NATURAL ENVIRONMENT RESEARCH COUNCIL

BRITISH GEOLOGICAL SURVEY

Geological Survey of England and Wales

Geological notes and details for 1:10 000 sheets

SHEET SY 09 SW

(Aylesbeare, Devon)

Part of 1:50 000 Sheet 325 (Exeter)

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EXETER: BRITISH GEOLOGICAL SURVEY 1984

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1. INTRODUCTION

1.1 Previous work

The original geological survey of the 25 km^2 of ground depicted on 1:10 000-scale sheet SY 09 SW (Aylesbeare) was made by Sir Henry de la Beche at the one-inch scale (1:63 360), and published in 1834 as part of his geological map of Devon. W A E Ussher re-surveyed the area on the same scale between 1873 and 1876, and the results were incorporated in New Series one-inch Geological Sheet 325 (Exeter), published in 1899; the accompanying explanatory memoir was issued in 1902.

1.2 Description of the project

The primary 1:10 000-scale survey of Sheet SY 09 SW was carried out by R A Edwards in 1983 under the direction of R W Gallois, District Geologist, as part of a geological survey of Exeter and its environs, commissioned by the Department of the Environment (Contract PECD7/1/054). The map area lies to the east of Exeter and is one of nine 1:10 000 sheets (Figure 1) surveyed in 1982 and 1983 with the objectives of collating existing data and interpreting the lithology and hydrogeology of the superficial deposits and the Permo-Triassic rocks for use in future resource assessment and land use planning. This report and the accompanying map summarise the results of earlier work and the 1982/1983 survey. Discussion of the geology of all nine sheets that comprise the Exeter project is contained in a separate BGS report (Bristow and others 1984).

1.3 Fieldwork

The field survey was carried out by detailed examination on the ground of all exposures, the geological boundaries in unexposed areas (which predominate in the Aylesbeare district) being traced by intensive sampling with a 1.2 m hand auger combined with examination of topographical features and soil types. Aerial photographs at about the 1:20 000 scale were used, mainly as an aid in tracing features. All borehole records in the BGS archives for the sheet area were studied and the data incorporated,

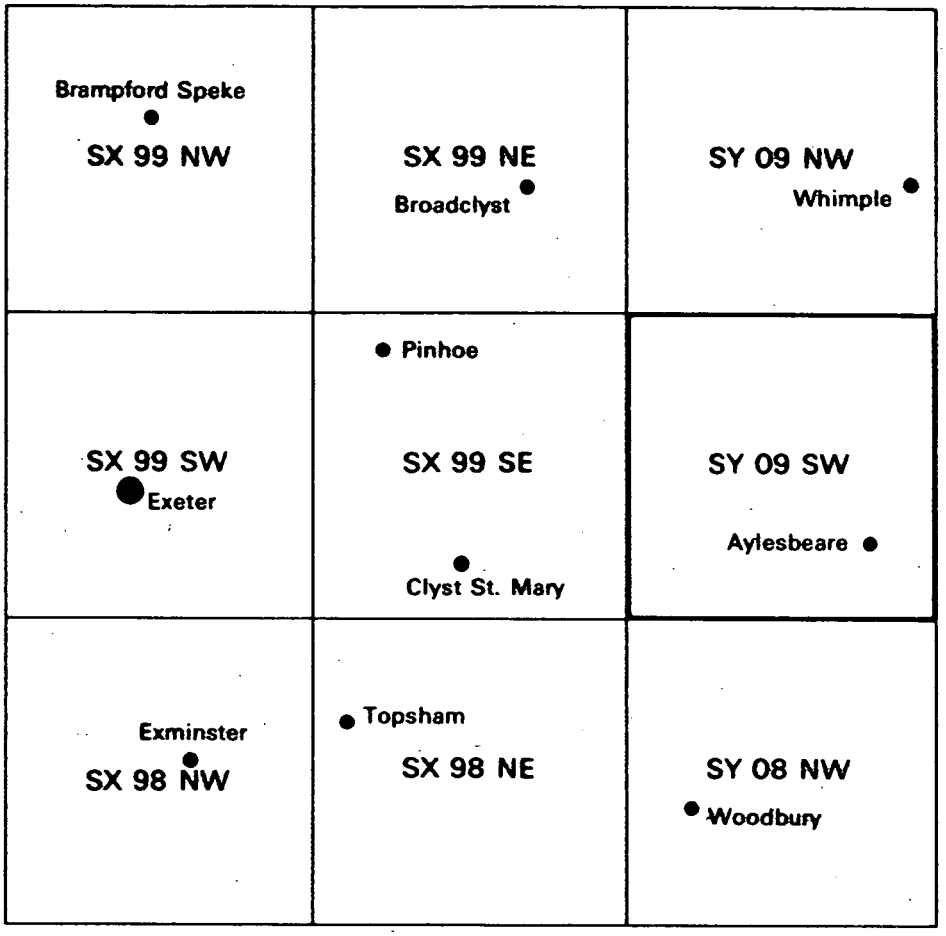

Figure 1. Index map showing the area covered by the Exeter project and this report. Black and white dyeline copies of all these maps and accompanying reports are available from B.G.S. offices.

where appropriate, into the map and report. The particle size distributions of 13 samples of sands collected from the Permian formations of the area were determined, and statistical parameters calculated using a computer program. Observations on the land use of the district were made during the course of the geological survey and the results are presented in Figure 2.

1.4 General description of the district: topography, drainage, settlements, communications

Most of the district, underlain by Permian mudstones and sandstones (Aylesbeare Mudstone in the north; Exmouth Mudstone and Sandstone and Littleham Mudstone in the south), is undulating ground rising steadily eastwards from around 20 m above OD in the NW to around 120 m above OD in the SE where the Permian outcrop is bounded by a scarp capped by Triassic gravels (Budleigh Salterton Pebble Beds) which forms the highest ground (166 m) in the district. The southern half of the district is drained by small unnamed streams which flow westwards to the River Clyst. Other small streams in the northern half of the area flow north-westwards to Rockbeare to join, north of the area, the Cranny Brook, itself a tributary of the River Clyst.

The district is predominantly rural in character, the main settlement being the small village of Aylesbeare; the smaller villages and hamlets are Marsh Green, Farringdon, and Perkin's Village. Part of the village of Rockbeare extends into the northern part of the district. The eastern half of Exeter Airport occupies about 1 km^2 in the NW corner of the area, and an industrial estate is currently under development on the southern side of the airport.

A short (0.65 km) length of the A30 London to Penzance trunk road, designated as a National Route in the Devon County Structure Plan (Anon, 1981) traverses the north-western corner of the district, while the A3052 Clyst St Mary to Colyford road, designated a Main County Route in the Structure Plan, crosses the area from west to east close to its southern margin.

1.5 Land use

Except for the airport and its associated industrial estate, the area is predominantly agricultural; Figure 2 shows the main land use in 1983. Most of the area (c 80%) was given over to grassland, upon which dairying is the main type of farming. About 16% of the area was occupied by arable crops, mainly wheat and barley, with smaller amounts of kale, potatoes, turnips, and silage mixtures (barley/oats/peas). The outcrop of the Littleham Mudstone was used almost exclusively for growing grass. Arable crops, mostly wheat and barley, were grown mainly on the outcrop of the Exmouth Mudstone and Sandstone, which includes the larger areas of better drained sandy loams and loamy sands. The boundary between the Littleham Mudstone and the Exmouth Mudstone and Sandstone is shown on Figure 2 to illustrate the relationship between geology and agricultural land use. However, the relationship between arable crops and sandstones in the area should not be overstressed, for cereals were also widely grown in areas underlain predominantly by mudstones, for example west of Farringdon; in such cases agricultural land use is determined by individual farm management policy.

Woodland occupies a small part (c 1 km^2) of the district. Commercial coniferous woodland, mainly part of the Clinton Devon Estate, is present at Manor Plantation [048 918] and in Hawkerland Wood [047 902]. They form part of a discontinuous belt of plantations that occur at the foot of the Budleigh Salterton Pebble Beds scarp, and extend southwards into the area of Sheet SY 08 NW (Edwards 1984 b, Figure 2). Other woodlands in the Aylesbeare district are mainly deciduous, occurring as narrow strips along stream courses (for example, along the headwaters of the Grindle Brook [039 200 to 042 904]), or as small blocks, the largest of which is Farringdon Wood [013 922].

The soils of the district, described later in this report, are mainly included in land capability class 3 of Clayden (1971) characterised as "land with moderate limitations that restrict the choice of crops and/or demand careful management".

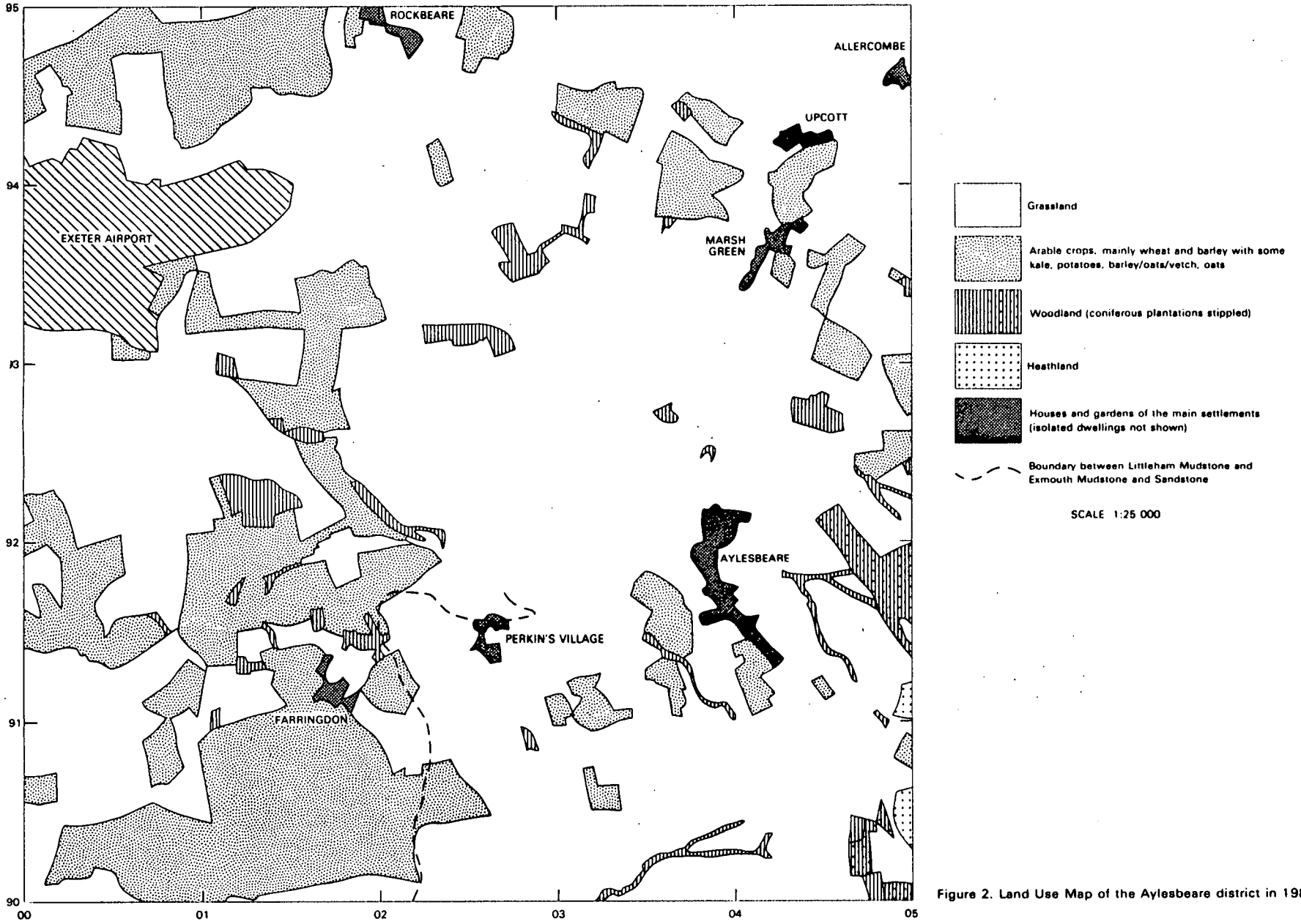

Figure 2. Land Use Map of the Aylesbeare district in 1983.

