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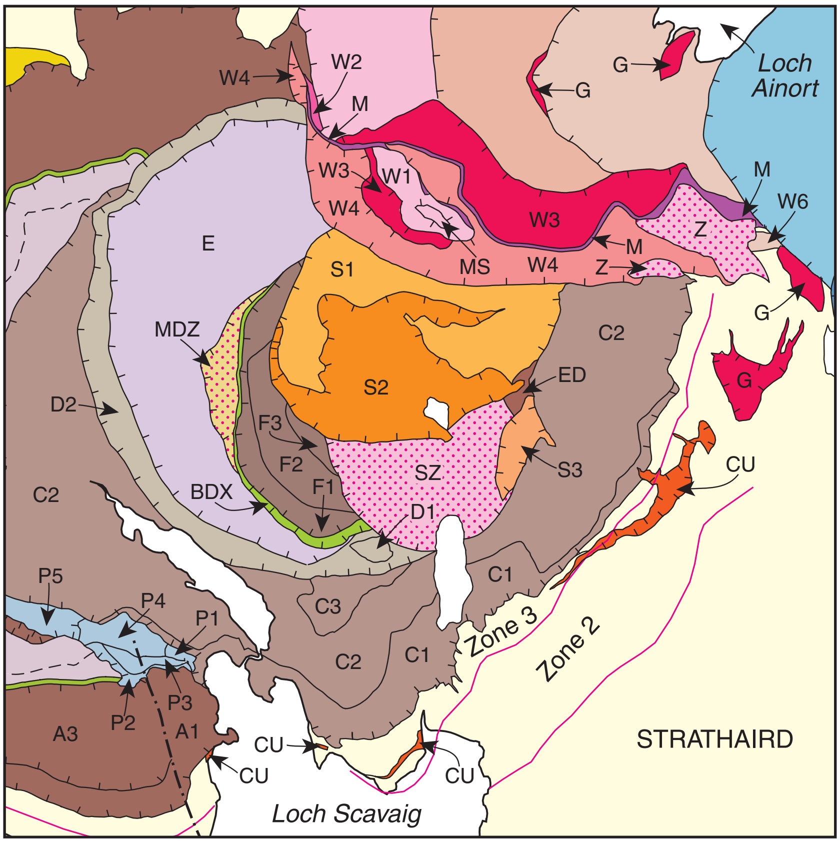
BGS classification of lithodemic units: Proposals for classifying units of intrusive rock

RESEARCH REPORT RR/08/05



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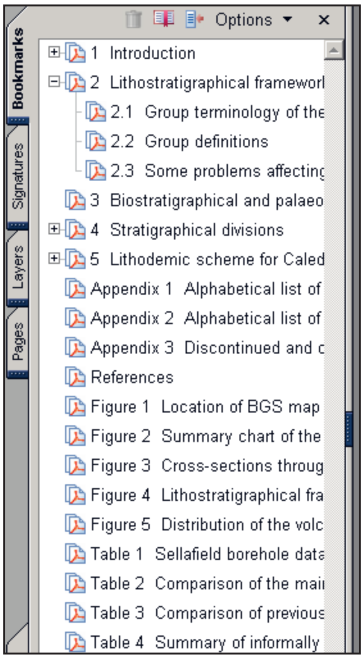

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BRITISH GEOLOGICAL SURVEY

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Front cover

Geological map of the Skye Central Complex showing the lithodemic units (adapted from British Regional Geology—the Palaeogene volcanic districts of Scotland. Fourth edition. 2005).

Key words

Lithodemic unit, lithodemic classification, intrusive units, mixed units, UK, onshore

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Keyworth, Nottingham British Geological Survey 2008

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FIGURE

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Summary

This report sets out a framework and terminology for classifying and naming lithodemic units composed entirely or predominantly of intrusive rock. It has been written with the geology of the UK in mind, but the principles and definitions recommended here should be applicable globally. The report anticipates a second phase of work, in which a BGS lithodemic classification for onshore intrusions in the UK will be constructed using the recommendations set out here. It is expected that this classification will in future be extended to include other classes of lithodemic unit (highly deformed, highly metamorphosed and 'mixed'), and lithodemic units in offshore parts of the UK.

A hierarchical framework of six formal ranks is proposed. Recommendations are made for classifying lithodemic units within the hierarchy and for constructing formal names for lithodemic units. A comprehensive glossary contains definitions for 'approved' lithodemic terms and for other terms associated with lithodemic classification.

Some amendments to the existing form for making entries to the *BGS Lexicon of Named Rock Units* are suggested in order to make it compatible with some of the special characteristics of lithodemic units. It is proposed that a Lithodemic Framework Committee be established to approve new names for lithodemic units and to oversee management and development of the classification. Examples showing how the proposed classification and nomenclature will work are set out in an Appendix, generally in the form of simplified geological maps accompanied by a 'classification' of the illustrated lithodemic units in a hierarchical chain.

In anticipation of a second phase of work that will produce a full lithodemic classification, it is proposed that intrusive lithodemic units associated with each of the four major Phanerozoic tectonothermal events to have affected the UK ('Caledonian', 'Variscan', 'Carboniferous and Permian', and 'Atlantean') be grouped at the highest formal rank proposed here to create four 'supersuites'; a brief summary is provided of the salient aspects of each of these four events.

1 Introduction

Lithodemic units are the mappable geological units in terrains in which rocks generally lack primary stratification. Unlike lithostratigraphical units, lithodemic units do not obey the *Law of Superposition* (North American Commission on Stratigraphic Nomenclature (NACSN), 1983; Rawson et al., 2002). They consist predominantly of intrusive, highly deformed, and/or highly metamorphosed rock, and can include lithostratigraphical units. Formalised lithostratigraphical classifications, such as those set out in British Geological Survey (BGS) Stratigraphical Framework reports, are now accepted widely and used on all modern BGS maps, in publications, in databases and associated digital products. Units of extrusive igneous rock have been integrated into a formal lithostratigraphical hierarchy (e.g. Rushton and Howells, 1998; Millward, 2004). This report sets out a framework and terminology for classifying lithodemic units composed entirely or predominantly of intrusive rock. The great majority of these have an igneous origin but some, including salt 'domes' and some sediment-filled fractures, do not. Although the report is concerned primarily with igneous intrusive units, those of non-igneous origin can be treated in the same way (see Section 2.7). It is anticipated that the scheme discussed here will be extended in future to include the other main classes of lithodemic units (highly deformed, highly metamorphosed, and 'mixed' units not dominated by intrusive rocks).

Lithodemic units are not recognised in the *International Stratigraphic Guide* (Salvador, 1994), which considers intrusive igneous bodies and non-stratified metamorphic rocks to be special cases within lithostratigraphy. As pointed out by Rawson et al. (2002), this approach provides little help to geologists mapping in igneous and metamorphic terrains.

The need in the British Geological Survey for a formal lithodemic classification of intrusive igneous rocks of the UK has been demonstrated during the recent development of major projects such as the *Lexicon of Named Rock Units* and the *Digital Geological Map of Great Britain* (DigMapGB). Recent reviews of the Caledonian igneous rocks and the Carboniferous and Permian igneous rocks of Great Britain (Stephenson et al., 1999, 2003), undertaken as part of the Geological Conservation Review, and preparation of the fourth edition of *British Regional Geology: the Palaeogene volcanic districts of Scotland* (Emeleus and Bell, 2005), provided opportunities to begin developing a practical, formal, lithodemic scheme. A formalised scheme for the Early Palaeozoic igneous rocks of northern England, arising from almost 20 years of recent BGS work in the Lake District, has been published (Millward, 2002, table 1).

The recent work outlined above has emphasised the need to revise and expand current BGS guidelines for the terminology of lithodemic units, which were set out by Allen (1995). This report does that, and sets out the foundations for a hierarchical classification of intrusive igneous lithodemic units of the UK. The production of a full classification is planned in two phases:

- this report, the outcome of Phase 1, sets out recommendations for a hierarchical structure and terminology for the classification
- the intrusive lithodemic units of the UK will be classified and named according to these recommendations in Phase 2.

The main purpose of the classification is to promote widespread use of a consistent lithodemic nomenclature and hierarchy within the UK, and thereby assist in communicating UK igneous history. The general principles of the classification, and the associated terminology, should apply to intrusive rocks anywhere in the world and hence should be followed, where appropriate, by BGS teams working overseas. The scheme will over time be presented to a wider national and international audience, for example through BGS publications and collaborations, and the BGS website, and it, or a derivative from it, may eventually attain general and widespread usage.

The approach and terminology recommended here are based to an extent on established schemes, particularly the *North American Stratigraphic Code* (NASC), devised by the North American Commission on Stratigraphic Nomenclature (NACSN, 1983). We have also considered how various terms have been used by geologists in parts of the world where intrusive igneous rocks contribute extensively to the geology (e.g. W S Pitcher and coworkers in Peru; A J R White and others in Australia). However, the requirements of the BGS, and the geology and geological history of the UK, have dictated that the scheme recommended here is distinctly different from other published schemes.

It is intended that all exposed and known concealed bodies of intrusive igneous rock in onshore areas of the UK be included in the classification (Phase 2). Lithodemic units that crop out in (or are concealed beneath) offshore parts of the UK will not be included initially, but may be classified at a later date using an extension of the approach and terminology recommended here. Similarly, lithodemic units not composed predominantly of intrusive rock will not be classified initially. The scheme should be sufficiently flexible to allow these to be added readily at a later date.

Every effort has been made to provide recommendations for best practice, though as with all attempts to classify natural systems there is no ideal solution. The robustness of the recommendations set out here will be tested thoroughly only when the full classification is prepared during Phase 2; it may be necessary at that stage to alter some aspects of the scheme.

2 The BGS lithodemic classification

The recommendations set out here deal specifically with lithodemic units composed of intrusive rocks only and those that are mixed (i.e. contain two or more classes of rock unit) but composed predominantly of intrusive rock. The recommendations are built around two important components: a glossary of approved terms and their definitions, and a hierarchical framework for classifying lithodemic units.

2.1 THE GLOSSARY

All successful classifications are underpinned by clearly defined terms used in a consistent way. Selecting and defining 'approved' terms for, or relevant to, lithodemic units formed an important part of the process of creating the present scheme. The approved terms, their definitions, and some indications of how we recommend or expect them to be used in BGS, are given in the glossary. Expanded definitions of several key terms are given in the following text, but readers should refer to the glossary to find formal definitions for approved terms. The glossary also draws attention to some terms that should **not** be used in a lithodemic context.

2.2 THE HIERARCHY

The classification framework recommended here is set out in Figure 1. It has a hierarchical structure and six formal ranks, numbered 1 to 6; Rank 1 is taken to be the highest. The figure incorporates the two classes of lithodemic unit that form the subject of this report — intrusive units and mixed units of mainly intrusive rock. Lithodemic units classified in Ranks 1 and 2 are common to both classes, whereas those classified in Ranks 3–6 are unique to each class. Classification is based on the principle that a unit classified in any rank other than 6 may be used to group two or more units of lower rank.

Single intrusions are classified at Rank 6. Units classified at Ranks 5, 4 and 3 group intrusions that have a spatial association and/or an association with a particular phase of magmatism. Units classified at Ranks 2 and 1 (and 'subsuite' at Rank 3) group 'natural associations' of intrusions.

Most classified units will be part of simple 'parent–child' chains spanning up to six ranks. However, as in lithostratigraphy, **classified units do not need to have a 'parent'** either at the next rank up in the chain, or indeed at any higher rank. It is, for example, perfectly acceptable to classify a unit at Rank 6 or 5 with no parent or child at any other rank. This could be because the unit has no 'relatives', or because its lithodemic relationship with other units is unknown or uncertain. It is also acceptable for a parent–child relationship to skip one or more ranks. For example, a unit classified at Rank 5 may have a parent classified at Rank 2. However, the only type of intrusive unit classified at Rank 3 — subsuite — must have a parent classified at Rank 2, for reasons outlined in Section 2.3.1.5.

