Natural Environment Research Council

BRITISH GEOLOGICAL SURVEY

PLANNING FOR DEVELOPMENT

Thematic Geology Maps Bridgend Area

A report produced under contract to the Department of the Environment on behalf of the Welsh Office

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With contributions by
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ABERYSTWYTH BRITISH GEOLOGICAL SURVEY 1985

ERRATA

4.1 Paragraph 1, line 6

For 'ST 066 862' read 'ST 066 864

4.1 Paragraph 3, line 14

For 'unknown' read 'also known'

5.5 line 4

For 'abandoned' read 'disused'

7.1 Paragraph 2, line 2

For 'north-east' read 'north-west'

MAP 6 Legend.

For ' Polish resistance values'
read 'Polished stone value'

For 'Abrasion resistance values'
read 'Aggregate abrasion value'

INTRODUCTION

This report summarises the work carried out during Phase 4 of a contract (PECD 7/1/004) commissioned by the Department of the Environment for the Welsh Office. The objectives of Phase 4 were to provide an up-to-date geological base in the form of thematic geology maps as a guide to planning for future development within the Bridgend and Llantrisant areas. It follows directly from a pilot study of the Bridgend area during Phase 1 (Fletcher, C. J. N., and others, 1982), which developed techniques and explored the potential of thematic geology maps for this area.

The requirement of the Welsh Office during Phase 4, was for the production of modern maps at 1:25 000 scale on a variety of geological themes as follows:

1) Bedrock Geology
2) Unconsolidated Deposits
3) Boreholes and Rockhead Contours
4) Mining Activities
5) Ground Conditions
6) Mineral Resources (Solid)
7) Mineral Resources (Drift)
8) Hydrogeology

The compilation of these thematic maps utilised data acquired during the recent geological survey of the Bridgend district (1:50 000 Geological Sheet 262), which comprised Phases 1 – 3 of the contract, together with material from the National Geoscience Database. Additional borehole and geotechnical data was supplied by County and District Authorities, and mineplans of the National Coal Board were consulted. This work was supplemented by a short drilling programme to ascertain the nature, thickness and engineering properties of the superficial deposits. Samples of both bedrock and superficial deposits were collected and subjected to additional laboratory testing to determine their mineral potential. Details of these tests are given in Appendix 2.

This series of thematic maps presents components of the existing geological data in simple cartographic form. The following sections describe in detail the data portrayed by each map and how it can be utilised. The maps are intended to be used only for preliminary studies and are no substitute for on-site investigation. The attention of the reader is drawn to the cautionary note and other explanatory text which accompanies each of the maps.

DESCRIPTION OF THEMATIC MAPS.

1. Bedrock Geology (Sheets 1 and 1A).

This map has been compiled from the component 1:10 000 and 1:10 560 sheets of the geological surveys of the Pontypridd, Newport, Bridgend and Cardiff districts, which were completed in the period 1954 to 1984. It is one of the basic geological maps, from which much of the thematic information is drawn. It presents, in a simplified form, the bedrock (solid) geology most likely to occur at the surface or beneath a cover of superficial (drift) deposits. It differs from the traditional geological map in that rocks are shown according to their dominant lithologies (limestone, sandstone etc.), rather than by adopting a local stratigraphic nomenclature. The division of rock types into geological systems has been made because their gross lithological characteristics differ between systems; for example, sandstones within the Upper Carboniferous are markedly different in physical properties from sandstones within the Devonian. A brief description of the main lithologies within each geological system is given in the legend on Sheet 1; details of thicknesses and correlations with the lithostratigraphic units on the Bridgend 1:50 000 Geological Sheet are shown in table 1. The accuracy of boundaries between lithologies is variable; broken lines indicate uncertainty. Faulted contacts, where they occur, produce discontinuities and/or thickness variations in the sequence. In terrain covered by superficial deposits, lines may be conjectural. Major areas of opencasting have been included on this map, since they affect the disposition of geological boundaries.

A simplified geological cross-section is given with each map. These are sections across the map, along the lines indicated, which show the disposition of the various rock types and their projection below surface level. They illustrate the inclination and relationships of the rocks below the surface and demonstrate the overall structure of the area.

The Bedrock Geology maps should be used in conjunction with the other thematic maps to assess the factors which may be influenced by bedrock characteristics, such as landslip potential, distribution of swallow holes etc. Although the engineering parameters of bedrock are beyond the scope of this map,it may be used as a general guide. Reference should be made to the current Code of Practice for Foundations (British Standard CP2004, 1972), which gives presumed load-bearing capacities for various types of unweathered rock. However, the map does not illustrate the depth of weathering or degree of fracturing and jointing, both of which are likely to reduce the bearing capacity of any rock, and are thus important in geotechnical studies.

2. Unconsolidated Deposits (Sheets 2 and 2A)

This is the traditional "drift" map, which shows the nature and distribution of the unconsolidated deposits at the surface; generally, they are 1 m or more thick. These subsoil deposits are distinguished by their mode of formation (e.g. Storm Beach Deposits), by the type of sediment (e.g. Peat) or by a combination of both (e.g. Glacial Silts and Clays). Made Ground and Landslips are also shown, since they constitute a special type of unconsolidated deposit or superficial structure. Opencast sites have been included in the map as they affect the disposition of the drift deposits and generally contain variable amounts of backfill. The map does not show the variation of the unconsolidated deposits with depth. Several different drift deposits may be encountered in boreholes before bedrock is reached. As far as possible, in the legend, the deposits are listed in order of increasing age, with the youngest at the top. Because the user is often more concerned with the nature of the subsoil rather than its origin or morphology, a brief description of the lithology of the deposits is given in the legend on Sheet 2.

The map of unconsolidated deposits is another basic source of thematic information and, like the Bedrock Geology map, may be studied by itself or in conjunction with others of the series; for example, when combined with the overlay of boreholes and rock-head contours the variation in drift thickness can be readily appreciated.

In addition to the compilation of the Unconsolidated

Deposits map, several of the drift deposits were investigated to determine a number of engineering parameters and to assess their mineral potential. The variability of the drift precluded any in-depth analysis of the engineering properties of individual deposits and ruled out the possibility of constructing a map along these lines. However, by comparing existing data with that gathered in the current investigation, it is possible to make some general comments about the engineering properties of the drift deposits.

2.1. *Engineering Properties of the Unconsolidated Deposits*
The range of materials encountered in the drift of the Bridgend and Llantrisant areas range from non-cohesive deposits such as Blown Sand, Beach Deposits and some sands and gravels, to cohesive deposits such as Glacial Silts and Clays and some Till (Boulder Clay). The degree of consolidation also varies, between normally consolidated deposits such as Alluvium, to overconsolidation in some of the glacial clays and tills. Organic deposits (Peat) are present and Made Ground, highly variable in character, occurs locally.

2.1.1. *Landslips* These are superficial structures which are formed by mass-movement processes and give rise to a variety of landforms; they occur in the Llantrisant area at [ST 020 864] and [ST 041 832]. The landslipped ground is likely to be unstable and sensitive to physical changes, for example, by undercutting the toe of the landslip during road construction. The characteristics of the landslips in the Llantrisant area are described in detail in section 5.

2.1.2. *Worked Ground (Opencast sites)* Worked ground, in the large opencast sites for coal and iron ore, is likely to be highly disturbed and also contains variable amounts of backfill. The numerous quarries and stone pits throughout the area also contain backfill, ranging from farm and household refuse to building and industrial waste; these materials are likely to be extremely variable in composition and properties. There are few Standard Penetration Test (S.P.T.) N values and values of Natural Moisture Content (N.M.C.) available, and these may not be meaningful. The opencast sites and major quarries are described fully in sections 4 and 5.

2.1.3. *Made Ground* Made Ground is a man-made deposit tipped onto a natural ground surface and is likely to be extremely variable in composition and properties. It ranges from domestic, to industrial and colliery waste, or as natural materials on sites which have been regraded and landscaped. Recorded S.P.T. tests gave N values of 7 and 11 on colliery waste with a N.M.C. of 20%, but these figures may also be misleading. Made Ground is described fully in section 5.

2.1.4. *Blown Sand* The Blown Sands are fine to medium grained, non-cohesive, loose to medium-dense quartz sands. Recorded S.P.T. N values range between 5 and 26, with N.M.C. values in the range 9% to 26%. There is probably a relationship between the values of S.P.T. and N.M.C. which reflects the degree of saturation and position of the contemporary water table. The Blown Sands are probably of medium to high compressibility, although there are no available records.

2.1.5. *Peat* Deposits mapped as peat also include those classified as highly organic alluvial clays; in general, the peat deposits are interbedded with alluvial silts and clays. Peat deposits are soft and highly compressible with low bulk densities. An S.P.T. N value of 7 was obtained from a highly organic silty clay encountered in a borehole (B.G.S. Record No. SS97NE/31; Appendix 1) drilled during the current contract. This deposit had a high plasticity, with a N.M.C. of 89% and a bulk density of 1.34–1.63 Mg/m^3. (Appendix 2).

2.1.6. *Alluvium* Alluvium is the deposit of present day river systems. It generally comprises normally consolidated, cohesive silts and soft laminated clays interbedded with non-cohesive, loose sands and gravels and locally contains peat intercalations. Recorded S.P.T. tests gave N values ranging between 14 and 47 (Figure 1) and N.M.C. values in the range 7% to 39%, with the majority between 10% and 30% (Figure 2). Plasticity indices, from recorded Atterberg Limits, suggest that alluvial silts and clays are generally of low to intermediate plasticity (Figure 3); they are probably of medium to high compressibility, although records of tests are not available.

2.1.7. *Alluvial Fan Deposits* These are generally cohesive, clayey, sandy gravels, which occur in the Llantrisant area at [024 827]. There are no records of their engineering properties.

2.1.8. *River Terrace Deposits* These are generally coarse, non-cohesive sands and gravels, locally with clay and silt intercalations. There are no records of their engineering properties, but they are likely to be similar in characteristics to the Glacial Sands and Gravels.

2.1.9. *Beach Deposits* Beach Deposits generally comprise non-cohesive sands with some gravels. There are no records of their engineering properties.

2.1.10. *Storm Beach Deposits* These are coarse, poorly sorted gravels, cobbles and boulders in elongate banks above high water mark. There are no records of their engineering properties.

2.1.11. *Head Deposits* Head Deposits are formed by downslope mass movement processes and accumulate against obstacles or in valley bottoms. They are heterogeneous deposits, whose composition reflects the nature of the parent material(s) upslope. Head Deposits range from normally consolidated, cohesive, silty and sandy clays with a variable stone content, to non-cohesive, poorly sorted sands and gravels. They vary from loose to medium dense, with recorded S.P.T. N values in the range 7 to 53. N.M.C. values range from 7% to 42% and recorded Atterberg Limits are indicative of materials of low to high plasticity (Figure 3). Head Deposits probably fall in the range of materials of medium to high compressibility.

2.1.12. *Glacial Sands and Gravels* Glacial Sands and Gravels form mounds and ridges in the Margam and Pyle areas, and occur as terrace-like deposits near Bridgend and Llantrisant. They are generally non-cohesive, medium to coarse, sands and gravels, locally with cobbles and boulders of sandstone; they have a variable clay content and often contain bands of laminated clays and till. The variation in recorded S.P.T. N values is plotted on Figure 1. The majority of gravels lie within the range of medium dense to dense; some of the higher values i.e. those above 50, probably reflect the presence of boulder obstructions within the gravels during testing. N.M.C. values lie within the range 8% to 42% (Figure 2); the higher values may be related to an increased clay content within the matrix of the gravels. Glacial Sands and Gravels are probably materials of medium compressibility, although no test results are available.

2.1.13. *Till (Boulder Clay)* The tills of the Bridgend and Llantrisant areas are heterogeneous glacial deposits comprising firm to stiff, poorly sorted, silty or sandy, gravelly clays and claybound gravels with many cobbles and boulders, dominantly of sandstone; they are generally structureless, but locally contain lenticular masses of gravel or laminated silt and clay. The tills are mainly firm to stiff and cohesive. They fall within the range of medium dense to dense materials; most of the recorded S.P.T. N values (Figure 1) lie within the range 10 to 50, with a slight maximum between 20 and 30. Recorded N.M.C. values range from 6% to 75% with a majority of readings in the range 10% to 30% (Figure 2). Most tills are of low to intermediate plasticity (Figure 3); they are probably of low to medium compressibility, although no test results are available.

2.1.14. *Glacial Silts and Clays* These are structureless or thinly laminated silts, clays and, locally, fine sands with scattered small pebbles and sporadic lenticles of fine gravel. Samples of these deposits, collected during the drilling programme, were tested for Bulk and Dry Density, Natural Moisture Content (N.M.C.), Atterberg Limits, and Consolidation tests; the results are given in Appendix 2. They are generally cohesive and range from firm to very stiff, although the silts are usually softer. Most of the samples tested were of low to intermediate plasticity (Figure 3), but recorded data gave a greater range of values; this variation is partly due to the problems in identifying Glacial Sands and Gravels from other materials in records of borehole logs. S.P.T. N values for the silts and clays (Figure 1) give a spread of readings between 5 and 136; the higher values may be due to poor penetration against pebbles or gravel lenses. N.M.C. values fall mainly in the range 10% to 20% (Figure 2). Test results (Appendix 2) show that the Glacial Silts and Clays are of low permeability and low to medium compressibility.

3. Boreholes and Rockhead Information (Sheets 3 and 3A)

This map shows the distribution of selected boreholes and heights of the solid/drift interface (rockhead) above Ordnance Datum. It has been compiled from data held in the B.G.S. 1:10 000 record system, together with data from the various local and service authorities, the National Coal Board and site investigation consultants. Boreholes drilled during the course of the contract are detailed in Appendix 1. Rockhead contours are indicated where there is sufficient data available; this is confined to the Ewenny and Ogmore valleys.

After collation of all the available borehole information, including engineering properties, the data was processed onto the Quaternary database coding forms as currently in use by the B.G.S. Geoscience Database Unit. These forms include details of lithologies, thicknesses and geotechnical properties. A separate file containing the grid references, heights above Ordnance Datum and the values of rockhead was also compiled. This file and the coding forms were then combined on the B.G.S. GEC 4000 computer, thus enabling the borehole sites, with the relevant data, e.g. drift thicknesses, engineering properties etc. to be plotted out at 1:25 000 scale.

From these plots boreholes were selected to give a representative and even coverage of the district. The most dense clusters occur along the M4 motorway, major roads and in population centres; for cartographic clarity some of these sites have not been included on the map. There are, in addition, numerous boreholes drilled by the NCB for potential opencast sites.

Rockhead contours can only be drawn with any degree of reliability, within the Ewenny and Ogmore valleys. These contours show that the valleys are broadly symmetrical, except to the immediate west of Pencoed, where a sharp gradient indicates steep slopes in the underlying rock surface, and between Aberkenfig and Bridgend, where the narrowing of the contours indicates a narrow "v"-shaped form to the rock surface.

4. Mining Activities (Sheets 4 and 4A)

This map shows areas that have been mined for coal, iron-ore and lead. It has been compiled mainly from mining records held by the National Coal Board and geological data from the British Geological Survey. The map defines the main areas of working for which records exist; these records however, may not be complete. The position of mineshafts and adits has been plotted, but these sites are approximate as different records often show more than one site for the same shaft; there are also likely to be other mineshafts and adits for which there are no records. Areas of old shallow and surface workings, mainly for coal, are shown on the map, though these are by no means complete; current and past sites of opencast working have also been plotted.

This map does not distinguish between the type (pillar and stall, longwall) or age of workings, nor does it give details of mine plans or any assessment of future reserves. Despite limitations due to the lack of recorded data, it affords an immediate visual appreciation of the extent to which the ground may have been undermined. The liability of such ground to subside due to mining is dependant on a number of factors such as age, depth and type of working, and no attempt has been made to show areas of potential subsidence; in any undermined area however, it is prudent to conduct a full site investigation before any development takes place.

The following sections give brief descriptions of the mining activities within the Bridgend and Llantrisant areas.

4.1. *Coal Mining*

Coal has been mined throughout the region from an early date, but certainly since the 16th century . The main expansion in coal mining occurred during the early 19th century and reached a peak in the early 20th century, since when it has slowly declined. Today only the Cwm-Coedely mine [ST 066 862] works coal in the north of the Llantrisant area, although coal is currently being extracted from opencast pits at Llanilid [SS 980 815] and Parkslip Extension [SS 870 840]; these sites and those of former opencast coal workings are shown on the map.

The areas outlined as shallow workings on the map includes both surface and shallow subsurface workings for coal, iron ore and lead; in practice, it is difficult to distinguish between old surface diggings and old bell pits which were sunk to shallow depths to work limited areas of coal around the shaft. The migration of collapse cavities to the surface in these areas produces "crown holes" which are also indistinguishable from the other features. These shallow and crop workings are generally the oldest mined areas in this part of the coalfield and, as a result, there are few existing records. They should be stabilised using appropriate remedial treatment.

The later workings are generally in the deeper parts of the coalfield, but here too there are large areas for which there are no existing records, even though mineshafts are known to be present. Most of the coal seams in these areas have been worked at various times. The common method of mining these seams was by "longwall" techniques. By this method, panels of coal were removed and the roof allowed to collapse, between roads which were permanently supported for access; subsidence was generally rapid and regular, with most settlement occurring within a few years, although roads could remain open much longer and may require stabilisation before any proposed development. Mining by "pillar and stall" (room and pillar etc.) techniques is unknown in this part of the coalfield. The predictable patterns of subsidence in old workings may be complicated by the area of overlap of workings at different depths and the presence of faults.

A more important problem to development is the presence of numerous old mineshafts and adits. The older shafts may not be sealed to current specifications and will generally require investigation. Portal zones of adits may remain supported long after the workings behind have collapsed, and may also require stabilisation.

4.2. *Ironstone and Iron Ore*

There is evidence that iron ore has been worked in South Wales since Roman times. The early iron industry was based on the ironstones within the Coal Measures. In the Bridgend area, these were exploited, from surface workings (patchworks), between Aberkenfig [SS 894 837] and Pont Rhyd-y-maen [SS 854 840], and from Cwm Ffos [SS 869 834] westwards towards Kenfig Hill [SS 840 831]; they were also mined at several localities, notably Bryndu Colliery [SS 835 838], Old Cefn Slip Colliery [SS 8487 8338] and, reputedly, at Brynnau Gwynion [SS 978 828], to the west of Llanharan. In the Llantrisant area, early surface workings for ironstone may be present around Llanharan and Pontyclun. There are few records of these ironstone workings and they have not been distinguished on the map.

With the development of mining techniques, the higher-grade hematite ores became accessible and mining of ironstones within the Coal Measures declined. The hematite ores extend in a narrow belt between Llanharry [SS 997 807] and Brofiskin [ST 070 819]. The earliest workings were from opencast sites at Mwyndy, Bute and Patch Cottages (Llanharry), which are known to have been active prior to 1859. Most of the deep mining (locally to depths of − 300 m O.D.) occurred during the 20th century, until operations finally ceased at Llanharry in 1976. The deep workings were generally stoped or worked by "pillar and stall" techniques, and were reached by a number of shafts and adits; at Mwyndy and Bute, adits to the deeper ore bodies extend from the floor of the opencast pits. There are, in addition, several trial shafts which failed to prove substantial ore bodies. The remarks concerning the stabilisation of mineshafts and adits within the Coal Measures also apply to those working iron ore. The subsidence associated with the iron ore workings at Llanharry is described in section 5.

4.3. *Lead Workings*

Lead (Galena) has been sporadically worked in the Vale of Glamorgan since Roman times until about 1880 (Lewis 1967). The most ambitious ventures were at Llangan [SS 9552 7720], where a shaft was sunk to 45 m, Penllyn Court [SS 9677 7688], where 141 tons of ore were produced between 1876 and 1878, and Pontyparc [ST 049 822], where 402 tons were produced between 1757 and 1760. Mines and surface workings for lead in the Bridgend area, during the 18th and 19th centuries, include those at Ogmore Down [SS 885 762], the Golden Mile [SS 942 767], Newton [SS 841 780], Coychurch [SS 940 797] and Merthr Mawr [SS 883 775]; in the Llantrisant area, workings are also recorded at Llwynmilwas [ST 068 822]. Mineshafts were sunk at several localities throughout the Vale of Glamorgan, but it is not known if these were trials or if lead was worked from them; at least one of these shafts, near Porthcawl [SS 8278 7940], appears to have been sunk for iron ore.

The galena occurs in narrow veins associated with calcite and barytes, along fault zones within the Carboniferous Limestone; it also occurs as stringers and pockets, or in a more disseminated form, in the Triassic and Jurassic conglomerates. The map shows the major lead veins along which former surface workings occur. There are no records of underground workings, but they may be inferred to exist from the tonnages extracted and the presence of mineshafts and adits; any underground workings probably do not extend far beyond the margins of the veins. The remarks concerning the stabilisation of mineshafts, adits and workings within the Coal Measures also applies to those sunk for lead.

5. **Ground Conditions (Sheets 5 and 5A)**

This map shows the known areas of disturbed, unstable and man-made ground, but excludes those undermined for coal, details of which are given in section 4.

