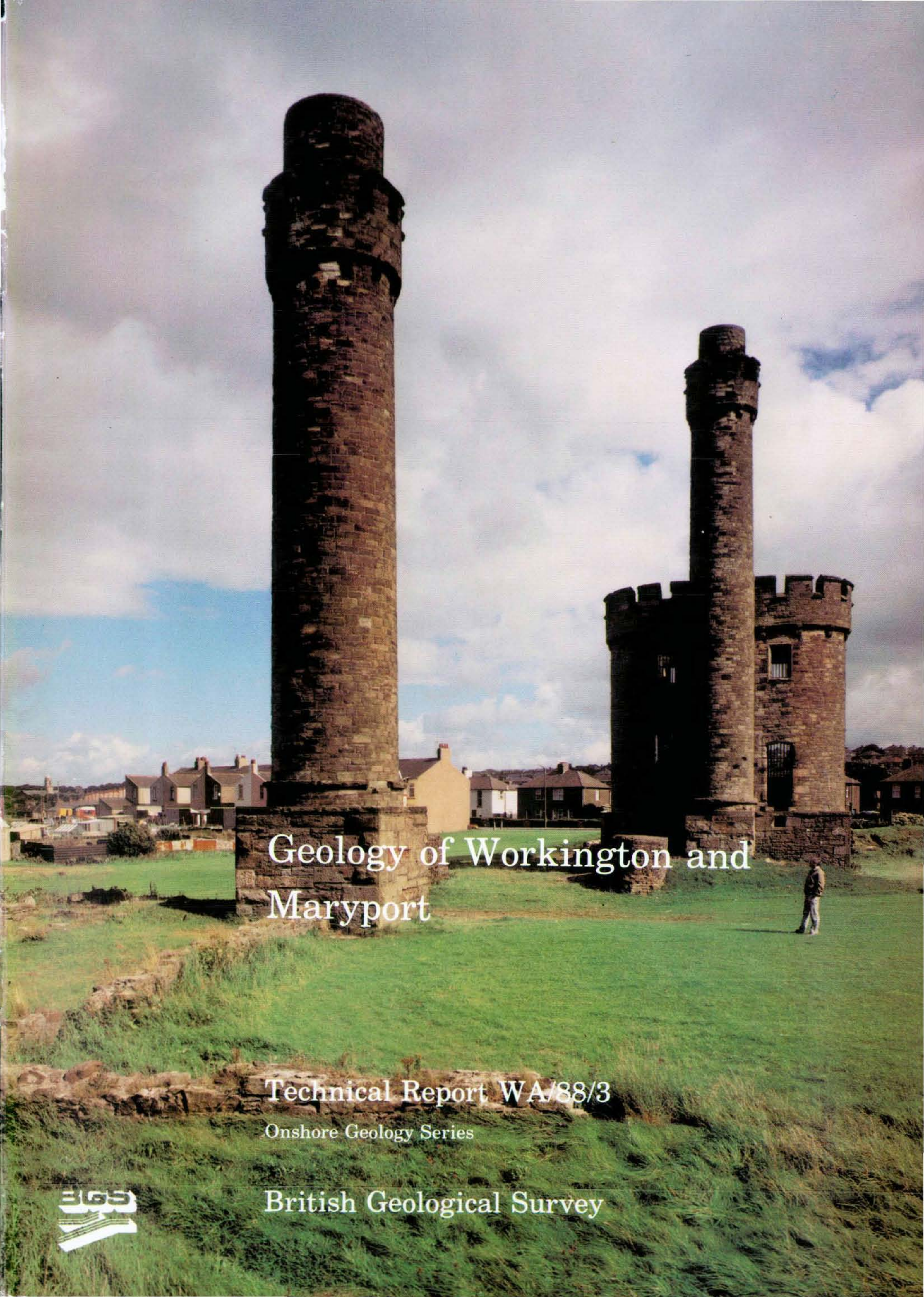

Geology of Workington and Maryport

Technical Report WA/88/3

Onshore Geology Series

British Geological Survey

RESEARCH REPORT WA/88/3

Geology of Workington and Maryport

1:10 000 sheets NY 02 NW, 03 NW, SW; NX 92 NE, and part of 93 SE. Parts of 1:50 000 sheets 22 (Maryport) and 28 (Whitehaven)

R P Barnes, B Young, D V Frost and D H Land

BRITISH GEOLOGICAL SURVEY

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BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WA/88/3

Onshore Geology Series

Geology of Workington and Maryport

1:10 000 sheets NY 02 NW, 03 NW, SW; NX 92 NE, and part of 93 SE. Parts of 1:50 000 sheets 22 (Maryport) and 28 (Whitehaven)

R P Barnes, B Young, D V Frost and D H Land

Geographical index

UK, NW England, Cumbria

Subject index

Geology, Carboniferous, Dinantian, Namurian, Westphalian, Coal Measures, Drift, Mining, Planning

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CONTENTS

FIGURES

MAPS

1:10 000 scale

The geological maps are overprinted on Ordnance Survey topographic bases and produced for the following sheets:

NY 02 NW
NY 03 NW
NY 03 SW (and part of NX 93 SE)
NY 92 NE (and part of NX 93 SE)

Thematic maps are in three categories as follows:

Rockhead elevation
Drift thickness
Borehole and shaft sites

For each of these three themes there are three maps produced for the following topographic bases:

NY 02 NW and NX 92 NE
NY 03 SW and part of NX 93 SE
NY 03 NW

1:25 000 scale (in pocket)

Structure contours
Shallow coal workings

ABSTRACT

This report describes the geology, mineral resources and geotechnical aspects of the Workington and Maryport area of Cumbria (Sheets NY02NW, 03NW,SW, NX92NE,SE). Lower, Middle and Upper Coal Measures (Westphalian A, B and C), which crop out over most of the district, are of fluvial facies, 500 m thick, with some 19 workable coals. Quaternary sediments which are commonly up to 30 m thick conceal much of the solid rocks. Coal has been mined extensively, but resources remain which could be worked opencast. Geotechnical problems result from subsidence over coal workings and shafts, many of which are inadequately documented. Weak clays, silts and peat in the Quaternary sequence may also cause foundation difficulties.

Notes

It is emphasised that the maps in this report should not be used as a substitute for normal site investigations.

National Grid references are given in square brackets as 6 or 8 figure co-ordinates. Those beginning with 9 lie in 100 km square NX, those beginning with 0 in square NY.

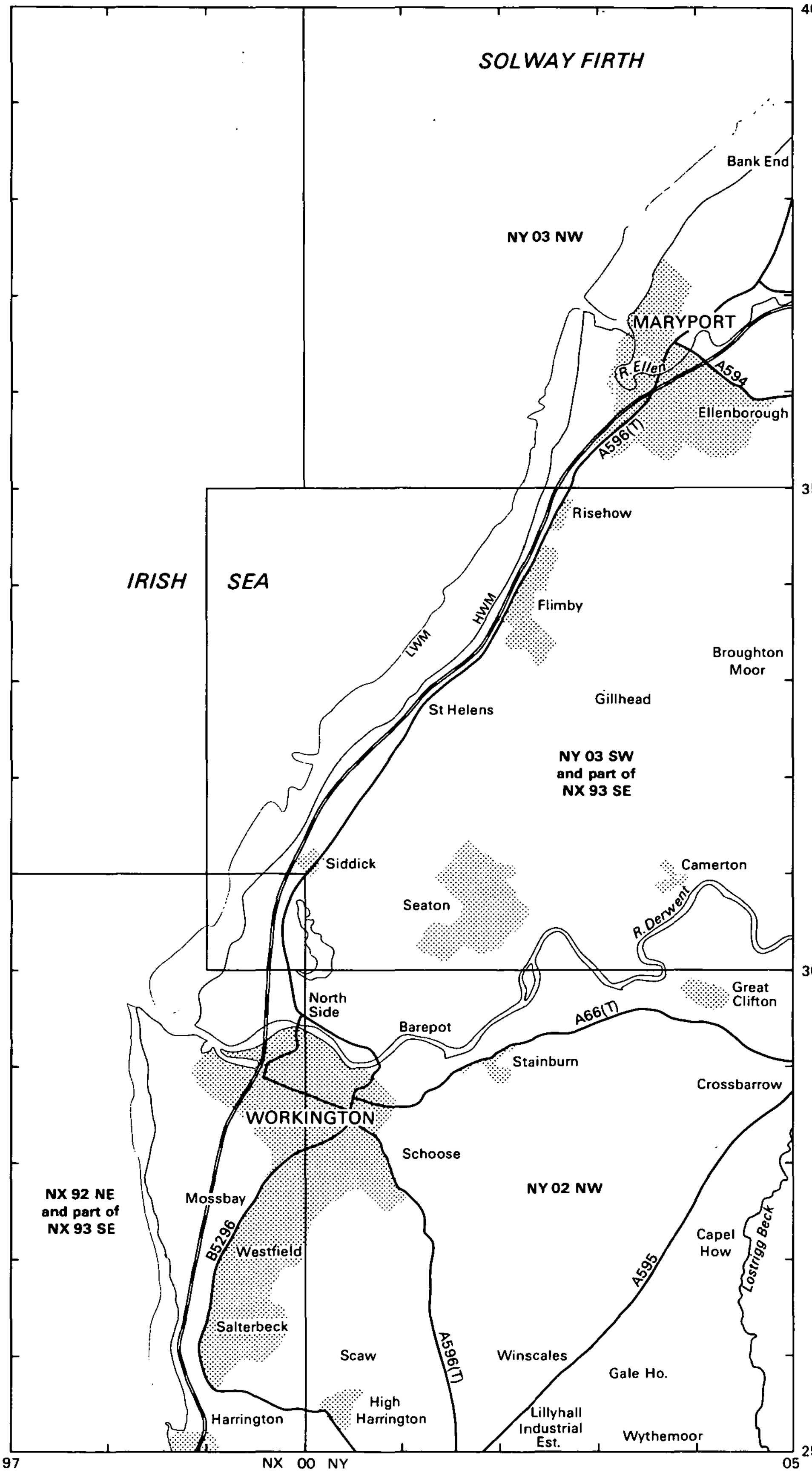

Figure 1 Location map

PREFACE

This account describes the geology of the 1:10,000 scale sheets NY02NW, 03NW, 03SW, NX92NE and 93SE which lie within the 1:50,000 geological sheets 22 (Maryport) and 28 (Whitehaven). The resurvey was commissioned by the Department of the Environment with a provision for 50 per cent of the funding.

The area was first surveyed at the six-inch scale by T. V. Holmes, R. Russell and J. C. Ward in 1878 and published in 1892 as the old series one-inch Sheet 101 SW (Workington area) and in 1895 as Sheet 101 NW (Maryport area). After revision by J. G. Goodchild and A. Strahan in 1895 a resurvey of the area was undertaken by T. Eastwood between 1922 and 1926. The new series one-inch geological map, Sheet 22 (Maryport) was published in 1930 together with an explanatory memoir. Sheet 28 (Whitehaven) was published in 1929 with a memoir covering the Whitehaven and Workington district in 1931. The 1:10,000 geological maps remained unrevised until the present survey was made in 1985-86 by R. P. Barnes (NY03NW and SW), B. Young (NY02NW) and D. V. Frost as project leader (NX92NE), with D. H. Land as programme manager. I. Basham and A. Bloodworth carried out mineralogical studies.

We are grateful for much help and valuable information provided by British Coal, both the deep mines North-Western Area and the Opencast Executive, Cumbria County Council, Cumbria County Records Office and English Estates.

SUMMARY

One of the key objectives of the Department of the Environment's Geological and Mineral Planning Research programme is the collection and interpretation of geological information for land use planning purposes. The British Geological Survey also collects and interprets geological data within its wider remit of research in all aspects of geology. Geological maps are the basic tools for demonstrating such interpretation, and may be general or show limited themes (eg drift thickness).

This report describes the geology, mineral resources and geotechnical aspects of the Workington-Maryport district, comprised within sheets NY02NW, 03NW and SW, and NX92NE and SE. The ground was first surveyed in 1878 and resurveyed in 1922-26. Since then, enough new data has come to hand to justify a complete resurvey and re-interpretation, which is described in this report and its accompanying maps. The work was commissioned by the Department and jointly funded with the Survey.

This part of the West Cumbria Coalfield comprises, Lower Middle and Upper Coal Measures (Westphalian A, B and C). Coal has been worked underground for several centuries but this has now ceased despite some resources remaining. Opencast working is in operation and useful reserves remain for the future.

Quaternary sediments which are commonly up to 30 m thick conceal much of the solid rocks. Till or boulder clay forms the most common superficial deposit and is of a fairly uniform composition. Glacial valleys cut into the boulder clay are filled with complex drift deposits including peats, silts and laminated clays and are often floored by sand and gravel.

Alluvial and River Terrace deposits are extensive only in the Derwent and Ellen valleys. Marine and estuarine alluvium (Warp) occurs principally in the Workington area.

Made Ground, mostly in the form of colliery spoil and furnace slag, covers some 20 per cent of the area. Many of the old tips have been landscaped but establishing vegetation upon the sulphur rich slag is difficult. The use of slag as aggregate must be carefully monitored.

Extensive coal mining in the past now places restraints on planning and development of the area. Subsidence from deep mines should be complete but that associated with collapse of old workings at shallow depths is difficult to predict and may not be complete. Ancient pillar and stall workings are often less than 30 m deep and may be unrecorded. The positions of numerous old shafts are uncertain.

Till and sand and gravel provide good foundation conditions but other superficial deposits are more variable with weaker engineering properties. A large area of west Workington is underlain by such deposits. Steep slopes in drift will fail if overloaded or over-steepened.

Economic resources of building stones, fireclays, brick clays, shales and ganister are present in the area if required but much of the sand and gravel is sterilised beneath the urban areas.

Mineralisation within veins or flats is unknown in the district.

Widespread mining in the area has disturbed the natural hydrogeological regime and potable groundwater is unlikely to be obtainable in large quantities. As offshore workings are flooded by seawater there is danger of saline contamination of groundwater near the coast. Wells in the Maryport area drew supplies from the St Bee's Sandstone but they are long since disused and mains water for the whole district is obtained from reservoirs outside the area.

Numerous old sand and gravel quarries at High Harrington are now partially-filled with domestic and other refuse. The possibility of contaminated leachate escaping into streams at a lower level should be monitored. Redevelopment of infilled quarries should ensure that load bearing walls do not span the quarry margins in order to eliminate differential settlement.

Destruction of natural drainage by localised mining and tipping has resulted in some low lying ground being flooded.

Coastal erosion south of Maryport was halted by tipping iron and steel industry waste into the sea. The resulting slag heaps are of variable composition and certain areas, particularly north of Workington Docks, are liable to rapid erosion and undercutting. Further man-made sea defences may be required for this area of coastline.

