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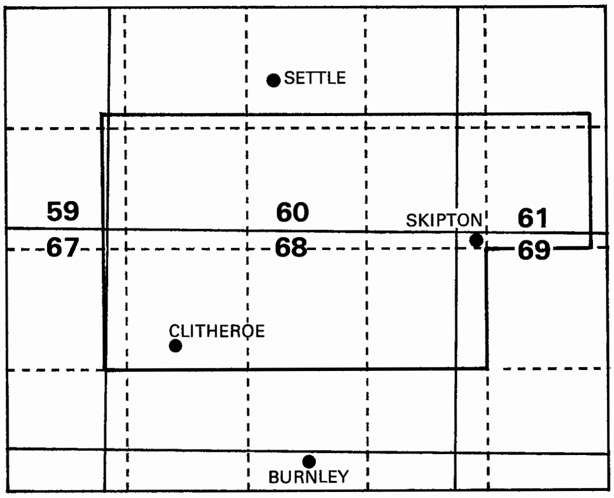

The limestone resources of the Craven Lowlands

Description of parts of 1:50 000 geological sheets 59, 60, 61, 67, 68 and 69

D. J. Harrison

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The first twelve reports on the assessment of British sand and gravel resources appeared in the Report Series of the Institute of Geological Sciences as a subseries. Report 13 and subsequent reports, including several on the assessment of limestone resources, appear as Mineral Assessment Reports of the Institute. Details of published reports appear at the end of this Report.

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PREFACE

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

The interdepartmental Mineral Resources Consultative Committee recommended that limestone should be investigated, and following a feasibility study initiated in 1970 by the Institute and funded by the Department of Education and Science, the Industrial Minerals Assessment Unit (formerly the Mineral Assessment Unit) began systematic surveys in 1972. The work is now financed by the Department of the Environment and is being undertaken with the co-operation of members of the British Quarrying and Slag Federation.

The report describes the limestone resources of some 760 km^2 of country in the Craven Lowlands area of North Yorkshire and Lancashire, shown on the accompanying 1:50 000 scale resource map. The assessment was conducted by D. J. Harrison with the assistance of D. W. Murray. R. Thompson, H. Mathers, J. Dennis, S. P. Sobey and M. E. Hill provided additional support.

The assessment is based on geological surveys at the 1:10 560 scale by J. R. Earp, D. Magraw, E. G . Poole, D. H. Land and J. J. Whiteman (Sheet 68), and R. S. Arthurton, and L. C. Jones, (Sheet 60). In addition, the assessment of the Skipton-Bolton Abbey area is based on the work of R. G. S. Hudson and G. H. Mitchell (1937).

Gamma-ray logs of the boreholes were obtained with the support of K. J. Barton and M. G. Baxter of the Institute's Applied Geophysics Unit. Chemical analyses were carried out by A. E. Davis and A. N. Morigi of the Analytical Chemistry Unit. K. S. Siddiqui of the Petrology Unit carried out X-ray diffraction analyses. Photographs were taken by K. E. Thornton of the Photographic Department.

W. N. Pierce (Land Agent) was responsible for negotiating access to land for drilling. The ready co-operation of land owners, tenants and quarrying companies in this work is gratefully acknowledged.

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SUMMARY

The study of borehole cores and samples from quarries and natural exposures, together with information from the records and geological maps of the Institute of Geological Sciences, forms the basis of the assessment of limestone resources in the Craven Lowlands.

The limestones are classified on their calcium carbonate content, and the accompanying 1:50 000 resource map shows the distribution of the categories of limestone recognised at outcrop.

Eleven resource blocks have been outlined and for each, the geology, the categories of limestones and the occurrences of other rocks are described. The results of investigations of chemical and mechanical properties are presented with outline borehole logs.

Bibliographical reference

HARRISON, D. J. 1982. The limestone resources of the Craven Lowlands: description of parts of 1:50 000 Geological Sheets 59, 60, 61, 67, 68 and 69. **Miner. Assess. Rep. Inst. Geol. Sci.**, No. 116.

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INTRODUCTION

Limestone production in the United Kingdom has doubled over the past 20 years and, although production has fallen slightly in recent years, national production is currently totalling about 84 million tonnes annually (Institute of Geological Sciences, 1981). Most of this tonnage is extracted from limestones of Carboniferous age which also give rise to much of the impressive scenery associated with the Pennine uplands. If the amenity value of such limestone terrains is to be protected whilst they continue to supply industry with an essential raw material, then information on the nature of the limestone resources is needed to ensure that land-use and mineral planning is carried out with the benefit of the most up-to-date geological background. The provision of such information relating to the physical and chemical characteristics of the limestones of the Craven Lowlands is the objective of the present survey.

The methods of assessment used here embody the procedures for assessing limestone resources on a regional scale outlined by Cox and others 1977. However, due to the poor exposure, complex geology and relatively low purity of the limestones in the present district, the survey has been conducted at a reconnaissance level and the resource map presented at the 1:50 000 scale rather than at the 1:25 000 scale adopted in earlier reports on limestone resources in Derbyshire. Consequently detailed information is restricted to the areas where rock samples have been obtained from cored boreholes, natural sections and quarry faces. Petrological, mineralogical, chemical and selected physical properties of all samples have been determined in the laboratory. Conventional geological nomenclature has been used for technical descriptions, ensuring compatibility between this report and the geological literature. A glossary is appended. The rocks are classified in terms of their calcium carbonate ($CaCO_3$) content so that the relation between limestone category and possible end use may be deduced (Table 1).

Detailed results and conclusions are set out in this report and its appendices, but the presentation adopted for the accompanying resource map is more generalised. The survey has benefited from the co-operation of members of the minerals industry who have made available borehole logs and chemical data.

DESCRIPTION OF THE DISTRICT

The district* embraces parts of North Yorkshire and Lancashire and includes, in the south-east, adjoining small areas of West Yorkshire. It is predominantly rural but there are good road and rail communications between the main commercial centres of Skipton, Barnoldswick and Clitheroe and the surrounding conurbations (Figure 1). The local economy is based largely on pastoral farming, together with light engineering and the mineral extractive and manufacturing industries. In the past limestones were worked in small quarries for building, walling and lime-burning, but more recently large quarries have been

* In this report the term 'district' means the area outlined on the resource map.

Table 1 Classification of limestones by purity with some possible industrial uses.

	Category	Percentage $CaCO_3$	Equivalent CaO	Possible industrial use*
1.	Very high purity	>98.5	>55.18	steel, glass, rubber, plastics, paint, whiting
2.	High purity	97-98.5	54.34-55.18	iron, ceramics, general chemical use, Portland cement, sugar
3.	Medium purity	93.5-97	52.38-54.34	paper, animal feeding stuffs, agriculture
4.	Low purity	85-93.5	47.62-52.38	asphalt
5.	Impure	<85	<47.62	natural cement, mineral wool

* $CaCO_3$ content is only one of several chemical specifications governing end use: silica, iron, phosphorus, magnesium, sulphur and certain trace elements may be as important in some applications.

developed for the manufacture of cement and aggregates. In addition, sandstone and sand are quarried at Waddington Fell for building purposes.

Topography

The Dinantian limestones form an extensive undulating lowland area which is drained by the rivers Ribble, Aire and Hodder and, in the east of the district, by the Wharfe (Figure 2). The Pennine watershed, separating the westward-flowing tributaries of the Ribble from the eastward-flowing tributaries of the Aire, traverses the central part of the district, but it has little physical significance in the low lying area north of Barnoldswick where it is at a lower level, about 425 ft (130 m) OD, than at any other point along its entire length. For much of its course the Ribble meanders through wide, terraced alluvial flats but near Gisburn it flows through a gorge in Dinantian limestones.

Notable minor features of the lowland area are the numerous drumlins and, also, the limestone knolls around Clitheroe and neighbourhood. Locally the quarrying of limestone has modified the scenery.

The rivers are bounded by gently-sloping, well-wooded meadowland rising gradually into steeper moorlands which are underlain by Namurian mudstones and sandstones and characterised by dip- and scarp-slope topography. The moorlands rise to over 1000 ft (305 m) OD and the Pendle escarpment, which extends from Clitheroe to the Aire gap, reaches a maximum height of 1831 ft (558 m) at Pendle Hill. The Newton and Croasdale Fells are physically part of the extensive Bowland Fells which lie to the north-west of the district.

General geology

Most of the district is covered by parts of Geological Sheets 60 (Settle) and 68 (Clitheroe) and this geological account is based mainly on published information in the Clitheroe memoir (Earp and others, 1961) together with the geological investigations which are to be detailed in the forthcoming Settle memoir (Arthurton and others, *in prep*). The geology of the Skipton-Bolton Abbey area is based on the report by Hudson and Mitchell (1937).

Most of the district is underlain by sedimentary rocks of Carboniferous age and no pre-Carboniferous rocks are known. During the early Carboniferous the district formed part of a marine sedimentary basin (Craven Basin) which was bounded to the north by the stable Askrigg Block. Sedimentation began early in Dinantian times and great thicknesses of limestones interbedded with muddy sediments accumulated. Knoll-reefs of almost pure lime sediment developed locally within the basin during this period. Deposition of marine mud dominated the late Dinantian and this gave way to deltaic muds and sands during the Namurian.

During the Carboniferous period the sediments of the basin were faulted, and folded into north-east to south-west trending anticlines with intervening broad synclines. Outcrops of the older Dinantian rocks are largely confined to the anticlines.

The Carboniferous rocks are largely obscured by a cover of drift deposits of Pleistocene and Recent age. The drift is of variable thickness ranging up to some 60 m in places. Boulder clay of glacial origin is the most extensive drift deposit and is moulded into drumlins in the Broughton-Hellifield-Gisburn and the Grindleton-Sawley-Chatburn areas, as well as in the Hodder Valley.

Stratigraphy of the Dinantian rocks

The complex structure, lithological variation and poor exposure of the Dinantian rocks in the Craven Lowlands have resulted in a lithostratigraphy containing a large number of local rock names. These have been formalised for the southern part of the district in a stratigraphic scheme (Earp and others, 1961) but this has been modified in its application to the northern part of the district (Arthurton and others, *in prep*). The stratigraphy of the Skipton Anticline is adapted from Hudson and Mitchell (1937). The schemes are summarised and related in Figure 4.

Lateral facies-changes from limestone to mudstone occur and the vertical sections in Figure 4 are generalised, serving only as a guide to the sequence in each area.

The Dinantian rocks comprise a thick sequence of limestones with variable amounts of interbedded shales. The limestones consist mainly of the calcareous skeletons of marine animals and plants, broken and comminuted by wave and current action and mixed in varying proportions with lime mud and clay. Replacement of calcium carbonate, particularly by silica and dolomite, is a common feature of the limestones. Chert as nodules and layers occurs sporadically and is common locally.

The oldest Dinantian rocks seen in the district are dark grey shales and mudstones with subsidiary limestones. They belong to the Chatburn Limestone Group and are termed the Gisburn Cotes Beds where they are exposed in the core of the Gisburn Anticline, and the Haw Bank Limestones with Shales in the Skipton Anticline. The thickest development is in the Gisburn Anticline where some 1200 m may occur.

These shaly beds pass upwards into a sequence of dark grey, well-bedded limestones up to 300 m thick which, for the most part, contain relatively few shales

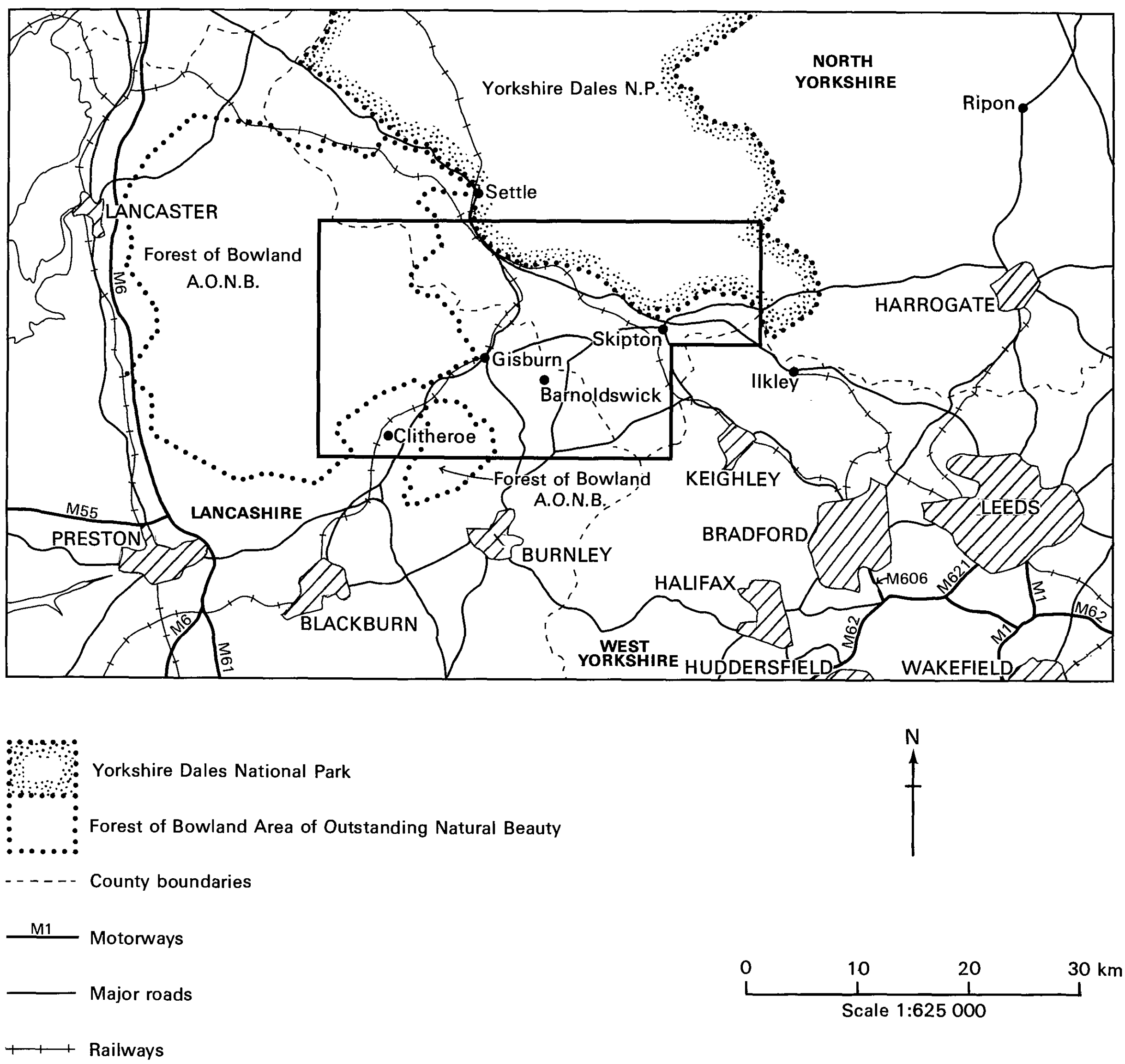


Figure 1 Location of the district.

and are well exposed in the Clitheroe, Gisburn, Swinden, Thornton and Broughton anticlines where they are known as the Chatburn Limestone (Earp and others, 1961). Similar beds, exposed in the Slaidburn and Skipton anticlines, are known as the Slaidburn Limestone and the Haw Bank Limestone, respectively. These limestones are actively quarried for aggregates and cement. The Chatburn Limestone is overlain by a variable sequence of mudstones and limestones, locally with knoll-reefs. This sequence includes the Thornton Limestone (Hudson, 1944), Hetton Limestone and Bridge End Limestone and forms the uppermost part of the Chatburn Limestone Group (Figure 4). These strata are well exposed in the Airton, Hetton and Slaidburn anticlines. They contain a substantial amount of argillaceous material but a clay-free grainstone facies is developed in the Hetton Limestone of the Airton Anticline.

The beds overlying the Chatburn Limestone Group belong to the Worston Shale Group (Earp and others, 1961) and comprise a thick sequence of mudstones and limestones. The limestones, which are known by a number of local names (Figure 4), are mostly uniform in lithology, though variable in thickness. Slump folds are common and some limestones show graded bedding. Limestone debris beds made up of jumbled boulders and blocks of massive limestones occur within the sequence near Bell Busk [SD 905 565] and Coniston Cold [SD 902 550]. The base of the Group is unconformable in several places.

Also included in the Worston Shale Group are the knoll-reef limestones of Clitheroe and neighbourhood. These range in thickness from less than 30 m to over 600 m. The cores of the knoll-reefs are formed of massive calcite mudstones containing a specialised fauna; around and between the mound-like cores are bedded coarsely crinoidal limestones. The knoll-reefs contain the most consistently pure limestones in the district and are described more fully later.

The uppermost part of the Worston Shale Group is formed by the Pendleside Limestone, which marks the end of carbonate deposition in the basin and is overlain by black mudstones of the Bowland Shale Group. The Pendleside Limestone (known as the Draughton Limestone in the Skipton Anticline) ranges up to at least 100 m thick and consists largely of fine-grained cherty limestones. Graded bedding and burrow bioturbation are also typical of these limestones. In the north of the district the top of the division is marked by a sequence of limestone conglomerates and boulder beds.

Structure

The Dinantian rocks of the district were folded and faulted by earth movements which took place intermittently over a long range of time, but were most

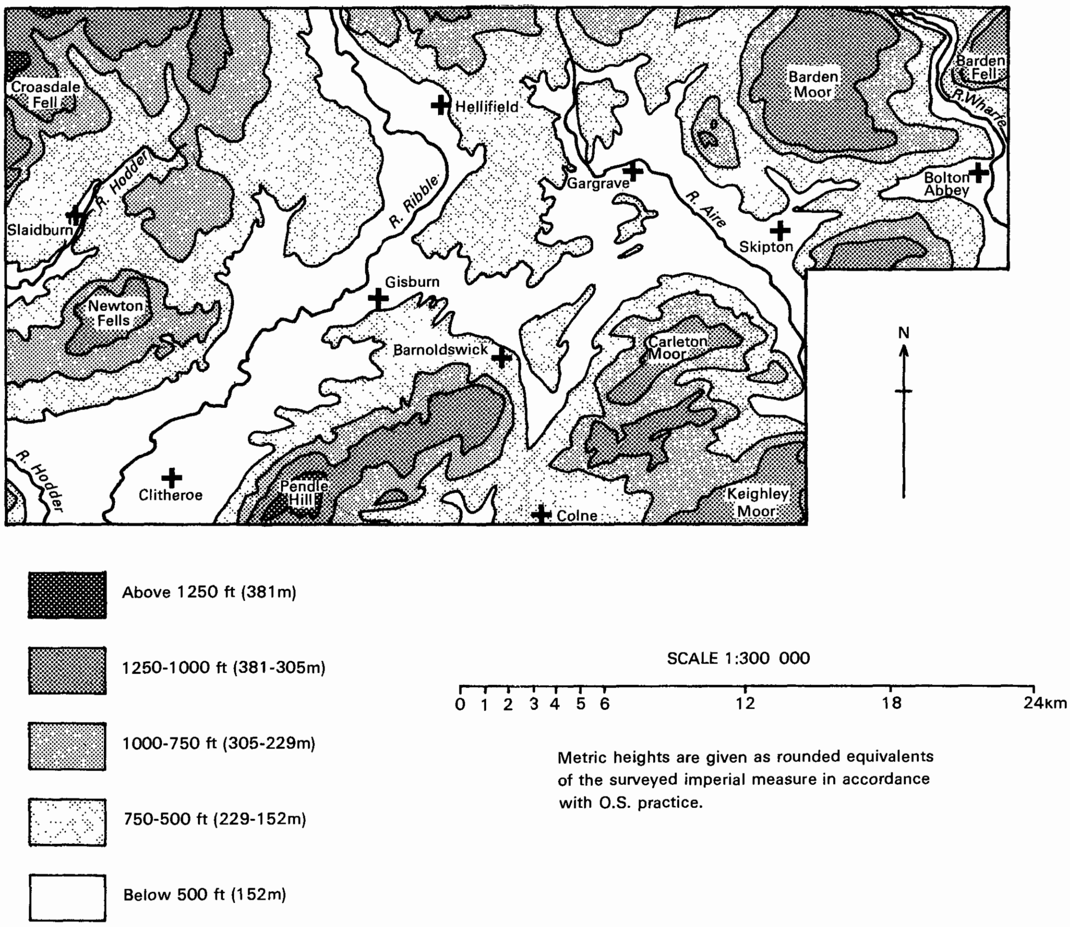


Figure 2 Topography.

intense at the end of the Carboniferous period. Some earth movements took place during sedimentation and unconformities are recorded within the Dinantian rocks. The main structural components are shown in Figure 5.

The anticlinal structures of the district form part of the Ribblesdale Fold Belt which trends west-south-west from the neighbourhood of Ripon to Preston. Most of the folds trend north-east to south-west but the Airton Anticline, a periclinal structure, trends west-north-west, and the Bell Busk Anticline, a pericline located between the Swinden and Hetton Anticlines, has an arcuate axial trace. Most of the anticlines are asymmetric and plunge to the north-east. Dips on the limbs of the main folds are typically high and are particularly steep in the more tightly folded anticlines.