5.1. *Landslips*

These are superficial structures, formed by downslope mass- movement, and are initiated when the strngth of the slope-forming materials is reduced, or the shear stresses acting upon them are increased to beyond a critical level. They form under a variety of natural or man-made processes and conditions which are summarised in a report on South Wales Coalfield landslips prepared by the British Geological Survey for D.O.E. (Conway, B. E., and others, 1980).

Two landslips have been recorded in the Llantrisant area at [ST 020 864] and [ST 041 835]. The former comprises a series of debris slides and flows in unconsolidated deposits on Upper Coal Measure sandstones and mudstones; it is now dormant, being degraded and vegetated. The latter site is a shallow translational debris slide in unconsolidated deposits on Upper Coal Measure sandstones; it is also dormant.

Landslips pose major problems to development, as any disturbance to their state of equilibrium could cause reactivation. The absence of landslips is no evidence that a slope is stable, since it may be in a near critical state; a comparison of local conditions with those of slipped areas may help to determine the susceptibility of a slope to failure. Landslips and areas of potential failure should be investigated thoroughly and appropriate stabilisation techniques undertaken before any proposed development.

5.2. *Backfilled Ground*
These are areas in which a man-made excavation has been wholly or partly replaced by fill; they differ from areas of Made Ground, where the tipped material rests on the original ground surface. The map shows only the major sites which have been or are currently being backfilled; these are the locations of disused or working opencast pits for coal and iron ore. In general, most of the quarries throughout the Bridgend and Llantrisant areas contain variable amounts of backfill.

Backfilled sites are often restored to their original ground level and regraded and, unless detailed site plans exist, it may be difficult to determine the limits of the excavation. Before any development is undertaken the extent and depth of the excavated site should be determined, together with the type and engineering properties of the fill material, and appropriate remedial treatment carried out where necessary.

5.3. *Tipped Material*
This material has many of the characteristics of backfill (composition, degree of consolidation etc.), but has been tipped onto the original ground surface. It generally forms well defined features such as colliery spoil heaps or rubbish tips, but is often unrecognisable when regraded and landscaped. In some cases it is impossible to distinguish between tipped material and backfill; in these instances the symbol for Made Ground has been used on the map. Variable thicknesses of tipped material cover much of the urban and undermined areas, particularily in the vicinity of mineshafts and adits. The smaller road and rail embankments are generally not distinguished as Made Ground on the map.

The general comments regarding development on backfilled material also apply to tips. On steep slopes, under certain conditions, tipped material may also be subject to downslope mass movement as debris slides or flows. Disturbance of old colliery spoil in particular, may lead to problems of spontaneous combustion.

5.4. *Subsidence*
The map shows those areas, excluding the coalfield, where features due to subsidence have been recorded, and has been compiled from maps and records held by the British Geological Survey, site investigation reports and published papers; the subsidence characteristics of the mined areas are described briefly in section 4. No attempt has been made to delineate areas of potential subsidence on the map.

The subsidence features outlined on the map are either natural or man-made. The following sections give brief descriptions of these features and their possible causes.

5.4.1. *M4 Motorway [SS 8410 8096] to [SS 8490 8104]* This feature is probably due to a number of coalescing natural collapse structures, which have disrupted bedding in the overlying Triassic sandstones and marls; collapse may be due to dissolution of the underlying Carboniferous Limestone or re-distribution of unconsolidated Triassic deposits within a system of swallow holes.

5.4.2. *Bridgend Town Centre [SS 905 798]* Shoring and butressing of some buildings has been recorded in this part of Bridgend and may be due to settlement of foundations on alluvium.

5.4.3. *Bridgend [SS 907 795]* This site is referred to as a "Great Pit" on fieldslips of the geological survey of 1898; no further information exists.

5.4.4. *Bridgend [SS 906 793]* This area of natural collapse was the subject of a paper by F. J. North (1952). It is thought to be due to dissolution of the Jurassic limestones, possibly along fault or major joint surfaces, beneath a thin cover of Glacial Sands and Gravels.

5.4.5. *Brackla Hill [SS 926 806], [SS 928 806] and [SS 927 800]* These are natural cavities in Jurassic limestones, and are locally recognisable by the presence of sinkholes and disturbed ground above the cavity system. They were first recognised in 1942 (see also North, F. J. 1952), and were the subject of a report in 1975 to Mid-Glamorgan County Council. It is possible that these cavities have migrated upward into the Jurassic rocks from the underlying Triassic limestones.

5.4.6. *Llanharry [ST 011 809] (and surrounding sites; see map)* These comprise a series of subsidence scars due to the mining of iron ore, together with several "crown holes", caused by the migration of cavities to the surface from the "pillar and stall" and stoped workings of the ore bodies.

5.5. *Major Quarries*
The map shows the location of the main quarries for limestone and sandstone in the Bridgend and Llantrisant areas. All the working quarries are shown, together with the largest of the abandoned ones; the choice of the latter is based on their size as gauged from current Ordnance Survey maps. It is not possible to assess the number of small quarries or stone pits within these areas.

5.6. *Swallow Holes*
Swallow holes are fissures or pipes ("chimneys"), formed by the dissolution of limestone by groundwater; they may be vertical or inclined and are often recognisable as "sinks", where streams disappear underground. In the Bridgend and Llantrisant areas, most of the recorded swallow holes occur on the Carboniferous Limestone, particularly along major fault zones, but there are a few localities where natural solution cavities occur in other rocks (section 5.4.). Some swallow holes may be recent features, but many are Triassic in age and are filled with loose, rubbly Triassic conglomeratic deposits; these are prone to settlement, particularily when groundwater is directed down the hole, and thus are potentially unstable.

6. **Mineral Resources [Solid] (Sheets 6 and 6A)**
This map shows the distribution of potential hard rock aggregates and mineral resources in the district, and has been compiled from the existing 1:10 000 and 1:10 560 geological maps. Recent assessments of the aggregate potential of the various lithologies have also been incorporated.

The boundaries of the deposits are clearly defined except where they are overlain by thick Mesozoic or superficial deposits. The broad thickness and lithological variations are detailed below for the various deposits, but an investigation of the existing borehole data and detailed site investigation would be required before an accurate assessment of the resource potential can be made.

Open holes and quarries within the resources are indicated, where known. The mineral deposits of lead and iron ore generally occur within the Carboniferous, Jurassic and Triassic rocks.

6.1. *Limestone Resources*
The area of potential limestone aggregate resources extends over a wide area from Cornelly in the west to Creigiau in the east, and includes most of the outcrop of the Lower Dinantian (Carboniferous) Limestones. The thickness variations of the individual units are shown in Figure 4. The upper oolite group cannot clearly be differentiated east of Miskin village though the limestones generally retain a high purity. Dolomitic impurities, by comparison, increase throughout the limestone succession to the east of Miskin, but rarely reach commerical grades (i.e. 20% MgO).

A summary of the chemical and mechanical properties of the limestone is shown in Table 2 . The reader is referred to recent reports (Harrison, D. J., 1983, 1984) for details of the individual units, production figures and other problems affecting the resource potential.

The marginal facies of the Jurassic have similar chemical and mechanical properties to the Carboniferous limestones and have also been included as a potential resource, but their heterogeneity has precluded any extensive exploitation in the past. The relatively impure Jurassic limestones at Aberthaw [0358 6720] have been improved as a cement grade resource by the addition of Carboniferous limestones; elsewhere the Jurassic limestones have been quarried locally for building stone.

6.2. *Sandstone Resources*
The sandstones of the Pennant (Upper) Measures, the Namurian and the Lower to Middle Coal Measures constitute the major resources of this rock in the district and have been sporadically quarried at various sites.

The degree of variation within the sandstones which can be recognised and accurately quantified at resource level, precludes any further subdivision of the geological formations into resource categories, but the following comments can be made. The Lower Coal Measure sandstones appear to comprise of two distinct lithological types; the finer grained sandstones are relatively strong and durable and form a resource of aggregate materials suitable for most constructional purposes. The coarser grained sandstones have high AIV values and hence are unsuitable for using as aggregate. The Pennant sandstones by analogy with the Caerphilly area can be expected to have high PSV values, moderate strengths and thus constitute a major resource, but properties and potential depend upon degree of weathering and amount of mudstone impurities in the succession.

The Rhaetic and Devonian sandstones are generally weak, with low abrasion values and variable porosities, and are unsuitable as aggregate. The Rhaetic sandstones were quarried in the past at Quarella (Bridgend) and at Pencoed as sources of silica sand and building stone.

The reader is referred to the marginal comment on the map and to a recent report by D. J. Harrison and others (1982) for further details on the properties of these rocks. A summary of the physical and mechanical properties is shown in Table 3.

6.3. *Coal Resources and Mineral Deposits*
The area indicated on the map includes the major grouping of coal seams in the Lower to Middle Coal Measures from the GARW to the No. 3 RHONDDA seams. Within this area the coals are relatively closely spaced and occur at, or near, the surface; they are structurally complex and are overlain by variable amounts of superficial deposits. The N.C.B. have extensively exploited the coals in these areas using both open cast and deep mining methods; details of production figures and borehole logs are confidential to the N.C.B.

Along the northern part of the district, above the No. 3 RHONDDA, numerous coal seams occur within the Upper Pennant Measures. In these areas opencast mining is not practicable due to the irregular topography and relatively wide spacing of the coals, and exploitation of the coal resources has been carried out using deep mining methods.

Details of the Coal Measure succession and the variation across the district are given in Figure 5 and further details can be found in B.G.S. memoirs and reports (Woodland and Evans, 1964; Smith, 1984a, 1984b). At present there are two active opencast sites at Llanilid [SS 980 815] and Park Slip [SS 870 840], and an active deep mine at Cwm-Coed Ely [ST 066 862].

Lead deposits occur as stringers and pockets with the Triassic and Jurassic marginal facies, and in vein material along major fault planes cutting the Carboniferous limestones. Iron ore (hematite) has been extensively mined at various localities between Llanharry and Brofiscin, the last workings having closed in 1976. The concentrations of the ore appear to occur along the Carboniferous/Namurian boundary, in areas where it is overlain by Triassic deposits. These concentrations take the form of sheets or irregular bodies of massive hematite, which commonly infill or replace hollows and fissures in the limestones. Several attempts to delineate the extent of the ore bodies have proved unsuccessful and it does not seem probable that there will be any future exploitation of these resources in the district.

7. **Mineral Resources [Unconsolidated Deposits] (Sheets 7 and 7A)**
This map shows the known distribution of sand and gravel and brick clays within 1m of the surface, and has been compiled from the existing 1:10 000 and 1:10 560 Geological Sheets for the area. There are areas where these materials are overlain by other superficial deposits, but it has not proved possible to delineate their extent. The areal extent and thicknesses, where proved in boreholes, are indicated; these parameters give a measure of volume per unit area for the resource. Due to problems of consistency between borehole logs, and the extreme variation in the percentage of boreholes penetrating the full drift thickness, no detailed estimate of the value or quantity of the potential resource can be made at this stage.

7.1. *Sand and Gravel*
The recent geological survey of the Bridgend district has proved sand and gravel deposits within the Ewenny, Ogmore and Ely valleys; these comprise glacial outwash sands and gravels and more recent river gravel deposits. Their position in relation to population centres and topography has largely precluded their exploitation. The early geological surveys indicated a large area of sand and

gravel extending from Pencoed to Pendoylan; this is now known to be erroneous and has been reinterpreted as boulder clay with a high content of Pennant sandstone fragments which weather to form a sandy matrix to the deposit.

The largest spread of sand and gravel (6 km^2), and the main area of potential resource, occurs in the north-east corner of Sheet 7A. Examples of grading curves obtained from this deposit are shown in Figure 6; a preliminary investigation suggests that this deposit has a high ratio of sand and gravels compared to clays and silts, but a more detailed study would have to be made before this deposit can be categorised. Further details, as proved in boreholes drilled during this contract, are listed in Appendix 1.

The sand and gravel deposits of the Llantrisant area (Sheet 7) have been the subject of an earlier preliminary report by C. James (1981). The likely distribution and thicknesses of the deposits were assessed using data contained in the B.G.S. 1:10 000 Record System. The report concluded that sand and gravel deposits are present within, and beneath, boulder clay, and hence their true extent cannot be conjectured with any degree of accuracy; also, although some 12 km^2 has been mapped, there are problems with identification, especially where the sands and gravels are associated with boulder clay.

No active sand and gravel workings are known in the district but the following abandoned sites were worked in the past, probably to supply a local demand only.

Map No.	*Location*	*GR*	*Deposit worked*
SS 87	Merthyr Mawr	844 771	River Terrace Gravels
ST 08	Brynsadler	c 029 812	Sandy Boulder Clay
ST 08	Pontyclun	031 817	Sandy Boulder Clay
ST 08	Castell-y-mwnws	021 806	Sandy Boulder Clay

7.2. *Brick and Pot Clay*

Lacustrine clays, suitable for brick and pot making have been worked in the past at Ewenny and Pencoed where they are closely associated with the Glacial Sand and Gravel deposits; at Pencoed [SS 9578 8203] they were worked for brick manufacture and at Ewenny [SS 9052 7780] as a pottery clay. Brick works also occur at Tondu and Bryncethin; these presumably worked the mudstones of the Lower Coal Measures. Minor amounts of silts and clays of unknown age, also occur south-west of Llanharry and commonly infill hollows in the rugged boulder clay country west of Llanilid. In addition, variable amounts of stiff laminated clays occur within the boulder clay deposits, but these are not thought to be extensive.

The deposits comprise dark grey to brown silts and clays with a variable stone content. The thicknesses and properties of these deposits, from boreholes drilled during the contract, are listed in Appendix 1.

8. **Hydrogeology**

This map defines the outcrop of the Carboniferous, Triassic and Jurassic rocks, which form the main aquifers within the Bridgend and Llantrisant areas. It shows the main springs, wells, boreholes and shafts for which hydrological data exists and gives the location of the major landfill sites.

The Carboniferous Limestone is the major aquifer of the district and, whilst the rock is generally impervious, the presence of joints and fissures, particularly in zones of faulting, may facilitate the flow of groundwater; the presence of swallow hole systems within the Carboniferous Limestone may also influence groundwater movement. Most of the Carboniferous Limestone outcrop is either drift-free or is overlain by thin, generally permeable drift. In such circumstances groundwater flow can be rapid and the retention time of groundwater (and contained pollutants) in the aquifer can be correspondingly short, measured in periods of days or possibly weeks. Where significant thicknesses of boulder clay are present or the Carboniferous Limestone is directly overlain by relatively impervious bedrock, the retention time will be increased appreciably. When overlain by other aquifers such as Triassic breccias, conglomerates or sandstones, the strata will be in hydraulic continuity.

The Coal Measures form a multi-layered aquifer, the groundwater being contained for the most part in fissures within the sandy horizons. The permeability of these beds is generally low (Ineson, 1967), but may locally be increased by fracturing and faulting. Coal mining operations have also had a significant effect by increasing drainage and so lowering the water table. Although the Coal Measures represent in theory a considerable groundwater resource, yields to individual boreholes are generally small. There would be some potential in mine drainage, since a mine acts as a collector well with a wide area of influence, but no mine discharges are known to take place within this district.

The potential of the Triassic rocks as a source of water is limited by their thickness (generally not more than 30 m) and composition; only the sandstones, breccias and conglomerates are likely to yield significant amounts of water and these are locally impersistent in outcrop.

The Jurassic limestones and shales form a multi-layered aquifer; each of the limestones comprises an individual aquifer unit, which probably has only limited continuity with other limestone beds in the sequence. The limestone and shale sequence higher in the Jurassic succession has an extensive outcrop from Bridgend to Llangan, amounting to approximately 20 km^2. Assuming a mean annual infiltration of 300 mm, the replenishment would be of the order of 6 million m^3/a. However, the presence of shales, interbedded with the limestones will restrict groundwater movement, and the formation is unlikely to be a useful aquifer other than for relatively small and local demands. Where the strata directly overlie the Carboniferous Limestone, the latter would offer greater potential for borehole construction.

Gravel deposits underlying the Alluvium of the major river valleys may prove to be useful aquifers although they have not been investigated as a source of supply. The map of boreholes and rockhead information gives contours showing the form of the Ewenny and Ogmore valleys, which suggests that they may represent a potential source of water. The problems of such a source, however, would be the probability of induced recharge from the adjacent river and the consequent change in groundwater quality.

Much of the water supply for the district is obtained from springs and boreholes located within the Bridgend and Llantrisant areas, with the balance being met from outside the district. The springs commonly occur in the limestone outcrop, either thrown by relatively impervious mudstones that are interbedded with the limestones, or where the ground surface intersects the water table. The major springs at Schwyll [SS 888 771], which have been further developed by a collector well, are licensed for 8.0 million m^3/a. and the total licensed amounts in 1983 were approximately 11.0 million cubic metres for public, private and industrial supplies. In addition, a licence for 13.6 million cubic metres per annum was in force for a disused iron mine at Llanharry [SS 999 806], although this source is no longer in use, mainly on account of the water quality. Groundwater was at one time taken from a borehole at Ffynnon Fawr [SS 823 780], which could yield between 500 and 700 m^3/d, but this source is also disused. Small private supplies from boreholes are licensed for the Crown Brewery site [ST 030 810] at Pontyclun (150000 m3/a) and Hendy Quarry [ST 053 811] (56000 m^3/a).

The potential effects of pollutants from landfill sites on groundwater supply should be recognised. Locations of known landfill waste disposal sites are plotted on maps 8 and 8a. Any extraction of groundwater should be monitored for contamination if pollution is suspected. Further information on the vulnerability of aquifers has been prepared by Monkhouse (1983).

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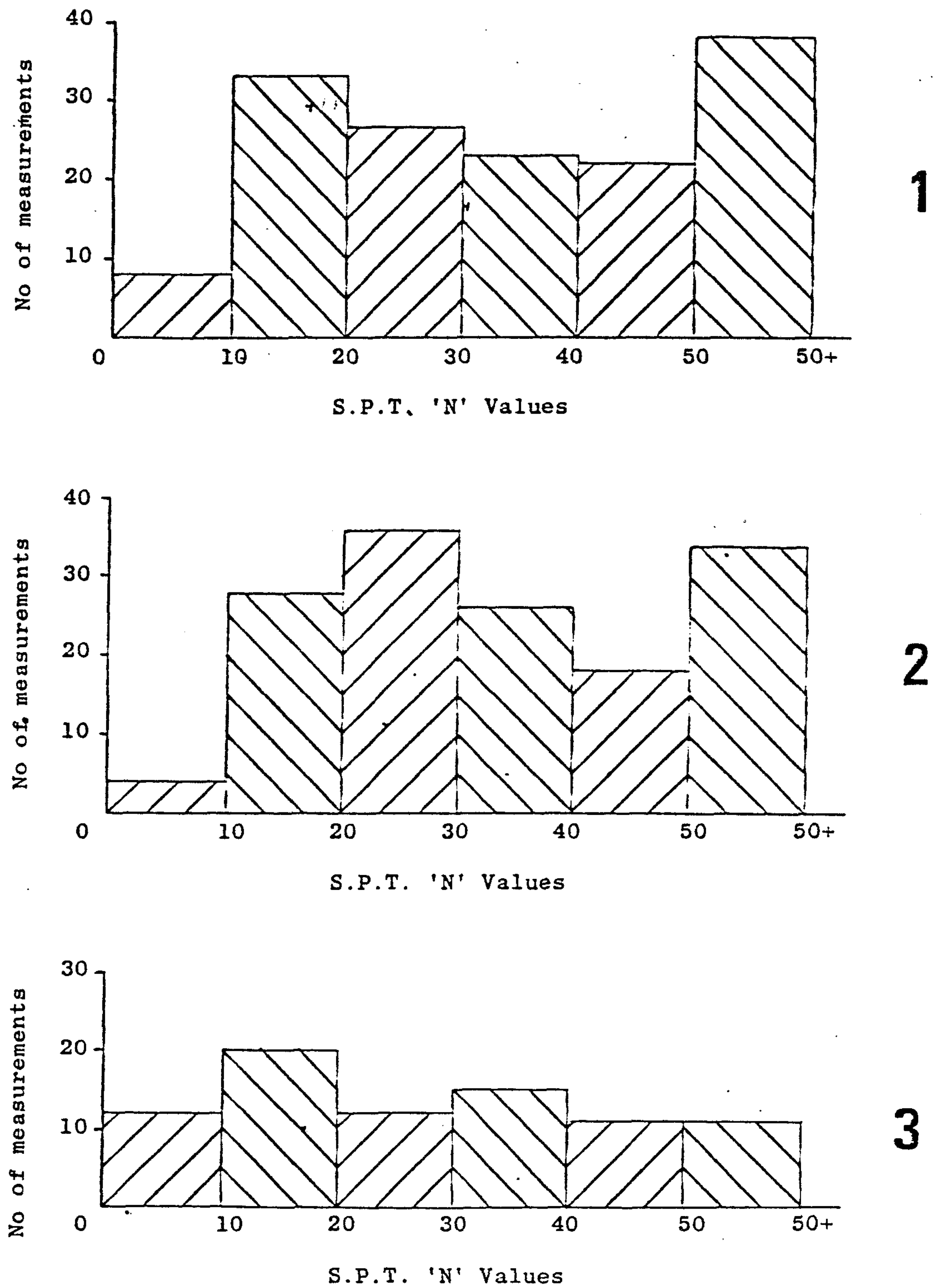