Individual types of lithodemic unit may span several orders of magnitude of size; for example, some dykes persist for no more than a few metres, whereas the largest ones can straddle much of a continent. Unlike lithostratigraphy, where a depositional origin for all units means that thickness is a useful means of recording and comparing size, the only meaningful measure of the size of lithodemic units is their volume. However, volume is generally impossible to determine accurately from the outcrop; a dyke 10 m thick at outcrop may in its full extent contain many cubic kilometres of rock and be as voluminous as a pluton. For these reasons, scale cannot be incorporated practically into a lithodemic classification. Therefore, as in lithostratigraphy, **the size of a lithodemic unit is irrelevant in determining its position in the classification hierarchy**. A dyke is classified at Rank 6 regardless of whether its outcrop is 10 m long or 100 km long, and a pluton is classified at Rank 5 regardless of whether its outcrop covers 1 km^2 or 1000 km^2.

For similar reasons, **the number of lithodemic units is not critical in determining the type or rank of lithodemic unit used to group them**. A number of dykes may be grouped within a dyke-swarm regardless of whether there are 2 or 2000. Similarly, two or any larger number of units classified at Ranks 6 and 5 may be grouped at Rank 4 in a cluster or centre.

The Appendix contains several examples of lithodemic hierarchies for intrusive rocks in different parts of the UK. Appendix, Example 1 shows one possible classification of the Caledonian Igneous Supersuite (highest ranks). Names used in Appendix, Example 1 appear in the other examples, but it is emphasised that they are illustrative and currently have no formal status; they are all liable to be revised during Phase 2.

2.2.1 Lithodemic terminology in the North American Stratigraphic Code

The recommendation made here for six formal ranks in a hierarchical classification of lithodemic units is a significant departure from the scheme set out in the North American Stratigraphic Code (NACSN, 1983). In the NASC, only three types of intrusive lithodemic unit are recognised: supersuite (Rank 1), suite (Rank 2) and lithodeme (Rank 3). The terms supersuite and suite are adopted here and placed in the two highest ranks of this classification. In traditional usage these terms commonly imply a genetic (familial) relationship between intrusions, and their use in a lithodemic context is therefore not ideal. However, it is justified in being consistent with the NASC, and because there are no established terms that are more suitable for grouping intrusive lithodemic units.

The NASC defines lithodeme as '… *the fundamental unit in lithodemic classification. A lithodeme is a body of intrusive, pervasively deformed, or highly metamorphosed rock, generally non-tabular and lacking primary depositional structures, and characterized by lithic homogeneity. It is mappable at the Earth's surface and traceable in the subsurface. For cartographic and hierarchical purposes, it is comparable to a formation*.'

A single type of lithodemic unit in a rank below that of suite is clearly inadequate to meet fully the needs of digital

<table>
<tr><th>CLASS</th><th>RANK
6</th><th>RANK
5</th><th>RANK
4</th><th>RANK
3</th><th>RANK
2</th><th>RANK
1</th></tr>
<tr><td rowspan="16">Intrusive units</td><td rowspan="4">INTRUSION</td><td>PLUTON</td><td rowspan="16">CENTRE

CLUSTER</td><td rowspan="16">SUBSUITE</td><td rowspan="20">SUITE</td><td rowspan="20">SUPERSUITE</td></tr>
<tr><td>RING-INTRUSION</td></tr>
<tr><td>LOPOLITH</td></tr>
<tr><td>INTRUSION-SWARM</td></tr>
<tr><td>LACCOLITH</td><td>LACCOLITH-SWARM</td></tr>
<tr><td>PLUG</td><td>PLUG-SWARM</td></tr>
<tr><td>VENT</td><td>VENT-SWARM</td></tr>
<tr><td>PIPE</td><td>PIPE-SWARM</td></tr>
<tr><td>NECK</td><td>NECK-SWARM</td></tr>
<tr><td>DIATREME</td><td>DIATREME-SWARM</td></tr>
<tr><td>SHEET</td><td>SHEET-SWARM</td></tr>
<tr><td>DYKE</td><td>DYKE-SWARM</td></tr>
<tr><td>SILL</td><td>SILL-SWARM</td></tr>
<tr><td>RING-DYKE</td><td>RING-SWARM</td></tr>
<tr><td>CONE-SHEET</td><td>CONE-SHEET-SWARM</td></tr>
<tr><td>VEIN</td><td>VEIN-SWARM</td></tr>
<tr><td rowspan="4">Mixed units of mainly intrusive rock</td><td rowspan="4" colspan="2"></td><td>SHEET-COMPLEX*</td><td>CENTRAL COMPLEX</td></tr>
<tr><td>SILL-COMPLEX*</td><td>OPHIOLITE-COMPLEX</td></tr>
<tr><td>RING-COMPLEX*</td><td>VOLCANO-COMPLEX</td></tr>
<tr><td>VEIN-COMPLEX*</td><td></td></tr>
</table>

Figure 1 Proposed hierarchical classification of lithodemic units composed wholly or predominantly of intrusive rock.

Only swarms grouping a single type of Rank 6 unit are listed in Figure 1, for example plug-swarm. Many other Rank 5 lithodemic terms consisting of two or more types of Rank 6 feature are possible, for example plug-and-vent-swarm. 'Centre' and 'cluster' are positioned in the Rank 4 column to be near to the types of Rank 5 and 6 units they are most likely to encompass; that is, one or more plutons will usually form a major part of a centre, whereas swarms of minor intrusions will probably form a major part of most clusters. However, many combinations of units classified at Ranks 6 and 5 may have either a centre or a cluster as their parent.

* These terms have hitherto been used commonly for intrusive lithodemic units; for example, 'sill-complex' used to group a number of sills. They must now be used **only** for units that meet the definition of a 'complex' (see section 2.3.2 and the glossary); for example, a sill-complex is a mappable unit consisting of a number of sills **and** the country-rock between them. The examples shown here are not exhaustive, and others may be defined in due course.

maps and databases. The recommendation presented here for four ranks (3, 4, 5 and 6) below that of suite in which to classify lithodemic units should provide sufficient flexibility to satisfy current BGS requirements, and reflects the manner in which the terms for lithodemic units assigned to these ranks have been used previously. There is no geological, cartographical or databasing need for such a broadly defined formal term, and **'lithodeme' is therefore not an approved term in the present scheme**. All of the terms in all ranks of Figure 1 are regarded as referring to 'lithodemic units'.

Mixed units (see Section 2.3.2) are unranked in the NASC, and therefore are not included in formal hierarchical classifications of lithodemic units that follow the NASC. It is proposed here that in the BGS scheme they are classified formally in a hierarchy that is parallel with that for intrusive units (Figure 1). A complete hierarchical chain for all lithodemic mixed units will be developed in due course, when proposals are prepared for classifying the other classes of lithodemic unit.

2.2.2 Differences between lithodemic and lithostratigraphical classification

Lithostratigraphical classification (e.g. Rawson et al., 2002) is also based on a hierarchical chain of six formal ranks (though one of these, containing the unit 'subgroup', is used rarely), and in this respect lithostratigraphical classification and the proposed lithodemic classification are similar. However, the strongly contrasting ways in which intrusive lithodemic units and lithostratigraphical units are formed (i.e. emplacement *versus* deposition) mean that there are a number of fundamental differences. The most obvious of these are:

- The shape of lithodemic units is highly variable and is the principal criterion used to classify single units of intrusive rock. The lithodemic classification hierarchy therefore contains a large number of types of unit in Rank 6. By contrast, Rank 6 of the lithostratigraphical hierarchy contains only two types of unit — bed and flow.
- Intrusive lithodemic units may be associated spatially in a large number of ways, ranging from simple groups of two or more units of the same type to highly complicated groups involving numerous units of different type, rank and relative disposition. Twenty-two 'types' of lithodemic unit shown in Ranks 5 and 4 in Figure 1 reflect this diversity; those shown in Rank 5 represent only a subset of those that can be formed at Rank 5 by combining two or more types of Rank 6 unit, e.g. plug-and-vent-swarm. By contrast, related lithostratigraphical units are invariably associated spatially in a relatively simple manner, as part of a depositional succession, hence the lithostratigraphical hierarchy contains only one type of unit classified at each of Ranks 5 (member) and 4 (formation).

Thus, although the lithostratigraphical chain *bed – member – formation – subgroup – group – supergroup* has a similar hierarchical structure to a lithodemic chain such as *intrusion – pluton – centre – subsuite – suite – supersuite*, lithostratigraphical and lithodemic units classified at the same rank (e.g. member and pluton, both in Rank 5) should not be thought of as 'equivalent'.

A further important contrast lies in the philosophy underpinning lithostratigraphical and lithodemic classification. The 'basic unit' of lithostratigraphy is the formation, classified at Rank 4 (Whittaker et al., 1991). Higher and lower ranking units in a stratigraphical sequence are classified once the formations are defined. The classification procedure proposed here for lithodemic units is less formal, with no 'basic unit'.

2.3 LITHODEMIC UNITS IN FORMAL RANKS

2.3.1 Intrusive units

2.3.1.1 Intrusive lithodemic units of Rank 6

Thirteen types of lithodemic unit are classified at Rank 6 (Figure 1). Each denotes an intrusion that was emplaced effectively in a single phase. Twelve are distinguished primarily on the basis of intrusion shape and, in some cases, setting. The term 'intrusion' carries no connotation of shape or setting, and may be used (with a capital 'I') in the formal name of a lithodemic unit classified at Rank 6, the shape of which is not known or is not described adequately by one of the other Rank 6 terms (e.g. Iron Crag Microgranite Intrusion; see Appendix, Examples 2, 3, 4, 6, 7 and 8). The term 'intrusion(s)' may also be used generically (with a lower case 'i') to refer to any intrusive lithodemic unit(s).

2.3.1.2 Intrusive lithodemic units of Rank 5

Lithodemic units of Rank 5 generally group two or more intrusions of Rank 6 that are spatially associated and/or associated with a particular phase of magmatism (Appendix, Examples 2 and 6).

Groups of Rank 6 intrusions are in many cases classified at Rank 5 using the term 'swarm'. Thus, a group of dykes is a dyke-swarm, and a group of cone-sheets is a cone-sheet-swarm. Longer names may be constructed to denote groups of more than one type of intrusion, for example dyke-and-sill-swarm (such names are not shown in Figure 1, but many combinations are possible). The term intrusion-swarm may also be used to denote groups of two or more types of intrusion, or of intrusions of unknown shape.

The propensity of natural systems to defy rigorous classification means that a degree of pragmatism will commonly be required in using Rank 5 terms (and, indeed, terms for lithodemic units in all ranks). For example, a group of spatially associated intrusions of which 95 per cent are dykes and 5 per cent are sills could still be termed 'dyke-swarm', as that describes the *essential character* of the lithodemic unit.

Plutons, lopoliths and ring-intrusions may consist of single intrusions or multiple intrusions. Hence, all plutons, lopoliths and ring-intrusions are classified at Rank 5, even though some may be essentially single intrusions (Appendix, Examples 2, 4, 7 and 8). Plutons and lopoliths are, by definition, quite large features (kilometre scale and larger, see glossary), and typically larger than many units classified at Rank 6.