Most of the folds are dislocated by faults trending north-west to west-north-west. Many of these faults have a tear component. The South Craven Fault system extends into the north-eastern part of the district and the Broughton, Skipton, Bell Busk, Hetton and Airton anticlines are bounded or truncated by this major dislocation. Thrust faulting occurs in the Grindleton and Clitheroe areas. The Horrocksford Hall Thrust at Clitheroe has a displacement ranging from 300 m at Clitheroe to 670 m at Chatburn and 300 m at Downham.

Mineralisation

At various times after the end of the Carboniferous Period certain faults, fractures and cavity systems in the Dinantian rocks of northern England became the host for sulphide ores and associated calcite-baryte-fluorite gangue minerals. The district lies outside the main orefield and the few minor veins which occur are thought to be economically insignificant. However, baryte and galena have been worked in the past from mineralised faults at Lothersdale [SD 942 454] and also from small veins in the Chatburn Limestone near Rimington [SD 815 453]. The knoll-reef limestone at Ashnott [SD 694 481] has also been worked for galena, and patchy mineralisation is recorded from several other knoll-reefs.

ASSESSMENT OF RESOURCES

The assessment is based on information from IGS maps and memoirs together with the results of a field survey which provided the rock samples for study in the laboratory and the data for interpretation. The procedures adopted are similar to those used in the assessment of limestone resources in the Southern Pennines (Cox and others, 1977).

Procedures

Field Survey

The number of boreholes required to assess the limestones of the district was determined with the aid of up to date 1:50 000 geological maps, and with reference to natural exposures and quarry sections. Fifteen boreholes were drilled to depths ranging from 42 to 221 m to provide continuous core of at least 47 mm diameter. These boreholes were drilled by contractors using trailer-mounted rigs and water flush techniques. In general core recovery exceeded 95 per cent but some difficulties were encountered in steeply dipping, thinly-bedded strata and in disturbed strata. The boreholes were logged by a portable Mount Sopris gamma logger which gave continuous readings of the natural radioactivity of the rocks and hence indicated the relative amounts of clay in the strata.

Samples were collected from quarry and natural sections and these were supplemented by a collection of spot samples.

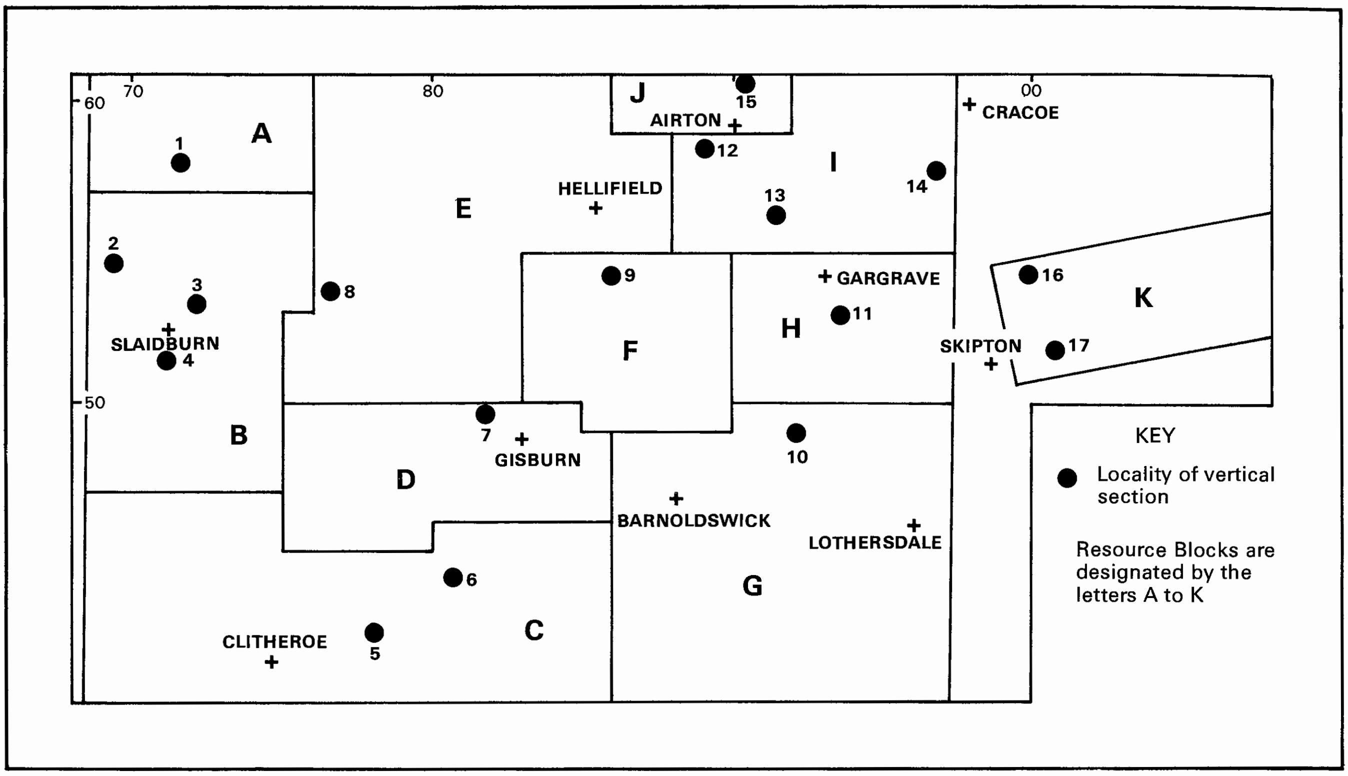


Figure 3 Location of vertical sections given in Figure 4, together with the outlines of the Resource Blocks (A to K),

Laboratory Programme
Lithological, petrological and mineralogical determinations were made using a combination of microscopical and staining techniques applied to sawn and etched rock surfaces. Additional mineralogical data were determined by X-Ray diffraction analysis of selected acid-insoluble residues and some rock powders.

A primary classification of the rocks, based on carbonate content (Cox and others, 1977), was achieved by measuring the amount of the acid-insoluble residue in aggregated rock samples from successive 5 m runs for all boreholes and sections. The insoluble residues of individual spot samples were also determined.

Chemical analyses for major and trace elements were performed by the Analytical Chemistry Unit of the Institute on 5 m or 10 m aggregated samples from all borehole cores and from selected exposures. Analyses were performed using direct electron excitation X-Ray spectrophotometry for Ca, Mg, Si, Al, Na, K, S, Sr, P, F and Fe; Cu, Pb, Zn and Mn were determined by atomic absorption spectroscopy and As by colorimetry (Roberts and Davis, 1977).

Since the colour of the rock powder is important if a limestone is to be used as a whitening agent, or, in an end-use where the colour of a manufactured product is important, a reflectance spectrophotometer was used to determine the reflectivity, relative to a $MgCO_3$ standard, of powdered samples (<63 micrometres particle size) of the knoll-reef limestones.

In order to provide guidance on the likely performance of the rocks as aggregates, most of the samples were subject to the Aggregate Impact Value (AIV) test (British Standards Institution, 1975).

Classification
The two methods of classification chosen for use in this report are based on petrology and on calcium carbonate ($CaCO_3$) content (Table 1). The former (Dunham, 1962) is used to describe the rock in lithological terms, but the latter is preferred for use in the description of resources.

The map
The resource assessment map is folded into the pocket at the end of this report. The base map is a compilation of parts of Ordnance Survey 1:50 000 Sheets 98, 99, 103 and 104. Geological boundaries and other data are adapted from Geological Sheet 68 (published 1960) and from a provisional edition of Geological Sheet 60 prepared specially for this report. The resurvey of Sheet 60 has necessitated a revision of some geological boundaries on the northern half of Sheet 68; the revised lines are included on the map. In addition, the geological boundaries in the Skipton-Bolton Abbey area are adapted from the work of Hudson and Mitchell (1937). Precise drift boundaries have not been mapped in the latter area and the boundaries shown are the best interpretation of the information available at the time of the survey. Structural information is shown on the resource map in red, and geological boundaries in black.

The limestone resources of the district are indicated on the assessment map by colours. Shades of purple through blue to green demonstrate the average purity of the exposed limestones and also indicate the likely purity of limestones which are concealed beneath drift. Areas of partial dolomitisation are indicated by green dots. Purity values were determined at sample points and this information combined with additional field observations (for example, presence or absence of chert) indicated the composition of the limestone resources on a regional scale. Over most of the district carbonate purity is closely related to the stratigraphy, and hence the category boundaries are also solid geological boundaries.

The map is subdivided for descriptive purposes into 11 Resource Blocks, which are labelled A to K and outlined in blue.

At the site of each borehole or extensive natural section, the purity and generalised lithology of the limestones are indicated in a tablet. The purity was averaged for each 10 m increment of strata and this value determined the category of limestone according to the classification shown on the map, and given in Table 1.

The various limestone divisions are identified by

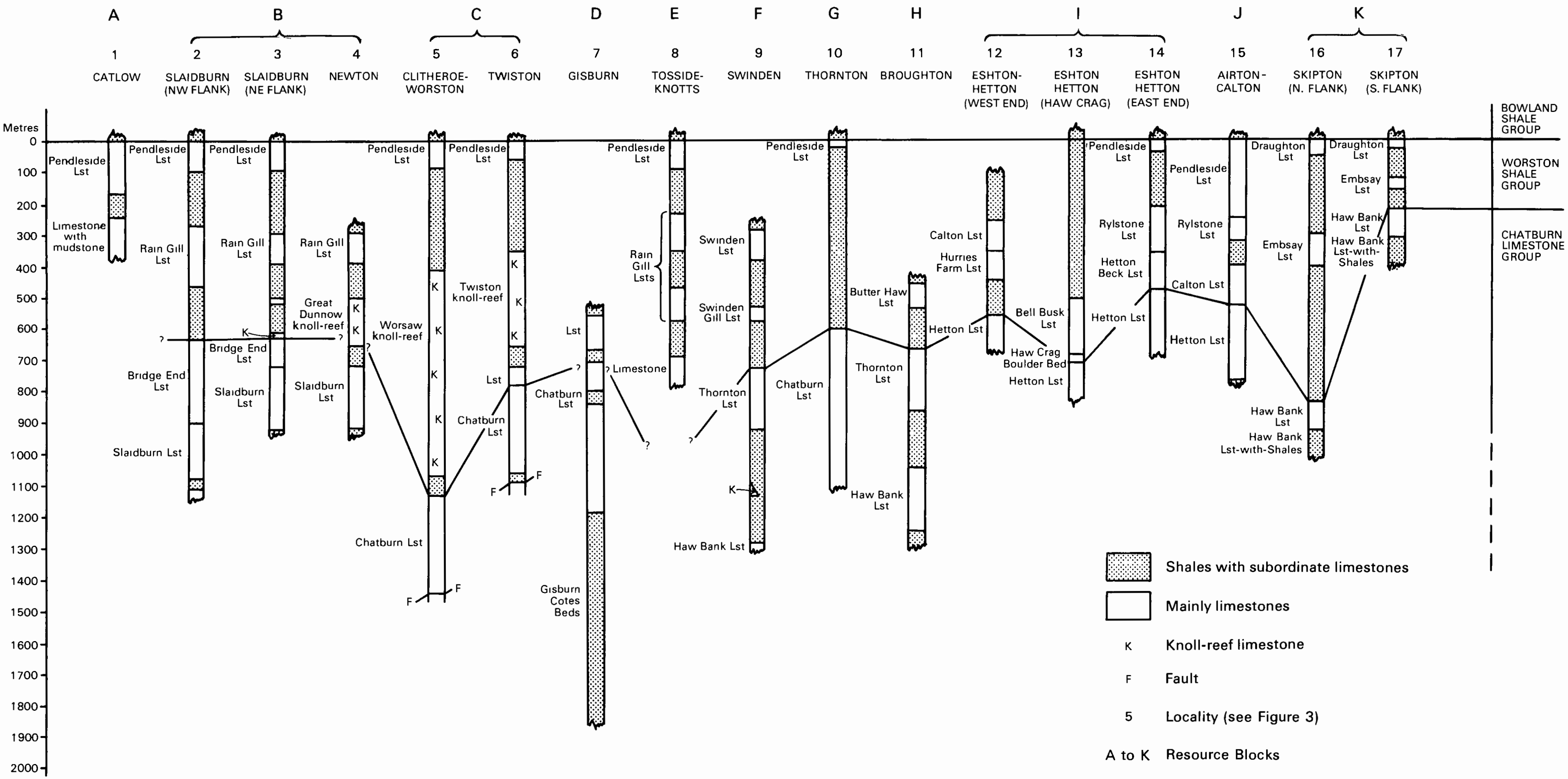


Figure 4 Generalised vertical sections of the Dinantian rocks.

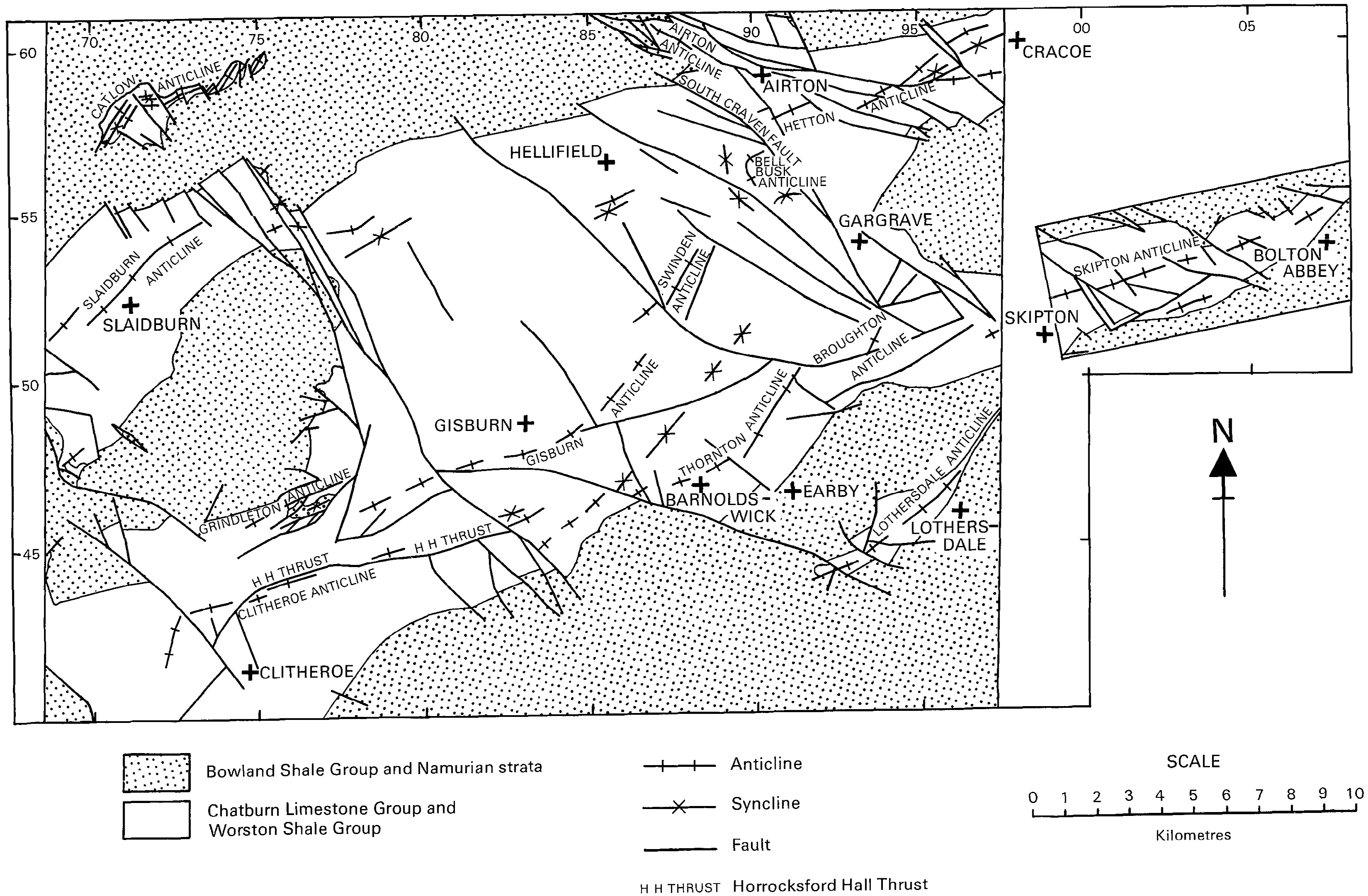


Figure 5 Structure.

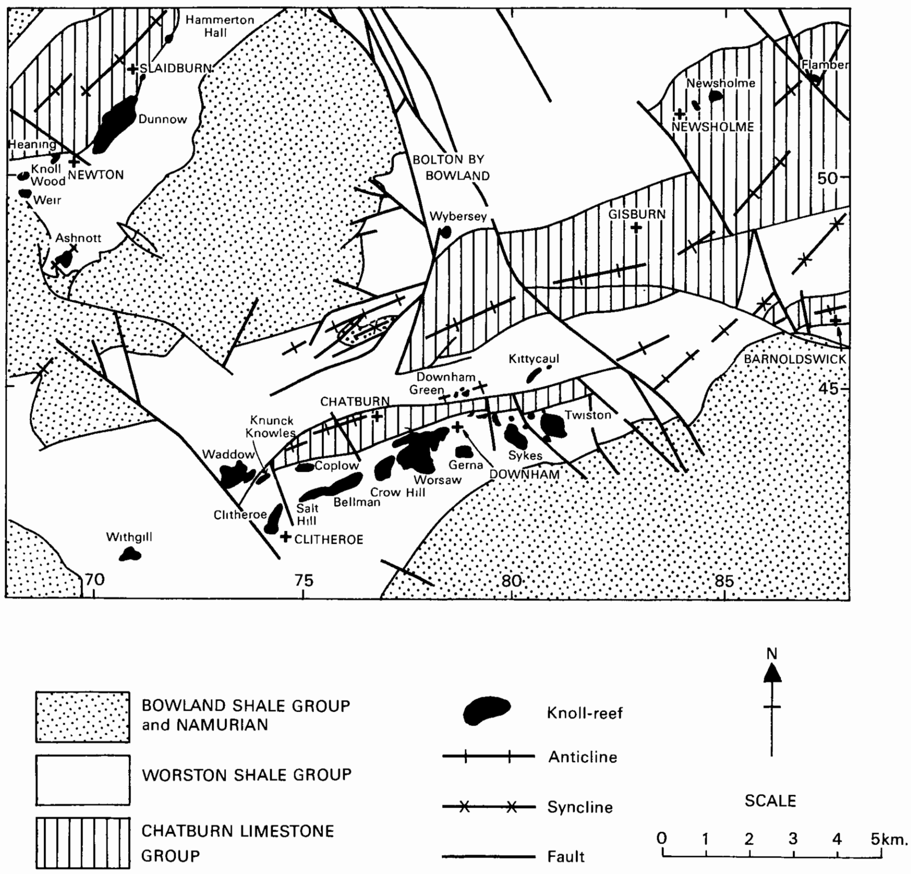


Figure 6 Distribution of knoll-reefs in western parts of the district.

stratigraphical symbols, but the intervening shale/mudstone divisions are un-named. An explanation of the symbols is included.

Description of resource blocks

For descriptive purposes the district is divided into 11 resource blocks, labelled A to K. Each of these resource blocks is occupied by one or more of the major fold structures. The following text describes the geology and limestone resources within each resource block. However, the high purity knoll-reef limestones are described separately in an account which follows the description of Block C.

Block A Catlow

The Catlow Anticline occupies a small area in the north-west corner of the district. Structurally, it is a complex north-east trending asymmetric pericline with the north-west limb steeper (50° - 70°) than the south-east limb (20° - 30°). The axial trace is dislocated by a number of west-north-west to north trending tear faults.

About 350 m of Dinantian strata (Figure 4) are exposed beneath the Bowland Shales. The un-named beds exposed in the core of the anticline are dark grey, fine-grained limestones interbedded and interlaminated with fissile mudstones. They include some coarse-grained, sharp-based beds and also some thick slumped beds. About 65 m of shales separates this limestone/mudstone sequence from the overlying **Pendleside Limestone,** which consists of well-bedded, mid-grey to dark grey, cherty limestones with subordinate argillaceous limestones and shales. The upper part of the Pendleside Limestone includes boulder beds and olistoliths of reef limestone; these debris beds pass upwards by intercalation into Bowlands Shales. The lower parts of the sequence are mostly drift covered, but the Pendleside Limestone is well exposed.

Sampling in this area was restricted to a few spot samples from the Pendleside Limestone and no data on the chemical or physical properties of the rocks are available. The debris beds in the upper part of the Pendleside Limestone gave some low insoluble residue values (1.2 per cent and 3.0 per cent) but the beds are very heterogeneous and insoluble residues range to over 7 per cent. Patchy silicification affects some of the reef-limestone clasts and reduces carbonate levels locally. The lower part of the Pendleside Limestone is cherty, argillaceous and contains layers of mudstones. In addition, fine silica and some dolomite are typically disseminated throughout the limestones, and insoluble residues are therefore usually more than 10 per cent and commonly greater than 15 per cent. The lower part of the Pendleside Limestone is hence classified as impure or low purity limestone, whereas the upper part is classified as variable, but predominantly medium purity limestone.

