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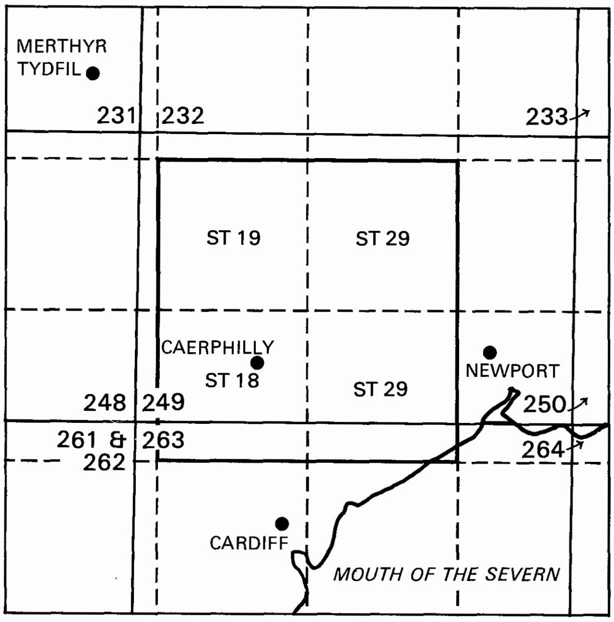

The hard-rock resources of the country around Caerphilly, South Wales

Description of parts of 1:50 000 geological sheets 249 and 263

K. A. McL. Adlam, D. J. Harrison and J. B. L. Wild

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PREFACE

National resources of many industrial minerals may seem so large that stock-taking appears unnecessary, but the demand for minerals and for land for all purposes is intensifying and it has become increasingly clear in recent years that regional assessments of resources of these minerals should be undertaken. The publication of information about the quantity and quality of deposits over large areas is intended to provide a comprehensive factual background against which planning decisions can be made.

Following recommendations by the Welsh Office, the Department of the Environment commissioned the Industrial Minerals Assessment Unit of the Institute in 1981 to undertake a feasibility study to investigate methods for assessing hard rock resources in the Caerphilly-Pontypridd area and Swansea-Neath area of South Wales. The results and recommendations of the feasibility study were applied to an assessment survey of the hard rock resources of the Caerphilly area in 1982. The work was financed by the Department of the Environment for the Welsh Office and has been undertaken with the co-operation of members of the British Quarrying and Slag Federation (now superseded by the British Aggregate Construction Materials Industries).

The report describes the hard rock resources of some 400 km^2 of country in the Caerphilly area of South Wales, shown on the accompanying 1:50 000 scale resource map. The report also includes the data obtained during the feasibility study from the Pontypridd and Swansea areas. The assessment was conducted by K. A. McL Adlam, D. J. Harrison and J. B. L. Wild. R. Thompson, H. Mathers and G. P. Wealthall provided additional support.

The assessment is based on geological surveys at the 1:10 560 and 1:10 000 scales by H. C. Squirrell, R. A. Downing, G. D. E. Lewis, B. Kelk and A. W. Woodland (Sheet 249) and R. A. Waters (Sheet 263).

J. D. Burnell ISO and G. I. Coleman (Land Agents) were responsible for negotiating access to land for drilling. The ready co-operation of land owners, tenants, quarrying companies and the National Coal Board in this work is gratefully acknowledged.

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SUMMARY

The study of borehole cores and surface samples of Pennant sandstone and other hard rocks, together with information from the records and geological maps of the Institute of Geological Sciences, form the basis of the assessment of hard rock resources in the Caerphilly area of South Wales.

The hard rocks are classified on their aggregate properties and the accompanying 1:50 000 resource map shows the distribution of the groups of aggregate materials recognised at outcrop. The geology and aggregate properties of the hard rocks are described and the survey data are listed in the Appendices.

The survey has shown that Pennant sandstone shows little variation in its aggregate properties, although the effects of weathering and the occurrence of mudstone bands locally downgrades what is otherwise a high grade, polish-resistant aggregate material. Dolomite and limestone aggregates from the Carboniferous Limestone are more susceptible to polishing, although they are generally slightly superior to Pennant sandstone aggregates in strength and resistance to abrasion. The sandstones and conglomerates of the Lower and Middle Coal Measures, Millstone Grit and Old Red Sandstone produce aggregates of variable quality, although most Old Red Sandstone aggregates are relatively weak and porous.

Bibliographical Reference

ADLAM, K. A. Mc.L., HARRISON, D. J., WILD, J. B. L. 1984. The hard rock resources of the country around Caerphilly, South Wales: description of parts of 1:50 000 geological sheets 249 and 263. **Miner. Assess. Rep. Inst. Geol. Sci.**, No. 140.

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INTRODUCTION

Hard rock resources contribute over one half of the United Kingdom's aggregates requirements, but in South Wales, where there is a lack of indigenous sand and gravel, hard rock resources assume an even greater importance. In recent years South Wales has produced over 12 million tonnes of aggregate annually (South Wales Working Party on Aggregates Interim Report, 1977) and approximately 80 per cent of this output has been crushed hard rock. Carboniferous Limestone is the most important rock in terms of tonnage but Pennant sandstone is extracted from four quarries within the South Wales Coalfield.

Although resources of hard rocks are extensive in South Wales, concern for environmental planning has made it clear that more detailed and comprehensive information on hard rock resources is required. This information is needed to ensure that land use and mineral planning by central and local government is carried out against a background of relevant geological data. The provision of such information relating to the geological, physical and mechanical characteristics of the hard rocks of the Caerphilly area is the objective of the present survey.

The methods of assessment were developed from a feasibility study (Harrison and others, 1982) which determined the most effective field and laboratory procedures for assessing hard rock resources. The materials for study have been obtained from cored boreholes and from an extensive collection of samples from natural sections and quarry faces. The petrological and mineralogical properties of the samples were determined primarily in the field, but the physical and mechanical properties of all samples have been investigated in the laboratory. Conventional geological nomenclature has been used for the technical descriptions; a glossary is appended. The rocks are classified in terms of their strength (AIV) and durability (AAV, PSV) so that the relationship between hard rock category and possible end use may be deduced.

Detailed results are set out in this report and its appendices, but the accompanying resource map gives a more generalised summary of the regional variations in aggregate properties.

DESCRIPTION OF THE DISTRICT

The district[1] embraces parts of Mid Glamorgan, South Glamorgan and Gwent (Figure 1) and includes the south-eastern part of the South Wales Coalfield. The coalfield area is typified by 'ribbon development', that is, most of the buildings and lines of communication follow the valleys because of the steepness of their sides. Because of the limit to expansion there are few large towns, the biggest being Caerphilly with a population of about 30 000. The major urban centres lie outside the coalfield. Cwmbran, in the north-east of the district, has expanded rapidly in recent years, and Cardiff and Newport, which lie adjacent to the southern and south-eastern margins of the district, are major industrial towns and ports. A modern network of roads (including the M4 motorway) and railways connects the district with the surrounding areas.

[1] In this report, the word 'district' is used to denote the area depicted on the accompanying resource map.

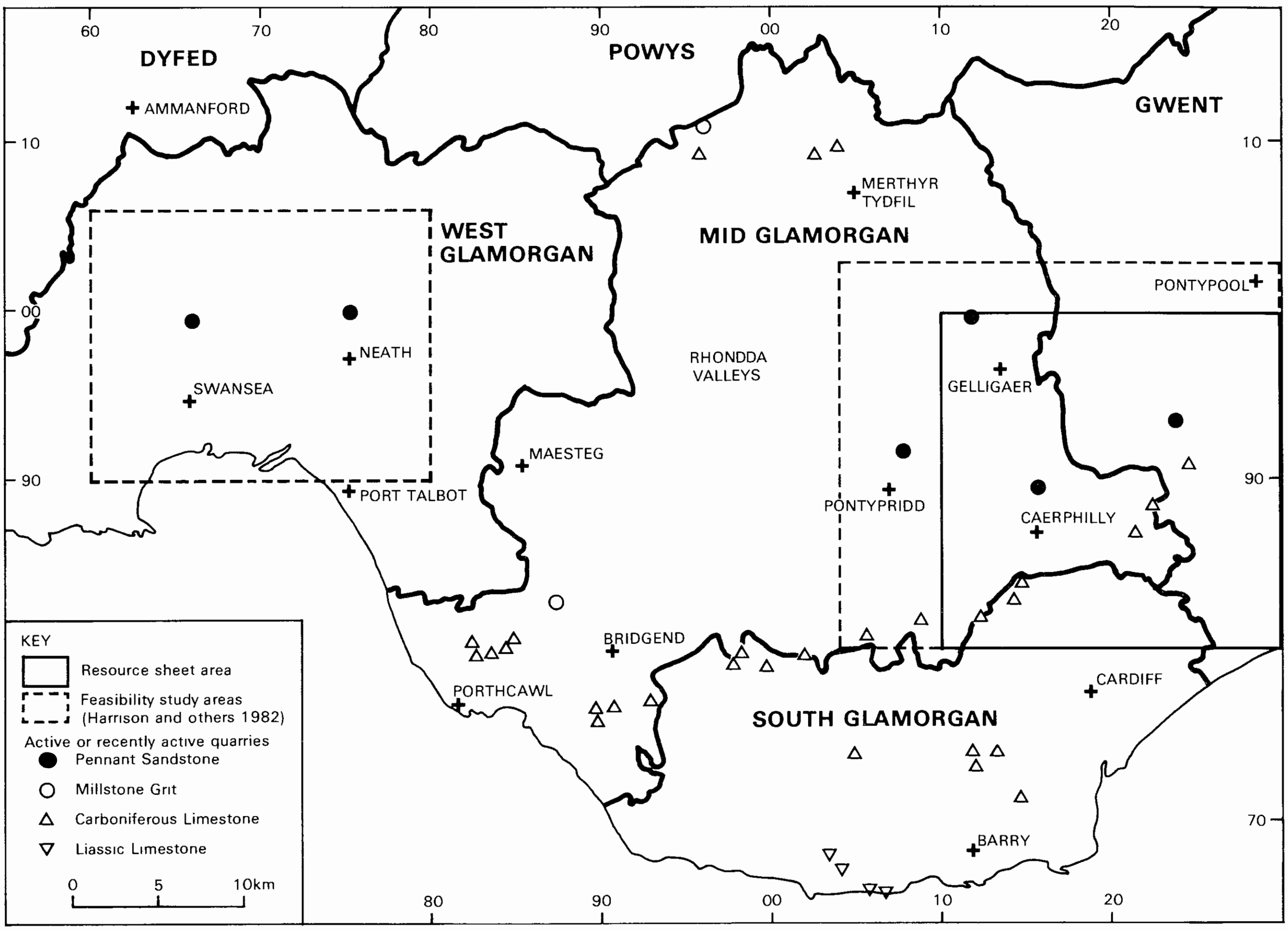


Figure 1 Location of the district.

The local economy is based largely on coal mining and on various manufacturing industries. Pastoral farming and forestry are carried out on the generally poor land within the Coalfield, but agriculture is particularly significant in areas outside it. In the past, limestone and sandstone were worked in small quarries for building and walling and some limestone was extracted for lime-burning. More recently larger quarries have been developed for the production of aggregates. Currently, five quarries within the district produce dolomite for use as roadstone, concrete aggregate and railway ballast, and a further two quarries work Pennant sandstone for the production of a variety of aggregate materials, including road-surfacing aggregates.

Topography

The district is characterised by a variety of landscapes ranging from the high moorlands of the coalfield to the flat-lying areas bordering the Bristol Channel in the south-east of the district (Figure 2). In the north and west of the district the deeply dissected Pennant Measures plateau rises to over 305 m (1 000 ft) at Mynydd Maen (472 m), Cefn Crib (391 m), Mynydd y Lan (385 m), Mynydd Machen (362 m), Gelligaer Common (360 m), Mynydd Eglwysilan (355 m) and Mynydd y Grug (345 m). The Carboniferous Limestone and the sandstone units within the Old Red Sandstone form prominent ridges bordering the coalfield. The south-eastern part of the district is typified by a lower, gently undulating landscape and by the alluvial flats east of Cardiff.

The plateau is drained by deeply incised southward-flowing rivers; the most important are the Taff, Rhymney, Sirhowy and Ebbw. The rivers reach the lower-lying areas south of the coalfield through gaps cut in the bordering ridges, the most spectacular being the steep-sided gorge of the Taff at Taff's Well.

General Geology

The district is covered by parts of 1:50 000 Geological Sheets 249 (Newport) and 263 (Cardiff), and the following general geological account is based mainly on published information in the Newport memoir (Squirrell and others, 1969).

The district lies mostly within the south-eastern part of the South Wales Coalfield, an east-west-trending asymmetric downfold in which is preserved some 2 500 m of sedimentary rocks traditionally referred to as the Coal Measures. The outcrops of the Lower and Middle Coal Measures mainly occupy a narrow peripheral area of the coalfield while the Upper Coal (or Pennant) Measures occupy the central plateau. The district also includes narrow outcrops of Millstone Grit and Carboniferous Limestone surrounding the coalfield and a large tract of Old Red Sandstone. Small areas (mainly drift-covered) of Triassic mudstone, Jurassic limestones and clays and Silurian strata occur in the south and south-east of the distict.

HARD ROCKS

For the purposes of this survey the term 'hard rock' has been taken to include any rock which is likely to be potentially useful for aggregate. This definition therefore includes the sandstones and greywackes of the Coal Measures, the sandstones and conglomerates of the Millstone Grit, the dolomites and limestones of the Carboniferous Limestone and the sandstones and conglomerates of the Old Red Sandstone (Figure 3). The following

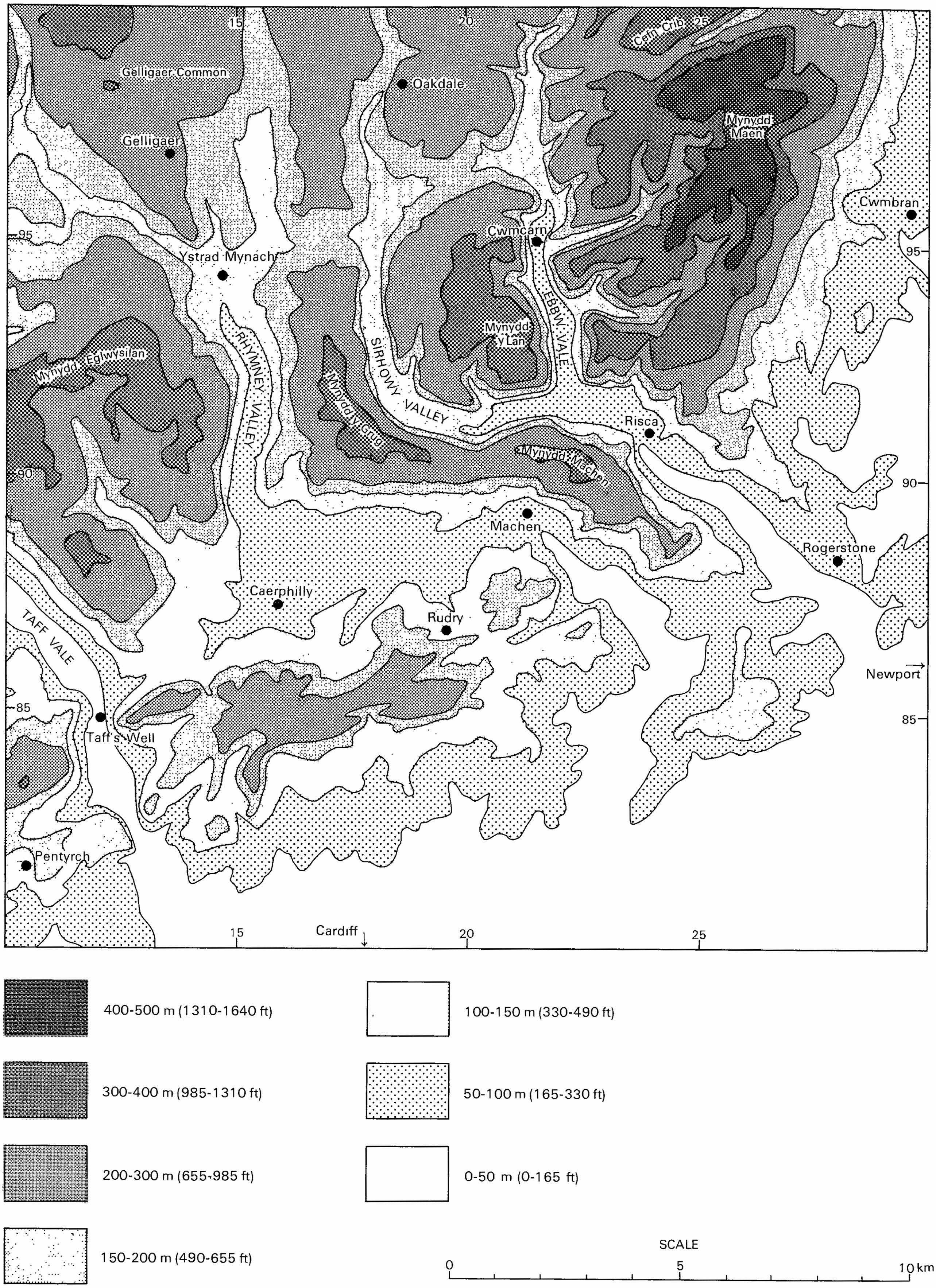


Figure 2 Topography of the district.

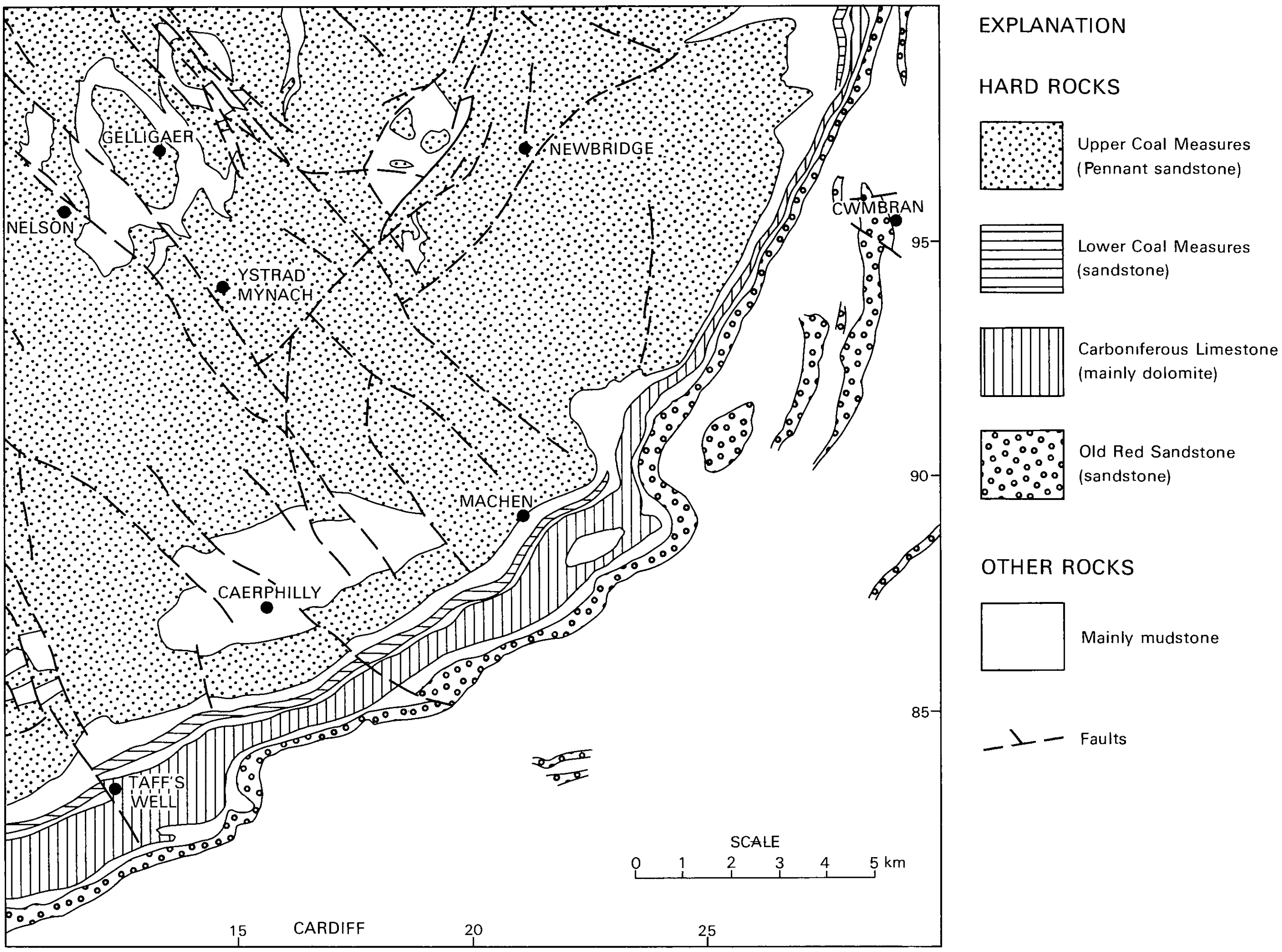


Figure 3 Distribution of the hard rocks.

account briefly outlines the stratigraphy and lithology of these hard rocks.

Old Red Sandstone

The Old Red Sandstone consists mainly of mudstones and soft sandstones with some harder sandstones, conglomerates and limestones. It is divided into the Upper and Lower Old Red Sandstone, the latter being subdivided into the Raglan Marl Group, St Maughan's Group and Brownstone Group (Table 1). Red mudstones predominate in the Raglan Marl Group and St Maughan's Group, but they are subordinate in the Brownstone Group and Upper Old Red Sandstone, which contain a high proportion of sandstones. These reddish brown sandstones vary from soft, fine-grained argillaceous sandstones, to harder, coarse-grained, sometimes conglomeratic sandstones. Their bedding varies from flaggy to massive and the rocks are typically cross-bedded. Mica occurs commonly. Beds of pedogenic limestone up to 8 m thick occur locally within the Raglan Marl and St Maughan's Group.

The thickness of the various divisions of the Old Red Sandstone are given in Table 1. Most of the sandstone beds that occur within the Raglan Marl and St Maughan's Group are relatively thin (6–15 m), but thicker sandstones are developed locally at several horizons, and where mapped, are shown on the resource map. Many of these sandstones are laterally impersistent and of variable thickness. Most of the Brownstone Group consists of sandstones which form a prominent escarpment running from just east of Pontypool south-westwards through Risca and Machen to Radyr in the south-west of the district. Quartz conglomerates and hard sandstones form a laterally impersistent basal unit of the Upper Old Red Sandstone. They are overlain by a mixed sequence of soft sandstones and marls. The conglomerates, consisting of quartz pebbles in a quartz matrix, occur in lenticular beds up to 24 m thick, and where best developed are shown on the resource map.

Carboniferous Limestone

The narrow outcrop of Carboniferous Limestone between Creigiau and Pontypool is almost completely dolomitised, although some unaltered limestones are preserved in the upper part of the sequence in the south-west.

The sequence has been divided lithologically as shown in Table 2.

In general the sequence thins from the south-west to the north-east with local variations. For example, the Main Limestone attains 540 m at Taff's Well, only 300 m at Thornhill and at Rudry and thins from 210 m at Machen and 125 m at Risca to 15 m at Llanderfel. Ninety metres have been recorded at Pontypool.

The description of the **Lower Limestone Shale** sequence given in the Newport Memoir is partly incorrect because the authors failed to recognise the true base of the division. Recent remapping of the Cardiff Sheet has established a three-fold lithological classification of the Lower Limestone Shale which should be applied throughout the Caerphilly district. Thus, a lower mudstone division (about 50 per cent limestone and 50 per cent mudstone) is overlain by a limestone and dolomite division which in turn is overlain by an upper mudstone division (about 20 per cent limestone and 80 per cent mudstone). The limestone division consists of massive crinoidal and oolitic limestones which are locally affected by dolomitisation and iron-staining.

Table 1 Geological sequence (solid rocks) in the Caerphilly district.