1.6 Outline of geology

Most of the area is underlain by Permian rocks that dip gently ESE at between 3° and 5°, so that successively younger parts of the geological sequence are present from NW to SE of the district. The oldest Permian rocks thus outcrop in the NW, and consist of a small outcrop of sands belonging to the Dawlish Sandstone Formation. Much the greatest part of the district is, however, underlain by mudstones and minor sandstones of the Aylesbeare Mudstone, divided in the southern third of the area into two members - the Exmouth Mudstone and Sandstone below and the Littleham Mudstone above. The extensive outcrop of mudstone is bounded in the SE corner of the district by a scarp capped by the Budleigh Salterton Pebble Beds: the base of the pebble bed is thought to mark the base of the Triassic (Smith and others, 1974). Alluvium, minor amounts of River Terrace Deposits and Valley Head occur along valleys and considerable parts of the area outside valleys are mantled by Older Head.

The geological succession proved at outcrop in the area is shown in Table 1. The nomenclature used in this report, compared with earlier names used for the strata, is summarised in Table 2.

Table 1

Geological Sequence

DRIFT	Quaternary	Alluvium	
		River Terrace Deposits, undivided	
		Valley Head	
		Older Head	
			thickness in m
SOLID	Triassic	Budleigh Salterton Pebble Beds	c 10
	Permian	Aylesbeare Mudstone (undivided)	c 400
		Littleham Mudstone	c 200
		Exmouth Mudstone & Sandstone	c 200
		Dawlish Sandstone Formation	c 15

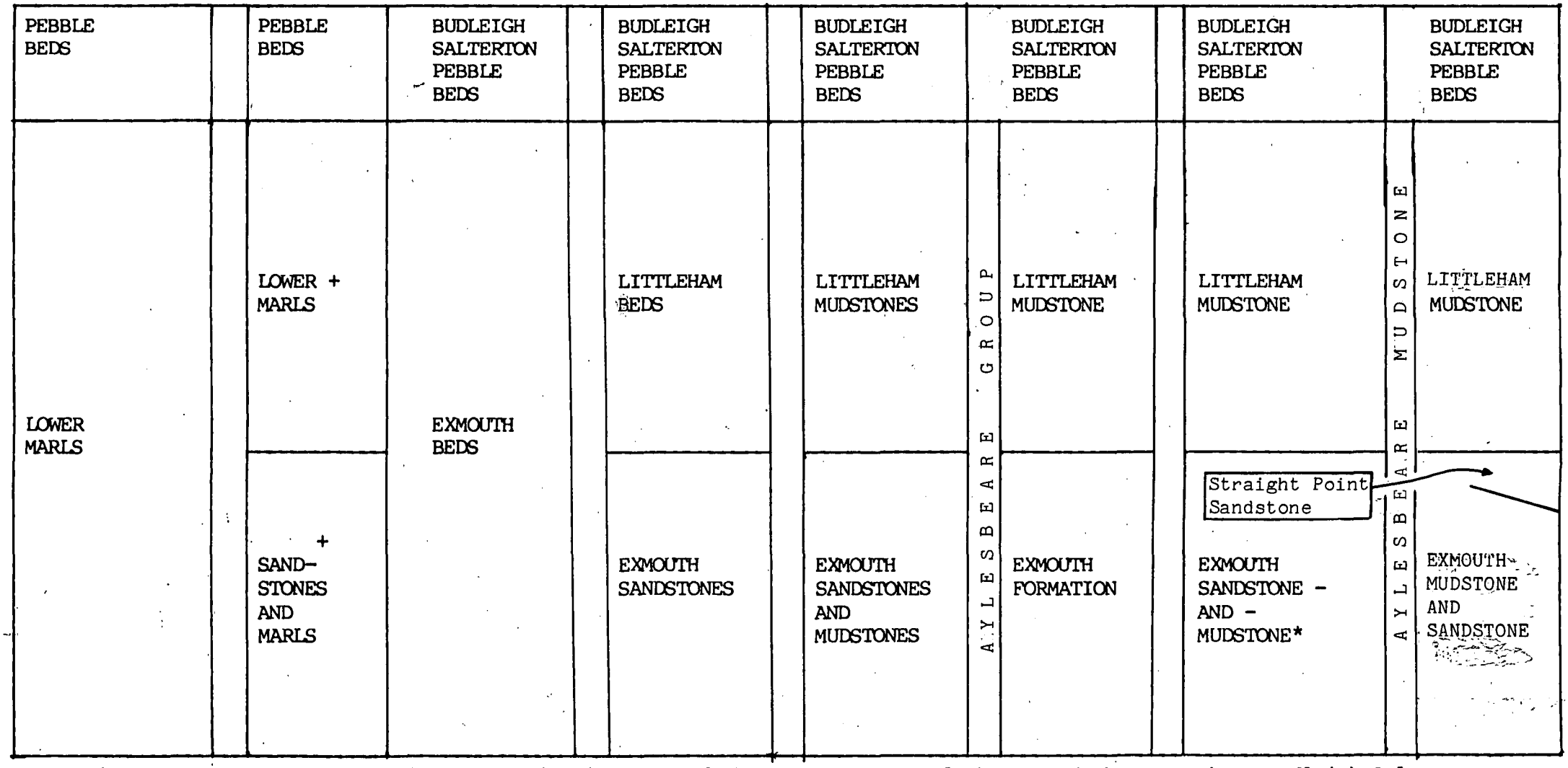

Table 2. Nomenclature of the Permo-Triassic rocks of the area between Aylesbeare and the Exmouth to Budleigh Salterton Coastal section.

\+ On the Teignmouth 1:63360 geological map (1913) the division between "Lower Marls" and "Sandstones and Marls", described in the Memoir (Ussher 1913) is not shown, the beds being grouped together as "Lower Marls with occasional Sandstone".

* Not hyphenated on the Newton Abbot geological map (Sheet 339) 1976.

2. SOLID FORMATIONS

2.1 Dawlish Sandstone Formation

2.1.1 GENERAL DESCRIPTION

The oldest rocks in the area belong to the Dawlish Sandstone Formation, which has a small outcrop area (< 1 km^2) in the NW of the district. The formation occupies, in areas W and SW of the Aylesbeare district, a stratigraphical position between the Aylesbeare Mudstone above and the Teignmouth Breccia Formation below. That part of the formation lying within the Aylesbeare district was included in the Lower Sandstone of Ussher (1902). Only the topmost 10 m of the formation and the contact with the Aylesbeare Mudstone crop out in the Aylesbeare district.

The formation at outcrop consists of reddish-brown sands or weakly cemented sandstones that grain-size analyses show to be fine- to medium-grained, moderately to poorly sorted, with near symmetrical grain-size distributions (Table 3). At outcrop in cliffs near Dawlish, in quarries near Exeter, and in boreholes in the present district, the formation is a soft sandstone with a variable degree of ferruginous cementation. In analysed sand samples, that part of the distribution coarser than 0.5 mm is very well sorted and composed of rounded to well rounded quartz and feldspar grains which may have been transported by wind action; the < 0.5 mm fraction consists of sub-rounded to subangular grains that were probably transported by rivers. Evidence from the Pinhoe and Clyst St Mary district where the Dawlish Sandstone Formation has a large outcrop, suggests that it is predominantly composed of fluvial sand, with a lesser proportion of aeolian sand (Bristow and Williams, 1984).

2.1.2 DETAILS OF EXPOSURES AND BOREHOLES

Reddish-brown, fine-to medium-grained sands very close to the top of the formation are poorly exposed in road cuttings [0000 9469 to 0008 9473] beside the A30 road. Statistical grain-size parameters of two samples are given in Table 3, and grading percentages for the same two samples in Table 5. A nearby borehole [0005 9451] penetrated the top 6.85 m of the formation which was very dense reddish-brown, fine- to medium-grained sand.

Table 3

Statistical grain-size parameters of sands from the Aylesbeare Mudstone and Dawlish Sandstone Formation

Formation	Locality National Grid Ref.	Mean (ϕ)	Sorting (ϕ)	Skewness	Kurtosis
Dawlish Sandstone	0004 9470	1.96	1.01	- 0.01	0.73
" "	0001 9468	1.96	1.01	- 0.10	1.00
Exmouth Mudstone & Sandstone	0156 9007	2.68	0.66	0.02	1.14
"	0250 9140	2.18	1.14	- 0.12	0.78
"	0078 9052	2.51	0.72	0.13	1.10
"	0210 9051	1.73	0.58	0.14	1.04
"	0166 9001	1.60	0.90	0.40	0.98
Aylesbeare Mudstone (undivided)	0441 9468	2.26	0.76	0.32	1.13
"	0385 9304	2.36	0.53	0.04	0.97
"	0449 9422	2.30	0.69	- 0.02	1.01
"	0457 9457	2.25	0.86	0.04	1.02
"	0442 9384	1.97	0.90	0.07	1.01
"	0459 9356	2.66	0.69	- 0.08	1.20

Notes

1. The phi (ϕ) scale is a logarithmic transformation of the millimetre size scale thus:

   $\phi = -\log_2 S$ where S is the size in millimetres.

   The scale is widely used in sedimentological studies. Tables for conversion of the ϕ scale to millimetres are available. For example, 0.5 mm = 1.0ϕ 0.25 mm = 2.0ϕ; 0.125 mm = 3.0ϕ.

2. The parameters were calculated using the formulae contained in Folk and Ward (1957).

Explanation of parameters

Mean. The mean is one measure of the average size of a sample. The measure used in the table is the graphic mean of Folk and Ward (1957), which is based on three points of the grain-size curve.

Sorting. Sorting is a measure of the degree of scatter of a grain-size distribution, that is, the tendency for the grains to all be in one grain-size class. The following verbal classification of sorting is used: 0.50ϕ to 7.1ϕ moderately well sorted; 0.71ϕ to 1.00ϕ moderately sorted; and 1.0ϕ to 2.0ϕ poorly sorted.