Block B Slaidburn

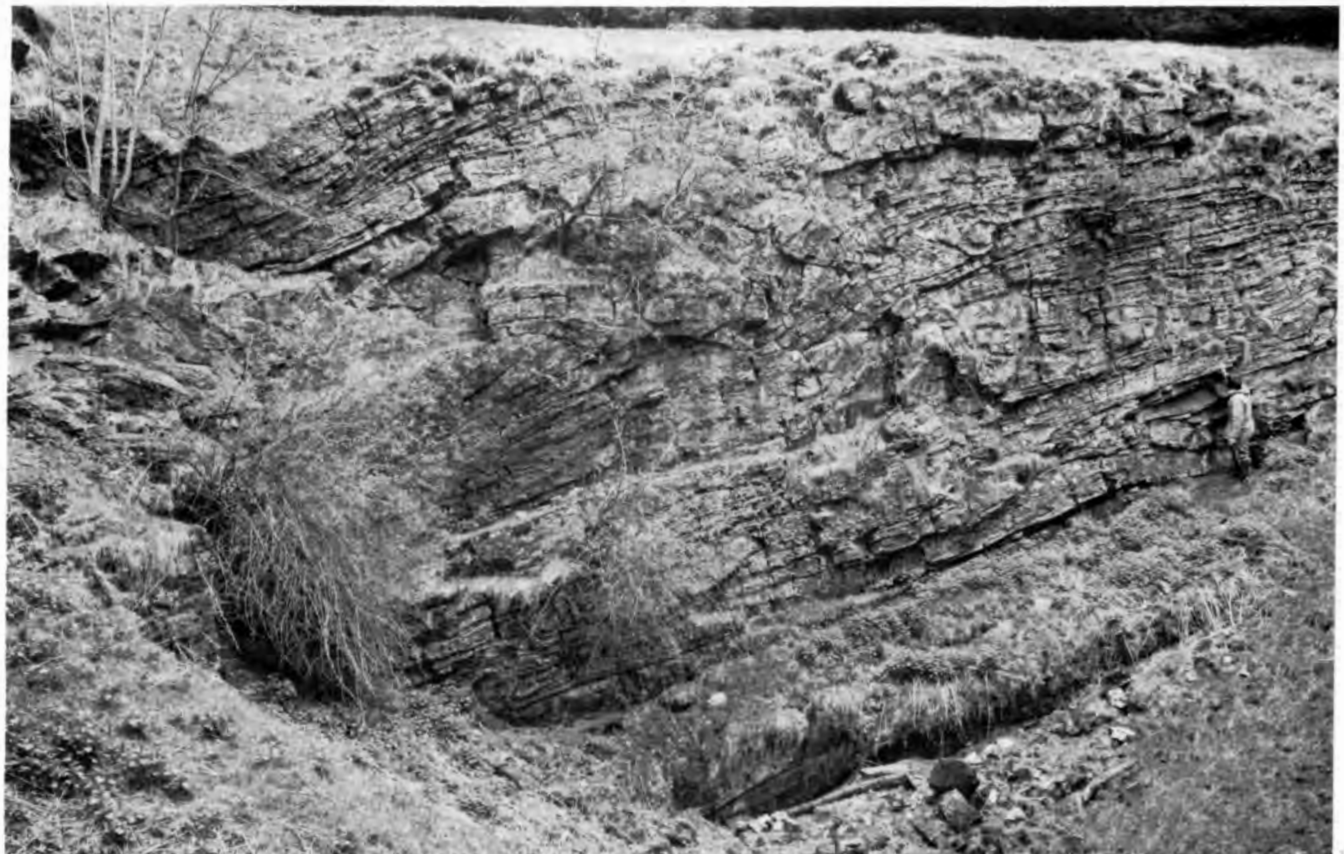
This area lies almost entirely within the Hodder Valley and is bounded on the west by the Namurian gritstone hills of the Forest of Bowland, and on the south-east by the high moorlands of the Easington, Newton and Waddington Fells, also composed of Namurian gritstone.

The main structural feature is the Slaidburn Anticline which folds the Dinantian rocks along a north-east trending axis. The anticline is asymmetric with dips on the north-western limb steeper (45° - 60°) than those on the south-eastern limb (up to 30°), and the fold plunges to the north-east at 10° - 20°. In the southern part of the area, near Ashnott, a small anticline trends north-east and exposes knoll-reef limestone at its core.

About 1100 m of limestones and shales are exposed beneath the Bowland Shales, although the sequence is thicker on the north-western flank of the anticline than on the south-eastern flank (Figure 4). About 175 m of **Slaidburn Limestone** (Plate 1) are exposed in the core of the anticline and the sequence consists of well-bedded, dark grey limestones with shale partings and some thicker mudstone bands. In the northern part of the area

Plate 1 Slaidburn Limestone. Well-bedded limestones with muddy partings. New Biggin, Slaidburn. [SD 6907 5254].

Plate 2 Rain Gill Limestone. Slump folded,cherty limestones. Black House, Slaidburn. [SD7224 5483].



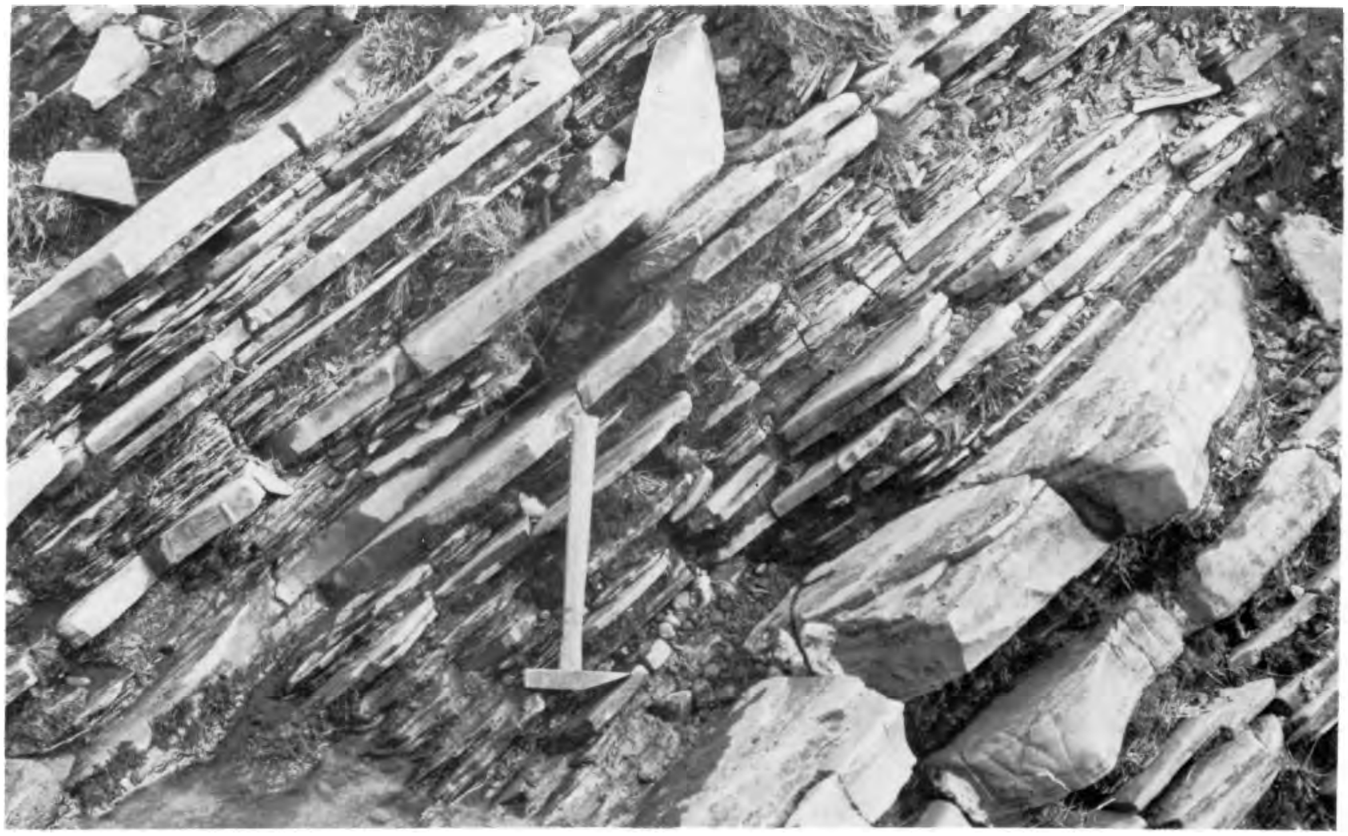


Plate 3 Rain Gill Limestone. Laminated flaggy limestones interbedded with mudstones. Dunsop Brook, Procters Farm, Slaidburn. [SD 6935 5410].

Plate 4 Pendleside Limestone. Well-bedded, fine-grained limestones. Chert prominent at tops of beds. Bottoms Beck, Gisburn Forest. [SD 7453 5662].

Plate 5 Pendleside Limestone. Limestone conglomerate (limestone debris bed) overlies bedded limestones. Higher Clough, Slaidburn. [SD 7290 5861].

Plate 6 Chatburn Limestone. Well-bedded limestones with shale partings and interbeds. Chatburn by-pass, Chatburn. [SD 7741 4418].

Plate 7 Small knolls of knoll-reef limestone. Downham Green, Downham. [SD 7892 4500].

Plate 8 Chatburn Limestone. Well-bedded argillaceous and dolomitic limestones with interbedded shales. Stock Beck, Gisburn. [SD 8305 4962].

the Slaidburn Limestone is overlain by the **Bridge End Limestone** (also Chatburn Limestone Group) which consists of variable, mid-grey to dark grey, cherty limestones with some mudstone interbeds. The top of the Bridge End Limestone is an erosion surface and the division thins from about 270 m in thickness on the north-west flank, to less than 100 m on the south-east flank and is progressively cut-out south of Slaidburn.

The beds overlying the Chatburn Limestone Group comprise a mixed and laterally variable sequence of shales and limestones including some knoll-reef limestones. The lithological character of the sequence varies from predominantly argillaceous in the south to partly calcareous in the north where the **Rain Gill Limestone** is developed. The Rain Gill Limestone consists of well-bedded, cherty, dark grey limestones which are slump folded (Plate 2). To the north-east the unit thickens and incorporates laminated limestones and mudstones (Plate 3) similar to beds exposed in the core of the Catlow Anticline.

The overlying **Pendleside Limestone** (Plate 4) maintains a thickness of about 95 m throughout most of the area, but it thins and becomes increasingly shaly in the south-eastern part of the area until, at Ashnott, it is represented entirely by shales. The beds are lithologically similar to the Pendleside Limestone of the Catlow Anticline, and locally contain limestone debris beds towards the top of the division (Plate 5).

Alluvium conceals most of the Dinantian rocks in the Hodder Valley south of Slaidburn, and boulder clay covers much of the higher ground. However, several areas of limestone in the central part of the anticline are free of drift and there are also patchy exposures elsewhere in the area.

Borehole information is restricted to cored boreholes sunk through knoll-reef limestones at Ashnott and Dunnow. The chemical and mechanical data obtained from the cores are discussed below in the section on knoll-reef limestones. Elsewhere in the area limestone resource data are based on field observations augmented by data from spot samples. Insoluble residue values obtained from the Slaidburn Limestone commonly fall in the range 4 per cent - 12 per cent, and these beds are, therefore, categorised as medium and low purity. Individual beds, however, which are not affected by silicification and are uncontaminated by shale partings, may have insoluble residue values of less than 3 per cent and so fall into the high purity limestone category. The cherty Bridge End Limestone produces higher and more variable insoluble residue values which vary with the chert content, but, in general, medium to impure grades can be anticipated.

Individual limestone beds from the Rain Gill Limestone produce insoluble residue values in the range of 6 per cent to 7 per cent, but higher residues are typical of the sequence as a whole, which contains mudstone partings and some mudstone interbeds. Most of the Rain Gill Limestone is, therefore, categorised as low purity limestone with some impure limestone. The laminated beds which are incorporated in the north-eastern outcrops of the division, contain a high proportion of mudstone and are classified as impure limestones. Insoluble residue data from a limited number of spot samples of Pendleside Limestone suggest that this division is of similar purity to the Pendleside Limestone of the Catlow Anticline (see Block A).

Block C Clitheroe-Downham

Dinantian rocks occupy the low lying ground drained by the rivers Ribble and Hodder which is flanked on the north-west by the Newton Fells and on the south-west and south-east by Longridge Fell and the Pendle escarpment respectively. Dinantian mudstones and shales occupy most of the area but limestones are a major feature of the Clitheroe - Chatburn - Downham area and support a thriving quarrying industry.

The Clitheroe Anticline is the principal fold in the area and trends east-north-east between Waddow [SD 737 427] and Downham Green [SD 788 448]; south-west of Waddow the position of the axis is uncertain although it probably trends south-south-west. A major fault structure, the Horrocksford Hall Thrust, lies close to the axis of the Clitheroe Anticline and cuts out much of its northern flank. The thrust has an estimated maximum displacement of 670 m at Chatburn. The anticline is further dislocated by a number of north-west to south-east trending tear faults. Beds on the southern limb of the anticline are generally southerly dipping at angles of 30° to 35° but close to the thrust dips steepen and the limestones are sheared and brecciated.

The thickness of the Dinantian strata is variable, being related to the presence in some localities of large limestone knoll-reefs, but over 1000 m of beds occur beneath the Bowland Shales in the Chatburn - Downham area (Figure 4). About 365 m of **Chatburn Limestone** outcrop in the core of the anticline and comprise a sequence of dark grey, well-bedded limestones with shale partings and some thicker mudstones. Some limestone beds are argillaceous and patchy silicification is a common feature but chert is uncommon. Pyrite is widely disseminated throughout the limestones and disseminated dolomite occurs sporadically. The Chatburn Limestone is well exposed in the A59 road-cutting (Plate 6), and also in the quarries at Chatburn where the limestones are extracted for the manufacture of road aggregates and cement.

The overlying beds of the Worston Shale Group consist of mudstones interbedded with thin limestones. In the vicinity of Downham a thin limestone is developed at the base of the Group and this gradually thickens when followed north-eastwards until it becomes about 75 m thick near Twiston Mill [SD 807 445] (Figure 4). The limestone is fossiliferous and appears to become increasingly shaly upwards. At various horizons in the Clitheroe - Downham area knoll-reef limestones are developed (Plate 7). These are described below, in the next section. In a restricted area near Chatburn, knoll-reef limestones pass laterally into the thickly bedded, cherty **Peach Quarry Limestone** which has a maximum development of 65 m and contains some shale partings and patchily silicified and dolomitised beds. The **Middop Limestone,** which is developed in the eastern part of the area, near Middop Hall [SD 834 453], is lithologically similar to the Peach Quarry Limestone and is about 30 m thick. A thin (4.5 m to 6.0 m) but distinctive series of fine-grained limestones with mudstone partings, known as the *Bollandoceras hodderense* Beds, are developed at a horizon in the upper part of the Group. The **Pendleside Limestone** is widely developed at the top of the Group, but south-west of Clitheroe, in the Hodder Bridge area, it is not separately mapped and about 150 m of shales with thin cherty limestones overlie the *B. hodderense* Beds. The Pendleside Limestone is a dark grey cherty limestone containing a variable amount of interbedded shale. The division is about 76 m thick along the lower slopes of Pendle Hill, but east of Hook Cliffe [SD 790 427] it thins and partially passes into shale. In the eastern part of the area, between Middop Wood [SD 838 445] and Higher Clough [SD 853 457], the Pendleside Limestone is very shaly.

Most of the area is obscured by drift of variable thickness. The most widespread deposit is of boulder clay but this thins abruptly against the knoll-reefs, leaving these features well-exposed. The boulder clay also thins out against the higher ground of the Pendle escarpment, exposing the Pendleside Limestone.

The assessment of the area is based on four boreholes, nine sections and numerous spot samples. Two of the boreholes, at Withgill (SD 74 SW 7) and Waddow (SD 74 SW 8), proved knoll-reef limestones which are discussed separately below. A further borehole (SD 74 SW 9) at Withgill, sited close to the knoll-reef

Table 2 Summary of the aggregate impact values obtained from the Chatburn Limestone Group.

Borehole or Section	Limestone Division	Location (letter indicates Resource Block)	Number of samples	Aggregate Impact Value Maximum	Minimum	Mean	Standard Deviation
SD 74 SE 1	Chatburn Limestone	Downham [C]	15	19	16	18	1
SD 74 SE 1 s	Chatburn Limestone	Chatburn [C] by-pass	10	23	20	22	1
SD 74 NE 3	Chatburn Limestone	Sawley [D]	4	34	22	30	-
SD 85 SE 16	Thornton Limestone	Nappa [F]	7	18	16	17	-
SD 95 SW 29	Chatburn Limestone	Broughton [H]	8	22	17	20	2
SD 95 SW 30	Thornton Limestone	Broughton [H]	6	23	17	19	-
SD 95 NW 7	Hetton Limestone	Eshton [I]	11	24	20	22	1
SK 95 NE 1	Hetton Limestone	Rylstone [I]	4	25	20	23	-
SD 86 SE 8	Hetton Limestone	Airton [J]	22	27	16	19	2
SE 05 SW 2 s	Haw Bank Limestone	Skibeden [K] Quarry	3	26	23	24	-
SE 05 SW 3 s	Haw Bank Limestone	Skibeden [K] Quarry	1	-	-	24	-
SE 05 SW 4 s	Haw Bank Limestone	Far Skibeden [K] Quarry	2	24	24	24	-
SE 05 SW 5 s	Haw Bank Limestone	Far Skibeden [K] Quarry	2	25	25	25	-

outcrop, penetrated over 35 m of mudstones with thin limestone interbeds belonging to the Worston Shale Group. At this locality the bedrock is covered by more than 9 m of boulder clay.

The Chatburn Limestone was sampled in borehole SD 74 SE 1 at Smithfield Farm, Downham [SD 7893 4450] and in a section (SD 74 SE 1s) from the A59 road-cutting [SD 7731 4399] near Chatburn. Most of the beds sampled at these localities were found to contain between 4 per cent and 12 per cent non-carbonate material although values greater than 15 per cent were recorded sporadically from some of the muddier limestones. The sequence, as a whole, has therefore been classified as medium to low purity. The chemistry of the Chatburn Limestone from borehole SD 74 SE 1 and section SD 74 SE 1s is given in Appendix D. The analyses emphasize the variability of the limestones, particularly, in respect of their clay mineral and silica levels. Several high sulphur values reflect the presence of pyrite in the beds and the MgO values, which vary between 1.31 and 2.85 per cent, confirm the patchy occurrence of disseminated dolomite.

Table 2 summarises the aggregate impact values (AIVs) from beds belonging to the Chatburn Limestone Group throughout the district. The Chatburn Limestone typically produces relatively low AIVs.

Two sections, SD 74 SE 2s and SD 74 SE 5s, sampled the Peach Quarry Limestone which gave extremely variable insoluble residue values, although most values are greater than 6.5 per cent. The Peach Quarry Limestone is, therefore, categorised as low purity limestone, although it comprises impure beds and beds of medium purity limestone. The Middop Limestone produces similar insoluble residues and is similarly classified. Chemical analyses of the Peach Quarry Limestone are given in Appendix D. Five AIVs of Peach Quarry Limestone range between 22 and 24 (Table 3).

Spot samples from the Pendleside Limestone contained usually more than 6.5 per cent non-carbonate material, although values varied considerably with the chert content of the rock. The Pendleside Limestone is, therefore, designated as low purity limestone over most of its outcrop, but east of Hook Cliffe [SD 790 427], where the limestones are shaly, it is shown as impure.

Knoll-reef Limestones

Outcrops of knoll-reef limestones are recognised in several parts of the district (Figure 6); they are most common around Slaidburn and Newton and in the Clitheroe-Downham area where the largest and thickest knoll-reefs are developed. Estimates of the maximum thickness of most of the knoll-reefs are given in Table 4 and boreholes and sample points are listed in Tables 5 and 6.

The knoll-reefs are typically composed of massive, mid-grey, calcite mudstones (micritic facies), surrounded by, and sometimes interdigitating with, well-bedded, coarsely crinoidal limestones (crinoidal facies). Cored boreholes through the base of some of the knolls (Ashnott, Dunnow and Newsholme) show a vertical transition from calcite mudstone, through more crinoidal and clay-rich lithologies into the argillaceous beds beneath. In many of the reefs the micritic facies predominates but crinoidal facies limestones are well exposed flanking the cores of Salthill-Bellman Knoll and Coplow Knoll. The same facies makes up most of Withgill Knoll.

The dark grey, fine-grained limestones proved at the south-eastern margin of Waddow Knoll (SD 74 SW 8, SD 74 SW 2s) are unlike either of the facies described above, and beds in the lower half of the borehole proved to be very clay-rich. This sequence appears to be transitional between the knoll-reef limestones and basinal sediments.

Knoll-reef limestones are the purest limestones in the district (tables 7, 8 and 9) and, with insoluble residue

Table 3 Summary of the aggregate impact values obtained from the Worston Shale Group.