	Thickness (m)
Jurassic	
Lower Lias: clays and limestones	up to 20
Triassic	
Penarth Group: mudstones, sandstones and limestones	7
Mercia Mudstone Group: mudstones	113
Major unconformity	
Carboniferous	
Coal Measures	
Upper Coal (Pennant) Measures -	
Grovesend Beds: mudstones and sandstones, few coals	up to 152
Minor unconformity	
Hughes Beds: sandstones and mudstones, few coals	122 - 198
Brithdir Beds: sandstones and mudstones, few coals	46 - 244
Rhondda Beds: sandstones and mudstones, few coals	46 - 204
Llynfi Beds: mudstones and sandstones, few coals	34 - 100
Middle Coal Measures: mudstones and coals, subordinate sandstones	107 - 213
Lower Coal Measures: mudstones and coals, subordinate sandstones	82 - 183
Millstone Grit: mudstones, sandstones and conglomerates	37 - 55
unconformity	
Carboniferous Limestone	
Main Limestone: limestone and dolomite	12 - 540
Lower Limestone Shale: mudstones, limestones and dolomites	36 - 107
Devonian	
Upper Old Red Sandstone: conglomerates, sandstones and mudstones	76 - 122
unconformity	
Lower Old Red Sandstone	
Brownstone Group: sandstones, few mudstones	122 - 183
St. Maughan's Group: mudstones, sandstones, limestones and conlomerates	457 - 610
Silurian	
Raglan Marl Group: mudstones, sandstones and limestones	335 - 610
Ludlow Series: mudstones with subordinate sandstones, siltstones and limestones	c 50

Despite it considerable thickness the **Main Limestone** has not been subdivide in the Newport Memoir, although it contains a variety of lithologies. In the south-western part of the district the uppermost 100 m or so consist of predominantly undolomitised oolitic limestone but this division is cut out north-east of Taffs Well [ST 125 830] by the Namurian unconformity. The dolomites forming the lower division (Plate 1) are typically massive or thickly bedded, mid-grey and fine- to medium-grained. Locally, particularly in the Thornhill - Cefn Onn - Rudry area, the upper part of the dolomite sequence contains very fine-grained porcellanous dolomites interbedded with coarser-grained dolomites. These deposits also contain thin mudstone beds. Locally some coarsely granular dolomites are developed. Along parts of its outcrop the Main Limestone contains hematite deposits along joints and bedding planes and in cavities in the rock. Associated minerals are baryte, calcite and galena.

The Main Limestone is the most extensively quarried formation in the district, supplying a variety of aggregates for the construction industry and small amounts of high purity dolomite for the steel industry.

Millstone Grit

The Millstone Grit consists of two lithological divisions, an impersistent, basal sandstone and conglomerate group up to 25 m thick, overlain by 21 to 53 m of mudstones. The basal sandstones and conglomerates (Plate 2) are best developed between Machen and Risca and near Pontypool, but but are thin or absent throughout the remainder of the area. The fine- to coarse-grained, well cemented sandstones are flaggy to massively bedded and are commonly interbedded with massive grits and quartz conglomerates.

Lower and Middle Coal Measures

The Lower and Middle Coal Measures crop out along a narrow strip of country around the edge of the coalfield. As well as coals and their seatearths, the sequence contains rocks ranging from mudstones, through siltstones to coarse-grained sandstones. However, mudstones predominate and relatively thick sandstones are only developed in the lower part of the Lower Coal Measures and, to a lesser degree, in the upper part of the Middle Coal Measures. Most of the sandstones are massive, white or grey, coarse and quartzitic with conglomeratic beds, but well bedded, fine-grained, micaceous quartzitic sandstones (Plate 3) are developed at some horizones. Feldspar is a minor constituent but is locally common. The sandstones are laterally impersistent and are highly variable in thickness although individual beds in the lower part of the Lower Coal Measures average between 20 and 30 m. The thickest sandstone beds that have been mapped are shown on the resource map.

Table 2 Lithological divisions of the Carboniferous Limestone.

		Range of thickness (m)
Main Limestone		
Upper division	limestones with some dolomite	0 - 105
Lower division	dolomite with dolomitic limestone	12 - 425
Lower Limestone	mainly mudstones with some limestone and dolomite	50 - 112

Upper Coal (Pennant) Measures

The Upper Coal Measures are up to 850 m thick and comprise the largest outcrop of hard rocks in the district. Sandstones (traditionally referred to as Pennant sandstone) form an appreciable part of the sequence and are interbedded at irregular intervals with relatively thin mudstones and coals (Plate 4). Of the coals occurring in the Upper Coal Measures, only three have been exploited to any large extent, namely the No. 2 Rhondda, the Brithdir and the Mynyddislwyn (Figure 4), though a number of others have been worked on a smaller scale.

The sandstones are typically feldspathic and micaceous, poorly sorted, fine- to coarse-grained and contain a high proportion of lithic fragments. Petrographically they are classified as lithic greywacke or subgreywacke. The sandstones are typically bluish grey when fresh but rapidly become rusty brown on weathering. Large scale cross-bedding is a common feature (Plate 5), but massive units up to 6 m in thickness have been observed. Lamination is prominent in some sandstones and flaggy beds are also present, particularly in weathered outcrops (Plate 6). Mudstones occur as bedded units (forming the upper part of cyclothems) and more commonly infilling highly irregular channels within the sandstone (Plate 7). Some thin pebbly and conglomeratic layers are present with pebbles of quartz, coal and ironstone; carbonaceous layers also occur (Plate 8).

The depth of subaerial weathering is highly variable and commmonly ranges between 2 and 10 m. It is influenced by the distribution of joints and to a lesser degree by the occurrence of channell-fill mudstones. The joints are essentially vertical and are typically developed in at least 2 orthogonal sets, at spacings of about one metre.

The Pennant Measures outcrop is marked by numerous disused quarries but currently sandstone is extracted from two quarries near Gelligaer and Abercarn for the production of crushed rock aggregates.

The Pennant Measures are subdivided (Woodland and others, 1957) by using some of the more persistent coal seams as convenient markers, into two major groups and six subgroups:

Upper Pennant Measures	**Lower Pennant Measures**
Grovesend Beds	Brithdir Beds
Swansea Beds	Rhondda Beds
Hughes Beds	Llynfi Beds

The Swansea Beds are apparently absent in the Caerphilly area due to the presence of an unconformity or perhaps to attenuation and facies changes associated with the Usk Axis in the east of the district.

The basal sandstones of the Pennant Measures are pale grey orthoquartzites, similar to those of the Lower and Middle Coal Measures. A feature of the Lower Pennant Measures of the Caerphilly district is the presence of red and green mudstones and siltstones interbedded with the predominantly grey mudstones and white quartzites. These are found mainly in the Llynfi and Rhondda Beds and are informally known as the 'Deri Beds'. Pennant sandstone facies (greywacke) sedimentation was firmly established by Rhondda Bed times in the south-west of the district, and this facies gradually spread north-eastwards, until it became firmly established over the whole of the coalfield by the time the Brithdir Beds were deposited.

Lithological and thickness variations in the Pennant Measures are indicated in Figure 4 and are summarised below. More detailed stratigraphical information is available in the Newport memior (Squirell and others, 1969). The regional distribution of the various subdivisions of the Pennant Measures is shown in Figure 5.

The **Llynfi Beds** crop out along a narrow belt of ground around the rim of the coalfield. Their maximum thickness, of about 100 m, is attained in the south-west of the district and they thin gradually eastwards to around 30 m at Cwmcarn. The measures are variable, but are dominated by mudstones with a few, relatively thin units of sandstone.

The **Rhondda Beds** crop out along a narrow belt of ground around the edge of the coalfield and are thickest (204 m) in the west of the district, thinning to about 46 m along the south-eastern crop. The measures are very variable in lithology, containing sandstones and mudstones in equal proportions, except in some easterly areas where sandstones predominate.

In much of the western and central parts of the district between 43 and 59 m of conglomerates and sandstones (the Saron Sandstone) occur above the basal coal (No 2 Rhondda), but elsewhere these are replaced to varying degrees by mudstones. Above the Saron Sandstone lies a predominantly argillaceous group of beds up to 73 m thick in the west, but thinning gradually and becoming more arenaceous eastwards. The uppermost part of the Rhondda Beds contains mudstones and sandstones in approximately equal proportions.

The **Brithdir Beds** crop out extensively in the Taff valley, in the lower Sirhowy, Ebbw and Carn valleys, and in a narrow belt of ground around the edge of the coalfield. The group is thickest (244 m) in the south-west but thins north-eastwards to under 60 m near Pontypool. The sequence consists largely of sandstones with subordinate mudstones, seatearths and coals. Some mudstones may attain 30 m in thickness, particularly in the west of the area.

The outcrop of the **Hughes Beds** covers a greater area than any other division of the Pennant Measures. Where the beds are completely preserved in the Llantwit-Caerphilly, Abercynon and Blackwood synclines, the thickness ranges from 152 to 198 m except in the north-east of the district, near Tirpentwys, where it is about 122 m. Massive sandstones make up most of the sequence but mudstones with coal seams occur at several horizons, particularly in the south-west of the district. Most of the mudstones are relatively thin, but one group of mudstones in the lower part of the Hughes Beds, reaches 40 m in thickness in the southern Taff Valley.

The **Grovesend Beds** crop out in the Llantwit-Caerphilly Syncline in the south, and in the synclinal belt of the Abercynon and Blackwood synclines in the north. The thickest development, some 150 m, occurs in the

Plate 1 A dissected fluvioglacial fan/delta in Glen Quey [NN 988 035]. The feature was formed by glacial meltwaters which flowed north-eastwards into a temporary, ice-ponded lake in lower Glen Devon. (D3444)

Plate 2 Glen Queich viewed from the south-east [NO 049 030]. The gorge through which the River South Queich now flows was cut by glacial meltwaters escaping from Glen Devon whilst the lower reaches of that valley were blocked by ice. (C3938)

Plate 3 Lower Coal Measures. Well-bedded quartzitic sandstones underlain by mudstone. Waun Fawr Quarry, Risca. [ST 2304 9100].

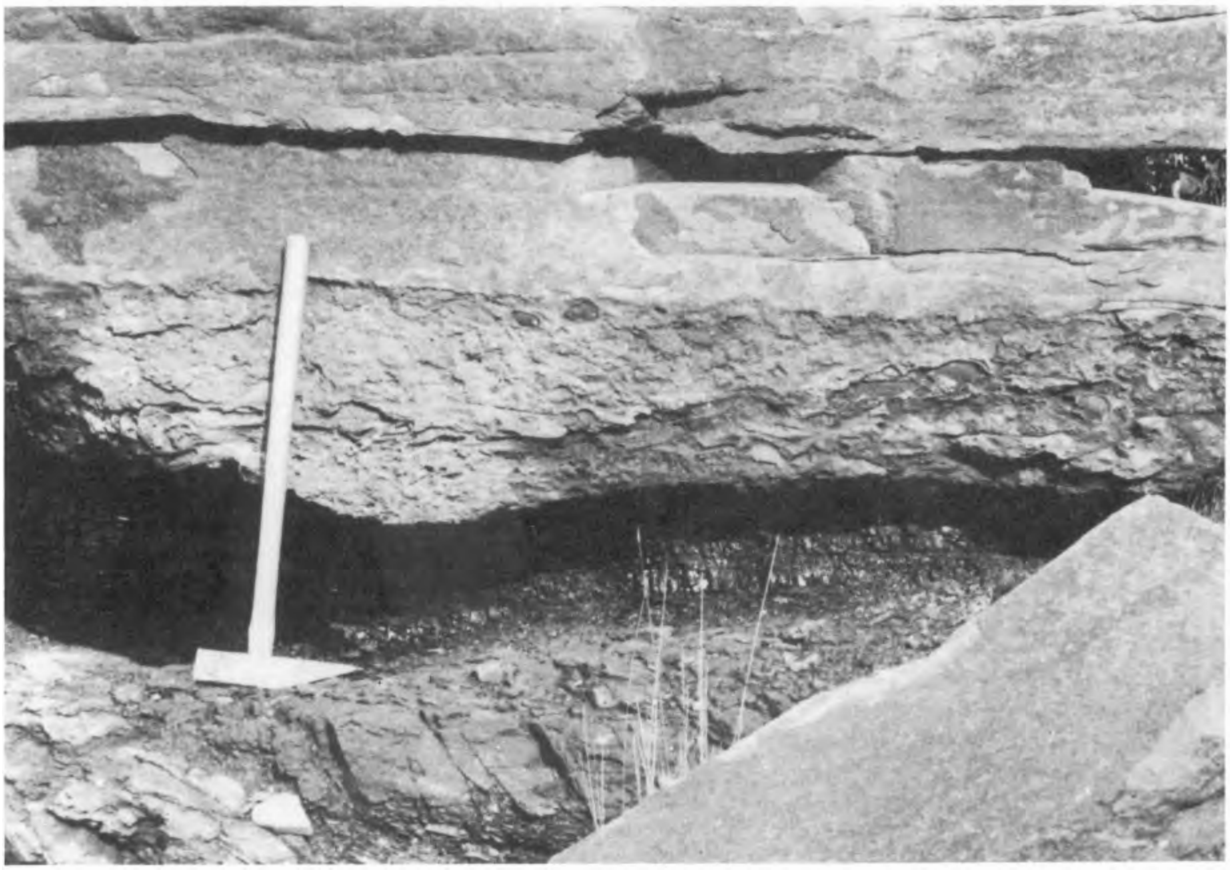


Plate 4 Pennant Sandstone. Coal seam within the Hughes Beds. Trehir Quarry, Bedwas. [ST 1157 9958].

Plate 5 Pennant Sandstone.
Well-bedded sandstones.
Pen-cae-mawr Quarry, Gelligaer.
[ST 1157 9958].

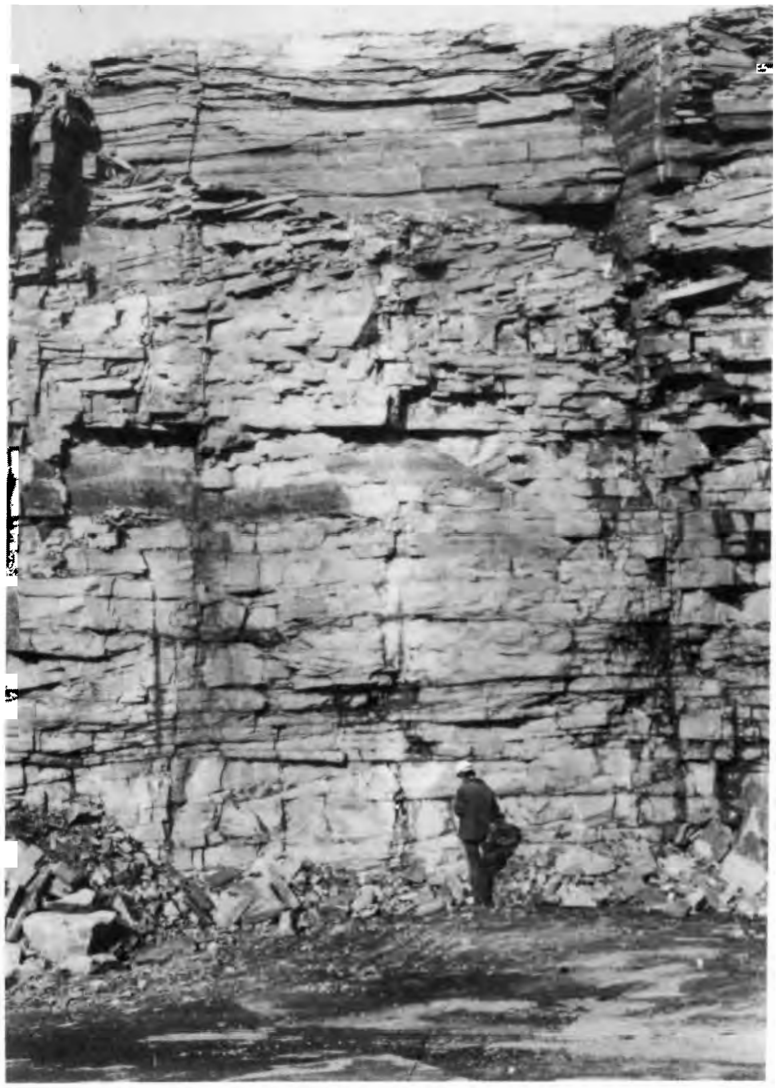


Plate 6 Pennant Sandstone.
Partially weathered, near-surface flaggy beds. Pen-cae-mawr Quarry, Gelligaer.
[ST 1157 9958].

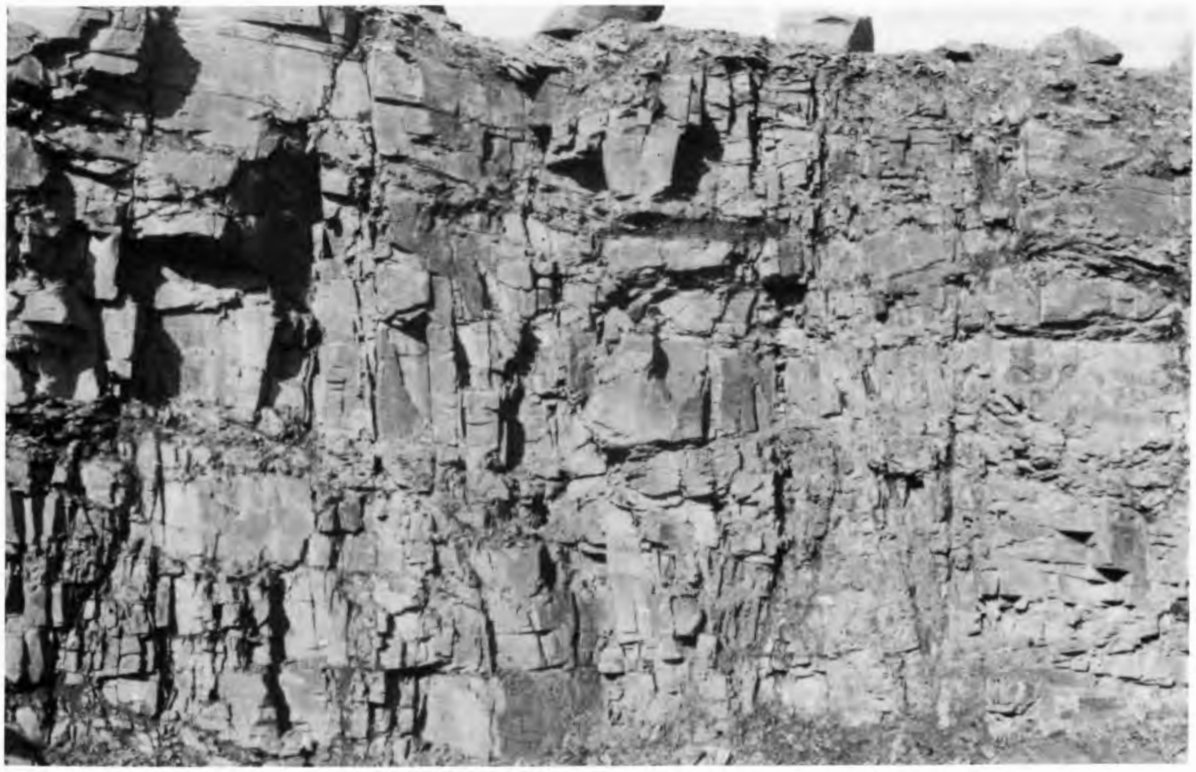


Plate 7 Irregular mudstone lenses in massively-bedded sandstone. Craig-yr-Hesg Quarry, Pontypridd. [St 0772 9170].

Plate 8 Pennant Sandstone. Carbonaceous plant fragments. Craig-yr-Hesg Quarry, Pontypridd. [ST 0772 9170].

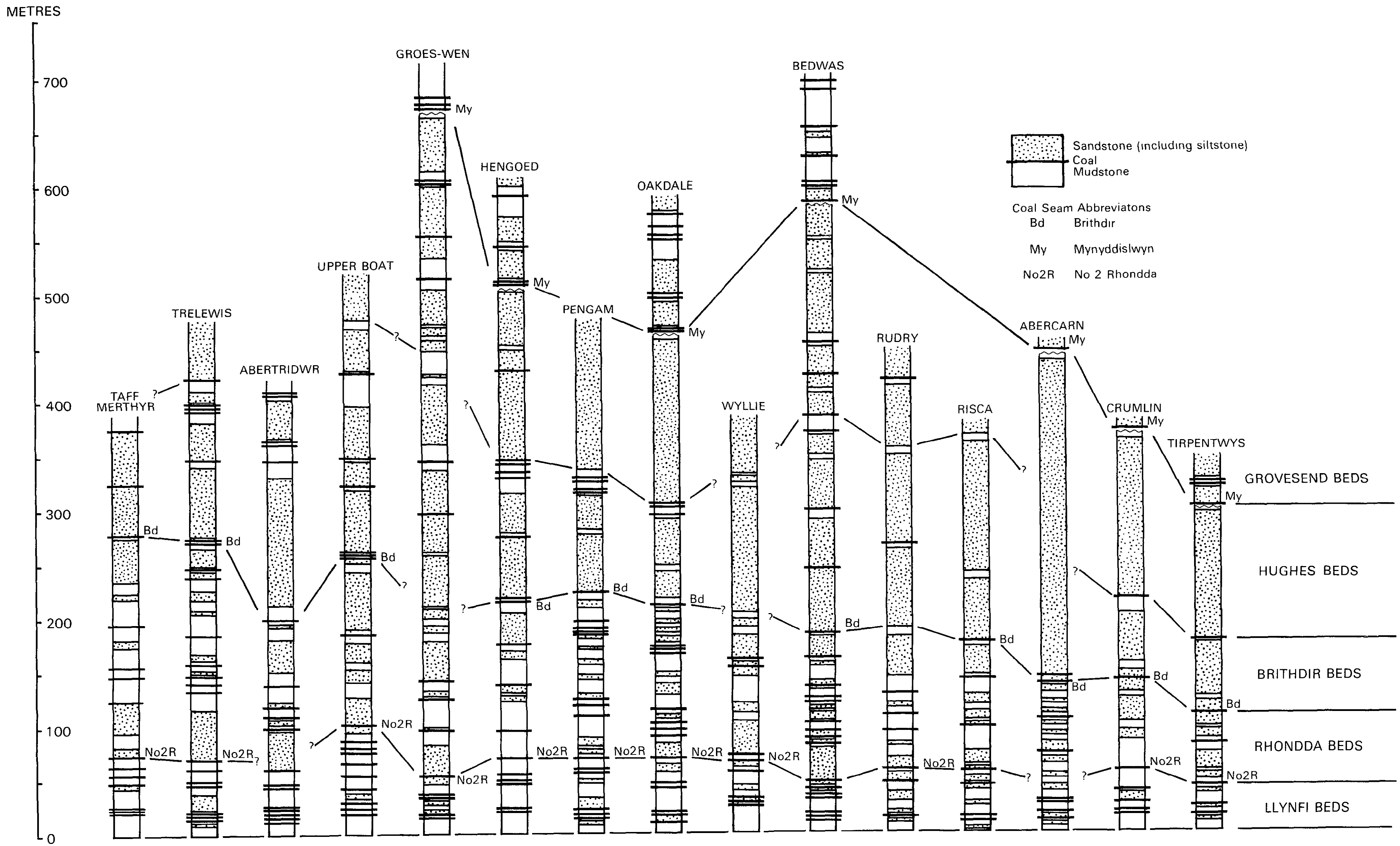


Figure 4 Generalised vertical sections of the upper Coal (Pennant) Measures.

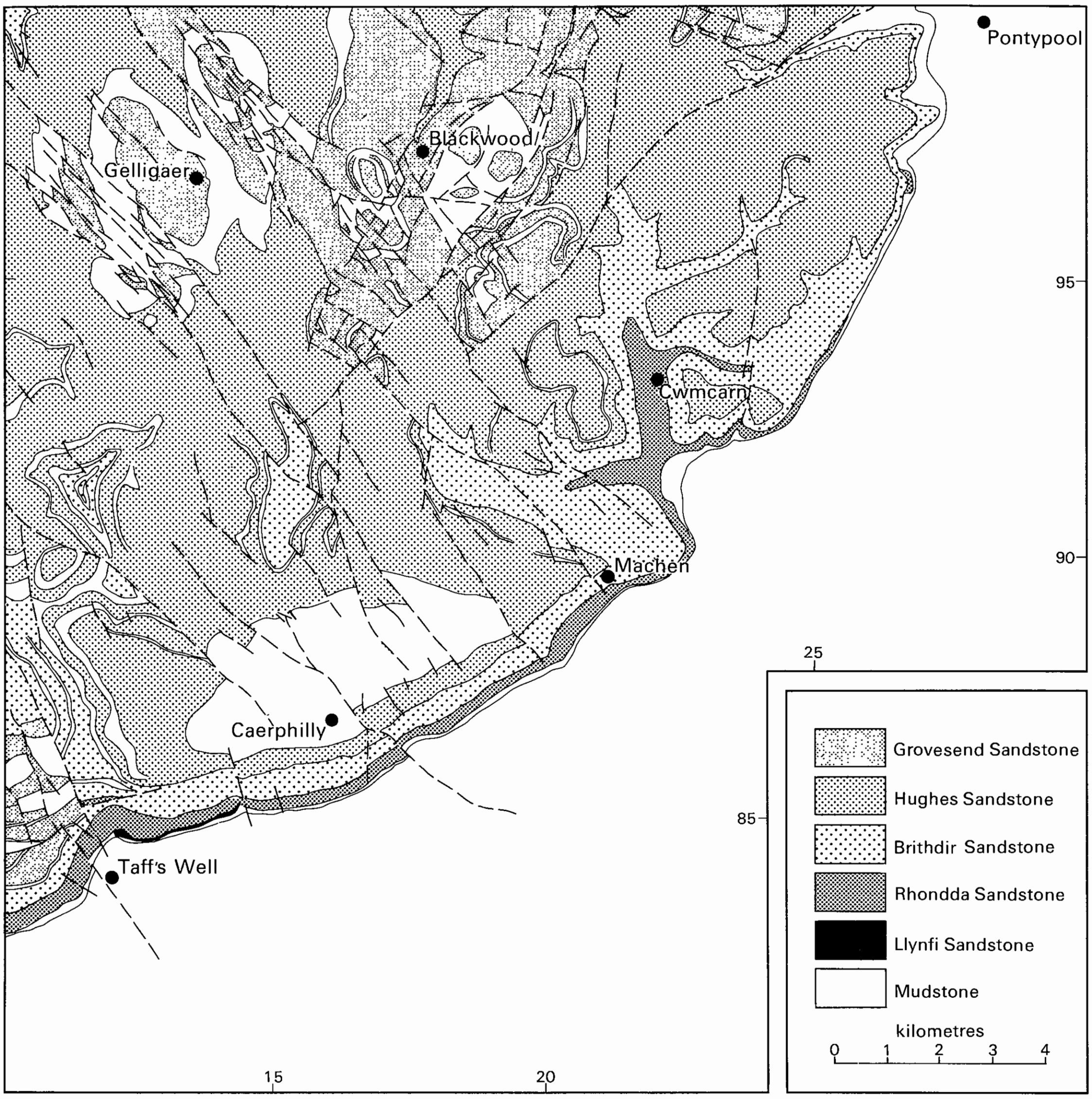


Figure 5 Geological map of the Upper Coal (Pennant) Measures.

small outcrop in the south-west of the district, but around 140 m of Grovesend Beds are present in the large outcrop around Caerphilly. In the north, up to 107 m of Grovesend Beds are developed in the Gelligaer area, about 140 m in the Blackwood area, and 49 m in the Cefn Crib area.