2.3.1.3 Intrusive lithodemic units of Rank 4

Two or more intrusions classified at Ranks 6 and/or 5 that are spatially associated may be grouped within two types of intrusive lithodemic unit classified at Rank 4 — centre and cluster. Centres encompass spatially tight groups of intrusive units focused around a central point, and clusters encompass less tight (more scattered) groups (Appendix, Examples 2, 3, 4 and 7). Classification at Rank 4 allows a diverse assemblage of units classified at Ranks 5 and 6 to be included in centres and clusters. A centre could, for example, comprise two intersecting plutons, several ring-dykes, an associated dyke-swarm, and a number of pipes. A cluster could consist of two dyke-swarms, a sill-swarm and numerous pipes, scattered over a wide area.

2.3.1.4 Intrusive lithodemic units of Rank 3

Only one type of intrusive lithodemic unit — subsuite — is classified at Rank 3. It is useful in some instances to identify within a suite (Rank 2, see Section 2.3.1.5) a smaller group (or groups) of lithodemic units that display shared characteristics. Subsuites can be identified only **after** the 'parent' suite has been defined. A subsuite may be formed by grouping two or more lithodemic units that share some similarities in a meaningful combination of observed features, and that are **already assigned to a single suite**.

Not all suites contain subsuites, and there is no need to group all the lithodemic units in a suite into subsuites. A suite could, for example, consist of a subsuite of three plutons and several other intrusive lithodemic units not assigned to a subsuite.

No subsuites have been defined formally in the UK to date. However, it is anticipated that some will be defined in the course of the forthcoming (Phase 2) formal classification of UK lithodemic units; Appendix, Example 1 illustrates how subsuites might be assigned in the Caledonian Igneous Supersuite.

2.3.1.5 Intrusive lithodemic units of Rank 2

Only one type of lithodemic unit — suite — is classified at Rank 2.

In the context of intrusive rocks, the term 'suite' has been used traditionally to denote a group of intrusions considered to have some direct genetic (familial) relationship; formal definitions of 'suite' typically include terms like 'cognate' (e.g. Challinor, 1978) and 'comagmatic' (e.g. Neuendorf et al., 2005). With such definitions, the term can be applied strictly only to rocks that are differentiates of a common parent magma, or are derived from a common and broadly homogeneous source. Such relationships are often difficult to prove, and will generally not apply to intrusions scattered across large areas. Defined in this way, the term 'suite' is not useful in a lithodemic context.

The term has also been used widely to group intrusions displaying a set of characteristics that imply *some degree* of genetic association, though they need not be comagmatic. Intrusions in such 'suites' typically display a set of common observed and/or measured characteristics, which may include some or all of the following: outcrop character, mode of emplacement, textural character, modal composition, geochemical character, isotope character, and age. A genetic association is inferred from the shared characteristics; for example, magmatism that yielded a group of spatially associated intrusions of broadly similar age and geochemical character is likely to have been triggered by one tectonothermal event, thus the intrusions may be assumed to have a genetic association without being necessarily comagmatic. Defined in this way, the term 'suite' is much better suited to use in a lithodemic context.

A suite is defined here as *a group of two or more lithodemic units of lower rank (i.e. Ranks 3 to 6), and of the same class (intrusive igneous, highly metamorphosed, highly deformed, or mixed), that display a degree of natural relationship through similarities in a meaningful combination of observed features, such as shape, spatial distribution, composition and/ or age* (Appendix, Examples 2, 4, 5, 6, 7 and 8). Mixed lithodemic units that are composed mainly of intrusive igneous rock (i.e. those included in Figure 1) may be included in a suite that also groups intrusive units. In this definition the term 'natural' replaces the term 'genetic' as it is used in the paragraph above. Terms such as 'comagmatic' and 'cognate' should not appear in formal names for lithodemic units.

Suite is comparable in rank to group in lithostratigraphy. Suites may be used on maps where the scale is too small to show the detail of component lithodemic units. There is no requirement for every lithodemic unit classified at Ranks 3 to 6 to belong to a suite, in the same way that every formation need not belong to a group.

2.3.1.6 Intrusive lithodemic units of Rank 1

Only one type of lithodemic unit — supersuite — is classified at Rank 1. Supersuite is the lithodemic unit of highest rank, and is comparable in rank to supergroup in lithostratigraphical classification. A supersuite is formed by grouping two or more suites and may include other lithodemic units of lower rank that are not part of these suites. In most cases, all the units must be of the same class (intrusive igneous, highly metamorphosed, highly deformed or mixed) and have a degree of natural relationship to one another (Appendix, Examples 2, 4, 5, 6, 7 and 8). However, mixed lithodemic units that are composed mainly of intrusive igneous rock (i.e. those included in Figure 1) may be included in a supersuite that also groups intrusive units.

It is proposed that in a UK lithodemic classification of intrusive igneous units, supersuites group lithodemic units associated with major tectonothermal events. Thus, for example, a Variscan Igneous Supersuite would encompass all the intrusive lithodemic units (and mixed units composed mainly of intrusive rocks) formed in association with the Variscan Orogeny. A summary of UK igneous supersuites is provided in Section 3.

2.3.2 Mixed units of mainly intrusive rock

A comprehensive classification of mixed lithodemic units is beyond the scope of this report, however mixed units that consist mainly of intrusive rock are dealt with here.

In the UK, the term 'complex' has been used widely in the past to refer to, and to name, complicated associations of rock units that may or may not be 'mixed' in a lithodemic sense; for example, some associations that have in the past been labelled a 'complex' actually consist entirely of intrusive units. It is proposed that, henceforth, the term 'complex' be reserved exclusively to refer to, and to name, mixed lithodemic units. The NASC defines 'complex' as '*an assemblage or mixture of rocks of two or more genetic classes, i.e. igneous, sedimentary or metamorphic, with or without highly complicated structure*'. That definition is extended here to include any mixture of lithodemic and lithostratigraphical units (e.g. intrusive with extrusive, sedimentary or metasedimentary units).

The term complex is unranked in the NASC. However, in a future comprehensive BGS classification of mixed lithodemic units the term complex is likely to be used for a mixed lithodemic unit in its own right, probably classified at Rank 2 (e.g. the Anytown Complex).

To name mixed units of mainly intrusive rock (Figure 1), a term to indicate the essential character of the intrusive unit(s) should be concatenated with the word complex using a hyphen, to produce names like sill-complex and volcano-complex.

Identification of such 'mixed' units is useful in two situations:

- where a complicated assemblage or mixture of rocks of two or more classes exists, and mapping of individual lithic components within it is impractical or undesirable at the mapping scale (e.g. a vein-complex of numerous vein intrusions in metasedimentary country rock)
- where it is useful to unite in a single lithodemic unit a close association of rock units of two or more classes (e.g. intrusive and extrusive rocks forming a volcano-complex)

The term complex should **not** be used to unite assemblages consisting of diverse types of a single class of rock, as has happened in the past; for example, a name like 'Garabal Hill–Glen Fyne Igneous-complex' cannot exist within a formal lithodemic scheme.

Mixed units of mainly intrusive rock are classified only at Ranks 4 and 3 (Figure 1).

2.3.2.1 Mixed lithodemic units of Rank 4

Four types of mixed unit are classified at Rank 4 (Figure 1). The name of each one combines the name of an intrusive unit classified at Rank 6 with the term complex: sheet-complex, sill-complex, ring-complex and vein-complex. These terms have hitherto been used commonly for intrusive lithodemic units; for example, the term 'sill-complex' has been used widely to group a number of sills. The terms must now be used **only** for units that meet the definition of a 'complex'; thus, a sill-complex is a mixed unit composed of a number of sills (a sill-swarm) **and** the country-rock that lies within the boundary of the defined unit. The Basal Andesite Sill-complex of the Glencoe Caldera Volcano-complex (Appendix, Example 5) is a good example; it includes sills and sedimentary country rock shown on current maps as a single unit.

The terms listed here (Figure 1) for mixed units of mainly intrusive rock are not exhaustive; others may be defined in due course. They are placed at Rank 4 so that they may contain lithodemic ± lithostratigraphical units classified at Rank 5; for example, a vein-complex may consist of a vein-swarm 'mixed' with other lithodemic and/or lithostratigraphical units of Rank 5 and/or 6. More recommendations for classifying and naming mixed lithodemic units will be presented with forthcoming proposals for dealing with the non-intrusive classes of lithodemic units.

2.3.2.2 MIXED LITHODEMIC UNITS OF RANK 3

Three types of mixed unit are classified at Rank 3 (Figure 1). They may contain lithodemic and lithostratigraphical units classified at Rank 4 and lower ranks (Appendix, Examples 5, 7 and 8), and they may form part of lithodemic units classified at Ranks 2 and 1. Because they are classified at Rank 3, they may not contain, or be part of, subsuites (which are also classified at Rank 3); situations where this would be desirable are likely to be rare, and a solution will need to be found on a case-by-case basis.

Strictly speaking, an ophiolite-complex is a structural unit composed in part of intrusive rock (see glossary definition). It is included in the present scheme because some ophiolite-complexes consist largely of intrusive rock, and could be considered to be intrusive lithodemic units.

2.3.2.3 OTHER CONSIDERATIONS

In certain circumstances the inclusion of lithostratigraphical or lithodemic units of higher rank **within** mixed lithodemic units classified at a lower rank is unavoidable, and has to be accepted. Thus, for example, a screen of Lewisian Gneiss Complex rocks (which will in due course probably be classified as a mixed lithodemic unit at Rank 1) may be part of a central complex (Rank 3), as on Skye and Rum (Appendix, Example 8).

For Lexicon and database purposes a lithostratigraphical unit forming part of a mixed unit cannot have two parents, that is one lithostratigraphical parent and one mixed lithodemic parent. It is recommended therefore that the formal parent should always be the 'natural' (lithostratigraphical) parent and not the 'adopted' (lithodemic) parent. Thus, the Glencoe Volcanic Formation is a major component of the Glencoe Caldera Volcano-complex (Appendix, Example 5), but its formal parent for database purposes is the Lorn–Glencoe–Ben Nevis Group (a formal name for this unit has not yet been identified by the Devonian Framework Committee).

2.4 COMMONLY USED TERMS EXCLUDED FROM THE FORMAL CLASSIFICATION

2.4.1 Terms used to divide single intrusions

The following terms should be used informally. They do not refer to formal lithodemic units and therefore are not included in Figure 1.

2.4.1.1 FACIES

The term *facies* is used widely in geology to refer to the characteristic features that distinguish a rock unit, including rock type, mineralogy, texture and structure. The term can also be used informally to refer to, or to name, parts of an intrusion that have distinctive features, but which are not bound by intrusive margins; for example '… the porphyritic monzogranite facies of the Starav Granite Pluton… ' (Appendix, Example 4). Note that the informal nature of such names is reflected in the use of lower case letters.

2.4.1.2 ZONE

The term *zone* is used to refer to, or to name, facies displaying a geometrical regularity, such as parallel or concentric layers; for example 'the inner concentric zone of granite', or '… the diorite zone of the Loch Doon Diorite–granite Pluton'. The term has been used widely for well-defined pseudostratigraphical units of mineralogical variation in layered intrusions, for example the 'Middle Zone' of the Insch Pluton; this zone is analogous to the 'Middle Zone' of the Skaergaard Intrusion, on which many subsequent zonal divisions of tholeiitic intrusions have been based.

2.4.2 Terms used to group associations of igneous lithodemic and lithostratigraphical units

It is commonly useful to indicate the wider geographical and/or petrogenetic associations of formal suites and supersuites of intrusive rocks, and to include their comagmatic and/or contemporaneous extrusive equivalents. The following terms should be used informally. They do not refer to lithodemic units and therefore are not included in Figure 1.

2.4.2.1 PROVINCE

The term *province* is used in published accounts usually to unite igneous rocks linked to a specific tectonothermal event, or series of related events, such as the Caledonian Orogeny or the opening of the North Atlantic Ocean. The rocks so grouped commonly occur over a wide geographical area that may extend beyond the onshore areas of the UK.