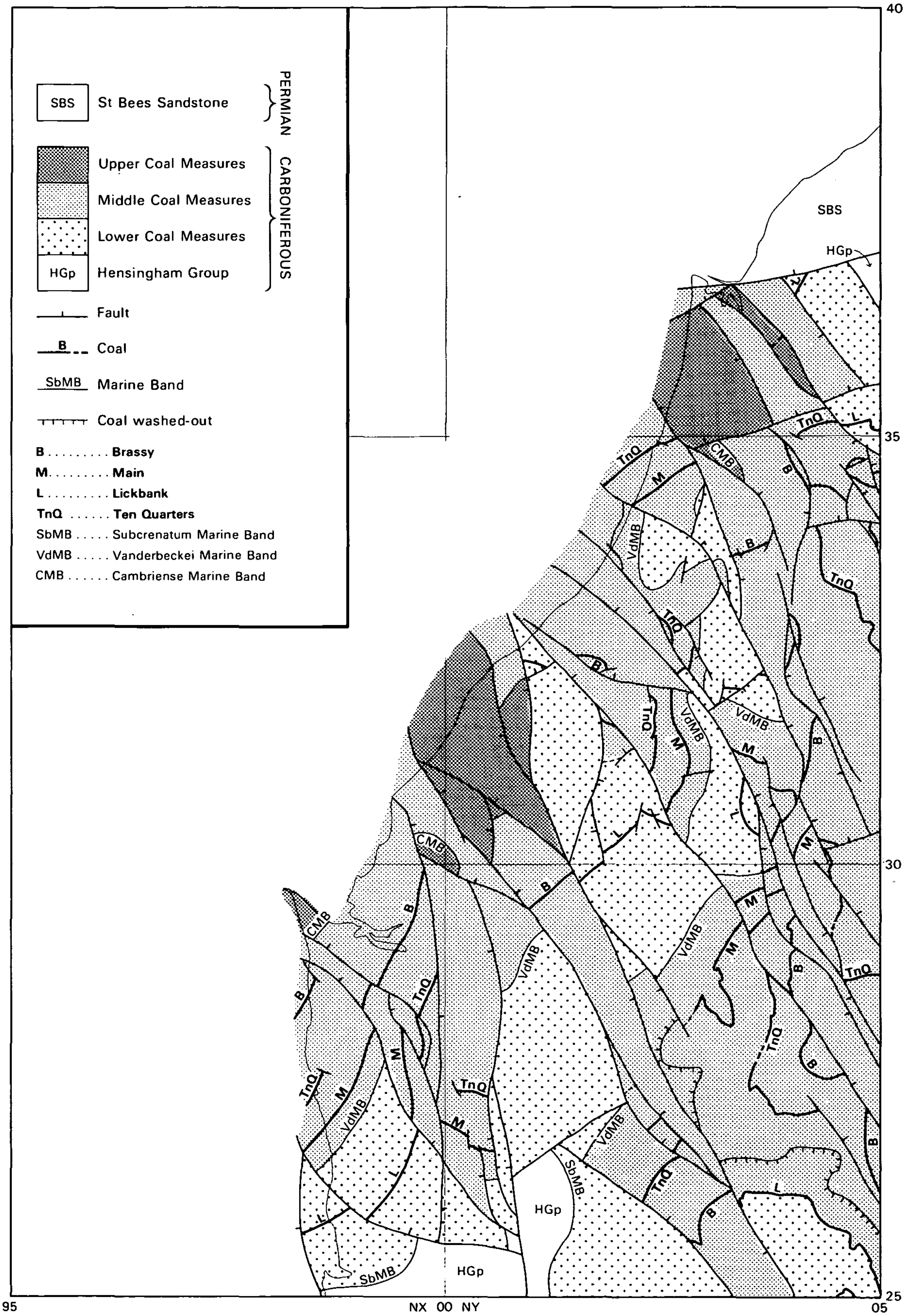

Figure 2 Simplified geology

INTRODUCTION

The ground described in this report includes Maryport and Workington and their hinterland, within the administrative county of Cumbria, and will be referred to here as the "district". It is bounded on the west by the Solway Firth from Bank End to Harrington, on the south by grid line 25 and on the east by grid line 05 (Figure 1). The River Derwent is the main drainage westwards through the centre of the district with the smaller River Ellen reaching the sea at Maryport. The highest point, near Winscales, attains 137 m.

The district is part of the West Cumbrian coalfield. Coal Measures strata crop out over most of the district, with an inlier of Namurian Hensingham Group strata at High Harrington (Figure 2). In the north, Triassic St Bees Sandstone overlies Permian strata beneath which are Coal Measures. The regional geology is summarised by Moseley (1978) and the district was described in detail by Eastwood (1930) and Eastwood and others (1931). Taylor (1961, 1978) gave a modern summary of the stratigraphy of the Coal Measures. In the present resurvey, these earlier works together with more recent information from boreholes and mining have all been critically reviewed and re-correlated. All available mine plans were examined and the ground resurveyed in detail.

Coal has been worked for several centuries, and for many of the older workings, plans are deficient or non-existent. Hence the positions of many old shafts are uncertain, and in some areas shafts probably exist about which nothing is known. A careful effort has been made to record all shafts as accurately as possible. Coal mining, as distinct from opencast extraction, is now extinct. It is unlikely that it will ever become economic to mine any remaining resources, though scope remains for further opencast work.

In the past, urban development was limited to Workington and Maryport, at the mouths of the rivers Derwent and Ellen. Buildings were constructed of locally quarried Coal Measures sandstone, Triassic sandstone and occasionally of Carboniferous limestone. Coal and the associated iron and steel industry began to change the landscape in the 18th Century and by the beginning of the 19th Century deep mines working large areas resulted in a consequential expansion of settlements and population.

After the Second World War the mines became exhausted and workings beneath the sea proved to be uneconomic. Closure of many works meant loss of jobs and a movement away from the area, resulting in empty and derelict housing. The 1970's saw many of the older terrace houses pulled down and some rebuilding at a lower density attempted. When the region was declared a development area with special government funding a new impetus was given, new roads made, old coal and slag tips landscaped, quarries infilled, new factory and trading estates constructed and a major reclamation scheme developed for the Workington Iron and Steel Works.

Small outlying rural villages attract new building as residential areas for "out of town" commuters. Land and property are relatively cheap and well able to provide for the next generation of workers employed in the new industries and commerce that have been encouraged to set up in the region.

CHRONOSTRATIGRAPHY		LITHOSTRATIGRAPHY: This Report	LITHOSTRATIGRAPHY: Former Lithostratigraphy
Upper Carboniferous	Westphalian C Aegiranum MB	Upper Coal Measures Cambriense (St. Helens) MB	Whitehaven Sandstone Series
	Westphalian B	Middle Coal Measures Vanderbeckei (Solway) MB	Productive Coal Measures
	Westphalian A	Lower Coal Measures Subcrenatum MB	Harrington Four Foot seam
	Namurian	Hensingham Group	Millstone Grit 'Series'
			Hensingham Group
Lower Carboniferous	Dinantian	First Limestone Chief Limestone Group	Chief Limestone Group

Figure 3 Carboniferous classification

GEOLOGICAL HISTORY

The district lies on the north-west flank of the Lower Palaeozoic inlier of the Lake District, and is underlain by Carboniferous rocks which rest unconformably on the older strata (Moseley, 1978). In Lower Carboniferous times the district was part of a shallow tropical sea in which limestones were deposited, giving way to fluvial and deltaic swamps in the Upper Carboniferous. Sedimentation kept pace with subsidence which was less over the Lake District to the SE than over the Solway area to NW, hence Carboniferous strata all thicken north-westwards (Figure 5).

Following end-Carboniferous uplift, deformation and erosion, Permian and Triassic sediments were deposited, but are now preserved within the district only north of Maryport. Of later episodes there is no evidence until the Quaternary. A late-Devensian glaciation deposited a mantle of till, sand and gravel, and in post-glacial times, alluvial and beach deposits were formed.

CARBONIFEROUS

Strata at outcrop range from very low Namurian (near the base of the Hensingham Group) to high Westphalian C (low in the Upper Coal Measures). The classification is shown in Figure 3 and that adopted here follows Eastwood and others (1968). The lithostratigraphical boundary between the Chief Limestone Group and the Hensingham Group is retained at the top of the First Limestone, though the base of the Namurian is a little below the base of that limestone.

The base of the Coal Measures is taken at the internationally accepted Subcrenatum Marine Band which is only a few metres below the Harrington Four Foot Seam, previously taken as the base in this district. Following Eastwood and others (1968) the Hensingham Group is redefined to include the "Millstone Grit Series" of Eastwood (1930). Finally, the Whitehaven Sandstone "Series" of Eastwood (1930) is abandoned as being no more than secondarily reddened Coal Measures, and these are now divided (as nationally) into Lower, Middle and Upper at the Vanderbeckei (Solway) and Cambriense (St Helens) Marine Bands.

Chief Limestone Group

The lowest strata proved were reached in Branthwaite Outgang borehole [0484 2509]. Here 1.22 m of limestone at the bottom of the hole are assigned to the Second Limestone. This is overlain by 6.4 m of shale and sandy shale with a 0.1 m thick coal seam immediately beneath the First Limestone. No lithological or faunal details are recorded in the borehole log.

Although not exposed at the surface the First Limestone has been reached in three boreholes in the southern part of the district. In the Schoose Borehole [0147 2766] 3.23 m of grey limestone were recorded at the bottom of the hole and the nearby Workington Coal Royalty No 1 Borehole [0324 2791] bottomed in 7.14 m of dark grey limestone. Only in the Branthwaite Outgang Borehole [0484 2509] was the full thickness of the limestone penetrated. The log of this borehole records 15.85 m of "hard limestone: two small bands of shale about 1 inch [25 mm] thick", overlying 1.42 m of "limestone". Fossils noted in the core included crinoids, *Alveolites depressus*, *Zaphrentis sp.*, *?Productus giganteus*, *Productus sp.* and *Pustula sp.*

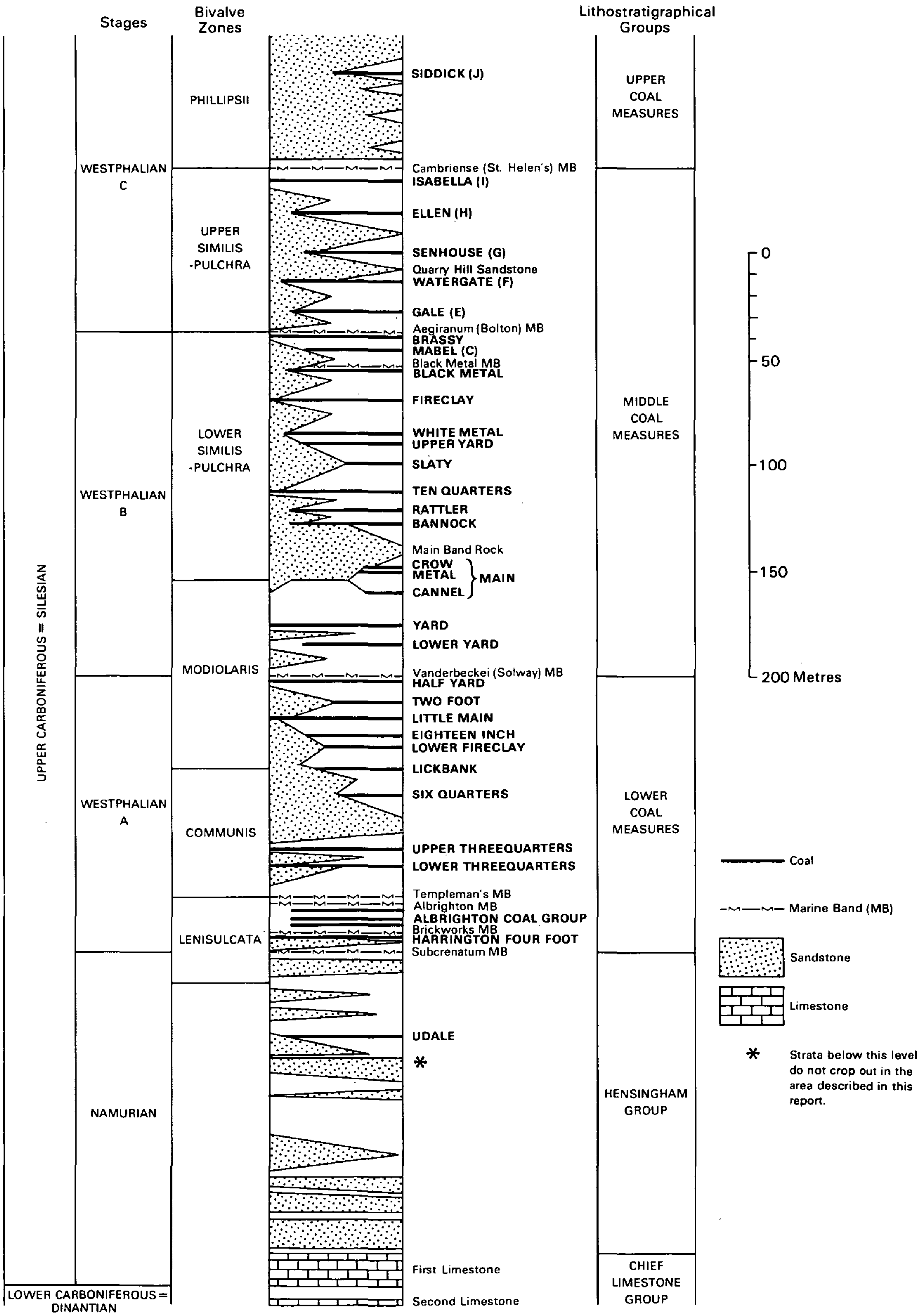

Figure 4 Generalized vertical section of the Upper Carboniferous

Hensingham Group

Hensingham Group strata crop out at High Harrington and east of Maryport, but are not exposed (Figure 4). They are known from a few widely spaced boreholes which indicate a total thickness of about 140 m in the south increasing to about 300 m towards Maryport, and over 500 m at the Bank End Borehole [0512 3845] a little to the north of the district. The strata are mudstones and sandstones with seatearths, thin coals and marine bands with productoids, crinoid columnals and *Lingula*. The lowest 30 to 50 m of the sequence is largely sandstone, medium- to coarse-grained, the "Hensingham Grit". This is succeeded by a cyclic sequence of mudstones, fossiliferous at the base, followed by sandstones, seatearths and thin coals. Near the top, the Udale Coal is overlain by the *Gastrioceras cambriense* Marine Band.

Coal Measures

Classification. Figure 4 (based on Taylor, 1961) shows a generalised section of the Coal Measures with their stratigraphical divisions. The base is taken at the base of the Subcrenatum Marine Band, and the section extends to 70 m above the Cambriense Marine Band. There is a steady increase in thickness in a north-westerly direction, as the isopachytes in Figure 5 show, reflecting deposition in a basin which deepened in that direction.

Sedimentology. In common with most other areas of English Coal Measures, the strata here were deposited on a fluvial and deltaic plain with fresh water mires and rare marine incursions. A rhythmic or cyclic sequence is developed with a pattern of fossiliferous mudstone overlain by unfossiliferous mudstones and sandstones capped by seatearth with overlying coal. Cycles are often incomplete and vary laterally with individual members splitting or dying out. The bulk of the strata are unfossiliferous mudstones, silty mudstones and shaly sandstones. Sandstones range from fine-grained to pebbly and in many areas have erosive bases cutting out earlier strata. The Six Quarters and Main seams are thus washed out over considerable areas.

Stratigraphy. This account is based on Taylor (1961), revised by re-correlation of all boreholes, examination of all mine plans and consideration of additional information from opencast exploration (Figure 4). Faunal lists are all from Taylor (1961) and have not been revised.

Few of the seams in the higher part of the sequence above the Black Metal, have been much worked and are largely un-named. British Coal Opencast Executive apply a system of nomenclature whereby these seams are known in ascending order as Un-named C, Un-named D, etc, but the Geological Survey has named them from geographical localities.

Reddening. Higher parts of the Coal Measures show secondary reddening, with destructive oxidation of the coal seams. These reddened strata were earlier classed as the Whitehaven Sandstone "Series" and were regarded as a separate formation with an unconformable base (Eastwood, 1930). However it was later shown that the reddening was entirely a secondary effect superimposed on normal grey measures, caused by oxidation in pre-Permian times, when the climate was arid and the water table lay well below the surface (Taylor, 1961).