The Grovesend Beds contain a mixed sequence of mudstones, coals and sandstones. Mudstones are particularly common in the southern outcrops and are predominant in the Caerphilly area. In northern outcrops, a maximum of 43 m of mudstones overlie the Mynyddislwyn seam in the Gelligaer-Fleur-de-Lis area, but east of this area the basal measures contain up to 27 m of sandstone. The beds above these measures contain between 18 and 34 m of sandstones overlain by 18 to 49 m of mudstones. Above these beds is a series of sandstones and mudstones up to 55 m thick near Blackwood and 67 m thick west of Treforest.

STRUCTURE

The major structural features of the district are shown in Figure 6. The main elements are the Usk Anticline and the Coalfield Syncline, the latter being subdivided into the Llantwit-Caerphilly and Abercynon synclines separated by the Pontypridd Anticline. Superimposed upon these structures are a number of minor folds, while faults occur in varying abundance and complexity, most commonly in the Coal Measures. The structures were produced by post-Carboniferous earth movements.

The major structure affecting the Old Red Sandstone is the Usk Anticline, a symmetrical fold which results in dips of between 10° and 30°. Subsidiary flexures near Tongwynlais and Risca affect the Upper Old Redstone Sandstone and Carboniferous Limestone. The Carboniferous Limestone usually dips at angles between 20° and 60°, but the local structure may be complex involving thrusting and folding within the confines of the outcrop. Throughout most of the Coal Measures outcrop, dips values are shallow (5° to 20°) but they are steeper on the southern limb of the Llantwit-Caerphilly Syncline, generally varying between 25° and 60°. Numerous faults affect the Coal Measures strata, particularly in the north-west and south-west of the outcrop. Most of the faults cross the fold axes and trend north-west to south-east, but others have an east-west trend. Thrust faults occur in the south-west of the district. Joint systems, the dominant sets tending to follow the major fault trends, are an important structural element in the Pennant Measures.

DRIFT

Drift deposits cover large areas of the district (Figure 7). The glacial deposits are broadly divisible into boulder clay, glacial sand and gravel and morainic drift.

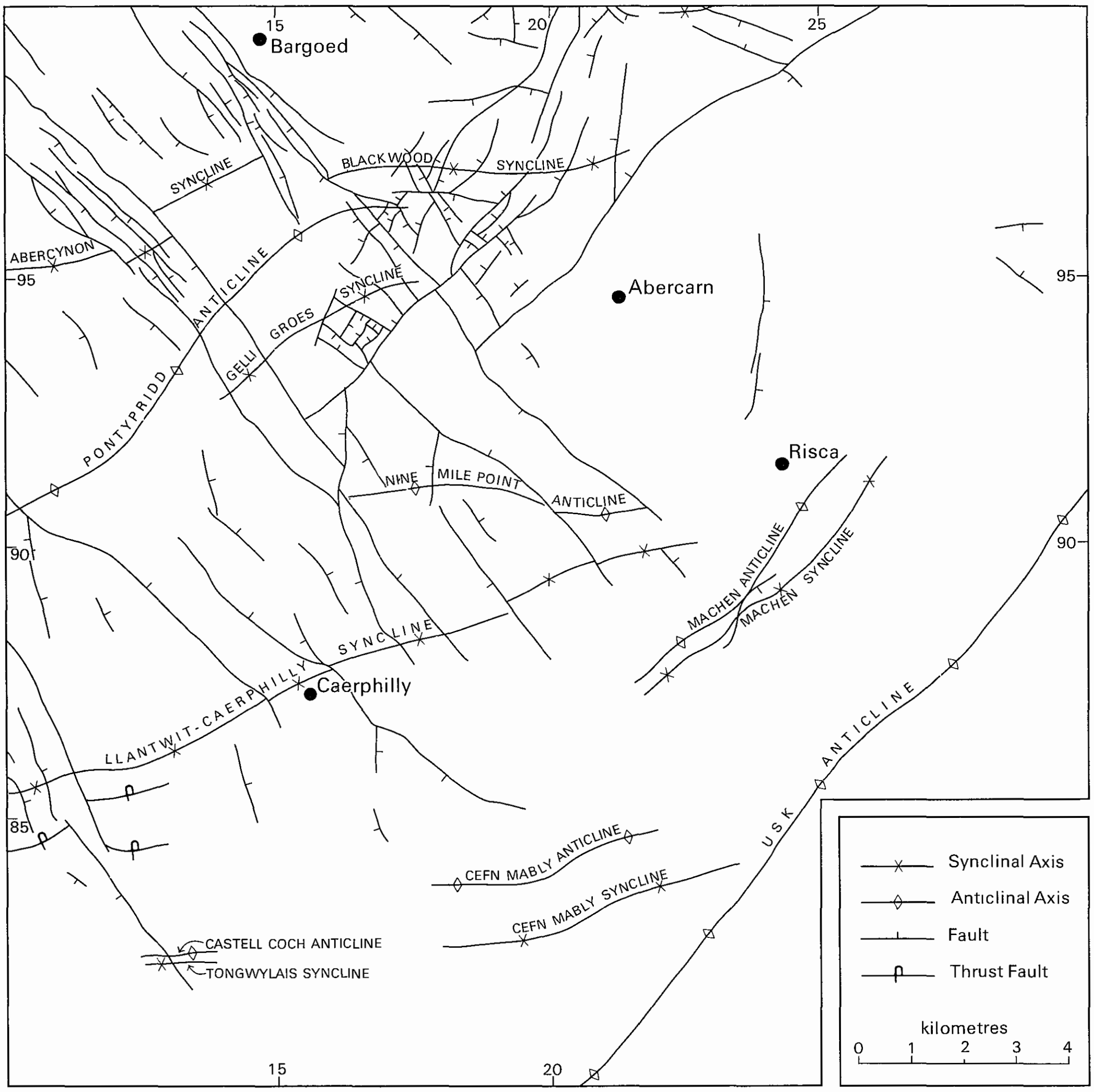


Figure 6 Structure.

In general the boulder clay occurs in the northern reaches of the valleys and passes down-stream into sand and gravel. The gravelly morainic drift occurs in hummocky masses around the southern rim of the coalfield.

The most widespread deposit is boulder clay, which constitutes the bulk of the valley-fill drift, forms a veneer on the middle slopes of the valleys, tends to occur on the lee slopes of hills, and is present in hollows on high ground. Thicknesses of up to 30 m are attained in the northern reaches of the valleys. Gravity accumulations ('Head') veneer most valley slopes and landslips are common in the coalfield. Alluvium (gravelly, silty or sandy) forms flat spreads in the valley bottoms.

ASSESSMENT OF RESOURCES

The assessment is based on a field survey which provided samples for study in the laboratory and the data for interpretation. The procedures adopted are similar to those investigated in the Hard Rock Feasibility Study (Harrison and others, 1982).

Procedures

FIELD SURVEY

Because up-to-date 1:10 560 geological maps were available, fieldwork primarily involved examining the extensive exposures of hard rocks and collecting bulk samples (each about 30 kg in weight) from those that were relatively unweathered. A total of 182 bulk samples was collected during the survey. Additionally, 18 boreholes were drilled to target depths ranging from 20 to 72 m, and continuous cores of at least 72 mm diameter were obtained. Twelve boreholes were drilled by contractors using air-flush methods and 6 by IGS using water-flush methods. A similar, and acceptable rate of bit-wear was recorded with both methods. In general the recovery of sandstone and limestone cores was almost 100 per cent, particularly when air-flush methods were employed, but some difficulties were encountered with broken and shattered strata and unconsolidated superficial deposits. All samples, whether collected from exposures or boreholes, were lithologically logged in the field. Most of the boreholes were also logged by a portable Mount Sopris Gamma logger which gave continuous readings of the natural radioactivity of the rocks, and hence indicated the relative amounts of clay in the strata and helped to locate clay bands and coals accurately.

LABORATORY PROGRAMME

Lithological, petrological and mineralogical determinations were made on limestone cores and on selected sandstone samples using a combination of microscopical and thin-section techniques. The bulk samples and core samples (mostly 5 m lengths of core) were prepared for testing by crushing in a laboratory crusher (Humboldt

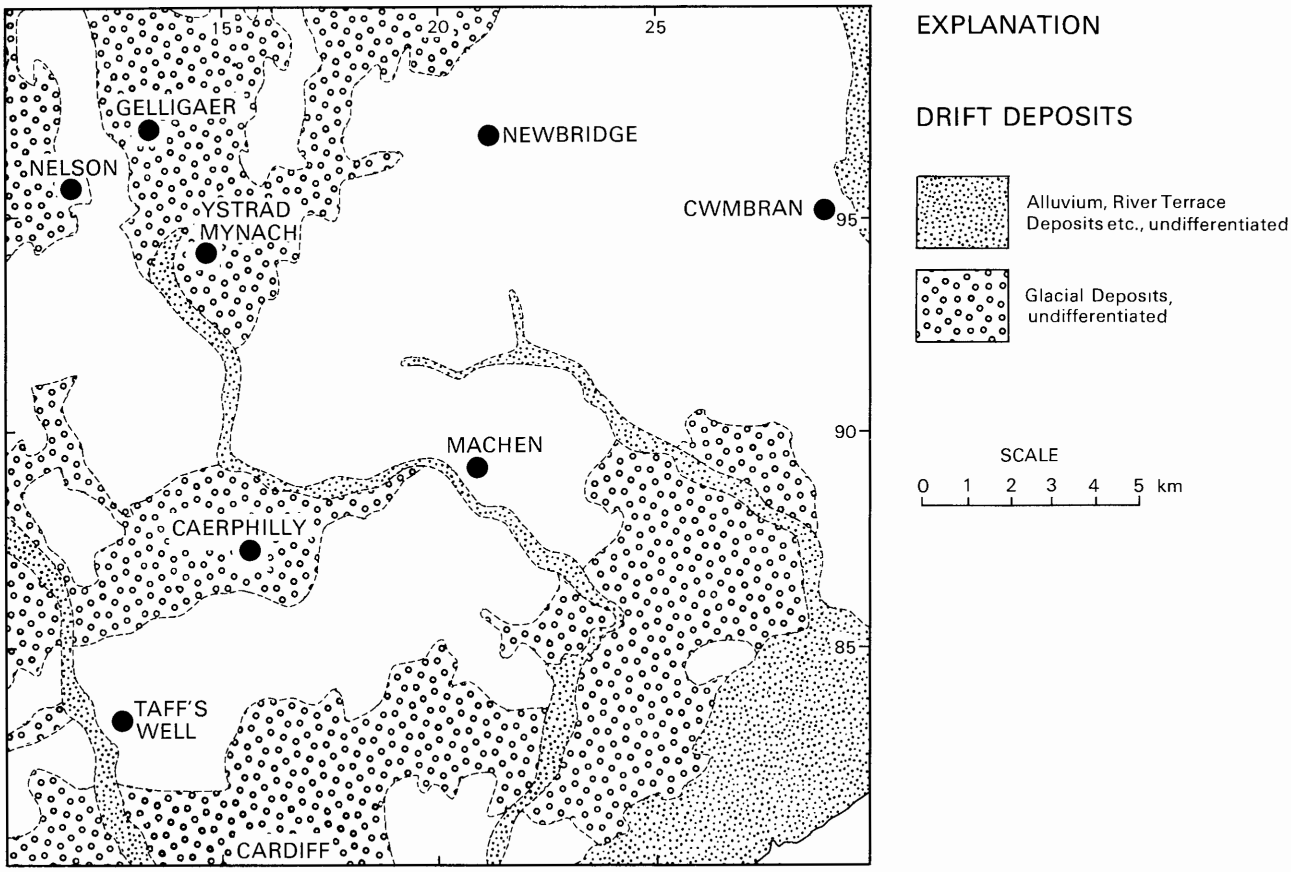


Figure 7 Distribution of drift deposits.

Table 3 Classification of crushed-rock aggregates based on their mechanical properties.

Group	Possible uses	Sub-group	Description	Typical index test results
1	Road surfacing aggregate. Also suitable for most construction purposes.	**1a**	Durable, strong, polish-resistant aggregate	PSV > 65 AIV < 23 AAV < 10
		1b	Durable, moderate strength, polish-resistant aggregate	PSV > 65 AIV 24-28 AAV < 10
		1c	Less durable, moderate strength, polish-resistant aggregate	PSV > 65 AIV 24-28 AAV 10-14
2	Base and sub-base (Roadstone). Concrete aggre-gate. Railway ballast.	**2a**	Strong, durable aggregate, low polish-resistance	PSV < 50 AIV < 20 AAV < 8
		2b	Moderate strength, slightly less durable aggregate, low polish-resistance	PSV < 50 AIV 21-28 AAV 8-11
3	Unsuitable for many construction purposes. Generally suit-able for rock-fill.	**3a**	Weak aggregate, low resistance to abrasion and polishing	PSV < 50 AIV > 30 AAV > 14
		3b	Weak but durable aggregate, high polish-resistance	PSV > 65 AIV > 30 AAV < 10
		3c	Weak aggregate with low durability, high resistance to polishing	PSV > 65 AIV > 30 AAV 10-14

Table 4 Summary of mechanical test data obtained from fresh (Grades 1 and 2)* rock samples.

Rock Type	AIV n	max	min	$\bar{x}$	SD	ACV n	max	min	$\bar{x}$	SD	AAV n	max	min	$\bar{x}$	SD	PSV n	max	min	$\bar{x}$	SD
Pennant Sandstone																				
	155	34	16	**24**	3.8	136	25	13	**19**	3.1	156	17.6	3.6	**9.1**	3.7	30	79	64	**72**	3.7
Carboniferous Limestone																				
Limestone																				
	13	26	20	**22**	1.8	-	-	-	-	-	13	10.8	7.8	**9.3**	1.0	1	-	-	**48**	-
Dolomite																				
	54	32	15	**20**	4.3	17	27	13	**18**	3.9	54	16.0	4.8	**7.8**	2.4	6	52	42	**47**	5.3
Lower Coal Measures Sandstone																				
	17	44	21	**29**	7.6	8	38	16	**23**	7.0	17	12.8	3.3	**6.9**	2.4	5	80	63	**69**	7.7
Old Red Sandstone (sandstone)																				
	9	36	21	**27**	5.1	3	24	21	**23**	1.5	9	11.4	2.6	**7.9**	3.3	2	66	55	**61**	7.8

n No of samples tested   * See Appendix A for definition of weathering grade
$\bar{x}$ Mean value
SD Standard deviation

Wedag MN 931/1) and screening into sizes suitable for test, namely, +10 -14 mm for the aggregate abrasion, crushing and impact tests, 10 mm nominal size for the polished stone value test, and 2 to 1½-inch for the attrition value test. In addition, the chippings for the aggregate abrasion and polished stone value tests had any flaky particles removed by using the appropriate flake-sorting sieve.

The following standard index tests (see Appendix B for a summary of the test procedures) were carried out on sub-samples taken from the crushed aggregate.

(a) **Physical Tests**	
Flakiness Index	BS 812: 1975
Relative Density	BS 812: 1975
Water Absorption	BS 812: 1975
(b) **Mechanical Tests: Strength**	
Aggregate Impact Value (AIV)	BS 812: 1975
Aggregate Crushing Value (ACV)	BS 812: 1975
(c) **Mechanical Tests: Durability**	
Aggregate Abrasion Value (AAV)	BS 812: 1975
Polished Stone Value (PSV)	BS 812: 1975
Wet Attrition Value (WAV)	BS 812: 1951

Most tests were carried out in the Institute's laboratories, but the PSVs, Attrition Values and a small number of AAVs were carried out by commercial testing laboratories. A summary of the results is given in Appendix C. More detailed records may be consulted at the Keyworth Office of the Institute on application to the Head, Industrial Minerals Assessment Unit.

CLASSIFICATION

The hard rocks investigated during this survey are classified in terms of their petrology (see Appendix A) and their aggregate properties (Table 3). The former is used to describe the rocks in lithological terms and the latter in the description of resources and on the resource map. The hard rocks were therefore classified into 3 groups and 8 sub-groups according to the level of results given by the mechanical tests.

The Map

The resource assessment map is folded into the pocket at the end of this report. The base map is part of Ordnance Survey 1:50 000 Sheet 171. Geological boundaries and other data are adapted from 1:50 000 Geological Sheets 249 and 263. Structural information is shown in red, and geological boundaries in black. Drift is shown by black ornament.

The hard rock resources of the district are indicated on the resource map by colours. Shades of yellow and orange demonstrate the average mechanical properties of the rocks at surface and also indicate the likely quality of the rocks concealed beneath drift. Uncoloured areas are underlain by mudstones, shales, marls, etc. In the report the hard rocks have been classified (Table 3) into groups and sub-groups of aggregate materials, but this has been simplified for the resource map which demonstrates the distribution of the three groups of aggregate materials.

The aggregate properties of the rocks are closely related to the stratigraphy and hence the group boundaries coincide with the solid geological boundaries. The various rock formations are identified by conventional stratigraphical symbols; an explanation is included. The site of each assessment borehole and section is indicated on the map.

Results

Old Red Sandstone

Most of the broad outcrop of the Old Red Sandstone surrounding the South Wales Coalfield consists of mudstones with subordinate thin sandy beds. However, thick units of sandstone are locally developed within the Raglan Marl Group and St Maughan's Group, whilst the Brownstone Group and the lower division of the Upper Old Red Sandstone are dominated by arenaceous deposits. The sandstones vary considerably in lithology but most may be classified as subarkose, arkose or lithic protoquartzite.

The assessment of the sandstones as a hard rock resource is based on the collection of 18 bulk samples, 9 of which were taken from the Upper Old Red Sandstone, 5 from the St Maughan's Group sandstones and 4 from sandstones within the Brownstone Group. In addition, one sample of nodular limestone was collected from the Raglan Marl Group.

Field observations revealed that most surface exposures (natural and old quarry sections) are partially weathered and, although care was taken to sample the freshest material available, it is likely that the aggregate properties of some of the samples will have been influenced by weathering. Results show some very high AIVs (in excess of 40) and AAVs (in excess of 30) and

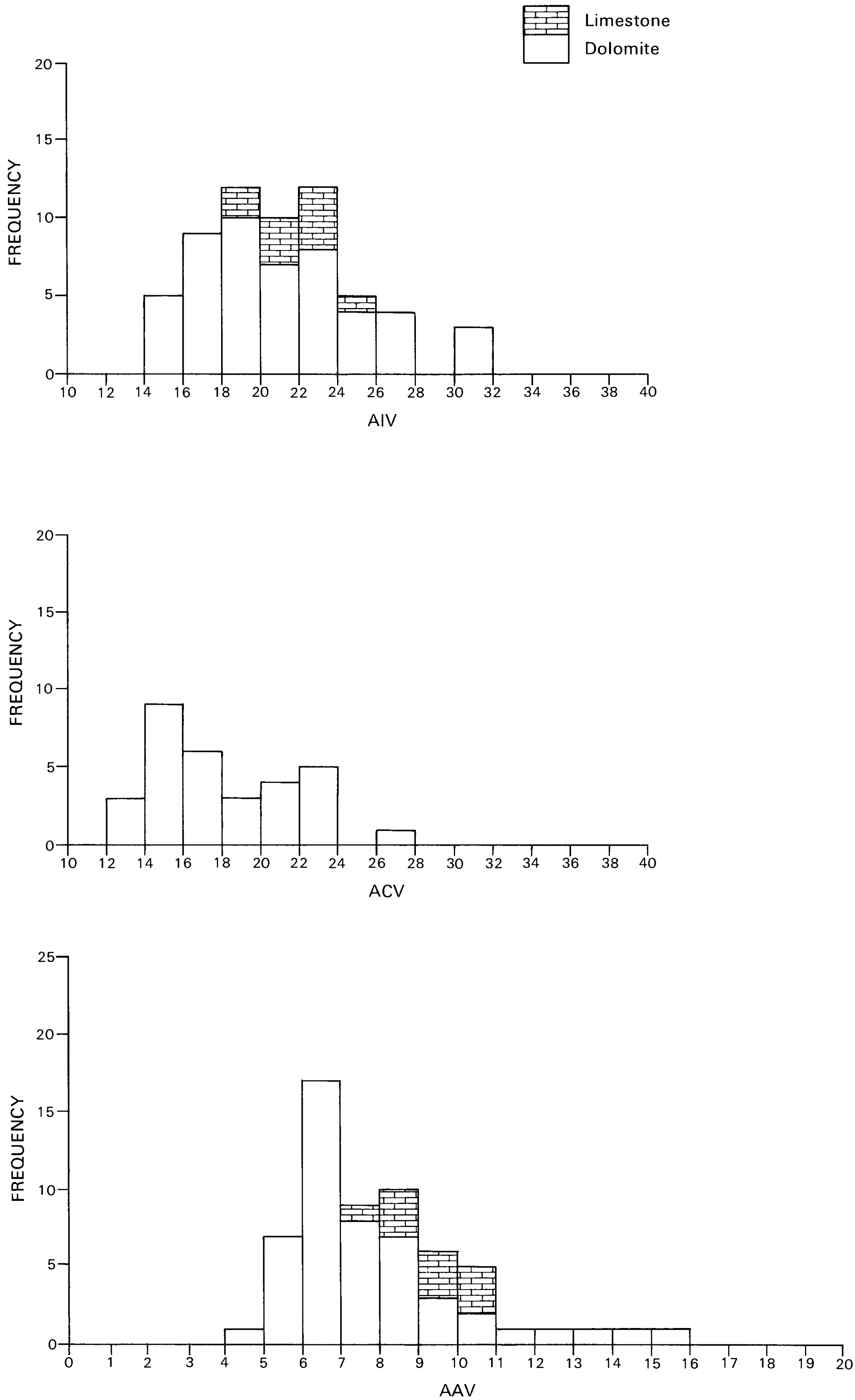


Figure 8 Frequency distribution of AIV, ACV and AAV data obtained from Carboniferous Limestone aggregates.

undoubtedly the strength and abrasion characteristics of the sandstone aggregates have been much reduced by weathering. However, results from relatively fresh (see Appendix A) samples (Table 4) indicate that some higher quality aggregates may be obtained. The fresh sandstones from the basal part of the Upper Old Red Sandstone were typically strong (AIV 21-25) and durable (AAV 2.6-8.3) whereas the fresh sandstone samples from the Lower Old Red Sandstone were relatively weak (AIVs 25-36) and somewhat less durable (AAVs 10.1-11.4). PSV data are restricted to one partially weathered sample from the Brownstone Group (PSV 83) and to two fresh samples from the Upper Old Red Sandstone (PSVs of 55 and 66 respectively). The relative density of the sandstone aggregates ranges between 2.52 and 2.60 and the water absorption values vary between 3.1 (weathered samples) to 0.5 (fresh samples). Samples of conglomerate from the Upper Old Red Sandstone were weak (AIV 33-46), but were nevertheless resistant to abrasion (AAV 5.3-8.2). The single sample of nodular limestone from the Raglan Marl Group gave an AIV of 28 and an AAV of 11.4.

Carboniferous Limestone

The dolomitised Main Limestone is the principal source of aggregate materials in the district and the Carboniferous Limestone outcrop is marked by numerous quarries, many of which are disused. The quarries provided ideal sites for sampling and 39 bulk samples (31 dolomite, 8 limestone) were collected from the Main Limestone and 4 samples (mainly dolomite) from the Lower Limestone Shale. In addition, core samples were obtained from 4 assessment boreholes (ST 18 NE 24, 25 and ST 18 SW 270, 271).