Igneous provinces typically include intrusive and extrusive rocks. This feature makes the province concept very useful as a means of indicating the broad-scale association between extrusive rocks, covered by lithostratigraphical nomenclature, and their contemporaneous intrusions, covered by lithodemic nomenclature. For example, the Skye Lava Group, the Mull Lava Group, the Hebrides Central Complex Suite and the North Britain Palaeogene Dyke Suite are all part of the (Palaeogene) Hebridean Igneous Province (known formerly as the British Tertiary Igneous [or Volcanic] Province). Mixed lithodemic units can perform a similar function on a smaller scale.

2.4.2.2 SUPERPROVINCE

The concept of 'large igneous provinces' has been developed recently in petrogenetic studies and their associated literature (e.g. Mahoney and Coffin, 1997). Some large igneous provinces could warrant the title of superprovince, that is where they consist of a set of related provinces. Thus, in Emeleus and Bell (2005), it is suggested that the Hebridean Igneous Province should be regarded as part of a North Atlantic Igneous Superprovince (offshore geologists have been referring to a North Atlantic Igneous Province for some time). This superprovince can be regarded as consisting of the Hebridean Igneous Province, an East Greenland province, a West Greenland province, an Iceland province, a Faroes province and possibly some others, although the formal definition and naming of such provinces (and superprovinces) is outwith the remit of the BGS. Similarly, the Caledonian Igneous Province of the UK could be regarded as part of a North Atlantic Caledonian Igneous Superprovince.

2.4.3 Batholith

Large masses of adjacent, contiguous and intersecting intrusions are referred to as batholiths in some parts of the Earth's crust, notably in Cordilleran mountain belts. These crop out over areas significantly greater than those of typical composite plutons and centres; for example, the well-documented Mesozoic and Cenozoic coastal batholiths of Peru have an along-strike length of over 1600 km, comprising perhaps as many as 1000 plutons. They can, and commonly do, include plutons that span a wide time range.

There are no exposed examples of batholiths in the UK, though several concealed examples are inferred from geophysical data to link plutons exposed at the surface. Perhaps the best known of the UK examples is the Cornubian Batholith in south-west England, which underlies the Dartmoor, Bodmin Moor, St Austell, Carnmenellis and Land's End granite plutons. The northern Pennines is underpinned by an inferred batholith, approximately 1800 km^2 in area and comprising at least five, entirely concealed, granitic plutons. Only one of these, the Weardale Granite Pluton, has been proved, and emplacement during the Acadian event has been inferred. The Lake District Batholith underpins an area of at least 1500 km^2 (Millward, 2002). It incorporates an Ordovician component, represented by the exposed Ennerdale and Eskdale granite plutons and by the Broad Oak Granodiorite Pluton, and an Early Devonian component represented by the Skiddaw and Shap granite plutons. The plutons of these two components belong to two suites (see Appendix, Example 2).

With no exposed examples in the UK, there is no need for batholith to be a type of formal lithodemic unit in the present scheme. Furthermore, the fact that they can include units formed during different events and/or assigned to different suites (as in the Lake District Batholith) makes it very difficult to incorporate them meaningfully into a lithodemic classification. Used informally, the term remains useful in the UK as a means of referring to inferred (concealed), continuous or near-continuous masses of more-or-less contiguous plutons (see the glossary for a full definition).

2.4.4 Subswarms

Examples exist in published accounts where authors have allocated sets of dykes to *subswarms*. However, the way in which this term has been used is not consistent. Where subswarms are components of a parent swarm, and are distinguished by location, composition or some other geological feature (e.g. compositional divisions of the 'Scourie Dyke Swarm'), this is a useful concept that is consistent with the hierarchical principles of this proposed lithodemic classification scheme. Unfortunately, the most commonly quoted subswarms in the British Isles are probably those defined by Speight et al. (1982) among the Palaeogene dykes of Scotland, where the subswarms are not components of the defined larger swarms, but are merely smaller, more-localised groups of dykes. This usage cannot fit into a hierarchical scheme and should be rationalised, however it is entrenched firmly in all post-1982 literature, including Emeleus and Bell (2005). No position is allocated for subswarm in Figure 1. Use of the term in a lithodemic context must be informal and still consistent with the formal hierarchy (i.e. a subswarm, even though informal, should group features that are part of a formal swarm).

2.4.5 Series

The term 'series' has been used in the past to group igneous lithodemic units. However, the term is now accepted formally as a chronostratigraphical division (e.g. Whittaker et al., 1991), and therefore **must not** be used in a lithodemic context. Examples of past use (now unacceptable) include Rum Layered Series (see Appendix, Example 8), and Mosedale Series (part of the Carrock Fell Centre; see Appendix, Examples 2 and 3).

2.5 NAMING LITHODEMIC UNITS

2.5.1 Naming intrusive lithodemic units in Ranks 6 and 5

Formal names for lithodemic units classified in Ranks 6 and 5 should consist of a geographical, a lithological and a 'shape' component, in that order, for example Eskdale Granite Pluton. The geographical component should refer to a settlement or feature within, or adjacent to, the outcrop of the lithodemic unit. An appropriate lithological name should be selected that is consistent with the BGS Rock Classification Scheme (Volume 1, Igneous rocks; Gillespie and Styles, 1999). En rules may be used for intrusions with two major lithological components, or to indicate the principal end-members in a pluton hosting a range of lithological components, for example Comrie Diorite–granite Pluton. A suitable 'shape' term (e.g. plug, dyke, pluton) that sits in an appropriate rank in the hierarchy should be selected from Figure 1 and using the glossary definitions. The Appendix provides many examples of lithodemic units named according to this convention.

2.5.2 Naming intrusive lithodemic units in Ranks 4, 3 and 2

Where possible and practical, the names of intrusive lithodemic units classified at Ranks 4, 3 and 2 should be composed of a geographical name followed by the term for the lithodemic unit, for example Carrock Fell Centre, Shetland Suite. However, in areas where there are multiple suites and/or suitable geographical names are at a premium, other features such as typical composition, age and/or typical intrusion shape may be added to help distinguish one unit from another, for example North Britain Palaeogene Sill Suite, North Britain Palaeogene Dyke Suite, North Britain Late Carboniferous Tholeiitic Suite.

2.5.3 Naming intrusive lithodemic units in Rank 1

Where possible and practical, supersuites are assigned a tripartite name consisting of a term referring to the tectonothermal event with which the magmatism is associated, followed by 'Igneous Supersuite', for example Caledonian Igneous Supersuite, Variscan Igneous Supersuite. Where there is no suitable term to describe the tectonothermal event, other information may be included in the name, for example Carboniferous–Permian Igneous Supersuite.

The terms suite and supersuite, and the essence of their definitions, have been adopted here from the NASC, where they were first used in a formal lithodemic context. The present widespread use of these terms in both lithodemic and non-lithodemic contexts reflects the absence of suitable alternative terms for grouping large-scale associations of intrusive units. Henceforth, use of these terms in formal names shall imply a lithodemic context unless stated otherwise. Where the context is not lithodemic this should be made clear; for example 'these plutons form a geochemical suite'.

2.5.4 Naming mixed lithodemic units

Where possible and practical, the names of mixed units should be composed of a geographical name followed by a term indicating the appropriate type of 'complex', for example Skye Central Complex, Ballantrae Ophiolite-complex. Where the term 'suite' is used to group two or more mixed lithodemic units of lower rank, it should be preceded by both a geographical term and a term identifying the type of unit, for example Iapetan Ophiolite-complex Suite (Appendix, Example 1).

2.5.5 Abbreviating formal names for lithodemic units

Some formal names for lithodemic units generated using the above recommendations will inevitably be long and rather clumsy. As in lithostratigraphical nomenclature, once the formal name for a lithodemic unit (e.g. Eskdale Granite Pluton) has been introduced in a report or publication it may thereafter be abbreviated if desired (in this case to, for example, Eskdale Granite, Eskdale Pluton, or Eskdale intrusion). In the interests of reducing possible sources of confusion in formal names and abbreviated names, geographical names should not be used more than once in formal names for lithodemic and lithostratigraphical units so far as is possible or practical: for example the term 'Eskdale' should not appear more than once in the Lexicon of Named Rock Units.

2.6 OTHER CLASSIFICATIONS

The terms subsuite, suite and supersuite have been used elsewhere in contexts different to that proposed here. For example, in south-east Australia, White et al. (2001) defined a set of granitic suites and supersuites based principally on the geochemical composition of plutons. Their aim was to understand the petrogenesis of the rocks and to characterise the source of the magmas. Some suites defined in this manner contain intrusions of widely disparate ages. Such usage should not be confused with a lithodemic classification.

2.7 NON-IGNEOUS INTRUSIVE UNITS

Some intrusive units do not have an igneous origin. Salt domes and some sediment-filled ('Neptunian') fractures are two examples. Such features can be classified and named in the same way as igneous intrusive units. Following the proposals set out above would create names such as Groucho Salt Intrusion, Chico Salt Pluton, Harpo Salt-intrusion Cluster, and Zeppo Salt-intrusion Suite.

3 Major intrusive lithodemic units in the UK

Most intrusions in the UK were emplaced during the Phanerozoic Eon, in association with four major tectonothermal events:

- the Caledonian Orogeny (associated with closure of the Iapetus Ocean) from the late Cambrian to Late Devonian
- crustal stretching during the Carboniferous and Permian periods
- the Variscan Orogeny (associated with closure of the Tethys Ocean), from the Mid Devonian to early Permian
- crustal stretching (prior to, and associated with, opening of the North Atlantic Ocean) from the end of the Cretaceous to the present day.

These associations provide an obvious basis for primary classification of UK intrusive lithodemic units, and we propose that in the BGS classification all intrusive rocks associated with each of the main Phanerozoic tectonothermal events are grouped at supersuite level (Rank 1). In this section, names for the more obvious supersuites are proposed, and some of the salient aspects of each are summarised, in order to 'set the scene' for the forthcoming (Phase 2) classification. With increasing geological age it becomes in general more difficult to recognise and classify meaningful groups of intrusive rocks. Consequently, no firm proposals for primary classification of Precambrian lithodemic units are made at this stage. A brief outline of Precambrian magmatism is provided below, with some indications of how primary classification might be addressed.

3.1 PRECAMBRIAN IGNEOUS SUPERSUITES

There are currently no obvious established names that can be utilised for the broad classification of Precambrian intrusive igneous rocks. The vast time range, and the number and extent of tectonic events and discrete terranes involved, will inevitably result in the generation of many supersuites if we are to avoid having units that span unrealistically long periods of time and/or multiple tectonomagmatic events. All of the rocks involved have been metamorphosed to a greater or lesser degree and hence the terminology has to be compatible with any future lithodemic scheme for the highly metamorphosed rocks of the UK. We suggest that Archaean, Palaeoproterozoic and Mesoproterozoic igneous rocks are incorporated into a future classification of highly metamorphosed lithodemic units, in accordance with the principles and examples laid down in this report.

By contrast, Neoproterozoic intrusions can be related to a reasonably well-established lithostratigraphy and chronology, and most can be allocated to specific tectonomagmatic events. In Scotland, two as yet unnamed intrusive events have been recognised (Strachan et al., 2002), at about 870 Ma (e.g. the West Highland Granite Gneiss and various mafic minor intrusions in the Northern Highlands), and at about 600 Ma in association with crustal extension that presaged the opening of the Iapetus Ocean. The latter led to emplacement of the Tayvallich and other volcanic rocks, numerous mafic minor intrusions in the Grampian Highlands, and A-type and/or S-type granite plutons such as those at Ben Vuirich, Keith, Portsoy and Carn Chuinneag. The 870 Ma and 600 Ma events have to be represented by two supersuites.