Lower Coal Measures

The Subcrenatum Marine Band was proved in several bores in the Siddick-Gillhead area, with a fauna which includes *Hindeodella sp.*, *Lingula mytilloides* and *Productus sp.* In this area only a metre or so of seatearth separates the marine band from the overlying Harrington Four Foot seam. Farther north, at Risehow and Maryport both marine band and coal seam die out, their horizons and associated strata passing into seatearths and ganisteroid sandstones.

The **Harrington Four Foot Seam** is thin and banded in the south-east (Lostrigg Beck area) but thickens westwards to 1.7 m in the Harrington-Workington-St Helens area where it generally includes a parting. North-eastwards it thins out and is less than 0.8 m thick at Gillhead.

Strata between the Harrington Four Foot and Albrighton seams are 8 to 12 m thick, mostly mudstone with a thin medial seam, and include the **Brickworks Marine Band** in the roof of the Four Foot and the **Siddick Marine Band** just above the thin seam. The Brickworks band carries *Lingula* and appears to be restricted to the Siddick-St Helens area, but the Siddick band, with *Rectocornuspira*? and *Lingula* is recorded from Workington to head as Gil well as in Greysouthen No 2 Bore [067 281] east of the district.

The **Albrighton Seam** is everywhere in two leaves separated by up to 5 m of strata, mostly mudstone. In the south-east the coals are very

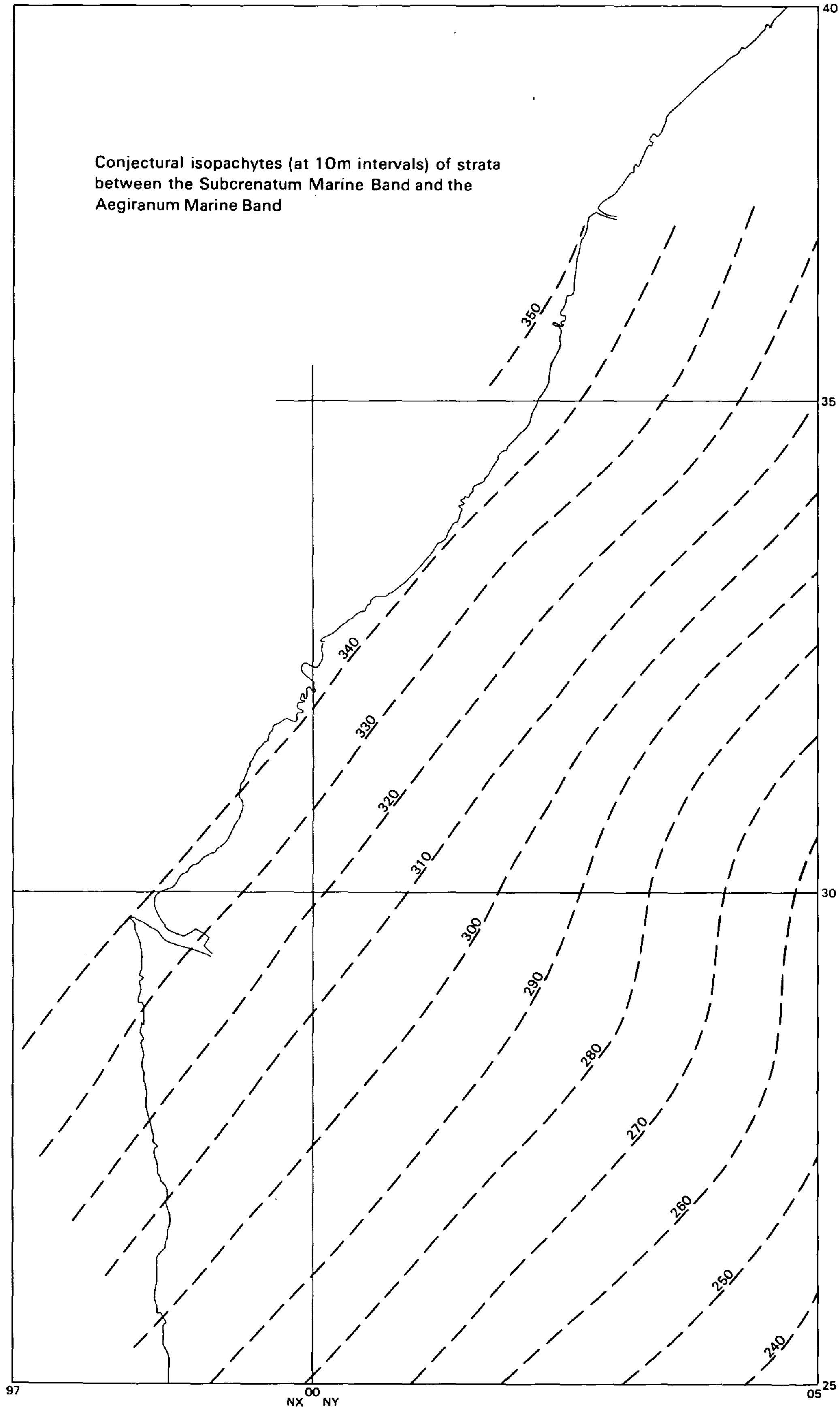

Figure 5 Thickness of Westphalian A and B

thin but at Workington and north of the Derwent the lower seam is up to 50 cm thick and the upper one up to 1 m. In the roof of the upper seam is the **Albrighton Marine Band** which is present throughout the district and yields *Rectocornuspira* and *Lingula*. A few metres above the Albrighton Marine Band is another thin coal with **Templeman's Marine Band** in its roof. This band is found at St Helens, Risehow and NE of Maryport and has a similar fauna to the two below. Between Templeman's Marine Band and the Lower Threequarters seam the strata are fairly consistently about 17 m thick, sandy in the upper part and with a thin impersistent medial coal (or seatearth) with a mussel band in its roof. The basal Communis zone fauna includes *Anthraconaia sp.*, *Carbonicola bipennis*, *C. communis*, *C. cristagalli*, *C. torus*, *Curvirimula* cf. *trapeziforma*, and *Naiadites flexuosus*, as well as fish scales and ostracods at the base.

The **Lower** and **Upper Threequarters** seams are separated by 5 to 7 m of mudstones in the south, the interval increasing to about 9 m in the north where it includes a thin sandstone. Both seams thicken northwards, the Lower from 0.3 to 0.8 m, the Upper from 0.6 to 1.1 m. In the Siddick-Camerton area the Lower seam generally has a thin (0.15 to 0.7 m) lower leaf separated by up to 1 m of seatearth from the main leaf.

Strata between the Upper Threequarters and Six Quarters seams are about 30 m thick in the south-east of the district, 17 to 22 m in the Clifton-Gillhead area, and thicken north-westwards to 52 m offshore of Flimby and Risehow. In this last area, one or two thin seams occur between the named coals and throughout the district the middle part of the sequence is sandstone. From St Helens and Seaton southwards through Workington and Schoose, the Six Quarters and the higher parts of the subjacent strata are washed out by the Sixquarters Rock. There is a mussel band in the roof of the Upper Threequarters, sometimes in two leaves separated by a thin coal and seatearth. The fauna includes *C. cristagalli*?, *C.* aff. *declivis*, *Carbonicola pseudorobusta*?, *Curvirimula sp.*, ostracods and fish scales indicative of the Communis Zone. The **Sixquarters** seam, except where washed out, varies rather irregularly between 0.4 and 1.2 m in thickness. In places at Risehow an extra leaf, about 0.45 m thick, underlies the main leaf; and in the Crossbarrow Borehole [0499 2836] the seam is 2.44 m thick.

Strata between the Sixquarters and Lickbank seams are mostly sandstone, the sandstone locally termed the **Sixquarters Rock**. In a belt in the east of the district, running from Flimby through Gillhead and Camerton and south to Wythemoor, the interval between the seams varies between 18 and 8 m with the lower part mostly sandstone. Offshore of Maryport and Risehow and at Workington the interval is between 28 and 33 m and the strata are almost wholly sandstone. In places the roof of the Sixquarters seam carries mussels including *Carbonicola* cf. *cristagalli* and *C.* aff. *pseudorobusta*.

The **Lickbank Seam** is present throughout the district. North of the Derwent and in the south-east the coal is generally thin, 0.1 to 0.7 m thick; at Workington it is 0.7 to 1.5 m thick, in places with a lower leaf. There is a thin mussel band in the Lickbank roof at Seaton.

Between the Lickbank and Eighteen Inch seams the strata are 10 to 19 m thick, generally thickening north-westwards, and include a sandstone low in the interval. In the Camerton-Clifton area and locally at Maryport and Workington, the **Lower Fireclay Seam**, up to 0.6 m thick, occurs near the top of the interval.

The **Eighteen Inch Seam** is generally between 0.3 and 0.6 m thick but is very thin or absent around Gillhead and Crossbarrow. In the roof of the coal there is generally a mussel band with a fauna characteristic of the lower part of the Modiolaris Zone and including *Anthracosia* cf. *regularis*, *Carbonicola* aff. *oslancis*, *Naiadites sp.* between *productus* and *quadratus*, *Carbonita humilis*, *Geisina arcuata*, and fish fragments. Ostracods are abundant in a thin bed below the mussel bed and above the basal cannelly shale with fish debris. Some 4 to 17 m (thickening northwards) of strata, mostly mudstone, separates the Eighteen Inch from the overlying Little Main seam.

The **Little Main Seam** is usually between 0.4 and 0.7 m thick, locally reaching 1.1 m. The roof mudstones carry a mussel band which includes *Anthraconaia* cf. *williamsoni*, *Anthracosia* cf. *regularis*, *Carbonicola* cf. *bipennis*, *C.* cf. *oslancis*, *C. venusta*, ostracods and fish. Strata between the Little Main and the Half Yard are variable in thickness, ranging from 9 to 32 m, and include sandstone in places. A few metres below the Half Yard is the intermittently developed **Lower Half Yard Seam** which is nowhere thicker than 0.5 m. The **Half Yard** itself, which is the topmost bed in the Lower Coal Measures, is also variable, but is generally between 0.3 and 0.4 m thick.

Middle Coal Measures

The **Vanderbeckei (Solway) Marine Band**, which marks the base of the Middle Coal Measures takes it name from Solway Colliery at Workington where it was found in sinking the No 1 Downcast Shaft [9911 2766]. The marine band occurs in a characteristic black, rather silty mudstone, with a fauna of foraminifera, including *Rectocornuspira*?, and *Lingula mytilloides*. Although the marine band has not been detected north of Solway Colliery its position in the sequence has been inferred.

Beds above the marine band are predominantly mudstones and commonly contain non-marine fossils characteristic of the Modiolaris Zone. Thin coal seams are present locally; roof faunas of two of these in the Solway No 5 up-borehole include *Anthraconaia modiolaris*, *Anthracosia* cf. *aquilina*, *A.* cf. *nitida*, *A. phrygiana*, *Naiadites sp.* and *Rhizodopsis* scales. One apparently impersistent thin seam within the measures between the Solway Marine Band and the Yard Seam was worked locally as the **Lower Yard**.

The **Yard Seam** varies from 0.43 to 0.66 m in thickness. It has been worked in places in the northern part of the district. South of the Derwent it appears to have been of little value though shallow workings [0325 2925] near Great Clifton are assumed to be in this seam. The mudstones which overlie the seam contain *Anthraconaia sp.*, *Anthracosia beaniana*, *A. carissima*, *A.* cf. *concinna*, *A.* cf. *lateralis*, *A. nitida*?, *A.* cf. *ovum*, *A.* cf. *phrygiana*, *A.* cf. *regularis* and *Naiadites quadratus*? The record of the St Helens No 3 Shaft [9979 3072] notes a 1.5 m "ironstone" immediately overlying the Yard Coal; this ironstone has not been recorded elsewhere. Much of the interval between the Yard and Main seams, averages around 20 m, which is largely mudstone, with a few thin sandstones and coals, including the **Lower Metals**.

The **Main Seam** or the **Main Band Seam** was, as the name implies, the principal seam not only throughout the district but through much of the Cumbrian Coalfield, and has been worked out over large areas both underground and opencast. It is a composite seam consisting of two or more discrete leaves which have received the separate names, in ascending order **Cannel**, **Metal** and **Crow**. South of the River Derwent these individual leaves are separated by thin mudstone partings which are generally less than 0.5 m thick. In this area the seam, including partings, is up to 4.34 m thick. North of the Derwent the partings become thicker, and in the Risehow area [026 345] up to 12.2 m of sandy shale and sandstone separate the Cannel and Metal and around 2.4 m of similar strata intervene between the Metal and Crow. Clay ironstone nodules are locally abundant above the Metal and were formerly worked at Clifton Colliery. The Main is characteristically overlain by a fine-grained pale grey or brown sandstone, the **Main Band Rock**, though this seems to be absent over a small area around Gillhead [033 237] and Watergate [032 343]. This sandstone probably occupies a major channel, the erosive base of which was exposed in the former Mabel Opencast Site [032 283] where the whole thickness of the Main Seam is abruptly washed out. The seam appears to be washed out over a large area south west of a line between Mabel Opencast Site and Lostrigg Beck [045 270] though the seam is present, and was extensively mined, west of the Great Upcast East fault around Moorclose [006 270].

Smaller washout channels up to 100 m wide and aligned approximately NNE-SSW were encountered in the Main workings between Crossbarrow [050 291] and Quarry Hill [042 279] and other washouts in the seam are recorded from Risehow Colliery. The Main Band rock varies considerably in thickness. Whereas it is commonly about 10 m or less in thickness, as much as 40 m of sandy measures were recorded in the Winscales No 1 Borehole [0279 2666]. Exposures of the Main Band Rock may be seen in Lostrigg Beck [0460 2619] and in the stream south of Capel How [0390 2675] A quarry in this sandstone was formerly worked at Hunday [0195 2647] but has now been completely filled. Sandstone comprises much of the interval between the Main and Bannock Seams over a large part of the district, though mudstones occur in places and locally one or more very thin coals have been noted. Silty mudstones with sandstone beds are exposed in Israel Gill [0400 3175] near Camerton.

The **Bannock Seam**, known as the **Brick Band** in Watergate Colliery, comprises a single seam or, in the Workington area, a group of coals with an aggregate thickness of a little over 1 m. The seam has been worked in places south of the River Derwent but there is little evidence that it has ever been worked north of the river. Sandstone commonly overlies the coal which is washed out in places. Grey sandy shale with thin beds of ironstone and sandstone, overlain by the 0.6 m thick Rattler seatearth were formerly exposed on the foreshore at Flimby [0210 3450].

The **Rattler Seam** was considered as an upper leaf of the Bannock by Taylor (1978, p.185) but in this district it is everywhere separated from the Bannock and considered as a separate seam. It is up to 1.24 m thick north of the River Derwent where it has been fairly extensively worked. South of the river it is up to 0.58 m in thickness and has been worked locally both underground and opencast. The seam is thin in the Workington area and probably not worked. Sandstone commonly underlies and overlies this seam which, like the underlying two seams, may be washed out in places. The seam is characterised locally by a black cannelloid shale roof.

The **Ten Quarters Seam**, which was known as the **Moorbanks** in the Workington area, is one of the most widely worked and better quality coals in the coalfield. It is typically a split seam with several coal leaves separated by thin mudstone or fireclay partings. The aggregate thickness varies from 0.46 to 2.82 m including partings. Sandstone forms the roof of the coal in parts of the Workington area and near Great Clifton, and at Workington forms most of the 20 m or so of measures between the Ten Quarters and the overlying Slaty Seam. Elsewhere mudstones and siltstones predominate and a thin coal has been noted locally about 6 m below the Slaty Seam in the area north of the River Derwent.