Samples from the partially dolomitised limestone unit which forms the middle part of the Lower Limestone Shale produced aggregates which typically gave AIVs of 21 to 24, ACVs of 20 to 23, and AAVs of 7.5 to 8.5. Slightly higher AIVs and ACVs (ie indicating lower strength) were given by samples of argillaceous dolomite and undolomitised limestone. A single PSV of 49 was obtained from a core sample taken from borehole ST 18 SW 270.

The dolomites of the Main Limestone are relatively uniform in both their lithology and their aggregate properties. Most of the outcrop consists of thick-bedded, mid-grey, fine and medium-grained dolomites which gave relatively uniform strength test results (AIVs 15 to 20, ACVs 13 to 19) and consistenly low abrasion values (AAVs 4.8 to 7.0). However, the coarse-grained dolomites which have been sampled at a few localities were relatively weak and gave AIVs usually in excess of 30 and AAVs of 11.0 to 16.0. The aggregate properties of the undolomitised oolitic limestones, which form the uppermost part of the Main Limestone around Taff's Well, are intermediate between those of the fine and coarse-grained dolomites. Thus, most limestone samples gave AIVs between 21 and 23 and AAVs between 8.0 and 11.0 (Figure 8); samples of partially dolomitised limestone gave higher values (AIVs of 28 and AAVs of 13.0). PSV results from both dolomite and limestone samples suggest that the rocks have low resistance to polishing. Although only a small number of wet attrition values (WAVs) were obtained during the survey, the data suggests that the dolomites are mostly highly resistant to wet abrasion (WAVs 3.0-8.1), although the coarse-grained, granular dolomites were significantly less resistant (WAVs greater than 10). The limestone aggre-

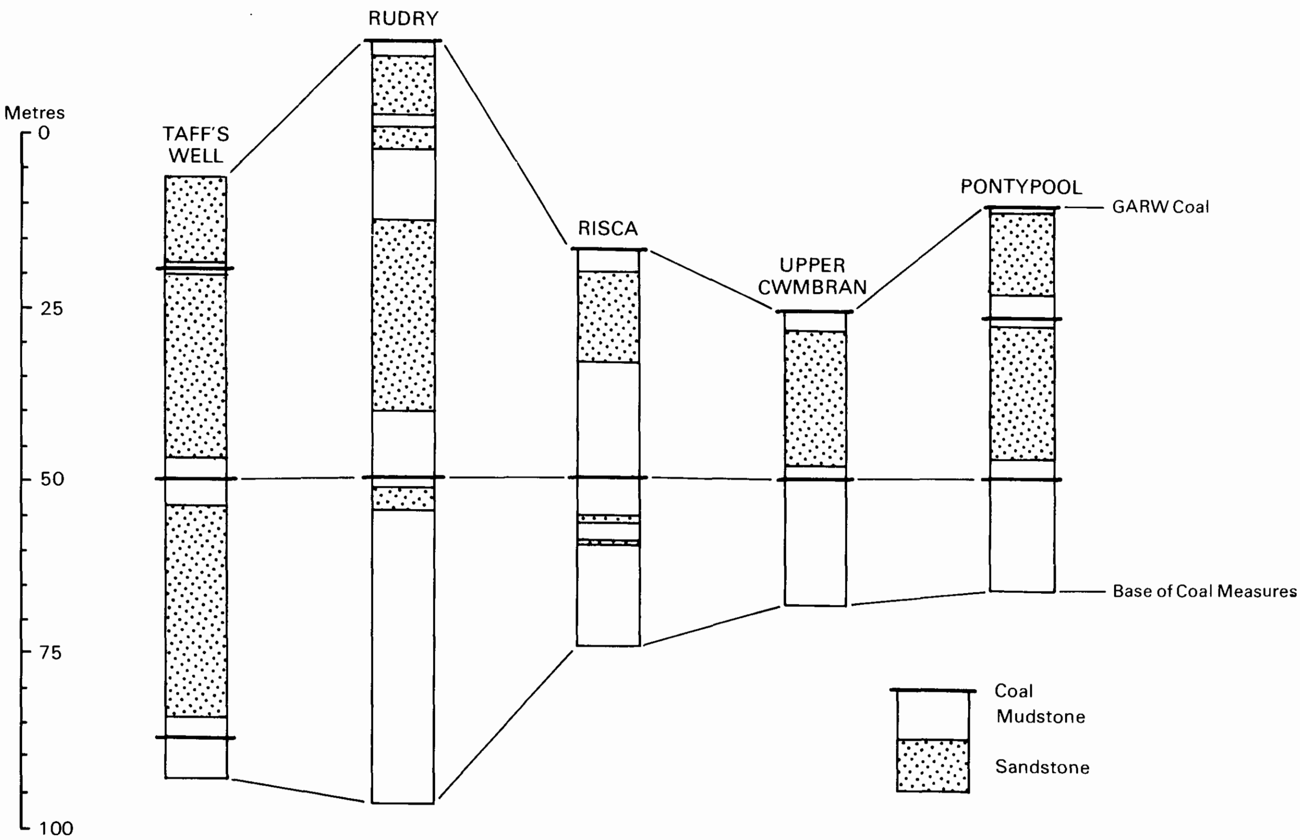


Figure 9 Generalised vertical sections of the lower part of the lower Coal Measures.

Table 5 Summary of the aggregate properties of the Lower and Middle Coal Measures sandstones.

Lithology	Mean Values (and number of samples tested)					
	AIV	ACV	AAV	PSV	Relative Density	Water Absorption
Massive coarse-grained quartzitic sandstone	39 (10)	30 (5)	6.6 (10)	65 (3)	2.56 (4)	0.6 (4)
Well bedded, fine-grained, quartzitic sandstone	25 (10)	20 (7)	8.3 (10)	72 (2)	2.66 (4)	0.9 (4)

gates also gave high WAVs (8.8 to 9.4) indicating low resistance to wet abrasion.

The physical properties of the dolomite and limestone aggregates were relatively uniform throughout the district, with relative densities of 2.82 and 2.70, respectively. Values for water absorption were only rarely higher than 0.7 from both dolomite and limestone aggregates.

Millstone Grit

The basal sandstones and conglomerates of the Millstone Grit are up to 25 m thick on the high ground [2305 8960] above Pontymister and also in the neighbourhood of Cwmnyscoy [2805 9979] in the north-east corner of the district. Elsewhere the sandstones are thin or absent. Large exposures of the sandstones are uncommon and sampling was therefore restricted to two localities. The fine- to coarse-grained sandstones are classified as protoquartzites or orthoquartzites and are commonly interbedded with massive conglomerates containing large pebbles of white quartz. Results obtained from the four samples suggest that the sandstones produce relatively strong (AIV 22 to 25) and very durable (AAV 3.3 to 4.0) aggregates whereas the conglomerates were less strong (AIVs > 30) but equally durable (AAVs 2.9 to 3.4). Although no PSV data has been obtained during the survey, it is anticipated that the Millstone Grit sandstones would give PSV results similar to those obtained from the quartzitic sandstones of the Lower Coal Measures.

Lower and Middle Coal Measures

The quartzitic sandstones of the Lower and Middle Coal Measures are mostly thin and impersistent but thicker sandstone units are developed locally. These are laterally variable but may attain a total thickness of over 20 m in the lower part of the Lower Coal Mesures (Figure 9) and also in the upper part of the Middle Coal Measures.

Surface exposures of the sandstones are confined to the perimeter of the coalfield, and mainly to the narrow outcrop of the Lower Coal Measures. Numerous small disused quarries mark the outcrop of the sandstones and provided suitable sites for sampling. In total, 14 bulk samples were taken, mainly from the Lower Coal Measures, and these were supplemented by an assessment borehole (ST 18 NE 26) which provided a further six samples of Lower Coal Measures sandstones.

The sandstones are classified petrographically as orthoquartzites or protoquartzites. Two distinct lithological types were recognised; a massive coarse-grained sandstone with pebbly layers, and a well bedded, fine-grained, laminated and micaceous sandstone. The two lithologies are commonly interbedded and the latter usually contains thin clay layers. Both lithologies were sampled and evaluated during the survey and results show that they differ in their aggregate properties (Table 5). The coarse quartzitic sandstones produced weak but durable aggregates, whereas the finer-grained lithologies were stronger (lower AIVs, ACVs) but relatively less resistant to abrasion. Both lithologies gave high PSVs, similar to, or only slightly less than results given by Pennant sandstone.

Table 6 Stratigraphical distribution of Pennant sandstone samples.

		Number of samples	
		Sections	Boreholes
Upper Coal (Pennant) Measures	Grovesend Beds	19	13
	Hughes Beds	72	56
	Brithdir Beds	18	25
	Rhondda Beds	6	-
	Llynfi Beds	3	-

Pennant Measures

The sandstones of the Pennant Measures have in past years provided considerable quantities of stone for building, paving and aggregates but in recent years output has declined considerably. The assessment of Pennant sandstone as a hard rock resource is based on the collection of 118 bulk samples from quarries and surface exposures, supplemented by a further 94 core samples from 11 assessment boreholes. The widespread geographical distribution of the sample points is shown in Appendix C and the stratigraphical distribution of samples in Table 6. The apparent sampling bias in favour of the Hughes Beds is a function of the large area of outcrop of this subgroup. The paucity of samples from the Rhondda and Llynfi Beds reflects both their small area of outcrop and their mixed mudstone/sandstone lithology.

Pennant sandstone is classified petrographically as a lithic greywacke or subgreywacke, terms which imply that a clay matrix comprises a considerable (over 10 per cent) amount of the total rock volume. Most of the samples were medium-grained (grain size 0.25-0.50 mm) but some finer and coarser grained varieties were recorded. With the exception of the orthoquartzites, found locally in the Llynfi and Rhondda Beds, the sandstones show little mineralogical variation in either a stratigraphical or a regional context. Detrital quartz is the dominant constituent (>50 per cent), but rock fragments are a major component (mostly greater than 25 per cent). Muscovite and feldspar occur in minor amounts. Carbonaceous material occurs sporadically, usually as thin, impersistent laminae. The granular components are set in a fine-grained clay matrix usually making up over 10 per cent of the rock. Iron carbonate (siderite) is the probable intergranular cement, but secondary quartz may locally act as a cementing agent.

The collection of large numbers of Pennant sandstone samples has enabled the aggregate properties to be thoroughly investigated. Results show, however, that despite its considerable thickness and widespread distribution, the Pennant sandstone is remarkably uniform in its mechanical properties. All aggregates

Table 7 Summary of the mechanical test data obtained from fresh (Grade 1) Pennant sandstone samples.

Sub-group	AIV n	max	min	$\bar{x}$	SD	ACV n	max	min	$\bar{x}$	SD	AAV n	max	min	$\bar{x}$	SD	PSV n	max	min	$\bar{x}$	SD
Grovesend Beds	21	29	21	**24**	2.2	21	24	15	**19**	2.6	21	12.9	6.8	**9.2**	2.0	7	79	6	**72**	2.0
Hughes Beds	64	30	16	**22**	3.1	57	25	13	**18**	2.9	65	15.2	4.8	**7.9**	2.2	13	78	64	**71**	3.7
Brithdir Beds	12	26	19	**22**	2.1	10	21	17	**19**	1.5	12	12.4	5.9	**7.6**	1.9	3	76	68	**71**	3.4
Rhondda Beds	1	-	-	**20**	-	1	-	-	**17**	-	-	-	-	**9.1**	-	1	-	-	**67**	-
Llynfi Beds	1	-	-	**22**	-	-	-	-	-	-	1	-	-	**5.6**	-	1	-	-	**66**	-

Table 8 Summary of the mechanical test data obtained from fresh and slightly weathered (Grades 1 to 3) Pennant sandstone samples.

Sub-group	AIV n	max	min	$\bar{x}$	SD	ACV n	max	min	$\bar{x}$	SD	AAV n	max	min	$\bar{x}$	SD	PSV n	max	min	$\bar{x}$	SD
Grovesend Beds	32	47	21	**26**	5.4	31	36	15	**21**	4.7	32	36.7	6.8	**12.6**	6.3	8	79	69	**73**	3.0
Hughes Beds	122	44	16	**24**	4.0	108	33	13	**20**	3.5	122	20.2	4.8	**9.0**	2.9	17	78	64	**71**	3.9
Brithdir Beds	42	39	19	**27**	4.4	36	32	17	**21**	3.4	41	37.5	3.6	**10.2**	5.5	7	89	68	**76**	7.2
Rhondda Beds	6	37	24	**30**	4.9	4	31	22	**27**	4.4	6	20.3	9.1	**14.7**	3.6	1	-	-	**67**	-
Llynfi Beds	3	38	22	**31**	8.3	-	-	-	-	-	3	14.8	5.6	**10.1**	4.6	2	70	66	**68**	2.8

were highly resistant to polishing: all PSVs were above 64 and most were greater than 70. The high polish resistance of the rocks is due to the range in hardness of their constituents, which results in a high degree of surface roughness. There is a greater variation in strength (AIV, ACV) and durability (AAV), but these do not vary greatly in relation to the stratigraphy (Tables 7 and 8). Weathering is the major cause of variation (Figure 10). Weathering weakens the aggregate and reduces its resistance to abrasion, although resistance to polishing tends to be increased. Even slight weathering (Grade 3, Table 10) may significantly affect the aggregate properties.

The physical properties of Pennant sandstone aggregates were also relatively uniform. The relative density ranges between 2.60 and 2.70, but most samples gave values around 2.65. Weathering does not apparently affect the relative density to any significant degree but the water absorption (porosity) is usually increased. Values of less than 1.0 were typical of unweathered aggregates, but values of between 1.0 and 3.0 were commonly recorded from weathered samples.

Fundamental petrographical characteristics such as grain size and mineral composition would be expected to influence both the physical and mechanical properties. However, there are few simple correlations between petrographical and mechanical data, although there is some evidence to suggest that grain size affects the aggregate strength. Thus fine-grained sandstones, by comparison with coarse-grained sandstones, tend to be relatively strong (low AIVs and ACVs); however, aggregate strengths cannot be predicted accurately by measurement of the grain size. Hawkes and Hosking (1972) have demonstrated that, for arenaceous rocks, the degree of consolidation of the rock has a greater effect on aggregate properties than the petrographical characteristics. Statistical analysis of the aggregate property data shows a significant regional trend (see below) which may be related to the degree of consolidation of the rocks.

Regional variation in the Pennant sandstone

Trend surface analysis and moving average techniques were used to reveal any significant regional variations in the mechanical properties of the Pennant sandstone. Trend surface analysis is a technique used to separate regional trends from local variations by fitting low-order polynomial surfaces to the data and then using statistical tests to determine the significance of the fit. Moving average techniques calculate average values within a specified search radius, the greater the search radius the greater the number of points averaged and therefore, the greater the smoothing of the data (ie. small search radii produce surfaces showing local details, while large search radii produce smoothed surfaces showing the general regional variations).

This study used the AIV and AAV data obtained from fresh section samples (Weathering Grades 1 and 2). The small amount of PSV data was not included because it was considered that the relatively small number of results would not show any significant regional trends, and the ACV data were not analysed because they are very similar to the AIV data. Borehole data were not included, although it would be expected that results from

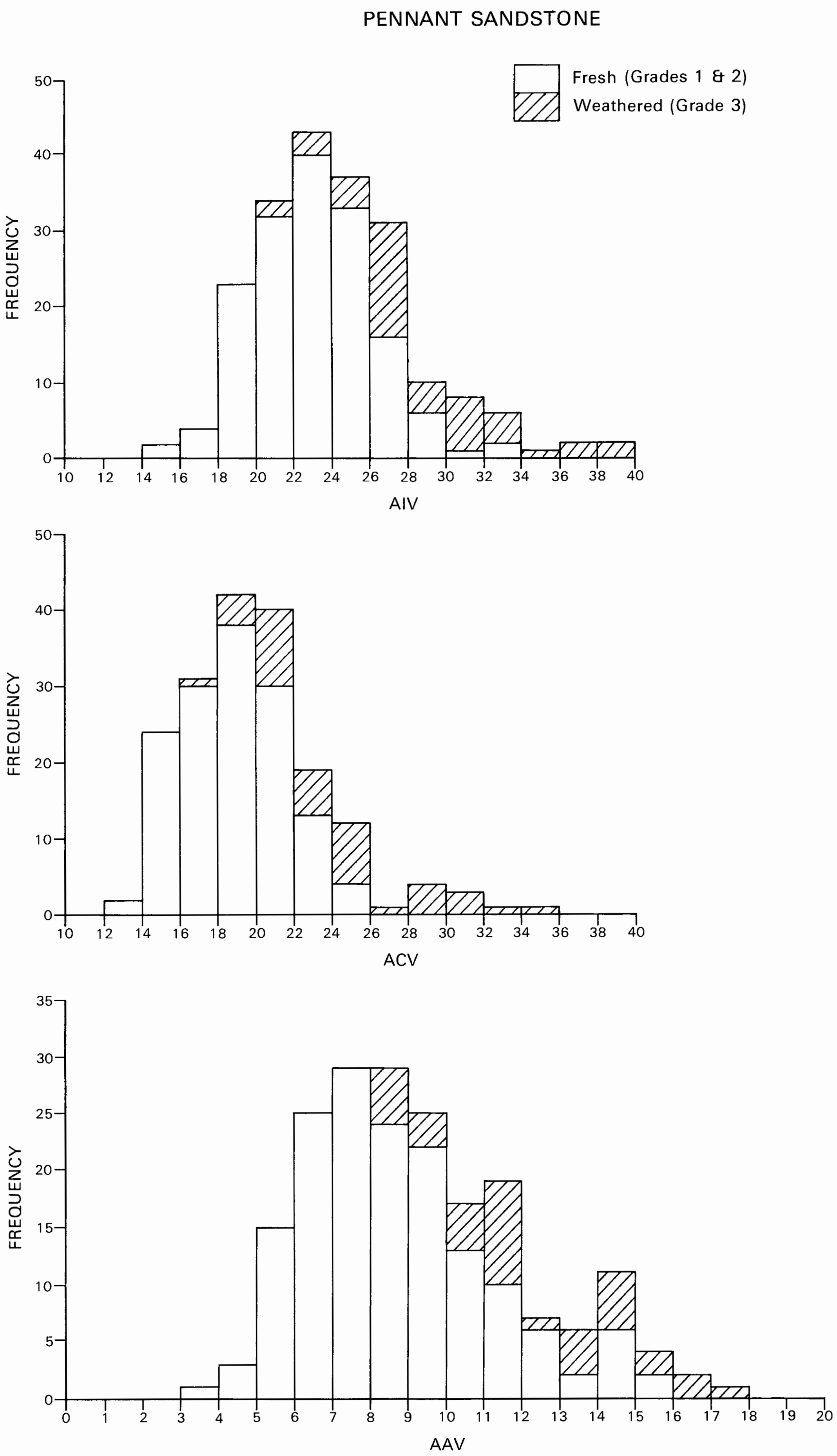
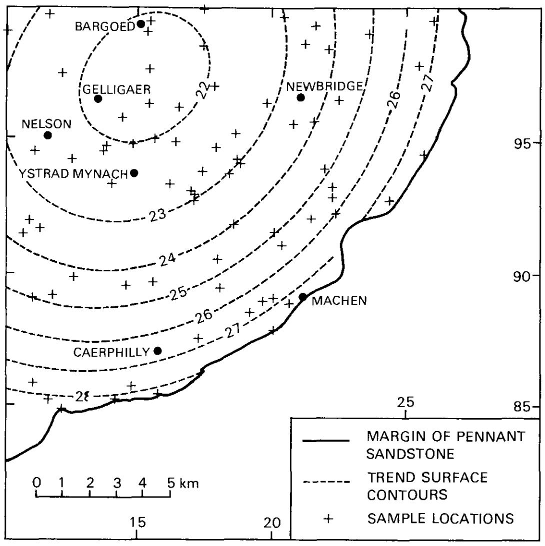


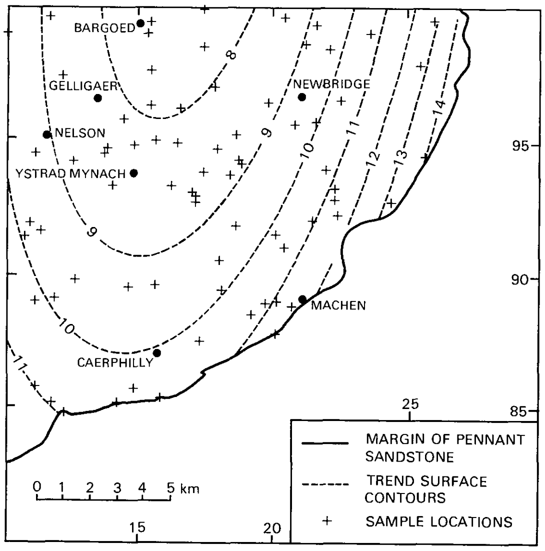
Figure 10 Frequency distribution of AIV, ACV and AAV data obtained from Pennant Sandstone aggregates.



STATISTICS*

No. of data points =77
LARGEST DEVIATIONS FROM SURFACE
-6.79 at ST 18 NE 8s
+9.79 at ST 18 NE 5s
F-TEST=4.79
CRITICAL VALUE FOR F-TEST at 2½% level =2.8
CORRELATION COEFFICENT =0.5024

Figure 11 Second order trend surface contours for AIV data (Pennant Sandstone) and table of summary statistics.



STATISTICS*

No. of data points =78
LARGEST DEVIATIONS FROM SURFACE
-7.93 at ST 29 SW 9s
+9.65 at ST 18 NE 5s
F-TEST=2.84
CRITICAL VALUE FOR F-TEST at 2½% level=2.8
CORRELATION COEFFICIENT =0.4060

* See Glossary for explanation of terms

Figure 12 Second order trend surface contours for AAV data (Pennant Sandstone and table of summary statistics.

boreholes would fit into regional pattern predicted from the section data (see below).

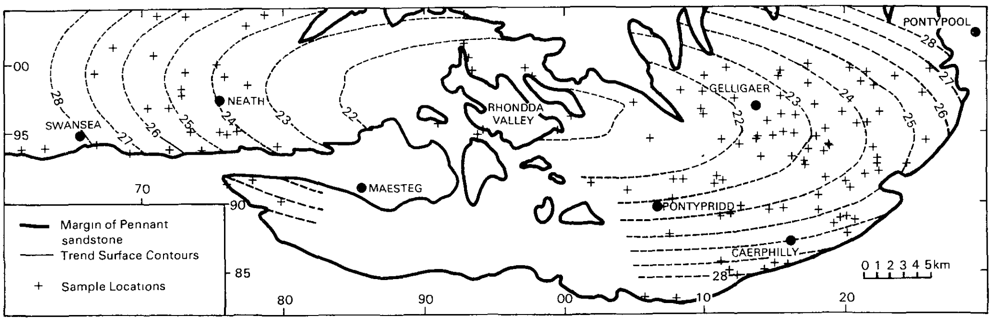
Both trend surface analysis and moving average techniques showed a regional variation in the aggregate properties of the Pennant sandstone. Second-order trend surfaces were accepted as most closely modelling the data because first-order surfaces showed no statistically significant fit and third-order surfaces showed no significant increase in the degree of fit (Figures 11 and 12). They show that in general the aggregate strength (AIV) of the Pennant sandstone increases towards the north-west of the district and decreases to the south and east towards the margins of the coalfield. The AAV results produced the same general trend except in the south-west of the district, near Caerphilly, where the actual results were relatively lower (indicating higher durability) than the predicted results. It must be emphasized that these are general trends which may point to general areas of stronger or weaker rock, but local variations cannot be deduced.

When the borehole data were compared with the regional trends predicted by the section data it was found that they conformed remarkably closely, except for the results from borehole ST 18 NE 28 near Caerphilly, which were lower (indicating stronger rock) than those predicted by the general trends.

When the study was expanded to include all the AIV data obtained from fresh Pennant sandstone samples collected throughout the South Wales Coalfieldd (mainly the Swansea-Neath and the Caerphilly-Pontypridd areas) a similar second-order trend was obtained which showed an increase in AIV (indicating lower aggregate strength) towards the margins of the coalfield (Figure 13).

Although similar regional trends have been obtained for both AIV and AAV data, and comparable trends have been found at both the western and eastern ends of the coalfield, there are no obvious or clearly defined explanations for the trends. As previously stated, Pennant sandstone (greywacke facies) shows little regional variation in lithology and mineralogy and there is no coherent relationship between petrography and mechanical properties.

The observed trends could be related to regional variations in the degree of weathering (although only relatively fresh material was used in this study) or to the degree of consolidation of the rocks, which in turn is related to diagenesis and tectonic compression. Further systematic and detailed research is required before this



STATISTICS (see Glossary)
No of data points=155

LARGEST DEVIATIONS FROM SURFACE
-8.58 at SS 79 NW 1s
+10.55 at SN 60 SE 1s
F-Test=8.72
CRITICAL VALUE FOR F-TEST at 1% level =3.2
CORRELATION COEFFICIENT =0.4821

Figure 13 Second order trend surface contours for AIV data (Pennant Sandstone) throughout the South Wales Coalfield and table of summary statistics.

regional variation in mechanical properties of Pennant sandstone can be satisfactorily explained.