Precambrian intrusions in England and Wales are all Neoproterozoic and broadly coeval, having been emplaced at around 600 Ma (Thorpe, 1979; Harris, 1992). However, they were emplaced in several terranes and therefore cannot be combined realistically into a single supersuite. Intrusions emplaced between 680 and 560 Ma as part of the Avalonian arc system (or 'Superterrane') may be regarded as part of an Avalonian Igneous Supersuite. The Coedana granite intrusion of Anglesey is emplaced in a separate terrane, and may be regarded as part of a Monian Igneous Supersuite. Precambrian intrusions in the Channel Islands are regarded increasingly as part of a separate terrane, and may best be considered part of a Cadomian Igneous Supersuite.

3.2 CALEDONIAN IGNEOUS SUPERSUITE

This supersuite comprises all intrusive igneous rocks associated with the Caledonian Orogeny. Stephenson et al. (1999) defined the Caledonian Orogeny to include all of the convergent tectonic and magmatic events arising from the closure of the Iapetus Ocean, marginal to which many of the rocks of later Proterozoic and early Palaeozoic age had been deposited. It therefore includes the accretion or obduction of oceanic crust and island arc material onto the flanking continental margins; subduction beneath the margins; and ultimately continent–continent collision, uplift and extensional collapse. It encompasses many identifiably separate 'events', several of which have commonly used specific names, most notably the Early to Mid Ordovician peak of deformation and metamorphism in the Scottish Highlands, termed the Grampian Event by many authors, and the mid- to late-Silurian deformation referred to widely as the Scandian Event. (Note: many authors refer to these events as separate 'orogenies'.) The brief (post-Scandian, Early to Mid Devonian) Acadian event, affecting northern England and Wales, is coeval with some Caledonian plutons in southern Scotland. By this definition, most Caledonian igneous rocks in the UK range in age from around 500 Ma (earliest Ordovician) to around 390 Ma (latest Early Devonian), with related activity continuing to around 360 Ma (end Late Devonian) in Orkney and Shetland.

3.3 VARISCAN IGNEOUS SUPERSUITE

This supersuite comprises all intrusive igneous rocks in south-west England that are associated directly with the Variscan Orogeny. They include the Lizard Ophiolite-complex, minor intrusions associated with basaltic volcanism of Devonian, early Carboniferous and early Permian age, and the late Carboniferous to early Permian 'Cornubian Batholith'. Floyd et al. (1993) have reviewed these intrusions. Not included are minor intrusions associated with various basaltic volcanic rocks that crop out between Bristol and Weston-super-Mare which, although now lying to the south of the final position of the Variscan Front, were emplaced to the north of the front in early Carboniferous times (Stephenson et al., 2003).

3.4 CARBONIFEROUS AND PERMIAN IGNEOUS SUPERSUITE

This supersuite comprises all intrusive igneous rocks that were emplaced in the UK and the adjacent continental shelf to the north of the Variscan Front during Carboniferous and Permian times. Although broadly coeval with the Variscan Orogeny, the magmatism cannot be classed as 'Variscan', since it is not orogenic in origin or nature. The magmas were emplaced in a cratonic region that, although affected by far-field tectonic effects of the orogeny, experienced typical intraplate magmatism due to crustal extension and eventual intracontinental rifting. Rocks of this supersuite are scattered widely from the Bristol Channel to the Orkney Islands. They include intrusions associated with the voluminous volcanic sequences in and around the Midland Valley of Scotland and the Solway Firth, intrusions in Derbyshire and the West Midlands of England, the large tholeiitic sill-swarms of north-east England and the eastern Midland Valley, and dyke-swarms that extend across parts of the Scottish Highlands. Stephenson et al. (2003) have reviewed them.

3.5 ATLANTEAN IGNEOUS SUPERSUITE

We propose the term 'Atlantean Igneous Supersuite' to include all intrusive igneous rocks resulting from magmatism that was a precursor to, and accompanied, the opening of the North Atlantic Ocean. We are not aware that 'Atlantean' has been used hitherto formally in such a context, but its use follows the convention used to name the Caledonian and Variscan igneous supersuites. Onshore in the UK the magmatism occurred almost entirely during the Paleocene Epoch, from about 62 Ma to about 55 Ma. However, offshore there are lavas of latest Cretaceous age, and volcanism continues to the present day at the Mid-Atlantic Ridge. Almost all of the intrusions in the UK and the north-west continental shelf can be regarded as components of the Hebridean Igneous Province (referred to in many earlier publications as the *British Tertiary Igneous Province* or *British Tertiary Volcanic Province*), which is part of the North Atlantic Igneous Superprovince. Onshore, they occur mainly in the Inner Hebrides, the Isle of Arran and Northern Ireland, but dyke-swarms extend over a wide area — from the Outer Hebrides, through central and southern Scotland and into northern England. There are also scattered occurrences of Palaeogene igneous rocks in Wales, in central England and forming Lundy Island in the Bristol Channel. Emeleus and Gyopari (1992), Bell and Williamson (2002) and Emeleus and Bell (2005) have reviewed these events.

4 Formal definitions and Lexicon entries

The proposed BGS lithodemic classification of UK intrusive rocks will be accompanied by a requirement to define each lithodemic unit formally, using the Lexicon of Named Rock Units. Formal definitions for lithodemic units will differ in some significant ways from those for lithostratigraphical units, and this will necessitate changes to the present table structure in the Lexicon database. Full definitions for lithodemic units of intrusive rock will require the following recommended information. Reference to the current Lexicon entry form (Version 7.0) is made, and items in **bold** are fields that differ from those used to define lithostratigraphical units.

SECTION 1 NAMED LITHODEMIC UNIT

Full name of lithodemic unit

Rank of lithodemic unit

Full name of parent unit

Rank of parent unit

Geological age (or age range, if appropriate) [for lithostratigraphical units the heading is Chronostratigraphy]. This should be the currently preferred age of emplacement, expressed in terms of geochronological divisions (e.g. late Silurian to Early Devonian). If this is based largely or wholly upon a radiometric age or ages, this should be stated clearly, with the published timescale to which it is related.

Note: the different radiometric systems used to 'date' intrusive rocks can reflect different stages in their cooling history. None of the systems dates emplacement directly; however, some reflect the period of transition from magma to solid rock ('crystallisation age'), and may approximate to an 'emplacement' age. Others reflect changes in crystal structure during rock cooling; these may not be reliable proxies of the age of emplacement or crystallisation.

Status of entry

Range of full entry definition

Extent of current use of the name in the UK

Computer code

SECTION 2.1 GEOLOGICAL DESCRIPTION OF THE NAMED LITHODEMIC UNIT

Lithology and lithological description (free text description using appropriate terminology from the BGS Rock Classification Scheme, Volume 1 Igneous rocks: Gillespie and Styles, 1999)

Major, subsidiary and trace rock types

Description of the form of the named unit (free text)

Lithodemic or lithostratigraphical unit(s) cut by named unit (free text description)

Units that cut or overlie the named unit (free text description)

Relationship of the named unit to sequence of deformation events (free text description). *Example* for Shap Granite Pluton: synchronous with formation of regional, Acadian, cleavage; Boulter and Soper, 1973.

Other geological evidence for age of emplacement of the unit (free text description). *Example* pebbles of the rock unit contained in the such-and-such conglomerate.

Preferred radiometric age of 'emplacement' (see note above under 'Geological Age' relating to radiometric ages)**, with 2σ error, method** (for example Rb-Sr, whole rock; K-Ar, hornblende) **and where age published**

Other published radiometric ages, with associated fields as above, and where appropriate their geological significance, e.g. whether they constrain the age of crystallisation, cooling, alteration or uplift

Previous name (s)

Alternative name(s)

Where definition published

SECTION 2.2 GEOGRAPHICAL DESCRIPTION

Geographical limits

Classification of type locality(ies)

Description and location of type locality(ies)

Reference(s) to published description of the above

National Grid Reference(s) of the type locality(ies)

SECTION 2.3 FULL BIBLIOGRAPHIC REFERENCES

SECTION 3 MAP CODES

5 Approval procedures and management

The proposed BGS lithodemic classification of UK intrusive rocks will require a mechanism for approving additions to, and modifications of, the scheme. The scheme as a whole will also require a degree of management, monitoring and steering that will ensure it is maintained and developed appropriately. This will be particularly important when the classification is extended to encompass other (non-intrusive) classes of lithodemic units, and those in offshore parts of the UK. We propose therefore that a BGS Lithodemic Framework Committee be established, with the same responsibilities, authority and support given to the existing BGS Stratigraphical Framework committees.

Appendix

Several examples of classification hierarchies for UK intrusive lithodemic units are set out below to provide an illustration of how the recommendations for classification and nomenclature proposed here can be applied in practice. The examples are intended to be indicative; other than in Example 1, many of the names for lithodemic units are those currently in use, and a proportion of these will change when the lithodemic units are classified formally.

Example 1 A possible lithodemic classification at Ranks 1, 2 and 3 of the Caledonian Igneous Supersuite

Example 2 The Lake District and adjacent areas

Example 3 The Carrock Fell Centre

Example 4 The Glen Etive area

Example 5 The Glen Coe area

Example 6 Late Carboniferous tholeiitic sills and dykes of northern England and the Midland Valley of Scotland

Example 7 The Skye Central Complex

Example 8 The Rum Central Complex

Example 1 A possible lithodemic classification at Ranks 1, 2 and 3 of the Caledonian Igneous Supersuite.

Time/event	Rank 3	Rank 2	Rank 1
Ordovician	Shetland Ophiolite-complex	Iapetan Ophiolite-complex Suite	Caledonian Igneous Supersuite
	Highland Border Ophiolite-complex		
	Ballantrae Ophiolite-complex		
Devonian–Carboniferous	West Shetland Granite Subsuite	Shetland Granite Suite	
	East Shetland Granite Subsuite		
Grampian	North-east Grampian Basics Subsuite	Highlands Older Suite	
	North-east Grampian Granite Subsuite		
	North-west Grampian Granite Subsuite		
Scandian	Assynt Subsuite*	Highlands Younger Suite	
	Argyll and Northern Highlands Subsuite		
	Deeside Subsuite**		
	South Grampian Subsuite		
	Glencoe Caldera Volcano-complex		
		Scottish Lowlands Suite	
Acadian	Galloway Subsuite	Hadrian's Wall Suite	
	Northern England Subsuite		
Ordovician	Cumbrian Mountains Subsuite	Lake District Suite	
		Central England Suite	
		Wales Suite(s)	
		North Britain Siluro-Devonian Dyke Suite	