The **Slaty Seam** is widely present throughout much of the district but is locally absent at Workington where it may have been washed out by the thick sandstone above the Ten Quarters. It has not been recognised in parts of the Great Clifton area. The seam is up to 1.76 m thick and commonly includes numerous thin shale partings, a feature which may have given the seam its name. The Slaty has been worked in places north of the Derwent. An exposure of the overlying strata in Risehow Beck [0429 3422] shows 2 m of sandstone on at least 3 m of mudstone with clay ironstone nodules, on grey laminated siltstone.

The **Upper Yard Seam** is widely developed north of the Derwent though it is absent from much of the area to the south. It is up to 0.81 m thick and has been worked locally, but in places is washed out by sandstone. Between 3 and 6 m of measures separate this seam from the overlying White Metal Seam.

The **White Metal Seam** is widespread and widely worked. South of the River Derwent it is typically a composite seam with mudstone or sandstone partings up to 2 m thick separating leaves of good quality coal. In this area up to 2.0 m of coal may be present excluding partings. North of the Derwent the seam has a central thin dirt parting, and varies considerably from as little as 0.15 m thick in the southern part of St Helens Colliery to 0.41 m at Watergate Shaft. The seam is commonly overlain by a thick sandstone which locally washes it out. Up to 12 m of measures separate the White Metal from the overlying Fireclay Seam. A good quality, widespread fireclay, up to 1.5 m thick, locally overlain by a ganister, which immediately underlies the Fireclay Seam no doubt gives the seam its name.

The **Fireclay Seam** is typically split over much of the district into a Bottom Fireclay and Top Fireclay whick have been worked separately in places, including the Mabel Opencast Site. However in the Workington area the separation into two seams is much less clear. The Bottom Fireclay may be up to 0.51 m thick separated by up to 3 m of sandstone, mudstone and fireclay from the Top Fireclay, which locally attains a thickness of 0.33 m. Up to 16 m of measures above the Top Fireclay comprise a variable sequence of mudstones with sandstone. A section in Lostrigg Beck [0445 2734], immediately beneath the Black Metal Coal, exposes the following section:

Seatearth-mudstone, pale grey with sphaerosiderite	3.0 m
Sandstone, fine-grained lenticular	0.2 m
Mudstone, grey with ironstone nodules	2.5 m
Seatearth-mudstone, pale grey with sphaerosiderite nodules up to 0.3 m containing pockets of white dickite and chalcopyrite up to 2 mm	1.0 m

The weathered surfaces of the lowest seatearth show conspicuous yellow crusts of earthy jarosite (BGS X-ray no.XE636).

Mudstones and sandstones belonging to the interval between the Fireclay and Black Metal seams are exposed in Canker Beck [0190 32440 to 0225 3220] near St Helens.

The **Black Metal Seam**, up to 0.7 m thick, is well exposed in the west bank of Lostrigg Beck [0445 2734]. It has been worked on a small scale at shallow depths nearby and also in the Mabel opencast site to the west. North of the River Derwent the coal is generally of poor quality and has been little worked. The roof of the seam consists of dark shales (hence its name) which include the **Black Metal Marine Band**. In the southern exposure in Lostrigg Beck the coal is overlain by up to 0.6 m of very dark grey shale. No fossils have been found here, but marine bivalves are reported in the shales at this level in the stream bed approximately 60 m farther north [0454 2742] (G.Jackson, *personal communication*), though this could not be confirmed during the course of the current survey. Taylor (1961) recognised this marine band at Winscales, Solway Colliery and Risehow where the fauna included *Glomospira*, *Rectocornuspira*? and *Lingula*.

Over much of the district a large proportion of the measures, up to 10 m thick, which overlie the Black Metal Seam comprise mainly mudstones and siltstones. Sandstones are present in the Workington area and in places north of the River Derwent, where a thin coal is also present locally at about 4 m above the Black Metal Coal. A small quarry in mudstones and sandstones at Moorhouse Guards, near Seaton, exposes a thin and apparently persistent bed of very pale grey to white clay up to 15 mm thick. An examination by x-ray diffractometry by A.Bloodworth of BGS Minerals Science and Isotope Geology Research Group, on the <15 μm fraction of this bed showed abundant kaolinite, together with small amounts of mica, lepidocrocite, chlorite, illite-smectite and quartz. The presence of abundant kaolinite accompanied by small amounts of illite-smectite suggests a tonstein-like mineralogy though the presence of the other constituents points to considerable contamination by terrigenous material. A possible tonstein bed at this horizon offers interesting possibilities for long distance correlation though lack of exposures or borehole cores from this interval have not allowed further examination of this possibility.

The **Mabel Seam** is a hitherto un-named coal named here after Mabel opencast site, south of Great Clifton where it was worked as Coal "C". In the Great Clifton area it is a split seam with a total thickness, including a central parting, of up to 1.23 m. It is widely present throughout the district though has only been of economic importance in the area from which it takes its name. Between 3 and 10 m of mudstones and siltstones, with a sandstone bed up to 2 m thick in the Crossbarrow area, overlie the Mabel Coal. Grey mudstones with a 0.3 m thick coal are exposed in Israel Gill [0409 3179] near Camerton. In Furnace Gill [0367 3377], Flimby, approximately 8 m of thickly bedded medium-grained purple-stained sandstone are exposed.

The **Brassy Seam** is widespread and up to 1.17 m thick though generally around 0.5 m. Its name suggests that, at least locally it contains appreciable quantities of pyrite, either in the coal or in the immediately adjacent beds. It has been worked locally, both underground and more recently in Mabel opencast site.

The **Aegiranum (Bolton) Marine Band** overlies the Brassy Seam and derives its local name from exposures in Pow Gill [2506 4433] near Bolton New Houses, 4 km S of Wigton (Eastwood, 1968, p.203). It was also called the Brassy Marine Band by Trotter (1953, p.34). Taylor (1961, p.15) reports it as 0.53 m thick in the Main Drift (-900 horizon) of Solway Colliery, where the following fauna was recovered:-

> *Ammonema sp.*, *Lingula mytilloides*, *Platyconcha*?, gastropods indet [small], *Dunbarella sp.*, *Posidonia sulcata*, *Metacoceras* cf. *perelegans* *Anthracoceras sp.* [juv], *Hindeodella sp.*, platformed conodonts and fish debris.

In St Helens No 11 Bore the fauna was:-

> Crinoid columnal, *Lingula mytilloides*, small gastropods including *Platyconcha*? and *Strobeus*?, pectinid (indeterminate), *Pernopecten carboniferus*, *Posidonia sulcata*, *Schizodus*?, coiled nautiloid, probably *Metacoceras cornutum*, orthocone nautiloid probably *Pseudorthoceras sp.*; *Anthracoceras* cf. *hindi*, *Politoceras* [*Homoceratoides*] *sp.* conodonts [abundant] including *Hindeodella sp.*, *Idiognathodus sp.*, *Lonchodus*?, *Ozarkodina sp.*, *Streptognathodus sp.*; fish debris including *Megalichthys sp.*, Palaeoniscid scales and perhaps fragments of *Listracanthus* spines.

The measures which overlie the Aegiranum Marine Band vary from about 8 to 20 m in thickness and comprise mudstones and in places thick sandstones. Exposures of these sandstones may be seen in Furnace Gill in Flimby Great Wood [0363 3382] and in Risehow Beck [0414 3417].

The **Gale Seam** is named here after Gale House, Winscales [0290 2567] near where it was worked as Coal "E" in the Wythemoor House opencast site. Over much of the district the seam is thin but between Great Clifton and Winscales it attains workable thickness. In this area it is a split seam with a bottom leaf up to 0.74 m thick and a top leaf of up to 0.53 m separated by a parting of mudstone or fireclay. In the Great Clifton area this parting is about 0.6 m thick though this increases southwards to around 3 m near Gale House. The seam has been little worked in the past, though a small area was extracted from the Annie Pit Drift [0304 2543] at the stream south-east of Gale House, and there are traces of other small workings, possibly in this seam, in the immediate neighbourhood. The seam was worked in both Wythemoor House and Mabel opencast sites.

Measures 10 to 20 m thick overlie the Gale Seam. Included in this sequence, in the area north of the River Derwent, are massive fine-grained sandstones which show marked reddening and which were referred to the Whitehaven Sandstone Series by Eastwood (1930). Exposures of these may be seen in Risehow Beck [0414 3418]. Here the red colour is variable, the sandstone a grey colour in places.

The **Watergate Seam**, named here after its occurrence in Watergate Colliery, is present throughout the district, but appears to have been little worked until the advent of opencast operations when it was exploited as Coal "F". South of the River Derwent the seam is generally without partings and up to 0.6 m thick. It has been worked here in both Wythemoor House and Mabel opencast sites, and there may be small old underground workings south-east of Gale House [032 254]. North of the Derwent the seam locally attains a thickness of 1.6 m including shale partings though there is no evidence that it has ever been worked in this area. It is exposed in Risehow Beck [0371 3407] where it is only 0.14 m thick and is overlain by approximately 1.5 m of mudstone which is in turn overlain by more than 4 m of siltstone and fine sandstone. The measures overlying the Watergate Seam up to the Senhouse are generally less than 15 m thick. However in the Crossbarrow area, south of Great Clifton up to 30 m of measures are present and include some 12 m of sandstone, the **Quarry Hill Sandstone**, which was formerly worked in small pits at Quarry Hill [0428 2792 and 0422 2784]. Sandstone is widespread at this level throughout the district. A small outcrop [0350 2569] between the restored Wythemoor House and Outgang opencast sites, shows conspicuous reddening, and other exposures occur in Risehow Beck [0388 3411].

The **Senhouse Seam** (formerly called the **Senhouse High**) is present over most of the district where the higher parts of the Middle Coal Measures are preserved. It is up to 1.22 m thick and was worked locally south of Maryport where it is of good quality. Almost 30 m of measures, comprising sandstones and some mudstones, overlie the Senhouse Seam. Sandstone at this horizon is well exposed in Risehow Beck [0367 3408 to 0350 3418].

The **Ellen Seam**, named here, is the top seam in Ellenborough Shaft and was previously known as Coal "H". It is up to 0.54 m thick and is restricted to the area north of the River Derwent. No workings are known in this seam. The measures above the Ellen Seam comprise approximately 10 m of mudstones and sandstones, locally with a thin coal about 8 m above the Ellen Seam.

The **Isabella Seam**, named here and previously known as Coal "I", is also known only from the area north of the River Derwent. It is up to 0.64 m thick and is not thought to have been worked. The seam is overlain by approximately 5 m of measures which include sandstone in the area north of Workington.

Upper Coal Measures

The **St Helens Marine Band**, which has been recognised only in two underground boreholes at St Helens Colliery [0066 3224 and 0011 3151], is a black mudstone bed with *Lingula*. A marine band with only foraminifera, recorded in a borehole at Risehow Colliery [0029 3604] is at a similar stratigraphical level and may be equivalent to the St Helens Marine Band. The faunal difference may indicate different depositional facies or preservation, or may be a result of incomplete collecting. The St Helens Marine Band is tentatively correlated with the Cambriense Marine Band which marks the base of the Upper Coal Measures.

Up to 60 m of the overlying strata have been recorded in boreholes, showing a variable sequence of sandstone and mudstone with some seatearths. Two coal seams occur in the St Helens Colliery sections. A thin seam, up to 0.30 m thick, at about 25 m above the St Helens Marine Band, was also seen in a borehole at Maryport [0382 3607]. A thicker seam, up to 0.84 m thick, previously known as Coal "J" and here named the **Siddick**, occurs at 42 m above the marine band. No workings are known in either of these seams. Thickly bedded sandstone about 10 m above the Siddick Seam is exposed in Hazel Gill [0107 3079].

Exposures on the foreshore south-west of Maryport at Risehow Scar [025 859] were formerly believed to be St Bees Sandstone

(Eastwood, 1930). However, the buff weathered, grey, fine to medium grained sandstone exposed here is only locally reddened. Similar sandstone exposed in Maryport Harbour [034 365] includes 4-5 cm diameter lenticular rip-up clasts of coal. Site investigation boreholes (NY03NW/57) at this locality showed up to 7 m of grey, fine to medium grained micaceous sandstone and siltstone with thin siltstone and mudstone interbeds. A nearby borehole (near [0341 3658], NY03NW, map Note 1) showed thickly interbedded sandstone and shale over a 0.43 m coal (possibly the Siddick Seam) at a depth of 40.38 m. These boreholes clearly indicate that the strata belong to the Coal Measures rather than the St Bees Sandstone, the most southerly exposures of which are just north of North Pier [0337 3684]. Therefore the Maryport Fault must pass through the North Harbour rather than its formerly mapped course through Risehow Scar.

TRIASSIC

Triassic St Bees Sandstone crops out on the foreshore north of Maryport and is exposed in disused quarries near Bank End [0417 3788] and Ellengrove [0474 3722] where it was worked for building stone. These exposures show massive, laminated or cross-laminated sandstone in beds up to 1 m thick with minor interbedded silty or sandy laminated shale. The sandstone is fine- to medium-grained, quartzose and variably micaceous. These strata are typically brick red in colour although they are locally reduced to greenish buff along bedding planes or over wider areas near faults.

The only indication of the thickness of the Triassic strata is in the Bank End Borehole [0514 3846). Here St Bees Sandstone, 86.26 m thick overlies red shales (St Bees Shale), 79.71 m thick with a 0.91 m thick breccia at the base, resting on Lower Coal Measures strata.