SUMMARY OF HARD ROCK RESOURCES

Hard rocks crop out over a considerable proportion of the district and aggregates are currently produced from seven quarries, five of which work Lower Carboniferous dolomites and two Pennant sandstone. The dolomite aggregates are mainly used for base and sub-base material in road construction, for railway ballast, and in the manufacture of concrete products, whereas Pennant sandstone aggregates are mainly applied to the wearing surfaces of roads in the form of precoated chippings and surface dressings, or in macadam and asphalt materials. The hard rock assessment is generalised owing to the widespread distribution of sample points, and detailed aggregate resource data are restricted to those results obtained from boreholes and surface samples.

In terms of outcrop area and thickness, the **Pennant Measures** are the major hard rock resource in the district. Although sandstones (greywackes) make up most of the sequence, thick beds of mudstone (waste material) are locally developed at several horizons and the sequence is laterally variable. Mudstones are particularly common in the Llynfi, Rhondda and Grovesend Beds and the thickest mudstone units recognised are shown on the resource map. A summary or the stratigraphical and regional variation in the Pennant Measures was given earlier in this report, but more detailed information can be found in the Newport memoir (Squirrell and others, 1969).

Despite the variable nature of the Pennant Measures, the aggregate properties of the sandstones do not vary widely, either in a stratigraphical or a regional context. The results obtained during the survey show that Pennant sandstone aggregates are consistently very resistant to polishing (very high PSVs) and in most cases combine durability (low AAVs) with good strength (low AIVs, ACVs). They are, therefore, classified as Group 1 (Sub-group 1a and 1c) aggregates (Table 3, Resource Map). The major cause of variation in aggregate properties was found to be weathering. All surface exposures of Pennant sandstone are weathered to some degree and the depth of weathering, which may vary from 2 m to over 10 m, is controlled by the distribution of joints and other rock discontinuities (eg. mudstone-filled channels). Joints are a common feature throughout the Pennant Measures outcrop, but it has been observed that jointing is more evident on the upper slopes of valley sides than on the relatively level ground of the plateau. The effects of valley cambering has caused opening of the joints resulting in accelerated weathering of the joint surfaces. It is, therefore, anticipated that steep valley sides would generally be poor targets for quarrying aggregate materials because the sandstones may be expected to be preferentially weathered. In addition, many of the steep valley sides are potentially unstable, as evidenced by the many landslips in the coalfield valleys (see Conway and others, 1980).

A further factor which affects the quality of Pennant sandstone as aggregate material is the distribution of silty mudstone-filled channels within the sandstones. As well as influencing the weathering of adjacent sandstone beds (by affecting the percolation of groundwater), the mudstones are waste material which is difficult to remove during quarry processing. The location of these mudstone-filled channels is, therefore, important for quarry evaluation. Field observations have shown, however, that they are sporadic in distribution and laterally impersistent, with the result that it is not possible to predict their occurrence at the resource level of appraisal. Other minor features which may affect the quality of the stone is the presence of carbonaceous layers and conglomeratic ironstone bands, but these are essentially local characteristics of the deposit, which cannot be predicted at the resource level of appraisal.

Despite the occurrence of weathered strata, mudstone-filled channels, ironstone pebbles and carbonaceous fragments within the deposits, modern quarrying of the Pennant sandstone is generally non-selective, except for the highest grade products (e.g. surface-dressed chippings), which are required to meet tight specifications of size and shape, and physical and mechanical properties. In general, however, most of the sandstone can be used as aggregate and there are only small amounts of waste. Some of the less desirable aggregate material, such as the flaggy sandstones which occur in the near-surface strata, may be used as flagstones or as crazy-paving.

Statistical analysis of the survey data shows a regional trend which indicates that the strength and abrasion resistance of the Pennant sandstone incresases towards the north-west of the district, and decreses towards the southern and eastern margins of the outcrop.

Although the porosity (as indicated by the low water absorption values) and primary permeability are low, the Pennant sandstone contains reservoirs of groundwater: discontinuities (joints, faults, bedding planes etc) within the rock allow it to store and transmit water. Seepages and springs comonly occur at the sandstone/mudstone junctions, and artesian conditions have been recorded locally. A study of the local hydrogeological conditions in the Pennant Measures is likely to be of importance in the siting and development of hard rock quarries.

The narrow outcrop of the **Carboniferous Limestone** is currently the major source of aggregate materials in the district. Most of the sequence is dolomitised and all current aggregate production is of dolomite from the Main Limestone. Significant thicknessess of undolomitised strata (limestone) are found in the upper part of the Main Limestone near Taff's Well, and to a lesser degree in the lower division of the Lower Limestone Shale.

The Carboniferous Limestone is generally classified as Group 2 aggregate material (Table 3) and most dolomite samples (Sub-group 2a) have been found to be slightly stronger and more durable than limestone aggregates (Sub-group 2b). Both were susceptible to polishing (low PSVs) and are therefore, concluded to be generally unsuitable for use as road surfacing materials. However, several samples gave PSVs above the minimum value of 45 required by the Department of the Environment (Anon, 1976) for Category C sites (lightly trafficked roads).

The fine and medium-grained, thick-bedded dolomites which make up most of the sequence, produce aggregates of uniformly good strength are are generally stronger and more durable that Pennant sandstone aggregates. Similarly, the very fine-grained porcellanous dolomites found in the upper part of the sequence in the Thornhill-Cefn Onn-Rudry area, produce strong and durable aggregates. However, the coarse-grained, granular varieties of dolomite are significantly weaker and much less durable. Field observations indicate that this coarse-grained dolomite occurs mainly in thickly bedded or massive units, although it is also associated with veins, cavities and fissures. Its distribution within the sequence is not clearly understoood and it is, therefore, not possible to reliably demonstrate its outcrop on the resource map.

The Main Limestone is generally free from mudstone contaminants except in the upper part of the sequence in the Thornhill-Cefn Onn-Rudry area, where there are thin mudstone beds. Mudstone bands, argillaceous dolomite and argillaceous limestone are more common in the lower division of the Lower Limestone Shale, particularly towards the base. Clay-filled fissures and joints occur sporadically throughout the outcrop and may be sufficiently large and persistent to cause quarrying problems.

The dolomites are of variable, but predominantly high, chemical purity and are a potential source of metallurgical flux and refractory materials. Some information on the chemistry of the Carboniferous Limestone of the Caerphilly area is given in a reconnaissance survey report by Harrison and others (1983).

Although the regional structure of the Carboniferous Limestone is relatively simple, the local structure may be complex, involving folding and faulting (including thrusting) within the confines of the outcrop.

The Carboniferous Limestone forms a fissured aquifer, particularly in the relatively broad outcrops south-west of Risca. Mudstone bands in the Main Limestone locally act as aquicludes and penetration of these bands during quarrying could result in seepage, and possibly artesian water.

The quartzitic sandstones (orthoquartzites and protoquartzites) of the **Lower and Middle Coal Measures** and **Millstone Grit** have narrow outcrops and are laterally impersistent. Nevertheless, their thickness, particularly in the Lower Coal Measures, is locally considerable and some outcrops could support a modern quarrying operation.

Although most of the survey data was obtained from sandstones within the Lower Coal Measures, all the quartzitic sandstone aggregates were found to be durable (low AAVs) and most were resistant to polishing (high PSVs), but strength varied with grain size. Thus the coarse-grained or conglomeratic sandstones were weak (high AIVs) and are classified as Group 3 aggregate material (Sub-group 3b), whereas the finer grained varieties were much stronger (lower AIVs) and are classified as Group 1 aggregate material (Sub-group 1b) (Table 3). The fine-grained quartzitic sandstones were also denser (higher relative density values) than the coarse-grained sandstone.

Both sandstone lithologies occur in relatively thick units which are usually interbedded. It is, therefore, not possible to map the outcrop of each lithology separately (except on a very large scale), and the Lower and Middle Coal Measures sandstone and Millstone Grit sandstones are shown on the resource map as intermixed Group 1 and Group 3 aggregate materials. Over 25 m of fine-grained well bedded, quartzitic sandstone with thin mudstone partings were proved in borehole ST 18 NE 26, and in the Rudry-Caerphilly area it appears that the lowest sandstones of the Lower Coal Measures are mainly fine-grained whereas those higher in the sequence are predominantly coarse-grained and pebbly.

The Lower and Middle Coal Measures sandstone are potential aquifers, but their narrow outcrops provide only limited catchments. Nevertheless, the occurrence of impervious argillaceous horizons within the sandstones could create wet quarrying conditions.

The **Upper and Lower Old Red Sandstone** contain a number of thick sandstones and it is likely that in the past the harder rocks were quarried locally for aggregate and building stone. Most surface exposures of the sandstones are partially weathered, and relaible resource assessment data were only obtained from a small number of fresh samples. However, it is anticipated that most sandstones within the Old Red Sandstone would produce relatively weak aggregate with, at best, only moderate resistance to abrasion, although it is also likely that the aggregates would be resistant to polishing. These sandstones are therefore, generally classified as Group 3 (Sub-group 3c) aggregate materials (Table 3). Some harder and more durable sandstones occur in the Brownstone Group, and the sandstones in the basal part of the Upper Old Red Sandstone typically produce strong, durable aggregates with relatively high polish resistance. These sandstones are classified as Group 1 (Sub-group 1a) aggregate material, but are interbedded with quartz conglomerates which are also durable but relatively weak (high AIVs). Conglomerates also occur at many horizons in the Lower Old Red Sandstone and can be expected to be relatively weak, and therefore, generally unsuitable for use as aggregate.

The beds of nodular and massive limestone which occur within the Old Red Sandstone have not been thoroughly evaluated due to their small outcrop and poor exposure, but it is anticipated that they may produce aggregates similar to Carboniferous limestones (Sub-group 2b aggregate material), although they may be expected to contain large amounts of waste (mudstone) material.

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APPENDIX A

CLASSIFICATION AND GLOSSARY

Classification

Sandstone classification

The lithological classification of the sandstones investigated during the survey is based on that of Hawkes and Hosking (1972), which describes the rocks in compositional terms. In most cases clastic quartz is the main constituent of the rock; all other components, including the proportion of clay matrix, are regarded as 'impurities'. When feldspar constitues a significant part of the total impurity the sandstone may be classed as a subarkose (5-10 per cent feldspar) or an arkose (10 per cent or more). Prefixes are used to describe important compositional elements; for example 'lithic' indicates that rock fragments are in excess of 10 per cent; whereas 'calcitic' implies the presence of at least 5 per cent calcite cement of secondary origin. The main sandstone types are defined in the glossary.

Dolomite classification

The mineral dolomite, Ca Mg $(CO_3)_2$ contains 21.9 per cent MgO and 30.4 per cent CaO. Rocks containing dolomite are classified as follows:

10 - 49.9 per cent	Dolomitic limestone
50 - 89.9 per cent	Calcitic dolomite
90 per cent and above	Dolomite

Limestone classification

The petrographic classification of limestones by Dunham (1962) is used in this report, and is summarised in Table 9.

The classification describes the depositional texture of the limestones. The presence or absence of mud differentiates muddy carbonate from grainstone. The relative abundance of grains allows muddy carbonates to be subdivided into mudstone, wackestone and packstone, and the presence of signs of binding during deposition characterises boundstone. The degree of packing differentiates packstone from wackestone. The former is composed of grains in close contact with each other whereas the latter consists of a relatively small amount of grains 'floating' in a mud matrix.

Weathering classification

The weathering classification of rocks by the Geological Society Engineering Group (Anon 1977) is widely accepted and is used in this report in a slightly modified form (Table 10).

Table 10 Classification of Rock Weathering (based on Anon 1977)

Grade	Term	Description
1	Fresh	No visible signs of rock weathering except discolouration of joint surfaces
2	Superficially weathered	Some discolouration of surface rinds but not all rock material is discoloured
3	Slightly weathered	Discolouration indicates weathering of rock material. All rock material may be discoloured
4	Moderately weathered	Some of the rock is decomposed and/or disintegrated to a soil

Glossary

Anticline An arch fold, the core of which contains the stratigraphically older rocks.

Aquiclude A body of relatively impermeable rock which functions as an upper or lower boundary of an aquifer or water-bearing stratum.

Table 9 Classification of carbonate rocks according to depositional texture (Dunham, 1962).

Depositional Texture Recognisable					Depositional Texture Not recognisable
Original components not bound together during deposition				Original components bound together during deposition	
Contains mud (clay and fine silt)			Lacks mud and is grain-supported		
Mud-supported		Grain-supported			
Less than 10 % grains	More than 10 % grains				
Mudstone	**Wackestone**	**Packstone**	**Grainstone**	**Boundstone**	**Crystalline carbonate**

Arenaceous rocks Detrital sedimentary rocks that contain sand-sized particles.

Argillaceous rocks Detrital sedimentary rocks that contain clay or silt grade material.

Arkose A protoquartzite which contains more that 10 per cent feldspar.

Correlation Coefficient A measure of the relationship of one variable to another. Perfect correlation =1, no correlation =0, perfect inverse correlation =-1. In terms of a trend surface the correlation coefficient is a measure of the relationship between the trend surface values and the sample values.

Cyclothemic sedimentation A term applied to a repetitive sequence of sediments which change their character progressively from one extreme type to another followed by a return to the original type.

F-Test A statistical method of comparing the variance of two populations. Thus the significance of a trend surface can be tested by comparing the variance of the trend (regression) against the variance of the residuals (deviations). If the regression is significant then the variance due to the deviations will be small compared to the variance of the regression. If the ratio of these variances falls below the F-Test critical value then the trend is not statistically valid and can be explained as a random effect.

Facies The sum of al the primary lithological and palaeontological characteristics exhibited by a sedimentary rock, from which its origins and environment of formation may be inferred.

Greywacke A sandstone with at least 10 per cent of clay and chlorite minerals in the matrix.

Largest Deviations These show the extremes due to local variation caused by geological factors and experimental error.

Oolith Small, oval, accretionary bodies with concentric layering. Usually formed of calcium carbonate.

Orthoquartzite A sandstone consisting of more than 95 per cent clastic quartz.

Pedogenic Pertaining to soil formation.

Petrography The systematic description of rocks in hand specimen and thin section.

Protoquartzite A sandstone in which clastic quartz is the main constituent, but which contains between 5 per cent and about 25 per cent of 'impurity'. The 'impurity' includes fragments of rock, feldspar, mica, etc., and up to 5 per cent of clay matrix.

Subarkose A protoquartzite which contains between 5 per cent and 10 per cent feldspar.

Subgreywacke A sandstone similar in compostion to protoquartzite, but containing between 5 per cent and 10 per cent clay matrix.

Syncline A trough fold, the core of which contains stratigraphically younger rocks.

Tectonic An adjective used to relate a particular phenomenon to a structural or orogenic concept.

Thrust An over-riding movement of one crustal unit over another, as in thrust faulting.

Unconformable Describes strata which do not succeed the underlying rocks in immediate order of age.

APPENDIX B
AGGREGATE TESTING PROCEDURES

The procedures used in each of the standard index tests are summarised below. In addition, the objective of each test is outlined and some guidance is given for the interpretation of the test results.

In all cases, with the exception of Polished Stone Value and Attrition Value determinations, the testing was carried out on +10 mm -14 mm sized aggregate. PSV tests used samples of +6 mm -10 mm aggregate and Wet Attrition Values were determined on +1½ -2 in sized aggregate.

(i) Physical Tests

(a) Flakiness Index. This test measures the weight-percentage of particles whose least dimension is less than 0.6 times the mean dimension. Test procedure involves the use of either a standard shape gauge or specially designed sieve.

In this test a higher numerical value indicates a more flaky aggregate. Flaky aggregates should be avoided because they are relatively weak, but aggregate shape can be improved by selective methods of crushing and screening.

(b) Relative Density and Water Absorption. Relative density was calculated on an oven-dried basis using a saturated aggregate sample, thus enabling water absorption (expressed as a percentage of the dry weight of the aggregate) to be measured during the same test procedure. Test values for relative density (specific gravity) are usually unspecified but values of at least 2.65 are desirable. The water absorption of an aggregate is important in assessing resistance to damage by frost. Classifications of absorption values are imprecise and debatable, but a low absorption value (the smaller the better), might reasonably be considered as less than 1 per cent.

(ii) Mechanical Tests : Strength

(a) Aggregate Impact Value (AIV). In this test a standard sample of aggregate is subjected to 15 blows from a hammer, weighing between 13.5 and 14.0 kg, falling through a standard height of 380 ± 5 mm. The sample suffers degradation to a graded assemblage of fines and the percentage of material passing a 2.36 mm sieve, relative to the initial sample weight, gives the AIV. It is a measure of the resistance of an aggregate to granulation under impact stresses. A lower numerical value indicates a more resistant rock.

(b) Aggregate Crushing Value (ACV). In this test a sample weighing approximately 2 kg is subjected to a steadily increasing load totalling 400 kN (about 40 tonnes) over a period of 10 minutes. As in the AIV test, the fines passing sieve BS 2.36 mm are calculated as a percentage of the initial sample weight and this is the ACV. Once again a lower value indicates a more resistant rock. The ACV gives a relative measure of the resistance of an aggregate to crushing under a gradually applied load.

(iii) Mechanical Tests : Durability

(a) Aggregate Abrasion Value (AAV). In this test a small number of aggregate particles are set into a resin backing allowing 6 mm protrusion of the aggregate. This sample is held against a rotating lap by a total load of 2 kg, for 500 revolutions. Leighton Buzzard sand, the abrasive medium, is fed at a known rate in front of the sample. The loss in weight during the test is expressed as a percentage of that of the original sample, to give the AAV. In this test a lower numerical value indicates a more resistant rock. This test provides an estimation of surface wear. The AAV reflects the hardness and brittleness of the constituent minerals, the influence of mineral cleavage and the strength of the intergranular bonds. The present DOE minimum abrasion requirements for road surfacing aggregates are an AAV of 10 for Category A sites (potentially dangerous sites) and 12 for Category B sites (Trunk Roads, Motorways and heavily trafficked urban roads).

(b) Polished Stone Value (PSV). This test is also carried out on aggregate set into a resin backing. A rotating rubber tyre bears on the aggregate with a total load of 40 kg, and an emery/water mix is fed continuously to the surface of the tyre. This simulates the action of dust-laden pneumatic tyres on road surfacing aggregates. The polish of the sample is then measured using a standard pendulum arc friction tester. The PSV is the coefficient of friction expressed as a percentage. A higher value signifies greater resistance to polishing (greater skid resistance). Values of over 65 indicate a highly polish-resistant rock especially suitable for road wearing courses in high-risk areas. The present DOE minimum PSV requirement for Category A sites is 62, and for Category B sites 59.

(c) Wet Attrition Value. In this test a 5-kg sample of aggregate is rotated in a closed, inclined cylinder which is also charged with an equal weight of water. This results in mutual attrition of the aggregates. The percentage of material broken from the sample is the Wet Attrition Value. This test is little used nowadays except by British Rail who employ it to evaluate aggregates for use as track ballast. The West Attrition Value should be as low as possible and a maximum of 6 has been specified for ballast used on UK main lines, rising to 8 on secondary lines.

APPENDIX C
RECORDS OF BOREHOLES AND SECTIONS

Details of the physical and mechanical test data obtained from both boreholes and sections in the

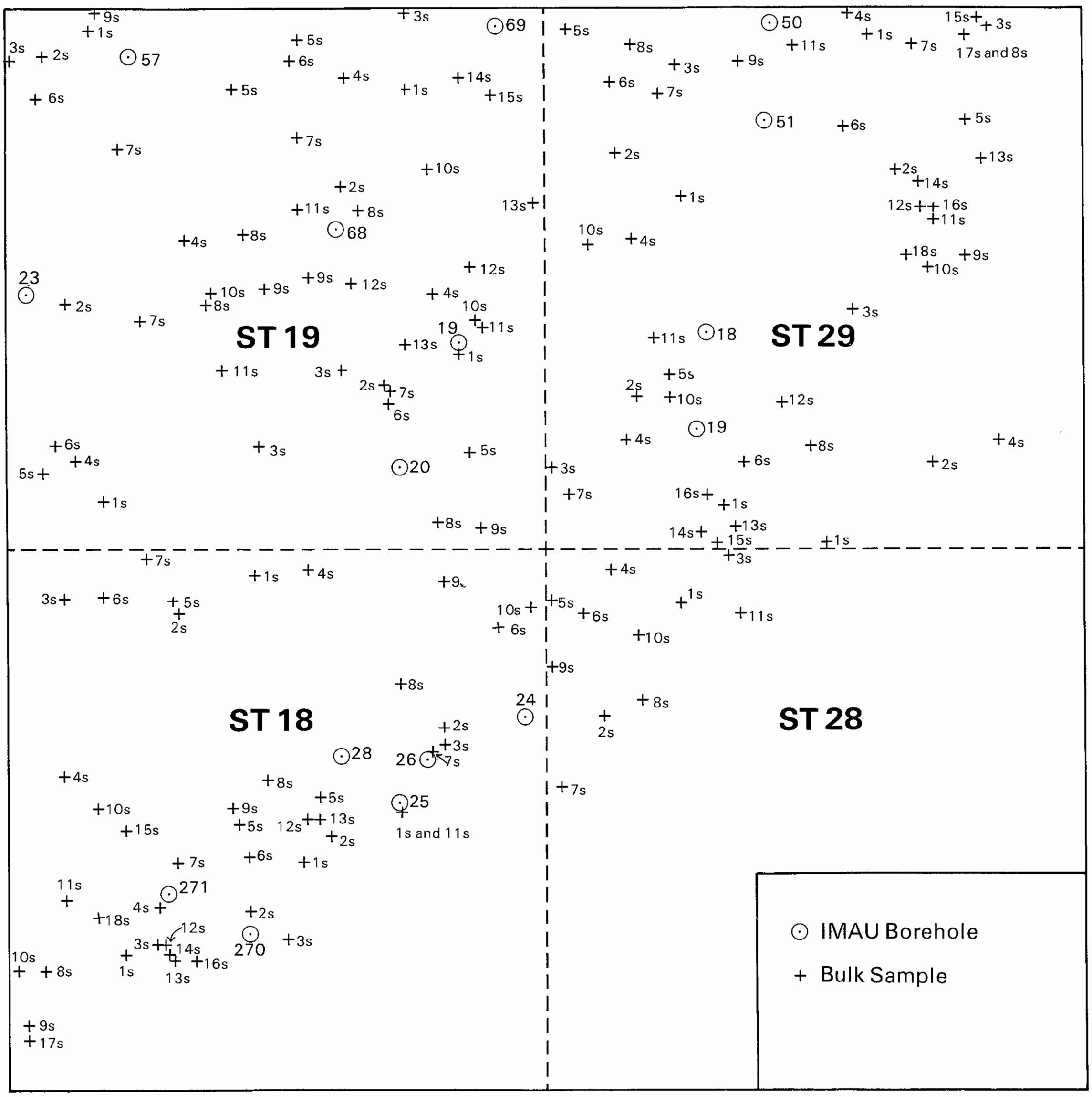

Figure 14 Distribution of data points.

Caerphilly district are listed below. The following list is arranged in the same order as data on the records.

1. The Registration Number. This consists of two statements:
   (i) The number of the 1:25 000 sheet on which the borehole lies, for example, ST 19.
   (ii) The quarter of the 1:25 000 sheet on which the borehole lies, and its number in a series for that quarter. Thus the full Registration Number, is, ST 19 NW 17.

   Collected sections are registered, in a similar manner using a separate series of numbers, suffixed by the letter 's'; for example, ST 19 NW 1s. Where more than one bulk sample has been collected from a section, each sample is numbered separately, for example, ST 19 NW 1s, 1, 2, 3.

2. Depth (boreholes). In most cases the data refers to 5-m lengths of borehole core.
3. Locality. Borehole and section locations are referred to the nearest named locality on the appropriate 1:10 000 or 1:10 560 map.
4. The National Grid Reference (NGR).
5. Geology. The stratigraphical names of the rock samples are listed.
6. Lithology. The lithology of the samples is briefly described using conventional geological terminology (see Appendix A).
7. Weathering Grade. The degree of rock weathering is given using the classification explained in Appendix A.
8. Flakiness. The flakiness index of most samples has been determined as explained in Appendix B.
9. Physical properties. The relative density and water absorption of selected aggregate samples have been determined as explained in Appendix B.
10. Mechanical properties (strength). The aggregate impact value (AIV) has been determined on almost all samples, and the aggregate crushing value (ACV) on most samples (see Appendix B for test procedures).
11. Mechanical properties (durability). For almost all borehole and section samples the aggregate abrasion value (AAV) has been determined. The polish stone value (PSV) has been determined on selected samples and the wet attrition value (WAV) on a few limestone and dolomite section samples (see Appendix B for test procedures).