Borehole or Section	Limestone Division	Location (letter indicates Resource Block)	Number of samples	Aggregate Impact Value		
				Maximum	Minimum	Average
SD 75 NE 12	Pendleside Limestone	Tosside [E]	10	21	17	19
SE 05 SE 1 s	Draughton Limestone	Hambleton [K] Quarry	1	-	-	20
SE 05 SW 7 s	Draughton Limestone	Wheelam Rock [K] Quarry	1	-	-	20
SD 95 NW 7	Bell Busk Limestone with Mudstone	Eshton [I]	2	21	20	21
SD 95 NE 1	Rylstone Limestone	Rylstone [I]	2	19	18	19
" " "	Bell Busk Limestone with Mudstone	Rylstone [I]	3	27	22	25
" " "	Hetton Beck Limestone	Rylstone [I]	11	26	18	20
SE 05 SW 6 s	Embsay Limestone	Halton East [K] Quarry	2	23	22	23
SD 74 SE 2 s	Peach Quarry Limestone	Chatburn [C]	3	24	22	23
SD 74 SW 5 s	Peach Quarry Limestone	Peach Quarry [C]	2	24	22	23

Table 4 Estimated maximum thicknesses of knoll-reefs.

Knoll	Thickness (m)	Knoll	Thickness (m)
Dunnow	180	Salthill-Bellman	110
Heaning	30	Crow Hill	260
Knoll Wood	30	Worsaw	650
Weir Knoll	30	Gerna	110
Ashnott	120	Sykes	300
Withgill	150	Twiston	300
Waddow	210	Downham Green	25
Knunck Knowles	80	Kittycaul	30
Clitheroe	150	Wybersey	90
Coplow	100	Newsholme	60

Table 5 Borehole in knoll-reef limestones.

Borehole	Location	Depth (m)	Thickness (m) of knoll-reef limestone
SD 64 NE 12	Ashnott	120.50	119.57
SD 75 SW 1	Dunnow	98.90	64.23
SD 85 SW 5	Newsholme	67.40	56.90
SD 74 SW 7	Withgill	129.00	129.00+
SD 74 SW 8	Waddow	100.60	100.60+

Table 6 Sections and other sample points in knoll-reef limestones.

Section	Locality	Spot Samples
SK 74 SE 3 s	Crow Hill	Knoll Wood
SD 74 SE 4 s	Bellmanpark	Salthill
SD 74 SE 7 s	Sykes	Warren
SK 74 SW 2 s	Waddow	Warsaw
SD 84 SW 1 s	Twiston	
SD 84 SW 2 s	Twiston	

values usually less than 3 per cent, can be classified as chemical grade limestone. Detailed sampling has indicated that car-bonate contents vary slightly from knoll to knoll and also within knolls. However, on the resource map the data are generalised and all knolls are shown as high purity. Samples from the crinoidal facies limestones at Withgill (SD 74 SW 7), Bellman (SD 74 SE 4s) and Twiston (SD 84 SW 1s) produced consistently low residue results (3 per cent), although minor amounts of chert were recorded sporadically at the first locality. More variable values were obtained from micritic facies limestones, due to the presence in these rocks of patchy silicification and rare authigenic quartz. Both forms of silica were recorded in calcite mudstones proved in boreholes at Dunnow, Ashnott and Newsholme, and in sections at Knoll Wood, Crow Hill and Twiston.

Beds of substantially lower purity were recorded near the base of the knoll-reefs at Dunnow and Ashnott, and also at higher levels in Ashnott where a borehole penetrated breccia horizons containing clays. At Waddow Knoll (SD 74 SW 2s) the exposed limestones are classified as high purity, although they contain shale partings and a little chert; however a borehole (SD 74 SW 8) drilled close to the exposed margin of the knoll proved low purity limestones at a depth of about 45 m. Chemical

Table 7 Chemistry of borehole samples of knoll-reef limestones.

Depth	Percentage by weight												Parts per million					
	IR*	CaO	MgO	SiO_2	Al_2O_3	Na_2O	K_2O	SO_3	P_2O_5	Loss at 1050°	F	SrO	Cu	Pb	Zn	Fe_2O_3	MnO	As
SK 64 NE 12 Ashnott Knoll																		
1-10	2.0	54.24	0.47	1.46	0.64	0.02	0.10	0.18	0.03	42.82	0.02	0.03	10	10	90	4600	290	
10-20	7.8	52.33	0.40	4.87	0.97	0.03	0.12	0.09	0.03	40.97	0.01	0.05	10	30	350	5900	310	
20-30	9.1	49.93	0.45	7.44	1.84	0.03	0.21	0.41	0.03	39.61	0.03	0.08	5	20	180	5600	330	
30-40	4.5	53.23	0.45	2.44	1.35	0.02	0.17	0.50	0.03	42.18	0.03	0.04	5	10	210	5100	280	
40-50	2.0	54.52	0.48	1.56	0.47	0.02	0.08	0.19	0.02	42.81	0.03	0.03	5	0	60	3400	280	
50-60	2.2	54.64	0.55	1.23	0.47	0.03	0.09	0.16	0.02	42.98	0.01	0.03	5	0	40	3100	250	
60-70	3.4	53.51	0.59	1.91	0.94	0.03	0.15	0.24	0.02	42.46	0.02	0.04	5	10	40	4100	200	
70-80	2.3	54.17	0.43	1.72	0.66	0.02	0.10	0.21	0.02	42.59	0.01	0.04	5	10	80	3400	320	
80-90	2.2	54.57	0.45	1.46	0.67	0.03	0.11	0.19	0.02	42.78	0.02	0.02	5	0	40	3400	290	
90-100	3.2	53.62	0.50	1.77	0.73	0.02	0.10	0.29	0.02	42.57	0.02	0.03	5	10	80	3900	410	
100-110	3.2	53.61	0.70	2.11	0.54	0.02	0.08	0.18	0.02	42.64	0.01	0.02	5	10	20	6600	800	
110-120	6.6	51.99	0.68	3.99	1.20	0.02	0.21	0.37	0.02	41.27	0.03	0.05	5	10	70	6400	500	
SK 74 SW 7 Withgill Knoll																		
1-10	1.9	54.38	0.41	1.84	0.31	0.03	0.05	0.06	0.02	42.73	0.02	0.01	5	0	20	3500	180	
10-20	1.9	54.72	0.43	1.60	0.29	0.04	0.05	0.09	0.02	42.35	0.04	0.01	5	0	10	3700	180	
20-30	2.8	54.55	0.38	2.39	0.23	0.03	0.04	0.08	0.02	42.49	0.07	0.02	5	0	20	2800	210	
30-40	1.2	55.04	0.47	1.02	0.24	0.08	0.05	0.12	0.01	43.03	0.01	0.00	0	0	10	3000	160	0
40-50	1.3	55.23	0.38	0.74	0.26	0.04	0.04	0.24	0.02	42.91	0.03	0.01	0	0	10	3300	170	
50-60	2.0	54.63	0.36	1.71	0.22	0.06	0.04	0.19	0.02	42.40	0.07	0.00	0	0	10	3400	190	
60-70	3.1	54.66	0.36	2.10	0.27	0.07	0.05	0.35	0.01	42.11	0.00	0.00	5	0	10	4700	200	
70-80	1.0	55.39	0.37	0.47	0.32	0.07	0.05	0.28	0.01	42.86	0.00	0.00	0	0	10	4000	200	
80-90	1.1	55.57	0.34	0.44	0.20	0.05	0.04	0.16	0.01	43.07	0.00	0.00	5	0	20	3200	200	
90-100	1.1	55.49	0.34	0.53	0.22	0.04	0.04	0.18	0.01	43.06	0.00	0.00	5	10	10	3400	200	1
100-110	2.1	54.86	0.39	1.09	0.37	0.04	0.06	0.27	0.02	42.63	0.00	0.00	5	0	10	4300	200	
110-120	1.7	54.76	0.40	0.99	0.50	0.05	0.07	0.16	0.03	42.88	0.00	0.00	5	0	10	3700	180	
120-129	2.4	54.64	0.44	1.21	0.52	0.05	0.08	0.70	0.03	41.91	0.01	0.01	0	0	10	6300	220	
SD 74 SW 8 Waddow Knoll																		
1-10	2.7	53.81	0.49	3.00	0.22	0.03	0.05	0.12	0.01	42.49	0.06	0.08	5	0	20	2600	320	
10-20	5.8	51.03	1.98	4.82	0.15	0.03	0.04	0.28	0.01	41.76	0.09	0.10	5	0	20	3900	270	
20-30	2.9	53.47	1.22	2.35	0.19	0.03	0.05	0.17	0.01	43.00	0.07	0.09	10	0	20	2500	230	
30-40	2.5	51.89	2.28	2.11	0.15	0.02	0.04	0.12	0.01	43.44	0.10	0.09	5	0	10	2900	220	
40-50	4.2	53.05	1.07	3.17	0.22	0.02	0.05	0.19	0.01	42.75	0.10	0.08	5	0	10	800	100	
50-60	10.3	49.10	1.19	8.59	1.02	0.03	0.18	0.59	0.01	39.81	0.07	0.12	5	10	50	5100	125	
60-70	8.7	49.63	1.53	6.36	1.31	0.04	0.22	0.78	0.01	40.56	0.11	0.10	5	0	20	5100	100	
70-80	11.4	48.11	1.52	7.47	2.01	0.04	0.32	1.08	0.01	39.20	0.08	0.12	5	10	20	8200	300	
80-90	6.3	51.78	1.04	4.66	0.83	0.02	0.14	0.51	0.01	41.47	0.05	0.10	5	0	50	4700	240	
90-100	8.5	49.85	1.38	6.53	0.98	0.03	0.17	0.60	0.01	40.84	0.07	0.09	5	10	230	6300	380	
SD 75 SW 1 Dunnow Knoll																		
2-5	3.1	53.69	0.45	2.95	0.30	0.02	0.06	0.14	0.02	42.15	0.01	0.02	5	0	10	4800	460	
5-10	2.4	54.35	0.52	2.01	0.25	0.02	0.06	0.04	0.02	42.49	0.01	0.02	5	0	10	3800	400	1
10-15	2.9	54.20	0.54	2.19	0.36	0.02	0.08	0.10	0.02	42.11	0.01	0.02	0	0	10	3100	400	
15-20	3.9	54.01	0.54	2.31	0.42	0.02	0.09	0.10	0.02	42.12	0.01	0.02	5	0	10	4300	470	
20-25	2.6	53.80	0.84	2.10	0.37	0.02	0.08	0.14	0.02	42.69	0.01	0.02	0	0	10	4500	500	
25-30	5.3	52.38	0.81	3.80	0.95	0.06	0.19	0.12	0.02	41.18	0.01	0.03	0	0	90	6500	470	
30-35	3.5	53.50	1.00	2.34	0.70	0.07	0.15	0.19	0.02	41.84	0.01	0.03	5	0	20	5400	400	
35-40	11.3	49.44	0.95	6.92	2.31	0.13	0.47	0.53	0.03	38.63	0.07	0.08	5	0	60	10200	600	
41-45	5.7	52.34	0.79	3.60	1.16	0.12	0.24	0.47	0.02	40.75	0.02	0.04	0	0	20	7200	500	
45-50	19.8	44.65	1.29	11.80	4.06	0.22	0.81	1.33	0.03	35.43	0.10	0.13	0	0	70	15400	510	
50-55	19.3	45.61	0.95	12.67	3.26	0.11	0.66	1.11	0.05	35.35	0.08	0.12	0	0	50	12700	950	
55-60	30.7	38.79	1.07	26.21	2.76	0.08	0.56	1.06	0.04	30.43	0.06	0.21	5	10	110	12200	1000	
60-65	32.8	37.25	1.07	26.34	4.09	0.13	0.80	1.35	0.04	30.44	0.08	0.24	5	10	100	16700	920	
SD 85 SW 5 Newsholme Knoll																		
1-5	2.9	53.51	0.91	1.94	0.19	0.01	0.05	0.03	0.02	42.47	0.00	0.01	5	0	10	9900	1700	
5-10	0.9	54.81	0.46	0.37	0.18	0.00	0.05	0.03	0.02	43.25	0.00	0.00	0	0	10	8800	1400	0
10-15	1.0	55.47	0.33	0.59	0.13	0.01	0.04	0.03	0.02	43.25	0.00	0.00	0	0	0	5400	1030	
15-20	1.7	54.91	0.43	1.13	0.12	0.00	0.04	0.03	0.02	42.89	0.00	0.00	0	0	0	7600	1230	
20-25	1.6	54.52	0.59	0.66	0.14	0.01	0.04	0.03	0.03	43.14	0.00	0.00	0	0	0	7500	1100	
25-30	1.8	55.00	0.49	0.58	0.34	0.01	0.06	0.04	0.03	42.91	0.00	0.01	0	0	10	6800	880	
30-35	7.1	52.05	0.60	5.28	1.00	0.05	0.17	0.27	0.03	40.63	0.01	0.05	0	0	30	5400	580	
35-40	2.3	54.20	0.63	1.29	0.57	0.02	0.10	0.11	0.02	42.80	0.00	0.03	0	0	0	5100	550	
40-45	1.7	54.53	0.60	0.94	0.46	0.02	0.08	0.09	0.02	42.88	0.00	0.01	0	0	0	5700	590	
45-50	7.0	51.64	0.73	5.09	1.30	0.02	0.22	0.37	0.03	40.67	0.02	0.06	0	0	10	6500	660	
50-55	1.1	55.21	0.36	0.56	0.37	0.01	0.06	0.04	0.02	43.27	0.00	0.01	0	0	10	5000	530	1

* Insoluble residue.

Table 8 Insoluble residue values of knoll-reef limstones obtained from section samples.

Section	Depth Interval (m)	Insoluble Residue %
SD 74 SW 2 s		
(Waddow)	1-5	2.2
	5-10	1.4
	10-16	2.7
SD 74 SE 3 s		
(Crow Hill)	1-5	3.6
	5-10	3.9
	10-16	2.0
SD 74 SE 4 s		
(Bellman)	2-5	2.8
	5-10	2.2
	10-15	2.8
	15-21	1.3
SD 74 SE 7 s		
(Sykes)	1-8	5.6
SD 84 SW 1 s		
(Twiston)	1-5	3.1
	5-10	2.1
	10-16	2.4
SD 84 SW 2 s		
(Twiston)	1-5	1.0
	5-10	2.1
	10-13	2.4

Table 9 Insoluble residue values of knoll-reef limestones obtained from spot samples

Knoll-reef	Number of spot samples	Insoluble residue value (%) Maximum	Minimum	Mean	Standard Deviation
Knoll Wood	20	3.6	1.3	2.3	1.0
Salthill	20	5.3	0.9	2.0	1.0
Bellman	14	4.6	0.9	2.5	1.1
Worsaw	40	10.6	0.6	2.6	2.0

analyses of borehole material from the knoll-reefs are listed in Table 7 while results from surfa^e samples are included in Appendix D. The results confirm the high purity of most of the knoll-reef limestones and particularly the crinoidal facies, which usually gives CaO values in excess of 54.5 per cent. Free silica is usually the chief impurity in the reefs and is present in the highest concentrations (>1.5 per cent) in the micritic facies. The other main impurities are clay minerals, pyrite and iron oxides. The relative amounts of clay in the various boreholes are indicated by the concentrations of alumina, soda and potash; anomalously high values of all three oxides indicated in boreholes SD 75 SW 1 (36 - 65 m) and SD 85 SW 5 (31 - 35 m, 46 - 50 m) represent the mixed sequence of knoll-reef limestones and argillaceous limestones/mudstones which forms the basal beds of the knoll-reefs.

Iron occurs in several mineral phases, the most common being pyrite which is widely scattered throughout all the knoll-reefs. Iron also substitutes into the dolomite lattice and correlations between MgO and Fe_2O_3 recorded in the micritic facies at Newsholme Knoll (SD 85 SW 5), and also found to a lesser extent in the other knolls, correspond with petrographic observations of ferroan dolomite. At Newsholme, the dolomite occurs as coarse, orange-stained rhombs filling cavities and as disseminated crystals; limonite is a common alteration product.

The elements normally associated with non-ferrous mineralisation (Cu, Pb, Zn and F) are all present in trace amounts and no anomalies were detected, although fluorite mineralisation was observed at outcrop at Withgill Knoll. It should be recognised, however, that by aggregating samples over 5 m, there is a considerable dilution factor and localised mineralisation is unlikely to be detected.

Manganese levels are consistent with values recorded in Carboniferous limestones elsewhere in the United Kingdom; the higher concentrations found in samples from Newsholme Knoll are presumably linked with the occurrence of ferroan dolomite.

Powders produced by finely grinding samples of knoll-reef limestones were tested for brightness to evaluate their suitability as whitening agents. The whitest powders (Table 10) were produced from limestones of crinoidal facies such as those at Withgill Knoll (SD 74 SW 7). Lithologically similar limestones from Bellman Knoll (SD 74 SE 4s) also gave comparable results with reflectance percentages of 81 to 82 per cent at a wavelength of 660 nm. Powders prepared from micritic facies limestones were noticeably darker and more variable in colour. The low reflectivity of the Waddow Knoll samples (SD 74 SW 8) was to be expected from the dark appearance of the rock at outcrop.

Table 10 Summary of powder reflectan^e results (per^entages) for knoll-reef limestones.

Wavelength (nm)	Borehole SD 64 NE 12 Ashnott (24)			SD 75 SW 1 Dunnow (10)			SD 85 SW 5 Newsholme (11)			SD 74 SW 7 Withgill (17)			SD 74 SW 8 Waddow (20)		
	Range	**Mean**	SD*	Range	**Mean**	SD	Range	**Mean**	SD	Range	**Mean**	SD	Range	**Mean**	SD
660	58-82	**76**	7	62-84	**76**	7	60-79	**71**	6	77-83	**80**	2	30-69	**48**	10
520	50-77	**70**	7	56-78	**70**	6	50-72	**62**	6	72-78	**74**	2	20-59	**38**	10
470	48-76	**69**	8	54-76	**68**	6	50-67	**58**	6	69-77	**72**	2	19-60	**34**	11

* Standard deviation

Table 11 Aggregate impact values of knoll-reef limestones

Borehole or section	Location	No. of samples tested	Aggregate Impact Value			
			Maximum	Minimum	Mean	Standard Deviation
SD 64 NE 12	Ashnott	12	24	21	23	1
SD 75 SW 1	Dunnow	7	25	21	24	-
SD 85 SW 5	Newsholme	5	25	22	24	-
SD 74 SW 7	Withgill	13	47	27	38	6
SD 74 SE 4 s	Bellman	1	-	-	44	-
SD 74 SW 8	Waddow	10	22	18	19	1

Aggregate impact value results are shown graphically for boreholes in Appendix C and are summarised in Table 11. The results demonstrate the inherent weakness of the crinoidal facies limestones and the unsuitability of such material for use as aggregates. Values from micritic facies limestones and from the fine-grained lithologies proved at Waddow Knoll range from 18 to 25 and are similar to the results normally expected for Carboniferous limestone.

Block D Gisburn

The Dinantian rocks, which occupy most of the area, are largely obscured by drift, although parts of the sequence are well exposed in the Ribble gorge near Gisburn and also in several drift-free areas near Sawley and Grindleton.

The major structural feature of the area is the Gisburn Anticline which trends north-eastwards from Sawley to south of Gisburn where it continues into the Swinden Anticline. In the Sawley area the northern limb dips from 20° to 55°, while on the southern limb dips are variable between 30° and 80°; high dips are associated with steep-sided, minor folds. In the Gisburn area dip values immediately north of the axis range between 40° and 60°, but reduce to 20° and 30° in the River Ribble. In the south-western part of the area the Dinantian rocks are folded into a north-easterly trending anticline, known as the Grindleton Anticline, and a complementary syncline. The northern limb of the Grindleton Anticline is folded into a series of subsidiary folds but the southern limb dips steadily at about 40° to the south-east. The Grindleton folds are crossed by a series of thrust faults which strike parallel to the fold axes and the folds are separated from the Gisburn Anticline at Sawley by a tear fault which has a considerable displacement. Several other major tear faults dislocate the Gisburn Anticline and trend in a north-west or north-north-westerly direction.

The core of the Gisburn Anticline is occupied by the **Gisburn Cotes Beds.** These comprise mudstones and argillaceous limestones interbedded with thin limestones. The overlying **Chatburn Limestone** is about 470 m thick and is exposed in a number of small disused quarries in the hills east of Sawley; elsewhere in the area, apart from river and stream sections, the beds are obscured by drift. The Chatburn Limestone is lithologically similar to the Chatburn Limestone exposed in the core of the Clitheroe Anticline, but in some sections, notably near Gisburn Park [SD 822 494], in Stock Beck [SD 831 497] (Plate 8) and near Sawley [SD 782 464], the beds are affected by dolomitisation.

The **Worston Shale Group** consists mainly of mudstones and shales interbedded with thin limestones, but there are also some thicker limestone units and an isolated knoll-reef (Wybersey Knoll) south of Bolton-by-Bowland. A series of limestones with subordinate shales exposed in the Ribble section north-west of Gisburn is assigned to the lower part of the Worston Shale Group. The **Pendleside Limestone** is well exposed in and around Grindleton where about 90 m of folded, dark grey, cherty limestones with some thin shale interbeds are developed.

The limited exposure in the area has restricted sampling to three natural sections, supplemented by a number of spot samples and one borehole. The interpretation of this scattered limestone resource data is, therefore, generalised. The Gisburn Cotes Beds are argillaceous in character and do not constitute a significant limestone resource. At localities where the Chatburn Limestone was sampled, purity levels of between 85 per cent and 90 per cent $CaCO_3$ were generally recorded; in most instances clay was found to be the chief impurity though a high proportion of siliceous material was also observed in some of the insoluble residues. In the Sawley-Swanside Beck area, the Chatburn Limestone is locally tightly folded by subsidiary folds within the main anticlinal structure and a borehole drilled in this area, near Cowgill Farm [SD 799 468], encountered an impure sequence comprising highly disturbed argillaceous limestones and mudstones.