* the alkaline intrusions, except Glen Dessarry

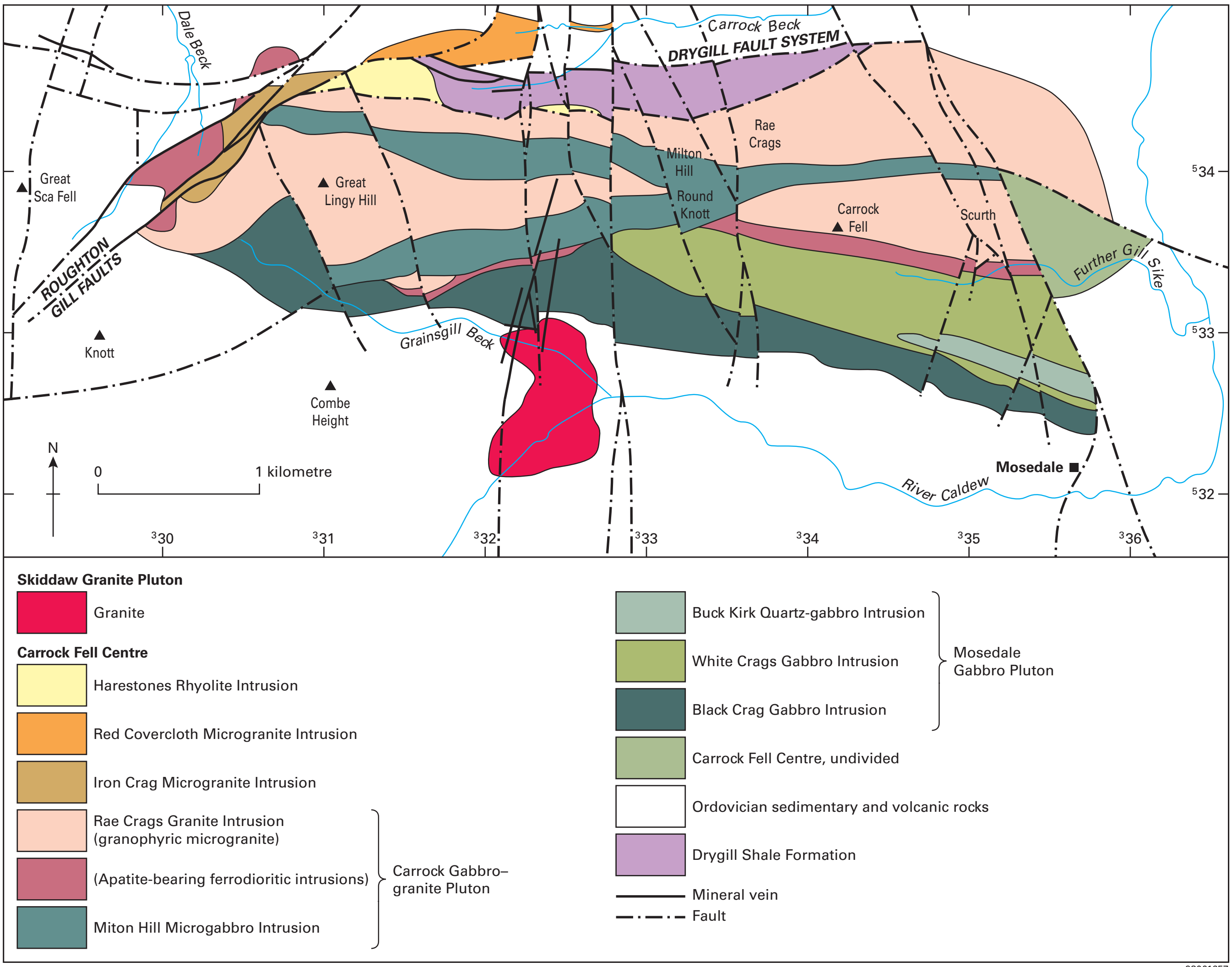
** a possible alternative name for Cairngorm Subsuite

Note: The names shown above for lithodemic units have been created to illustrate this example, and they are also used where appropriate in the following examples. They currently have no formal status.

Example 2 Proposed lithodemic classification of intrusive igneous rocks in the Lake District and adjacent areas. Modified from Millward (2002) with some additional, previously unused names. See Millward (2002, table 1) for details of lithology, size, age and information sources.

Rank 6	Rank 5	Rank 4	Rank 3	Rank 2	Rank 1
Many unnamed dykes			Northern England Subsuite	Hadrian's Wall Suite	Caledonian Igneous Supersuite
Rake Beck Microgranite Dyke	Duddon Valley Microgranite Dyke-swarm				
Other unnamed dykes					
	Weardale Granite Pluton				
	Shap Granite Pluton	Shap Felsic Cluster			
Many unnamed dykes	Shap Microgranite Dyke-swarm				
	Skiddaw Granite Pluton				
Many unnamed lamprophyre dykes				North Britain Siluro-Devonian Dyke Suite	
Many unnamed sills	Undefined sill-swarms	Borrowdale Sill Cluster		Lake District Suite	
Several unnamed plugs and sheets	Embleton Microdiorite Swarm	Derwent Mafic Minor Intrusion Cluster			
Dash Hornblendite Plug	Bassenthwaite Microdiorite Swarm				
Other unnamed intrusions					
Unnamed plugs, necks, pipes and dykes	Pike de Bield Andesite Swarm				
Many unnamed dykes	Wasdale Basalt Swarm				
Wallow Crag Gabbro Plug	Haweswater Gabbro–microdiorite Swarm				
Naddle Beck Dolerite Plug					
Birkhouse Hill Microdiorite Plug					
Other unnamed plugs and dykes					
Harestones Rhyolite Intrusion		Carrock Fell Centre			
Red Covercloth Microgranite Intrusion					
Iron Crag Microgranite Intrusion					
Rae Crags Granite Intrusion	Carrock Gabbro–granite Pluton				
Miton Hill Microgabbro Intrusion					
Buck Kirk Quartz-gabbro Intrusion	Mosedale Gabbro Pluton				
White Crags Gabbro Intrusion					
Black Crag Gabbro Intrusion					
	Eskdale Granite Pluton		Cumbrian Mountains Felsic Subsuite		
	Broad Oak Granodiorite Pluton				
	Ennerdale Granite Pluton				
Many unnamed dykes	Wast Water Felsic Dyke-swarm				
Threlkeld Microgranite Intrusion					
	Wensleydale Granite Pluton				

Example 3 Proposed lithodemic classification of the Carrock Fell Centre.



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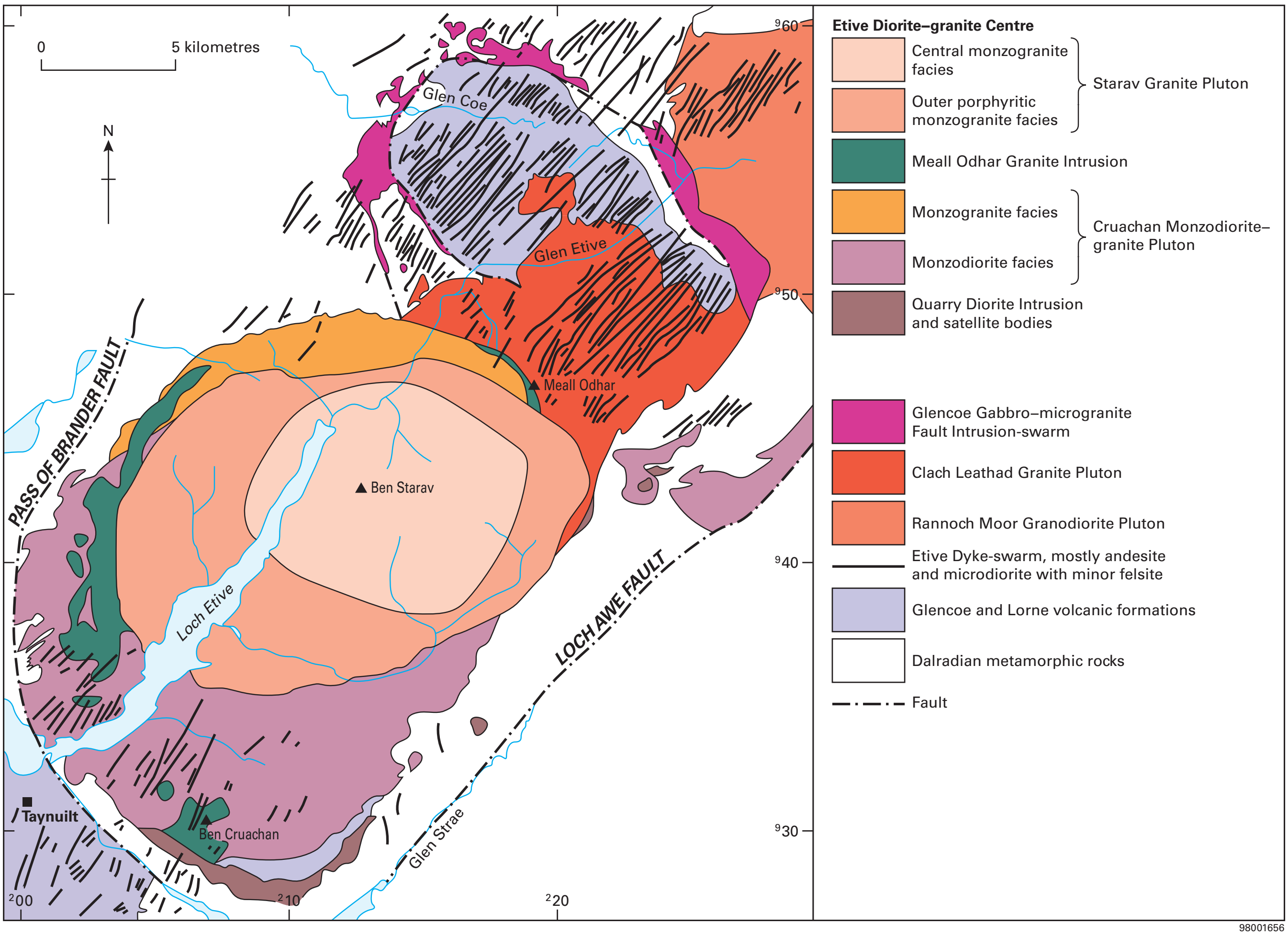
Example 4 A lithodemic classification of intrusive igneous rocks in the Glen Etive area.



Informal units	Rank 6	Rank 5	Rank 4	Rank 3	Rank 2	Rank 1
Monzogranite facies		Starav Granite Pluton	Etive Diorite–granite Centre	Argyll and Northern Highlands Subsuite	Highlands Younger Suite	**Caledonian Igneous Supersuite**
Porphyritic monzogranite facies						
	Meall Odhar Granite Intrusion					
Monzodiorite facies		Cruachan Monzodiorite–granite Pluton				
Monzogranite facies						
	Quarry Diorite Intrusion					
	Unnamed dykes	Etive Andesite–microdiorite Dyke-swarm				
		Glencoe Gabbro–microgranite Fault Intrusion–swarm				
		Clach Leathad Granite Pluton				
		Rannoch Moor Granodiorite Pluton				

Example 5 A hierarchical classification of lithodemic and lithostratigraphical units in the Glen Coe area.