Skewness. Skewness is a measure of the degree of asymmetry of a curve, that is its 'lop-sideness'. A curve with a fine-grained 'tail' is positively skewed; a curve with a coarse 'tail' is negatively skewed. Curves with skewness values between +0.10 to -0.10 are near-symmetrical.

Kurtosis. Kurtosis is a measure of the 'peakedness' of a curve.

Farther south, the contact with the Aylesbeare Mudstone extends beneath Exeter Airport, but is precise position is uncertain owing to the presence of made ground and Valley Head. An 8.7 m-deep well [0012 9330], now concealed beneath buildings on the southern side of the airport, is recorded as having passed through "marl" (Aylesbeare Mudstone) into "sand" (Dawlish Sandstone Formation), at an unspecified depth. A nearby water borehole [c 0022 9334] passed at 18.28 m depth into Dawlish Sandstone Formation which consisted of "red sand rock" penetrated to a depth of 45.7 m. Farther south, another water borehole (SY 09 SW/14) [0020 9305], 100 m SSW of Fair Oak Farm, can be interpreted as having penetrated 88.69 m of Dawlish Sandstone Formation beneath 47.25 m of Aylesbeare Mudstone (see Appendix).

2.2 **Aylesbeare Mudstone**

2.2.1 GENERAL DESCRIPTION

About 97% of the Aylesbeare district is underlain by a 400 m-thick sequence of reddish-brown mudstone, with impersistent, mostly thin sandstone beds,that was named Lower Marls by Ussher (1902). Laming (1966) applied the term Exmouth Beds to this sequence where it crops out in the cliffs between Exmouth and Budleigh Salterton. The name Aylesbeare Group was introduced by Smith and others (1974), and has since been widely used. The type area of the Group was named by Smith and others (1974, pp. 38-39) as the village of Aylesbeare [0492]. In view of the lack of inland exposure, the obvious type section is the excellent exposure in the sea-cliffs between Exmouth and Budleigh Salterton. Ussher (1902; 1913) recognised that the Lower Marls consisted of two members, the lower of which comprised "marls with sandstones, intercalated at irregular intervals", upon which rested an upper member of "marls without sandstone". However, he found it impossible to trace the boundary between the two members inland. Laming (1968) named the lower division the Exmouth Sandstones and the upper division the Littleham Beds, and these names have been used, with various modifications shown in Table 2, by subsequent authors. In this account, the term Aylesbeare Group is replaced by Aylesbeare Mudstone (of formational status). Where possible it is divided into two members, the upper being called the Littleham Mudstone, the lower lower the Exmouth Mudstone and Sandstone. The latter term is preferred to

Exmouth Formation because it provides information about the lithology of the unit, and it is preferred to the term Exmouth Sandstone and Mudstone which is thought to give an erroneous impression that sandstone is the dominant component of the member.

The base of the Aylesbeare Mudstone and the Exmouth Mudstone and Sandstone is taken at a sharp lithological change from sandstone to mudstone. Inland this boundary can readily be traced by augering. The highest bed of the Exmouth Mudstone and Sandstone in the coastal section is a 19 m-thick sandstone that forms Straight Point [SY 037 795], and which in this report is informally referred to as the Straight Point Sandstone. The base of the Littleham Mudstone is taken at the junction of this sandstone and the thick uniform mudstones that overlie it. When traced inland, the sandstone is separated by mudstone outcrops at several localities, and the resulting lenticular beds of sandstone that have been mapped out cannot categorically be stated to occur everywhere at the same stratigraphical horizon as the Straight Point Sandstone. It is believed, however, that the top of the Sandstone is at persistent stratigraphical level. A moderately persistent sandstone forms the top of the Exmouth Mudstone and Sandstone throughout much of the Woodbury district (Edwards, 1984b), and extends into the Aylesbeare district northwards as far as Perkin's Village [026 915]. Thus, in the southern third of the present district, the Aylesbeare Mudstone is divided into two members, each about 200 m thick. North of Perkin's Village, the Aylesbeare Mudstone contains only a few impersistent sandstones that cannot be correlated satisfactorily with the sandstones south of the village, and the Aylesbeare Mudstone is not divided into members.

Exposures of the Aylesbeare Mudstone are generally poor, the mudstones being readily degraded by weathering; natural exposures occur mainly in the banks and beds of streams beneath deposits of Alluvium or Head. Occasional artificial sections occur in road cuttings, drainage ditches, temporary excavations, and in the numerous old marl-pits which occur scattered over the outcrop. The sandstones are more resistant to weathering, and steep-sided topographical features are commonly related to the presence of a sandstone bed or beds. Locally, a distinctive topography is formed, such as that near the southern margin of the district where two

thick sandstones at the top of the Exmouth Mudstone and Sandstone form the prominent double feature of Windmill Hill [016 901] and the unnamed hill 0.25 km E of Windmill Hill. Most sandstone-based features are, however, more subdued.

In the weathering zone, the mudstones are weathered to clay, with more indurated clay and mudstone generally found in stream beds. The mudstones are generally massive and structureless with a characteristic blocky-weathering habit. As in the coastal exposures, occasional thin (0.1 to 1.0 m) beds of olive silt and silty fine-grained, commonly calcareous, sandstone occur within the predominantly mudstone succession. The clays and mudstones are usually moderate reddish-brown in colour (10R 4/6)* but commonly contain spherical pale greenish-grey (5GY 6/1) spots, irregular patches, and bands. The reddish-brown colour of the mudstones is due to the presence of ferric oxide, usually hematite, either as a coating to grains or as finely divided material in the clay-mineral matrix. Durrance and others (1978) recorded an average total iron content of about 5.5% in mudstones from coastal exposures of the Littleham Mudstone. The 'reduced' spots and zones transect depositional boundaries and are thus post-depositional.

Dark nodules 30 mm to 60 mm in diameter, surrounded by greyish-green haloes 80 mm 100 m in diameter were found during the resurvey of the Aylesbeare district within mudstones in a stream section [0331 9154 to 0335 9154] near Aylesbeare. Details of the exposures are given later in this report. The nodules are outwardly similar to nodules found on the coast near the base of the Littleham Mudstone at Littleham Cove, which have attracted considerable interest because they contain high proportions of metallic elements including vanadium, uranium, copper and nickel (Carter 1931; Perutz 1939; Harrison 1975; Durrance and George 1976; Durrance and others 1980). The discovery of a new locality during the present survey is of interest in demonstrating that the nodule-bearing strata extend northward, whether discontinuously or not is uncertain, for at least 11 km from the coastal sections. The stratigraphical level of occurrence - near the base of the Littleham Mudstone - is similar to the level of occurrence in the coastal localities. The vanadiferous nodules of the Aylesbeare

* Notations such as this refer to colours of the Geological Society of America Rock-color Chart, 1963.

Mudstone are at present being studied by another unit of BGS, under contract to the Department of Industry.

The mudstones of the Aylesbeare Mudstone consist of silt and very fine-grained sand grains of quartz and a few feldspar grains, in a hematite-stained clay matrix. In some samples, the coarser grains form thin impersistent laminae, but generally the mudstones are structureless. Henson (1971, p. 122) attributed the lack of structure to intensive bioturbation . He determined the grain-size distributions of mudstones from coastal exposures of the Aylesbeare Mudstone. No sample was analysed from the present district, but the lithologies are so similar and uniform that Henson's analyses are probably also applicable to the Aylesbeare district. Mudstones of the Exmouth Mudstone and Sandstone were found to contain usually between 4% and 8% of very fine-grained sand (although up to 11% was recorded), the remainder of the rock being made up of approximately sub-equal proportions of silt and clay-grade material (40% to 55% for each grade). The overall mean diameter for the particles within the mudstones was 4μm. Most Littleham Mudstone samples contained between 2% and 5% of very fine-grained sand (up to 7% recorded); silt contents varied between 30% and 53% and clay contents between 40% and 70%). The overall mean diameter for the mudstones was 3μm.

The silty mudstones of the Aylesbeare Mudstone were formerly called marls (Ussher 1902), but according to Pettijohn (1957, p. 410) marls should contain between 35% and 65% of calcium carbonate. Typical Aylesbeare Mudstone samples collected during the resurvey of the Exeter district were found to contain between 7% and 12% calcium carbonate; thus the term marl is inappropriate. However, the carbonate content is sufficiently high for the term 'marly clay' or 'marly mudstone' to be applied; the widespread presence of marl-pits in the Aylesbeare district indicates that the calcareous content was sufficiently high for the mudstone to be of value for the long-discontinued agricultural practice of marling.

The clay mineralogy of the Aylesbeare Mudstone of the Aylesbeare district has not been examined; Henson (1973) noted that samples of Aylesbeare Mudstone from the coastal exposures were predominantly composed of illite with subordinate amounts of kaolinite and chlorite.

Sandstone south of Perkin's Village forms a moderately persistent horizon that defines the top of the Exmouth Mudstone and Sandstone; north of the village sandstones are fewer and less persistent and are included in undivided Aylesbeare Mudstone. The sandstones are generally reddish-brown in colour, uncemented or weakly cemented where weathered at outcrop, with a range of mean size, indicated by grain-size analyses of eleven samples, between medium-grained and fine- to medium-grained sand (1.60Ø to 2.68Ø). The sands are mostly moderately well sorted to moderately sorted (0.53Ø to 1.14Ø); six of the samples have nearly symmetrical grain size distributions, one sample is negatively skewed, two are positively skewed, and two are strongly positively skewed. The range of skewness values is -0.12 to + 0.40. Statistical parameters for all samples are given in Table 3.

The sandstones are generally cross-bedded, but too poorly exposed for many measurements of cross-bedding foreset dips and directions to be obtained; at Windmill Hill [0166 9001 and 0180 9004] cross-bedding foresets dip to the ESE and SSE.

Towards the southern margin of the district, the sandstones in the Upham Farm to Windmill Hill outcrop attain thicknesses of up to 30 m, but mapping shows very marked lateral variations in thickness to almost zero, indicating that the sand bodies are lenticular in form.

In contrast to the Woodbury district to the south, the Exmouth Mudstone and Sandstone contains very few mappable sandstone beds below the topmost (?Straight Point) Sandstone. However, one borehole [0179 9107] near Farringdon (Appendix) penetrated several sandstones which apparently do not crop out. Sandstones in the undivided part of the Aylesbeare Mudstone north of Perkin's Village, such as those west of Allercombe, are 5 to 10 m thick.

Henson (1970, 1971, 1973), who studied the sedimentary structures and clay mineralogy of the coastal exposures, considered that the Aylesbeare Mudstone was deposited by rivers in a flood-plain complex. Thus, the lenticular sandstones of the Exmouth Mudstone and Sandstone represent fining-upward sequences deposited within river channels; they show sedimentary features characteristic of recent channel deposits, channel bars and point bars. The thinner silty sand intercalations in the formation were considered to be characteristic of overbank deposits, such as levees and crevasse splays. Red mudstones of the formation were deposited on a flood-plain; they show no obvious signs of subaerial exposure, however, and contain no recorded examples of suncracks, calcretes or ferricretes. They appear to have been intensively bioturbated by organisms of unknown type. The results of the present survey indicate that Henson's fluvial model for the deposition of the Aylesbeare Mudstone remains the most likely explanation for the sedimentary features of the formation. However, there is evidence for a northward facies change within the Aylesbeare area, in which sandstone becomes less common northwards. This change may coincide with the incoming of many thin gypsum bands and nodules which, although not recorded at outcrop in the Aylesbeare district, were penetrated in a borehole [SY 0659 9111] near Venn Ottery Common, only 1.5 km east of the eastern boundary of the Aylesbeare district.