Fig 1 Frequency distribution of S.P.T. values for (1) Glacial Sands and Gravels, (2) Till (Boulder Clay) and (3) Glacial Silts and Clays

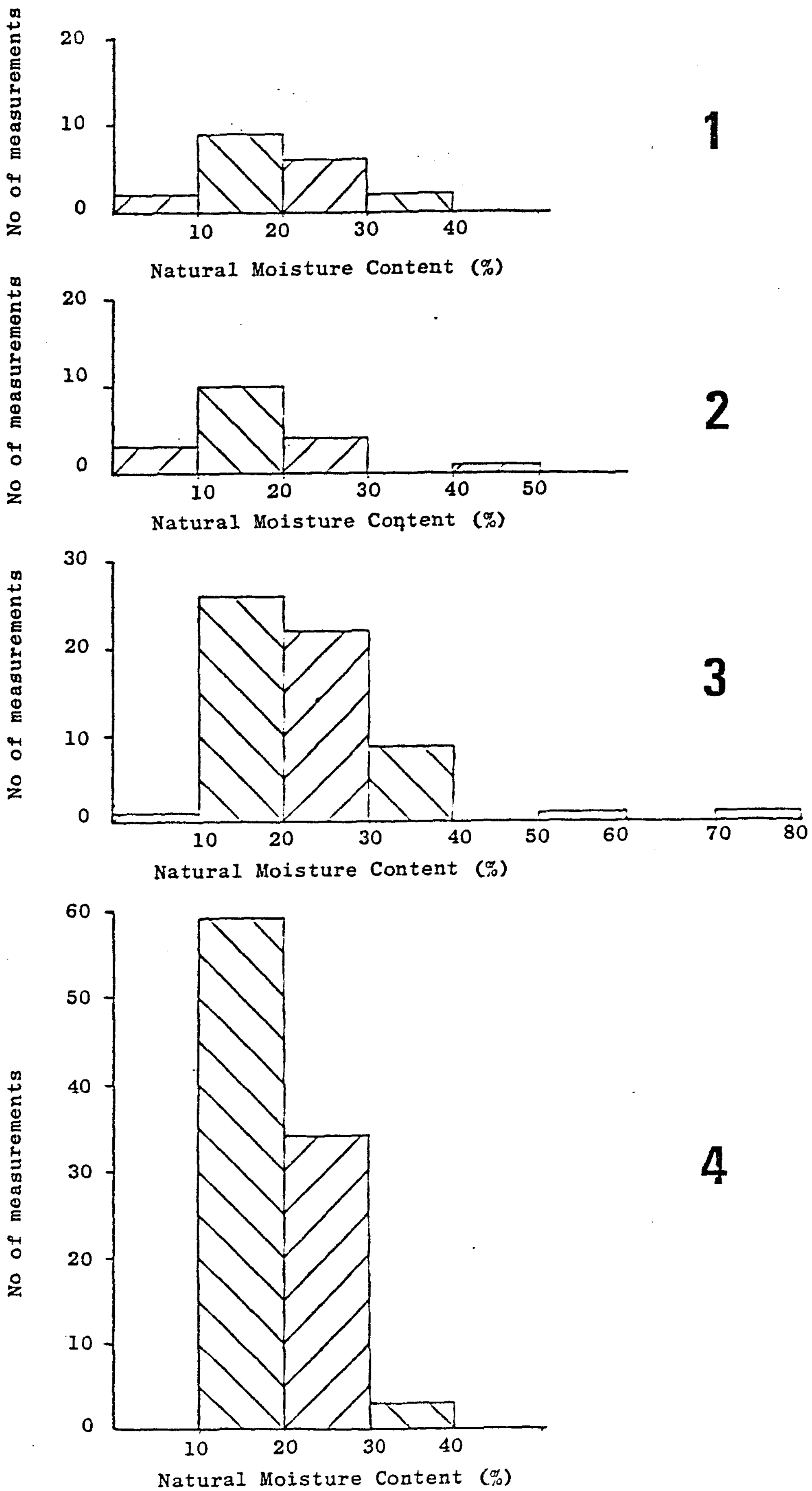


Fig 2 Frequency distribution of Natural Moisture Content values for (1) Alluvium, (2) Glacial Sands and Gravels, (3) Boulder Clay and (4) Glacial Silts and Clays

KEY	SOIL TYPE		PLASTICITY	
	M	silt	L	low
	C	clay	I	intermediate
	O	organic clay or silt	H	high
			V	very high
			E	extremely high

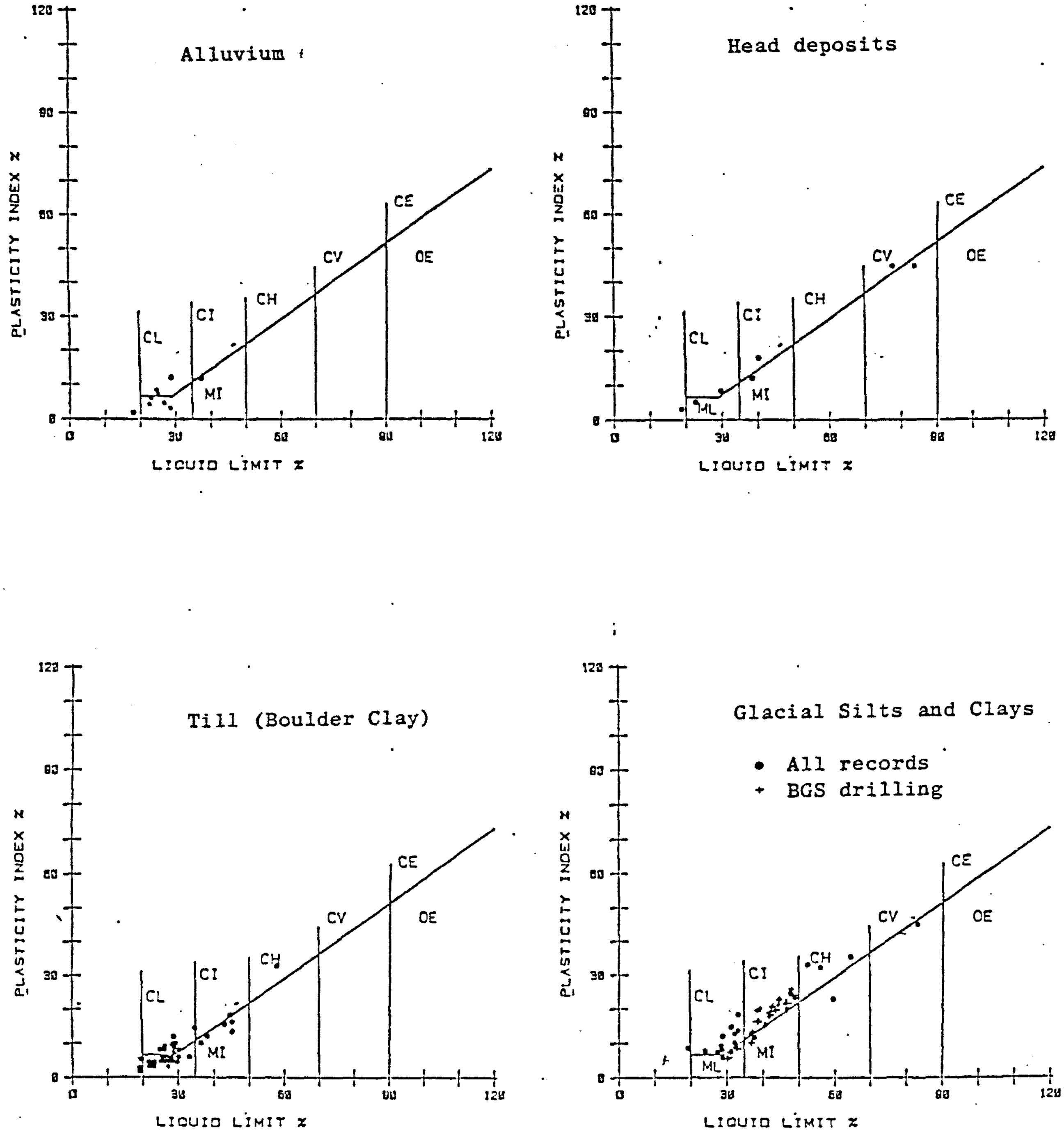
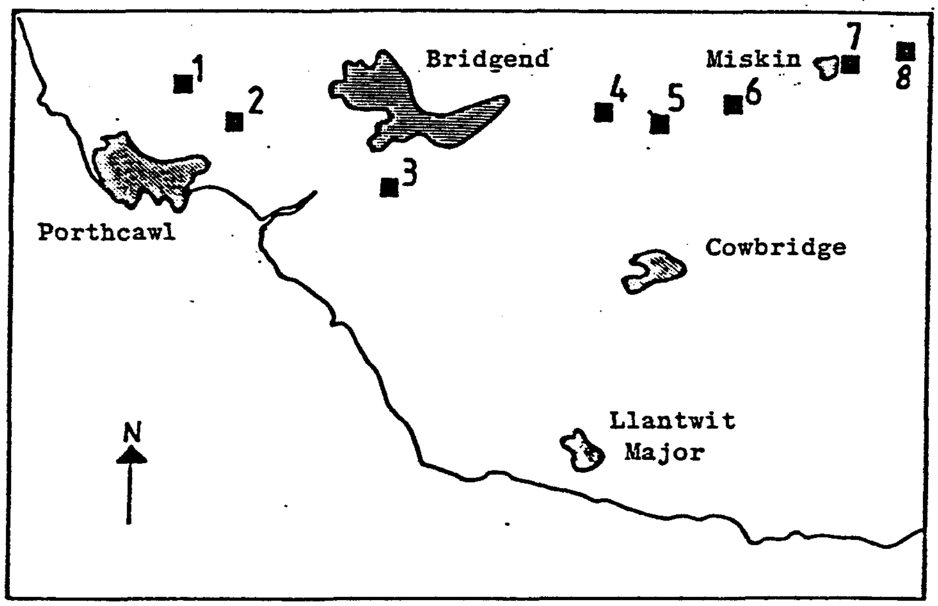
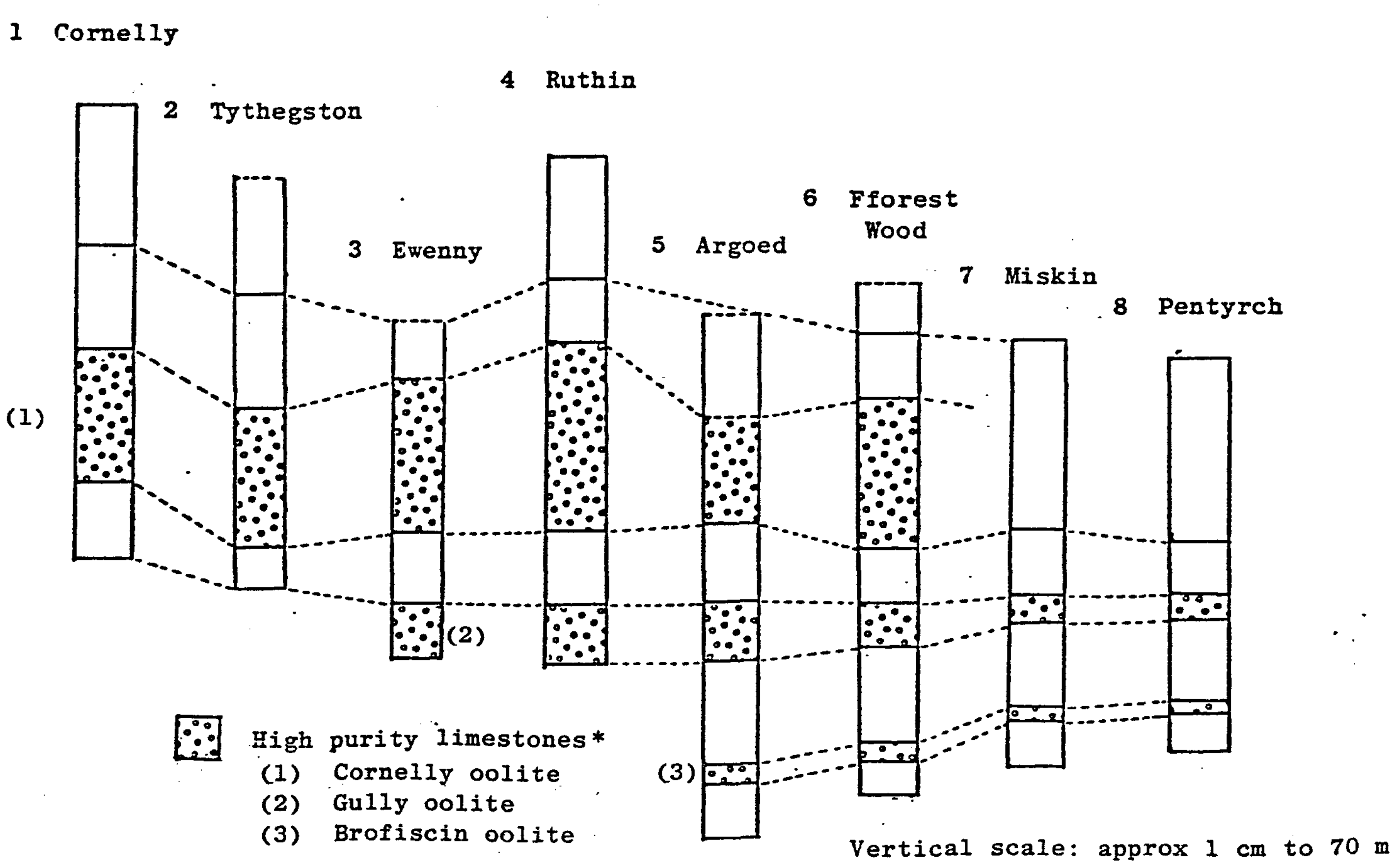


Fig 3 Plasticity charts for drift deposits

FIGURE 4 THICKNESS VARIATIONS IN THE LIMESTONE RESOURCES IN THE BRIDGEND DISTRICT





* See Table 1 for intervening lithologies

Fig. 5 Generalised Vertical Sections through Coal Measures

Scale: approx 1 cm to 50 m

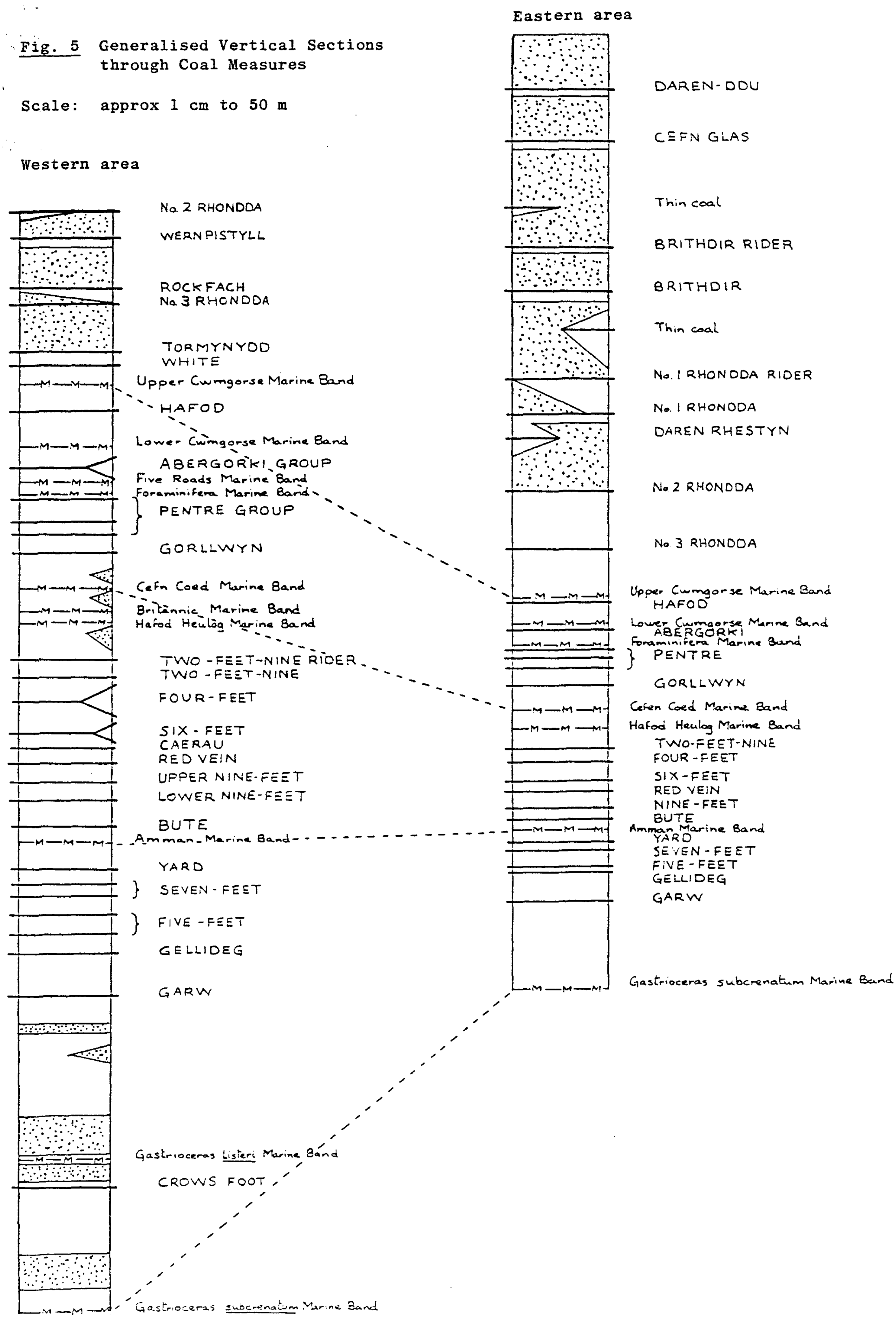
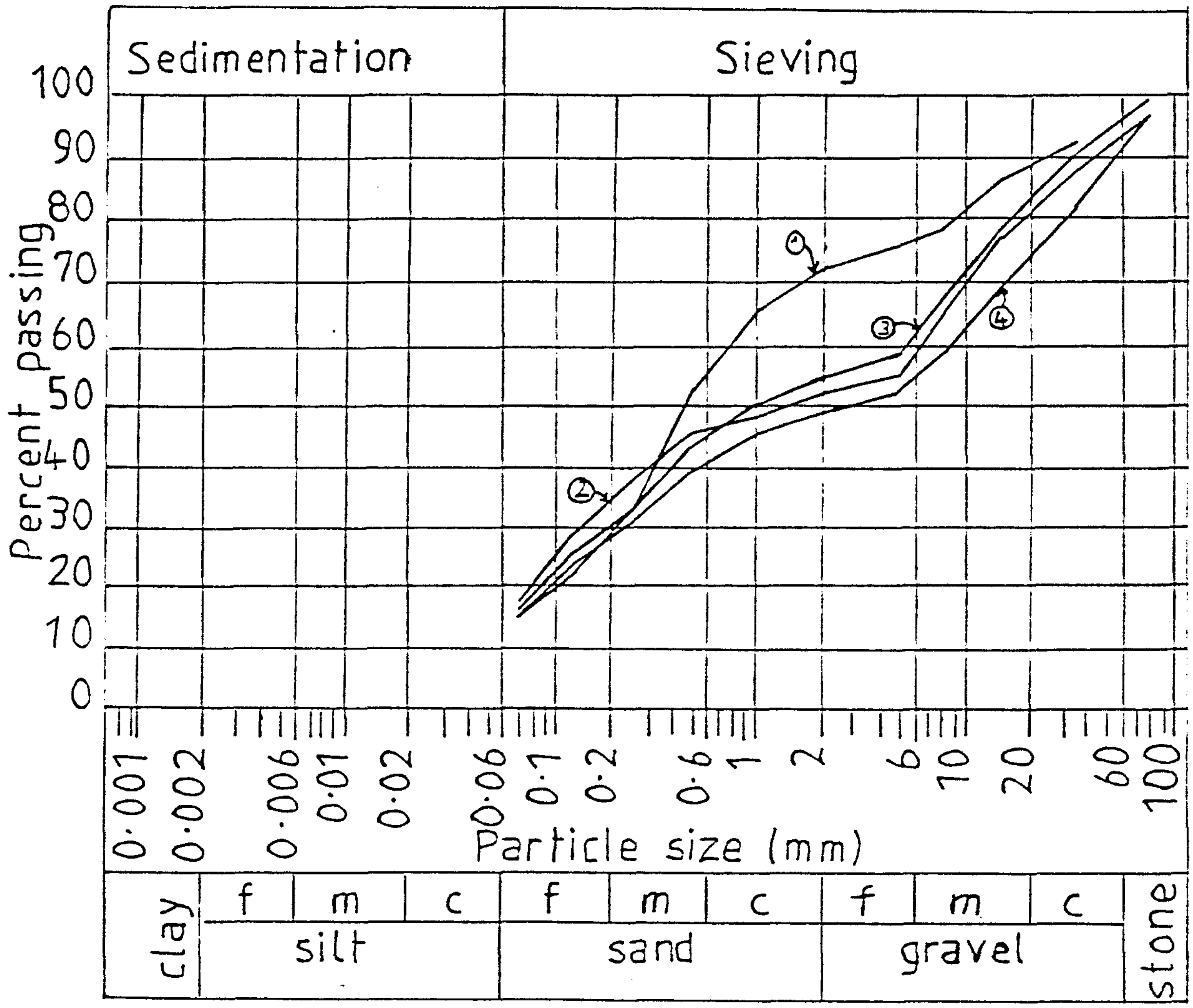


Figure 6 EXAMPLE OF GRADING CURVES FOR SAND AND GRAVEL DEPOSITS AT OLD PARK FARM (SS 8119 8477)



Depths below A.D.