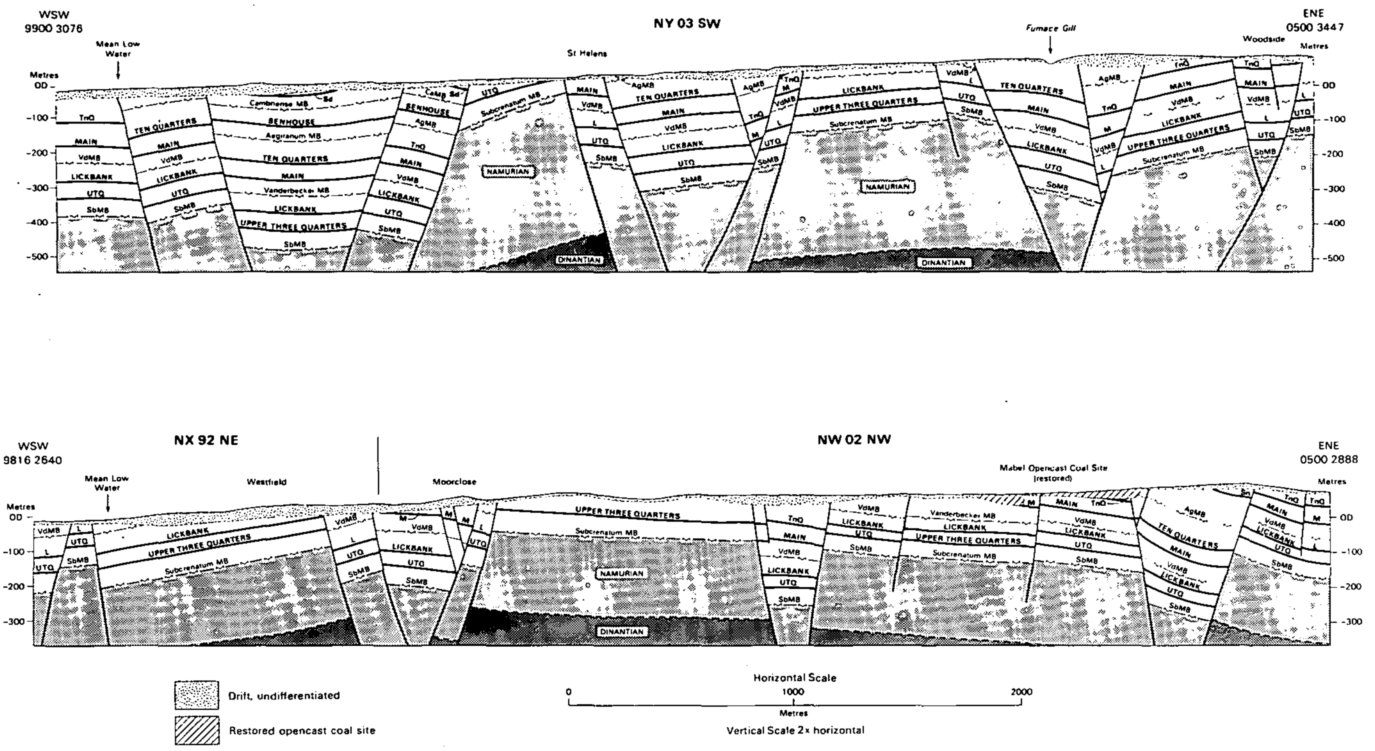

Figure 6 Horizontal sections

STRUCTURE

The structure of the Carboniferous strata is dominated by a major set of sometimes sinuous faults which have a NW-SE trend and throw down both to the north-east and south-west (Map in pocket). Swarms of minor faults, frequently encountered in underground workings, dominantly trend between N-S and NW-SE, although NE-SW trending cross-faults also occur locally. An unusual 100 m wide, N-S fault zone, encountered in workings in the Lickbank and Little Main seams at Great Clifton, is composed of en echelon NW-SE faults and suggests N-S sinistral shear on an underlying structure. A few major cross-faults, usually trending NE-SW or E-W and dominantly throwing down to the north, locally take up the main displacement from NW-SE trending faults. Hence it is likely that the two sets formed contemporaneously. There is little evidence of any major fold structures pre-dating faulting with the possible exception of a very open syncline plunging gently north-northeast towards Great Clifton [from 030 270 to 050 300]. Dips throughout the area are generally 3 to 11° to the west or north-west although greater dips, up to 20°, are encountered locally and are common west of Workington. Marked variation in the angle of dip occurs in some fault blocks suggesting that open folds developed contemporaneously with or post-faulting.

Dips in the Camerton area differ from the regional trend, being to the south or south-east, and much of the area of sheet NY02NW is characterised by gentle dips to the south-east. The marked variability of dip between adjacent fault blocks, locally in opposed directions, and complications introduced by cross faults and anastomosing oblique faults, cause rapid changes in the amount, and sometimes the direction, of throw of the north-west-trending fault set.

All of the faults are normal, hading in the direction of throw (Figure 6), with throws locally in excess of 300 m emplacing Upper against Lower Coal Measures (eg the Hazel Gill Fault, 012 306). The dip of the faults typically varies between 60° and 80° although lower angle structures are known. In detail a fault may be a closely spaced set of several fractures. Strata adjacent to a major fault may be disrupted for tens of metres on either side. Dips of up to 70° are not uncommon in such situations, rapidly becoming more gentle away from the zone of faulting.

The Carboniferous and Triassic strata are separated by a poorly known structure termed the Maryport Fault. This may be a narrow zone of intermittent fault movement contemporaneous with Triassic sedimentation. The only evidence of major faulting north of the Maryport Fault is on the foreshore near Bank End [043 382] where minor open folding appears to be related to a NW-trending fault. Otherwise the St Bees Sandstone dips predominantly gently north-west or north. The fault structure of the Carboniferous strata was probably largely established prior to the Triassic. There is no evidence in this area for fault movement contemporaneous with deposition of the Carboniferous strata. For example, isopachytes on Westphalian A and B (Figure 5) are highly oblique to the main fault trend. Hence faulting must have occurred principally in late Carboniferous or early Permian times and was likely to have resulted from a north-east to south-west extension event. The cross-faults, which are parallel to the Maryport Fault, may include an element of Triassic movement. The overall gentle dip north-west or north, of both the Carboniferous and Triassic strata may have been imposed at a much later date.

Earthquakes

A minor earthquake was recorded in the Maryport area on 18 October 1879. According to contemporary press reports the tremor was felt over a wide area between Workington and Aspatria. Furniture and ornaments are reported to have been disturbed and boats in Maryport Harbour were shaken. The intensity of the shock, which appears to have been felt most strongly at Maryport, is assessed as 5 MSK (R Musson, *personal communication*). Another minor tremor, of magnitude 1.5 ML was recorded in the Maryport area on 1 December 1986 (R Musson, *personal communication*).

The source of this minor seismic activity is not known, but it is likely that it results from the collapse of old mine workings. An alternative association with the Maryport Fault or some other fracture is possible, though it is unlikely that any of the faults are still active.

Though seismic risk is slight the possibility of earthquakes should be taken into account in designing sensitive structures.

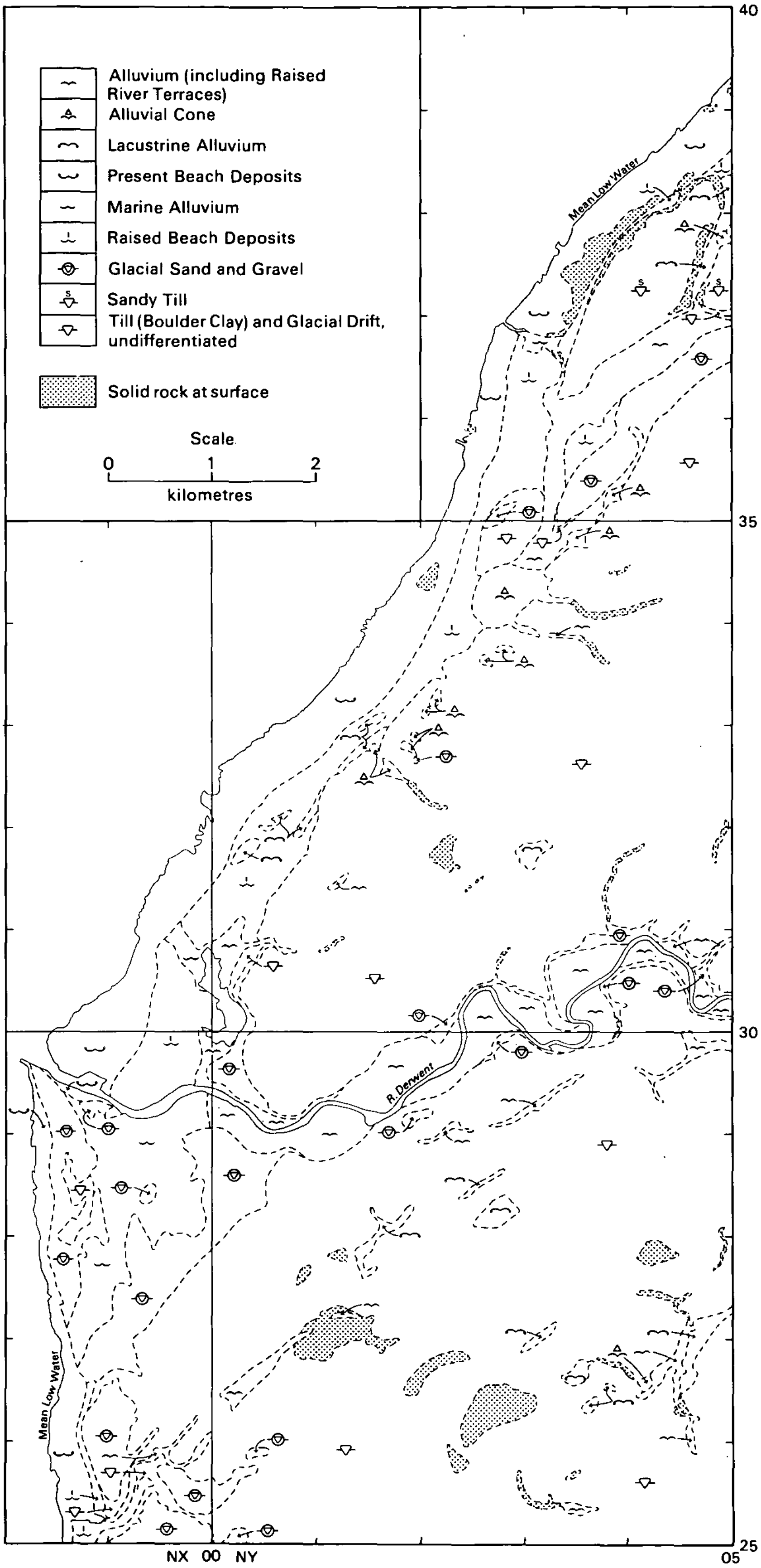

Figure 7 Quaternary deposits

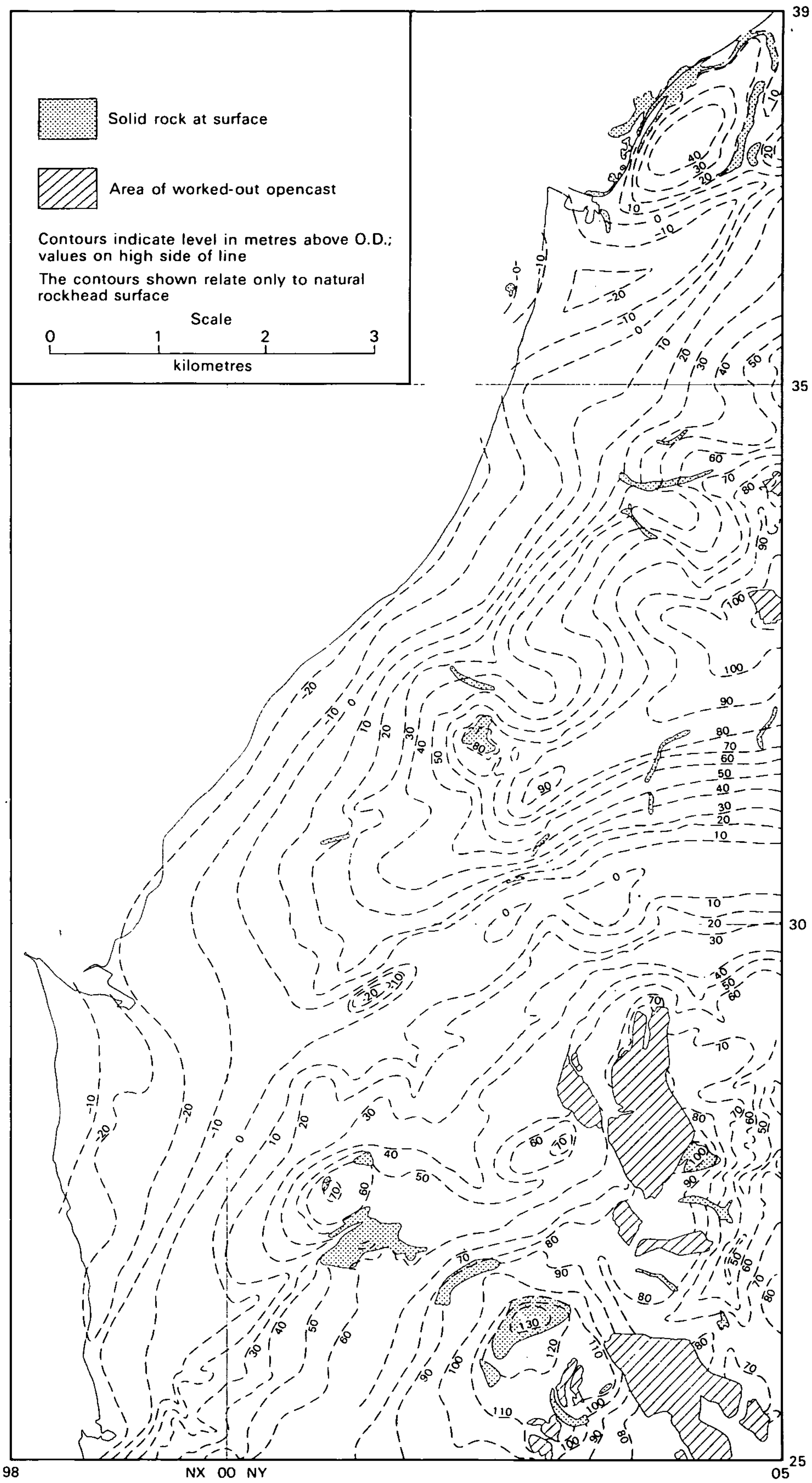

Figure 8 Rockhead elevation

QUATERNARY and MADE GROUND

Superficial Quaternary deposits ("Drift") include sediments of glacial origin which cover most of the district and post-glacial alluvium and raised beach deposits which are of limited extent. (Figure 7).

Till (boulder clay) is the main glacial deposit, with sand and gravel interbedded with and overlying it. Other Quaternary deposits of significance include silts, clays and sands up to 30 m thick in buried valleys or up to 12 m thick associated with raised beaches.

Rockhead

The rockhead surface broadly reflects the present topography although with a more pronounced relief (Figure 8). Drift cover is between 5 and 25 m thick over most of the district, with thicker drift, up to 45 m, in buried channels (eg beneath Workington and the present Ellen and Derwent valleys, and in corrie-like hollows in the seaward facing slope near St Helens [028 322] and along the southern side of the buried Derwent valley (Figure 9). Exposures of solid rock occur as knolls in the rockhead surface and in deeply incised stream valleys. Many of the the rockhead slopes are, in detail, dip slopes parallel to bedding in the underlying Coal Measures.

A different pattern is present over the area of Triassic strata north of Maryport where relatively steep sided ridges are capped with till and exposure occurs on their flanks. Drift in the intervening valley is relatively thin.

Quaternary Deposits

Till (Boulder Clay) mantles much of the district. Its surface shows well developed low eliptical ridges (drumlins) with a NE-SW alignment parallel to the trend of rockhead ridges, both reflecting the direction of ice flow. Good exposures of boulder clay are restricted to a few localities in the banks of the Rivers Ellen and Derwent [eg 0149 2964] and to small incised stream valleys.

Over most of the district, the till is a lodgement till and consists of grey to brownish grey, sandy, stony clay. Included erratics are typically rounded to subrounded, with boulders up to 1 m across of locally derived sandstone, mudstone, clay ironstone and limestone, in addition to exotic rocks from the Lake District and southern Scotland. Beds or lenses of sand and gravel occur in the till. Within 1-2 m of the surface it is weathered to a brown sandy, stony clay, which may include ablation or flow till.

North of the River Ellen the till is much more sandy, reflecting its derivation largely from the underlying St Bees Sandstone. It is red-brown in colour and fragments of St Bees Sandstone are abundant together with numerous exotic rocks mostly from southern Scotland. The matrix varies from sandy clay, exposed to 12 m at Mote Hill [0346 3624], to clayey sand, exposed to 10 m in Bankend quarries [0419 3785]. This till passes upwards into sand and gravel beneath Maryport [035 364]. Very sandy till is also present north of Ellengrove [049 371].