With the exception of the relatively pure limestones forming Wybersey Knoll, the bulk of the limestones within the Worston Shale Group are either shaly or cherty and are categorised as impure or of low purity. Samples collected from the Pendleside Limestone gave insoluble residue values typically greater than 6.5 per cent.

No chemical or aggregate testing has been carried out on rock samples obtained from this area.

Block E Tosside-Hellifield

The Dinantian rocks in this area are for the most part covered by drift and exposures are restricted to stream sections and to a few small isolated outcrops. Structurally, the area lies on the southern limb of a broad east-north-east trending syncline located between the Catlow Anticline and the Gisburn - Swinden Anticlines. The limb incorporates a broad flexure giving an east-north-east trending anticline/syncline pair in the Tosside [SD 769 561] - Knotts [SD 768 533] area. Dips are about 10° to 20° in this neighbourhood and are typically less than 30° elsewhere in the area. The strata are dislocated in the west by north-west to north-north-west trending tear faults.

About 750 m of strata belonging to the Worston Shale Group crop out beneath the Bowland Shales (Figure 4). The sequence consists of mudstones, interlaminated limestones and mudstones and some thicker limestones, including the Pendleside Limestone. The lowest exposed limestone unit is developed north of Forest Becks [SD 785 513] and consists of dark grey, thickly bedded limestones with subordinate mudstones. This unnamed limestone passes upwards into mudstones and shales which are overlain in turn by the **Rain Gill Limestone.** The latter is estimated to be about 350 m thick in the Tosside area and is divided into an upper and a lower division separated by mudstones. Both divisions contain some thickly-bedded limestones, as well as interlaminated limestones and mudstones. In the Hellifield area, the **Bell Busk Limestone with Mudstone**

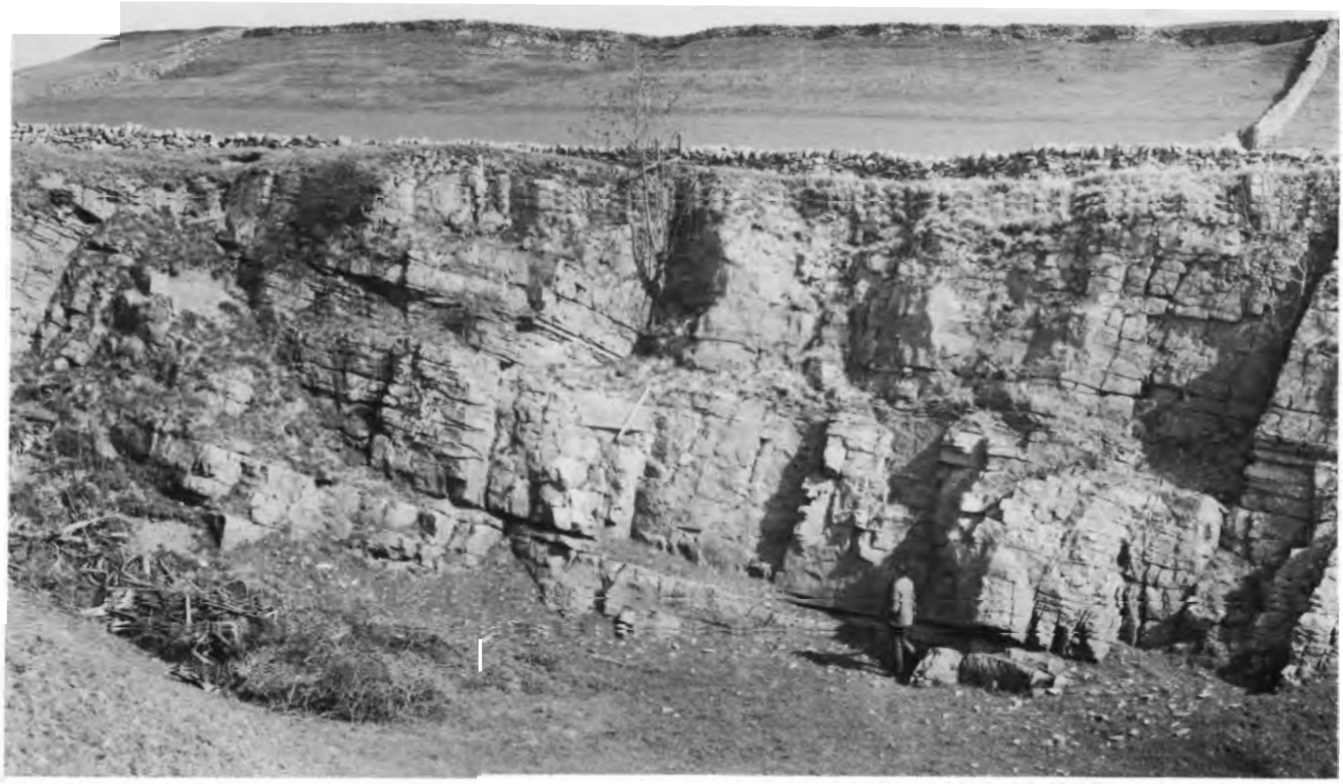


Plate 9 Thornton Limestone. Bedded and massive limestones with thin shale interbeds. Marton Scars, West Marton. [SD 8802 5160].

Plate 10 Chatburn Limestone. Steeply dipping, well-bedded limestones with interbedded shales. Thornton Quarry, Thornton-in-Craven. [SD 9125 4897].

Plate 11 Hetton Limestone. Well-bedded limestones. Eshton Moor. [SD 9115 5669].

Plate 12 Haw Crag Debris Bed. Jumbled blocks and boulders of limestones within limestone debris bed. Haw Crag Quarry, Bell Busk. [SD 9142 5637].

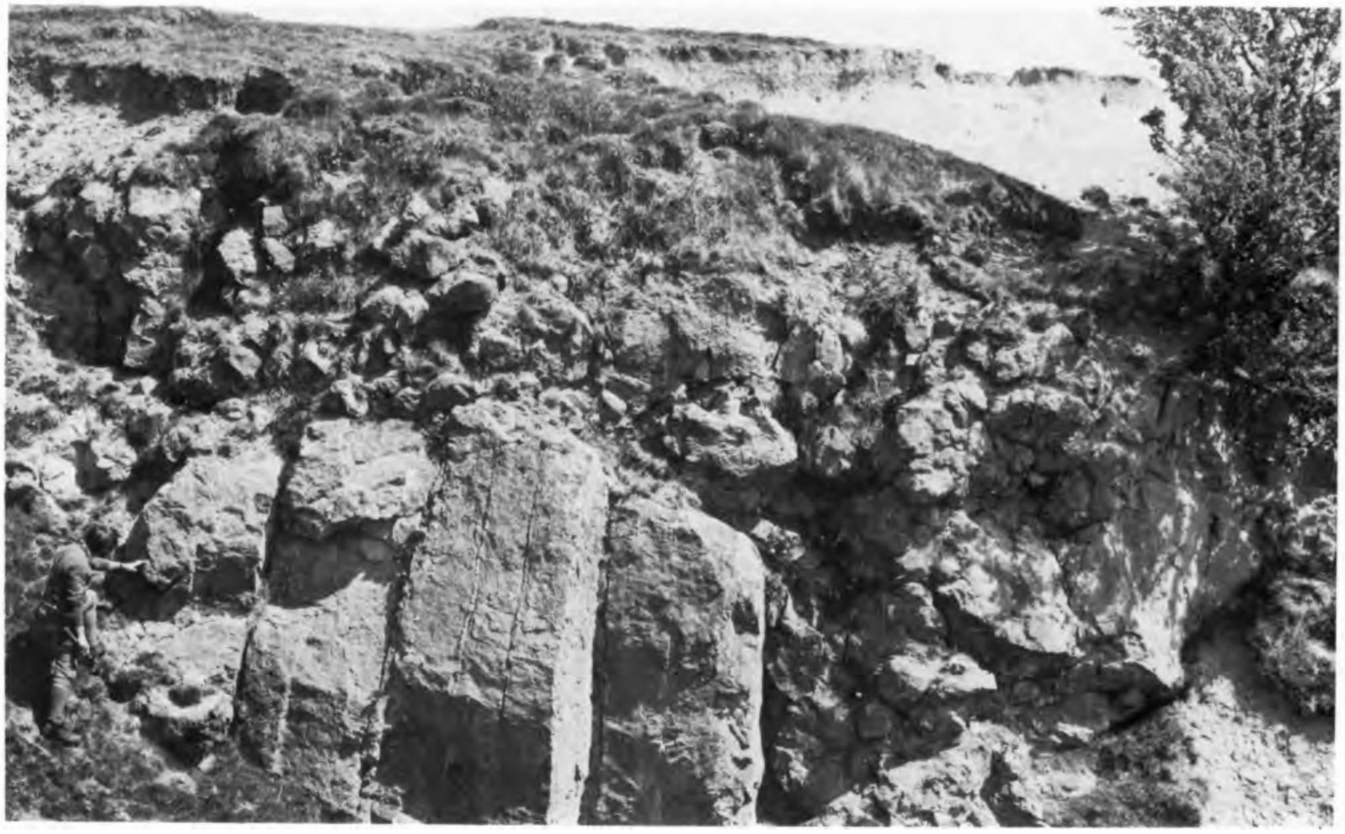
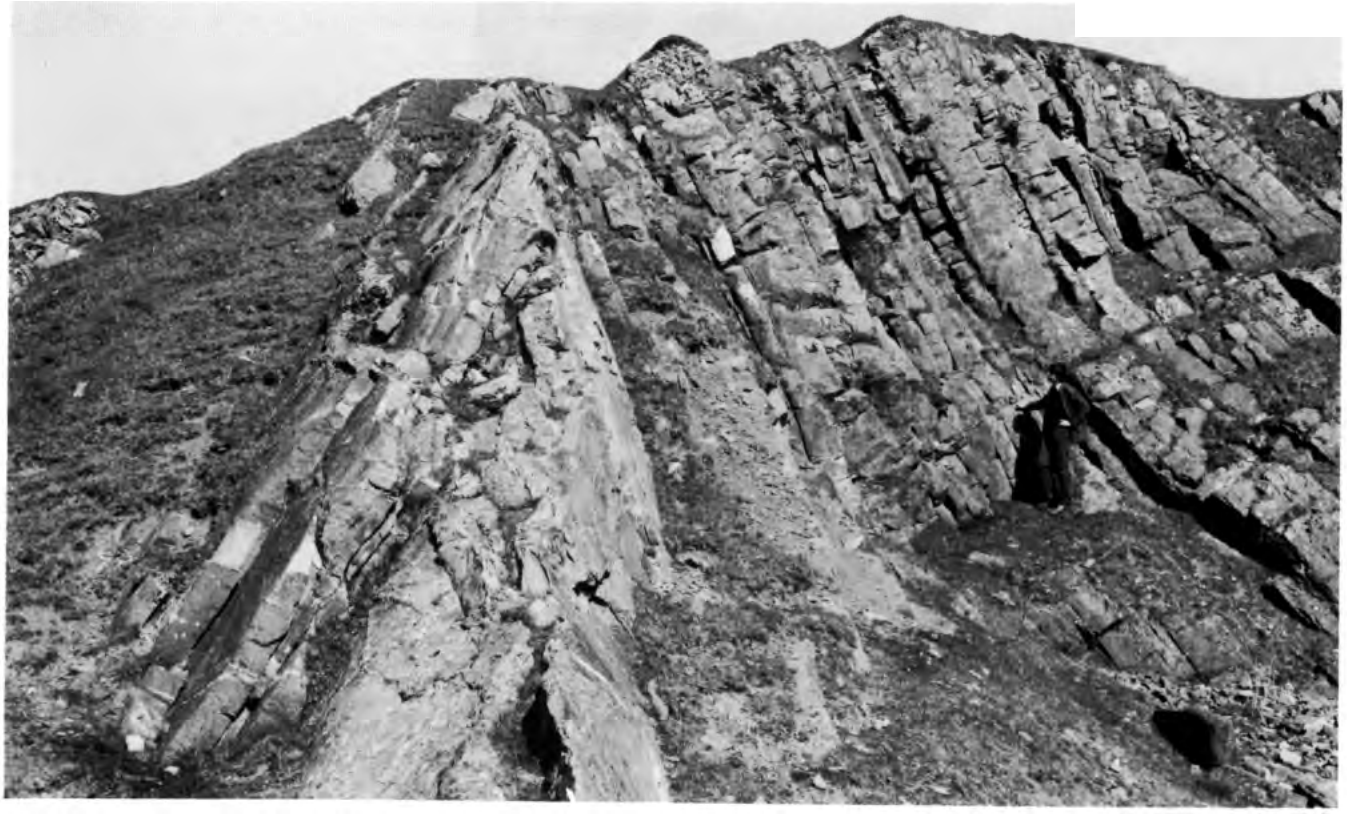


Plate 13 Rylstone Limestone. Thinly bedded limestones and argillaceous limestones interbedded with calcareous mudstones. Railway cutting, Rylstone. [SD 9632 5814].

Plate 14 Hetton Limestone. Pale grey, grainstone-facies limestones. High Scarth Barn, Airton. [SD 8891 5987].

Plate 15 Hetton Limestone. Dolomitised grainstone-facies limestones. Old Quarry, Scosthrop Lane, Airton. [SD8902 5965].

Plate 16 Draughton Limestone. Tightly folded, well-bedded limestones with shale partings. Wheelam Rock Quarries, Draughton [SE 0319 5216].



is the probable equivalent of the Rain Gill Limestone. The **Pendleside Limestone** is developed at a higher stratigraphical level and is about 90 m thick in the Tosside-Wigglesworth area but thins to about 40 m east of Long Preston. Small exposures are seen near Knotts, Tosside and Wigglesworth and the unit has been sampled by assessment borehole SD 75 NE 12 near Tosside. The Pendleside Limestone consists of dark grey, fine-grained limestones and argillaceous limestones which typically contain chert bands, patchily silicified beds and some disseminated dolomite. The lower part of the unit is argillaceous and shaly but the upper part contains some boulder beds with debris of reef limestone. East of Long Preston, the lower shaly part of the unit is absent and the Pendleside Limestone is represented largely by debris beds.

Owing to the lack of exposure, sampling was restricted to one borehole, one section and several spot samples from the Pendleside Limestone. The purity of the other limestone units has been deduced from field observations and by reference to similar beds occurring in other areas. Insoluble residue values obtained from the Pendleside Limestone usually ranged between 10 per cent and 20 per cent. The Pendleside Limestone is, therefore, shown on the map as low purity limestone although beds of impure limestone are also present. The debris beds in the upper part of the unit, however, commonly produce lower residue values and are classified as medium purity, although again the purity is likely to be variable. A 12 m section (SD 85 NE 2s) of these debris beds on Newton Moor [SD 852 583] gave insoluble residue values of 2 per cent to 3 per cent.

The low and variable purity of the Pendleside Limestone is also shown by chemical analyses from borehole SD 75 NE 12 (see Appendix D). CaO values vary between 42 per cent and 49 per cent and all the analyses give high but variable values of SiO_2, Al_2O_3, SO_3, K_2O_3 and MnO. The silica content of the Pendleside Limestone is particularly high and the samples analysed contain between 9 per cent and 32 per cent silica.

Aggregate impact values of the Pendleside Limestone in borehole SD 75 NE 12 range between 17 and 21, with a mean value of 19 from 10 samples.

Block F Swinden

The area forms the central part of the Craven Lowlands between the rivers Ribble and Aire. A large belt of drumlins forming low rounded hills covers much of the ground and natural exposures of Dinantian rocks are rare.

Most of the area is occupied by the Swinden Anticline, a broad, symmetrical north-east trending fold, which is a continuation of the Gisburn Anticline to the south-west. The dip over the anticline is regular, around 25°, and the fold plunges to the north-east at 10° to 20°. The fold is cut by north-west and north-north-east trending faults.

The oldest Dinantian rocks in the area occur under a cover of boulder clay in the core of the anticline around Horton [SD 856 504]. However, the rocks are known from a borehole [SD 8597 5051] near Horton, which proved over 700 m of strata similar to the Gisburn Cotes Beds of the Gisburn Anticline, beneath 21.50 m of drift (Institute of Geological Sciences, 1979 p.26). The succeeding beds within the Chatburn Limestone Group are mostly blanketed by drift, but the uppermost beds (**Thornton Limestone**) are exposed in small disused quarries situated in several areas of patchy, thin drift cover. Chert, occurring as bands and nodules, is a feature of the Thornton Limestone, which comprises a highly variable mixture of mid-grey to dark grey, well-bedded limestones (Plate 9) with interbedded argillaceous limestones and mudstones. Parts of the sequence are dolomitic and distinctive undulating bedding occurs locally. There is a general increase in argillaceous material towards the top of the unit. The Thornton Limestone is about 200 m thick and 70 m were proved in borehole SD 85 SE 16 near High Laithe [SD 861 530]. Three small areas of knoll-reef limestone occur within the upper beds of the Chatburn Limestone Group near Newsholme [SD 840 516], and Flambers Hill [SD 876 523] and have been described above.

Shales and mudstones belonging to the Worston Shale Group overlie the Chatburn Limestone Group and these pass upwards into the **Swinden Gill Limestone**, a mid-grey, well-bedded, coarsely crinoidal limestone containing some interbedded argillaceous limestone and mudstone. The limestone is about 45 m thick and is in part dolomitic and patchily silicified. A sequence of shales with subsidiary limestones separate the Swinden Gill Limestone from the **Swinden Limestone** which is about 100 m thick and outcrops in the northern part of the area around Swinden [SD 862 544]. The Swinden Limestone consists of massive, well-bedded, fossiliferous limestones in the lower 25 m and passes upwards into more argillaceous limestones. The limestones are patchily dolomitic throughout and are locally partially silicified.

The limestone resources of the drift-covered ground occupied by the Chatburn Limestone have been inferred by reference to other areas where similar rocks occur. However, the upper beds of the Chatburn Limestone Group exposed around Marton Scar gave insoluble residue values between 2.4 per cent and 23.4 per cent, indicating the variable purity of these beds. The Thornton Limestone was sampled in borehole SD 85 SE 16 and section SD 85 SW 2s and additional data have been obtained from spot samples. Insoluble residue values fall between 4 per cent and 27 per cent, but most values are less than 15 per cent. The Swinden Gill Limestone and Swinden Limestone have been sampled by spot samples which gave high insoluble residue values demonstrating the low purity or impure nature of these beds.

Chemical analyses of the Thornton Limestone of borehole SD 85 SE 16 are given in Appendix D. The low purity of these beds is confirmed by the variable but high values of silica and alumina and the corresponding low values of CaO. MgO, Fe_2O_3 and SO_3 occur in variable, but significantly high, proportions. A fairly constant aggregate impact value of 17 was obtained from the Thornton Limestone of borehole SD 85 SE 16.

Block G Thornton - Lothersdale

The Dinantian rocks of the area are folded into two major structures, the Thornton and Lothersdale anticlines. The Thornton Anticline has a sinuous axial trace, which trends north-eastwards from around Barnoldswick to north of Thornton in Craven where it abuts against a tear fault. This fault separates the fold from the Broughton Anticline to the north-east. The south-eastern limb of the Thornton Anticline is generally steeper than the north-western limb and dips vary from 20° to 90° but average around 50°. Small north-west trending faults affect the anticline. The Lothersdale Anticline has a well-defined, north-east trending arcuate axis and dips on both limbs typically range between 20° and 50°. Several west-northwest and north-northeast trending faults dislocate the fold, some following arcuate courses.

Most of the Thornton Anticline is covered by boulder clay which is very variable in thickness but is likely to exceed 30 m in places. The Lothersdale Anticline similarly, is covered by boulder clay although the Dinantian rocks are largely drift-free south-west of Lothersdale village.

The **Chatburn Limestone** crops out in the core of the Thornton Anticline and is well exposed in disused quarries near Barnoldswick and Thornton in Craven (Plate 10). The sequence is similar to the Chatburn Limestone in other areas of the district and consists of well-bedded, dark grey limestones with variable amounts of interbedded shales.

The limestones which crop out in the core of the Lothersdale Anticline were included in the Chatburn Limestone Group by Earp and others (1961), but palaeontological evidence (Fewtrell and Smith, 1978; Metcalfe, 1980) has established a younger age for these beds, which are correlated now with the Embsay Limestone of the Skipton anticline. The beds, which are actively quarried for roadstone, comprise massively-bedded limestones, well-bedded limestones with shale partings, and cross-bedded and oolitic limestones. In places a little chert occurs.

Beds higher in the sequence are mainly concealed by thick boulder clay. There are sporadic exposures of shales with subordinate limestones (Worston Shale Group) in the Barnoldswick - Thornton area and a few sections of similar shaly beds are seen around Lothersdale. The **Pendleside Limestone** is exposed locally between Salterforth [SD 889 458] and Earby [SD 904 467] where it is about 75 m thick and consists of dark grey, fine grained limestones with interbedded argillaceous limestones and shales. Between Earby and Elslack [SD 925 490] it is thin and poorly exposed, but north-east of Elslack the beds thicken to about 30 m and some cherty, folded limestones are seen, sporadically. The Pendleside Limestone is also cherty in the Carleton [SD 963 498] area. In the Lothersdale Anticline the Pendleside Limestone is about 75 m thick and several disused quarries show small exposures of well-bedded argillaceous limestones with some chert, though north-east of Lothersdale village the beds are covered by boulder clay.