<table>
<tr><th>Rank 6</th><th>Rank 5</th><th>Rank 4</th><th>Rank 3</th><th>Rank 2</th><th>Rank 1</th></tr>
<tr><td>Upper Dalness Ignimbrite</td><td rowspan="4">Dalness Ignimbrite Member</td><td rowspan="24">Glencoe Volcanic Formation</td><td rowspan="32">Glencoe Caldera Volcano-complex</td><td rowspan="32">Highlands Younger Suite</td><td rowspan="32">Caledonian Igneous Supersuite</td></tr>
<tr><td>Coire nan Easan Tuffs</td></tr>
<tr><td>Lower Dalness Ignimbrite</td></tr>
<tr><td>Coir Eilde Tuffs</td></tr>
<tr><td>Unnamed andesite lavas</td><td>Bidean nam Bian Andesite Member</td></tr>
<tr><td>Unnamed beds of sandstone, conglomerate and siltstone</td><td>Glas Choire Sandstone Member</td></tr>
<tr><td>Upper Streaky Andesites (extrusive components)</td><td></td></tr>
<tr><td>Church Door Buttress Breccias</td><td rowspan="9">Three Sisters Ignimbrite Member</td></tr>
<tr><td>Upper Queen’s Cairn Breccias</td></tr>
<tr><td>Upper Three Sisters Ignimbrite</td></tr>
<tr><td>Lower Queen’s Cairn Breccias</td></tr>
<tr><td>Dalness Breccias</td></tr>
<tr><td>Queen’s Cairn Conglomerates</td></tr>
<tr><td>White Corries Breccias</td></tr>
<tr><td>Lower Three Sisters Ignimbrite</td></tr>
<tr><td>Lower Streaky Andesites (extrusive components)</td><td></td></tr>
<tr><td>Upper Etive Rhyolite</td><td rowspan="7">Etive Rhyolite Member</td></tr>
<tr><td>Crowberry Ridge Tuffs</td></tr>
<tr><td>Middle Etive Rhyolite</td></tr>
<tr><td>Raven’s Gully Tuffs</td></tr>
<tr><td>Lower Etive Rhyolite</td></tr>
<tr><td>Kingshouse Tuffs</td></tr>
<tr><td>Kingshouse Breccias</td></tr>
<tr><td rowspan="2">Unnamed sills of andesite with a conglomerate and sandstone host</td><td>Unnamed clastic sedimentary unit</td><td rowspan="2">Basal Andesite Sill-complex</td></tr>
<tr><td>Unnamed Sill-swarm</td></tr>
<tr><td>Unnamed multiple intrusions of gabbro, diorite, tonalite, monzonite and granite</td><td>Glencoe Gabbro–Microgranite Fault Intrusion-swarm</td><td rowspan="6"></td></tr>
<tr><td>Unnamed sheets of andesite with mingled rhyolite</td><td>Upper Streaky Andesites (intrusive components)</td></tr>
<tr><td>Unnamed sheets of andesite with mingled rhyolite</td><td rowspan="2">Lower Streaky Andesites (intrusive components)</td></tr>
<tr><td>Unnamed intrusions of rhyolite and aplitic microgranite</td></tr>
<tr><td>Unnamed sheets and sills of andesite</td><td rowspan="2"></td></tr>
<tr><td>Unnamed dykes of volcaniclastic breccia and tuffisite</td></tr>
</table>

Example 6 Proposed lithodemic classification of late Carboniferous tholeiitic sills and dykes of northern England and the Midland Valley of Scotland.

<table>
<tr><th>Rank 6</th><th>Rank 5</th><th>Rank 4</th><th>Rank 3</th><th>Rank 2</th><th>Rank 1</th></tr>
<tr><td>Great Whin Dolerite Sill</td><td rowspan="4">Whin Dolerite Sill-swarm</td><td rowspan="9">Northern England Cluster</td><td rowspan="16"></td><td rowspan="16">North Britain Late Carboniferous Tholeiitic Suite</td><td rowspan="16">North Britain Carboniferous–Permian Igneous Supersuite</td></tr>
<tr><td>Holy Island Dolerite Sill</td></tr>
<tr><td>Alnwick Dolerite Sill</td></tr>
<tr><td>Little Whin Dolerite Sill</td></tr>
<tr><td>Holy Island Dolerite Dyke</td><td rowspan="5">Northern England Late Carboniferous Tholeiitic Dyke-swarm</td></tr>
<tr><td>High Green Dolerite Dyke</td></tr>
<tr><td>St Oswald’s Chapel Dolerite Dyke</td></tr>
<tr><td>Hett Dolerite Dyke</td></tr>
<tr><td>Other dolerite and basalt dykes</td></tr>
<tr><td>Lomond Hills Dolerite Sill</td><td rowspan="4">Midland Valley Dolerite Sill-swarm</td><td rowspan="7">Central Scotland Cluster</td></tr>
<tr><td>Stirling Dolerite Sill</td></tr>
<tr><td>Ratho Dolerite Sill</td></tr>
<tr><td>Other quartz-dolerite sills</td></tr>
<tr><td>Lenzie–Torphichen Dolerite Dyke</td><td rowspan="4">Central Scotland Late Carboniferous Tholeiitic Dyke-swarm</td></tr>
<tr><td>Dullatur Dolerite Dyke</td></tr>
<tr><td>Cumbernauld Dolerite Dyke</td></tr>
<tr><td>Other dolerite and basalt dykes</td></tr>
</table>

Based on Stephenson et al. (2003).

Example 7 A hierarchical classification of lithodemic and lithostratigraphical units of the Skye Central Complex.

Informal units	Rank 6	Rank 5	Rank 4	Rank 3	Rank 2	Rank 1
	Raasay Granite Sill			Skye Central Complex	Hebrides Central Complex Suite	**Atlantean Igneous Supersuite**
	Scalpay Granite Intrusion					
	An Sithean Granite Intrusion					
	Unnamed composite sheets of basaltic andesite and rhyolite					
	Unnamed sheets of granite and microgranite					
	Unnamed intrusions of gabbro and dolerite					
	Unnamed volcaniclastic breccias					
		Beinn na Caillich Granite Pluton	Eastern Red Hills Centre			
		Creag Strollamus Granite Pluton				
		Beinn an Dubhaich Granite Pluton				
		Beinn na Cro Granite Pluton				
		Glas Bheinn Mor Granite Pluton				
	Broadford Gabbro Intrusion					
	Beinn na Cro Gabbro Intrusion					
	Small individual intrusions	Kilchrist Hybrid Intrusions				
		Kilchrist Breccias				
	Eas Mor Granite Ring-dyke		Western Red Hills Centre			
	Meall Buidhe Granite Ring-dyke					
	Maol na Gainmhich Granite Ring-dyke					
		Loch Ainort Granite Pluton				
		Beinn Dearg Mhor Granite Pluton				
	Marsco Granite Intrusion					
	Southern Porphyritic Granite Intrusion					
	Glen Sligachan Granite Intrusion					
		Northern Porphyritic Felsite Pluton				
		Glamaig Granite Pluton				
	Marsco Hybrids Ring-dyke					
	Marsco Summit Gabbro Intrusion					
	Blaven Granite Intrusion		Srath na Creitheach Centre			
	Ruadh Stac Granite Intrusion					
	Meall Dearg Granite Intrusion					
	Volcaniclastic-breccia, lapilli-tuff and tuffaceous-sandstone		Srath na Creitheach Volcaniclastic Rocks			
	Intrusion breccia		Cuillin Centre			
	Meallan Dearg Breccia Pipe					
	Coire Uaigneich Granite Intrusion					
	Gars-bheinn Peridotite Sill					
F1, F2 & F3	Inner Gabbro Intrusion					
	Inner Bytownite Troctolite Intrusion					
D1 & D2	Druim nam Ramh Bytownite Gabbro Ring-intrusion					
C1, C2 & C3	Outer Bytownite Gabbro Intrusion					
	P1, P2, P3, P4, P5 & P6	Layered Peridotite Intrusions				
B1, B2 & B3	Outer Bytownite Troctolite Intrusion					
	A1, A2 & A3	Outer Gabbro Intrusions				
	Trachyte and rhyolite lavas and volcaniclastic rocks		Fionn Choire Formation			

Example 8 A hierarchical classification of lithodemic and lithostratigraphical units associated with the Rum Central Complex.

<table>
<tr><th>Informal units & other units</th><th>Rank 6</th><th>Rank 5</th><th>Rank 4</th><th>Rank 3</th><th>Rank 2</th><th>Rank 1</th></tr>
<tr><td>Ruinisval zone</td><td rowspan="3">Central Mafic Intrusion</td><td colspan="2" rowspan="7">Formerly grouped as the ‘(Rum) Layered Series’, then as the ‘(Rum) Layered Suite’ (e.g. on 50k Sheet 60). The former term is no longer approved because ‘series’ is now a chronostratigraphical division, and the latter term is no longer approved because of the inappropriate rank of the term ‘suite’.</td><td rowspan="19">Rum Central Complex</td><td rowspan="19">Hebrides Central Complex Suite</td><td rowspan="19">Atlantean Igneous Supersuite</td></tr>
<tr><td>Long Loch zone</td></tr>
<tr><td>Dornabac zone</td></tr>
<tr><td>Harris Bay zone</td><td rowspan="3">Western Layered Mafic Intrusion</td></tr>
<tr><td>Transitional zone</td></tr>
<tr><td>Ard Mheall zone</td></tr>
<tr><td>Layered units 1–15</td><td>Eastern Layered Mafic Intrusion</td></tr>
<tr><td rowspan="9"></td><td></td><td>Western Granite Pluton</td><td></td></tr>
<tr><td>Individual intrusions and extrusive units, some named</td><td rowspan="2"></td><td rowspan="2">Southern Mountains ‘mixed unit’</td></tr>
<tr><td>Papadil Microgranite Intrusion</td></tr>
<tr><td>Individual intrusions and extrusive units, some named</td><td rowspan="4"></td><td rowspan="4">Northern Marginal ‘mixed unit’</td></tr>
<tr><td>Coire Dubh Breccia</td></tr>
<tr><td>Am Mam Breccias</td></tr>
<tr><td>Long Loch Microgranite Intrusion</td></tr>
<tr><td>Individual plugs</td><td>Mafic and ultramafic plug-swarm</td><td rowspan="2"></td></tr>
<tr><td>Individual sheets</td><td>Mafic sheet-swarm</td></tr>
<tr><td colspan="3" rowspan="2"></td><td>Eigg Lava Formation</td></tr>
<tr><td>Broadford Beds</td></tr>
<tr><td colspan="4">Lewisian Gneiss Complex</td></tr>
</table>

Notes:

1. The names of informal units and of units classified at Ranks 6, 5 and 4 in this example are based on those currently in use (Emeleus and Bell, 2005), however some of these have been modified to reflect the system for naming units set out in this scheme. Others will be modified, where appropriate, in Phase 2.
2. The Southern Mountains and Northern Marginal ‘mixed units’ are shown at Rank 4 without an approved lithodemic unit name. Appropriate formal names for these units will be defined in due course (during Phase 2), and they may be classified formally at Rank 5.
3. Representatives of the Eigg Lava Formation, the Broadford Beds (Formation) and the Lewisian Gneiss Complex are all included within the Rum Central Complex, making it a ‘complex’ in the full sense of the formal definition.
4. The inclusion of lithodemic or lithostratigraphical units of higher rank (e.g. Lewisian Gneiss Complex, which is likely to be classified at Rank 1) within a central complex (Rank 3) is unavoidable in many mixed units (complexes) and is acceptable. Their parent has to be the one allocated in their main scheme and not the central complex.