Glacial Sand and Gravel forms extensive deposits at Workington and Harrington and along the Derwent and Ellen valleys. In the Workington and Moss Bay areas sand and gravel up to 20 m thick has been worked in several places [eg 9900 2560 and 9925 2675]. Much of this deposit forms a relatively flat bench at an elevation of 14 to 20 m AOD. Relics of what may be a related flat top to the sand and gravel deposits which filled the pre-glacial Derwent valley occur at an elevation of 25 m at Camerton Church [0335 3010], Ribton Hall [0473 3057] and below Fernbank [0225 3005]. Exposures in several places in the steep banks of the Derwent, noticably at Hagworm Brow [0054 2924], Priestmans Brow [0238 3023] and east of Camerton where small workings [0396 3095 and 0401 3095], show up to 10 m of well-bedded sand and gravel. The gravel is typically well-rounded, with pebbles usually less than 10 cm in diameter although scattered boulders up to 0.5 m are also present. This deposit extends beneath the river alluvium, resting on rockhead at Camerton and to the east. Sand and gravel, 27 m thick was proved in a borehole south of Camerton [0398 3026]. In the deep part of the pre-glacial Derwent Valley at Barepot [013 294], glacial outwash and more recent sand and gravel is interbedded with clay and locally includes lenses of peat up to 0.6 m thick. The Derwent sand and gravel deposit, overlain by boulder clay on either side of the present river valley, probably dies out rapidly to the north and south.

Near Maryport, along the south side of the Ellen, sand and gravel is up to 20 m thick, resting on boulder clay. At Netherton [0445 3632] trial pits up to 2 m deep showed bedded, well-sorted, fine to coarse sand and gravel with rounded pebbles usually less than 3 cm diameter with some up to

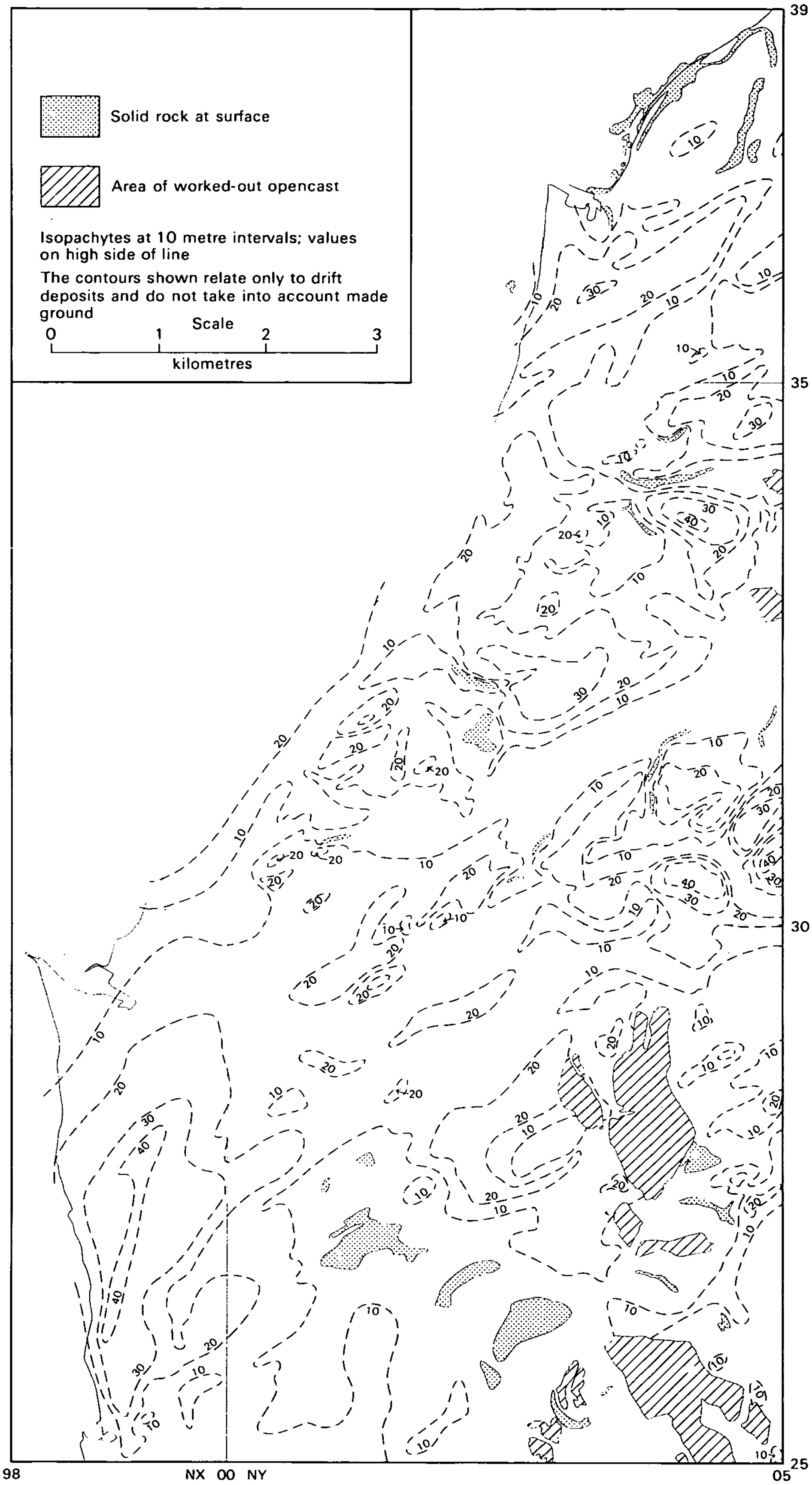

Figure 9 Drift thickness

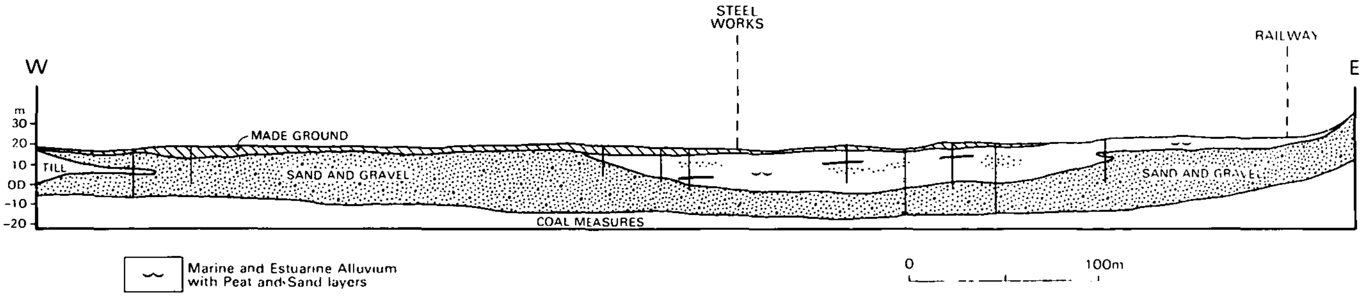

Figure 10 Section through buried channel at Workington

20 cm. The sand matrix is locally clayey. No workings are known.

Small isolated outliers of sand and gravel cap low knolls of at several localities, for example Risehow [028 351], Stainburn [020 292] and Great Clifton [044 295]. A number of boreholes in the area have encountered beds or lenses of sand and gravel within the boulder clay.

Alluvium and River Terrace Deposits are extensive only in the Derwent and Ellen valleys where the deposits are terraced 3-5 m above river level. Alluvial deposits are principally silty sand or sand and gravel with some clay layers. Peat may occur in former channels, and is recorded at Barepot [031 294] as lenses up to 0.6 m thick. Thin alluvial deposits occur in numerous small stream valleys throughout the area.

Lacustrine Alluvium occurs as flat-surfaced deposits of silt and clay with some peat in enclosed basins which probably mark the sites of former lakes. These lie in low areas of the raised beach, between boulder clay ridges or drumlins and in dammed channels. Examples of the latter can be seen near Lostrigg Beck [048 272], in what may have been a glacial overflow channel, and in an abandoned distributary of the Ellen [047 374] dammed by the raised beach ridge.

Alluvial Fan deposits, which are similar to river alluvium, have been mapped where tributary streams emerge onto the gently sloping surfaces. Fan deposits rarely exceed 3-4 m thickness.

Marine and Estuarine Alluvium (or Warp) occurs principally in the Workington area, where the thickest deposits lie in an arcuate channel aligned approximately north to south, separating Chapel Hill on the west from the main part of the town to the east. They comprise soft grey-brown, blue and black silty and sandy clays, silts, laminated clays and peat. The clays are "organic" in places and referred to in borehole logs as "fibrous and rooty". Some are also rich in shell debris. Peat beds and lenses are commonly up to 1.20 m thick and dark grey sand lenses reach 4 m in thickness. The channel varies between 300 m and 1200 m in width and is deepest in the west where nearly 20 m of superficial deposits accumulated. The bottom of the channel, cut into sand and gravel, is proved to be nearly 10 m below Ordnance Datum. (Figure 10).

Raised Beach Deposits fringe much of the coastline and are particularly well developed between Workington and Maryport where the raised beach is from 200 to 600 m wide. Its surface is broadly flat, with low ridges, at an elevation of 5 to 10 m. The beach deposits are principally sand and gravel up to 12 m thick, and have been worked in many places especially near Flimby, Maryport and Siddick, though all of the excavations are now filled. Site investigation bores near Siddick show thin clay beds, some with peat, locally interbedded within the sand and gravel of the raised beach.

Marine Beach Deposits are composed principally of shingle with some areas of sand. The modern beaches include a considerable amount of steelworks slag and colliery waste resulting from extensive tipping of the material onto the foreshore near Maryport, Workington and Harrington.

Made Ground and backfilled opencast sites cover about 20 per cent of the district (Figure 11). Colliery spoil and furnace slag are predominant along the coastal strip. Many old tips have now been landscaped, the largest example of which is Slag Bank [986 285] in the Chapel Hill area of Workington, where the waste products of the once flourishing iron and steel industry reached heights of over 30 m. Attempts were made during reclamation to match the original contours of Chapel Hill by redistribution of the slag. The area is now being re-soiled with the hope of establishing vegetation upon it, but the high sulphur content of the slag makes this particularly difficult. Slag was commonly tipped alongside the beach and now forms man-made cliffs in places 20 m in height. In places the foreshore consists of fused slag forming unnatural "reefs" dipping gently seawards on which marine life cannot easily establish. The variable "cementation" of the slag results in some parts of the coastline being liable to rapid erosion and undercutting. In areas such as north of Workington [992 302], limestone blocks have been tipped on the shore to slow the rate of wave action on this poorly consolidated slag.

Large areas of colliery spoil are present around the sites of St Helens Colliery near Seaton and Risehow Colliery near Maryport. Smaller sites are scattered throughout the area particularly around Camerton where every coal shaft is marked by its associated pit tip. In urban areas such tips are usually levelled and built upon, making location of the original shaft difficult. In pastoral areas, the tips slowly grass over and cause only mild inconvenience, though they often upset the natural drainage in their immediate vicinity.

Sandstone quarries are generally small in area and average about 10 m deep but east of Workington one of 20 m deep was recorded. The fill in these excavations is variable - earth fill has been noted east of Workington but it may include domestic waste. Compaction of the fill leading to differential settlement of any structure built across the edges of the excavations is a particular hazard. Known quarries are shown on the geological maps but there may be others now obscured by urban spread.

Made ground shown as "undifferentiated" may contain a mixture of slag and colliery spoil together with building, brickworks and quarry waste as well as domestic refuse. Old sand and gravel quarries at High Harrington have been filled with such a mixture of material. A high proportion of domestic refuse is present in the old gravel pit [990 255] on the southern end of Walker's Brow. Large areas of the raised beach between Siddick and Maryport have been worked for sand and the old pits restored by infilling, usually with ash. In places, the surface of alluvial areas once liable to flooding has been raised by tipping colliery waste, (eg near Ewanrigg [038 352]. Between Siddick and North Side, subsidence coincident with low-lying alluvium appears to have led to flooding part of this area.

Made ground is commonly found in some of the smaller valleys raising the level of the land and obscuring the alluvium, with the stream culverted out of sight. Detection of these areas is now only possible by reference to the older geological surveys where the now obscured alluvium is mapped. Such areas occur at Salterbeck [992 265] in Workington and at Ellenborough [041 348] in Maryport.

Backfilled opencast sites are extensive south of Great Clifton. One of the largest sites, called Mabel, worked eleven seams over an area of 111 hectares to a maximum depth of about 40 m. Dates of the completion of coaling are given for each site on the geological maps. Opencast excavations are filled with the overburden which was originally taken from them.

MINERAL and GROUNDWATER RESOURCES

Coal seams of economic significance occur within a sequence some 300 to 350 m thick in the Lower and Middle Coal Measures with only a handful of seams of lesser value in the lowest part of the Upper Coal Measures. Most of the production has come from some 19 seams, all of which are known to vary in thickness and quality throughout the district and are not economically workable in all places. Minor seams, and local splits of the main seams, assume importance locally. In places even the better seams deteriorate in thickness or quality or have been removed completely by washouts (known locally as "nips"). Washouts particularly affect the Main and Six Quarters seams over considerable areas. Shale partings are common in several seams, particularly the Slaty, and locally the Metal and Ten Quarters, and in places render them unworkable.

The Workington and Maryport district has had a long history of coal mining, supplying good quality bituminous coal for coking, gas making, steam raising and household purposes. Until recently this production came almost entirely from underground mines until the closure of the last deep collieries at Solway, Clifton, St Helens and Risehow in the 1950/60s brought this traditional method of extraction to an end.

The interest in opencast coal extraction which arose during World War II led to exploration for suitable sites in west Cumberland including several in the present district but production here did not begin until 1958 at Broughton Moor [048 330]. Since then several large sites have been worked, mainly in the south. A considerable proportion of opencast coal has been obtained from seams, particularly those at higher stratigraphical levels, which could not be economically mined. To date, well in excess of 2.5 million tonnes of opencast coal have been won. At present (September 1986) no coal is being raised within the district though Low Close Site [073 335] at Broughton Moor, a short distance to the east, is in production and development has started at the large new Potato Pot Hall site, [037 246] in the extreme south. Prospecting for further reserves near Broughton Moor and around Lostrigg Beck is in progress.

Some coal remains locally in areas of former underground mining, commonly as isolated patches within fault blocks, in barriers between colliery working areas (takes) and in thin seams which were not worked. Where such coal is within reach of opencast mining it constitutes a possible reserve. One area which might be an economic opencast prospect is sterilized beneath a military establishment. Resumption of underground mining to recover unworked coal is considered extremely unlikely.

All coal raised from opencast sites in Cumbria is currently transported by lorry to a central stock yard and despatch facility adjacent to the railway at Maryport.

Sandstone. Several of the more massive, thickly bedded and well-cemented Coal Measures sandstones have been worked at a number of places. The principle quarries were in the relatively wide outcrops of the Six Quarters and Main Band Rocks and also in the Quarry Hill Sandstone, overlying the Watergate Coal, in the Quarry Hill area [0428 2792] south of Great Clifton.

Many of the quarries were small and clearly met only a very local demand. The majority of these have been wholly or partly filled and obliterated. Larger quarries were established in the Six Quarters Rock at Schoose [0124 2784] and at Castle Gardens Bridge [0105 2726]. Most of these are now filled though somewhat overgrown sandstone faces may still be seen at both places. At the time of the previous geological survey (1928) up to 9 m of thickly-bedded coarse-grained white sandstone were exposed at Schoose Quarry. Much of the stone from these quarries was used locally as rough-hewn blocks in random masonry though some ashlar blocks and ridge tiles were produced. Numerous examples of the stone may be seen in nearby buildings including the remarkable series of buildings at Schoose Farm [0144 2800]. A sandstone, here correlated with the Six Quarters Rock, was formerly worked in small pits [0244 2532], now obscured by filling and landscaping, at the north-eastern corner of the Lillyhall Industrial Estate.