The purity of the Chatburn Limestone varies with the relative amounts of limestone and shale, but insoluble residue values are typically greater than 6.5 per cent and increase to over 25 per cent in the more shaly parts of the sequence. The Chatburn Limestone, therefore, usually contains low purity or impure beds, but the more massive, shale-free parts of the sequence may contain medium purity limestones. The limestones quarried for roadstone at Lothersdale, gave insoluble residue values which ranged between 6.5 per cent and 9 per cent. These beds comprise a consistent deposit of low purity limestone. No sampling of the Pendleside Limestone was undertaken but the persistent cherty and shaly character of the beds suggests that they consitute an impure or low purity resource.

No chemical analyses have been determined from the rocks of this area and aggregate testing data is restricted to a single AIV of 15 obtained from the limestones of Raygill Quarry, Lothersdale.

Block H Broughton

The area is occupied by the north-easterly trending Broughton Anticline which plunges to the north-east at 10° to 20°. The fold is separated from the Thornton Anticline to the south-west by a tear fault and from the Skipton Anticline to the north-east by a north-west trending fault belonging to the South Craven Fault system. A complex of other faults cuts the anticline, the most important of these trending north-west to west-north-west. Dips in the core of the anticline are locally as steep as 60° but elsewhere in the area they usually range between 10° and 30°.

The Dinantian rocks of the area, particularly the shale divisions, are largely drift-covered and the ground north of East Marton and Broughton is a drumlin field.

The uppermost 490 m of the Chatburn Limestone Group (Chatburn Limestone and Thornton Limestone) are chiefly of limestone, but there are about 350 m of shaley beds, poorly exposed in the core of the anticline, which are probably equivalent to the Gisburn Cotes Beds of the Gisburn Anticline. The **Chatburn Limestone** is exposed in three disused quarries near Broughton Fields [SD 922 504] and consists of well-bedded limestones with some argillaceous limestone and mudstone interbeds. Some beds are patchily silicified or contain disseminated dolomite and the lower beds, exposed in Micklethorn Quarry [SD 927 508], contain nodular chert. The **Thornton Limestone** is about 200 m thick and is similar lithologically to the Thornton Limestone of the Swinden Anticline. Although the sequence is locally very argillaceous there is a general increase in argillaceous material towards the top of the unit. The Thornton Limestone is patchily exposed in several areas of thin drift and in several small disused quarries. The overlying beds of the Worston Shale Group are poorly exposed and consist mainly of shales with some interbedded argillaceous, sometimes cherty, limestones. However a limestone division, known as the **Butterhaw Limestone,** is widely developed about 130 m above the Thornton Limestone and consists of about 70 m to 80 m of limestones with subordinate interbedded argillaceous limestone and mudstone. Minor dolomitisation is a feature of the limestones but chert is not seen. In the north-western part of the area the Worston Shale Group also includes some interlaminated limestones and mudstones which pass laterally into the Bell Busk Limestone with Mudstone of the Bell Busk Anticline.

The **Pendleside Limestone** is not developed in the north-eastern part of the area, except for a thin outcrop near Thorlby [SD 965 530]. Where it is seen in the south-eastern corner of the area [SD 964 500] it is thin and cherty.

The limestone resources of the area have been assessed with the aid of two boreholes augmented by an extensive collection of samples from the numerous disused quarries. Insoluble residue results from various localities (SD 95 SW 1s to 4s, 6s, and SW 29, 30) illustrate the variability of the Chatburn and Thornton Limestone sequence. Of the samples tested, the majority exhibited carbonate levels in the range 90-96 per cent, but the patchily silicified and more argillaceous beds in the upper part of the sequence at Butterhaw (SD 95 SW 30) and in the lower part at Broughton Fields (SD 95 SW 29) are clearly of impure grade. The Butterhaw Limestone is classified as low purity limestone as insoluble residues range between 10 per cent and 13 per cent.

Chemical analyses and aggregate impact values of the Chatburn Limestone of borehole SD 95 SW 29, and the Thornton Limestone of borehole SD 95 SW 30, are given in Appendices C and D. The upper 33 m of strata in borehole SD 95 SW 29 is relatively clay-free and CaO values range between about 51 per cent and 53 per cent and silica varies between 3.9 per cent and 6.5 per cent. Below 33 m argillaceous strata gave CaO values between 32.8 per cent and 47 per cent, SiO_2 values between 10.0 per cent and 22.7 per cent and Al_2O_3 values vary between 2.2 per cent and 8.2 per cent. Fe_2O_3 and SO_3 values are also much higher in the argillaceous strata due to the common occurrence of pyrite.

The aggregate impact values obtained from the Chatburn Limestone in SD 95 SW 29 and from the Thornton Limestone in SD 95 SW 30 are summarised in Table 2.

Block I Eshton-Hetton

Most of the area is occupied by the Eshton-Hetton Anticline, but a second fold, the Bell Busk Anticline, is located between the Swinden and Eshton-Hetton anticlines and occupies the south-western corner of the area. The Eshton-Hetton structure is an east-north-east trending asymmetric anticline with the northern limb steeper (40° to 60°) than the southern limb (up to 30°). The fold bifurcates at its eastern end, the two components plunging east-north-east. Subsidiary tight folds affect strata at the western end of the northern limb. The anticline is truncated to the west by a major tear fault, a component of the South Craven Fault system. A number of other north-west to west-north-west trending faults also dislocate the anticline. The Bell Busk Anticline is a pericline with an arcuate axial trace and impinges to the south on the Swinden Anticline.

About 900 m of Dinantian rocks (Figure 4) are exposed beneath the Bowland Shales. The oldest rocks, the **Hetton Limestone,** crop out in the cores of both anticlines and are estimated to be over 220 m thick. Good exposures are seen on Eshton Moor [SD 914 572] (Plate 11) and around Winterburn [SD 940 587] where the drift cover is relatively thin. The Hetton Limestone comprises thick-bedded, dark grey limestones containing a variable amount of argillaceous material. Chert is generally sparse but may be common in the lower part of the exposed sequence. The limestones commonly contain a variable amount of disseminated dolomite.

The overlying beds of the Worston Shale Group comprise a laterally variable mixture of limestones and mudstones which show evidence of syntectonic sedimentation. The top of the Hetton Limestone is an erosion surface and the **Hetton Beck Limestone** rests unconformably on the Hetton Limestone in borehole SD 95 NE 1. At Haw Crag [SD 914 565] a boulder bed (Plate 12) is developed which rests with marked irregularity on the Hetton Limestone and is overlapped by the Bell Busk Limestone with Mudstone. The boulder bed is up to 25 m thick and consists of jumbled blocks of limestones of various types, including reef-facies limestones, set in a mudstone matrix. Similar lithologically heterogeneous boulder beds are developed near Coniston Cold [SD 892 551]. Pale grey, reef-facies limestones are poorly exposed overlying the Hetton Limestone near Bell Busk and Scarnber [SD 940 579].

The Hetton Beck Limestone is developed on the southern limb of the Eshton-Hetton Anticline and similar beds are recognised in the Bell Busk Anticline. About 115 m of Hetton Beck Limestone are developed south of Hetton (borehole SD 95 NE 1) but the beds are cut out near Eshton. The sequence comprises dark grey limestones and argillaceous limestones with subsidiary mudstones. Partings and layers of mudstone are particularly common towards the base of the division. Chert is most common in the uppermost 20 m but silicified material occurs patchily throughout the sequence. On the northern flank of the Eshton-Hetton Anticline, the basal sequence of the Worston Shale Group is represented by mudstones rather than limestones. At the western end of the northern limb, these pass up into a series of well-bedded, dark grey limestones with mudstone partings, known as the **Hurries Farm Limestone.**

A sequence of thinly-bedded cherty limestones with variable amounts of interbedded mudstones succeed the Hurries Farm Limestone and Hetton Beck Limestone. These beds are known as the **Calton Limestone with Mudstone** in the northern part of the area whereas in the south they are referred to as the **Bell Busk Limestone with Mudstone.** They have a maximum development of about 350 m, but the thickness is variable and the base is locally unconformable. In most parts of the area the limestone/mudstone sequence is succeeded by shales and mudstones, but in the eastern part of the Eshton-Hetton Anticline the succeeding beds are well-bedded, dark grey limestones with some muddy partings (Plate 13). This limestone is termed the **Rylstone Limestone** and has a maximum thickness of about 120 m. Chert is generally sparse but the beds contain much secondary, fine grained siliceous material.

The upper beds of the Worston Shale Group comprise a laterally variable mixture of limestones and mudstones, but the typical **Pendleside Limestone** lithology is widely developed at the top of the group. In ther north of the area, the uppermost part of the Pendleside Limestone contains layers with abundant limestone clasts. These debris beds have a maximum development of over 10 m but thin out to the south. Clasts of reef-facies limestones are a common constituent of these beds and are presumably derived from the knoll-reef limestones which form the Malham - Cracoe Reef Belt to the north. One of these knoll-reefs, Swinden Knoll, occurs in the north-east corner if the area.

Two boreholes (SD 95 NW 7 and SD 95 NE 1), two sections (SD 95 NW 1s and SD 95 NE 1s) and a number of spot samples provide the basis for the assessment of carbonate resources. Insoluble residue values obtained from the Hetton Limestone commonly range between 2.5 per cent and 9.0 per cent but most of the values are between 3 per cent and 7 per cent. The argillaceous strata and cherty beds within the Hetton Limestone commonly give residue values which are greater than 15 per cent. The Hetton Limestone is, therefore, broadly classified as medium or low purity limestone, but it also contains some high purity limestone and impure limestone. Blocks of limestone taken from the boulder beds at Haw-Crag and Coniston Cold gave insoluble residue values around 4 per cent to 6 per cent. The deposits are very heterogeneous but are classified as medium purity limestone. The Hetton Beck, Hurries Farm, Rylstone and Pendleside limestones contain over 10 per cent non-carbonate minerals and are categorised as low purity or impure limestones. The Calton Limestone with Mudstone and Bell Busk Limestone with Mudstone are consistently impure. The limestone debris beds gave some low insoluble residue values of around 3 per cent, but the beds are heterogeneous and are classified as medium purity limestone. A few spot samples of knoll-reef limestone from Swinden Knoll gave insoluble residue values of 1.4 per cent to 2.1 per cent, and these beds are generalised as high purity limestone on the map.

Chemical analyses of the strata proved in boreholes SD 95 NW 7 and SD 95 NE 1 are tabulated in Appendix D. Most of the analyses are of Hetton Limestone, which commonly contains between 51.5 per cent and 54.3 per cent CaO and around 2.5 per cent silica and 0.6 per cent alumina. The less pure beds within the Hetton Limestone usually give markedly lower CaO values, and silica and alumina values may increase to over 14 per cent and 4 per cent, respectively. Fe_2O_3 and SO_3 values are also relatively high in analyses of these argillaceous beds, due to the common occurrence of pyrite. MgO values vary between 0.8 per cent and 1.8 per cent reflecting the amount of dolomite disseminated in the limestones. Analyses of the Hetton Beck Limestone usually show high silica values (9 per cent to 13 per cent) and low CaO values (44 per cent to 49 per cent). This is also typical of the Rylstone Limestone, although these beds may contain over 23 per cent silica. Two analyses of the Bell Busk Limestone with Mudstone gave silica values of 27 per cent and 12 per cent, and alumina values of 5.0 per cent and 2.5 per cent.

Aggregate impact values obtained from limestones in this block are summarised in Tables 2 and 3, and lie between 18 and 27.

Block J Airton

The Dinantian rocks of the area are folded into the Airton Anticline, a complex west-north-west trending pericline cut by several west-north-west trending faults. The fold is bounded by a major tear fault to the south and extends northwards to the Malham Syncline, beyond the limits of the district. Dips are variable, up to 40°.

Most of the area is drift covered but there are good exposures of the **Hetton Limestone** (Figure 4) in the core of the anticline. The Hetton Limestone is about 245 m thick and comprises thickly bedded limestones and argillaceous limestones. A grainstone facies is widely developed in the upper part of the sequence and is remarkable for its high purity. Clay is absent, chert is sparse and in most beds there are only relatively minor amounts of siliceous material. However, dolomitisation, which is apparently fault-controlled, affects some of the grainstone beds (Plate 15) and is associated with patchy silicification. An indication of the thickness of this facies is given by a borehole drilled at High Ings Barn

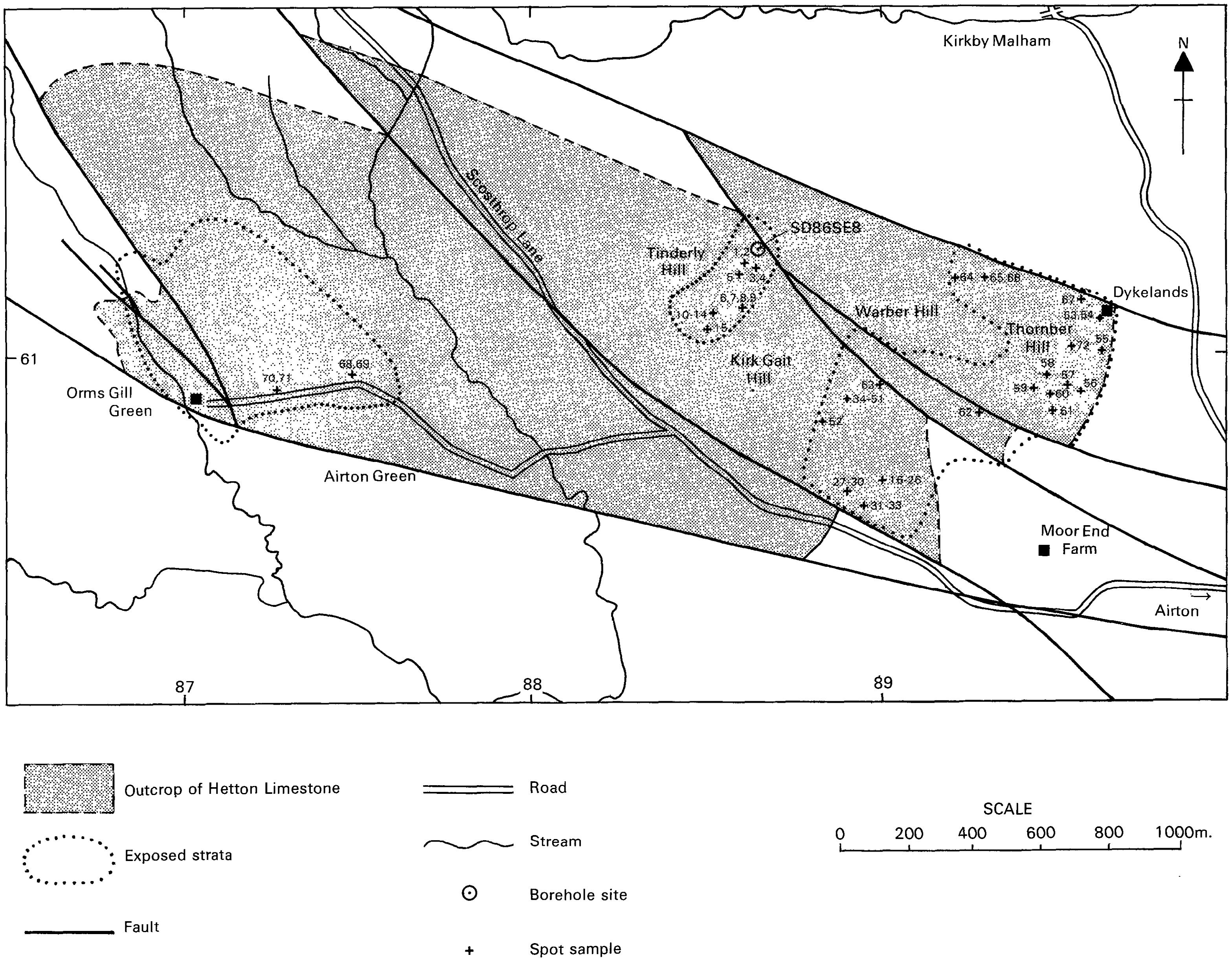


Figure 7 Sketch map of the Airton Anticline showing the outcrop of the Hetton Limestone and distribution of sample points.

Table 12 Lithology and insoluble residue data of spot samples from the Hetton Limestone of the Airton Anticline.

Spot Sample No.	Lithology	Insoluble Residue	Category	Spot Sample No.	Lithology	Insoluble Residue	Category
1	Grainstone	4.0	3	37	Grainstone	1.4	1
2	Grainstone (dolomitic)	3.2	3	38	Grainstone	2.5	2
3	Grainstone	3.0	3	39	Grainstone	1.8	2
4	Grainstone (dolomitic)	3.1	3	40	Grainstone	1.2	1
5	Grainstone	2.1	2	41	Grainstone	1.6	2
6	Grainstone	3.0	3	42	Grainstone	3.0	3
7	Grainstone	1.6	2	43	Grainstone	1.9	2
8	Grainstone (dolomitic)	3.0	3	44	Grainstone	1.1	1
9	Grainstone	1.9	2	45	Grainstone	2.2	2
10	Argillaceous limestone	7.7	4	46	Grainstone	1.6	2
11	Grainstone	2.4	2	47	Grainstone	1.5	2
12	Wackestone	6.7	4	48	Grainstone	2.2	2
13	Wackestone	3.5	3	49	Grainstone	2.0	2
14	Argillaceous limestone	6.6	4	50	Grainstone	1.9	2
15	Cherty argillaceous limestone	20.0	5	51	Grainstone	5.0	3
16	Dolomite	2.7	2	52	Cherty argillaceous limestone	>20.0	5
17	Dolomite	6.5	4	53	Grainstone	2.9	2
18	Dolomite	10.4	4	54	Grainstone (dolomitic)	1.4	1
19	Dolomite	3.0	3	55	Grainstone	3.5	3
20	Grainstone (dolomitic)	11.8	4	56	Grainstone	2.3	2
21	Dolomite	8.3	4	57	Grainstone	1.4	1
22	Dolomite	2.5	2	58	Grainstone	1.2	1
23	Dolomite	>50.0	5	59	Grainstone (dolomitic)	1.5	2
24	Dolomite	17.3	5	60	Grainstone (dolomitic)	3.1	3
25	Dolomite	13.3	4	61	Grainstone	2.2	2
26	Dolomite	2.9	2	62	Grainstone	2.6	2
27	Dolomite	13.1	4	63	Grainstone	1.5	2
28	Dolomite	2.5	2	64	Grainstone (dolomitic)	7.9	4
29	Dolomite	7.2	4	65	Grainstone	4.5	3
30	Dolomite	11.2	4	66	Grainstone	3.5	3
31	Grainstone (dolomitic)	1.2	1	67	Grainstone (dolomitic)	3.6	3
32	Grainstone (dolomitic)	1.7	2	68	Grainstone	6.2	3
33	Grainstone (dolomitic)	4.2	3	69	Grainstone	4.4	3
34	Grainstone	2.2	2	70	Dolomite	15.0	5
35	Grainstone	0.8	1	71	Dolomite	55.1	5
36	Grainstone	1.2	1	72	Grainstone	2.0	2

(SD 86 SE 8) which proved 97 m of grainstones before passing into a sequence of argillaceous limestones with subsidiary mudstones.

About 475 m of limestones and mudstones of the Worston Shale Group overlie the Hetton Limestone, but are poorly exposed. Three limestone divisions are recognised and the lowest of these, the **Calton Limestone with Mudstone,** is about 70 m thick and consists of cherty, thin-bedded, argillaceous limestones with interbedded mudstones. The overlying **Rylstone Limestone** and **Pendleside Limestone** are restricted to the northern flanks of the fold, and are lithologically similar to their equivalent beds in the Eshton-Hetton Anticline. The Pendleside Limestone is thickly developed (150-200 m) just to the north of this area, and chert is common in most sections. The upper part of this division contains debris beds, up to 40 m thick, consisting of pale grey, massive, fossiliferous limestones with common limestone clasts.

The limestone resources of the area have been assessed with the aid of one borehole supplemented by an extensive collection of spot samples. Sample points from the Hetton Limestone are shown in Figure 7 and the lithology and purity of the samples are summarised in Table 12. The grainstone facies is mainly of high purity (insoluble residue 1 per cent to 3 per cent) except where dolomitised, when the purity is locally downgraded. Chemical analyses for this facies are tabulated for material from borehole SD 86 SE 8 in Appendix D. The dolomitised beds in the upper part of the borehole contain between 35.6 per cent and 36.0 per cent CaO and between 15.5 per cent and 13.3 per cent MgO. The dolomites are iron-rich (3.4-5.0 per cent Fe_2O_3) and also contain significant amounts of SiO_2 and MnO. The high purity of the unaltered grainstones is confirmed by CaO values of around 55.5 per cent and relatively low SiO_2, MgO and Fe_2O_3 values. Other oxides and trace elements are absent or are present in trace amounts only. The lower, argillaceous beds of the Hetton Limestone contain high proportions of non-carbonate minerals and insoluble residue values are variable between about 7 per cent and 30 per cent. These beds are therefore categorised as low purity of impure limestones.