1	2.80 - 3.25 m
2	6.40 - 6.80 m
3	11.00 - 11.30 m
4	16.40 - 16.70 m

TABLE 1. CLASSIFICATION OF GEOLOGICAL FORMATIONS IN THE BRIDGEND AND LLANTRISANT AREAS

	LITHOSTRATIGRAPHY*	THEMATIC MAP CLASSIFICATION	LITHOLOGICAL DESCRIPTION	THICKNESS (m)
JURASSIC	Porthkerry Formation	Jlsh	Fine-grained, flaggy impervious, porcellaneous limestones and interbedded dark grey shales extensive jointing	c. 130
	Lavernock Shales	Jsh	Dark grey, fissile impervious shales with occasional nodular limestones	12
	St. Mary's Well Bay Formation	Jlsh	As for Porthkerry Formation	16 - 20
	Marginal Facies	Jc	Coarse-grained, flaggy permeable calcarenite and oolitic limestones and conglomerates with thin interbedded shales	0 - 30+
TRIASSIC	Lilstock Formation	Tsh	Poorly bedded, flaggy buff shales and marls interbedded with thin limestones and siltstones, generally impermeable	8 - 20
	Westbury Formation	Tsh	Black fissile pyritous shales	
	Marginal Facies	Ts	Medium to coarse grained, well bedded, shelly, pebbly and silica-rich sandstones, permeable	5
	Mercia Mudstone Group	Tm	Red and green, mottled marls and mudstones impervious	0 - 85
	Marginal Facies	Tc	Coarse, rubbley, massive limestone chip conglomerates and breccias with impersistent bands of marl and sandstone	
CARBONIFEROUS	Upper Pennant Measures	UCs (mudstones within)	Massive, well bedded, micaceous, coarse-grained sandstones with interbedded mudstones and thin siltstones. Generally permeable	157+
	Lower Pennant Measures	UCs (mudstones within)	As for Upper Pennant Measures	200 - 595
	Middle Coal Measures	UCm (sandstones within)	Fine-grained, repetitive sequence of mudstones siltstones, coals and seatearths, well bedded, flaggy to fissile in nature	190 - 455
	Lower Coal Measures	UCm (sandstones within)	Interbedded with laterally impersistent sandstones. Disturbed by numerous faults and fractures. As for Middle Coal Measures	125 - 490
	Millstone Grit	UCm (sandstones within)	As for Middle Coal Measures	50 - 355
	Oystermouth Beds	LClsh	Interbedded black shales, siltstones and limestones, flaggy, impervious, highly disturbed by faulting	0 - 55
	Oxwich Head Limestone	LCl	Massive, medium to fine-grained shelly limestones with thin impersistent mudstone horizons strongly jointed	0 - 130
	Stormy Limestone	LCl	Massive, fine-grained shelly and micritic limestones	55 - 65
	Cornelly Oolite	LCl	Coarse-grained, granular oolitic limestones, generally massive	130 - 180
	High Tor Limestone	LCl	Medium to coarse-grained jointed limestone	55 - 115
	Caswell Bay Mudstone	LCl	Thin, impersistent, muddy limestones and mudstones; flaggy, impervious	0 - 15
	Gully Oolite	LCl	Coarse-grained, granular, massive oolitic limestones	30 - 70
	Friar's Point Limestone	LCl	Coarse-grained, fetid, shelly, massive limestone, locally dolomitic	85 - 260
	Brofiscin Oolite	LCl	Coarse-grained, granular, well bedded oolitic limestone, permeable	13 - 20
	Barry Harbour Limestone	LCl	Coarse-grained, flaggy, shelly limestones, locally dolomitic	35 - 80
	Cwmynyscoy Limestone	LClsh	Thin, flaggy, fine-grained limestones with shales, generally impermeable	45 - 50
	Castell Coch Limestone	LClsh	Red, coarse-grained, massive, well bedded, granular oolitic and calcarenitic limestone	15 - 20
	Tongwynlais Formation	LClsh	Interbedded, thin, flaggy, micritic limestones, shales and calcareous sandstones	35 - 45
DEVONIAN	Old Red Sandstone	ORS	Fine to medium, red brown micaceous sandstones and massive coarse conglomerates, permeable	90 - 250

* See open file reports for 1:10 000 Sheets SS 88, SS 98 and ST 08 for full details of lithostratigraphy and chronostratigraphy

TABLE 2 SUMMARY OF MECHANICAL, PHYSICAL AND CHEMICAL PROPERTY DATA OBTAINED FROM CARBONIFEROUS AND JURASSIC LIMESTONES. (After D.J. Harrison (1983))

FORMATION	ROCK TYPE	PURITY	FLAKINESS	AIV	AAV	PSV	DENSITY	WATER ADSORPTION
Jurassic, marginal facies	Porcellaneous, oolitic and lithoclastic limestone	Medium to high	24-40	19-25	7.6-10.8		2.69-2.73	0.5-1.2
Jurassic, normal facies	Interbedded limestones and shales	Low	34-49	15-24	6.1- 9.4		2.71-2.72	0.4-0.8
Oxwich Head Limestone	Thick bedded, pale grey, mottled limestone	Medium to high	27-32	19-22	9.4-11.2		2.67-2.70	0.1-0.4
Pant Mawr Sandstone	Fine-grained, laminated sandstone	Impure	36	24	3.7			
Stormy Limestone	Porcellaneous limestone	Medium to high	36-39	22-24	7.5- 8.6		2.66	0.1-0.4
Cornelly Oolite Limestone	Oolitic limestone	High	32-44	20-23	7.9- 8.2	44	2.69-2.71	0.2-0.8
High Tor Limestone	Thickly bedded, fine crinoidal limestone	Medium	31-44	18-22	6.9- 9.9		2.69-2.85	0.1-0.5
Gully Oolite	Oolitic limestone	High	30-37	18-23	7.7-10.1		2.70-2.74	0.1-0.5
Friar's Point Limestone	Crinoidal limestones and dolomites	Medium	25-36	17-21	6.1- 8.6	45	2.77-2.83	0.1-1.0
Brofiscin Oolite	Oolitic Limestone	High	31-39	23	7.7- 8.6		2.72	0.3
Barry Harbour Limestone	Dolomitic and crinoidal limestones	Low	30-50	17-23	6.2- 8.6		2.67	1.1

TABLE 3 SUMMARY OF MECHANICAL AND PHYSICAL PROPERTY DATA OBTAINED FROM SANDSTONES IN THE BRIDGEND DISTRICT. (After Harrison et al (1982))

LITHOLOGY	AIV	ACV	AAV	PSV	FLAKINESS	RELATIVE DENSITY	WATER ADSORPTION
Pennant Sandstones	22*	20*	8.1*	70*		2.65*	1.1*
Lower to Middle C.M. Sandstones (coarse)	38-53	36-29	7.5- 9.8		14-24	2.55-2.64	0.8-1.6
Lower to Middle C.M. Sandstones (fine)	21-24	13-19	6.2-12.9		19-26	2.64-2.92	1.3-1.6
Old Red Sandstone[1]	36		29.1	83		2.52	3.1

* Mean value

1 Data from report by Harrison et al (1982), samples taken from Risca area

Appendix 1

LIST AND GEOLOGICAL CLASSIFICATION OF BOREHOLES DRILLED DURING CONTRACT

APPENDIX 1

LIST AND GEOLOGICAL CLASSIFICATION OF BOREHOLES DRILLED DURING CONTRACT

(Numbers are those of the BGS 1:10 000 record system)

(figures preceded by + are levels in metres above Ordnance Datum)

SS 87 NE : 13 /8858 7719/

Surface level c + 5.0	Depth (m)
TOPSOIL	
Soil, yellow brown sandy silts	1.20
GLACIAL SANDS AND GRAVELS	
Coarse yellow brown sand and gravel with cobbles and pebbles of Pennant sandstone	
SPT at 3.2 - 3.6 m (34 blows)	
7.2 - 7.6 m (12 blows)	7.6
BOULDER CLAY (? TILL)	
Red-brown mottled stiff silty clay with occasional pebbles	8.1
SOLID	
Hard black fetid crinoidal limestones	8.15

SS 88 SW : 154 /8391 8194/

Surface level c + 150.0	
TOPSOIL	0.15
ALLUVIUM	
Orange brown and grey mottled silty clay with rounded pebbles passing down into	0.4
HEAD	
Dark reddish brown and grey mottled silty clay with pebbles	2.10
SPT at 1.20 - 1.65 (7 blows)	
GLACIAL SILTS AND CLAYS (LACUSTRINE ?)	
Dark brown to grey, fine clayey silts laminated occasional small rounded pebbles	4.15
SPT at 3.10 - 3.55 (8 blows)	
U4 at 2.50 - 2.95 (12 blows)	
3.10 - 3.55 (8 blows)	
3.95 - 4.40 (66 blows, hit obstruction)	
SOLID	
Coarse, poorly sorted angular sandy gravel with large cobbles of Lias-weathered bedrock	4.35

SS 88 SW : 155 /8119 8477/

Surface level c + 175.0

TOPSOIL	0.15
GLACIAL SANDS AND GRAVELS	
Brown fine-grained silty sand with occasional clayey laminae interbedded with coarse well-sorted gravels	6.00
SPT's at 1.40 - 1.85 (23 blows)	
2.80 - 3.25 (18 blows)	
4.90 - 5.35 (14 blows)	
BOULDER CLAY (? TILL)	
Dark brown poorly sorted coarse sand and gravels with sandy clay bound gravels and light brown clayey, silty sands	18.50
SPT's at 6.40 - 6.85 (18 blows)	
8.40 - 8.85 (34 blows)	
10.30 - 10.75 (23 blows)	
11.90 - 12.35 (41 blows)	
13.75 - 14.20 (27 blows)	
15.00 - 15.45 (40 blows)	
16.80 - 17.25 (51+ blows)	
18.40 - 18.85 (38 blows)	
GLACIAL SILTS AND CLAYS	
Dark brown, greyish pebbly clay and sandy clays with coal laminae structureless pebbly at base	19.10
BOULDER CLAY (? TILL)	
Dark brown to orange mottled pebbly clayey sand and gravel, poorly sorted	19.90
SPT at 19.80 - 20.25 (30 blows)	
GLACIAL SILTS AND CLAYS	
Light brown clayey silt, laminated with thin silty bands	20.15
BOULDER CLAY	
Dark brown clayey silts with abundant pebbles and large cobbles	23.1
SOLID	
Pale grey clayey silt with fragments of fine-grained mudstone (Westphalian B)	23.50

SS 97 NW : 109 /9030 7814/

Surface level c + 32.0

TOPSOIL	0.4
MADE GROUND	
Silty sandy	1.90

GLACIAL SAND AND GRAVEL

Light brown sand and gravel, locally clayey passing down into clayey sands and gravels — 5.60

SPT's at 2.90 - 3.35 (27 blows)
4.90 - 5.35 (21 blows)

GLACIAL SILTS AND CLAYS

Structureless reddish-brown to purple stiff clays slightly micaceous, passing down into variegated greenish grey laminated clays with thin silt layers, scattered pebbles, sharp base — 9.95

SPT's at 6.70 - 7.15 (29 blows)
8.80 - 9.25 (20 blows)
U4's at 6.10 - 6.55 (44 blows)
7.90 - 8.35 (60 blows)

SOLID

Limestone dark grey, fine-grained (Lias) — 10.00

SS 97 NW : 110 /9458 7913/

Surface level c + 17.0

TOPSOIL — 0.3

ALLUVIUM

Fine sand and silt with rootlets passing into soft grey clayey fine sand — 1.10

GLACIAL SAND AND GRAVEL

Brown and red mottled medium - coarse-grained sands with abundant Pennant sandstone pebbles
Sandy intercalations at 7.60 and 8.55 — 8.60

SPT's at 1.30 - 1.75 (18 blows)
4.50 - 4.95 (15 blows)
6.50 - 6.95 (53 blows)
8.00 - 8.45 (67 blows)

SOLID

Reddish brown stiff clays with scattered limestone nodules, locally silty
(weathered Lias) — 13.85

SPT's at 11.40 - 11.85 (20 blows)
13.40 - 13.85 (18 blows)
U4's at 8.65 - 9.10 (56 blows)
10.20 - 10.65 (40 blows)

SS 97 NE : 31 /9539 7990/

Surface level c + 20.0 m

TOPSOIL — 1.2

ALLUVIUM
Yellow brown mottled clayey sands with gravels 3.18
SPT's at 1.70 - 2.15 (11 blows)
2.40 - 2.85 (15 blows)

PEAT
Dark brown fetid with wood fragment passing down into silty and peaty clays with gravel lenticles 5.7
SPT's at 4.00 - 4.45 (7 blows)
3.40 - 3.85 (16 blows)
4.75 - 5.20 (14 blows)

GLACIAL SAND AND GRAVEL
Coarse poorly sorted gravels of Pennant sandstone 7.75
SPT at 6.05 - 6.45 (18 blows)

GLACIAL SILTS AND CLAYS
Smooth reddish brown clays 7.90

GLACIAL SAND AND GRAVEL
Fine to medium grained gravels 8.40

SOLID
Triassic conglomerate 8.45

SS 98 SE : 152 /9580 8216/

Surface level c + 38.0 m

MADE GROUND
Clay and stone fill 1.30

GLACIAL SILTS AND CLAYS
Dark reddish brown, locally mottled silty stiff laminated clays with scattered sandy laminae at 3.50, 4.05 and 9.60
silty at base
borehole terminated at 17.00
SPT's at 2.20 - 2.65 (10 blows)
4.20 - 4.65 (11 blows)
5.80 - 6.25 (25 blows)
7.40 - 7.85 (10 blows)
9.30 - 9.75 (78 blows)
11.20 - 11.65 (10 blows)
13.00 - 13.45 (27 blows)
U4's at 1.60 - 2.05 (19 blows)
3.60 - 4.05 (34 blows)
5.20 - 5.65 (42 blows)
6.80 - 7.25 (50 blows)
8.70 - 9.15 (60 blows)

ST 08 SW : 177 /0344 8191/

Surface level c + 40.0 m

TOPSOIL	0.9
ALLUVIUM	
Yellow brown and grey mottled clayey sand and silt	1.1
GLACIAL SAND AND GRAVEL	
Coarse sands and gravels with abundant Pennant Sandstone pebbles	7.75
SPT's at 2.30 - 2.75 (46 blows)	
4.00 - 4.45 (34 blows)	
5.40 - 5.85 (43 blows)	
7.00 - 7.45 (13 blows)	
GLACIAL SILTS AND CLAYS	
Dark brownish grey smooth silty, micaceous clays, laminated with sandy layers at base	11.35
SPT's at 8.60 - 9.05 (12 blows)	
10.20 - 10.65 (10 blows)	
U4's at 8.00 - 8.45 (36 blows)	
9.55 - 10.00 (37 blows)	
11.20 - 11.65 (88 blows - aborted)	
BOULDER CLAY	
Coarse poorly sorted gravels with stiff sandy clays	17.60
SPT's at 11.85 - 12.30 (12 blows)	
13.20 - 13.65 (34 blows)	
SOLID	
Dark brownish grey silty mudstone	17.65

ST 08 SW : 178 /0414 8242/

Surface level c + 48.0 m

TOPSOIL	0.4
ALLUVIUM	
Grey and orange brown mottled silts	0.65
GLACIAL SAND AND GRAVEL	
Coarse Pennant gravels with clayey sands and fragments of coal measure mudstones	9.00
SPT's at 3.35 - 3.80 (16 blows)	
5.45 - 5.90 (15 blows)	
7.30 - 7.75 (23 blows)	
GLACIAL SILTS AND CLAYS	
Dark brownish grey clay with thin laminae of sand and scattered pebbles	15.00
U4's at 9.30 - 9.75 (59 blows)	
11.00 - 11.45 (32 blows)	
13.40 - 13.85 (33 blows)	

BOULDER CLAY	
Reddish brown clayey silts and sand with angular cobbles and pebbles of sandstone	17.60
SPT's at 15.95 - 16.40 (45 blows)	
17.25 - 17.70 (60+ blows - aborted)	
SOLID	
Reddish yellow marls (Triassic)	17.65

Appendix 2

GEOTECHNICAL TESTING ON SOILS FROM THE BRIDGEND AREA FOR THE BRIDGEND THEMATIC INFORMATION MAPS (SHEET 262)

D. C. Entwistle

CONTENTS

APPENDICES

BRIDGEND ENVIRONMENTAL GEOLOGY MAP:

Geotechnical tests on U4 samples from eight boreholes.

1 Introduction

Nineteen U4 samples were sent to Engineering Geology during October 1984. Various Geotechnical tests were carried out on seventeen of them. The tests were; natural moisture content, liquid limit, plastic limit, bulk and dry density, laboratory shear vane and two consolidation tests on selected samples. The tests were done during December 1984 and January 1985.

The tests performed according to BS1377 (1975) are listed below;

Tests	Methods	
Moisture content	Test 1A	
Liquid Limit	Test 2A	NOTE 2
Plastic Limit	Test 3	NOTE 1

2 Bulk and Dry Density and Moisture Content

Method

After the U4s had been opened, extruded and split (for description when necessary) a density ring of known weight and volume was pressed into the sample. With the aid of a knife, to remove the excess, the density ring was filled. This was then placed into a tin of known weight. The density ring, plus sample plus tin was then weighed and placed into an oven at $105^{\circ}-110^{\circ}$ C. After 24 hours the ring, sample and tin were left to cool for 2 hours in a dessicator. They were then reweighed.

Results

$$\text{Natural Moisture Content} = \frac{W_3}{W_2} \times 100\%$$

$$\text{Bulk Density } \gamma_b = \frac{W_1}{V} \ \text{Mg/m}^3$$

$$\text{Dry Density } \gamma_d = \frac{W_2}{V} \ \text{Mg/m}^3$$

W_1 = Sample weight wet g

W_2 = Sample weight dry g

$W_3 = W_1 - W_2$. g

V = Volume of ring. cm^3

3 Atterberg Limits

The Atterberg limits are based on the concept that a fine-grained soil can exist in one of four states dependent on its water content. Thus a soil is solid when dry, and upon the addition of water proceeds through semi-solid, plastic and finally liquid states. The water content of the boundaries between adjacent states are termed the shrinkage limit, plastic limit and liquid limit.

In this case the plastic limit and liquid limit were investigated. The plastic limit is defined as the minimum water content at which soil can be deformed plastically, ie the minimum content at which a soil can be rolled into a thread 3 mm thick. The liquid limit is the minimum water content at which a soil will flow under a specified small disturbing force. This force is defined by the conditions of the test. The core penetrometer was employed for this test.

Test Methods

The methods used were those set down in BS1377 (1975). Test 3 (plastic limit) and Test 2 (liquid limit). The soil at natural moisture content was used and medium sand and larger particles were removed by hand. The liquid limit test was done using three or four points.

Some samples were not cohesive and/or too sandy (not containing enough fine matter) and hence there was no result.

Derived from liquid limit and plastic limit results are the Plasticity Index (PI) and with natural moisture content the Liquidity Index (LI).

Plasticity Index (PI) = Liquid limit - Plastic limit.

$$\text{Liquidity Index (LI)} = \frac{\text{Natural Moisture Content - Plastic Limit}}{\text{Plasticity Index}}$$

The plasticity index (generally 0-540) is used for classifying the sample and with some empirical formulae.

The liquidity index indicates which state the sample is in in the ground. If there is a negative result then the material is drier than the plastic limit and will tend to be stiff or hard. If there is a positive result then the material is at a greater moisture content than the plastic limit and will tend to be soft.

4 Consolidation Tests

The method used was that set down in BS1377 (1975) 5.2 Test 17. A static head oedometer was used with a 75 mm diameter by 20 mm high sample.

The Engineering Geology Research Group swell test apparatus was used to find the swell pressure of the sample from BH 7 and an oedometer was used for the swell pressure of BH 13.

The pressure used where:

Borehole	Depth M	Load Increment	Stress kPa
7	8.25	O	Swell Pressure
		1	122
		2	222
		3	444
		4	888
		5	111
13	8.80	O	Swell Pressure
		1	111
		2	222
		3	444
		4	888
		5	111

The time displacement graphs were drawn on semi-log paper and so the t_{50} was used for calculating M_v and C_v (The Casagrande method).