ST 19 NW 57

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
19 NW 57	2-5	Gelligaer Common	1231 9914	Penn. Sst Hughes Beds	Greywacke, medium-grained	3	16			26	22	8.7	
"	5-10	" "	"	" "	Greywacke, medium-grained; some silty mudstone bands	1	21			19	16	6.2	69
"	10-15	" "	"	" "	Greywacke, medium-grained; some carbonaceous partings	1	19	2.68	0.7	19	16	4.8	
"	15-20	" "	"	" "	Greywacke, fine to medium-grained	1	26			16	15	8.6	
"	20-25	" "	"	" "	Greywacke, fine to medium-grained; rare pebbly bands	1	25			16	13	5.8	
"	25-30	" "	"	" "	Greywacke, fine-grained, with thin conglomeratic bands	1	21			17	15	6.6	67
	30-33	" "	"	" "	Greywacke, medium-grained; many carbonaceous partings	1	21			18	15	6.3	

ST 19 NE 68 and 69

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
19 NE 68	1-5	Gelli Haf	1614 9592	Penn. Sst. Grovesend Beds	Greywacke, medium-grained, jointed	3	21			28	21	9.3	
"	5-10	" "	"	" "	Greywacke, medium to coarse-grained; some coal laminae; rare thin mudstones	2	29			26	19	11.4	
"	10-15	" "	"	" "	Greywacke, medium to coarse-grained, relatively massive	1	19			22	21	7.1	72
"	15-20	" "	"	" "	Greywacke, medium to coarse-grained; some carbonaceous partings	1	22			21	16	6.8	69
19 NE 69	2-5	Gwrhay Fawr	1910 9971	Penn. Sst. Grovesend Beds	Greywacke, medium-grained; many joints	3	18			26		8.6	
"	5-10	" "	"	" "	Greywacke, medium-grained, with clasts of coal, mudstone and ironstone	1	16			24	19	8.1	72
"	10-15	" "	"	" "	Greywacke, fine to medium-grained, partly flaggy; some carbonaceous debris	1	21			24	18	8.4	
"	15-20	" "	"	" "	Greywacke, medium-grained	1	23	2.66	0.4	23	17	8.6	
"	20-25	" "	"	Grovesend Beds (Small Rider)	Coal/seat-earth sequence, mainly silty mudstone; 2 thin coals	1	16			27	21	12.6	
"	25-30	" "	"	" "	Greywacke, fine to medium-grained	1	21			23	17	8.5	73

ST 19 SW 23

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
19 SW 23	4-5	Tai'r-heol	1042 9471	Penn. Sst. Hughes Beds	Greywacke, medium-grained; some coal fragments	2	26			25		7.0	
"	5-10	" "	"	" "	Greywacke, medium-grained; some carbonaceous partings	1	28			25	19	9.2	
"	10-15	" "	"	" "	Greywacke, medium-grained; some coal fragments	1	26	2.67	0.6	25	18	7.8	
"	15-20	" "	"	" "	Greywacke, medium-grained; some fine-grained beds, locally micaceous	1	25			20	16	6.7	70
"	20-25	" "	"	" "	Greywacke, fine to coarse-grained	1	27			22	18	7.5	
"	25-30	" "	"	" "	Greywacke, fine to coarse-grained	1	21			24	18	8.4	
"	30-35	" "	"	" "	Greywacke, fine to coarse-grained, with mudstone bands; some conglomeratic beds	2	19			28	20	7.7	
"	35-40	" "	"	" "	Greywacke; fault breccia 35 to 38.6 m. Mineralised core, some mudstone	3	18			44	33	14.2	
"	40-45	" "	"	" "	Greywacke, medium-grained; several conglomeratic bands	1	20			23	18	6.5	
"	45-50	" "	"	" "	Greywacke, medium-grained	1	21			25	20	7.9	
"	50-55	" "	"	" "	Greywacke, fine to medium-grained; some thin mudstone bands; locally conglomeratic	1	16			25	19	7.2	
"	55-59	" "	"	" "	Greywacke, medium-grained; some coal laminae; locally conglomeratic	1	21			22	17	5.7	67

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
19 SE 19	0-5	Caerllwyn Quarry	1838 9376	Penn. Sst. Hughes Beds	Greywacke, medium-grained, some carbonaceous material	1	23			21	18	5.9	
"	5-10	" "	"	" "	Greywacke, fine to medium-grained, some carbonaceous material	1	21			20		6.8	
"	10-15	" "	"	" "	Greywacke, fine to medium-grained some carbonaceous material	1	27			19	16	7.9	
"	15-20	" "	"	" "	Greywacke, fine to medium-grained, some carbonaceous material	1	21			19		6.5	
"	20-25	" "	"	" "	Greywacke, fine to medium-grained, some carbonaceous material; conglomerate, mudstone	1	16			19	15	5.4	70
"	25-30	" "	"	" "	Greywacke, medium-grained	1	22	2.65	0.4	19		5.2	
"	30-35	" "	"	" "	Greywacke, medium-grained	1	22			21	16	5.6	
"	35-40	" "	"	" "	Greywacke, medium-grained; some conglomeratic beds	1 1	23 23			20 20		5.3 5.3	
"	40-45	" "	"	" "	Greywacke, medium-grained; some carbonaceous material	1	18			20	15	5.9	
"	45-50	" "	"	" "	Greywacke, medium-grained; some carbonaceous material	1	21			20		7.0	
"	50-55	" "	"	" "	Greywacke, medium-grained; some conglomeratic beds	1	19			19	16	6.2	
"	55-60	" "	"	" "	Greywacke, medium-grained; some mudstone beds	1	17			20		6.6	
"	60-65	" "	"	" "	Greywacke, medium-grained; varying amount of carbonaceous material	1	19			18	15	7.4	
"	65-70	" "	"	" "	Greywacke, medium-grained; with mudstone interbeds	1	16			20		7.4	
"	70-72	" "	"	" "	Greywacke, fine to medium-grained; some carbonaceous material	1	17			19	15	6.4	

ST 19 SE 20 and ST 29 NW 50

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
19 SE 20	1-5	Mynydd y Grug	1730 9146	Penn.Sst. Hughes Beds	Greywacke, medium to coarse-grained, jointed	3	14			28	20	14.0	
"	5-10	" "	"	" "	Greywacke, medium to coarse-grained, jointed	3	15			33	22	11.8	
"	10-15	" "	"	" "	Greywacke medium to coarse-grained; some carbonaceous material	2	24			28	21	9.3	
"	15-20	" "	"	" "	Greywacke, medium-grained; some carbonaceous material	2	16	2.62	1.2	28	20	9.0	
"	20-25	" "	"	" "	Greywacke, medium-grained; some carbonaceous material	2	22			30	22	11.8	
"	25-30	" "	"	" "	Greywacke, medium-grained, massive	1	20			25	19	10.2	
"	30-35	" "	"	" "	Greywacke, fine to medium-grained; some carbonaceous debris, mudstone	1 1	14 14			24 24	19 19	12.4 12.4	
"	35-40	" "	"	" "	Greywacke, medium-grained	1	12			23	17	9.2	73
"	40-45	" "	"	" "	Greywacke, medium-grained; some mudstone and coal clasts	1	13			23	18	8.6	74
"	45-50	" "	"	" "	Greywacke, medium to coarse-grained	1	17			24	16	10.2	
29 NW 50	5-10	Cefn Crib	2420 9972	Penn. Sst. Grovesend Beds	Greywacke, medium to coarse-grained; some coal clasts	3	24			47	36	20.7	
"	10-15	" "	"	" "	Greywacke, fine to medium-grained; some coal and ironstone clasts	3	13			40	31	20.3	
"	15-19	" "	"	Grovesend Beds (Small Rider)	Coal/seath-earth sequence. Mainly silty mudstone	3	24			35	30	36.7	

ST 29 NW 51

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
29 NW 51	2-5	Ysgubor Wen	2412 9790	Penn. Sst. Hughes Beds	Greywacke, fine to coarse-grained; some carbonaceous fragments	3	24			28		11.9	
"	5-10	" "	"	" "	Greywacke, fine to medium-grained	3	29			28	25	14.8	
"	10-15	" "	"	" "	Greywacke, fine to medium-grained	2	29			26	25	14.1	
"	15-20	" "	"	" "	Greywacke, fine to medium-grained	2	37			26	25	13.8	
"	20-25	" "	"	" "	Greywacke, fine to medium-grained, with conglomeratic layers and coaly debris	1	25			27	25	9.1	
"	25-30	" "	"	" "	Greywacke, fine to medium-grained, with conglomeratic layers and coaly debris	1	33			25	23	8.5	
"	30-35	" "	"	" "	Greywacke, fine to medium-grained; some carbonaceous, conglomerate, mudstone layers	1	27	2.68	0.7	25	22	8.5	
"	35-40	" "	"	" "	Greywacke, medium-grained; with common conglomeratic beds	1	30			26	21	8.4	
"	40-45	" "	"	" "	Greywacke, medium-grained; some carbonaceous debris	1	24			27	21	9.4	
"	45-50	" "	"	" "	Greywacke, medium-grained; some carbonaceous drebis	1	23			27	24	8.7	
"	50-55	" "	"	" "	Greywacke, medium-grained;	1	32			23	20	7.2	
"	55-60	" "	"	" "	Greywacke, medium-grained; some mudstone and conglomerate layers	1	30			25	22	8.6	

ST 29 SW 18 and SW 19

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
29 SW 18	1-5	Cwm Gofappy	2304 9404	Penn. Sst. Brithdir Beds	Greywacke, medium to coarse-grained; thin coaly partings	3	19			33	23	13.6	
"	5-10	" "	"	" "	Greywacke, medium to coarse-grained; some mudstone beds; common coal clasts	3	16			31	21	8.4	
"	10-15	" "	"	" "	Greywacke, fine to coarse-grained; some mudstone and carbonaceous bands	3	18	2.64	1.6	29	18	10.9	
"	15-20	" "	"	" "	Greywacke, fine to coarse-grained; some mudstone and carbonaceous bands	2	14			26	19	10.2	
"	20-25	" "	"	" "	Greywacke, medium-grained; common carbonaceous laminae	2	17			25	19	11.6	
"	25-30	" "	"	" "	Greywacke, medium to coarse-grained; some mudstone beds	2	17			26	19	10.6	
"	30-35	" "	"	" "	Greywacke, medium to coarse-grained; some mudstone and coaly bands	2	13			24	17	9.1	75
29 SW 19	1-5	Cwm Byr	2279 9217	Penn. Sst. Brithdir Beds	Greywacke, medium-grained	3	28			31	22	11.7	
"	5-10	" "	"	" "	Greywacke, medium-grained	2	23			30	22	11.7	
"	10-15	" "	"	" "	Greywacke, medium to coarse-grained; some coal clasts	2	22	2.60	2.0	30	21	11.8	
"	15-20	" "	"	" "	Greywacke, medium to coarse-grained; some coal clasts	2	13			28	19	11.4	
"	20-25	" "	"	" "	Greywacke, medium to coarse-grained; some coal clasts	2	14			29	20	10.8	
"	25-30	" "	"	" "	Greywacke, medium-grained, massive	1	15			26	19	9.3	76
"	30-35	" "	"	" "	Greywacke, fine-grained, silty, muddy	2	21			39	24	37.5	

ST 18 NE 24, 25 and 26

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
18 NE 24	1-20	Rudry	1964 8690	Carb. Lst. Main Lst.	Dolomite, very fine-grained and coarsely granular; mudstone partings	1		2.78	0.9	22	18	7.5	
"	20-40	"	"	" "	Dolomite, very fine-grained and coarsely granular; mudstone partings	1		2.78	0.9	20	18	7.0	
"	40-60	"	"	" "	Dolomite, very fine-grained and coarsely granular; mudstone partings	1		2.82	0.7	20	17	9.9	
18 NE 25	1-5	Cefn Onn	1729 8533	" "	Dolomite, fine to coarse-grained. Sporadic vughs and birds' eyes	1	20			22		8.8	
"	5-10	" "	"	" "	Dolomite, very fine and coarse dolomite. Porcellanous	1	25			21		7.0	49
"	10-15	" "	"	" "	Dolomite, fine to medium-grained, vughy; some mudstone partings	1	24			26		8.1	
"	15-20	" "	"	" "	Dolomite, very fine to coarse-grained; some mudstone bands and partings	1	37			23		7.1	
"	20-26	" "	"	" "	Dolomite, fine-grained, partly argillaceous; some mudstone bands	1	31			28		9.1	
18 NE 26	2-5	Tyn-y-parc	1780 8614	L. Coal Measures Sst.	Protoquartzite, fine-grained, laminated, common carbonaceous laminae, mudstone partings	3	39			28	22	9.3	
"	5-10	" "	"	" "	Protoquartzite, fine-grained, laminated, common carbonaceous laminae, mudstone partings	1	39	2.67	1.0	25	20	6.9	
"	10-15	" "	"	" "	Protoquartzite, fine-grained, laminated, common carbonaceous laminae, mudstone partings	1	28			23	20	9.6	80

ST 18 NE 26, 27 and NE 28

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
18 NE 26	15-20	Tyn-y-parc	1780 8614	L. Coal Measures Sst.	Protoquartzite, fine-grained, laminated, common carbonaceous laminae, mudstone partings	2	32	2.67	1.0	26	20	8.1	
"	20-25	" "	"	" "	Protoquartzite, as above, core shattered and rubbly. Fault zone	2	26			28	21	7.7	
"	25-28	" "	"	" "	Protoquartzite, as above, core shattered and rubbly. Fault zone	2	30			25		8.3	
18 NE 27	4-10	Warren Drive	1620 8618	Penn. Sst. Brithdir Beds	Greywacke, medium-grained; some conglomerate and coaly fragments	3	34			30		9.6	
"	10-15	" "	"	" "	Greywacke, fine to coarse-grained; with some mudstone, conglomerate and coaly partings	1	34			23		8.7	
"	15-19	" "	"	" "	Greywacke, fine-grained; some carbonaceous laminae	1	28			22		8.0	
18 NE 28	6-10	Warren Drive	1619 8618	Penn. Sst. Brithdir Beds	Greywacke, medium to coarse-grained; some carbonaceous laminae	2	28			26	23	7.8	
"	10-15	" "	"	" "	Greywacke, fine to coarse-grained; some conglomerate and carbonaceous laminae	2	29			25	22	8.1	
"	15-20	" "	"	" "	Greywacke, fine to medium-grained; some carbonaceous laminae	1	31	2.66	0.6	22	20	7.9	70
"	20-25	" "	"	" "	Greywacke, fine-grained; some mudstone and conglomeratic bands	1	30			23	21	5.9	
"	25-30	" "	"	" "	Greywacke, fine to coarse-grained; some conglomerate and carbonaceous debris	1	31			22	19	7.4	
"	30-35	" "	"	" "	Greywacke, medium to coarse-grained; some mudstone, carbonaceous laminae	1	28			19	17	6.1	
"	35-41	" "	"	" "	Greywacke, medium-grained	1	31			19	18	6.3	

ST 28 SW 270

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
18 SW 270	6–10	Rhiwbina Farm	1452 8295	Carb. Lst. L.Lst. Shale	Dolomitic limestone/limestone, grainstone, thin calcilutite. Some hematite.	1	18			22	21	7.6	
"	10–15	" "	"	" "	Limestone/dolomite, grainstone some mudstone, hematite-stained	1	17			27	23	7.2	
"	15–20	" "	"	" "	Dolomite/dolomitic limestone, crinoidal grainstone, hematite-stained	1	17	2.79	0.5	21	21	8.1	49
"	20–25	" "	"	" "	Dolomite/dolomitic limestone crinoidal grainstone, hematite-stained	1	19			23	22	8.4	
"	25–30	" "	"	" "	Dolomite/dolomitic limestone crinoidal grainstone, hematite-stained	1	19			23	22	8.6	
"	30–35	" "	"	" "	Dolomitic argillaceous limestone: wackestone, some packstone	1	19			21	20	8.1	
"	35–40	" "	"	" "	Dolomitic argillaceous limestone: wackestone, some grainstone beds	1	18			24	23	8.3	
"	40–45	" "	"	" "	Dolomitic, argillaceous limestone	1	23			25	20	7.2	
"	45–50	" "	"	" "	Dolomitic limestone; some thin mudstone bands	1	16			21	18	5.2	

ST 18 SW 271

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
18 SW 271	1–5	Ty-rhiw	1297 8363	Carb. Lst. Main Lst.	Limestone, grainstone, oolitic, some shelly packstone	1	35			23		10.6	
"	5–10	"	"	" "	Limestone, grainstone, oolitic, some shelly packstone	1	32			23		8.9	
"	10–15	"	"	" "	Limestone, grainstone, oolitic, some shelly packstone	1	26	2.71	0.6	24		9.1	48
"	15–20	"	"	" "	Limestone, grainstone, oolitic, some shelly packstone	1	34			22		8.1	
"	20–25	"	"	" "	Dolomite, fine-grained and granular, vughy, hematite-stained	1	26			28		13.2	52
"	25–30	"	"	" "	Dolomite/limestone, dolomite passing into grainstone	1	31			25		10.5	
"	30–34	"	"	" "	Limestone, grainstone, oolitic	1	33			23		10.8	

ST 19 NW Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
19 NW 1s 1	Pen-cae-mawr	116 996	Penn. Sst. Hughes Beds	Greywacke, flaggy	2				22	20	9.6		
" 2	"	"	" "	Greywacke, massive	1		2.70	1.1	20	21	8.1		
" 3	"	"	" "	Greywacke, massive	1				21	23	7.1		
19 NW 2s	Pen-craig-Fargoed	107 991	" "	Greywacke, medium to coarse-grained. Flaggy	3	15			29	23	8.5		
19 NW 3s	Cwm Bargoed	100 990	" "	Greywacke, fine-grained	2	25	2.67	0.9	23	19	10.1		
19 NW 4s	Cefn-llwynau	133 957	Penn. Sst. Grovesend Beds	Greywacke, fine to medium-grained	3	23			28	19	9.2		
19 NW 5s	Dei Gratia	142 985	" "	Greywacke, fine, silty, some ironstone pebbles	3	28			26	26	25.2		
19 NW 6s	Taff Merthyr	106 983	Penn. Sst. Hughes Beds	Greywacke, medium-grained flaggy	3	23			27	26	8.7		
19 NW 7s	Tophill	121 974	Penn. Sst. Grovesend Beds	Greywacke, medium-grained flaggy	2	19			26	20	9.1		
19 NW 8s	Cefn Hengoed	144 958	Penn. Sst. Hughes Beds	Greywacke, medium-grained massive	1	26			20	18	5.0		73
19 NW 9s	Cefn Gelligaer	117 000	" "	Greywacke, medium-grained, flaggy	3				27				

ST 19 NE Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
19 NE 1s	Cwmgelli Quarry	174 985	Penn. Sst. Grovesend Beds	Greywacke, fine to medium-grained, flaggy	1				25	22	11.8		
19 NE 2s	Fleur de lis	162 967	" "	Greywacke, medium-grained, flaggy	3				24	20	20.8		
19 NE 3s	Argoed Uchaf	174 999	" "	Greywacke, fine to medium-grained	2	51	2.72	0.7	24	18	10.5		
19 NE 4s	Ffynnon Wen	163 987	" "	Greywacke, medium to coarse-grained	3	26			27	25	15.5		
19 NE 5s 1	Bargoed Colliery	154 994	Penn. Sst. Hughes Beds	Greywacke, coarse-grained	1	20			19	16	5.6	73	
" 2	" "	"	" "	Greywacke, fine to medium-grained	1	28			21	17	6.9		
19 NE 6s	Gwaelod-y-waun	153 990	" "	Greywacke, coarse-grained, flaggy	1	24			23	18	6.2		
19 NE 7s	Brittania Colliery	154 976	" "	Greywacke, medium to coarse-grained, flaggy	2	21			22	17	6.8		
19 NE 8s	Tyfry Bungalow	165 962	Penn. Sst. Grovesend Beds	Greywacke, medium-grained, flaggy, some carbonaceous material	2	15			24	19	12.6		
19 NE 9s	Maes-y-cwmner	156 950	Penn. Sst. Hughes Beds	Greywacke, medium-grained, massive	1	21			21	16	4.8		
19 NE 10s	Woodfieldside	178 970	Penn. Sst. Grovesend Beds	Greywacke, medium-grained, massive	1	20			21	15	8.7		
19 NE 11s	Twyn	154 963	" "	Greywacke, medium-grained, massive	2	31			21	15	7.9		
19 NE 12s	Cwm-nant-yr-odyn	186 952	Penn. Sst. Hughes Beds	Greywacke, medium-grained, massive	1	20			19	14	8.2		
19 NE 13s	King Charles Road	198 964	Penn. Sst. Grovesend Beds	Greywacke, medium-grained, massive	2	22			24	17	12.9		
19 NE 14s	Oakdale Colliery	184 987	" "	Greywacke, medium-grained, massive	3	30			27	23	16.0		
19 NE 15s	Oakdale	190 984	" "	Greywacke, flaggy	3	21			27	20	12.2		

ST 19 SW Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
19 SW 1s	Senghenydd	118 909	Penn. Sst. Hughes Beds	Greywacke, massive	3				27	26	13.4		
19 SW 2s 1	Bryncoch Quarry	111 945	" "	Greywacke	1				18	21	6.0	64	
2	" "	"	" "	Greywacke, flaggy	3	23	2.72	0.7	24		10.1		
19 SW 3s	Graddfa	147 919	" "	Greywacke, flaggy	3				22	21	10.3		
19 SW 4s	Senghenydd	113 916	" "	Greywacke, coarse-grained; some carbonaceous fragments	2	27			25	21	9.7		
19 SW 5s	Parc Quarry	107 914	" "	Greywacke, coarse-grained; some carbonaceous laminae	2	26			26	21	13.7		
19 SW 6s	Ty-canol	109 919	" "	Greywacke, fine-grained, flaggy	1	29			23	21	15.1		
19 SW 7s	Pen-y-wawn	125 942	" "	Greywacke, medium to coarse-grained, flaggy	2	29			24	22	7.3		
19 SW 8s	Tredomen Quarry	137 945	" "	Greywacke, fine-grained, massive	2	26			23	18	9.4		
19 SW 9s	Railway Cutting, Hengoed	148 948	" "	Greywacke, medium-grained; some carbonaceous fragments	2	28			24	20	6.2	65	
19 SW 10s	Penalltau Rock	138 949	" "	Greywacke, coarse-grained	2	31	2.65	1.4	24	22	8.3		
19 SW 11s	Brynteg Cottage	140 933	" "	Greywacke, medium-grained	2	30			23	16	6.9	72	

ST 19 SE Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
19 SE 1s 1	Caerllwyn Quarry	184 937	Penn. Sst. Hughes Beds	Greywacke, massive	1				21	18	8.8	73	
2	" "	"	" "	Greywacke, coarse-grained	2				25	22	8.6		
19 SE 2s	Ffynnon-y-gwaed	170 930	" "	Greywacke, medium-grained; some carbonaceous fragments	1	30			24	18	9.6		
19 SE 3s	Twyn-shon-evon	162 933	" "	Greywacke, medium-grained; some carbonaceous fragments	2				25	20	6.7		
19 SE 4s	Gelligroes	197 947	" "	Greywacke, coarse-grained	2				21	24	11.0		
19 SE 5s	Cwmfelinfach	186 918	Penn. Sst. Brithdir Beds	Greywacke, medium-grained; some carbonaceous fragments	1		2.67	0.7	19	20	6.0		
19 SE 6s	Bryn-ysgawen	171 927	Penn. Sst. Hughes Beds	Greywacke, fine-grained, flaggy	1	31			20	15	7.9		
19 SE 7s	Ffynnon-y-gwaed	171 929	" "	Greywacke, medium-grained, flaggy	2	30			27	21	9.4		
19 SE 8s	Mynydd-y-grug	180 905	" "	Greywacke, coarse-grained	2	21	2.65	0.9	27	24	11.5		
19 SE 9s	Pen-heol-machen	188 904	" "	Greywacke, medium-grained, flaggy	3	30	2.63	1.1	33	26	14.4		
19 SE 10s	Pen-heol-eae'r-llwyn	187 942	Penn. Sst. Grovesend Beds	Greywacke, medium and coarse-grained, flaggy	2	23			23	22	11.9		
19 SE 11s	Ty-Pentre	188 941	" "	Greywacke, fine-grained	1	32			22	16	9.7		
19 SE 12s	Railway cutting, Maes-y-cwmmer	164 949	" "	Greywacke, coarse-grained	1	29			27	20	12.5	74	
19 SE 13s	Wyllie Halt	174 938	Penn. Sst. Hughes Beds	Greywacke, medium-grained, flaggy	2	25			24	19	5.8		