The low grade character of the Calton Limestone with Mudstone and Rylstone and Pendleside limestones has been deduced from field observations and by reference to similar beds which occur in other areas nearby. However, a few spot samples have been collected from the limestone debris beds at the top of the Pendleside Limestone, and these gave insoluble residue values between 3.0 per cent and 5.4 per cent, indicating medium purity limestone.

Aggregate impact values (AIVs) determined from the Hetton Limestone of borehole SD 86 SE 8 are shown graphically in Appendix C and are summarised in Table 2. The dolomitised limestones gave AIVs of 27 to 23, but the AIVs obtained from the non-dolomitised grainstone-facies limestones and argillaceous limestones ranged between 21 and 16, with a mean value of 19.

Block K Skipton-Bolton Abbey

This area lies outside the limits of the Settle and Clitheroe Geological sheets and the geological account is based on Hudson and Mitchell (1937).

The area is occupied by the Skipton Anticline, which trends east-north-east from Skipton to north of Bolton Abbey. The northern limb dips steadily at around 40° - 50°, but the southern flank is locally sharply folded by a number of subsidiary folds. This folding is most intense near Draughton [SE 038 526]. A number of north-west trending faults, dislocate the main anticline and some of them show tear movement. A few faults have a north-easterly trend.

The Dinantian succession, beneath the Bowland Shales, is about 1000 m thick on the northern flank of the anticline and around 400 m thick on the southern flank (Figure 4). Unconformities have been recognised within the sequence. The lowest beds in the succession, the **Haw Bank Limestone with Shale** and **Haw Bank Limestone,** crop out in a narrow belt along the axis of the fold, and form a prominent ridge known as Haw Bank. They are extensively quarried for aggregates and the disused and working quarries provide many sections. The Haw Bank Limestone with Shale, which is locally exposed in the core of the anticline, consists of silty, micaceous, argillaceous limestones with interbedded shales. The limestones contain much fine grained siliceous material. These beds pass upwards into the Haw Bank Limestone which is about 150 m thick and comprises a sequence of dark grey, well-bedded limestones of various lithofacies, with some interbedded argillaceous limestone and shale. Chert and patchy silicification occurs sporadically throughout the sequence, and some beds contain disseminated dolomite. Pyrite is also common, particularly in the argillaceous limestones.

The overlying succession of the Worston Shale Group is one of mudstones, shales and argillaceous limestones in varying proportions. At two levels limestone is more abundant than shale, and these are termed the **Embsay Limestone** and **Draughton Limestone.** Both the thickness and lithology of the Embsay Limestone are very variable. Near Embsay [SE 012 538] it is about 107 m thick, but on the southern outcrop in Halton Gill [SE 053 537] it is less than 18 m thick and contains conglomeratic layers at its base. The Embsay Limestone consists of well-bedded limestones and argillaceous limestones with some shale bands and partings. Chert occurs sporadically throughout the sequence and the limestones commonly contain fine-grained siliceous material, disseminated dolomite and pyrite. The Draughton Limestone, which is equivalent to the Pendleside Limestone, crops out in a nearly continuous belt in the north of the area, while in the south the outcrops are broken and separated. The full succession of about 30 m occurs near Draughton where it is intensely folded (Plate 16). Layers of limestone clasts occur throughout the Draughton Limestone, but are most common in the lower part of the sequence. Bedded and nodular chert is common and the limestones contain variable amounts of siliceous material, dolomite and pyrite. Shales are mostly encountered in the upper part of the sequence.

Precise drift boundaries have not been mapped, but the limestone ridge of Haw Bank is generally drift-free, as is the area of complexly-folded strata west of Draughton. Outcrops of the limestones are often marked by prominent ridges, but the ground is much obscured by drift east of Halton East [SE 043 540] and Draughton.

Eight quarry sections provided material for laboratory analysis. Section SE 05 SW 1s sampled the Haw Bank Limestone with Shale at the core of the anticline in Skibeden Quarry, and gave very high insoluble residue values between 25 per cent and 43 per cent. The overlying Haw Bank Limestone, sampled in four sections, SE 05 SW 2s to 5s, gave insoluble residue values between 2 per cent and 21 per cent, although most of the values ranged from 4 per cent to 9 per cent. These beds are, therefore, classified as medium and low purity limestone, but they contain some impure limestone. Section SE 05 SW 6s from Halton East Quarry, augmented by a few spot samples, provides the basis for the assessment of the Embsay Limestone, which is classified as low purity limestone with insoluble residue values between 8 per cent and 12 per cent. Samples of the Draughton Limestone taken from Hambleton Quarry (SE 05 SE 1s) and Wheelam Rock Quarries (SE 05 SW 7s) gave insoluble residue values between 11 per cent and 22 per cent, indicating low purity or impure limestone.

Chemical analyses and aggregate impact values (AIVs) obtained from most sections are given in Appendices C and D. The variable purity of the Haw Bank Limestone is demonstrated by the chemical analyses. Section SE 05 SW 2s gave CaO values around 51 per cent to 52 per cent, but section SE 05 SW 3s contained between 44 per cent and 49 per cent CaO. Silica is the major impurity; the two sections gave values of 2.7 per cent to 4.9 per cent silica and 11.5 per cent to 15.1 per cent silica, respectively. Both analyses also show significant amounts of Al_2O_3 and MgO, and variable proportions of Fe_2O_3 and SO_3. The small number of analyses obtained from the Embsay and Draughton limestones display the siliceous character of these beds. Silica values from the Embsay Limestone vary between 6.5 per cent and 9.0 per cent and from the Draughton Limestone between 11.5 per cent and 23.3 per cent.

AIVs obtained from the Haw Bank Limestone, Embsay Limestone and Draughton Limestone average 24, 22, and 20, respectively.

SUMMARY OF LIMESTONE RESOURCES

Limestones occupy a considerable proportion of the district and are currently quarried for use in the construction industry at Chatburn, Lothersdale and Skipton. The limestone assessment is generalised owing to the widespread distribution of sample points and the lithological variability and poor exposure of the limestones. Detailed limestone resource data are restricted to results obtained from boreholes, sections and spot samples.

Knoll-reef limestones provide the most consistent deposits of pure limestone in the district, and some knoll-reefs have been extensively quarried. Many knoll-reefs occur in relatively small masses although some would be large enough to support a modern quarrying operation. Most samples of knoll-reef limestones contain between 97 per cent and 98 per cent Ca CO_3; impurities only rarely total more than 3 per cent of the rock. The chief impurity is silica, but clay minerals, pyrite and ferroan dolomite may locally downgrade the limestone. The highest grade knoll-reef limestones determined by the survey are from a borehole at Withgill Knoll. This proved nearly 129 m of high and very high purity limestone of uniform chemistry. These limestones also produced very white limestone powders, as did similar crinoidal knoll-reef limestones from Bellman Knoll. Limestone powders obtained from other knoll-reef limestones gave lower and more variable brightness values. Most of the knoll-reef limestones give aggregate impact values which suggest that they are strong enough to be used as aggregates. However, the coarsely crinoidal facies, found in some of the knolls, is weaker and is probably unsuitable for most aggregate uses.

The bulk of the limestones in the district are of low chemical grade and are lithologically and chemically more variable than the knoll-reef limestones. They are interbedded with variable amounts of shale and mudstone and may contain chert and other impurities. Nevertheless, certain beds are economically important and are quarried for aggregates and cement.

The overall content of non-carbonate minerals in the Chatburn Limestone (and the equivalent Slaidburn Limestone and Haw Bank Limestone) is high, usually ranging between 4 per cent and 12 per cent, but some individual beds contain less than 3 per cent non-carbonate. Nevertheless, argillaceous and cherty beds may produce insoluble residue values greater than 15 per cent. The purity of the Chatburn Limestone and equivalent beds is therefore variable; however, over the whole outcrop it is likely that low and medium purity limestones predominate. Silica is the major impurity, averaging around 5 per cent to 6 per cent, but exceeding 10 per cent in some samples. Most of the limestones contain between 1 per cent and 2 per cent MgO, less than 1 per cent Fe_2O_3, 2 per cent Al_2O_3, 1 per cent SO_3 and 0.5 per cent total alkalis. Higher values are typical of the more argillaceous beds.

The Thornton Limestone of the Swinden - Broughton area and the Bridge End Limestone of the Slaidburn area are also categorised as medium and low purity limestone, but the beds are generally more variable than the Chatburn Limestone. Chert and patchy silicification are common features and analyses of the Thornton Limestone show between 6 per cent and 15 per cent silica.

The Hetton Limestone, which occupies the cores of the Eshton - Hetton, Bell Busk and Airton anticlines, is a lateral equivalent of the Thornton Limestone. Over most of its outcrop, it is classified as medium or low purity limestone, but the upper part of the sequence in the Airton Anticline is relatively free of impurities and here the beds are categorised as high purity, though they are affected by dolomitisation. Almost 100 m of these beds were proved in borehole SD 86 SE 8 and the non-dolomitised limestones typically contain between 97 per cent and 99 per cent Ca CO_3. However, the dolomitised limestones in the upper part of the borehole are also partially silicified and insoluble residue values range from 3 per cent to over 15 per cent. Dolomite and dolomitic limestones are also locally recorded at outcrop, often in the vicinity of faults. Most of the outcrop, however, is unaffected by dolomitisation and the upper part of the Hetton Limestone in the Airton area generally comprises a uniform deposit of high purity limestone. The lower part of the sequence in the Airton Anticline is similar lithologically to the Thornton Limestone, and contains mudstone and argillaceous limestone interbeds and some chert. The lowest exposed Hetton Limestone in the Hetton area is also cherty, but the overlying succession does not contain high purity limestones comparable with those proved in the Airton Anticline. Instead, most of the outcrop consists of well-bedded, dark grey limestones with some muddy partings and interbeds. The limestones usually contain between 93 per cent and 97 per cent Ca CO_3 but argillaceous strata often contain less than 85 per cent Ca CO_3. Chemical analyses of material from borehole SD 95 NW 7 demonstrate the variable purity of these beds; most samples contain between 1.2 per cent and 3.0 per cent SiO_2, between 0.8 per cent and 1.8 per cent MgO and less than 0.1 per cent Fe_2O_3.

The limestones of the Chatburn Limestone Group have comparable aggregate impact values (AIVs). High AIVs are given by samples of dolomitised Hetton Limestone (borehole SD 86 SE 8) and structurally disturbed Chatburn Limestone (borehole SD 74 NE 3).

The Worston Shale Group contains mudstones, shales, argillaceous limestones and limestones in varying proportions, but at various levels limestone is more abundant than shale. These limestone divisions, which are known by a number of local names, are generally classified as low purity or impure limestone, with the major exception of the high purity knoll-reef limestones previously described. In addition, debris beds, which include blocks and boulders of knoll-reef limestone, are classified as medium purity limestone, although they are lithologically very heterogenous.

The Peach Quarry and Middop limestones usually contain over 7 per cent non-carbonate minerals, although, exceptionally, insoluble residue values of 2 per cent to 3 per cent have been recorded. Silica is the major impurity and levels around 10 per cent were recorded in analyses of the Peach Quarry Limestone. Similarly the Swinden, Swinden Gill, Butterhaw, Hurries Farm, Hetton Beck, Rylstone and Embsay limestones and parts of the Rain Gill Limestone are also siliceous, usually containing over 10 per cent non-carbonate minerals. These divisions form fairly consistent deposits of low purity limestone.

The interbedded and interlaminated limestone and mudstone sequences forming part of the Worston Shale Group, including much of the Rain Gill Limestone, the Calton Limestone with Mudstone and the Bell Busk Limestone with Mudstone, are classified as impure limestone. Chemical analyses of borehole samples of the Bell Busk Limestone with Mudstone give CaO values of 35.3 per cent to 46.1 per cent, and silica values of 27 per cent to 12 per cent.

The Pendleside Limestone and its equivalent, the Draughton Limestone of the Skipton Anticline, have not been widely sampled, but chert is evident at many localities and the division contains some interbedded mudstones. Exceptionally, the Pendleside Limestone is entirely replaced by mudstone. Over most of the district, however, the Pendleside Limestone is of low purity or is impure. In northern areas, the upper part of the division contains limestone debris beds, of variable thickness, shown generalised on the map as medium purity limestone.

The strength and resistance to impact (AIV) of the limestones in the Worston Shale Group appear, from limited data, to be closely similar to those of limestones of the Chatburn Limestone Group.

Structurally the district is folded into tight anticlines and broad synclines. The limestones are often steeply dipping and this may cause difficulties in developing safe and economical quarrying operations. The high density of faulting in certain areas is also liable to give rise to quarrying problems. The main structural features of the district are indicated on the resource map.

Most of the limestones in the district are covered by superficial (drift) deposits. Generally, the floors of the river valleys are covered by alluvial deposits, but boulder clay is more extensive and obscures large areas of limestone outcrop. The boulder clay is of variable thickness and locally forms drumlin feaures. Areas of exposed limestone, including areas in which drift thickness is likely to be less than about 5 m, are shown on the map. Knoll-reef limestones are particularly well exposed, as are some of the ridges formed by limestones within the Chatburn Limestone Group.

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APPENDIX A.
LIMESTONE CLASSIFICATION AND GLOSSARY

LIMESTONE CLASSIFICATION

The petrographic classification of limestones of Dunham (1962) is used in this report. The classification is summarised in Table 13. The classification describes the depositional texture of the limestones. The presence or absence of mud differentiates muddy carbonate from grainstone. The relative abundance of grains allows muddy carbonates to be subdivided into mudstone, wackestone and packstone, and the presence of signs of binding during deposition characterises boundstone. The degree of packing differentiates packstone from wackestone. The former is composed of grains in close contact with each other whereas the latter consists of a relatively small amount of grains 'floating' in a mud matrix.

In addition to purely textural parameters the classification used in this report recognises several basic grain types. These are bioclasts, peloids, lithoclasts, oncolites and ooids.

GLOSSARY

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

Argillaceous rocks Detrital sedimentary rocks that contain clay or siltgrade material.

Authigenic Referring to those constituents that came into existence with or after the formation of the host rock.

Bioturbation The churning and stirring of a sediment by organisms.

Clast A rock fragment.

Cross-bedding Arrangement of strata inclined at an angle to the main planes of stratification.

Drumlin A low, smoothly rounded, elongate oval hill of compact glacial drift.

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

Gangue A mineral in a vein other than an ore mineral.

Graded bedding A type of bedding which displays a gradual and progressive change in particle size, usually from coarse at the base of the bed to fine at the top.

Grainstone A mud-free grain-supported limestone.

Hydrothermal The products of the action of heated water.

Olistolith An *exotic block* transported by submarine gravity sliding or slumping.

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

Packstone A grain-supported limestone which contains some calcareous mud.

Pericline A structure that dips radially outwards from a centre to form a dome.

Plunge The inclination of a fold axis measured in the vertical plane.

Slump fold An intraformational fold produced by slumping of soft sediments.

Table 13 Classification of carbonate rocks according to depositional texture (Dunham, 1962).

<table>
<tr><td colspan="5">Depositional Texture Recognisable</td><td rowspan="5">Depositional Texture Not recognisable</td></tr>
<tr><td colspan="4">Original components not bound together during deposition</td><td rowspan="4">Original components bound together during deposition</td></tr>
<tr><td colspan="3">Contains mud (clay and fine silt)</td><td rowspan="3">Lacks mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>Less than 10 % grains</td><td>More than 10 % grains</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td><td>Crystalline carbonate</td></tr>
</table>

Strike The direction of trend that a structural surface takes as it intersects the horizontal (trend in a direction at right angles to the dip).

Stromatactis A sedimentary structure characterised by a horizontal bottom, up to about 10 cm in diameter, and an irregular or convex upwards upper surface, infilled by sparry-calcite cement.

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

Syntectonic Said of a geological process occurring during any kind of tectonic activity.

Tear fault A steep to vertical fault in which the movement is dominantly strike slip.

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

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

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

Wackestone
A mud-supported limestone containing more than 10 per cent grains.

APPENDIX B
EXPLANATION OF FORMAT FOR BOREHOLE AND SECTION LOGS

The following list is arranged in the same order as data on the borehole records. The numbered paragraphs below also correspond with the annotations on the first record (Appendix C).

1 The Registration Number. This consists of two statements:

(i) The number of the 1:25 000 sheet on which the borehole lies, for example SD 95.

(ii) The quarter of the 1:25 000 sheet on which the borehole lies, and its number in a series for that quarter. Thus the full Registration number is SD 95 SW 29.

Collected sections are registered in a similar manner using a separate series of numbers, suffixed by the letter s, for example, SD 95 SW 1s.

2 The National Grid Reference.

3 Location. Borehole and section locations are referred to the nearest named locality on the 1:50 000 base map.

4 Surface level. The surface level at the borehole site is given in metres above Ordnance Datum. For collected sections surface level is taken to be the top of the sampled sequence.

5 Date of drilling or sample collection.

6 The stratigraphical names of the main limestone divisions are listed.

7 Each major rock type is briefly described using the classification explained in Appendix A.

8 Depth. The figures given relate to depths to the base of the lithologies described in the log.

9 Major rock types are represented on a graphical log and diagnostic lithologies are shown using an ornamental overprint. A complete list of symbols is given in Figure 8.

10 Gamma-ray log. The Gamma-ray log is a measurement of the natural radioactivity of the rocks. In sedimentary rocks the Gamma-ray log normally reflects the shale/clay content. Clean formations usually have a very low level of radioactivity. Gamma-ray logs are recorded for each borehole. Non-absolute units of counts-per-second (cps) are quoted.

11 Colour. The percentage reflectance of red light (peak wavelength at 660 nm) from flat, acid-etched rock surfaces and from powder discs of borehole samples of knoll-reef limestones are shown graphically. In addition, the colour of the etched surfaces of rocks from several other boreholes is also shown. A white magnesium carbonate standard with a reflectance value of 100 per cent was used to calibrate the spectrophotometer.

12 Mechanical properties.

(i) For most boreholes and sections, the fracture spacing index If (as defined by Franklin and others, 1971) is measured in millimetres.

(ii) For all boreholes and most sections, the aggregate impact value (AIV) is determined on 10 m aggregated samples.

13 Insoluble residue data. Residue values are expressed as weight percentages and are calculated over consecutive 5 m intervals.