Henson (1971) considered that the Aylesbeare Mudstone was up to 530 m thick in the coastal succession, as compared with a considerably thinner (around 400 m) sequence in the Aylesbeare area.

2.2.2 DETAILS OF EXPOSURES AND BOREHOLES

Aylesbeare Mudstone (undivided)

A borehole (SY 09 SW/67) [0052 9454] on the Aylesbeare Mudstone outcrop near Treasbeare Cottages in the NW of the district penetrated reddish-brown very stiff (hard below 8.8 m depth) silty clays and mudstones 18.05 m thick. Layers of weakly cemented reddish-brown sandstone were recorded (4.60 to 8.80 m depth) and, near the base (15.35 to 15.70 m), a bed of reddish-brown silty sand. The full log is given in the Appendix.

A nearby borehole (SY 09 SW/68) [0086 9467] penetrated (beneath 3.55 m of Older Head) very stiff to hard reddish-brown silty clay to 12.00 m depth, beneath which were reddish-brown silty mudstones with a few beds up to 0.55 m thick of weakly cemented greyish-green silty fine-grained sandstone, penetrated to 19.60 m depth (see Appendix for log).

Trial pits [eg. 0120 9391] up to 2 m deep at Exeter Airport proved weathered Aylesbeare Mudstone clays that consisted of reddish-brown, silty, hard, fissured clay with pockets of very sandy clay. The fissures were closely spaced with black surface staining; there was some softening along fissure boundaries. The excavated clay broke into angular gravel-sized fragments.

A water borehole (SY 09 SW/14) [0020 9305], south of Exeter Airport, penetrated Aylesbeare Mudstone to 47.25 m depth, on Dawlish Sandstone Formation. The drillers log records alternations of "red rock" and "red marl" (see Appendix). The Aylesbeare Mudstone succession in a nearby borehole [0025 9281] was all reddish-brown silty clay, stiff to very stiff above 5.80 m depth, strata below that depth to the terminal depth at 15.0 m being recorded as "hard red friable silty clay with consistency of soft mudstone at various levels".

A borehole [0132 9294], near Beautiport Cottage, showed the following succession in the Aylesbeare Mudstone, beneath 0.45 m of topsoil:

	Thickness (m)	Depth (m)
Clay, stiff, red, friable, silty, with traces of sand	2.90	3.35
Clay, stiff to very stiff, friable, silty, with traces of sand	4.65	8.00
Clay, hard, red, friable, silty, with bands of mudstone	7.25	15.25

Small exposures [0098 9253 to 0215 9270] of reddish-brown silty clay and mudstone occur beneath Alluvium in the banks and bed of the unnamed stream north of Farringdon Wood. One exposure [0098 9253] shows about 0.2 m of reddish-brown silty mudstone with patches and streaks of greyish-green sandy silt.

The stream that flows northwards from Perkins's Village shows small stream-bed exposures of mudstone with some sandstone. Good exposures [0238 9189] in a meander bend are of reddish-brown silty mudstone and clayey siltstone with bands of calcareous greenish-grey (5GY 7/1) silty fine- to very fine-grained sand.

Small stream-bed exposures [0244 9179] show yellowish-brown-weathering sandstone; a dip of about 10°/60° was measured, but nearby dips are to the west, indicating the presence of faulting or cross-bedding. Another small stream-bed exposure [0240 9186] of sandstone was noted.

A borehole [0307 9489] beside Gribble Lane, about 1 km E of Rockbeare, penetrated the following Aylesbeare Mudstone sequence beneath 2.5 m of soil and alluvial clay:

	Thickness (m)	Depth (m)
Clay, firm, red-brown, silty, with some sand and layers of grey-green silt ..	1.50	4.00

	Thickness (m)	Depth (m)
Clay, stiff, red-brown, silty, with traces of sand and layers of grey-green silt, passing down at 6.7 m into hard friable red-brown silty clay	11.00	15.00

At Rockbeare House, a water borehole [0322 9401] penetrated 64.00 m of "marl and clay", overlying 6.10 m of "gravel". The identity of the latter is uncertain.

Small exposures of reddish-brown silty clay are visible at intervals in the bed of the unnamed stream between a point [0371 9454] about 400 m SE of Tanner's Farm, Rockbeare and Allercombe [0480 9468]. A borehole (SY 09 SW/8) [0425 9468] 250 m W of Turkey Lane, Allercombe showed the following sequence:

	Thickness (m)	Depth (m)
Alluvium	2.0	2.0
Aylesbeare Mudstone		
Clay, firm, red, friable, silty ...	1.6	3.6
Clay, hard, red, friable, silty ...	0.9	4.5
Sandstone, weathered, red-brown ...	0.1	4.6
Clay, stiff, red, friable, silty ..	9.4	14.0

Another borehole [0441 9487] 0.25 km NE of the last-mentioned borehole, penetrated 10.3 m of stiff to hard red silty clay with two beds of weakly cemented red-brown sandstone between 7.0 to 8.9 m, and 10.05 to 10.3 m depth. The higher sandstone crops out on the hillside to the west,

and the same horizon is well seen in small stream bank exposures [0440 9468 to 0444 9470] 100 m W of Turkey Lane, which show the following sequence:

	Thickness (m)	Depth (m)
Alluvium	1.90	1.90
Aylesbeare Mudstone		
Sand, reddish-brown	0.15	2.05
Sandstone, reddish-brown, well-laminated, possibly cross-bedded, weakly cemented, fine- to medium-grained ..... up to	0.30 seen	2.35

Grain-size analysis shows that the sandstone is moderately sorted and strongly positively skewed (Table 3).

The same sandstone can be traced intermittently by augering and features towards Marsh Green. It was formerly extracted from a small sandpit [0404 9404], about 50 m west of which it dies out.

Sandstone in lane-side exposures [0457 9457; 0459 9448] in Turkey Lane, Allercombe (noted by Ussher (1902, p. 46)) forms a well-defined feature for about 200 m W of the lane. Augering E of the lane indicates that the sandstone bifurcates and then dies out within 100 m. Grain-size analysis of a sample from a lane-side exposure [0457 9457] indicates that the sandstone is fine- to medium-grained, moderately sorted, with a near-symmetrical grain-size distribution (Table 3).

The sandstone at Turkey Lane may be at the same stratigraphical horizon as the Straight Point Sandstone, but this cannot be stated with certainty, and it and another stratigraphically lower sandstone exposed in the stream section W of Turkey Lane, described above, are mapped as sandstones within undivided Aylesbeare Mudstone.

The banks of Allercombe Lane contain small exposures [0492 9449 to 0487 9442] of reddish-brown silty clay which at one place [0490 9443] contains a 30 mm-thick bed of greyish-green, very clayey, silty fine-grained sand.

Exposures (0442 9384) in a ditch along the N side of Marsh Green Hill show about 1.2 m of well-bedded reddish-brown silty mudstone with 5 bands of pale olive grey (5Y 6/1), fine- to medium-grained, calcareous to very calcareous, fine-to medium-grained moderately sorted sandstone from 25 mm to 50 mm thick. One sandstone forms the floor of the ditch for about 4 m. Two of the sandstone beds are joined by a number of vertical sandstone pipes which transect the intervening mudstone. Similar sandstone pipes in the cliffs at Exmouth were interpreted by Henson (1971) as dewatering structures.

Exposures of calcareously-cemented, pale olive grey (5Y 6/1) silty sandstone occur in the stream bed [0459 9356] 200 m NW of Great Houndbeare Farm. The sandstone, about 0.15 m thick, occurs within a reddish-brown silty mudstone sequence.

Sandstone underlies the steep slopes [0345 9305 to 0388 9309] S of Westcott Lane, about 1 km SW of Marsh Green. Small exposures in a ditch [0385 9304] are of reddish-brown sand and weakly-cemented, fine- to medium-grained, moderately well-sorted sandstone. Small sections [0342 9335; 0418 9299] beneath Alluvium in the stream N of Westcott Lane show reddish-brown silty clay and mudstone with green 'reduction' patches.

The sandstone at Rill Farm [030 925], noted by Ussher (1902, p. 46), is lenticular. There is no exposure and the outcrop has been determined by augering.

The stream that flows westward from Aylesbeare village to Perkin's Village contains scattered small exposures [eg. 0430 9181; 0410 9181; 0371 9186; 0348 9184] of up to 2 m of reddish-brown silty clay and fissured silty mudstone. One exposure [0348 9184] shows 1.5 m of reddish-brown silty mudstone with 10 cm-thick bands of flaggy greyish-green clayey siltstone.

Exmouth Mudstone and Sandstone

In Perkin's Village there are several exposures of reddish-brown sand and sandstone, mainly in stream-bed exposures. The junction with the overlying Littleham Mudstone is present in a stream section [0262 9132] S of the village. Sandstone was recorded in the foundations of a cottage extension [0255 9146]. Exposures of yellowish-brown and reddish-brown sandstone are present in the stream bank [0256 9141] south of the village. Other stream-bed exposures [0250 9140] west of the village show up to 1.5 m of flaggy-bedded, reddish-brown, fine-to medium-grained, poorly sorted sandstone. It is uncertain in view of the small size of the exposure, whether the dip measured (8°/76°) is cross-bedding or true bedding.

The sandstone at Perkin's Village caps a distinct feature W of the village and expands in thickness near Farringdon, where reddish-brown sand was formerly extracted from a small sandpit [0186 9149], now overgrown. East of Farringdon, the sand dies out for about 200 m, but reappears and rapidly thickens near Upham Farm [0210 9065]. Small exposures [0213 9069] near the farmhouse are of reddish-brown sand with bands of shaly mudstone; 100 m E, reddish-brown sandstone and sand is present in lakeside exposures [0224 9068]. A disused sandpit [021 905] S of Upham Farm, contains small exposures of reddish-brown, medium-grained, moderately well-sorted sand.

South of the A3052, the sandstone thickens to a maximum of about 30 m, and bifurcates to form two scarp features, that of Windmill Hill [0162 9009], and the unnamed hill [0187 9013] 250 m E of Windmill Hill. Small exposures [0156 9007] on the W side of Windmill Hill are of reddish-brown, weakly cemented, fine- to medium-grained, moderately well-sorted sandstone. Exposures [0166 9001] on the S side of Windmill Hill show about 1.0 m of cross-bedded, reddish-brown, medium - grained moderately sorted sandstone with cross-bedding dips of 26°/110°. Cross-bedding in a nearby sandstone exposure [0180 9004] dips 13°/148°.