Results

Voids ratio e = the ratio of voids to material

Initial voids ratio $e_o = \frac{S_g}{\gamma_d} - 1$

When S_g = Specific gravity

γ_d = Dry density of the sample used for the consolidation test

M_v is the modulus of volume change or the coefficient of compressibility and is used to estimate the magnitude of settlement.

$$M_v = \frac{1}{1 + e_1} \times \frac{de}{dp}$$

where e_1 = the voids ratio after the previous load

de = the change in voids ratio from the end of the previous effective stress to the end of the present one

dp = the change in effective stress from the previous load to the present one

Values are given for each pressure. The units are m^2/MN. The rate of consolidation is given by C_v, the coefficient of consolidation. When using the Casagrande method

$$C_v = \frac{0.026\ \bar{H}^2}{t_{50}} \quad m^2/year$$

Where $\bar{H}$ = the mean thickness of the sample during a loading increment

and t_{50} = the time to 50% primary compression

The consolidation results are given in Appendix 4.

Permeability can be derived from consolidation as

$$K = C_v \ M_v \gamma_w$$

Where K = Coefficient of permeability

γ_w = Density of water

5 Undrained Shear Strength

Laboratory Shear Vane

The shear vane is a rapid method of testing for undrained shear strength of clays. The laboratory vane is a small scale version of the field vane. The vane consists of four blades set a right angles, attached to a central circular rod. The vane is pushed into the soil up to a mark and a torque is applied to the circular rod and is steadily increased. Failure of the soil is noted by the torque of increasing or by a reduction in the torque. It is assumed that the soil fails on a cylindrical surface area enclosing the extremities of the four blades.

The shear is applied through a spring of known torque and a vane of known size. In this model the electric motor increases the stress at 10^{o} per minute.

Undrained shear strength = Torque constant for spring of shear vane per degree x degrees

Generally the result is taken for reading of 30^{o}-180^{o}. Results are given in Appendix 3 and Figures 1 and 2.

6 Discussion of the Results

i) Moisture Content

The natural moisture contents of the samples varied between 89.0% of the highly organic silt clay from Coychurch to 16.3% from the lower samples from Ewenny.

In some samples there was a large difference between the moisture content at the top and the bottom of the U4. This is probably due to disturbance whilst the sample was collected.

ii) Densities

There is little clear pattern to the variation in bulk density except for the organic clay-silt of Coychurch which had a low bulk density (1.34 Mg/m^3 and 1.63 Mg/m^3). The clay samples tend to have a greater dry density than the clay-silts. The highly organic sample have a low dry density.

iii) Atterberg Limits

The results of the Atterberg limit are plotted on Figures 1 and 2. The liquid limit and plasticity index were plotted on a Casagrande plasticity chart, Figures 3, 4 and 5.

The samples can be classified using this chart into the following groups.

Extremely high plasticity organic silt/clay.	Coychurch	BH11	
Intermediate plasticity inorganic clay	Ewenny	BH 7	6.10- 6.55m
	Treoes	BH10	All samples
	Pencoed	BH13	All samples
Intermediate plasticity silt/clay	Ewenny	BH 7	7.30- [illegible]
	Llantrisant	BH17	11.00-11.45m
			13.45-13.85m
	Pontyclun	BH18	9.55-10.00m
Intermediate plasticity silt	Pontyclun	BH18	8.00- 8.45m
Low plasticity silt	Llantrisant	BH17	9.30- 9.75m

iv) Liquidity Index

Most of the clay samples had a negative liquidity index whereas most of the clay silt samples were positive.

The samples with a positive liquidity index had a lower undrained shear strength. This is partly due to a higher moisture content. Hence most of those samples with a negative liquidity index were stiff or very stiff whereas most of those with positive liquidity index were soft to firm.

There tends to be an increase in undrained shear strength with depth within a similar soil type, ie Pencoed.

v) Consolidation

The results are given in Appendix 3 and fig. 6 shows the change in voids ratio with increasing effective stress and fig. 7 shows the change of the modulus of volume change (M_V) with increasing effective stress. The pressures used in the consolidation tests were not great enough to join the field on laboratory margin line, ie there was no straight position to the line. It is probable that the samples tested were overconsolidated or pseudo-overconsolidated. This could be shown by using the large oedometer.

The M_V results are typical of a medium to low compressibility clays such as boulder clays and lake deposits.

A comparison of the consolidation samples from Ewenny BH 7 and Pencoed BH 13.

Parameter	Ewenny 8.3 m	Pencoed BH 13 8.80 m
Initial moisture content %	16.4	24.2
Dry density Mg/m^3	1.89	1.67
Bulk density Mg/m^3	2.20	2.08
Initial voids ratio	0.46	0.67
Swell pressure kPa	20 low	55 moderate
M_V	Medium-low compressibility	Medium-low compressibility
C_V	Fairly constant	Fairly constant
Permeability	Practically impermeable, that of clay	Practically impermeable, that of clay
Rebound (unloading)	Little response to unloading	When unloaded, large swell response

The main characteristics of the two samples are similar except for the swell and unloading response in which the Pencoed sample is much more active. This could be due to less silty matter.

The C_V results taken from consolidation data is sometimes dubious, however, these tests probably indicate the order of C_V if not an accurate figure.

Summary

The samples can be catagorised into 4 groups, using the available information.

i)	Soft to firm sandy silty clay	BH 2
ii)	Stiff to very stiff or hard intermediate plasticity Medium to low compressibility, slightly silty clay	BH 7, 6.10-6.50 BH 10 BH 13
iii)	Soft organic silt	BH 11
iv)	Firm clay-silt or silt	BH 7 7.90-8.35 BH 17 and 18

7 Comments

Appendix 2 contains the test programme. When the test is left blank, the test was not done; a D means the test was attempted but not possible and N means the test was not attempted as there was not enough material. The STP test attempted on site should only be used as an indicator of strength as the test is only designed for coarse silt and sand.

8 Reference

British Standards Institution 1975.
Methods of Test for Soils for Civil Engineering Purposes.
British Standard BS 1377, London, p. 143.

APPENDIX 1

Site Grid reference	Borehole Number	Depth m.	Description
Pyle Old Park Farm 8119 8477	BH 2	3.90- 4.35	Clay bound sand coaly laminae and scattered rounded pebbles.
Glanwenny Ewenny 9030 7814	BH 7	6.10- 6.55	Reddish brown to purple structureless, stiff clays. With scattered pebbles of Pennant-type sandstone and flint, more micaceous lower at 7.90-8.35. Lacustrine.
Moor Farm Treoes 9458 7913	BH 10	8.65- 9.10	Reddish orange brown, stiff clay with sand from stratum above (badly disturbed at top of U4).
		10.20-10.65	Dark brown stiff clay with some limestone nodules of gravel size.
Coychurch 9538 7988	BH 11	4.75- 5.20	Brown-grey silty clayey peat.
Brick Works Pencoed 9584 8211	BH 13	1.60- 2.05	Dark reddish brown stiff clay, upper part of sample disturbed, has roots and shows some oxidation/reduction reactions.
		3.60- 4.05	Dark chocolate brown stiff clay.
		5.20- 5.65 6.80- 7.25 8.70- 9.15	Dark brown stiff clay with some silt. Sand at 5.40-5.65 m. Sample wetter at 6.80 m possibly due to disturbance.
Talbot Green Llantrisant 0414 8242	BH 17	9.30- 9.75	Slightly brown, grey stiff silt with some clay, laminated.
		11.00-11.45 13.40-13.85	Slightly brown, grey soft to stiff clay silts.
Pontyclun 0344 8191	BH 18	8.00- 8.45 9.55-10.00	Slightly brown grey soft to stiff clay silts.
Pen-y-Castell Pyle 8391 8194	BH 19	2.50- 2.95	Laminated soft to stiff sands, silts and clays - Varve deposit.

APPENDIX 2 Tests Undertaken

Bore-hole	Depth	Position	Moisture Content	Densities	Liquid Limit	Plastic Limit	Lab Shear Vane	Consolidation
2	3.90-4.35	Top	✓	✓	D	D	✓	
		Bottom	✓	✓	D	D	✓	
7	6.10- 6.55	Top	✓	✓	✓	✓		
		Bottom	✓	✓	✓	✓		
	7.90- 8.35	Top	✓	✓	✓	✓		✓
		Bottom	✓	✓	✓	✓		
10	8.65- 9.10	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
	10.20-10.65	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
11	4.75- 5.20	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
13	1.60- 2.05	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
	3.60- 4.05	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
	5.20- 5.65	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
	6.80- 7.25	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
	8.70- 9.15	Top	✓	✓	✓	✓	✓	✓
		Bottom	✓	✓	✓	✓	✓	
17	9.30- 9.75	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	D	✓	
	11.00-11.45	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
	13.40-13.85	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
18	8.00- 8.45	Top						
		Bottom	✓	✓	✓	✓		
	9.55-10.00	Top	✓	✓	✓	✓	✓	
		Bottom	✓	✓	✓	✓	✓	
19	2.50- 2.95	Silt	✓	✓	D	D		
		Clay	✓	✓	N	N		

APPENDIX 3

Moisture Content, Bulk and Dry Densities, Atterberg Limit Data and Unconfined Compressive Strength (Lab Shear Vane)

Site	BH No	Depth m	Position	Moisture Content %	Densities Bulk Dry Mg/m^3	Liquid Limit	Plastic Limit	Plastic Index	Liquidity Index	S_u Lab Shear Vane kPa
Pyle	2	3.90- 4.35	T	19.3	1.72 1.44	-	-	-	-	22
			B	23.7	1.85 1.50	-	-	-	-	29
Ewenny	7	6.10- 6.55	T	19.2	2.07 1.74	42.4	21.7	20.7	-0.12	-
			B	19.2	2.11 1.77	38.6	21.7	16.9	-0.15	-
		7.90-8.35	T	16.3	2.15 1.83	36.9	23.5	13.4	-0.54	-
			B	16.4	2.20 1.89	37.4	24.1	13.3	-0.58	-
Treoes	10	8.65- 9.10	T	24.8	2.02 1.62	38.3	18.6	19.7	0.32	21
			B	25.9	2.03 1.61	39.2	18.9	20.3	0.34	75
		10.20-10.65	T	21.3	2.10 1.73	44.3	21.5	22.8	-0.01	110
			B	21.3	2.05 1.69	44.6	21.7	22.9	-0.02	116
Coychurch	11	4.75-5.20	T	89.0	1.34 0.71	100.8	42.3	58.5	0.80	53
			B	45.2	1.63 1.12	101.4	43.4	58.0	0.03	65
Pencoed	13	1.60- 2.05	T	22.2	2.05 1.68	44.3	23.0	21.3	-0.04	28
			B	20.3	2.06 1.74	41.5	22.6	18.9	-0.12	51
		3.60- 4.05	T	22.4	2.06 1.68	43.5	23.8	19.7	-0.07	77
			B	20.2	2.01 1.68	41.7	23.5	18.2	-0.18	82

APPENDIX 3

Moisture Content, Bulk and Dry Densities, Atterberg Limit Data and Unconfined Compressive Strength (Lab Shear Vane)

Site	BH No	Depth m	Position	Moisture Content %	Densities Bulk Dry M_g/m^3	Liquid Limit	Plastic Limit	Plastic Index	Liquidity Index	S_v Lab Shear Vane kPa
Pencoed	13	5.20- 5.65	T	19.3	2.14 1.79	38.6	22.3	16.3	-0.18	97
			B	21.2	2.10 1.73	46.4	24.2	22.2	-0.13	102
		6.80- 7.25	T	26.9	2.21 1.74	47.7	21.8	25.9	0.20	90.5
			B	18.85	2.09 1.76	47.6	22.7	24.9	-0.15	223
		8.70- 9.15	T	24.0	1.94 1.56	48.4	24.2	24.2	-0.01	218
			B	23.5	2.01 1.63	49.1	25.7	23.4	-0.09	226
Llantrisant	17	9.30- 9.75	T	21.0	2.01 1.66	30.0	24.3	5.7	-0.58	50
			B	17.6	2.03 1.73	27.7	-	-	-	60
		11.00-11.45	T	30.8	1.92 1.47	41.6	24.9	15.7	0.38	28
			B	29.5	1.90 1.46	40.7	26.2	15.5	0.21	23
		13.40-13.85	T	26.0	1.94 1.55	37.0	24.6	12.6	0.11	43
			B	26.8	1.86 1.47	35.2	23.7	11.5	0.27	42
Pontyclun	18	8.00- 8.45	T	-	- -	-	-	-	-	-
			B	24.2	1.98 1.52	36.8	26.6	10.2	-0.24	-
		9.55-10.00	T	27.9	1.96 1.53	36.4	23.7	12.7	0.51	40
			B	28.9	1.96 1.52	32.6	24.3	8.3	0.55	24
Pyle	19	2.50- 2.95	Sand/silt	31.0	2.22 1.70	-	-	-	-	-
			clay	27.6	1.99 1.56	N	N	N	N	-

APPENDIX 4 CONSOLIDATION DATA

Site	BH No	Depth m	M C %	Densities Mg/m^3 Bulk	Dry	Load kPa	e	Swell Pressure kPa	Mv m^2/MN	Cv m^2/yr	k m/sec
Ewenny	7	8.3	16.4	2.20	1.89		0.457	20			
						122	0.429		0.192	2.26	1.34×10^{-10}
						222	0.415		0.098	2.62	7.84×10^{-11}
						444	0.394		0.067	2.76	5.64×10^{-11}
						888	0.369		0.040	3.46	4.22×10^{-11}
						111	0.391		0.021		
Pencoed	13	8.7	24.2	2.08	1.67		0.674	55			
						111	0.656		0.162	1.29	6.39×10^{-11}
						222	0.630		0.146	1.35	6.01×10^{-11}
						444	0.597		0.091	1.40	3.91×10^{-11}
						888	0.558		0.057	1.85	3.22×10^{-11}
						111	0.626		0.057		

FIG 1

Summary of Laboratory Data i

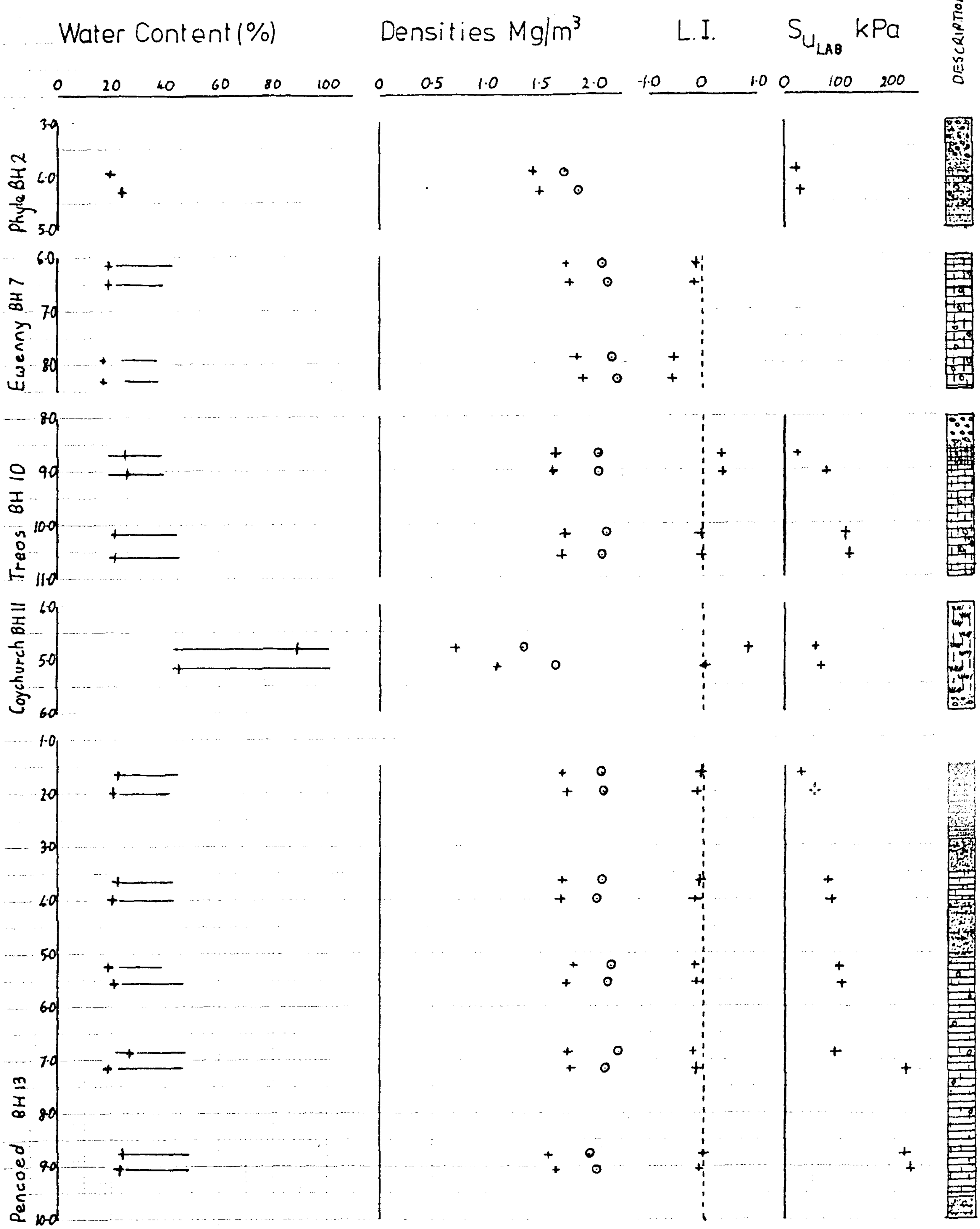


FIG 2

Summary of Laboratory Data ii

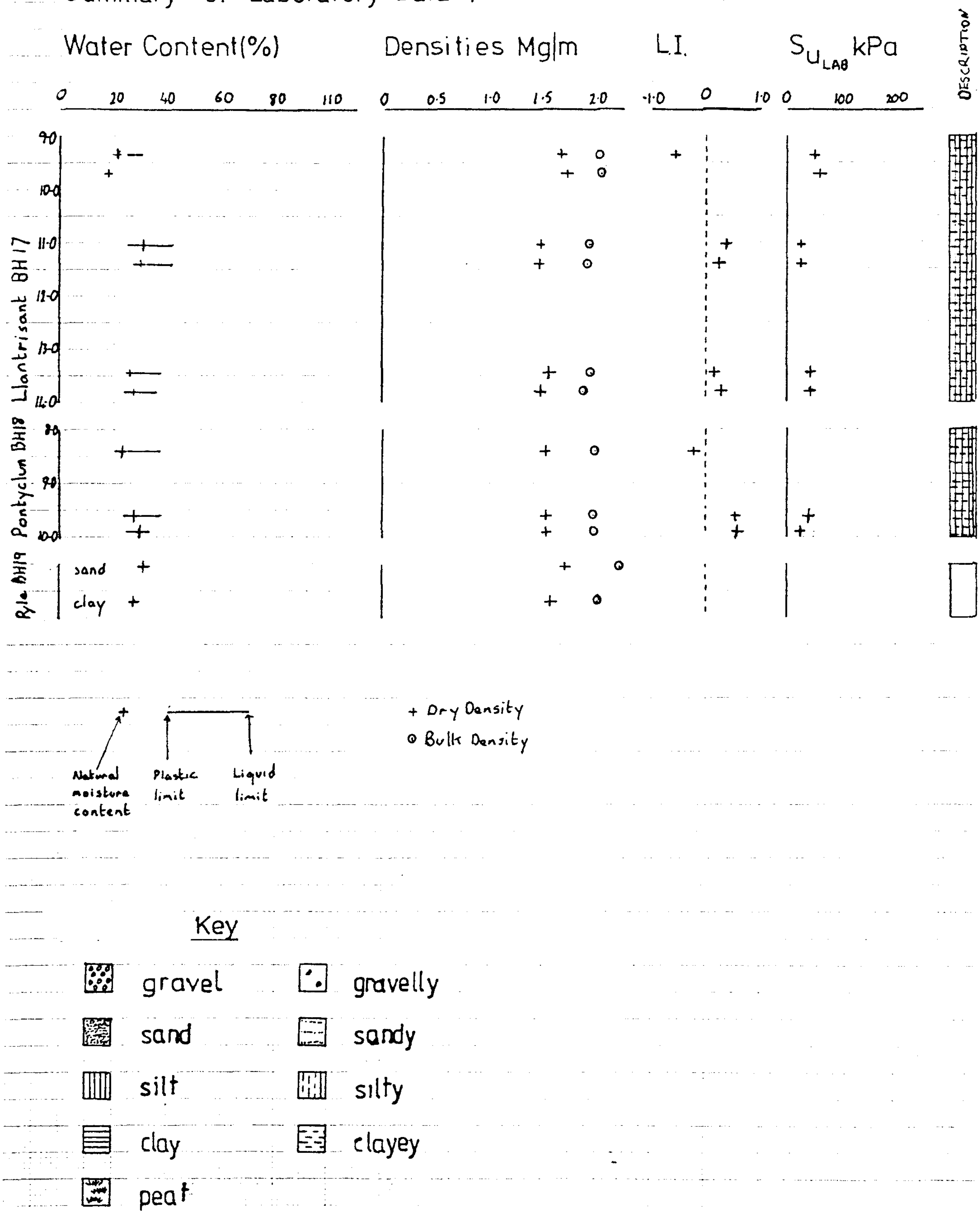


FIG 3

Plasticity chart

Key

soil type		plasticity	
M	silt	L	low
C	clay	I	intermediate
O	organic clay or silt	H	high
		V	very high
		E	extremely high