At Hunday [0195 2647] a quarry in the Main Band Rock formerly provided fine-grained pale grey sandstone, but is now completely filled with farm waste. Other very small quarries in this sandstone may be seen by the stream [0390 2676] south of Caple How and in the east bank of Lostrigg Beck [0452 2634] at Stargill. The old pits [0428 2792 and 0421 2784] in the Quarry Hill Sandstone at Quarry Hill are now either filled or degraded and overgrown.

The St Bees Sandstone was extensively quarried at Maryport [0415 3790] and provided excellent quality building stone for both rough and fine work. Apart from its extensive local use in Maryport and surrounding villages a good deal of stone was sent for use outside of the district. Quarrying at Maryport is understood to have ended in the 1920s.

Other building stones. Throughout the district a variety of erratics from the glacial deposits have been used as a readily available source of cheap building stone, mainly in field boundary walls and older cottages and farm buildings. Prominent rock types include Lake District granites, lavas and tuffs of the Borrowdale Volcanic Group, vein quartz, sandstones probably derived from the Skiddaw Group, Lower Carboniferous limestone and in places Criffel granodiorite.

Fireclay, shale and ganister. Several shales and seatearths within the Coal Measures have been worked in conjunction with coal for the manufacture of building bricks and refractory products. Brickworks were operated at both Camerton and Gillhead Collieries [039 308 & 033 327] and clay from Seaton Moor Colliery [040 329] was taken to Broughton Moor Works where sanitary ware was made. Shales above the Black Metal Seam were worked for the manufacture of building and refractory bricks at Moorhouse Guards [0214 3178], Seaton. It is possible that several seatearths within the district may possess the properties of fireclays though the quantities available are unlikely to be sufficient to attract commercial interest, especially where the associated coals have been worked. However if suitable material could be identified some refractory clays could perhaps be obtained as a by-product of opencast coal mining.

Siliceous sandstone, or ganister, is said to have been raised for refractory purposes as a by-product of coal mining in the Maryport area, though the sites at which it was worked are not recorded (Eastwood, 1930, p.125). Ganister was also worked in the nearby Branthwaite and Distington areas.

Iron Ore. Nodules of impure siderite or "clay ironstone" are common in many of the shales within the Coal Measures and may well have provided small local supplies of iron ore in the past. The only record of ironstone working in the district refers to Clifton Colliery [040 300] where nodules in the shale bed above the Metal Seam (one of the split leaves of the Main Seam) were worked along with the coal. Cantrill (1920, p.98) records that this ore assayed about 25 per cent metallic iron; working ceased in about 1900. No records of the extent of the iron ore workings or of the tonnages produced have been traced.

Glacial clays. Boulder Clay was dug for brickmaking from shallow pits in the field south of the "Oily Johnies" public house at Windscale [0286 2599]. Small hollows in boulder clay topography elsewhere may mark the sites of other small excavations for local brickmaking.

Marine clays. The pale coloured clay known as warp was formerly dug for the manufacture of rough pottery in the area between Workington and Moss Bay.

Sand and gravel. Glacial sand and gravel has been worked from several pits in the Harrington area where the deposit is up to 20 m thick. All the pits are abandoned and most are either degraded and overgrown or have been backfilled with refuse. The only extensive spreads of glacial sand and gravel within the district are completely sterilised beneath the urban areas of Workington and Maryport. Beds of apparently good quality sand and gravel crop out beneath boulder clay in the banks of the River Derwent between Workington and Great Clifton. Up to 10 m thickness of gravel is present locally and although the bed may be fairly extensive beneath the boulder clay, the thickness of overburden and topographic situation do not encourage investigation as a workable deposit.

Sand and gravel have been worked from the raised beach in the Siddick and Flimby areas [004 311 & 019 333]. Further reserves are likely to be present though some are now sterilized beneath industrial sites.

Slag. Steel works slag is currently being removed from the extensive heaps at Moss Bay, Workington, for use as a sub-base in road construction, as hardcore and fill for farm roads.

Non-ferrous mineralisation. No such mineralisation is known in the district. Traces of chalcopyrite noted in sphaerosiderite nodules in Lostrigg Beck [0445 2734] are likely to be of diagenetic origin and unconnected with any epigenetic mineralising episode. The First Limestone, formerly exposed in Barfs Quarry, Distington [005 241] 1 km south of the district, exhibited local secondary dolomitisation and in places large (>10 cm) patches of coarsely crystalline white baryte were common on joint faces. This type of mineralisation, which may be associated with the major NW-SE fault direction, could be present within the limestones at depth beneath the area though is unlikely to be of economic interest.

Groundwater. No groundwater is now abstracted for public consumption. The district is supplied by mains water from reservoirs elsewhere. Two wells at Maryport, at the former tanyard and brewery, drew supplies from the St Bees Sandstone (Eastwood, 1930, p.127) but both wells are now disused. Reliable yields of up to one million gallons per day could be obtained from the sandstone.

In common with other similar areas of former extensive coal mining large supplies of potable groundwater are unlikely to be obtainable in the coalfield. Widespread old workings lower the quality of the groundwater and disturb the natural hydrogeological regime; also the almost complete cover of boulder clay, urban areas and back-filled opencast sites effectively seals the underlying rocks from most natural recharge. Potential yields of up to 1000 gallons per day may be obtainable, but water quality could not be guaranteed.

GEOLOGICAL IMPLICATIONS FOR LAND-USE PLANNING

Mineral Resources

One of the purposes of land use planning is to ensure that potential mineral deposits are not knowingly sterilised by an alternative and possibly less economic use of that land.

There are no large deposits of sufficient economic importance to warrant widespread restriction of development. However if planning permission is sought for future development a restrictive covenant may be considered applicable in certain coalfield areas to allow the working of any shallow coals by opencast methods prior to that development. This process would have the added advantage of locating any shallow workings or access shafts and adits thereby enhancing foundation prospects without the additional cost of boreholes for site investigation.

Coal Mining

A large percentage of the district has been undermined by workings in at least one coal seam. In some areas, for example near St Helens Colliery, up to seven seams have been extracted.

The most important economic seams occur in the Lower and Middle Coal Measures but the presence of many large faults results in a complex pattern of workings. Small areas north and east of Workington are mapped as Upper Coal Measures which are predominantly sandstone.In the south west near Harrington, the Hensingham Group crops out and includes the Udale Coal, which is some 0.36 m thick but is thought not to have been worked. To the north of Maryport, the Coal Measures are overlain by the St Bees Sandstone and no mining has taken place.

The most productive seams are those from the Harrington Four Foot to the Ten Quarters inclusive. Historically the most important seam was the Main which was extensively extracted beneath Workington. Hopes of major extensions of the coalfield, working this seam westwards beneath the sea in the early 1800's were hindered by the discovery of further complex faulting. Many workings were lost in 1837 when the sea broke into the workings of the Main Seam in Moss Bay. The new sinking of Solway Colliery in 1916 with levels and driveages farther west met with limited success because of faulting and ventilation problems.

The earliest extant mine plans date from the beginning of the 18th century in the Main Seam, but earlier workings and many in the 18th and 19th centuries are unrecorded. The complex structure and mining methods then in use necessitated the sinking of numerous shafts to win the Main coal from small areas and different fault blocks. In the Workington area, thick drift deposits overlying steeply dipping coals, ensured that workings rapidly became deep. Early mining was by pillar and stall. Later, pillars were sometimes robbed, especially when a pit was threatened with closure and mining limits became more clearly defined.

Subsidence beneath Workington related to these early workings therefore should by now have taken place. As all collieries have now closed in this district, dangers of future subsidence are slight and it is likely to occur only on a local scale. Modern mining by long wall working causes subsidence to take place virtually contemporaneously with the extraction of the coal, and movement is generally considered to have ceased a few years after working. The area of standing water south of Siddick may be in part a subsidence feature related to mining. Subsidence cracks, not necessarily related to mining, are present in some of the older buildings in Workington and Harrington.

For safety reasons deep mining was restricted to below a depth of 150 ft (46 m). This cover limit minimised the danger of workings intersecting water-bearing or unstable superficial deposits or shallow old workings possibly contaminated by gas, silt, mud, peat or run-off of surface water. Records of such old workings, bell pits etc were rarely made or preserved.

Several general "rules" have been used to indicate the depth above which the majority of subsidence events which affect the surface are initiated. However, some of these may be of local use only and exceptions to almost all have been noted. It is necessary therefore to adopt an approximate "rule" which can be used by planners and developers so that potential instability can be reasonably taken into account prior to the development of the land.

In this study the commonly accepted basis that 10 times the seam thickness represents the maximum height of collapse through typical Coal Measure strata (Piggott and others, 1978). However, users of the results should always be aware that there will be exceptions to this "rule".

Applying this "rule", areas of shallow workings, less than 30 m or so below the surface, are shown on the shallow coal workings map.

The areas delineated are generalised and in considering particular sites it is useful to consult original documents. Workings known from mine plans can be anticipated and taken into account when planning, but areas of probable or possible workings are much less predictable. Evidence for shallow mining in areas not recorded on plans is derived from boreholes, features such as pitfalls and the discovery of old workings in opencast or other excavations. Ancient unrecorded workings may occur in any area where coal seams thick enough to be worked lie near the surface. Circular depressions commonly two to four metres in diameter known as pitfalls often form rectilinear patterns, resulting from collapse of pillar and stall workings. They have been identified during the survey, especially near the outcrop of the White Metal Seam and are noted on the geological maps. Typical examples can be seen near Swinsty Burn. Few definitive examples of bell pits were observed but wherever coal is near crop under thin drift it should be assumed to have been worked.

Mine shafts are present throughout the district and are particularly numerous east of Workington and near Seaton, where the complex structure and mining methods in use prior to the mid 19th century necessitated sinking numerous shafts each winning coal from a relatively small area.

Sites of all known shafts and adits are shown on the geological maps, but others may also exist. The positions of many old shafts are inadequately documented and, as they were commonly only capped at surface levels and remain open below. still present a hazard. The condition of shafts and adits needs investigation, in consultation with British Coal, before any development takes place.

Ground Conditions

Till or boulder clay mantles much of the district and where unweathered is regarded as a good foundation material which presents few problems in trenching, tunnelling and excavations. Other rocks and sediments occupy a much smaller area.

Till or boulder clay is, where unweathered, a tough over-consolidated lodgement till. Typical undrained shear strengths are in the range 100-350kN/m^2. It is a good foundation material but the presence of erratic boulders of hard rocks within the till are unpredictable in size and location and may cause problems, especially in tunnelling.

The uppermost 1 to 2 m of the till is weathered to a reddish-brown and yellow stony clay, which possesses different geotechnical properties, and is inherently weaker than the fresh material. If disturbed or moistened during site investigation or development, this uppermost till will have its shear strength rapidly reduced, becoming soft and plastic. Care should also be taken at contacts between till and sand where a spring line often develops and results in local weakening of the clays.

Mudstones and siltstones together comprise the bulk of the Coal Measures. Their clay minerals are stable but disseminated pyrite is commonly present, rapid weathering of which leads to ground water of high acidity ($<$pH4). The presence of abundant sulphate ions in the weathered mudstones, together with such secondary sulphate minerals as jarosite ($KFe(SO_4)_2$) and gypsum ($CaSO_4.2H_2O$) must be considered when contemplating placing concrete. Even when covered by a substantial thickness of drift, the topmost 1 to 3 m of mudstone are generally weathered. Trenching is relatively easy but tunnelling at depths of 12 m or less presents substantial support problems. Explosives are not generally required in surface excavations.

Sandstones. Excavation and tunnelling in sandstones presents few support problems but generally requires explosives for depths below 2 to 3 m. Some of the coarser-grained sandstones are gritty and highly abrasive and some sandstones are silica cemented and extremely tough. Ganister, a variety of sandstone seatearth found beneath some coals, is a particularly tough rock. Joint blocks that have been weakened by subsidence over old coal workings may require support in deep excavations and the presence of deep open joints may necessitate special precautions.

Seatearths contain readily-weathered clay minerals, which with the abundant random internal polished ("listric") surfaces, make them unstable both in excavations and under load. Disseminated pyrite may also be present and comments made above concerning the weathering of this mineral apply here too.

Laminated silt and clay, though subordinate in amount within the glacial sequence, are significant because of their low-strength engineering characteristics. Below the water table they are generally weak, with a shear strength commonly ranging from 25 to 70 kN/m^2. Under vertical

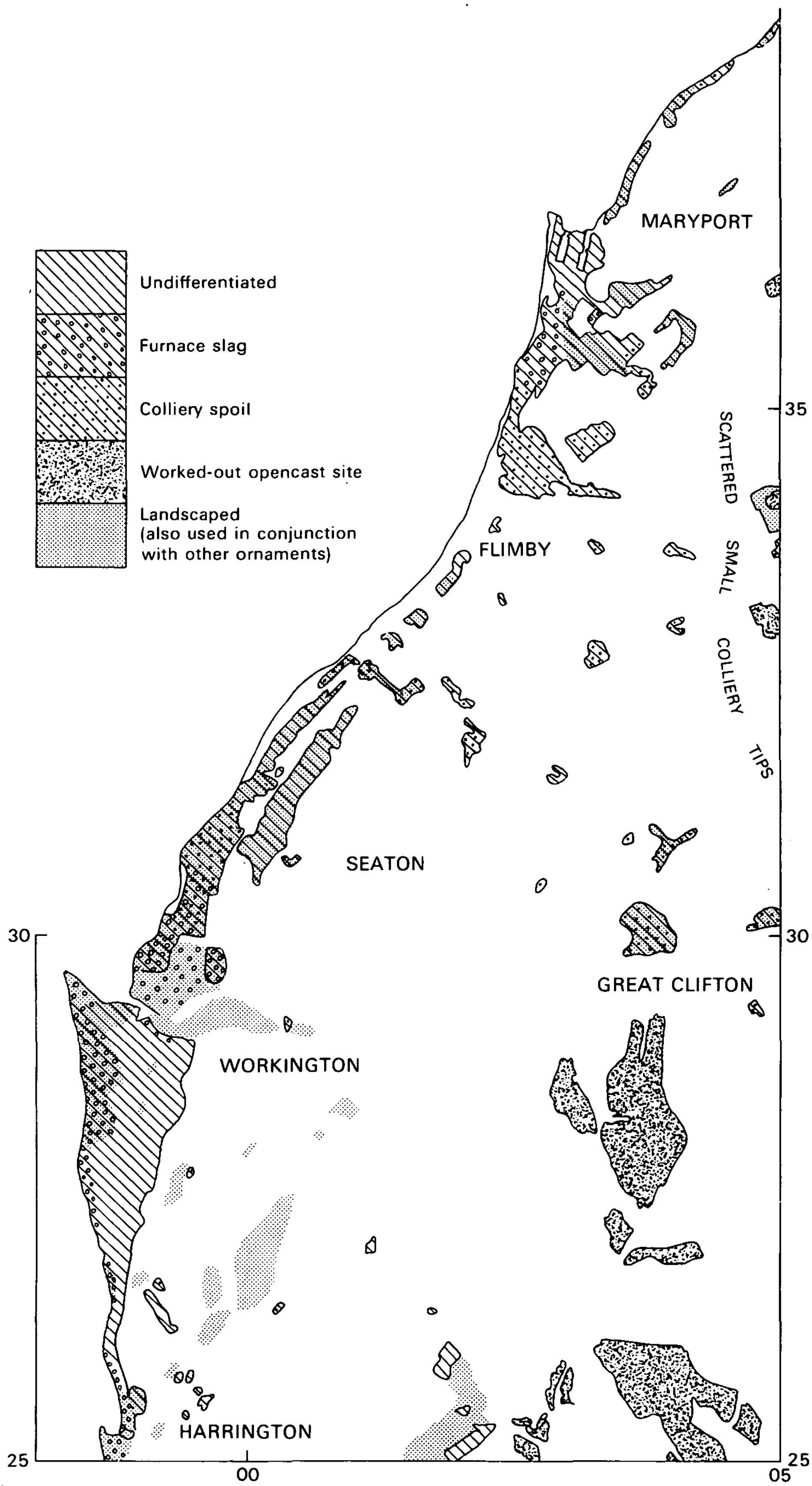

Figure 11 Index of made ground

load the clays are prone to strong compression and ductile flow, and foundations need to be specially designed: slab foundations or piling to rock or into strong till is generally necessary for heavy structures. Laminated clay and silt has a low safe angle of rest and excavations need close support; tunnelling and shaft sinking are moderately hazardous where these deposits are dry but call for extreme care where they are water-bearing and therefore highly prone to fluidization and ductile flow. Digging sewer trenches in these deposits has proved difficult in places.