ST 29 NW Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
29 NW 1s	Hafod Quarry	225 965	Penn. Sst. Hughes Beds	Greywacke, massive	1		2.63	1.3	22	17	8.0	72	
29 NW 2s	Newbridge	213 973	" "	Greywacke, medium-grained; some carbonaceous debris	1				24	20	8.7		
29 NW 3s	Swffryd Wood	224 989	" "	Greywacke, massive	3				24	22	11.1	75	
29 NW 4s	West End	216 957	Penn. Sst. Brithdir Beds	Greywacke, coarse-grained; common ironstone pebbles	1				24	21	5.9		
29 NW 5s	Caer-hendy	204 996	Penn. Sst. Grovesend Beds	Greywacke, medium-grained; some ironstone pebbles	2	26			26	21	10.6	79	
29 NW 6s	Crumlin	212 986	Penn. Sst. Hughes Beds	Greywacke, medium-grained	2	19			22	16	6.8		
29 NW 7s	Llwyna-wen	221 984	" "	Greywacke, medium-grained	2	26	2.68	0.5	25	19	9.7		
29 NW 8s	Bron-y-bryn	216 993	" "	Greywacke, medium-grained	2	24			24	18	9.9		
29 NW 9s	Cwm-y-lyn	236 990	" "	Greywacke, medium-grained	2	26			29	24	8.9		
29 NW 10s	Cwm Pennar	208 956	" "	Greywacke, medium-grained	1	25			21	19	7.4		
29 NW 11s	Craig Major	246 993	" "	Greywacke, medium-grained	3	25			25	21	10.9		

ST 29 NE Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
29 NE 1s 1	Bwarth Maen	260 995	Penn. Sst. Brithdir Beds	Greywacke, medium to coarse-grained	3				27	26	11.8		
2	" "	"	" "	Greywacke, medium-grained	3	37	2.60	2.0	24	24	14.2		
29 NE 2s	Blaen Bran	265 970	" "	Greywacke, coarse-grained	3	33			34	30			
29 NE 3s 1	Cwmynyscoy	282 997	Carb. Lst. Main Lst.	Dolomite, fine-grained	1	31	2.78	0.9	19	16	7.0		5.0
2	"	282 999	L. Lmst. Shale	Dolomitic limestone, argillaceous	1	39			20				
29 NE 4s	Graig Gwent	256 999	Penn. Sst. Hughes Beds	Greywacke, medium-grained	3	30			27	23	20.2		
29 NE 5s	Mountain Air P.H.	278 979	Carb. Lst. L. Lmst. Shale	Dolomitic limestone	2	26			27	22	10.1		
29 NE 6s 1	Mynydd Llwyd	254 978	Penn. Sst. Hughes Beds	Greywacke, fine-grained	3	36			22		11.5		
2	" "	255 978	" "	Greywacke, coarse-grained; some carbonaceous and pebbly layers	2	31			22	20	10.0		
29 NE 7s	Blaendare Farm	268 993	Penn. Sst. Brithdir Beds	Greywacke, medium-grained	3	21			28	22	14.5		
29 NE 8s	Penyrheol Reservoir	278 995	Lower Coal Measures Sst.	Protoquartzite, fine-grained	1	25	2.67	0.8	31	20	5.2	67	
29 NE 9s	Greenmeadow Farm	278 954	Lower O.R.S	Subarkose, fine-grained, flaggy	3	27			34	27	43.7		
29 NE 10s 1	Dowlais Brook	271 952	" "	Conglomerate, marl and sandstone clasts, micaceous, quartzose matrix	3	25			28		10.0		
2	" "	"	" "	Arkose, fine to medium-grained	3	14			35	26	23.4		
29 NE 11s	Park House Farm	272 961	" "	Conglomeratic arkose, some marl	2	15			33	23	10.8		
29 NE 12s	Gelli-Gravoy	270 963	Carb. Lst. L. Lmst. Shale	Dolomitic limestone, crinoidal	2	24			24		7.2		8.8

ST 29 NE/SW Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
29 NE 13s	Maes-gwyn	281 972	Lower O.R.S.	Subarkose, fine-grained	1	20			25	21	10.5		
29 NE 14s	Coed gwern-esgob	269 968	Middle Coal Measures Sst.	Protoquartzite, fine to medium-grained	3	20			37	28	5.3		
29 NE 15s 1	Cwmynyscoy	280 998	Millstone Grit	Protoquartzite, massive	2	18			25		3.3		
2	"	"	" "	Protoquartzite, flaggy; pebbly layers; carbonaceous laminae	2	21			22		4.0		
29 NE 16s	Upper Cwmbran	272 963	Upper O.R.S.*	Conglomerate, quartz pebbles; sandstone matrix	3	12			33	25	3.0		
29 NE 17s	Upper Race	278 995	Lower Coal Measures Sst.	Orthoquartzite, coarse-grained	3	21			43	34	8.8		
29 NE 18s	Llanderfel	267 954	Upper O.R.S.	Arkose, fine to medium-grained	2	21	2.57	0.7	44		8.2		
29 SW 1s 1	Danygraig	233 908	Carb. Lst. Main Lst.	Dolomite, very fine-grained, laminated, interbedded shale bands	1				19		6.2		
2	"	"	" "	Dolomite, coarse granular, vughy	1		2.83	0.5	31	27	16.0		10.6
3	"	"	" "	Dolomite, fine-grained, massive	1				16	14	6.8		4.1
29 SW 2s	Craig Carnau	217 928	Penn. Sst. Brithdir Beds	Greywacke, coarse-grained	3				27	23	11.1		
29 SW 3s	Craig-y-Trwyn	201 915	" "	Greywacke, medium-grained, massive	1		2.63	1.6	22	20	12.4		
29 SW 4s	Cox's Quarry	215 920	" "	Greywacke, fine to medium-grained	2				21	20	10.5		
29 SW 5s	Cwmcarn Quarry	223 932	" "	Greywacke, coarse-grained	2				25	21	7.9	71	
29 SW 6s 1	Risca Quarry	237 916	Carb Lst. Main Lst.	Dolomite, fine-grained	1	28	2.81	0.5	17	15	5.7		

* Old Red Sandstone

ST 29 SW/SE Section Samples

Sample Number		Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
29 SW 6s	2	Risca Quarry	237 916	Carb Lst. Main Lst.	Dolomite, fine-grained	1				15	13	6.0		8.0
29 SW 7s		Quarry Mawr	204 910	Penn. Sst. Brithdir Beds	Greywacke, medium-grained; much carbonaceous material	1	18			22	17	7.9		
29 SW 8s		Maes-mawr	249 919	Lower O.R.S.	Subarkose, fine-grained, micaceous	2	21	2.52	2.9	31	24	10.9		
29 SW 9s		Coed Mam-gu	224 922	Penn. Sst. Brithdir Beds	Greywacke, medium to coarse-grained	2	19			28	21	3.6		
29 SW 10s		Gelli Unig Farm	223 928	" "	Greywacke, medium to coarse grained	2	19			26	19	7.4	68	
29 SW 11s		Abercarn Fawr	220 939	" "	Greywacke, medium to coarse-grained	2	16			25		7.4		
29 SW 12s		Twmbarlwm	244 927	Penn. Sst. Hughes Beds	Greywacke, medium to coarse-grained, flaggy	2	19			32		17.6		
29 SW 13s		Tir-y-cwm	235 904	Upper O.R.S.	Arkose, fine-grained	2	23			21		5.7	66	
29 SW 14s		Waun pen-y-Garn	229 903	Lower Coal Measures Sst.	Protoquartzite, fine-grained	1	25			22		9.4	63	
29 SW 15s		Coed-y-machen	232 901	Carb Lst. Main Lst.	Dolomite, fine-grained	2	24			19		5.8		
29 SW 16s		Danygraig Tip	284 920	Lower Coal Measures Sst.	Protoquartzite, fine-grained	2		2.61	0.8	28		5.1		
29 SE 1s		Canal Quarry	252 901	Lower O.R.S.	Arkose, medium-grained, partly micaceous	3		2.52	3.1	36		29.1	83	
29 SE 2s		Ty coch	272 916	" "	Arkose, medium-grained, flaggy	3	28			40	34	37.8		
29 SE 3s		Craig Llywarch	257 944	Penn. Sst. Brithdir Beds	Greywacke, coarse-grained	3				34	32	22.4	89	
29 SE 4s		Pentre Bach	284 920	Lower O.R.S.	Limestone, nodular, marly	2	19			28		11.4		

ST 18 NE Section Samples

Sample Number		Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
18 NW 1s	1	Pwll-y-pant Quarry	146 895	Penn. Sst. Hughes Beds	Greywacke, medium-grained	2				28	22			
	2	" "	"	" "	Greywacke, massive	1		2.66	0.8	28	23	14.9	78	
	3	" "	"	" "	Greywacke, massive	1				24	20	9.8		
18 NW 2s		Craig-y-fedw	132 888	" "	Greywacke, coarse-grained	3	22			31	24	11.4	77	
18 NW 3s		St. Ilans Church	111 890	" "	Greywacke	2	28			24	21	9.5		
18 NW 4s		Rhyd-yr-Helyg	111 858	Penn. Sst. Grovesend Beds	Greywacke	2	22			29	24	7.2	75	
18 NW 5s		Abertridwr	131 890	Penn. Sst. Hughes Beds	Greywacke, coarse-grained; some carbonaceous material	3	23			29	25	11.2		
18 NW 6s		"	118 891	" "	Greywacke, medium-grained	2	19			25		10.8		
18 NW 7s		Nant Cwm Ceffyl	126 898	" "	Greywacke, medium-grained	2	19			27	18	9.0		
18 NW 8s		Watford	149 857	Penn. Sst. Rhondda Beds	Greywacke, medium-grained, flaggy	2	19			28		9.1		
18 NW 9s		Graig	142 852	Penn. Sst. Llynfi Beds	Greywacke, fine-grained, flaggy	2	31			34		14.8	70	
18 NW 10s		Coed-y-Gedrys	117 852	Penn. Sst. Brithdir Beds	Greywacke, medium-grained; flaggy	2	17			24		6.6		

ST 18 NE Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
18 NE 1s	Wern Ddu Quarry	173 853	Carb. Lst. Main Lst.	Dolomite, fine and coarse-grained	1	27			23		9.4		
18 NE 2s	Mynydd Rudry	181 867	Penn. Sst. Rhondda Beds	Greywacke, medium-grained, lithic	3	26			32	30	16.3		
18 NE 3s	Coed Parc-y-Van	181 864	Lower Coal Measures Sst.	Orthoquartzite, coarse-grained, pebbly	2		2.53	0.8	44	38	7.7	65	
18 NE 4s 1	Trehir Quarry	156 896	Penn. Sst. Hughes Beds	Greywacke, medium-grained	1	38	2.66	0.9	23	22	9.3	70	
2	" "	"	" "	Greywacke, flaggy	2				23	22	15.2		
3	" "	"	" "	Greywacke, coarse-grained	2		2.70	1.6	24	20	7.5	75	
4	" "	"	" "	Greywacke	3				32	30	16.7		
5	" "	"	" "	Greywacke, medium-grained	1				22	19	6.8		
18 NE 5s	Caerphilly Common	158 854	Penn. Sst. Rhondda Beds	Greywacke, fine to medium-grained	3				37	31	20.3		
18 NE 6s	Fountain Bridge	192 885	Penn. Sst. Grovesend Beds	Greywacke, fine-grained	1				23	23	10.9	71	
18 NE 7s	Limekiln Quarry	179 862	Lower Coal Measures Sst.	Protoquartzite, fine-grained micaceous	1	28			21	16	5.6		
18 NE 8s	Gwern-y-domen	173 875	Penn. Sst. Hughes Beds	Greywacke, medium-grained	1	25			19		7.6		
18 NE 9s	Trethomas Works	181 895	" "	Greywacke, medium-grained	2	22			21	18	9.9		
18 NE 10s	Gelli-wastad	197 889	" "	Greywacke, medium-grained	2	18			22	17	6.5		
18 NE 11s	Cefn-Onn Quarry	173 852	Carb. Lst. Main Lst.	Dolomite, fine-grained	1	28			17	16	6.3		
18 NE 12s	Tai-pen-star	156 850	Lower Coal Measures Sst.	Orthoquartzite, coarse-grained, pebbly	2	21	2.57	0.5	41		5.9		
18 NE 13s	Thornhill	158 850	" "	Orthoquartzite, coarse-grained, pebbly	2	16	2.55	0.5	42		7.5		

ST 18 SW Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
18 SW 1s 1	Walnut Tree	122 825	Carb. Lst. Main Lst.	Limestone, oolitic grainstone	1	25	2.67	0.8	26		9.9		
2	" "	"	" "	Dolomite, coarsely granular	1				32	24	15.0		
3	" "	"	" "	Dolomite, fine-grained	1	23			15		6.2		8.1
18 SW 2s	Gelli Quarry	145 833	" "	Dolomite, fine-grained	1	25	2.84	0.4	16	15	5.3		
18 SW 3s	Castell Coch	128 827	" "	Dolomite, fine-grained, argillaceous	1				18		6.8		
18 SW 4s 1	Ty Rhiw	128 834	" "	Dolomite, fine and coarse-grained	2	17	2.83	0.3	31		12.6		
2	"	"	" "	Limestone, oolitic grainstone	1	19			21		10.2		
18 SW 5s	Black Cock P.H.	143 849	Lower Coal Measures Sst.	Orthoquartzite, coarse-grained, pebbly	3	17			42		3.7		
18 SW 6s 1	Blaengwynlais	145 843	Carb. Lst. Main Lst.	Dolomite, fine-grained	1	25			20	16	6.7		
2	"	145 841	" "	Dolomite, fine-grained	1	22			17	13	6.2		
18 SW 7s	Craig-yr-Allt	132 842	Lower Coal Measures Sst.	Orthoquartzite, medium-grained	2	23			31		5.2	63	
18 SW 8s	Pentrych	107 823	Carb. Lst. Main Lst.	Limestone, fine-grained grainstone	1	24			22		8.4		9.4
18 SW 9s	Cwm-y-fuwch	104 812	" "	Dolomite, fine-grained	1	27			19		5.6		
18 SW 10s	Pentrych Chapel	102 822	" "	Limestone, oolitic grainstone	1	24	2.70	0.3	20		9.3		
18 SW 11s	Garth Hill	111 835	Penn. Sst. Rhondda Beds	Greywacke, medium to coarse-grained, flaggy	3	19			32	22	13.8		
18 SW 12s	Taff Gorge	129 827	Carb. Lst. Main Lst.	Dolomite, fine-grained	1	19			18	16	6.5		

ST 18 SW/SE Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
18 SW 13s	Tongwynlais	131 824	Carb. Lst. L. Lst. Shale	Dolomitic limestone, fine-grained, some coarsely fossiliferous bands	1	27			23		7.7		
18 SW 14s 1	Tongwynlais Road Cut	130 825	Upper O.R.S.	Arkose, medium-grained, lithic	1	25			25		6.3		
2	" "	"	" "	Arkose, medium-grained, flaggy	1	20			22		2.6	55	
18 SW 15s	Glan-y-llyn	123 848	Penn. Sst. Llynfi Beds	Greywacke, medium to coarse-grained	1	21			22		5.6	66	
18 SW 16s 1	Tongwynlais	135 824	Upper O.R.S.	Arkose, medium-grained, saccharoidal	1	31			36		8.3		
2	"	"	" "	Subarkose, micaceous, silty	3	23			47		11.3		
18 SW 17s	Cockid Uchaf	104 809	" "	Arkose, fine to medium-grained	2	38	2.74	0.5	24		4.2		
18 SW 18s	Georgetown	117 832	Lower Coal Measures Sst.	Protoquartzite, fine-grained; mudstone interbeds	2	40	2.69	0.8	22		12.8		
18 SE 1s	Castell-y-briwydd	155 842	Upper O.R.S.	Conglomerate, quartz pebbles, sandstone matrix	2				46	33	5.3		
18 SE 2s	Thornhill	160 847	Carb. Lst. Main Lst.	Dolomite, fine-grained	1	22			18		6.9		
18 SE 3s	Typiea Cottage	152 828	Lower O.R.S.	Arkose, fine to medium-grained, pebbly	2	28			24		2.7		

ST 28 NW Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
28 NW 1s 1	Machen Quarry	225 890	Carb. Lst. Main Lst.	Dolomite, fine-grained	1	29	2.80	0.3	16	15	6.3	42	
2	" "	"	" "	Dolomite, coarsely granular, vughy	1				26	23	11.4		
3	" "	"	" "	Dolomite, fine-grained	1				17	15	6.4		3.9
28 NW 2s 1	Cwmleyshon Quarry	211 869	" "	Dolomite, fine-grained	1	25	2.83	0.8	17	19	6.1	46	
2	" "	"	" "	Dolomite, fine-grained	1				17	17	6.9		3.0
28 NW 3s	Ochrwyth	234 899	" "	Dolomite, fine-grained	1				19	16	7.6		
28 NW 4s	Machen	212 896	Penn Sst. Brithdir Beds	Greywacke, medium-grained	3				31	28	14.7	80	
28 NW 5s	Cae-back	201 890	" "	Greywacke, medium-grained	2	21			27	19	10.7		
28 NW 6s	Cae Quarry	207 888	Penn. Sst. Rhondda Beds	Greywacke, medium-grained	2	16			25		14.6		
28 NW 7s	Llwyn celyn	203 856	Lower O.R.S.	Conglomerate, coarse quartzite pebbles in marly, sandy matrix	3	14			35		5.2		
28 NW 8s	Hollybush House	218 873	Carb. Lst. Main Lst.	Dolomite, fine-grained	2	25			23		6.8		
28 NW 9s	Pen-twyn	201 878	Penn. Sst. Llynfi Beds	Protoquartzite, pebbly, pinkish colour	2	20	2.67	1.3	38	26	10.0		
28 NW 10s	Rhyd-y-gwern	217 884	Carb. Lst. Main Lst.	Dolomite, fine-grained	2	15			20		4.8		
28 NW 11s	Pant-teg	236 888	" "	Dolomite, fine-grained	2	25			19	17	5.5		
28 NW 12s 1	Mynydd Machen	231 896	Millstone Grit	Conglomerate, quartz pebbles in sandstone matrix	2				34		2.9		
2	" "	229 897	" "	Orthoquartzite, medium-grained	2				32		3.4		

APPENDIX D

Record of Boreholes and Sections in the Pontypridd and Swansea Areas (Feasilbility Study Data).

Details of the physical and mechanical test data obtained from the Pontypridd and Swansea areas during the Hard Rock Feasibility Study are listed below. The format for the records is the same as is used in Appendix C.

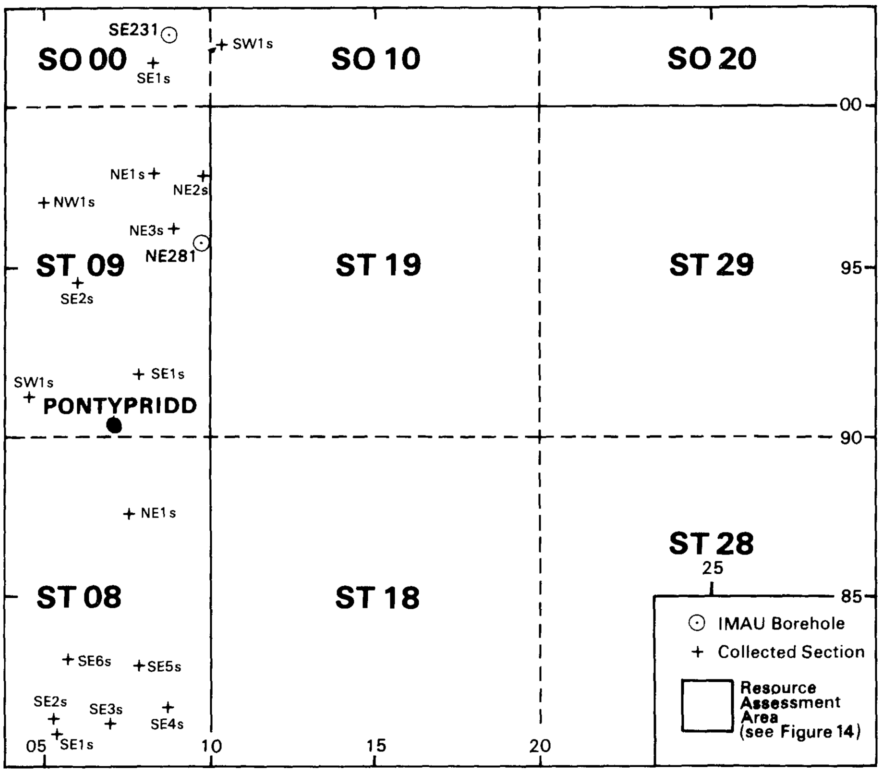

Figure 15 Distribution of data points in the Pontypridd area (Feasibility Study data).

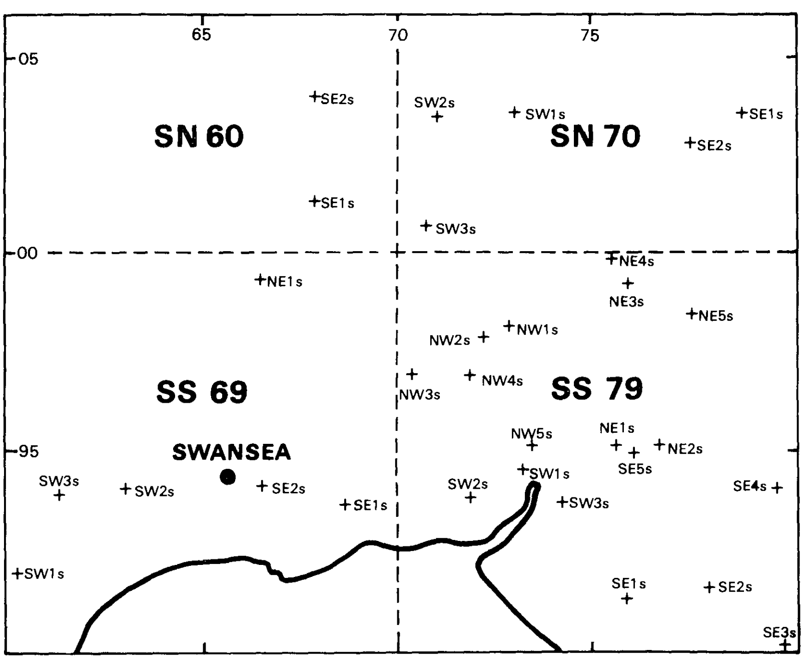

Figure 16 Distribution of sections in the Swansea area (Feasibility Study data).