Strata S of the stream that flows from Farringdon westward to just S of Denbow Farm [006 917] and then out of the map area, are assigned to the Exmouth Mudstone and Sandstone; strata north of the stream are included in undivided Aylesbeare Mudstone. Few sandstones occur within the Exmouth

Mudstone and Sandstone below the horizon of the main (?Straight Point) sandstone that forms the top of the member. A water borehole (SY 09 SW/22) [0179 9107] at Farringdon is, however, recorded as having penetrated sandstones at several levels in the Exmouth Mudstone and Sandstone, particularly below 42.67 m depth.

Road cuttings [0070 9055 to 0088 9049] on the A3052 opposite Waldron's Farm are mainly grassed-over exposures of up to 2 m of reddish-brown silty clay. The top 0.6 m is siltier and sandier than the beds below and contains scattered pebbles. A fine- to medium-grained sandstone within the mdustones dips eastwards at c 6°. The feature extending southwards from this locality is probably partly underlain by a thin sandstone, but no trace of sandstone could be augered in the steep slopes [0094 9007] S of Waldron's Farm.

Littleham Mudstone

Mudstones in the upper part of the Aylesbeare Mudstone that crop out S of the Aylesbeare - Perkin's Village stream are assigned to the Littleham Mudstone. A stream-bed exposure [0295 9158] near the base of the member shows 2.5 m of reddish-brown silty to very silty mudstone with irregular bands of pale greyish-green clayey silt and silty very fine-grained sand. One 0.15 m-thick bed of pale greyish-green sandstone forms a ledge protruding from the mudstone outcrop. About 300 m ESE, stream-bed exposures [0331 9154 to 0335 9154] of mudstone contain black to dark grey nodules. Similar nodules recorded from near the base of the Littleham Mudstones in the cliffs and foreshore exposures at Littleham Cove are radioactive and vanadium-rich. One of the stream-bed exposures shows greyish-green spherical reduction spots from 1 to 90 mm in diameter. Two of the nodules, 30 and 50 mm in diameter, occur at the centre of reduction spots that are 80 and 90 mm in diameter respectively. The two nodules are at approximately the same stratigraphical level, about 2 m apart. Another nodule, 60 mm diameter within a 100 mm-diameter spot, was collected from another locality [0335 9152] within the same stream section, about 40 m SE of the first-named locality. About 1 m from the nodule, exposures of very silty mudstone in the stream bed contain two spherical greyish-green spots about 60 mm in diameter with a dark central zone but no nodule.

Exposures in the Littleham Mudstone S of Aylesbeare occur at scattered intervals in most stream beds beneath Head or Alluvium. The stream-bed E of Withen Copse [0282 9098 to 0287 9086] contains good exposures of blocky-fracturing, reddish-brown mudstone with abundant greyish-green spots. The stream that runs northwards from Lower Nutwalls Farm toward Leats Farm exposes [0388 9109] reddish-brown silty mudstone containing spherical greyish-green spots and patches. The upper reaches of the Grindle Brook expose [0361 9027] reddish-brown mudstone with a 20-to 30-mm thick band of very clayey, silty, fine-grained sandstone. A nearby exposure [0405 9029] at a higher stratigraphical level, shows reddish-brown mudstone with green spots and impersistent greyish-green clayey silt bands.

A White Cross, former brickpits [0233 9042] are now largely infilled. East of the lane to Higher Greendale other disused brickpits contain a small exposure [0247 9034] of 0.6 m-thick sandstone in reddish-brown silty clay.

2.3 Budleigh Salterton Pebble Beds

The Budleigh Salterton Pebble Beds crop out in a small area (c 0.3 km^2) in the south-east corner of the Aylesbeare district, where they form a prominent scarp feature that rises above the Littleham Mudstone outcrop. The base of the pebble beds is taken at a sharp upward change from mudstone to gravel. No borehole penetrates the formation in the present district. The few exposures and abundant surface debris of pebbles and cobbles indicate that the formation consists predominantly of well-rounded pebbles and cobbles, mainly of metaquartzite, in a coarse- to fine-grained gravel and silty sand matrix. The proportion of sand in the formation is uncertain owing to the paucity of exposure. The only exposures of the formation in the present district are in a small disused pit [0476 9042] opposite the Halfway Hotel, where the following composite section was recorded:

	Thickness (m)	Depth (m)
Soil, grey, sandy with scattered pebbles	0.3	0.3
Budleigh Salterton Pebble Beds		
Gravel, pale grey, leached, with pebbles and cobbles up to 80 mm diameter ..	0.3	0.6
Gravel, yellowish-brown and orange brown, consisting of rounded pebbles and cobbles of metaquartzite up to 150 mm across in a matrix of silty sand and gravel. Part of an 0.3 m-thick lens of yellowish-brown clayey silty fine- to medium-grained sand is present in the face of the pit.....	1.5	2.1

Sedimentological evidence from pits in the Woodbury area (Edwards, 1984b), south of the present district, suggests that the Budleigh Salterton Pebble Beds were deposited by northward-flowing braided rivers.

3. STRUCTURE

Construction of cross-sections indicates that the Permo-Triassic formations of the Aylesbeare district dip gently E or ESE at between 3° and 5°. Because of the lack of lithological contrast in the Aylesbeare Mudstone, faults cannot be recognised with certainty, although the straight E- to ESE-trending portions of some stream courses may be fault-controlled. Faults have been recognised at several localities at the boundaries between lithologically distinctive formations. South-west of Marsh Green a NW-SE- trending fault [0330 9305] displaces a sandstone bed in the Aylesbeare Mudstone; east of Livermores Farm [0461 9106] an ESE-WNW-trending fault throws down Budleigh Salterton Pebble Beds to the south. A fault near South Whimple Farm [0028 9484] in the NW of the district, has an ENE-WSW trend and throws down Aylesbeare Mudstone to the south against Dawlish Sandstone.

4. QUATERNARY (DRIFT) DEPOSITS

4.1 Head

Structureless and poorly stratified, ill-sorted mixtures of clay, silt, sand and stones that are believed to have moved downslope by solifluction under periglacial conditions, together with weathered bed-rock ('regolith') that has moved little or not at all have been mapped as Head. Two generations of Head are present in the Aylesbeare district: Older Head and Valley Head. Pleistocene solifluction is believed to have been the dominant process in the formation of the Older Head; the Valley Head is likely to have been deposited by late Pleistocene and Holocene solifluction, soil creep and downwash. The latter two processes continue at the present day.

4.1.1 OLDER HEAD

Older Head is widespread and, particularly in the east of the district, forms extensive outcrops that cap ridges and the higher ground. The surfaces of the deposits have low relief and dip gently westward away from the Budleigh Salterton Pebble Beds escarpment. The Older Head is lithologically distinct from the underlying solid formations. It consists of pebbles and cobbles, mainly of metaquartzite derived from the pebble beds, set in a yellowish-brown, greyish-orange or reddish-brown matrix that varies from silty clay to clayey, silty, fine-grained sand. Many of the clasts are broken, presumably by frost-action. Their concentration varies and gives rise to stony clay where clasts are few, and clayey gravel where they are abundant. No systematic variation in the proportion of clasts was detected in the Older Head, although deposits around Manor Plantation [045 921] in the east of the district, and thus nearest the pebble beds outcrop, are more gravelly than more westerly occurrences. Although widespread, the deposit probably rarely exceeds 2 m in thickness; the maximum recorded thickness is 3.6 m.

The presence of abundant pebbles derived from the Triassic outcrop proves that the Older Head has been transported, but its structureless, ill-sorted character rules out a fluvial origin. The Older Head is

therefore, believed to have originated as a solifluction sheet which moved downslope from the higher ground in the eastern part of the district in a periglacial climate. The present outcrops are probably the dissected remnants of a widespread sheet.

Boreholes [eg. 0086 9467] through the central part of the Older Head that caps the ridge N of Treasbeare Farm penetrated 3.0 to 3.6 m of brown to reddish-brown and yellow, stiff, silty and sandy clay with some gravel and traces of organic matter. Thicknesses of up to 1.0 m were augered at other localities in the Treasbeare Farm deposit. The Older Head was 1.2 m thick in a borehole [0441 9487] near Allercombe where it was recorded in the drillers' log as "soft to firm red-brown silty clay with stones". Older Head forms a well-defined cap to the ridge E of Rockbeare House; up to 1.1 m of reddish-brown stony clay is visible in drainage ditches [0371 9391 to 0369 9380].

A similar Older Head - capped ridge is present about 1 km NW of Aylesbeare, but again exposures are limited to poor ditch sections [0313 9302 to 0357 9289] in stony orange brown and reddish-brown clay. East of Aylesbeare, very pebbly soils[044 922] and 1 m or more of clayey gravel in ditches [0456 9209 to 0488 9173], indicate a high proportion of clasts in the Older Head. This outcrop is only 1 km west of the Budleigh Salterton Pebble Beds outcrop.

A temporary exposure [0440 9011] near Higher Hawkerland Farm showed the following section in the Older Head:

	Thickness (m)	Depth (m)
Soil		
Loam, dark brown, sandy, with scattered pebbles	0.2	0.2
Older Head		
Sand, moderate yellowish-brown to greyish orange (10 YR 6/4), very clayey, fine-grained, with common metaquartzite and other pebbles and cobbles; many broken, passing down into		

	Thickness (m)	Depth (m)
Clay, reddish-brown (10 R4/4), soft very sandy, with metaquartzite and other pebbles and cobbles, passing down into	0.3	0.8
Clay, reddish-brown (10 R4/4), soft, becoming firm with depth, silty, structureless, with isolated pebbles	0.8	1.6

At Perkin's Village, a ditch exposure [0261 9142] shows 1.5 m of sandy clayey gravel. West and north-west of Perkin's Village, the outcrops of Older Head have been mapped on the basis of pebbly soils, features and augering. There is no exposure or borehole evidence.

4.1.2 VALLEY HEAD

As the name suggests, Valley Head is confined to the lower slopes and bottoms of valleys. Lithologically it is similar to Older Head and much of it in the present district is probably derived from Older Head. Valley Head is especially common in the south-east of the district, where the lower parts of steep-sided valleys are mantled by accumulations of gravelly clay and clayey gravel. A typical exposure [0331 9154] in a gully 700 m E of Perkin's Village, shows up to 2 m of sparsely pebbly reddish-brown brecciated clay with a concentration of pebbles and cobbles at its base, resting on Aylesbeare Mudstone.

4.2 **River Terrace Deposits**

River Terrace Deposits have been mapped at only one locality in the district, around Lions Farm [026 945], about 1 km SE of Rockbeare. The surface of the deposit is about 37 m above OD. The deposit is variable in composition and consists of 1.0 to 2.3 m of clay with gravel and of gravel with cobbles and brown silty sand. The western part is mostly clayey. East of Lion's Farm auger holes penetrate up to 0.6 m of brown loam on

gravel; the nature of the deposit north and west of Lion's Farm is indicated by the following borehole records, in which the figures given are the depths of the deposits: [0225 9467] soil 0.35, stiff brown sandy clay with gravel 1.10, hard fissured red-brown silty clay with traces of gravel and roots 2.20; [0234 9470] soil 0.20, gravel with cobbles and brown sandy clay 1.20; [0236 9467] soil 0.30, stiff friable brown sandy clay with roots and some gravel 0.75, firm brown sandy clay and gravel with some cobbles 2.60; [0241 9460] soil 0.40, firm brown sandy clay with some gravel 1.00, very dense brown sand and gravel 1.80; [0246 9468] soil 0.30, firm brown sandy clay with traces of roots and gravel 0.70, firm red-brown sandy clay and gravel 1.60; [0255 9472] soil 0.20, gravel with cobbles and brown silty sand 1.75.

