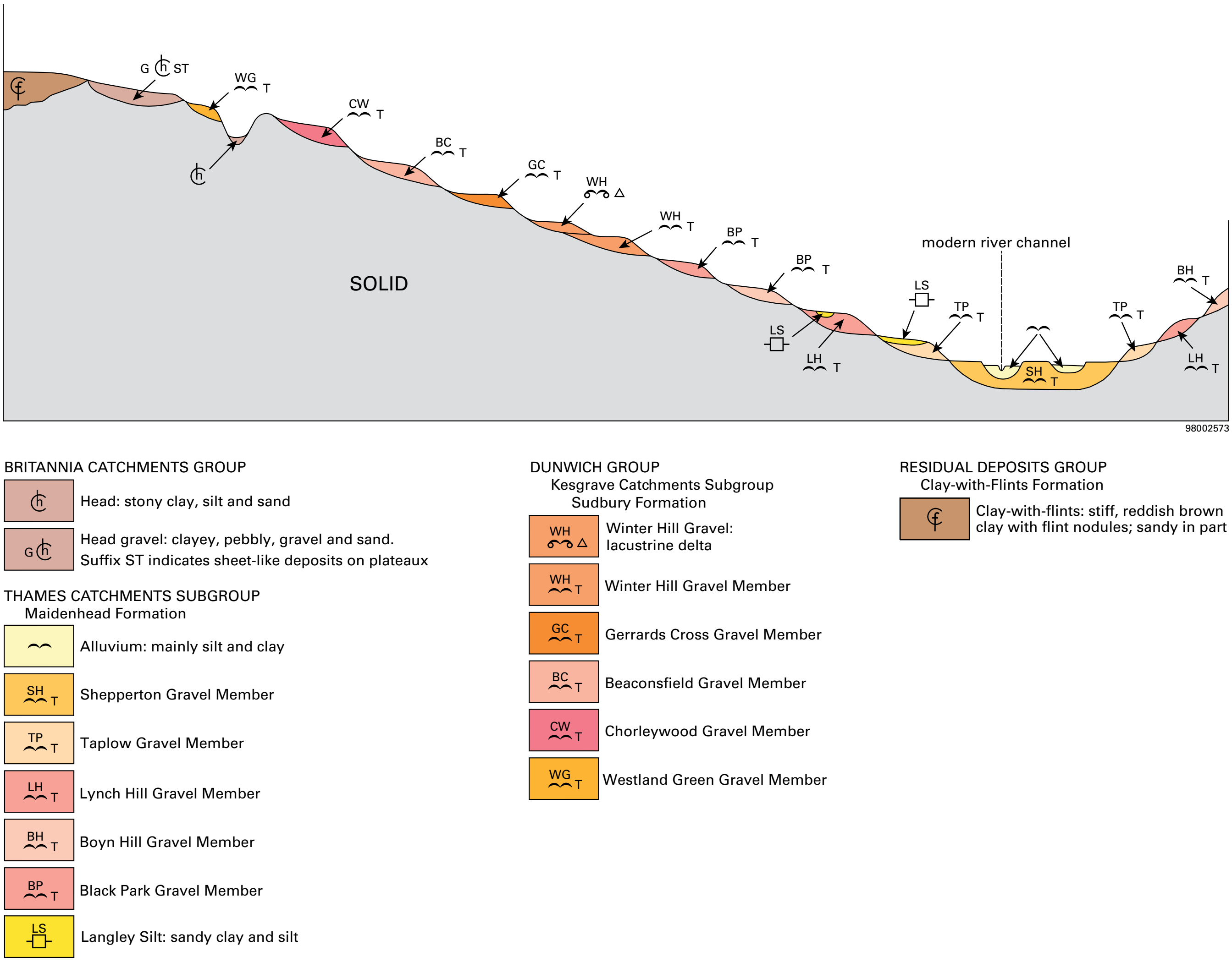


Figure 25 Terrace deposits of the Sudbury Formation (Kesgrave Catchment Subgroup) and Maidenhead Formation (after BGS 1:50 000 Sheet E255, Beaconsfield).