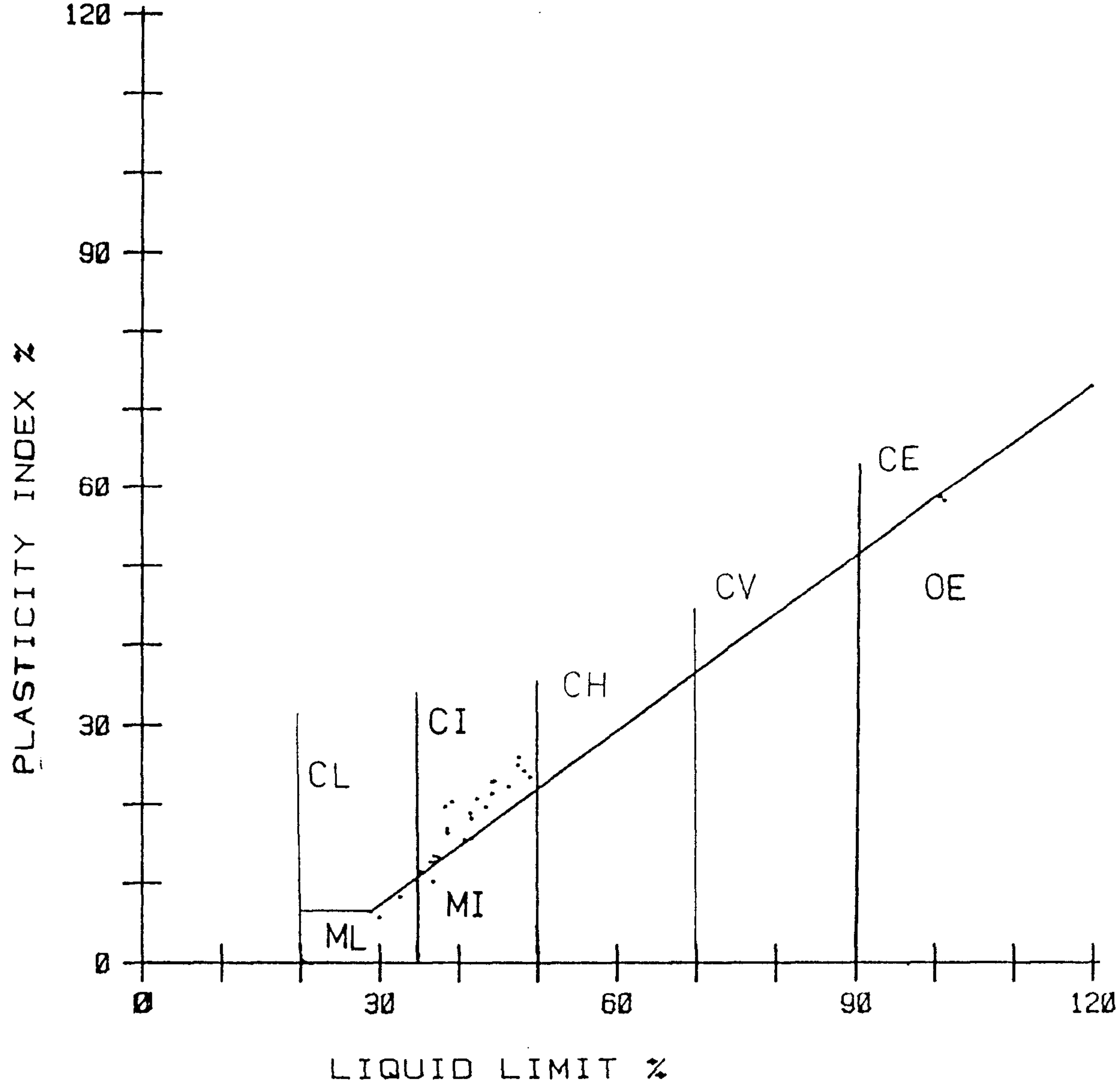


FIG 4

Plasticity chart with boreholes

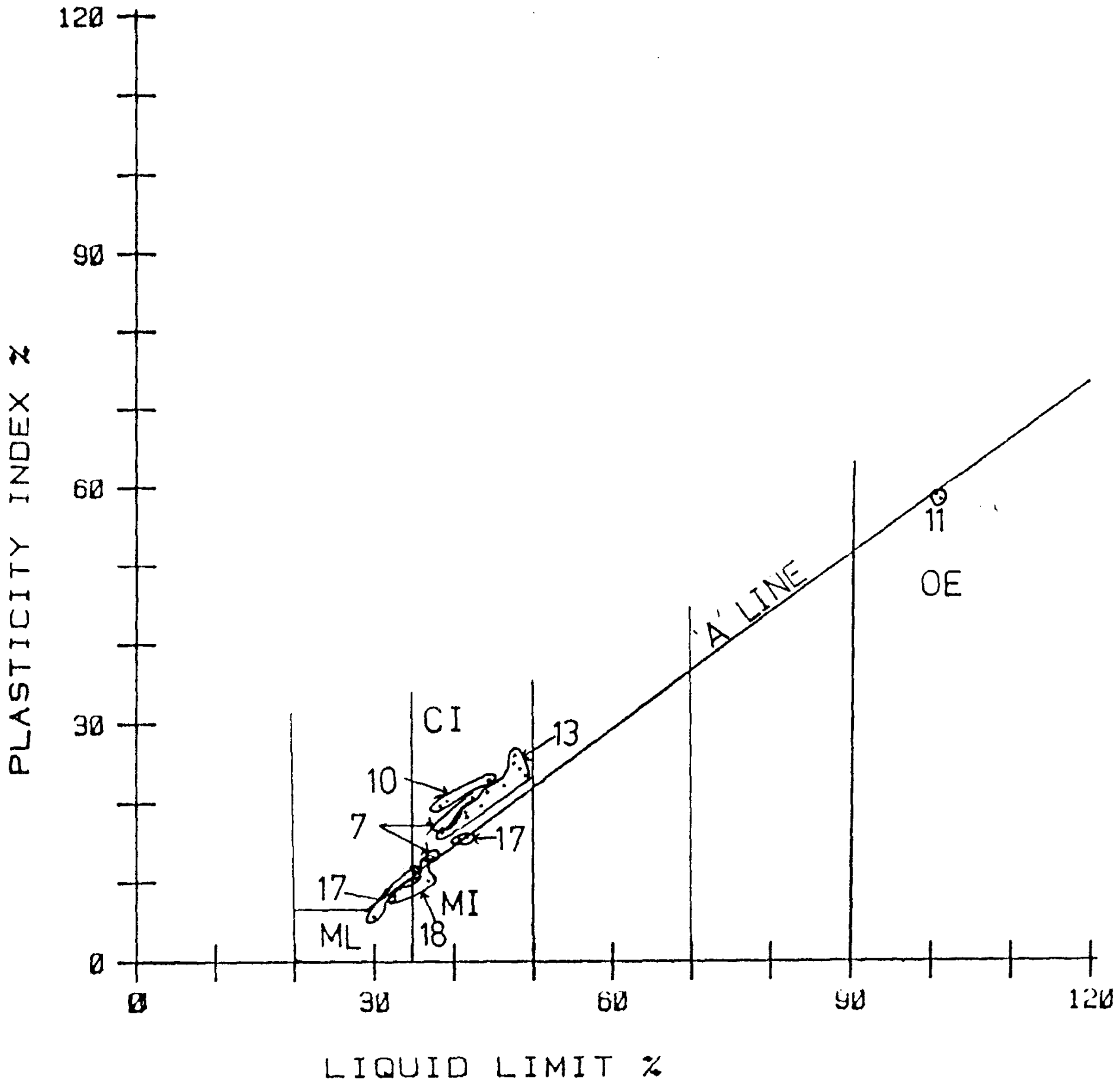


FIG 5

Plasticity chart

with samples grouped

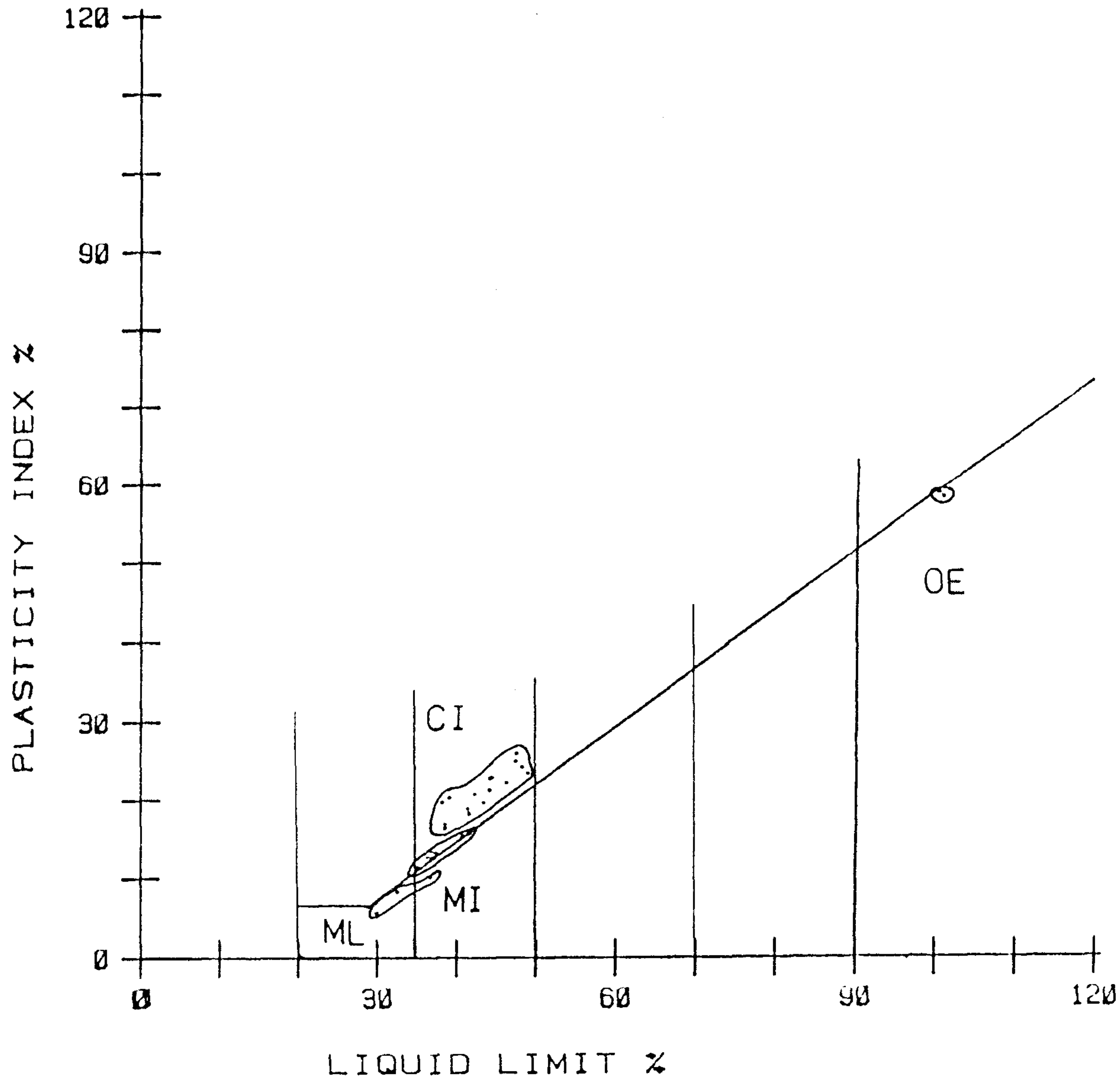


FIG. 6 VOIDS RATIO_Log Effective Stress

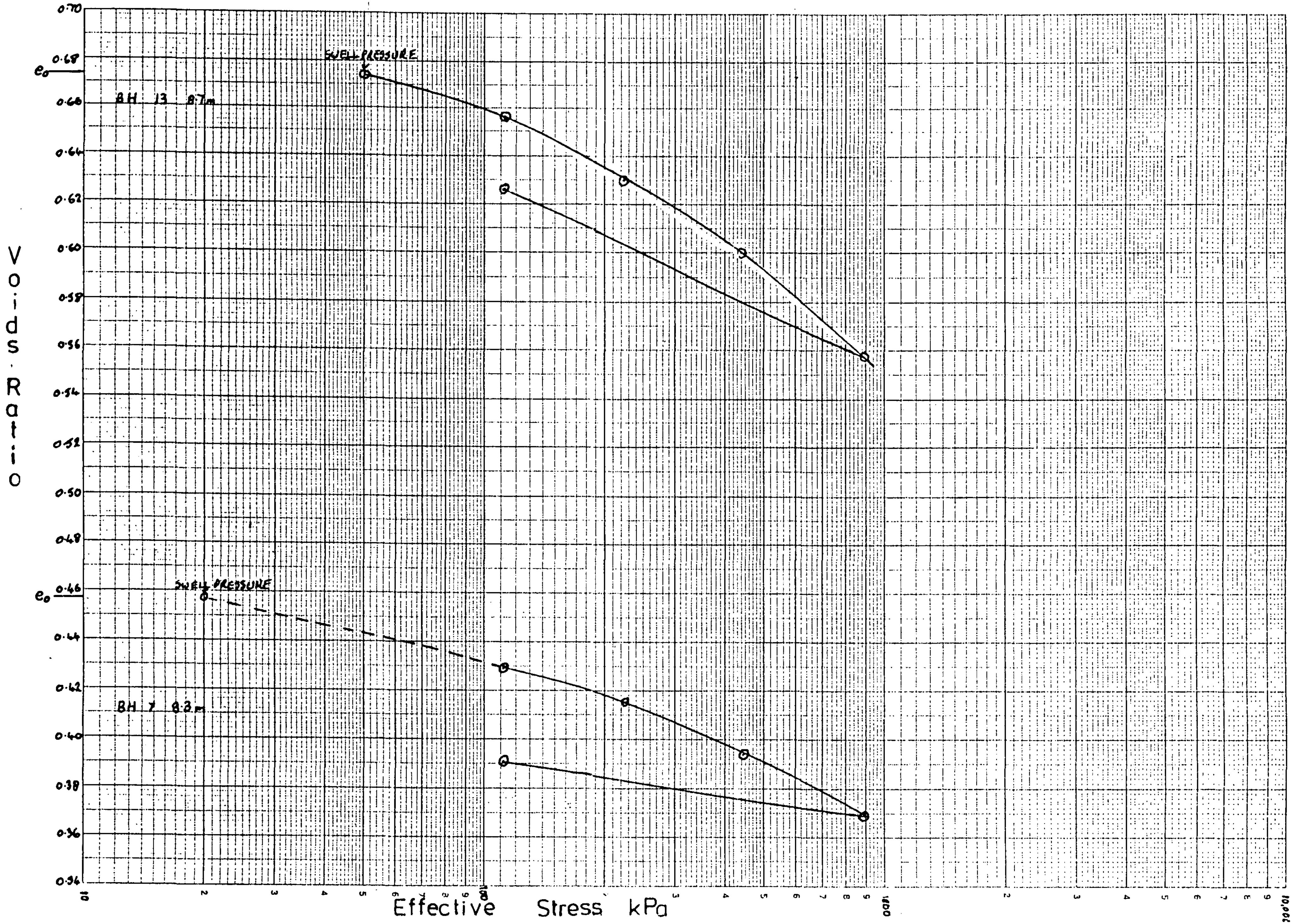
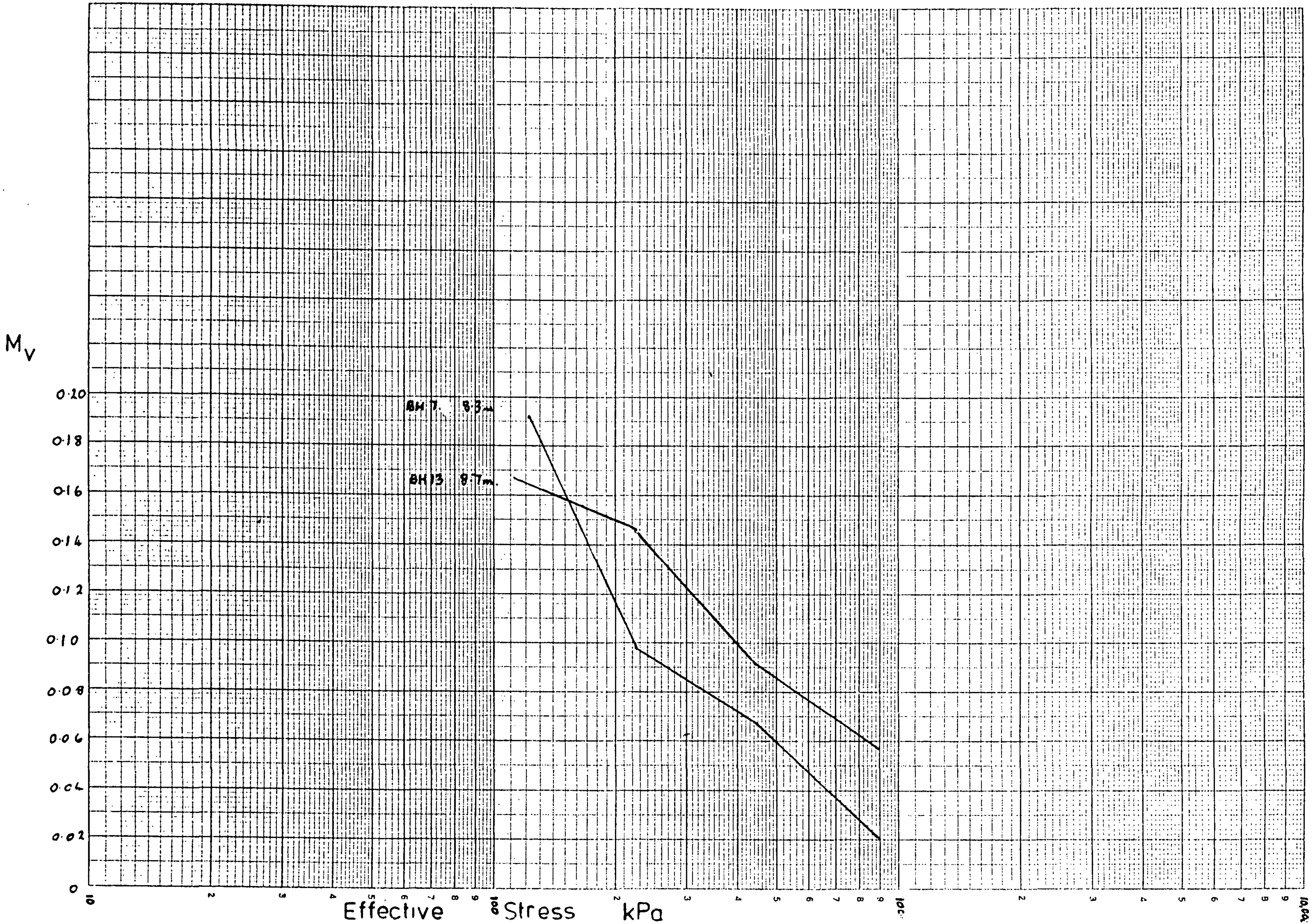
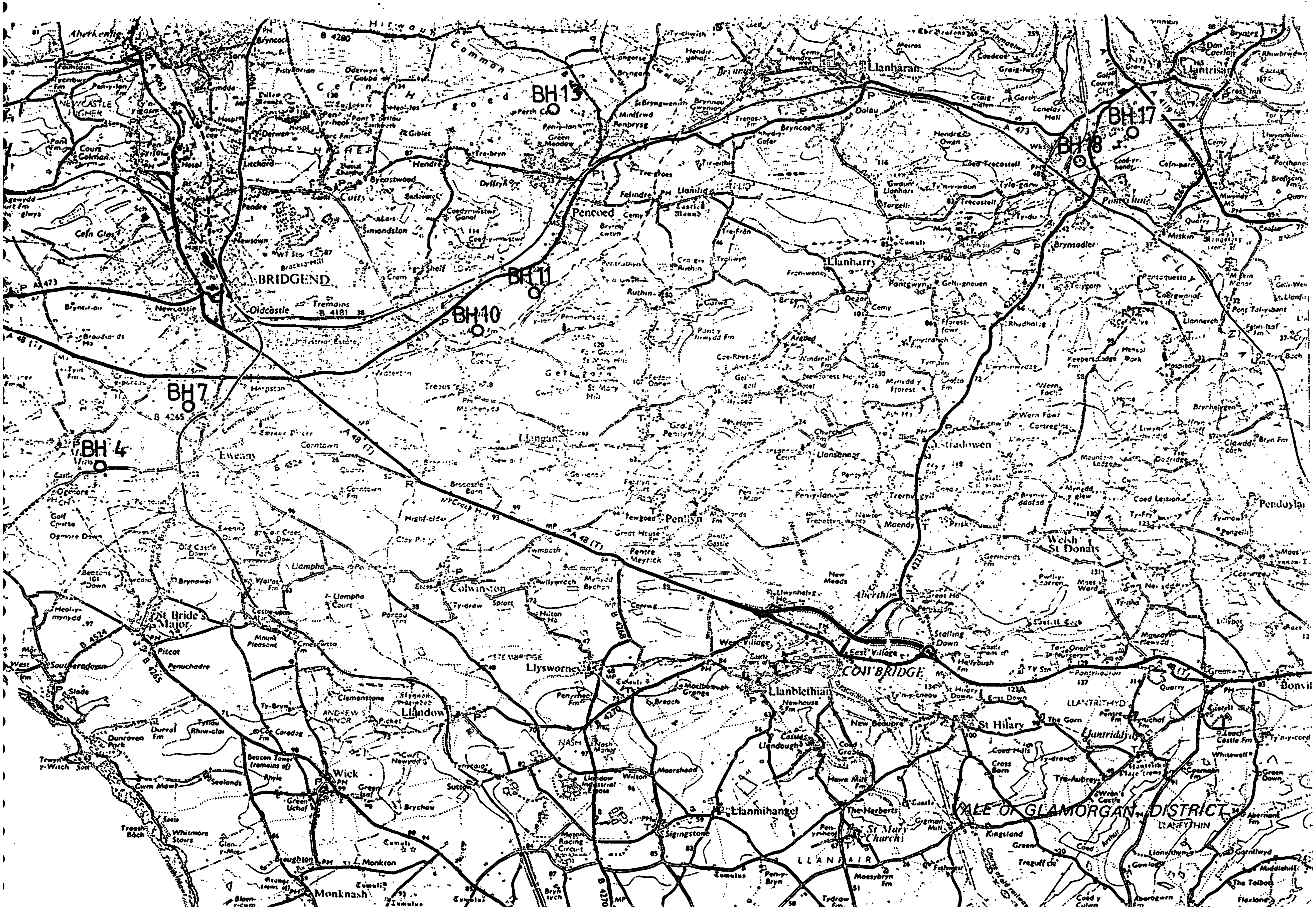