4.3 **Alluvium**

Alluvium occurs as narrow strips, generally 20 to 50 m wide, along most stream courses in the district. A more extensive alluvial tract is present just S of Rockbeare where several streams converge. Alluvium throughout the district can be divided into an upper unit of brown to reddish-brown silty sandy clay or silty sand (generally < 1 m thick) and a lower unit composed of pebbles and cobbles derived from the Budleigh Salterton Pebble Beds. The gravels rest with a sharp junction on the Permian strata. Exposures are fairly common in stream banks.

An exposure [0146 9460] just S of Rockbeare shows the following section:

	Thickness (m)	Depth (m)
Soil, brown, silty, sandy, clayey, with a few pebbles	0.15	0.15
Alluvium		
Clay, brown, silty, sandy	0.20	0.35
Gravel, base channeled	0.20 to 0.30	0.55 to 0.85

	Thickness (m)	Depth (m)
Aylesbeare Mudstone		
Clay, reddish-brown, silty	0.30 seen	0.85 to 1.15

A borehole [0181 9465] near Coppice Farm, on the same outcrop of Alluvium,proved the following alluvial sequence:

	Thickness (m)	Depth (m)
Soil	0.40	0.40
Alluvium		
Clay, firm, brown, sandy, with some gravel and traces of carbonaceous matter	0.50	0.90
Gravel, dense, sandy	1.00	1.90

A borehole [0277 9477], 280 m WNW of Ford Farm, proved 0.1 m of topsoil overlying 1.8 m of firm, pale brown, silty sand and coarse rounded gravel and some cobbles, resting on Aylesbeare Mudstone. By contrast, a borehole [0307 9489] near Ford Farm proved 0.4 m of topsoil on 2.1 m of soft, dark grey, silty clay, on Aylesbeare Mudstone.

The Alluvium bordering the streams that flow from Allercombe and March Green to Rockbeare consists of 0.2 to 1.2 m of clay and clayey sand resting on 0.15 to 0.7 m of gravel. A typical stream-bank section [0371 9454] near Tanner's Farm shows:

	Thickness (m)	Depth (m)
Alluvium		
Sand, reddish-brown, clayey, silty fine-to very fine-grained, with few pebbles	0.4	0.4
Clay, pale yellowish-grey, very silty with occasional pebbles; a line of pebbles occurs near the junction with the overlying unit	0.4	0.8
Gravel, mainly rounded pebbles and cobbles of metaquartzite	c 0.3	c 1.1
Aylesbeare Mudstone		
Clay, reddish-brown, very silty		

Farther upstream, a typical section [0444 9469] near Allercombe shows:

Clay, pale reddish-brown, very silty sandy, with some pockets of pebbles, passing down into	c 1.2	c 1.2
Gravel, metaquartzite and other pebbles and cobbles in a matrix of reddish-brown very clayey sand and silty sandy clay	up to 0.7	c 1.9

A section [0282 9429] in the alluvium of the stream that flows S of Rockbeare House shows 0.6 m of orange brown very clayey sandy silt upon 0.15 m of gravel. Further upstream, a good section [0355 9328] north of Westcott Lane shows the following strata:

	Thickness (m)	Depth (m)
Soil		
Loam, brown, clayey, with a few pebbles	0.15	0.15
Alluvium		
Sand, brown, clayey, silty, fine-grained, and clay, silty sandy, sparsely pebbly in places	c 0.50	c 0.65
Gravel of metaquartzite and other pebbles and cobbles, sharp junction on Aylesbeare Mudstone	0.40 to 0.50	1.05 to 1.15
Clay, reddish-brown, silty	0.4 seen	1.45 to 1.55

The Alluvium bordering the stream that flows through Aylesbeare and Perkin's Village is 20 to 30 m wide. It consists of 0.3 to 1.1 m of brown to reddish-brown, silty sandy clay and clayey silty sand, resting on 0.1 to 0.6 m of gravel. A stream bank section [0423 9182] near Aylesbeare shows:

	Thickness (m)	Depth (m)
Alluvium		
Clay, reddish-brown to yellowish-brown, silty, sandy	1.0	1.0
Gravel, pale yellowish-brown, with a matrix of sandy clay and clayey sand	0.6	1.6
Aylesbeare Mudstone		

	Thickness (m)	Depth (m)
Clay, reddish-brown, brecciated and fissured	0.6	2.2
Mudstone, reddish-brown, silty	0.3 seen	2.5

A section [0111 9268] farther downstream shows:

	Thickness (m)	Depth (m)
Alluvium		
Sand, reddish-brown, clayey, silty, fine-grained	0.6	0.6
Clay, reddish-brown, very sandy, and clayey, with a few pebbles	0.1	0.7
Gravel of metaquartzite and other cobbles and pebbles	0.3	1.0
Aylesbeare Mudstone		
Mudstone, reddish-brown, silty to very silty		

There are few sections in the Alluvium of the stream that flows through Farringdon. An exposure [0002 9139] S of New House Farm shows 0.6 m of reddish-brown stony clay resting on 0.3 m of gravel, resting on Aylesbeare Mudstone. A ditch section [0019 9000] in the Alluvium of the Grindle Brook in the SW corner of the Aylesbeare district consists of up to 0.4 m of brown clay and clayey silty sand resting on 0.6 m of cobble gravel.

5. HYDROGEOLOGY

Whether the Dawlish Sandstone persists at depth to form a clastic aquifer confined beneath the Aylesbeare Mudstone of the present district has yet to be proved. Boreholes [0022 9334 and 0035 9336] at Exeter Airport yielded 3.4 l/s (litres per second) and 1.05 l/s respectively, mainly from the Dawlish Sandstone. A nearby borehole [0020 9305], which penetrated 42.36 m of Dawlish Sandstone beneath 93.58 m of Aylesbeare Mudstone, yielded 12.7 l/s for a drawdown of 29.3 m after 6 days (Table 4). Cradock-Hartopp and others (1982) note that groundwater from the formation is generally of good quality; total hardness (predominantly carbonate) averages c 200 mg/l (milligrams per litre); chloride and sulphate concentrations are within the range 15 to 25 mg/l; and iron is rarely detected. Nitrate levels are locally high and were considered by Cradock-Hartopp and others (1982) to be likely to increase because catchment areas are intensively cultivated. Boreholes penetrating the Dawlish Sandstone need to be carefully designed to avoid silting up and clogging of pumps.

Several private boreholes and wells abstract groundwater from the Aylesbeare Mudstone. Yields are generally less than 1 l/s (Table 4), but higher yields occur where boreholes penetrate sandstones within the formation. Cradock-Hartopp and others (1982), commenting on the Aylesbeare Mudstone of south-west England as a whole, noted that chemical quality of water from the formation is very variable, with high total dissolved solids reflecting the presence of evaporitic layers; sulphate concentrations occasionally exceed 1000 mg/l. There are however, no analyses of chemical quality of Aylesbeare Mudstone groundwater from the present district.

The Budleigh Salterton Pebble Beds are part of the major Triassic aquifer of east Devon; they occupy only a very small part of the present district. Springs emerging from the base of the formation are held in shallow wells [0461 9072] at Mattocks for domestic supply, but most of the groundwater in the pebble beds flows eastwards and out of the district.

Borehole and date of sinking	Grid Reference	Depth (m)	Formation yielding water	Test Details					
				Yield (l/s)	Pumping time	Rest-level of water (RWL) below borehole top (m)	Depression below borehole top (m)	Draw-down (m)	Recovery time & depth (m)
Rockbeare House (1920)	0322 9401	70.1	Aylesbeare Mudstone	0.1	-	-	-	-	-
Glebe Farm Aylesbeare (1935)	0456 9129	37.8	Littleham Mudstone	0.23	2 hrs	4.6	22.9	18.3	7 hrs to 7.6
Lower Hawkerland Farm	0319 9050	47.4	Littleham Mudstone	1.0	2 hrs	22.9	22.6	0.3	-
Lower Southwood Farm (1937)	0224 9341	53.3	Aylesbeare Mudstone	0.4	2 hrs	2.1	8.5	6.4	2 hrs to RWL
Higher Southwood Farm (1947)	0216 9361	45.7	Aylesbeare Mudstone	0.33	2 hrs	2.7	14.0	11.3	-
Treasbeare Farm (1937)	0094 9436	51.8	Aylesbeare Mudstone	1.0	2 hrs	22.9	none	none	-
Farringdon (1946)	0179 9107	67.0	Exmouth Mudstone and Sandstone	2.15	24 hrs	9.7	13.4	3.7	10 mins to RWL
Marsh Green (1947)	0413 9356	36.6	Aylesbeare Mudstone	1.26	8 hrs	1.8	4.9	3.1	10 mins to RWL
White Cross Hotel (1944)	0241 9042	46.0	Littleham Mudstone/ Exmouth Mudstone and Sandstone	0.76		7.6	16.8	9.2	1 hour to RWL
Ford Farm, Rockbeare (1959)	0291 9472	38.1	Aylesbeare Mudstone	0.76	1 hr	1.8	-	-	-
Newlands, Higher Hawkerland (1959)	0460 9036	37.8	Littleham Mudstone	1.01	48 hrs	6.4	22.5	16.1	34 mins
Exeter Airport (1940)	0022 9334	45.7	Dawlish Sandstone	3.41	-	3.7	10.7	7.0	-
Exeter Airport (1943)	0020 9305	135.9	Aylesbeare Mudstone/ Dawlish Sandstone	12.7	6 days	20.7	50.0	29.3	6½ hrs to 32.4

Table 4. Details of selected water boreholes in the Aylesbeare district

6. ECONOMIC GEOLOGY

6.1 Soils

The soils of the Exeter region, including the Aylesbeare district, have been described by Clayden (1971). The main characteristics of the soils and their relationship to the geology of the district can be summarised as follows. The Dawlish Sandstone Formation gives rise to sandy loams and loamy sands (Bridgnorth soil series) that drain rapidly and allow cultivation for most of the year; despite low available water capacities and natural infertility these soils can be very productive under good management. They are included in class 2 of the land capability classification of Clayden (1971) - "land with minor limitations that reduce the choice of crops and interfere with cultivation".