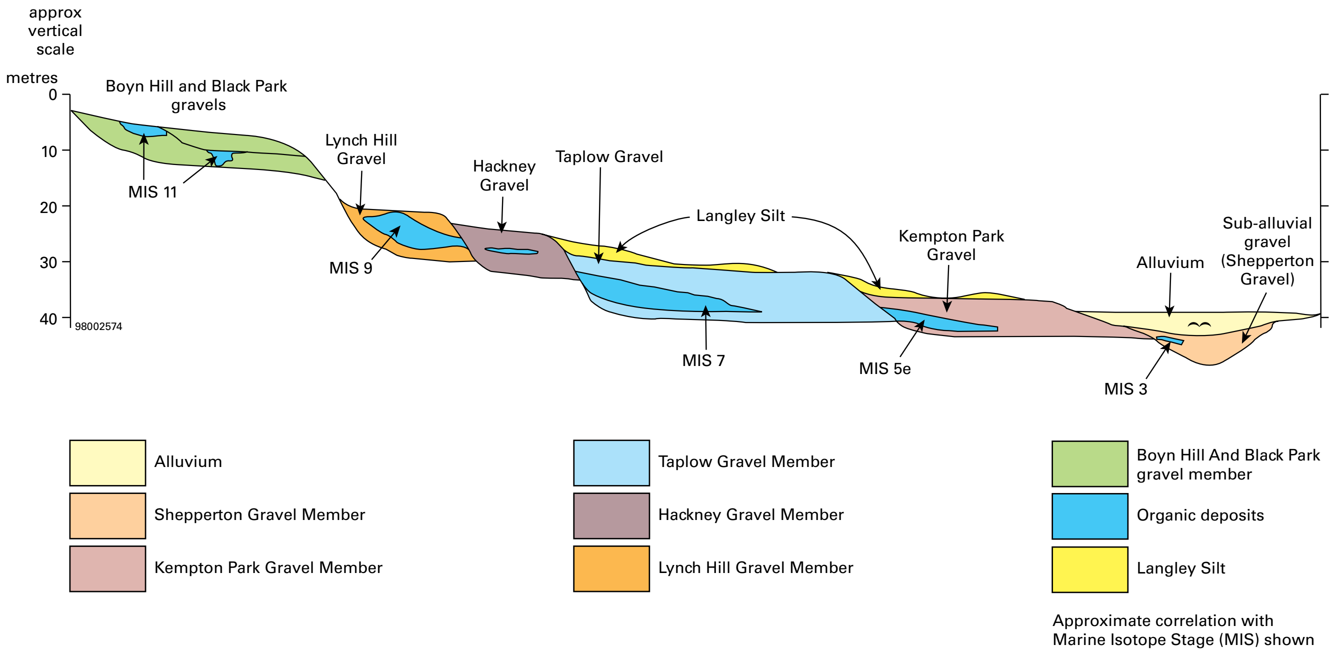


Figure 26 Terrace deposits of the Maidenhead Formation in London (after Bridgland, 1994, and Ellison et al., 2004).