FIG 7

M_V – Log Effective Stress



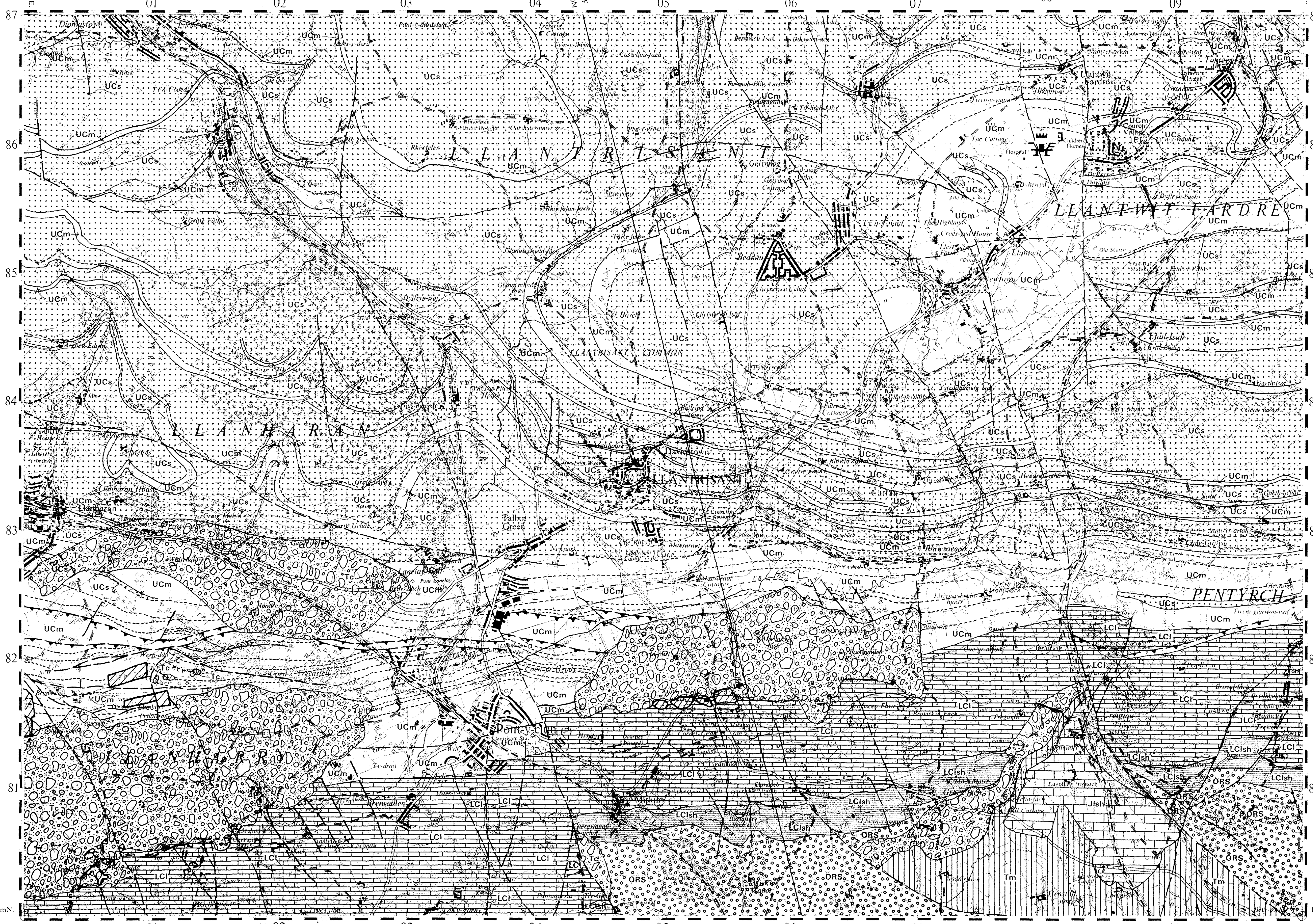


MAP LOCATION MAP OF SEVEN OF THE BOREHOLES (O.S. 1:50,000 1st Series. Sheet 170)

Sheets 1 and 1A

BEDROCK GEOLOGY

This map is only to be used for preliminary studies and not intended as a substitute for on-site investigation



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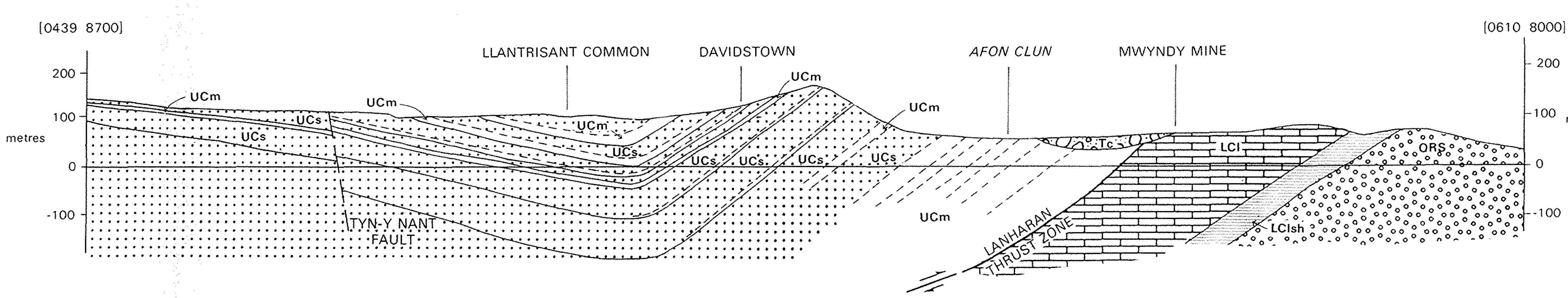
GENERALIZED CROSS SECTION ALONG LINE DRAWN ON MAP

Horizontal Scale 1:25 000; Vertical Scale four times the Horizontal



THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 1: BEDROCK GEOLOGY (LLANTRISANT)

LEGEND: for sheets 1 and 1A

Active or former sites of opencast working for coal or iron ore ; the pits may be wholly or partly backfilled

LOWER JURASSIC

Jlsh — Limestone and Shales: Interbedded, fine-grained limestones and dark grey shales

Jsh — Shales: Dark grey shales and thin nodular limestones

Jc — Limestone Conglomerates: Heterogeneous deposits comprising fine-to medium-grained limestone chip conglomerates and oolites; locally interbedded with shales

TRIASSIC

Tc — Limestone Conglomerates and Breccias: Crudely bedded, reddish brown limestone conglomerates and breccias

Tm — Mudstones and Marls: Reddish brown and green, mottled, marly mudstones

Tsh — Shales (Upper): Buff, greenish grey and black shales locally with thin limestones

Ts — Sandstones (Upper): Fine-to coarse, massive, flaggy quartzose sandstones

UPPER CARBONIFEROUS

UCs — Sandstones: Massive and flaggy, coarse-grained, yellow gritty sandstones

UCm — Mudstones, seatearths and Coals: Alternating dark grey shaly mudstones, seatearths and coal seams

LOWER CARBONIFEROUS

LCl — Limestones: Massive and well bedded, shelly and oolitic limestones, locally with dolomite and calcite mudstones

LClsh — Limestones and Shales: Dark grey shaly mudstones with thin limestones

DEVONIAN

ORS — Sandstones and Conglomerates : Purplish and reddish brown mudstones, sandstones and conglomerates

Geological boundary

Fault, crossmark indicates downthrow side

Thrust, symbol indicates sense of downthrown

Coal Seam

COMMENT

This map shows the rock type most likely to occur at the surface or immediately beneath the cover of unconsolidated deposits. It has been compiled from the component 1:10 000 and 1:10 560 BGS maps.

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 1A: BEDROCK GEOLOGY (BRIDGEND)

For legend see sheet 1

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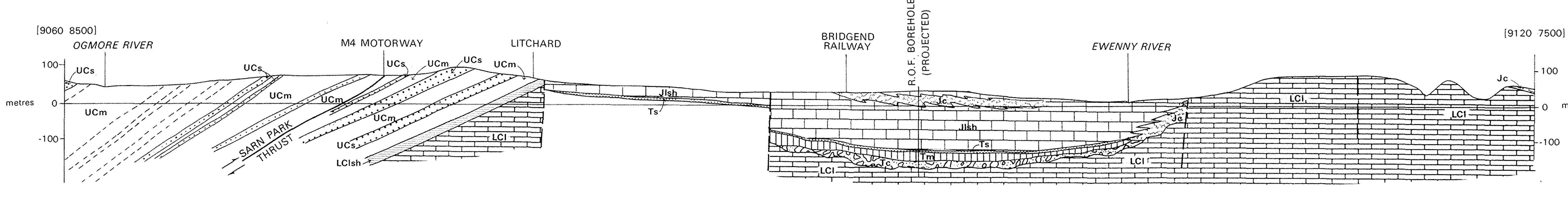
GENERALIZED CROSS SECTION ALONG LINE DRAWN ON MAP

Horizontal Scale 1:25 000; Vertical Scale four times the Horizontal



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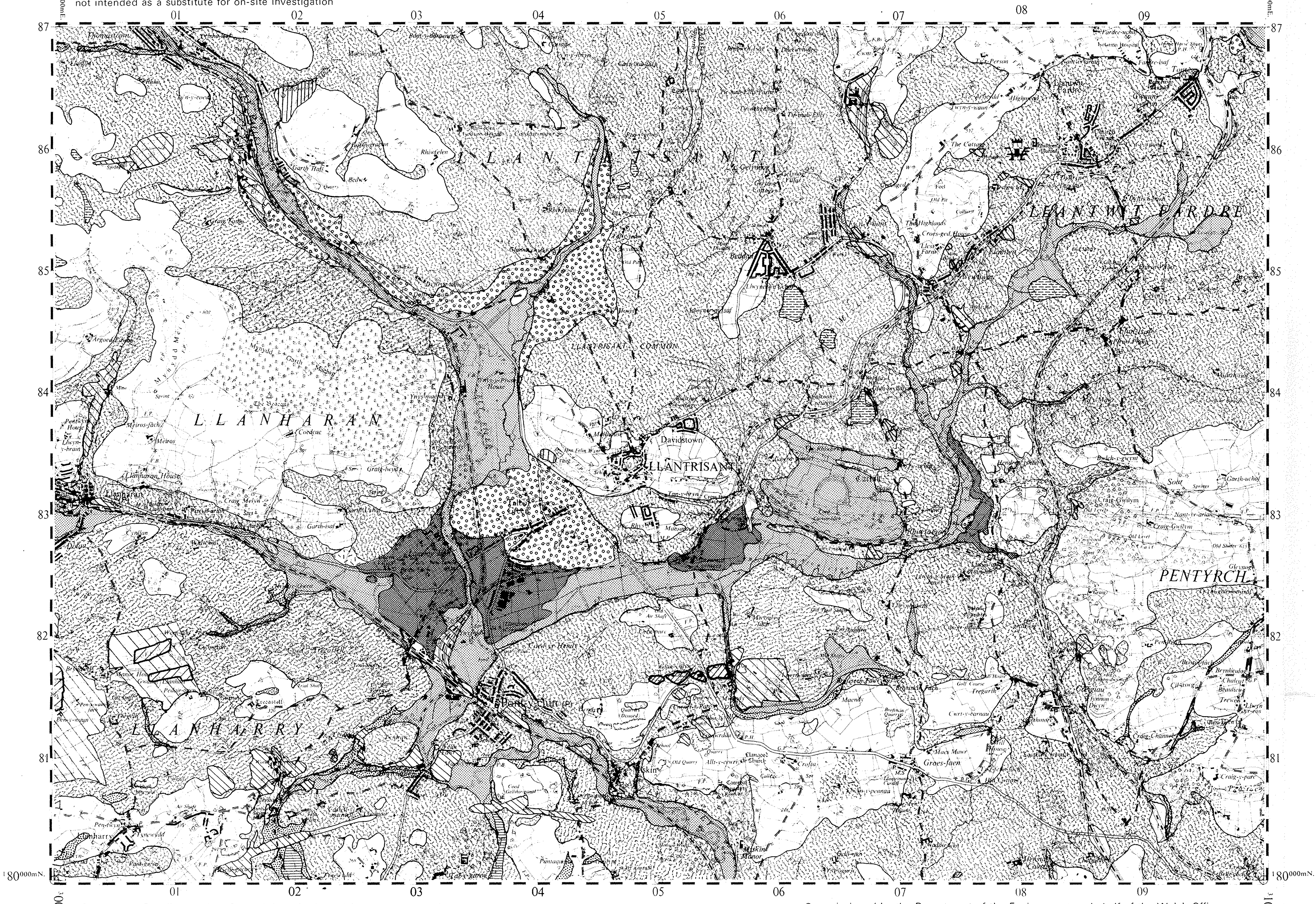

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THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 2: UNCONSOLIDATED DEPOSITS (LLANTRISANT)

LEGEND: for sheets 2 and 2A

- Landslip
- Active or former sites of opencast working for coal or ironstone; the pits may be wholly or partly backfilled
- Made Ground: man-made deposits on original ground surface

- Blown Sand: fine to medium, quartz sands
- Peat
- Alluvium, undifferentiated: mainly fine sands, silts and clays with thin peat intercalations; gravel occurs locally
- Alluvial Fan: clay and sandy gravels
- River Terrace Deposits: coarse sands and gravels
- Beach Deposits: quartz sands and poorly sorted gravels
- Storm Beach Deposits: coarse, poorly sorted gravels, cobbles and boulders
- Head Deposits: variable deposit, ranging from silty and sandy clays to clayey gravels

- Glacial Sand and Gravel, undifferentiated: medium to coarse, often clayey sands and gravels with bands of clay and till
- Till (Boulder Clay): heterogeneous deposits ranging from structureless silty and sandy pebbly clays to claybound gravels
- Glacial Silts and Clays: soft to firm, structureless or thinly laminated silts and silty clays with scattered small pebbles

- Bedrock, undifferentiated: at or near surface

- Geological Boundary

COMMENT

This map shows the nature and distribution of unconsolidated deposits at the surface, which are generally a metre or more thick; it does not show the variation in these deposits with depth.

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 2A: UNCONSOLIDATED DEPOSITS (BRIDGEND)

For legend see sheet 2

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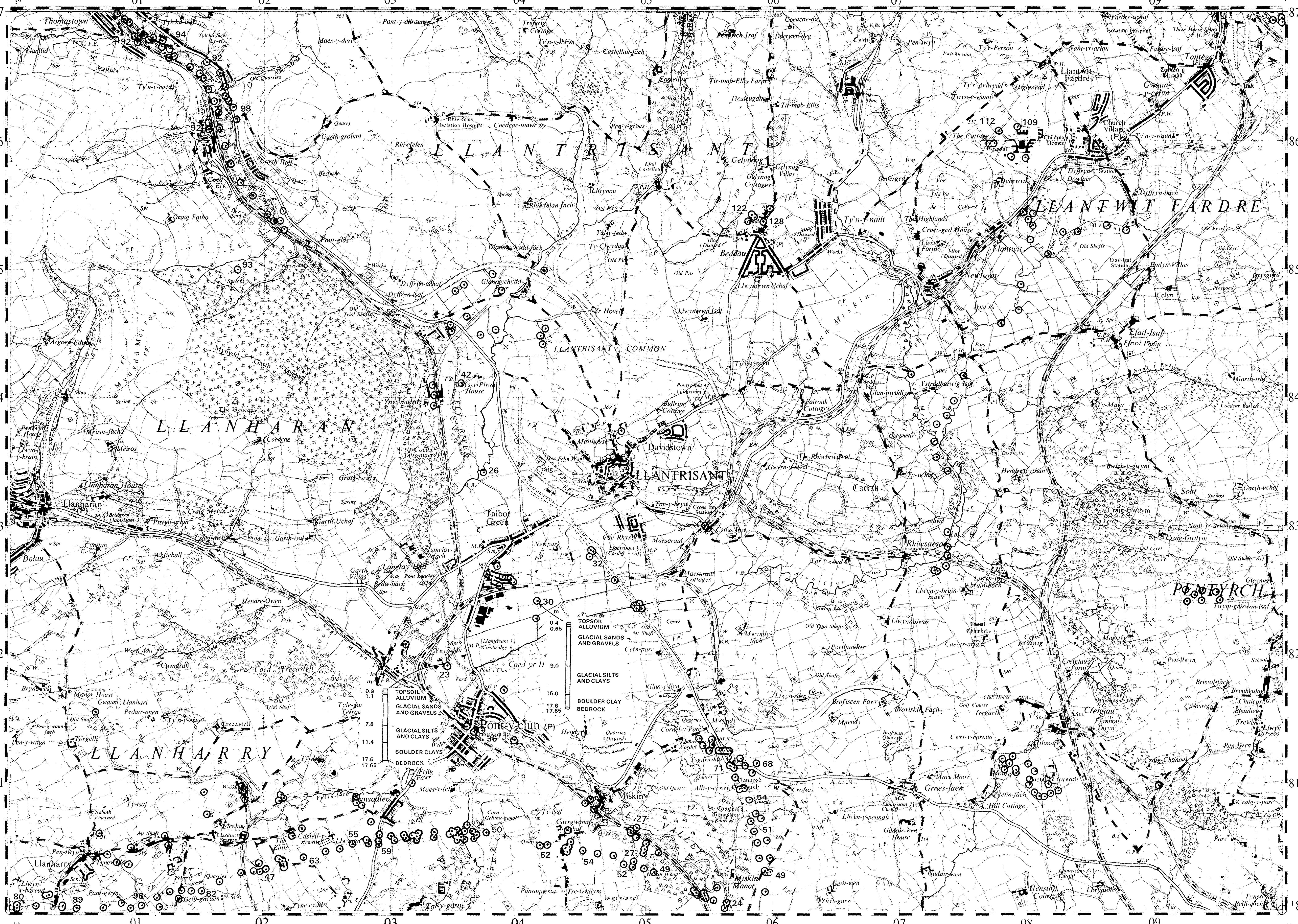

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THEMATIC GEOLOGY MAPS— BRIDGEND AREA

SHEET 3: BOREHOLES AND ROCKHEAD INFORMATION (LLANTRISANT)

LEGEND: for sheets 3 and 3A

⊙ Selected borehole sites

Numbers against boreholes refer to the height of the drift/solid interface (rockhead) above Ordnance Datum (O.D.)

10 / 5 Contours on rockhead in 5m intervals. (Ewenny and Ogmore valleys only)

Insets are of boreholes drilled during the contract by B.G.S.

COMMENT

This map shows the O.D. levels of rockhead and the inferred form of the rockhead surface, where the concentration of data enables contours to be drawn. The scale of the map does not permit all boreholes to be shown; for a full explanation of borehole spread see report.