Glacial sand and gravel. Water-bearing sands and gravel encountered within till sequences may be a problem but elsewhere sand and gravel, where dry or confined, can support considerable loads. Much of Workington is successfully built on such deposits. Where slopes in the deposit become oversteepened due to coastal erosion small slips occur, for example at the cemetery on Walkers Brow [989 263]. These are activated by spring lines at the base of the sand and gravel. Silt, peat and organic clays which are sometimes present as lenses within the sand and gravel can give rise to foundation problems.

Alluvium and lacustrine alluvium. Where it comprises sand and/or gravel, alluvium will pose few engineering difficulties, but beds of peat or silt which may be included will cause problems. Trial bores at Barepot [031 294] show peat beds up to 0.6 m thick in the Derwent alluvium. Alluvium is up to 30 m thick in this valley. In the smaller valley of the River Wyre it is proportionally thinner at less than 4 m but contains soft clays.

Warp or marine and estuarine alluvium and raised beach. An area of some 2 km^2 to the west of Workington is underlain by a complex series of soft, grey-brown silty and sandy clays interbedded and interlaminated with dark grey sands, peats, organic and fibrous clays and shell marls. These deposits, recognised by the early surveyors as "warp", are not ideal for foundations particularly as they contain largely unconsolidated peat in lenses up to 1.20 m thick, liable to compression and ductile flow. The plastic limits of the organic silts and clays range from 5 to 21 per cent. Lenses of dark grey sand up to 4 m thick may form local aquifers with a limited head of water.

Most of Workington steelworks were constructed on warp and BSC Track Products occupies the southern end of the buried channel. The lateral extent of the buildings compared with their height probably ensured a safe spread of loading upon the warp deposits particularly in their confined state and with their overconsolidation at depth. However any future excavations could be hazardous and require special care. Foundation problems are complicated by the variable nature of the deposits together with a wide range of moisture contents often exceeding 30 per cent. Raft foundations go some way to solving the stability of structures built on these deposits. Raised beach deposits, both to the north and south of Workington, comprise mostly sand and gravel and provide an ideal base for construction.

Landslips have been recorded where slopes have been oversteepened and undercut by the rivers Derwent, Ellen and Wyre. Slipping is a potential hazard wherever interbedded clays, silts and sands are excavated either naturally or artificially. Lubrication of laminated clay slip-planes by groundwater will give rise to gravitational and rotational slips. Loading of such deposits by tips or building will accentuate and accelerate such movements. Excavation or removal of any material from the toe of a landslip will create further instability and rapidly re-activate movement within the slip.

Made ground may pose problems because of its variability and, in places, because it may contain sulphur or methane generating material. Buildings founded on or partially on made ground may suffer differential settlement.

Waste Disposal and Ground Contamination

The suitability of old excavations in the district for disposal of waste is limited. As most of the excavations are in permeable formations (eg sand and gravel, sandstone or limestone) the type of waste material must be carefully monitored to ensure that the leachate does not contaminate nearby streams. Similarly percolation into the underlying formations must be slow enough to ensure natural detoxification and adequate dilution.

Recently, attempts to landscape tips, embankments and other man-made features have lessened their impact on the enviroment. Improvement of the impeded drainage around their margins has enabled reclamation of adjoining land. Future landscaping schemes may wish to consider the idea of creating space for waste disposal within or adjacent to the old tip.

Flooding

Because most of the towns and large villages in this district are sited upon sand and gravel terraces and raised beach deposits etc, well above river levels, flooding is not a major hazard. The largest river, the Derwent, even during the wettest periods of the year now has a regulated flow so discharges most surface run-off without flooding the flat alluvial tracts along its course.

Where minor flooding does occur in the district it is caused by artificial disturbance of the natural drainage. Examples are present around most pit tips and railway embankments. Between Siddick and North Side subsidence coincident with low-lying alluvium appears to have led to flooding part of this area.

The surface of alluvial areas once liable to flooding and avoided by developers in the past has now been raised by tipping of made ground in several localities, eg Salterbeck and west of the railway in Workington.

Coastal Erosion

Most of the shoreline in the district is masked by furnace slag and colliery spoil. North of Moss Bay this made ground has protected the natural low-lying coast from wave action. However the variable grade and cementation of the slag and subsequent disturbance by landscaping has resulted in renewed rapid erosion and undercutting, removing some of this protection. In the area of Workington north of the Docks [992 302] limestone blocks have been tipped on the shore to slow the rate of wave action on this poorly consolidated slag. Additional sea defences incorporating slag and boulders in wire-mesh containers will probably be required between Workington and Siddick.

Seismic Risk

The only known records of seismic activity within the district are those of two very minor earthquakes in the Maryport area; they may have been a result of collapse of old mine workings, though the possibility of a connection with the Maryport Fault or a related major fracture is not inconceivable. In view of this very sparse record of seismicity the district may be considered as having a low seismic risk. However, the possibility of appreciable seismic events must be considered in designing sensitive structures.

CONCLUSIONS

1. Extensive coal mining in the past now places restraints on planning or development, especially in areas where coal has been mined at shallow depth. Subsidence associated with the collapse of old workings will be greatest over areas of shallow ancient pillar and stall workings, some of which may be unrecorded. There are numerous shafts, many of which are poorly documented. Many shafts are not filled and may be poorly sealed.

2. Subsidence from deep mines should be complete but local settlement may still be anticipated.

3. The till which covers much of the district generally provides good foundation conditions; however the complex drift deposits of the buried valleys have more variable and weaker engineering properties. Steep slopes in drift will fail if overloaded or over-steepened.

4. Made ground, particularly that filling old quarries, poses problems of uneven settlement, especially for structures across the margins. Most slag heaps and colliery waste tips have been landscaped so stability is no longer a problem. North of Workington the coast is made of slag which is being undercut by the sea; some sea-wall protection may be needed here in the future. Backfilled opencast coal sites are numerous but their positions and former depths are well documented.

5. The district contains resources of coal which could be worked by opencast methods.

6. Resources of sand and gravel are restricted to two localities: the area east of Harrington, and the raised beach between Siddick and Flimby, though the latter area is partially overlain by made ground.

7. Sandstone has been quarried locally for building stone, and there are ample resources.

8. Apart perhaps for areas of near-crop coal which might be exploited opencast, there is no reason to recommend any measures to prevent sterilization of the few small remaining areas of mineral potential.

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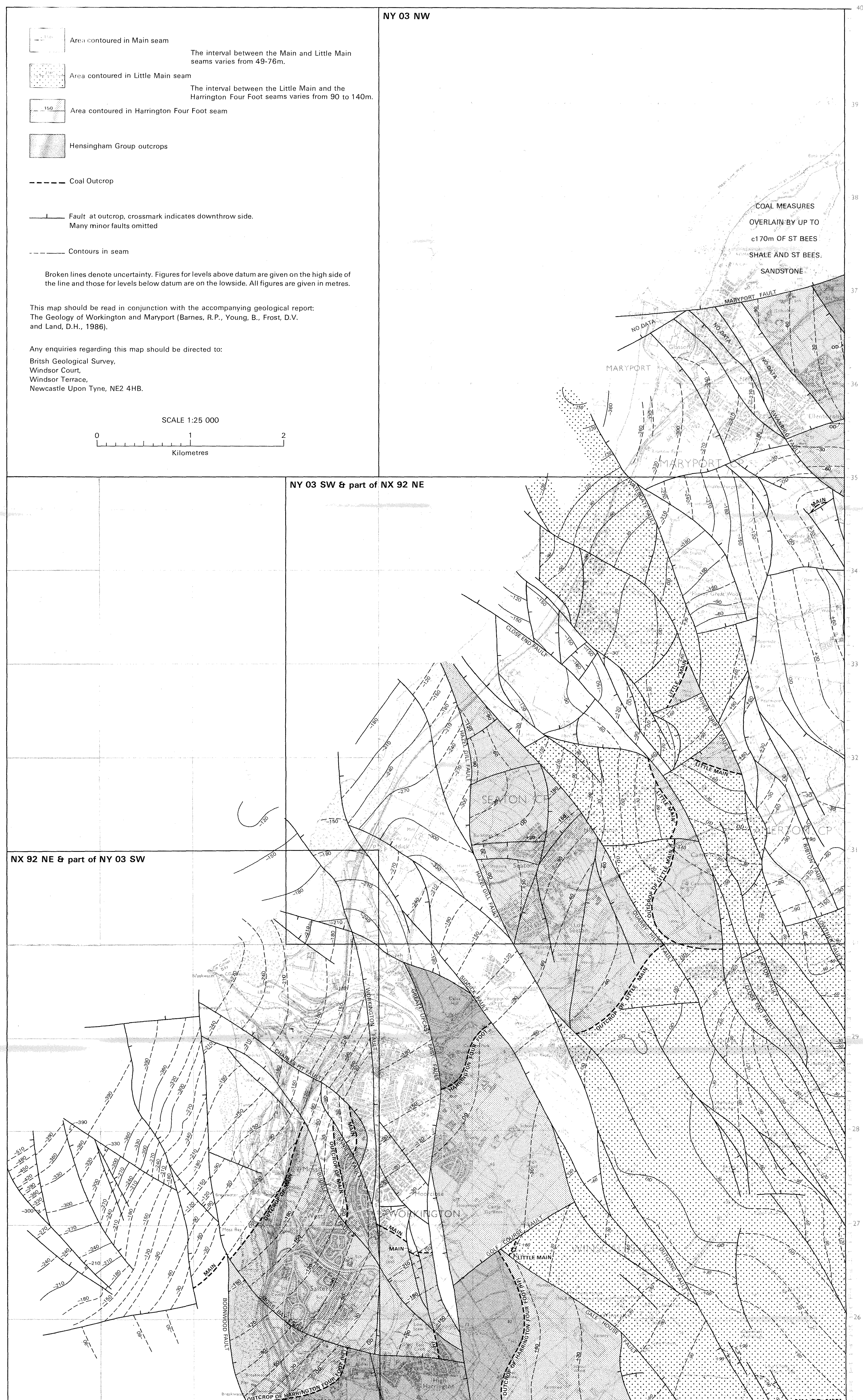

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THIS MAP GIVES AN INTERPRETATION OF DATA AVAILABLE AT THE LAST DATE OF SURVEY, ADITIONAL INFORMATION IS AVAILABLE IN BGS FILES.

STRUCTURE CONTOURS

WA/83/3

MINE WORKINGS WITHIN 30 METRES OF GROUND SURFACE

- Workings recorded on plans
- Some evidence for mining from surface features or borehole data, no plans available
- Local workings possible
- Workings absent within 30 metres of surface (includes areas where old workings have been removed during opencast excavations)

This map should be read in conjunction with the accompanying geological report.

The Geology of Workington and Maryport (Barnes, R.P., Young, B., Frost, D.V. and Land, D.H., 1986).

Any enquires regarding this map should be directed to:-

British Geological Survey,
Windsor Court,
Windsor Terrace,
Newcastle upon Tyne, NE2 4HB.

SCALE 1:25 000

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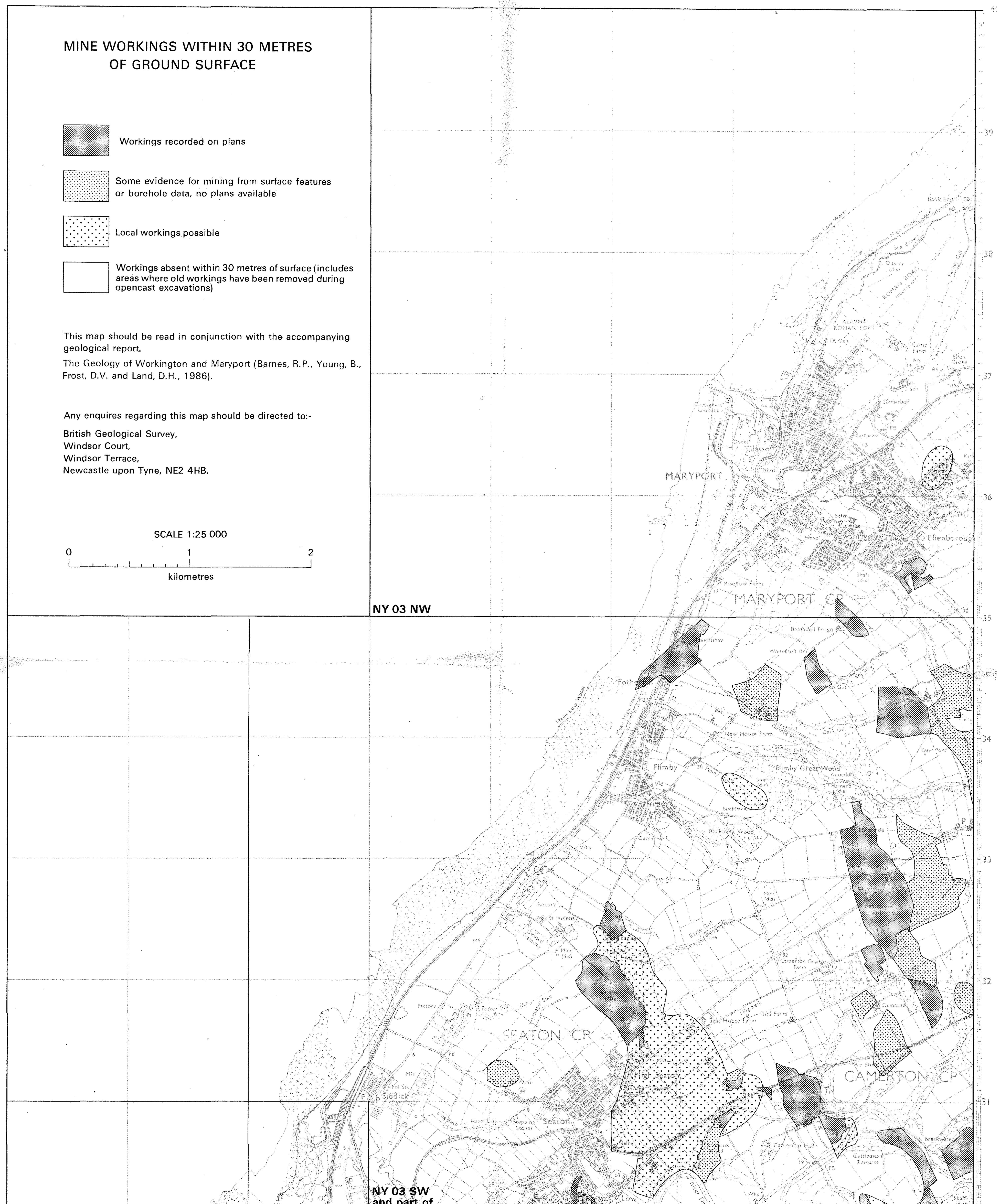

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SHALLOW COAL WORKINGS

WA/83/3