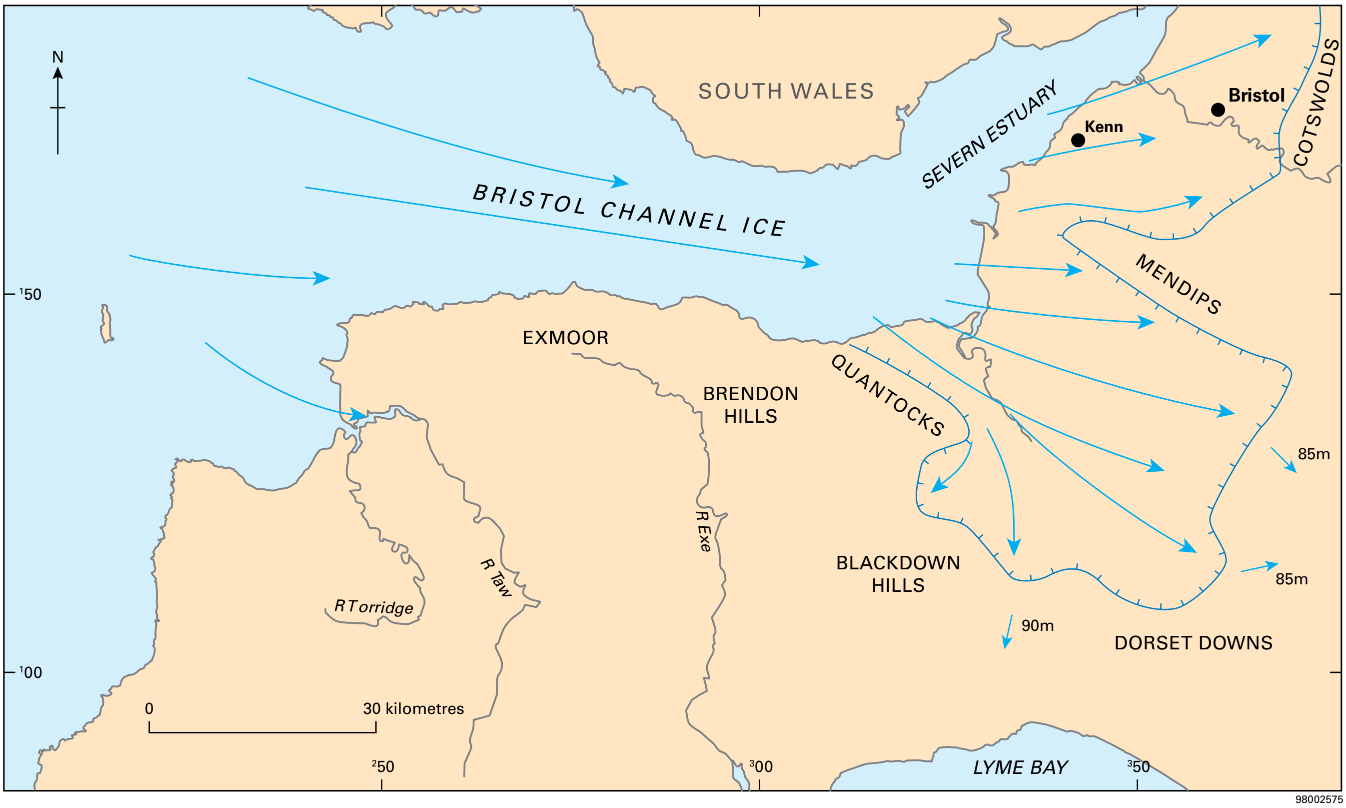


Figure 27 Suggested extent of Anglian glaciation east of the Severn Estuary (after Gilbertson and Hawkins, 1978).

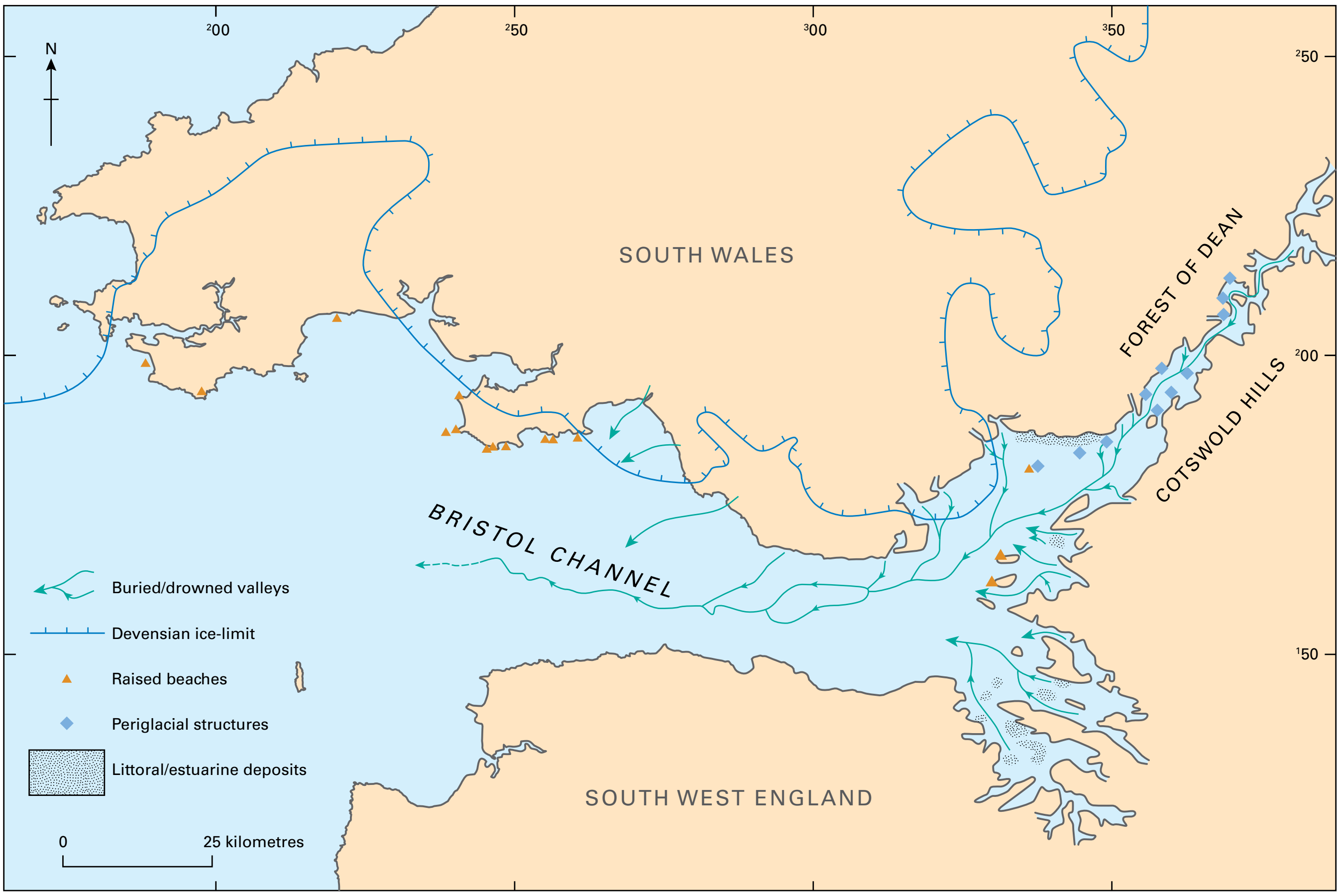


Figure 28 Maximum extent of Devensian glaciers and pre-Ipswichian buried valleys, Bristol Channel and Severn Estuary (after Haslett, 2001).