Most of the outcrop of the Aylesbeare Mudstone is overlain either by Older Head or a ubiquitous thin clayey surface layer containing metaquartzite pebbles. This surface layer gives rise to imperfectly to poorly drained gleyed brown earths of the Whimple soil series, with smaller areas of the more strongly gleyed Brinsea soil series. The topmost horizons of the Whimple series are reddish-brown stony silt-loams or clay-loam, generally about 40 cm thick, overlying about 35 cm of stoneless silty clay which is redder and has nearly twice the clay content of the overlying horizons. This last horizon passes down into partially weathered Aylesbeare Mudstone. Whimple soils are used mainly for dairying from permanent grass. Clayden (1971) noted that the length of time during which they were waterlogged limited their suitability for arable crops. On soils influenced by sandier horizons in the Aylesbeare Mudstone, arable crops are more widely grown, a relationship shown on Figure 2. Brinsea series soils are distinguished from Whimple series soils by a brown or yellowish-brown horizon which is usually mottled. Clayden (1971) considered that Brinsea soils were related to the presence of thicker and coarser-textured Head thatn that on which Whimple soils formed; this relationship was not confirmed during the present geological survey. The Whimple series and Brinsea series are included by Clayden (1971) in class 3 of the land capability classification - "land with moderate limitations that restrict the choice of crops and/or demand careful management".

The Budleigh Salterton Pebble Beds gives rise to the Mercaston soil complex that occupies agricultural land on the Pebble Beds and includes stony loams and sandy loams on a stone-dominant horizon at 45 to 65 cm depth. The Kiddens series, described by Clayden (1971) as "a somewhat heterogeneous group of strongly gleyed soils in loamy and sometimes gravelly Head over a fine-textured substratum" was mapped by him overlying Littleham Mudstone N and NE of Livermores Farm [046 911], but the recent survey shows little Head in that area. The Mercaston Complex is included in land capability class 3, and the Kiddens series in class 4 ("land with moderately severe limitations that restrict the choice of crop and/or require very careful management").

6.2 Sand and gravel

The Dawlish Sandstone Formation and sandstone beds within the Aylesbeare Mudstone are potential sources of sand. A small outcrop area (c 0.2 km^2) of Dawlish Sandstone Formation is present in the NW corner of the district and is used as agricultural land; the remainder of the outcrop is mainly beneath Exeter Airport. Grading percentages of two samples collected from road cuttings near South Whimple Farm are given in Table 5.

Sands and weakly cemented sandstones in the Aylesbeare Mudstone were formerly worked in a pit [0211 9050] near Upham Farm; and another [0186 9150] near Farringdon. Most sand beds in the Aylesbeare Mudstone are thin, impersistent, and contain cemented horizons. The thickest sand beds are around and south of Upham Farm. Grading percentages of 7 samples of sand or weakly cemented sandstone from the Aylesbeare Mudstone are given in Table 5.

Gravels occur in the lower part of the Alluvium of the district, but have a high clay and silt content and are generally less than 1 m thick and of limited extent. The River Terrace Deposits near Rockbeare are between 1 and 2.3 m thick. They consist mainly of gravel, but have a high clay content.

Table 5

Grading percentages of sands from the Dawlish Sandstone Formation; and of sands in the Aylesbeare Mudstone

Sample location		Formation	Fines Less than $\frac{1}{16}$ mm	Fine Sand $\frac{1}{16}$ mm to $\frac{1}{4}$ mm	Medium Sand $\frac{1}{4}$ mm to 1 mm	Coarse sand 1 mm to 4 mm
National Grid Reference	Place (approximate)					
0156 9007*	Windmill Hill	Aylesbeare Mudstone	4.5	80.5	15.0	-
0166 9001*	" "	" "	2.7	27.3	70.0	-
0210 9051	Upham Farm	" "	1.6	30.4	68.0	-
0250 9140	Perkin's Village	" "	3.5	52.5	43.0	1.0
0385 9304	New Ford Farm	" "	2.5	70.5	27.0	-
0449 9422*	Little Upcott	" "	1.8	64.2	33.5	0.5
0457 9457*	Turkey Lane	" "	4.6	57.4	37.9	0.1
0004 9470	South Whimple Farm	Dawlish Sandstone	4.0	48.0	48.0	-
0001 9468	" " "	" "	4.3	52.7	42.9	0.1

* indicates a sample that was weakly cemented.

All samples are taken from weathered outcrops

6.3 Building Materials

The sandstones of the Aylesbeare Mudstone and the Dawlish Sandstone Formation are generally so weakly cemented that they have little value as building stone. The clays of the Aylesbeare Mudstone have probably been used as a component of cob (a mixture of clay and straw) used for constructing buildings, but serious use of cob as a building material ceased about 100 years ago.

The clays and mudstones of the Aylesbeare Mudstone have been used in the past for brickmaking (Ussher 1902, p. 45) but no pit is in use at the present day. The bricks were, as far as is known, of satisfactory quality and the formation remains a potential resource of brickclays. Former brickpits mentioned by Ussher (1902, p. 45) include those at White Cross [0233 9042 and 0247 9031]; they are reported by Brighouse (1981, p. 241) to have closed in 1890.

6.4 Marl

The outcrop of the Aylesbeare Mudstone is liberally dotted with shallow pits, commonly containing water, ranging from a few metres across to about 0.5 hectares in area. About 180 such pits are present in the map area. Most of the pits were probably opened to obtain calcareous clays to spread on the soils of the district which are consistently non-calcareous (Clayden 1971, p. 67). Two mudstone samples analysed for the present survey contain 7.4% and 12.6% of calcium carbonate, and thus are marly clay or marly mudstone in the classification of Pettijohn (1957, p. 410). Ussher (writing before 1913) noted that the practice of marling had been discontinued at that date.

6.5 Made ground

The most extensive area of made ground in the Aylesbeare district lies beneath Exeter Airport. Its thickness, nature and precise extent is uncertain; it probably consists mainly of building rubble. Most other made ground in the district occurs as infillings of marl-pits, many of which contain builders' rubble, and miscellaneous agricultural and domestic refuse.

6.6 Vanadiferous nodules

The results of analyses made on nodules collected during the present survey from localities [0331 9154 to 0335 9154] on the Aylesbeare Mudstone outcrop have not yet been reported. Similar nodules collected from the same stratigraphical level at Littleham Bay have abnormal concentrations of vanadium, uranium, copper and nickel.

6.7 Engineering Geology

Few geotechnical data are available for the Aylesbeare district. Site-investigation information is mainly confined to the area between Exeter Airport and Rockbeare. A total of 43 boreholes and trial pits were made (Low and Parsons Brown, 1973) and a number of standard soil tests were carried out on the samples obtained. These included measurements on selected samples of natural moisture content, natural bulk density, dry density, specific gravity, liquid and plastic limits where applicable, grain-size distributions, sulphate content, organic content and pH; quick undrained, direct shear and oedometer tests were also made. The oedometer tests were mostly carried out on weathered samples from depths shallower than 2 m. Their degree of over-consolidation cannot, therefore, be determined because they have undergone several cycles of wetting and drying.

The geotechnical properties and the predicted engineering behaviour of the principal formations can be summarised as follows. Standard penetration test (SPT) results in one borehole [0006 9451] that penetrated the Dawlish Sandstone gave N values >50 (mean of 5 tests was 65). Cuttings and quarry facies in the Dawlish Sandstone in the Exeter region have stood unsupported at high angles for many years. Old cuttings [SX 9920 9328] near Exeter Airport stand vertically, as do 10 m-high faces at Bishops Court Quarry [SX 964 914]. This relative stability is probably due to the partially cemented nature of the sandstone. Excavations below the water table might be expected to encounter running sand and supports and/or dewatering might be necessary.

The Aylesbeare Mudstone consists of reddish-brown, weakly calcareous, over-consolidated silty mudstone that weathers to a stiff silty

clay. Thin, impersistent beds of weakly cemented sandstone occur within it. The depths to which the engineering properties of the rocks are significantly affected by weathering varies considerably within the district. At most localities fresh mudstone is absent in the top 3 to 4 m below ground level, and in some sections in boreholes, the mudstones have been observed to be weathered down to 9 m below ground level. Steeply dipping joints have been recorded in boreholes in the formation and were noted during the construction of the M5 Motorway. Plots on a Casagrande plasticity chart for Aylesbeare Mudstone clays (Figure 3) show them to be of generally low to intermediate plasticity, although some samples plot in the high plasticity range. Moisture contents are usually less than the plastic limit so that the liquidity index ($LI = \frac{m-PL}{LL-PL}$) is usually negative. Natural slopes on the Aylesbeare Mudstone outcrop are generally less than 13°, and no evidence of land-slipping has been observed. Although cuttings with angles up to 45° have been constructed in the mudstones in the Exeter region, care is needed in their design, especially where the mustones are more deeply weathered and where they contain beds of water-bearing sand.

The Aylesbeare Mudstone should present few problems for light structures on gentle slopes. Site investigations in these situations could be limited to providing the depth to unweathered mudstones and to confirming the strength and settlement characteristics of the weathered mudstone. On slopes, the presence or absence of water-bearing sand beds should be proved, and their effects on the proposed works predicted.

Geotechnical data for the Quaternary deposits of the district are very limited and not necessarily comprehensive or representative. They are available for samples of clay from within the Older Head, River Terrace Deposits and Alluvium. Plasticity data, plotted in Figure 4, show the clays to be of low to intermediate plasticity. However, the borehole logs show the bulk of these deposits to consist of gravelly sandy clays, sands and gravels. Some samples contain $>$ 5% organic material; many of these samples are from very shallow depths ($<$1 m). Peaty silty clays may occur within the Alluvium or River Terrace Deposits. Sulphate contents of the soil samples are low, 0.01 to 0.05%.

SILT (M-SOIL), M, plots below A-line
CLAY, C, plots above A-line
} M and C may be combined as FINE SOIL, F.