THEMATIC GEOLOGY MAPS—BRIDGEND AREA

SHEET 3A: BOREHOLES AND ROCKHEAD INFORMATION (BRIDGEND)

For legend see sheet 3

This map is only to be used for preliminary studies and
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Sheets 4 and 4A

MINING ACTIVITIES

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 4: MINING ACTIVITIES (LLANTRISANT)

This map is only to be used for preliminary studies and not intended as a substitute for on-site investigation

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LEGEND: for sheets 4 and 4A

Active or former sites of opencast working for coal or ironstone; the pits may be wholly or partly backfilled

Main areas of recorded coal workings

Area undermined for iron ore

Pb — Lead veins and workings

Area of shallow coal, iron ore and lead workings with numerous bell pits and crown holes

Mineshaft (active)

Pit or mineshaft (abandoned)

Adit or mine mouth (abandoned)

COMMENT

The position of abandoned mineshafts and adits is approximate. Additional shafts and workings may also exist. Abandonment does not necessarily imply that the pit or shaft is sealed at the surface, or wholly or partly filled in. This map is compiled from mine plans and geological maps held by the British Geological Survey and National Coal Board.

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 4A: MINING ACTIVITIES (BRIDGEND)

For legend see sheet 4

This map is only to be used for preliminary studies and not intended as a substitute for on-site investigation

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Sheets 5 and 5A

GROUND CONDITIONS

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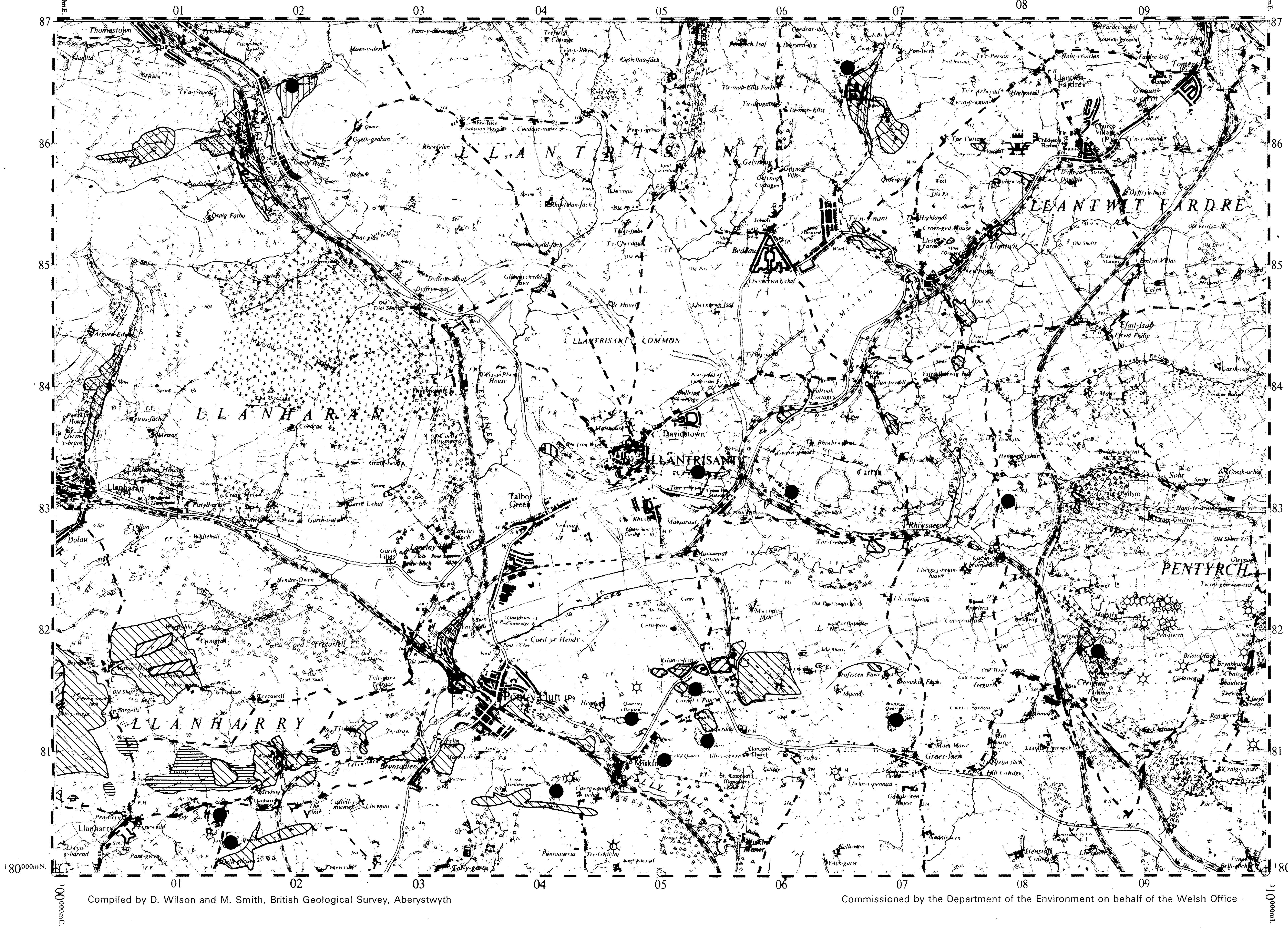

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THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 5: GROUND CONDITIONS (LLANTRISANT)

LEGEND: for sheets 5 and 5A

Landslip

Backfilled opencast coal and iron ore workings wholly or partly replaced by fill

Tipped material on original ground surface

Area of known subsidence (excluding coalfield)

Major quarries (limestone and sandstone)

Swallow holes

COMMENT

This map shows areas of disturbed or unstable ground, excluding those undermined for coal (see accompanying report). Made ground (backfill and tip) is only shown where it forms recognisable features; variable thicknesses of made ground cover much of the undermined and urban areas.

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 5A: GROUND CONDITIONS (BRIDGEND)

For legend see sheet 5

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Sheets 6 and 6A

MINERAL RESOURCES [SOLID]

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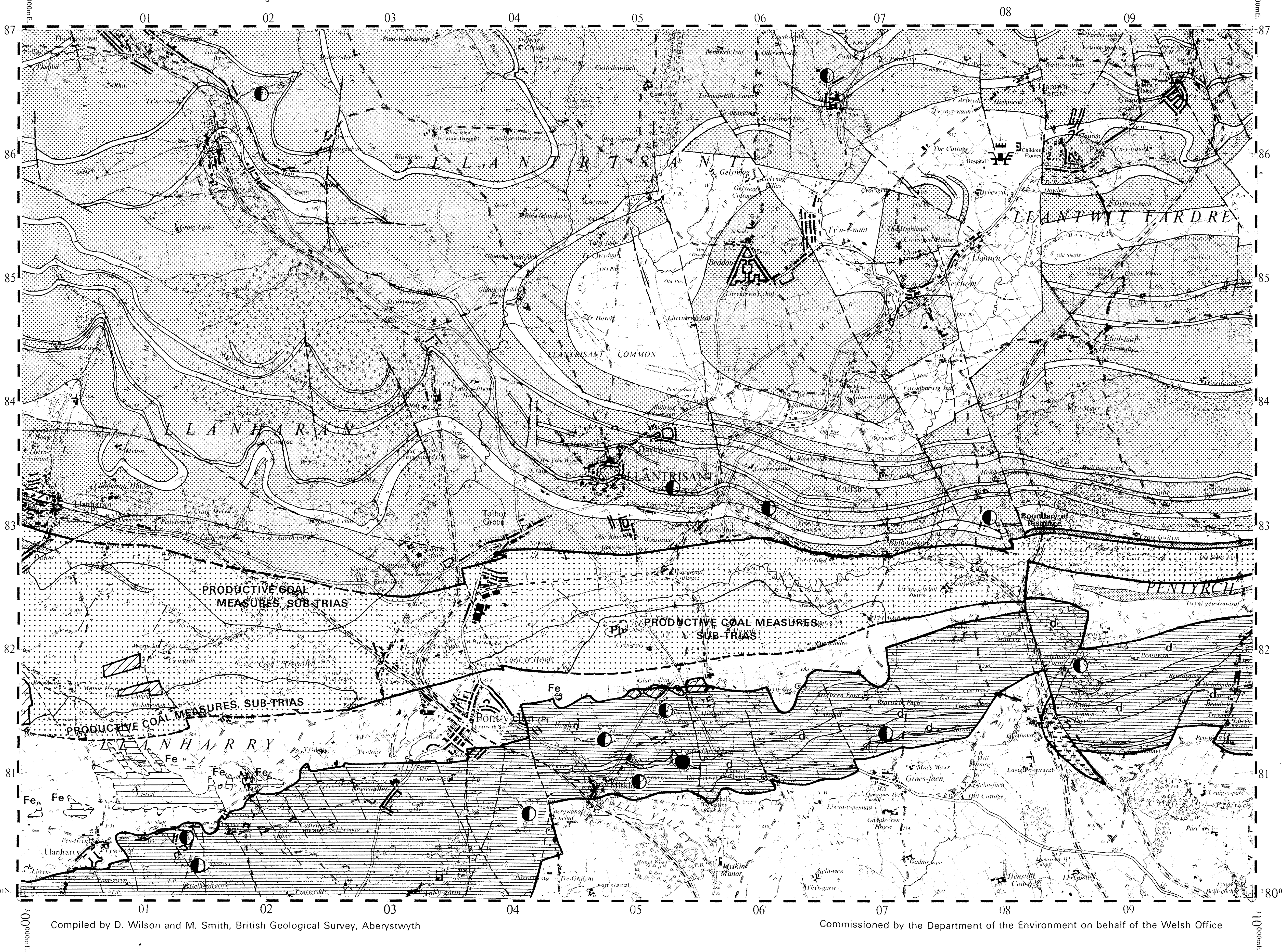

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THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 6: MINERAL RESOURCES [SOLID] (LLANTRISANT)

LEGEND: for sheets 6 and 6A

LIMESTONE RESOURCES

	PURITY VALUES	POLISH RESISTANCE VALUES (PSV)	ABRASIVE RESISTANCE VALUES (AAV)
Carboniferous Limestones d -dolomites within	Variable, >98% to 87%. Includes dolomite with 16-20% MgO	41-45	7.6-11.2
Jurassic Limestones	93-97% $CaCO_3$	—	7.6-10.1

COMMENT

The area of potential limestone aggregate is shown on the map. The resource area comprises Carboniferous and Jurassic limestones, which are shown seperately. This map complements an earlier report, Harrison (1984) on the limestone resources in the Bridgend area.

SANDSTONE RESOURCES

	POLISH RESISTANCE VALUES (PSV)	ABRASION RESISTANCE VALUES (AAV)
Pennant Sandstone (Upper Coal Measures)	64-71	14.9-22.4
Namurian, Lower and Middle Coal Measure sandstones	65-70	8-11.6

COMMENT

The sandstones shown on this map have been differentiated on their potential as aggregate. The Pennant Sandstones have been the subject of an earlier report, Harrison et al (1982) and are generally of high potential. The Coal Measure and Namurian sandstones are more variable but locally maybe of high aggregate quality.

SHALLOW COAL RESOURCES

Middle and Lower Coal Measures: above GARW, below No 3 RHONDA seams

COMMENT

The area of resource shown on the map is currently worked opencast by the NCB at a number of sites (also shown). Coal resources, present at depth have not been evaluated.

MINERAL DEPOSITS

Pb — Zone of lead workings

Pb — Worked lead veins. Lead has been sporadically worked since Roman Times to the late nineteenth century

Fe — Area of former iron ore workings in Carboniferous limestones. Iron ore has been worked since Roman Times; the most recent workings closed in 1976. Past ironstone workings in the Coal Measures are not shown, (see report).

MAIN QUARRIES

Active quarry at time of survey

Closed

Opencast site

Boundary of main resource

Fault, tick indicates sense of downthrow. Only faults within the resource area are shown

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 6A: MINERAL RESOURCES [SOLID] (BRIDGEND)

For legend see sheet 6

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Sheets 7 and 7A

MINERAL RESOURCES [UNCONSOLIDATED DEPOSITS]

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 7: MINERAL RESOURCES [DRIFT] (LLANTRISANT)

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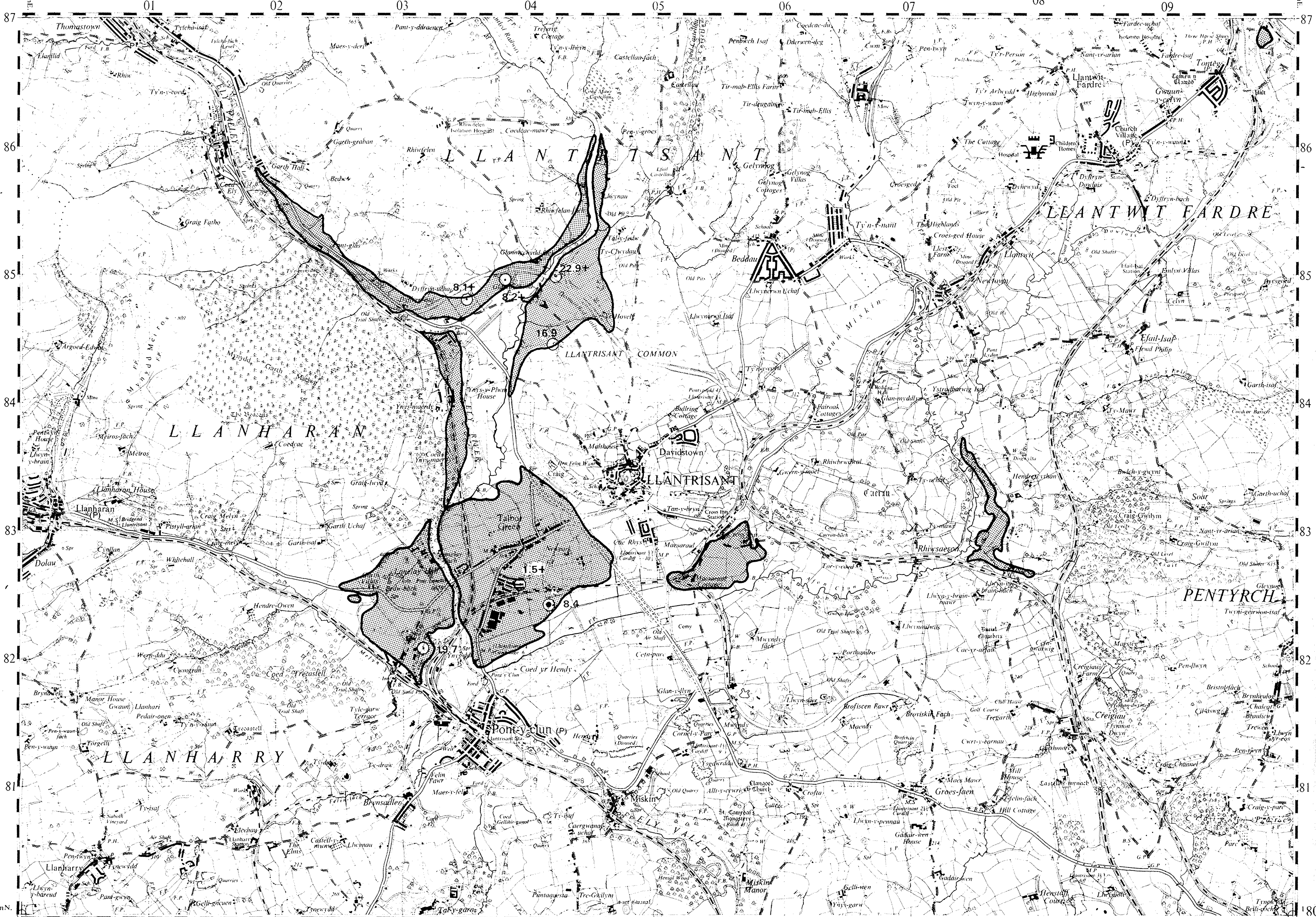

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LEGEND: for sheets 7 and 7A

Sand and Gravel, deposits shown where over 1 metre thick

COMMENT

Sands and gravels of variable origin and resource potential occur throughout the area. The map shows areas of likely resource with thicknesses where known. The extent of these deposits beneath other superficial deposits is not known.

Brick and Pot clays

COMMENT

The areas of potential brick and pot clay resources are shown with thicknesses where known. These have been worked in the past, notably at Pencoed and Ewenny.

Borehole Sites with resource thickness (metres)

5.0 ⦿ Drilled during survey as part of contract PECD 7/1/044

5.0 ⊙ From BGS 1:10 000 Record System

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 7A: MINERAL RESOURCES [DRIFT] (BRIDGEND)

For legend see sheet 7

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Sheets 8 and 8A

HYDROGEOLOGY

THEMATIC GEOLOGY MAPS — BRIDGEND AREA

SHEET 8: HYDROGEOLOGY (LLANTRISANT)

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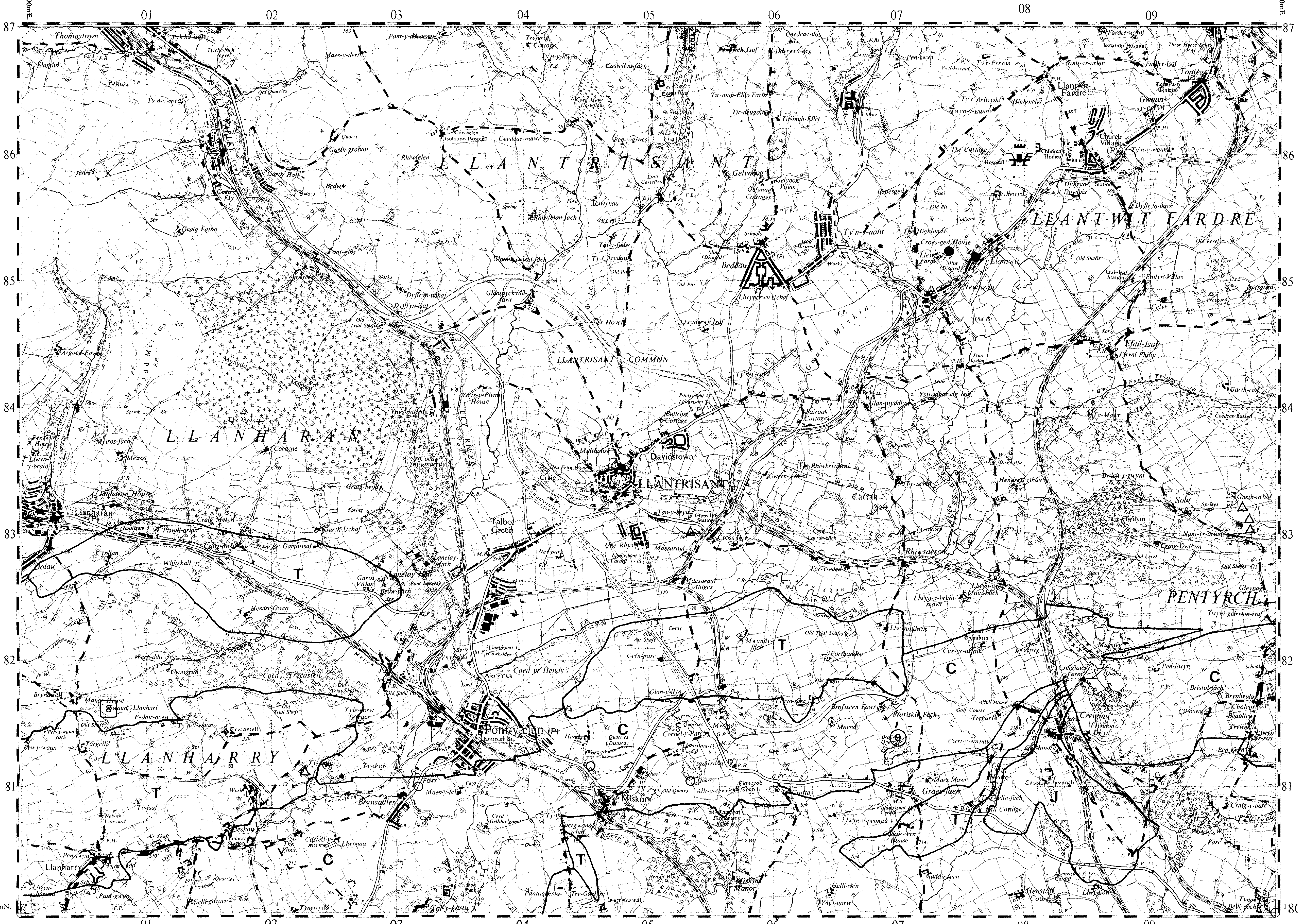

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LEGEND: for sheets 8 and 8A

J	Jurassic
T	Triassic
C	Carboniferous
○	Water well or borehole
●	Mineral borehole or mineshaft
△	Spring
□	Landfill waste disposal site (in use)
⑥	Landfill waste disposal site (not in use)
—	Geological boundary

COMMENT

This map shows potential aquifers in solid lithologies together with boreholes and wells where known hydrogeological data exists. ~~Numbers in landfill sites are referred to in the hydrogeological report which supplements this map.~~

THEMATIC GEOLOGY MAPS—BRIDGEND AREA

SHEET 8A: HYDROGEOLOGY (BRIDGEND)

For legend see sheet 8

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