Glossary

The definitions given here are relevant to this classification of igneous lithodemic units. Some terms may be defined differently where they are used in a different context. Approved terms for lithodemic units are highlighted in bold.

batch	a *mass* of magma of broadly uniform composition; c.f. *pulse*
batholith	an informal term, with no lithodemic rank, to denote a group of more-or-less contiguous *plutons* that collectively form a continuous or near-continuous mass that is significantly larger than typical *composite plutons*; the component plutons may span a wide range of ages and comprise more than one *suite*; there are no fully exposed examples of batholiths in the UK, however several concealed batholiths are inferred, including the Cornubian, Lake District and East Grampian batholiths
belt	a broadly linear swathe of *intrusions*
body	a useful informal term, without lithodemic rank, referring to any *intrusion*
boss	used by some authors for an *intrusion* that is roughly circular in plan; the term *pluton* is recommended instead
centre	a lithodemic unit of Rank 4, grouping lithodemic units classified at Rank 6 and/or 5 that are focused tightly around a central point, and usually intersecting, of similar age and common origin
central complex	a mixed lithodemic unit of Rank 3 composed of largely intrusive rocks with screens and irregular *masses* of associated *extrusive* rocks and country rocks, commonly but not necessarily arranged spatially around one or more focal points; a central complex can encompass several *centres;* at present, central complexes defined in the UK are generally considered to represent the roots of a central volcano at a relatively shallow crustal level — such an association is not necessarily implied by the definition proposed here
cluster	a lithodemic unit of Rank 4, grouping lithodemic units classified at Rank 6 and/or 5 that are associated spatially but not focused tightly, i.e. they are too scattered to be classified as a *centre*; a cluster may, for example, consist of two *dyke-swarms*, a *sill-swarm* and numerous *pipes*, scattered over a wide area
comagmatic	igneous rocks derived from a common parent magma, or at least from the same source region, at the same time and under similar physical and chemical conditions, as inferred from a set of common chemical and mineralogical features
complex	an assemblage of rocks consisting of a 'mixture' of lithodemic and lithostratigraphical units, or of intrusive, highly metamorphosed and/or highly deformed lithodemic units, with or without highly complicated structure; see Section 2.3.2
composite	an *intrusion* formed from two or more distinctive *pulses*; these are commonly, but not necessarily, of different composition
cone-sheet	a lithodemic unit of Rank 6 composed of a *sheet* with a cone shape that dips inwards towards a central focal point
cone-sheet-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *cone-sheets*
consanguinity	the genetic relationship that exists between igneous rocks presumed to derive from the same parent magma
cupola	a dome-shaped protruberance from the upper surface of an *intrusion*
diapir	a dome-shaped *body* of magma or igneous rock inferred to have deformed and ruptured its country rocks during its ascent; the term should be used as a descriptive qualifier (e.g. '…a diapiric *pluton* …'), not as a type of *lithodemic unit*
diatreme	a lithodemic unit of Rank 6 composed of a breccia-filled volcanic *pipe* inferred to have been formed by gaseous disruption
diatreme-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *diatremes*
dyke	a lithodemic unit of Rank 6 composed of a *sheet* of igneous rock emplaced along a steep, generally near-vertical fracture; normally discordant to the structure of its host rocks
dyke-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *dykes*
extrusion	a rock mass formed by eruption of magma onto the Earth's surface
extrusive	igneous rocks that have been extruded onto the Earth's surface

facies — the characteristic features that distinguish a rock unit, including rock type, mineralogy, texture and structure; the term can also be used in informal names for part of an *intrusion* that lacks intrusive margins but has distinctive features; see Section 2.4.1.1

gabbroid — used traditionally as an adjective to refer to rocks of gabbroic composition, but also used more recently as a noun to denote a *body* of gabbroic rock; it is recommended that the term 'gabbroic rock' is used instead of gabbroid as an adjective, and 'gabbroic intrusion' or 'gabbroic pluton' is used instead of gabbroid as a noun

granitoid — used traditionally as an adjective to refer to rocks of granitic composition, but also used more recently as a noun to denote a *body* of granitic rock; it is recommended that the term 'granitic rock' is used instead of granitoid as an adjective, and 'granitic intrusion' or 'granitic pluton' is used instead of granitoid as a noun

intrusion — a unit of geological material produced by an intrusive process and bounded by observed or inferred intrusive margins; usually used to refer to any unit of rock or magma formed by emplacement of magma and/or pyroclastic material into the subsurface, however units of non-igneous material can also result from an intrusive process, e.g. salt 'domes'; the term may be used formally (with a capital 'I') for a lithodemic unit of Rank 6, or informally (with a small 'i') to refer to any intrusive lithodemic unit(s); see Sections 2.3.1.1 and 2.7

intrusion-swarm — a lithodemic unit of Rank 5 composed of a *swarm* of *intrusions*

laccolith — a lithodemic unit of Rank 6 composed of an *intrusion* that is roughly circular in plan, concordant with the structure of the country rock, and generally has a planar floor and a domed roof

laccolith-swarm — a lithodemic unit of Rank 5 composed of a *swarm* of *laccoliths*

lithodeme — defined in the NASC as 'a body of intrusive, pervasively deformed, or highly metamorphosed rock, generally non-tabular and lacking primary depositional structures, and characterised by lithic homogeneity'; the NASC regards 'lithodeme' as the fundamental unit in lithodemic classification, broadly equivalent to the lithostratigraphical term 'formation'; the term lithodeme has not been adopted here for reasons outlined in Section 2.2.1; the term *lithodemic unit* is preferred for all units encompassed by the NASC definition of lithodeme, and for groups of such units at higher lithodemic ranks

lithodemic unit — a mappable unit, or group of units, distinguished and delimited on the basis of rock characteristics, that does not obey the Law of Superposition, i.e. is composed predominantly of intrusive, highly deformed, and/or highly metamorphosed rock, or a mixture composed of one or more of these with or without lithostratigraphical units; lithodemic units are the practical units of geological work in terranes in which rocks generally lack primary stratification

lopolith — a lithodemic unit of Rank 5 composed of a *body* of kilometre-scale or larger that is concordant, broadly saucer-shaped and typically layered; a 'simple' lopolith consists of essentially one *intrusion*, whereas a 'composite' lopolith consists of two or more; the intrusions in composite lopoliths are inferred to be related genetically, and to be associated spatially because the magma *batches* used a common pathway through the crust

mass — an informal term, without lithodemic rank, used to refer to a *body* of intrusive rock or magma

minor intrusion — any *intrusion* of small surface areal extent, for example most *dykes*, *sills* and small irregular *masses*

neck — a lithodemic unit of Rank 6 composed of the feeder 'pipe' of a volcano, which has been infilled with collapsed material from the surface *vent* and commonly intruded by magma, after eruption has ceased, to form a *plug*; exposed due to subsequent erosion

neck-swarm — a lithodemic unit of Rank 5 composed of a *swarm* of *necks*

ophiolite-complex — a mixed lithodemic unit of Rank 3 composed of ophiolite (a section or sections of the oceanic crust, with or without the subjacent upper mantle) that has been uplifted or emplaced to be exposed within continental crustal rocks, during which process the ophiolite becomes tectonically 'mixed' (usually interleaved) with crustal rocks; strictly speaking, an ophiolite-complex is a structural unit composed in part of intrusive rock; it is included in the present scheme because some ophiolite-complexes consist largely of intrusive rock, and could be considered to be intrusive lithodemic units

phase — a temporally distinct event or events; may be used informally to distinguish events (e.g. 'an early phase of magmatism'), or to denote units that are part of a recognised sequence of events; the term should not be used in formal names for lithodemic units, and hence should not be capitalised, e.g. Ben Rinnes Granite Pluton phase 1

pipe	a lithodemic unit of Rank 6 composed of a discordant, cylindrical *intrusion*, normally steeply orientated
pipe-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *pipes*
plug	a lithodemic unit of Rank 6 composed of the solidified remains of a cylindrical *intrusion* of magma, inferred to be intrusive into or associated with a volcanic *neck*
plug-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *plugs*
pluton	a lithodemic unit of Rank 5 composed of a *body* of intrusive rock, generally with a simple, regular margin, the whole being kilometre-scale or larger and with a cylindrical, lenticular or tabular shape; a 'simple' pluton consists of essentially one *intrusion*, whereas a 'composite' pluton consists of two or more; the intrusions in composite igneous plutons are inferred to be related genetically, and to be associated spatially because the magma *batches* used a common pathway through the crust; see Section 2.3.1.2
province	a region encompassing all igneous units (lithodemic and lithostratigraphical) related to a major tectonothermal event; c.f. *superprovince*; see Section 2.4.2.1 for further information
pulse	an injection of magma of broadly uniform composition; c.f. *batch*
ring-complex	a mixed lithodemic unit of Rank 4 composed of one or more *ring-intrusions*, *ring-dykes, cone-sheets, ring-swarms* and *cone-sheet-swarms*, with their country-rocks; see also Section 2.3.2.1
ring-dyke	a lithodemic unit of Rank 6 composed of a *sheet* that is arcuate or annular in plan, and usually vertical or inclined steeply outwards
ring-intrusion	a lithodemic unit of Rank 5 composed of an *intrusion* observed or inferred to have been emplaced within, or bounded by, a ring-fracture
ring-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *ring-dykes* with or without *cone-sheets*
series	a chronostratigraphical division; must not be used in a lithodemic context; see Section 2.4.4
sheet	a lithodemic unit of Rank 6 composed of an *intrusion* with broadly parallel margins and one dimension much shorter than the other two; most sheets have a broadly tabular shape, but they may be curved, sinuous or irregular
sheet-complex	a mixed lithodemic unit of Rank 4 composed of a *sheet-swarm* and its country-rocks
sheet-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *sheets*
sill	a lithodemic unit of Rank 6 composed of a *sheet* of igneous rock emplaced along a near-horizontal fracture; usually broadly concordant in stratified rocks
sill-complex	a mixed lithodemic unit of Rank 4 composed of a *sill-swarm* and its country-rocks
sill-swarm	a lithodemic unit of Rank 5 composed of a *swarm* of *sills*
stock	an *intrusion* that is smaller than but otherwise similar to a *pluton*; the term is virtually unused in the UK and there are no formally named examples; in some countries the term 'stock' is defined differently and used to name *lithodemic units*
subsuite	a lithodemic unit of Rank 3 grouping two or more *lithodemic units* from a single *suite* that share some similarities in a meaningful combination of observed features; the *lithodemic unit* next lower in rank to *suite*; see Section 2.3.1.4
subswarm	an informal unit grouping two or more *intrusions* that are part of a formally classified *swarm* but are distinguished by location, composition or some other geological feature(s); it is emphasised that subswarms must be informal, and cannot form part of a formal lithodemic classification; as such, the term should be used sparingly; see Section 2.4.4
suite	a lithodemic unit of Rank 2 grouping two or more *lithodemic units* of lower rank (i.e. Ranks 3 to 6), and of the same class (intrusive igneous, highly metamorphosed, highly deformed or mixed), that display a degree of natural relationship through similarities in a meaningful combination of observed features such as shape, spatial distribution, composition, and age; mixed lithodemic units composed mainly of intrusive igneous rock may be included in a suite otherwise grouping intrusive units; the lithodemic unit next lower in rank to *supersuite*; see Section 2.3.1.5
superprovince	a group of two or more *provinces* that are related to a major tectonothermal event; see section 2.4.2.2
supersuite	a lithodemic unit of Rank 1 grouping two or more *suites* that have a degree of natural relationship to one another; supersuites may also contain *lithodemic units* that are not assigned to suites; the highest ranking formal lithodemic unit; see Section 2.3.1.6

swarm a group of Rank 6 *intrusions* that are associated spatially and inferred to be related genetically; swarm is not a formal type of *lithodemic unit* (and therefore does not appear on its own in Figure 1), however many of the terms used for lithodemic units classified at Rank 5 have been created by linking the term swarm to Rank 6 terms, for example *dyke-swarm*, *sill-swarm*; see Section 2.3.1.2

vein a lithodemic unit of Rank 6 composed of a sheet-like *body* that is generally narrower and more irregular than features classified as *sills*, *dykes* or *sheets*; the term is also used for features that are not lithodemic units, e.g. the mineral filling in, or replacement around, a fracture

vein-complex a mixed lithodemic unit of Rank 4 composed of a *vein-swarm* and its country-rocks, the whole being typically intermediate in character between a xenolith-rich *pluton* and veined country-rock; see Section 2.3.2.1

vein-swarm a lithodemic unit of Rank 5 composed of a *swarm* of *veins*, typically with an irregular disposition

vent strictly, an opening at the Earth's surface through which volcanic material is extruded; on UK maps a vent usually represents the chaotic near-surface deposits formed by collapse of the original crater; c.f. *neck*; a lithodemic unit of Rank 6

vent-swarm a lithodemic unit of Rank 5 composed of a *swarm* of *vents*

volcano-complex a mixed lithodemic unit of Rank 3 composed of *extrusions*, related *intrusions* and volcaniclastic products, at a site of persistent volcanic activity; see Section 2.3.2.2

zone used to refer to, or to name, *facies* displaying a geometrical regularity, such as parallel or concentric layers; see Section 2.4.1.2

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British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk

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