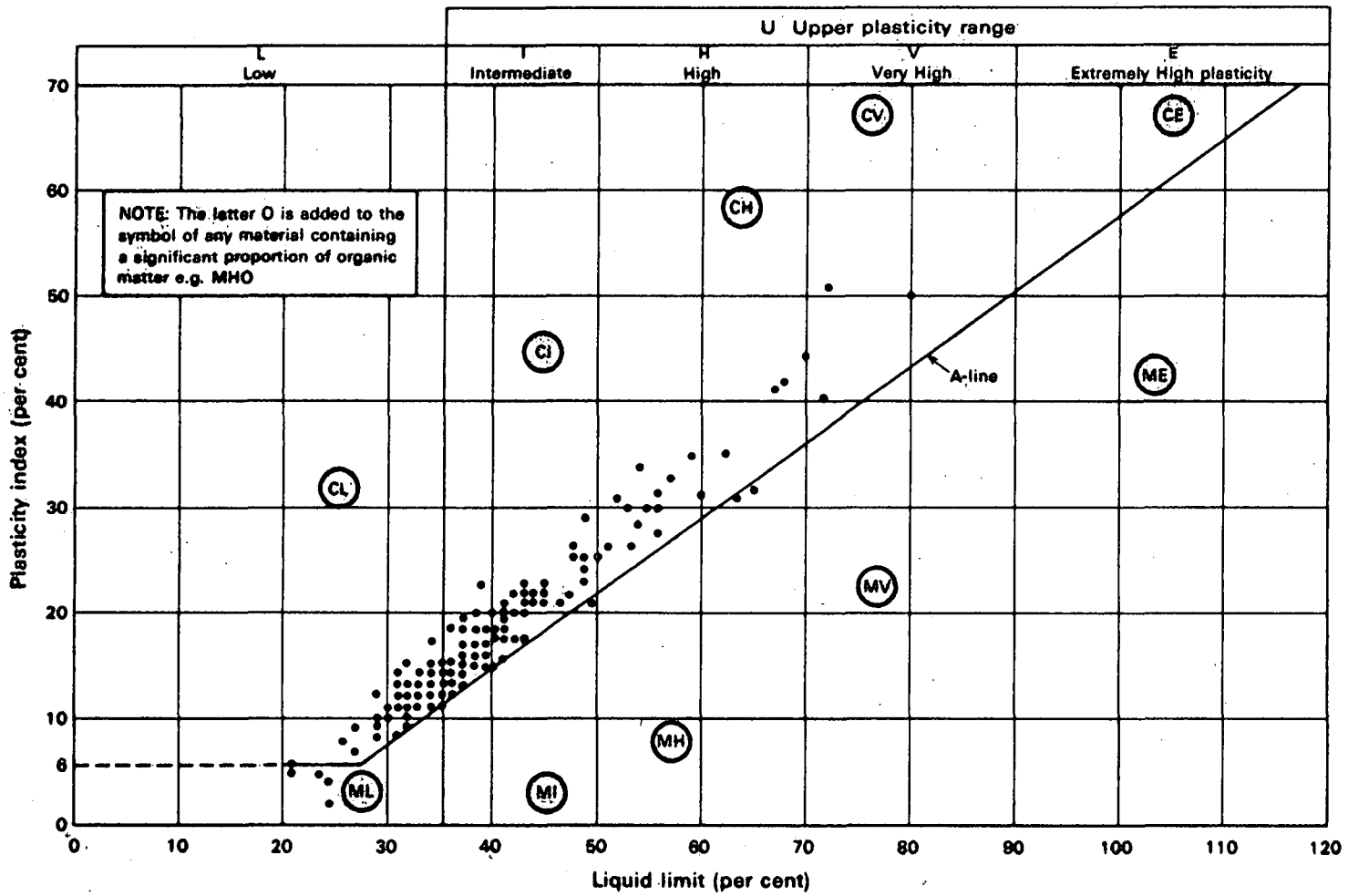

Figure 3. Plots of Aylesbeare Mudstone on a Casagrande plasticity chart (Data from Low and Parsons Brown, 1973).

SILT (M-SOIL), M, plots below A-line
CLAY, C, plots above A-line
} M and C may be combined as FINE SOIL, F.

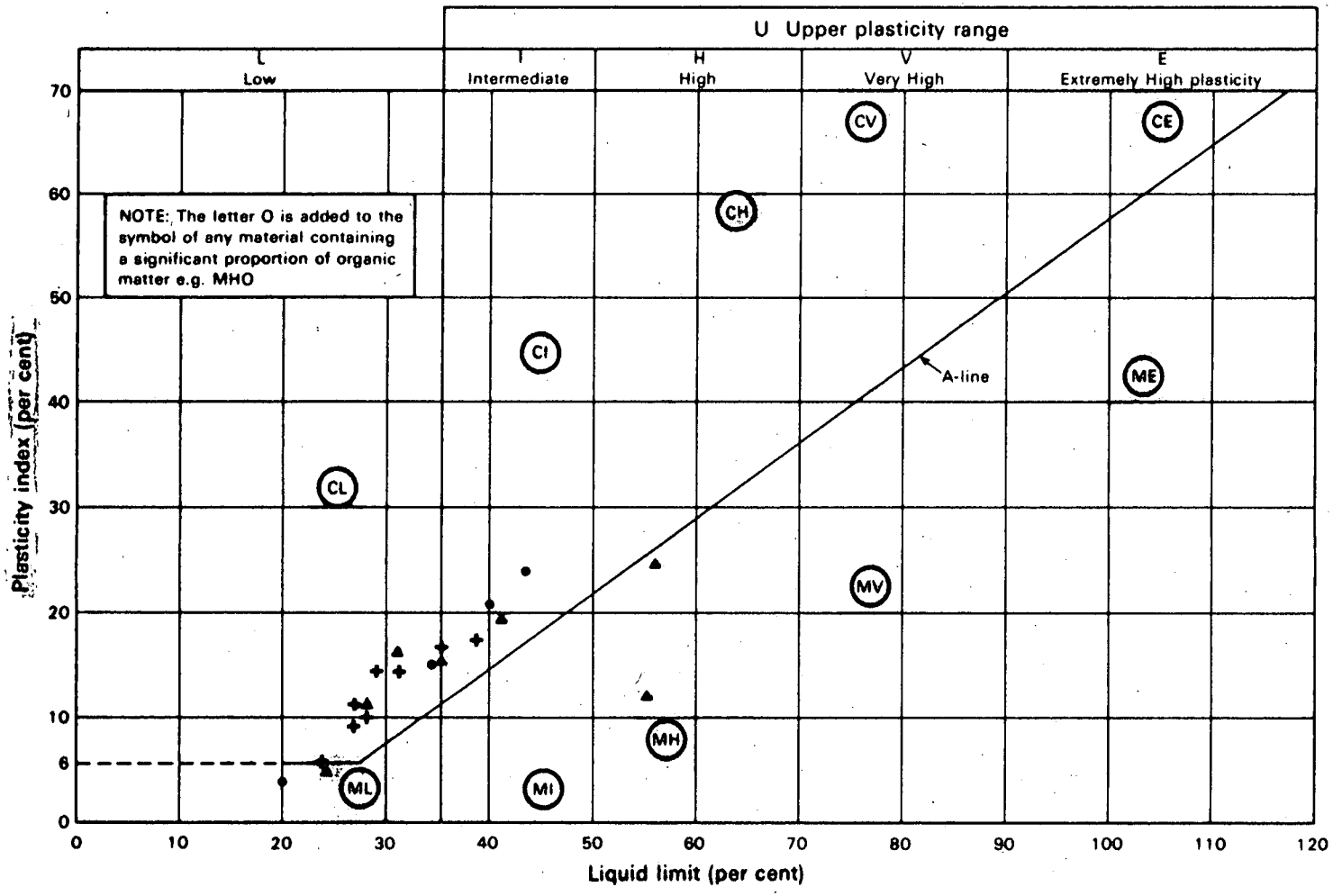

Figure 4. Plots of Older Head, River Terrace Deposits, and Alluvium on a Casagrande plasticity chart. Older Head samples are shown by dots; River Terrace Deposits samples by crosses; and Alluvium samples by triangles (Data from Low and Parsons Brown, 1973).

Site investigations in the Quaternary Deposits will generally need to be more elaborate than those in the solid deposits and will need to prove the nature, depth and variability of the deposits in relation to the structures proposed.

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APPENDIX

Logs of selected boreholes penetrating the Permian strata of the Aylesbeare district.

Borehole SY 09 SW/14 [0020 9305] Fair Oak Farm, near Exeter Airport. Water borehole, drilled by Duke & Ockenden Ltd for the Air Ministry, 1943. Surface level (estimated) + 29 m. Drillers' log (metricated and abbreviated).

	Thickness (m)	Depth (m)
Drift		
Sand and gravel	2.44	2.44
Aylesbeare Mudstone (undivided)		
Red rock and red marl interbedded in units 0.6 to 5.8 m thick	44.81	47.25
?Dawlish Sandstone Formation		
Red, grey and brown rock and sand, with 0.9 m of red sandy marl at 81.1 m	46.33	93.58
Dawlish Sandstone Formation		
Hard red sandstone and running sand with 0.6 m of brown marl at 135.3 m	42.36	135.94

Borehole SY 09 SW/22 [0179 9107], Farringdon. Water borehole, drilled by W Shepherd & Son, Exeter, 1946. Surface level (estimated) + 67 m OD. Drillers' log (metricated).

	Thickness (m)	Depth (m)
Top soil	1.22	1.22
Head?		
Clay and pebbles	1.22	2.44
Exmouth Mudstone and Sandstone		
Clay, sandy	6.09	8.53
Clay, sandy, with hard layers of red sandstone	15.84	24.38
Sandstone, fairly hard	2.44	26.82

	Thickness (m)	Depth (m)
Clay, sandy	7.31	34.14
Clay, sandy, with hard layers	8.53	42.67
Sandstone, fairly hard	6.09	48.77
Sandstone, hard	2.44	51.21
Sand, clayey	9.75	60.96

Borehole SY 09 SW/67 [0052 9454] site investigation borehole, drilled 1972 by Contract Drilling Ltd. Surface level + 31.55 m OD. Drillers' log.

	Thickness (m)	Depth (m)
Topsoil	0.60	0.60
Aylesbeare Mudstone		
Clay, stiff, brown, silty, with some fine sand	0.40	1.00
Clay, very stiff, red-brown, silty ...	2.80	3.80
Clay, very stiff, red-brown, silty with pockets and layers of grey-green silty fine sand	0.80	4.60
Clay, very stiff, fissured, red-brown, silty, with layers of weakly cemented red-brown sandstone	4.20	8.80
Clay, hard, friable, red-brown, silty, with some fine sand and traces of grey-green silty fine sand	6.55	15.35
Sand, red-brown, silty	0.35	15.70
Clay, hard, friable, red-brown, silty	1.15	16.85
Mudstone, weakly cemented, red-brown, silty	1.2	18.05

Borehole SY 09 SW/68 [0086 9467] site investigation borehole, drilled 1972 by Contract Drilling Ltd. Surface level + 43.10 m OD. Drillers' log.

	Thickness (m)	Depth (m)
Topsoil with gravel	0.40	0.40
Older Head		
Clay, very stiff, red-brown, silty, with some gravel and traces of carbonaceous material	2.50	2.90
Clay, stiff, red-brown, silty, with pockets and layers of yellow-brown sandy clay and traces of gravel	1.05	3.95
Aylesbeare Mudstone		
Clay, very stiff, red-brown, silty, with pockets and layers of grey-green silty fine sand, and grading to (below 7.0 m depth) hard friable red-brown silty clay with pockets and layers of grey-green silty fine sand and some layers of weakly cemented red-brown silty mudstone	8.05	12.00
Sandstone, weakly cemented, grey-green silty, fine-grained, with traces of black staining	0.55	12.55
Mudstone, weakly cemented, red-brown, silty	0.40	12.95
Clay, hard, red-brown, silty, with some fine sand	0.85	13.80
Mudstone, weakly cemented, red-brown, silty, with layers of red-brown silty clay and occasional pockets of grey-green silty fine sand	1.25	15.05
Clay, hard, red-brown, silty, with some fine sand	0.30	15.35
Mudstone, weakly cemented, red-brown, silty, with layers of red-brown silty clay and occasional pockets of grey-green silty fine sand	1.70	17.05
Sandstone, weakly cemented, grey-green, silty, fine-grained	0.30	17.35
Mudstone, weakly cemented, red-brown, silty	1.55	18.90
Sandstone, weakly cemented, grey-green, silty, fine-grained	0.30	19.20
Mudstone, weakly cemented, red-brown, silty	0.40	19.60