Pontypridd Area: SO 00 SE 231 and ST 09 NE 281

Borehole Number	Depth (m)	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV
00 SE 231	1-5	Merthyr Common	0828 0178	Penn. Sst. Brithdir Beds	Greywacke, medium-grained, flaggy, jointed	2	18			25	21	7.4	
"	5-10	" "	"	" "	Greywacke, medium-grained; common mudstone	1	27			24	20	5.2	
"	10-15	" "	"	" "	Greywacke, medium-grained; common mudstone	1	39			25	21	8.5	
"	15-20	" "	"	" "	Greywacke, medium-grained; some carbonaceous laminae	1	35			22	16	5.1	
"	20-25	" "	"	" "	Greywacke, medium-grained; some carbonaceous laminae	1	41			23	19	5.0	
"	25-30	" "	"	" "	Greywacke, medium-grained; some carbonaceous laminae	1	32			21	19	5.7	
"	30-35	" "	"	" "	Greywacke, medium-grained; some thin mudstone and conglomerate bands	1	34			21	19	5.9	
"	35-40	" "	"	" "	Greywacke, medium to coarse-grained; some carbonaceous partings	1	37			20	20	5.3	
"	40-45	" "	"	" "	Greywacke, medium to coarse-grained; some carbonaceous partings	1	31			23	19	5.6	
"	45-50	" "	"	" "	Greywacke, medium-grained, with mudstone bands, some carbonaceous laminae; conglomerate	1	33			23	22	8.7	
"	50-55	" "	"	" "	Greywacke, medium-grained, thin mudstone and carbonaceous laminae	1	32			20	17	7.4	
"	55-60	" "	"	" "	Greywacke, medium-grained, thin mudstone and carbonaceous laminae	1	38			21	19	5.6	
"	60-65	" "	"	" "	Greywacke, medium-grained; some coaly partings and conglomerate bands	1	31			23	20	5.5	
ST 09 NE 281	8-15	Quaker's Yard	0975 9658	Penn. Sst. Hughes Beds	Greywacke, coarse-grained, some carbonaceous partings; mudstones	2	20			21			
"	15-20	" "	"	" "	Greywacke, fine to coarse-grained, some carbonaceous streaks; mudstones	1	21			18	15	8.4	
"	20-25	" "	"	" "	Greywacke, fine to coarse-grained, some carbonaceous streaks; mudstones	1	20			17	14	7.5	
"	25-29	" "	"	" "	Greywacke, coarse-grained, common carbonaceous streaks	1	24			19			

Pontypyridd Area; SO 00, SO 10, ST 09 Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
SO 00 SE 1s	Mynydd-y-Chapel	083 013	Penn. Sst. Hughes Beds	Greywacke, fine-grained, flaggy	2	20			23	18	6.4		
SO 10 SW 1s 1	Blaenwynau Farm	105 019	Penn. Sst. Hughes Beds	Greywacke, coarse-grained	3		2.64	1.0	32			77	
2	" "	"	" "	Greywacke, coarse-grained	3				29	25	15.9		
ST 09 NW 1s	Perthcelyn	049 972	Penn. Sst. Hughes Beds	Greywacke, medium-grained, flaggy	2	14			25	20	8.3		
ST 09 NE 1s	Pen Bwlcha	083 980	" "	Greywacke, medium-grained, massive	1				25	22	8.5		
ST 09 NE 2s	Cefn Fforest	098 979	" "	Greywacke, medium-grained, massive	1				26	22	7.6		
ST 09 NE 3s	Prince Llewelyn	098 963	" "	Greywacke, medium-grained, massive	2				20	18	7.3		
ST 09 SW 1s	Trehafod Station	045 910	Penn. Sst. Rhondda Beds	Greywacke, medium-grained, massive	1				20	17		67	
ST 09 SE 1s 1	Craig-y-Hesg	078 917	Penn. Sst. Brithdir Beds	Greywacke, flaggy	2				22		6.8		
2	" "	"	" "	Greywacke, coarse-grained, massive	1				20	20	5.6	70	
3	" "	"	" "	Greywacke, some carbonaceous laminae and pebbly layers	1		2.67	0.9	18	17	4.2		
4	" "	"	" "	Greywacke, massive	1		2.67	0.9	19		5.4		
5	" "	"	" "	Greywacke, massive	1				20		6.1	69	
ST 09 SE 2s	Ynysybwl Quarry	061 946	" "	Greywacke, medium-grained	2				22	18	8.1		

Pontypridd Area: ST 08 Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
ST 08 NE 1s	Maendy Quarry	075 877	Penn. Sst. Brithdir Beds	Greywacke, medium to coarse-grained, flaggy	1				21	17	11.6		
ST 08 SE 1s 1	Hendy Quarry	053 811	Carb. Lst.	Dolomite, fine-grained, crinoidal	1	31			20		7.8		
2	" "	"	" "	Dolomite, fine-grained	1				18	17	7.0		
3	" "	"	" "	Limestone, oolitic grainstone	1				24	25	8.6		
ST 08 SE 2s	Mwyndy Quarry	053 815	" "	Limestone, grainstone	2				23	23	8.8		9.4
ST 08 SE 3s 1	Brofiscin Quarry	070 813	" "	Dolomitic Limestone, wackestone	2				22	22	11.3		8.8
2	" "	"	" "	Limestone, crinoidal wackestone	1		2.72	0.3	21				
ST 08 SE 4s	Creigiau Quarry	086 817	" "	Dolomite, fine-grained	1		2.83	0.2	20	19	8.3		8.1
ST 08 SE 5s	Coed-y-Graig	079 831	Penn. Sst. Rhondda Beds	Greywacke, medium-grained	1	21			27	23	9.0		
ST 08 SE 6s	Llantrisant	057 832	" "	Greywacke, coarse-grained, pebbly	2				28		10.3		

Swansea Area: SN 60 and SN 70 Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
SN 60 SE 1s	Gwnd-yn-Cadi	678 013	Penn. Sst. Swansea Beds	Greywacke, coarse-grained, carbonaceous	3	20			37	27	15.2		
SN 60 SE 2s 1	Rhyd-y-gwin	678 040	" "	Greywacke, medium-grained	3	22			32	26	13.6		
2	" "	"	" "	Greywacke, fine-grained, flaggy	3	28			28	21	12.9		
SN 70 SW 1s 1	Alltwen Quarry	730 034	Penn. Sst. Hughes Beds	Greywacke, coarse-grained	1					20	7.1		
2	" "	"	" "	Greywacke, fine-grained	1				20	18	10.0		
SN 70 SW 2s	Trebanos	710 035	" "	Greywacke, medium-grained, micaceous	1	18			22	24	8.9		
SN 70 SW 3s	Craig-y-Pal	707 006	Penn. Sst. Swansea Beds	Greywacke, medium-grained	1	19			25	21	8.1		
SN 70 SE 1s	Cefn Coed Colliery	786 035	Penn. Sst. Rhondda Beds	Greywacke, coarse-grained	1	26			21		4.3		
SN 70 SE 2s	Ty-r-lan Farm	773 027	Penn. Sst. Brithdir Beds	Greywacke, fine to medium-grained	3				27		12.8		

Swansea Area: SS 69 and SS 79 NW Section samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
SS 69 NE 1s 1	Cwmrhydyceirw	665 993	Penn. Sst. Swansea Beds	Greywacke, fine-grained	1	32			20	18	7.1		
2	"	"	" "	Greywacke, medium-grained	1		2.67	0.8	25	19	10.2	72	
SS 69 SW 1s	Clyne Valley Brickworks	601 920	Lower Coal Measures Sst.	Protoquartzite, fine-grained	2				25	22	11.3		
SS 69 SW 2s	Cockett Wood Park	630 940	Penn. Sst. Lower Penn. M.	Greywacke, medium-grained	1		2.63	0.8	29	24			
SS 69 SW 3s	Hendrefoilan Quarry	613 939	" "	Greywacke, coarse-grained	3		2.61	1.8	38	37	19.0	74	
SS 69 SE 1s	Port Tennant	686 936	Penn. Sst. Rhondda Beds	Greywacke, coarse-grained	2	20			26	22	5.8		
SS 69 SE 2s	Foxhole	665 941	" "	Greywacke, fine-grained	3	21			33	17	6.2		
SS 79 NW 1s 1	Neath Abbey	727 981	Penn. Sst. Swansea Beds	Greywacke, fine to medium-grained	1	27			19	18	7.4		
2	" "	"	" "	Greywacke, medium-grained	1	20			16	15	6.5		
3	" "	"	" "	Greywacked, fine-grained, flaggy, micaceous	2	25			20	18	10.2		
SS 79 NW 2s	Brithdir Farm	727 977	" "	Greywacke, fine to medium-grained	1	27			22	18	8.0		
SS 79 NW 3s	Crymlyn Quarry	703 969	" "	Greywacke, fine-grained	1				22	20	7.8		
SS 79 NW 4s	Wern goch	718 969	Penn. Sst. Hughes Beds	Greywacke, coarse-grained, flaggy	3	30			27	24	11.2		
SS 79 NW 5s	Giant's Grave	733 951	Penn. Sst. Brithdar Beds	Greywacke, coarse-grained, flaggy	2				26	22	10.5		

Swansea Area: SS 79 NE, SW, SE Section Samples

Sample Number	Locality	NGR	Geology	Lithology	Weathering Grade	Flakiness	Rel. Den.	Water Abs.	AIV	ACV	AAV	PSV	WAV
SS 79 NE 1s	Cefncoed Farm	754 951	Penn. Sst. Hughes Beds	Greywacke, medium-grained	2				25	21	8.8		
SS 79 NE 2s	Crythan Farm	766 951	" "	Greywacke, medium-grained	3	20			30	24	8.9		
SS 79 NE 3s	Cwm-bach	758 991	" "	Greywacke, fine to medium-grained	1				24	19	6.9		
SS 79 NE 4s 1	Gilfach	752 999	" "	Greywacke, massive	1		2.65	0.9	22	18	5.8	71	
2	"	"	" "	Greywacke, flaggy	1				23	20	6.8		
SS 79 NE 5s	Cydgoed	774 984	Penn. Sst. Brithdir Beds	Greywacke, fine-grained, flaggy	1				27	16	10.2		
SS 79 SW 1s	Briton Ferry	730 994	Penn. Sst. Rhondda Beds	Greywacke, medium-grained	1				21	20	6.3		
SS 79 SW 2s	Jersey Marine	718 938	Penn. Sst. Llynfi Beds	Greywacke, medium-grained, flaggy	3				33	27	6.9		
SS 79 SW 3s	Lay-by (A48)	741 937	" "	Greywacke, medium-grained	1				25	22	7.4	72	
SS 79 SE 1s	Pant-ysgawen	757 913	" "	Greywacke, medium-grained	2				29	23	5.9		
SS 79 SE 2s 1	Caerhendy	777 916	Penn. Sst. Brithdir Beds	Greywacke, fine-grained, flaggy and micaceous	2	23			25	19	9.9		
2	"	"	" "	Greywacke, medium-grained	2		2.60	1.7	23		7.1		
SS 79 SE 3s	Craig-y-Fforest	797 901	Penn. Sst. Rhondda Beds	Greywacke, medium-grained	2				25	23	8.5		
SS 79 SE 4s	Oakwood Quarry	795 940	" "	Greywacke, flaggy and micaceous	2		2.66	1.0	20	18	5.4	67	
SS 79 SE 5s	Cwm-nant-yarllwys	759 949	Penn. Sst. Brithdir Beds	Greywacke, fine-grained, flaggy	1	31			19	16	8.1		

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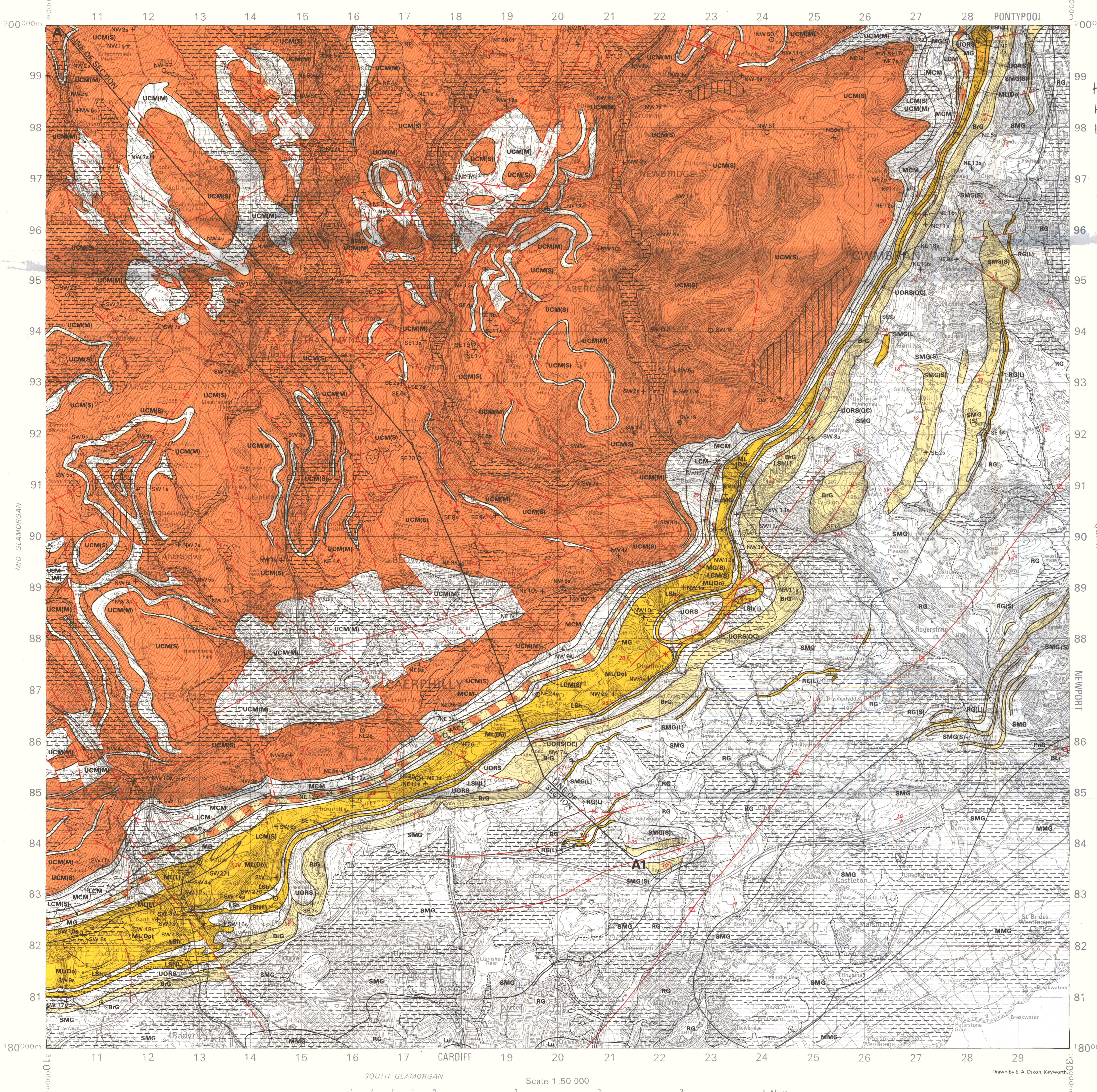
BRITISH GEOLOGICAL SURVEY
(INDUSTRIAL MINERALS ASSESSMENT UNIT)

THE HARD ROCK RESOURCES OF THE COUNTRY AROUND CAERPHILLY, SOUTH WALES

THE HARD ROCK RESOURCES OF THE COUNTRY AROUND CAERPHILLY, SOUTH WALES.



Hard Rock Assessment Survey by K.A.McL. Adlam, D.J. Harrison and J.B.L. Wild 1982-83.
R.G. Thurrell, Head, Industrial Minerals Assessment Unit.
Geological Sheet 249 by H.C. Squirrell, R.A. Downing, G.D.E. Lewis, B. Kelk and A.W. Woodland 1952-61.
V.A. Eyles and F.B.A. Welch, District Geologists. Published in 1968. Reprinted on 1:50 000 scale in 1975
Geological data for sheet 263 by R.A. Waters
1:50 000 Hard Rock Resource Sheet published 1984
G.M. Brown, DSc., F.R.S., Director, British Geological Survey.

This map should be read in conjunction with the accompanying Report, which contains details of the assessment of resources

Compiled from Ordnance Survey 1:50 000 2nd series mapping, sheet 171.
Revised 1979-80.
Major roads revised 1981.
Low water mark plotted from air photographs dated 1963-78.
The representation on this map of a Road, Track or Footpath, is no evidence of the existence of a right of way.
Made and published by the Ordnance Survey, Southampton.

Detailed records may be consulted on application to the Programmes Director PD-B (IMAU), British Geological Survey, Keyworth, Nottingham NG12 5GG

Compiled and produced by the Keyworth Drawing Office of the British Geological Survey.

EXPLANATION OF ASSESSMENT COLOURS

Colours are used to indicate the aggregate potential of the rocks at surface.

HRA-1 Group 1 aggregate materials (PSV > 65, AIV 20-28, AAV 7-14)
HRA-2 Group 2 aggregate materials (PSV < 50, AIV 15-26, AAV 5-11)
HRA-3 Group 3 aggregate materials (PSV 50-80, AIV >30, AAV 5-30)
HRA-4 Undivided Group 1 and Group 3 aggregate materials
HRA-5 Uncoloured areas are occupied by rocks (mainly mudstones) that are unlikely to be potentially useful for aggregate

CAPTURE ✓

BOUNDARY LINES

✓ Geological boundary, Solid

Geological boundary, Drift

STRUCTURAL SYMBOLS

✓ Fault (crossmark indicates downthrow side)

Axial trace of anticline

Axial trace of syncline

45 Inclined strata, dip in degrees

SITE LOCATIONS

Industrial Minerals Assessment Unit (IMAU) borehole

Collected section

LANDSLIP

✓ L-1

EXPLANATION OF STRATIGRAPHICAL SYMBOLS

		Approximate thickness (m)		
DRIFT				
	Alluvium, river and estuarine			RECENT AND PLEISTOCENE
	Glacial deposits, undifferentiated			RECENT AND PLEISTOCENE
SOLID				
BLi	Blue Lias - limestones and mudstones	up to 20		JURASSIC
PnG	Penarth Group - mainly mudstones	7		TRIASSIC
MMG	Mercia Mudstone Group - mainly mudstones	113		TRIASSIC
UCM	Upper Coal (Pennant) Measures - mainly sandstones (S) with some mudstones (M)	up to 850	COAL MEASURES	CARBONIFEROUS
MCM	Middle Coal Measures - mainly mudstones and coals; some sandstones (S)	107-213	COAL MEASURES	CARBONIFEROUS
LCM	Lower Coal Measures - mainly mudstones and coals; some sandstones (S)	82-183	COAL MEASURES	CARBONIFEROUS
MG	Millstone Grit - mainly mudstones; some sandstones (S) at base	37-55	MILLSTONE GRIT SERIES	CARBONIFEROUS
ML	Main Limestone - mainly dolomite (Do); some limestone (L) at top	12-540	CARBONIFEROUS LIMESTONE SERIES	CARBONIFEROUS
LSh	Lower Limestone Shale - upper mudstone division, lower limestone/dolomite division (L)	36-107	CARBONIFEROUS LIMESTONE SERIES	CARBONIFEROUS
UORS	Upper Old Red Sandstone - mudstones; some quartz conglomerate/sandstone (QC) at base	76-122	UPPER OLD RED SANDSTONE	DEVONIAN
BrG	Brownstone Group-mainly sandstone	122-183	LOWER OLD RED SANDSTONE	DEVONIAN
SMG	St. Maughans Group-mainly mudstones; some sandstones (S), and limestones (L)	457-610	LOWER OLD RED SANDSTONE	DEVONIAN
RG	Raglan Marl-mainly mudstones; some sandstones (S) and limestones(L)	335-610	LOWER OLD RED SANDSTONE	SILURIAN
Lu	Ludlow Series-mudstones, siltstones, sandstones and limestones	c.50		SILURIAN

CLASSIFICATION OF CRUSHED ROCK AGGREGATES BASED ON THEIR MECHANICAL PROPERTIES

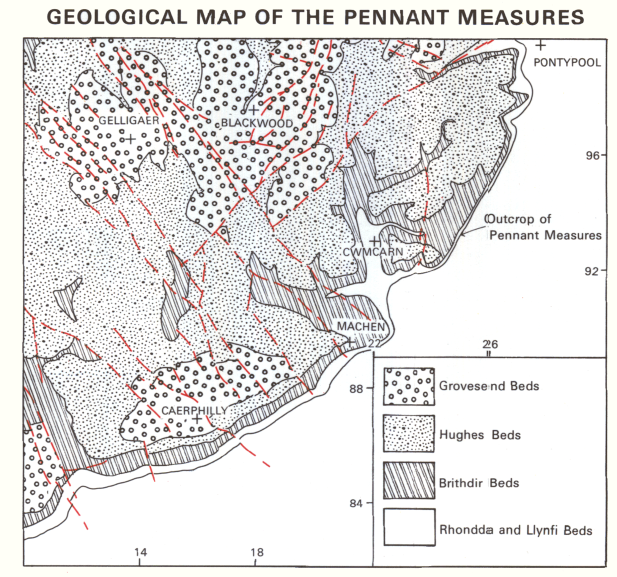
	DESCRIPTION	TYPICAL INDEX TEST RESULTS	POSSIBLE USES
GROUP 1 aggregate materials	Polish-resistant aggregate, moderate or good strength and abrasion resistance	PSV>65 AIV 20-28 AAV 7-14	Road surfacing, most other construction purposes
GROUP 2 aggregate materials	Strong aggregate, good abrasion resistance, low polish-resistance	PSV<50 AIV 15-26 AAV 5-11	Roadstone (except surfacing materials), concrete aggregate, railway ballast, armour stone etc.
GROUP 3 aggregate materials	Weak aggregate, variable resistance to abrasion and polishing	PSV 50-80 AIV>30 AAV 5-30	Unsuitable for many construction purposes, except rock fill

SUMMARY OF MECHANICAL TEST DATA OBTAINED FROM FRESH AND SLIGHTLY WEATHERED ROCK SAMPLES

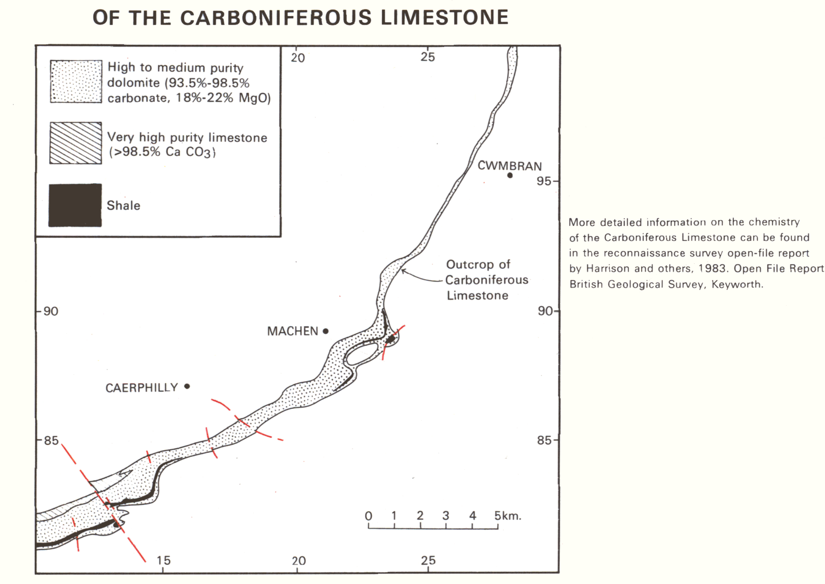
ROCK TYPE		AGGREGATE IMPACT VALUE (AIV)			AGGREGATE CRUSHING VALUE (ACV)			AGGREGATE ABRASION VALUE (AAV)			POLISHED STONE VALUE (PSV)		
		Range	Mean	S.D.*	Range	Mean	S.D.	Range	Mean	S.D.	Range	Mean	S.D.
PENNANT SANDSTONE		47-16	25	4.7	36-13	21	3.9	37.5-2.7	9.6	4.5	79-64	71	3.5
LOWER AND MIDDLE COAL MEASURES SANDSTONE		44-21	30	8.1	38-16	23	6.5	12.8-3.3	7.0	2.4	80-63	69	7.7
CARBONIFEROUS LIMESTONE	LIMESTONE	26-20	22	1.8	-	-	-	10.8-7.8	9.3	1.0	-	48	-
	DOLOMITE	32-15	20	4.3	27-13	19	3.6	16.0-4.8	7.5	2.4	52-42	47	4.3
OLD RED SANDSTONE SANDSTONE		47-21	33	7.8	34-21	27	4.9	43.7-2.6	13.0	11.8	83-55	68	14.1

*S.D. Standard Deviation

GEOLOGICAL MAP OF THE PENNANT MEASURES

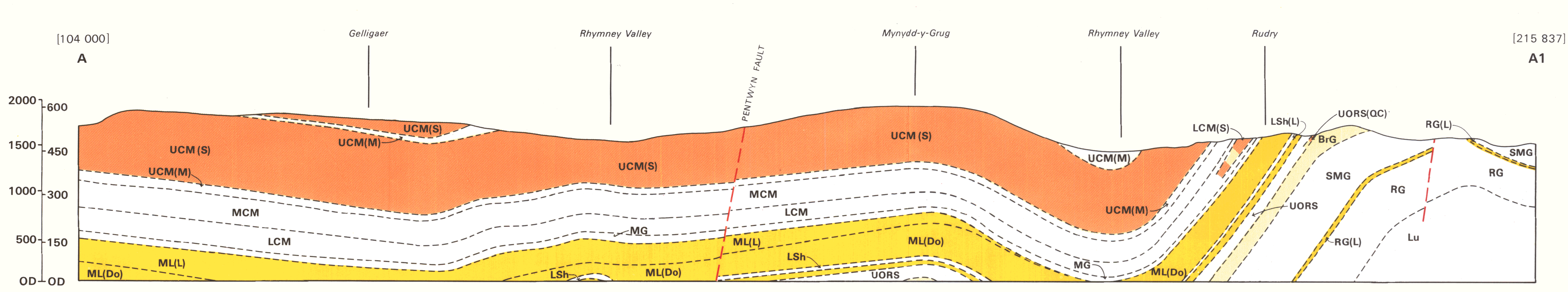


SUMMARY OF THE CHEMICAL PURITY OF THE CARBONIFEROUS LIMESTONE



More detailed information on the chemistry of the Carboniferous Limestone can be found in the reconnaissance survey open-file report by Harrison and others, 1983, Open File Report, British Geological Survey, Keyworth.

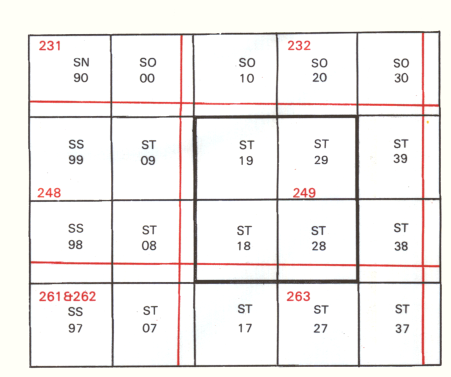
SECTION SHOWING THE GENERALISED GROUPS OF AGGREGATE MATERIALS ALONG THE LINE A-A1 DRAWN ACROSS THE MAP



VERTICAL SCALE TWICE THE HORIZONTAL

1000 0 1000 2000 3000 4000 5000 Feet
300 0 300 600 900 1200 1500 Metres

Diagram showing the relation of the Resource Sheet to the National Grid 1:25 000 sheets and the 1:50 000 New Series Geological Sheets 231, 232, 248, 249, 261 & 262, and 263



GENERALISED MAP OF THE SOLID GEOLOGY