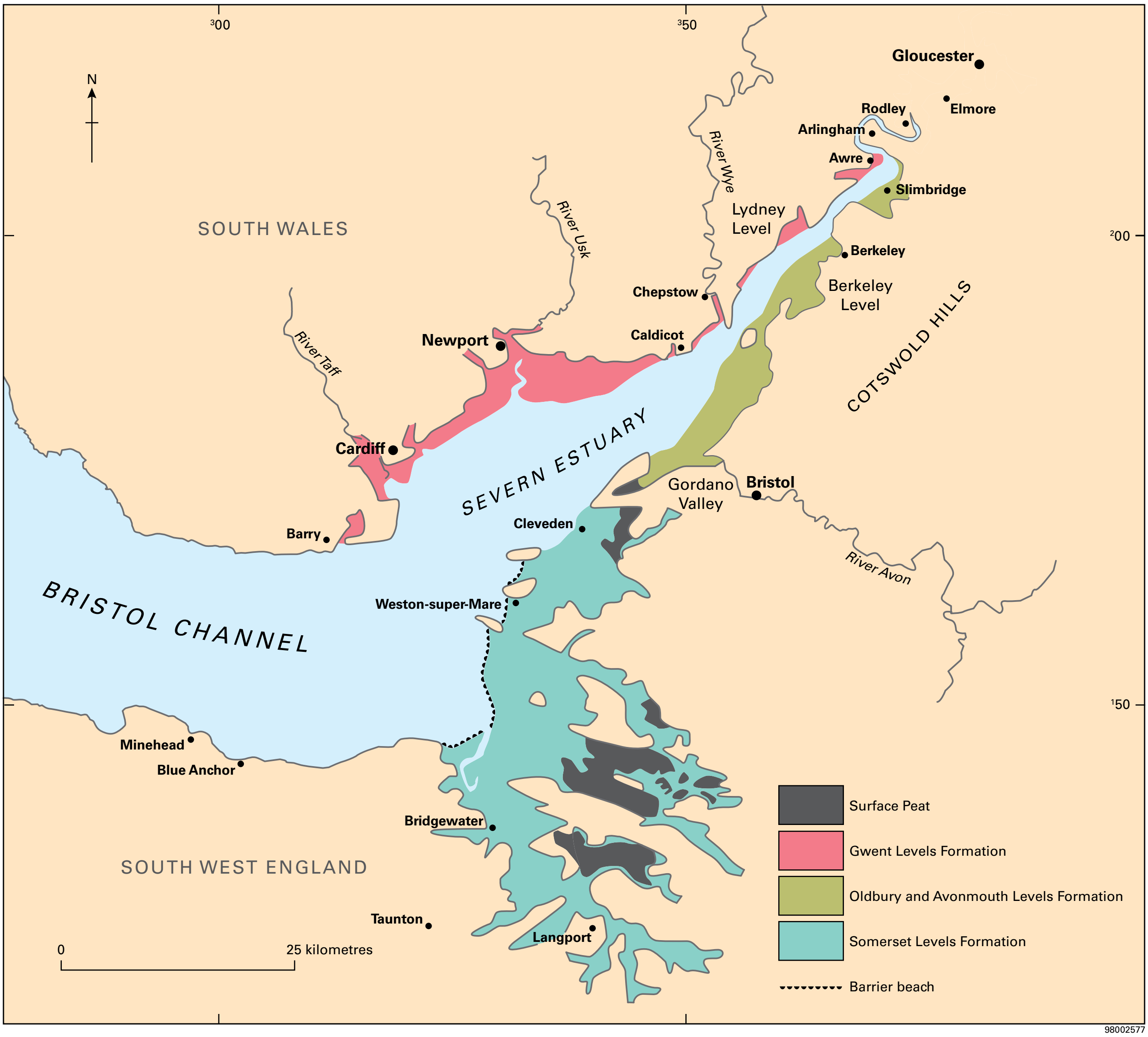


Figure 29 The Seven Estuary Levels and distribution of Holocene outcrops (after Allen, 2001b).