14 Purity. Classification into categories by carbonate content (see Table 1).

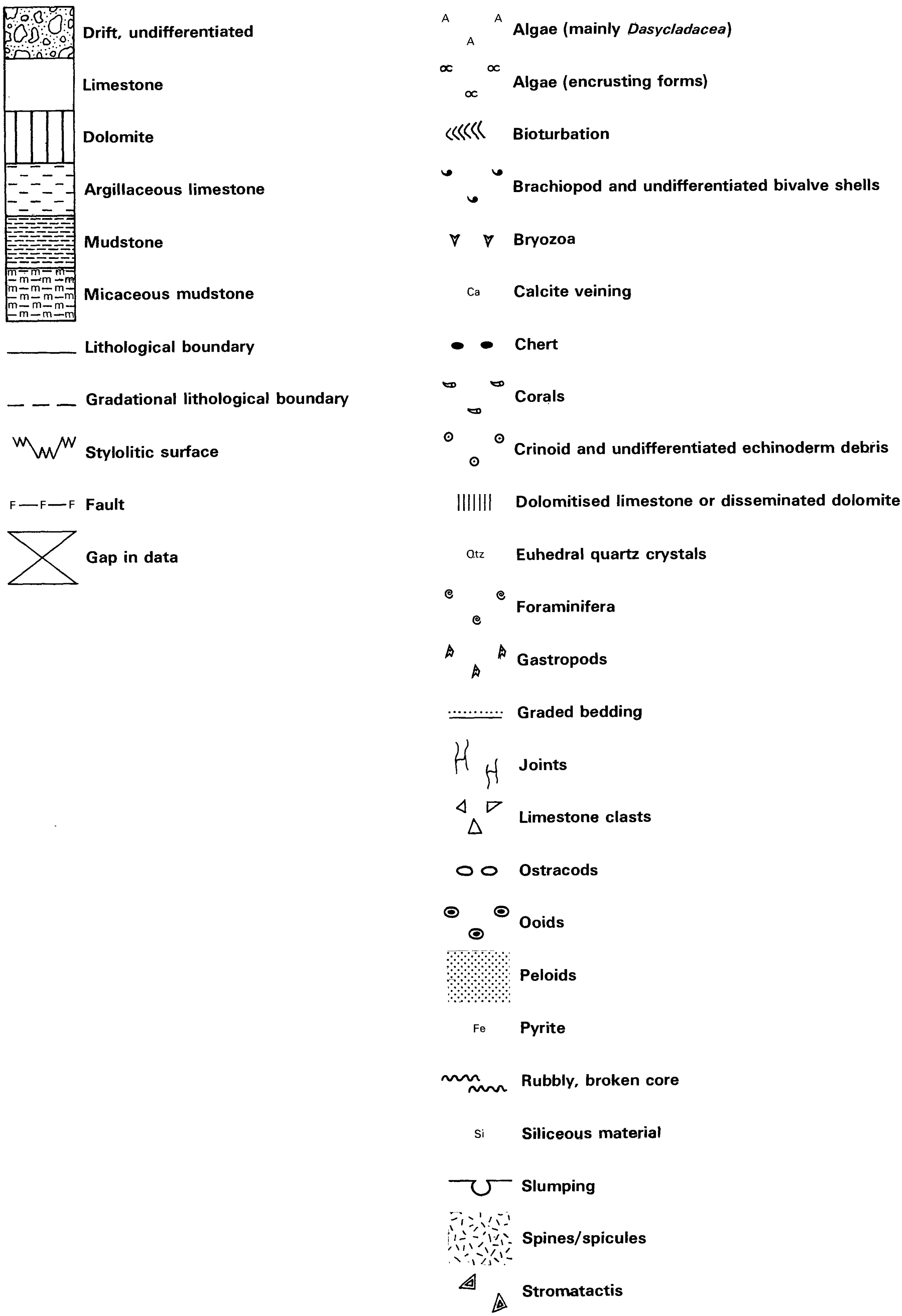
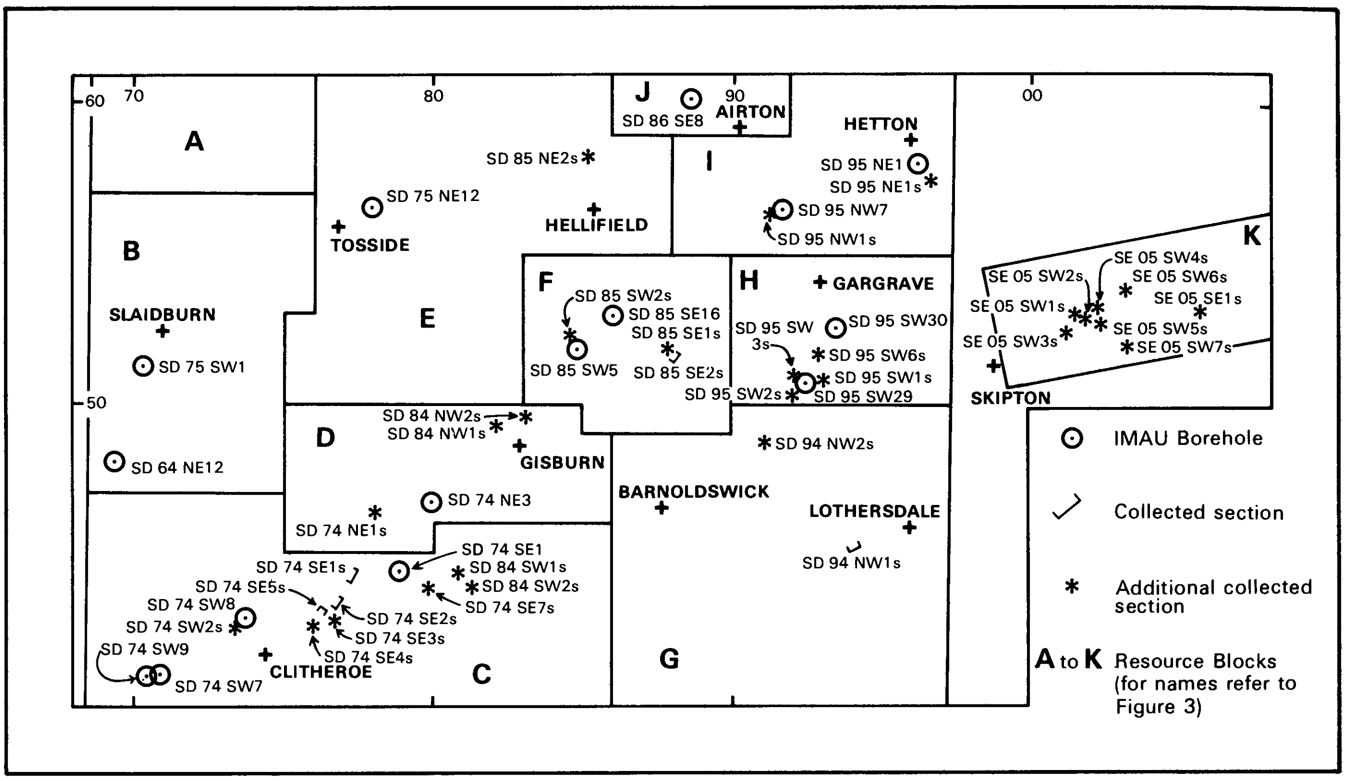


Figure 8 Explanation of symbols used on graphical logs.

APPENDIX C

RECORDS OF BOREHOLES AND SECTIONS



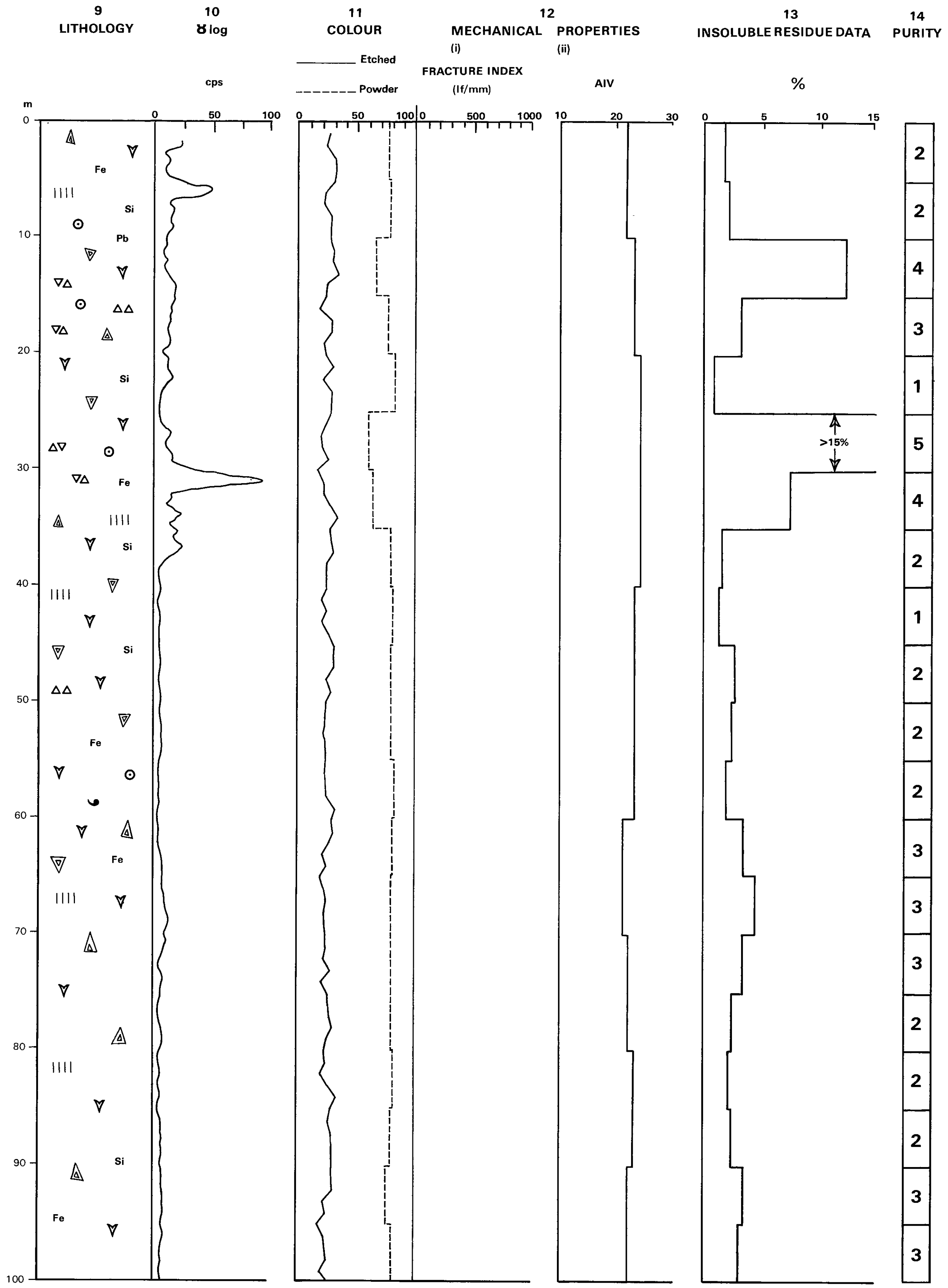
Resource Block	Registration Number	Grid Reference
B	SD 64 NE 12	6930 4809
	SD 75 SW 1	7029 5123
C	SD 74 SW 7	7093 4102
	SD 74 SW 8	7380 4290
	SD 74 SW 9	7055 4103
	SD 74 SE 1	7893 4450
	SD 74 SW 2s†	7381 4287
	SD 74 SE 1s	7731 4399
	SD 74 SE 2s	7678 4320
	SD 74 SE 3s†	7674 4289
	SD 74 SE 4s	7607 4265
	SD 74 SE 5s	7641 4322
	SD 74 SE 7s†	7990 4397
	SD 84 SW 1s†	8084 4435
	SD 84 SW 2s†	8116 4415
D	SD 74 NE 3	7992 4676
	SD 74 NE 1s†	7815 4636
	SD 84 NW 1s†	8218 4941
	SD 84 NW 2s†	8305 4965
E	SD 75 NE 12	7794 5661
	SD 85 NE 2s†	8520 5831
F	SD 85 SW 5	8471 5194
	SD 85 SE 16	8606 5301

Resource Block	Registration Number	Grid Reference
F	SD 85 SW 2s†	8461 5227
	SD 85 SE 1s†	8802 5161
	SD 85 SE 2s	8818 5161
G	SD 94 NW 1s	9417 4529
	SD 94 NW 2s†	9113 4883
H	SD 95 SW 29	9250 5077
	SD 95 SW 30	9346 5259
	SD 95 SW 1s	9281 5077
	SD 95 SW 2s	9232 5066
	SD 95 SW 3s	9249 5076
	SD 95 SW 6s	9292 5178
I	SD 95 NW 7	9166 5660
	SD 95 NE 1	9629 5813
	SD 95 NW 1s†	9137 5646
	SD 95 NE 1s†	9672 5748
J	SD 86 SE 8	8867 6031
K	SE 05 SW 1s†	0152 5303
	SE 05 SW 2s	0162 5286
	SE 05 SW 3s	0142 5278
	SE 05 SW 4s	0223 5331
	SE 05 SW 5s	0181 5298
	SE 05 SW 6s	0318 5385
	SE 05 SW 7s	0319 5214
	SE 05 SE 1s	0565 5325

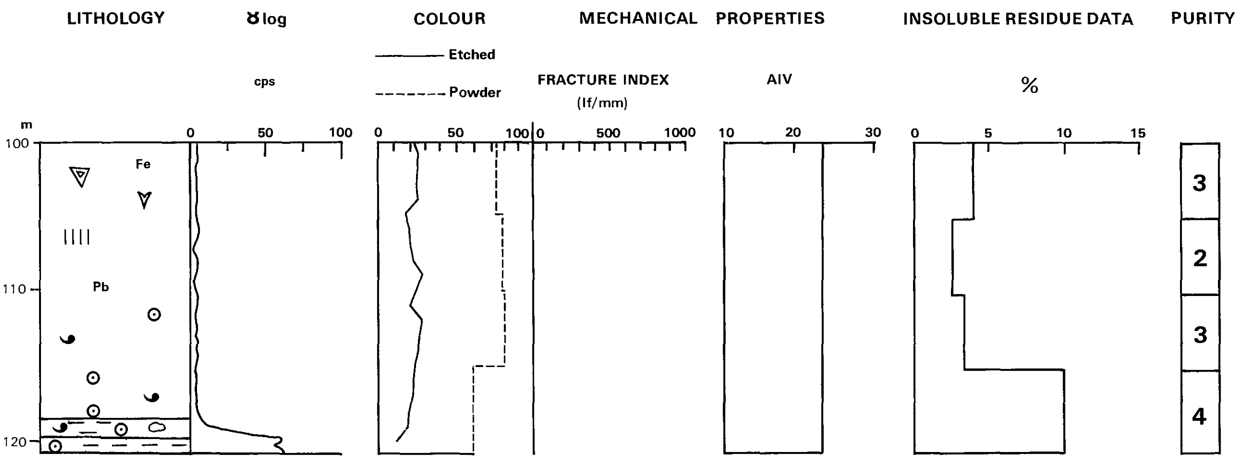
† Minor collected section not detailed in this appendix; log may be consulted on application to the Head, Industrial Minerals Assessment Unit at the Keyworth Office of the Institute.

Figure 9 Distribution of data points.

B
SD 64 NE 12



9 LITHOLOGY
10 γ log
cps
11 COLOUR
Etched
Powder
12 MECHANICAL PROPERTIES
(i) FRACTURE INDEX (lf/mm)
(ii) AIV
13 INSOLUBLE RESIDUE DATA
%
14 PURITY
m
>15%
Fe
Si
Pb



SD 64 NE 12[1] **6930 4809**[2] **Ashnott**[3] **Block B**

Surface level +233 m[4]
March 1980[5]

		Thickness m	Depth[8] m
	Topsoil	0.26	0.26
Knoll-reef[6] **Limestone**	Limestone[7], mid-grey, locally pale grey, medium arenite wackestone, waulsortian micrite. Common bryozoa, some crinoid, shell, ostracod, spine, foraminifera and algal debris. Common stromatactis. Some patchy dolomitisation and silicification and some unidentified buff-coloured, soft mineral infilling cavities. Trace hematite and pyrite. Uniform, monotonous lithology. Becoming darker 4.27 to 8.06 m. Trace galena. Limestone breccias in dark clay matrix 8.06-8.44 m, 13.39-13.70 m, 15.98-16.43 m, 17.87-17.94 m, 28.32-28.60 m. Some geopetal cavities, 20° to 30° dip. Some calcite veins with minor pyrite and galena. Some patchy grainstone and packstone. Darkening to mid-grey 26.27-28.32 m, with some breccia. Brecciated with clay and pyrite matrix 29.40-31.30 m. Continuing patchily brecciated with associated pyrite to 35.29 m. Brecciated 48.71-49.00 m. Some red (hematite) staining 48.18-48.71 m, 52.24-54.32 m, 63.00-70.00 m, and patchily below. Some bituminous cavities. Trace pyrite, ore minerals 97.00 to 120.50 m. Fine clay-grade silica common 100.00 to 120.50 m. Highly crinoidal and shelly in lowest 1.10 m.	118.27	118.53
	Limestone, abundant rudite crinoid and shell debris, some brecciation. Some fine silica.	1.04	119.57
	Argillaceous limestone, dark grey, abundant rudite crinoid debris, packstone/wackestone.	0.93	120.50

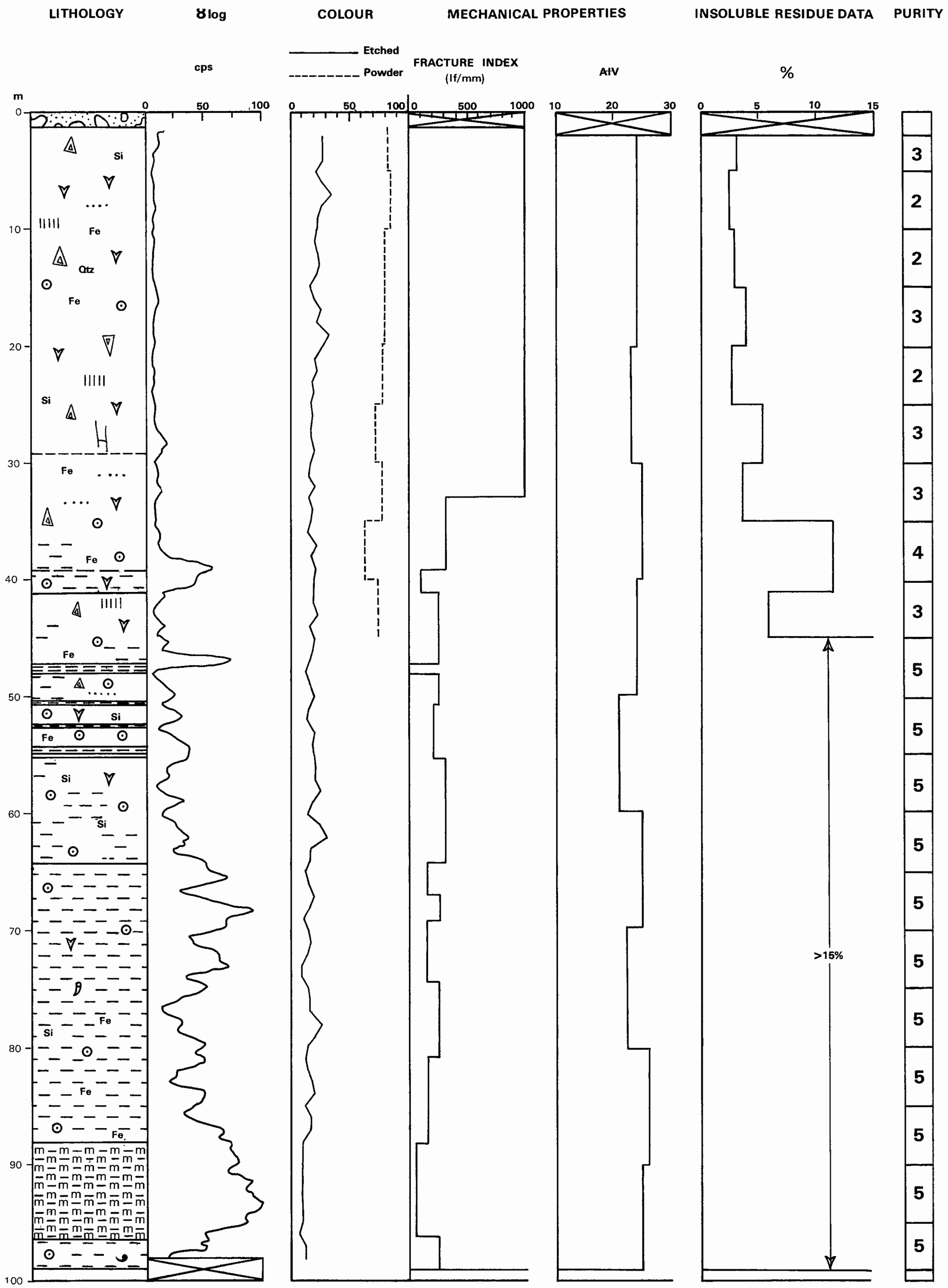
SD 75 SW 1 **7029 5123** **Blue Butts Farm**

Block B

Surface level +194 m
January 1980

		Thickness m	Depth m
	Topsoil	1.27	1.27
	Clay, brown.	0.27	1.54
Knoll-reef Limestone	Limestone, broken rubbly, waulsortian facies.	0.44	1.98
	Limestone, mid-grey, wackestone, waulsortian micrite. Common bryozoa, scattered rudite crinoid debris, rare grainstone pockets containing ostracods and algal-encrusted grains. Common stromatactis. Patchily silicified, locally common quartz euhedra, some cavity infillings of iron-rich dolomite locally altered to limonite. Clay-lined fissure 8.37-8.45 m. Widely-scattered flecks of pyrite below 9 m, some clay-coated stylolites.	8.02	10.00
	Limestone, mid-grey, wackestone, waulsortian micrite. Common crinoid and ostracod debris, some, locally common, bryozoa. Common stromatactis. Patchy silicification, abundant quartz euhedra 12.00-13.55 m. Some iron-rich dolomite infilling stromatactis. Locally common flecks of pyrite, some clay-lined stylolites 15.50-17.60 m.	7.60	17.60
	Limestone, pale grey to mid-grey, wackestone, waulsortian micrite. Common bryozoa, some rudite crinoid debris, subordinate shell, ostracod and algal-encrusted bioclastic debris. Common stromatactis. Alteration as above. Some black clay-coated stylolites with associated pyrite. Fractured, jointed core with some clay infilling 28.45-29.18 m.	11.58	29.18
	Mudstone, yellow-brown, non-calcareous, micaceous, silty.	0.07	29.25
	Limestone, mid-grey, wackestone, waulsortian micrite. Common bryozoa, crinoid debris, rare fragments of chambered algae. Common pockets of crinoid debris below 33 m. Rare gastropods 32.65 m. Some grainstone pockets, laminated fine arenite pelsparite 33.53-33.59 m. Broken core with clay-coated stylolites and fissures, some hematite and limonite staining, 29.87-30.26 m. Hematite and limonite staining 31.15-32.00 m, 33.59-34.17 m, 35.00-35.32 m. Clay-coated stylolites, cavity infillings, associated pyrite and linonite staining more common below 35.60 m. Increasingly muddy, pyritous crinoidal below 37.17 m. Very clayey, pyritous in lowest 0.23 m.	10.11	39.36
	Mudstone, dark grey, calcareous, common fine rudite crinoid, bryozoan debris. (dip 38°).	0.20	39.56
	Argillaceous limestone, dark grey, wackestone, common rudite crinoid debris, bryozoan debris, laminated. Pyritous.	1.73	41.29
	Limestone, mid-grey, wackestone, waulsortian facies. Crinoid and bryozoa are dominant allochems with subordinate shell debris. Stromatactis. Some minor silicification and dolomite. Some clay-lined stylolites and cavities with associated pyrite. Clay-rich, 41.85-41.92 m, 44.46-44.70 m, 46.16-46.34 m. Black mudstone parting 45.92 m. Increasingly clay-rich in lowest 0.03 m.	6.06	47.35
	Mudstone, black, scattered bryozoa and crinoid debris.	0.79	48.14
	Limestone, mid-grey to dark grey, waulsortian facies as above. Alterations and impurities as above. Clotted, peloidal micrite 49.60-49.76 m. Coarse arenite grainstone, 50.04-50.36 m. Coarsely crinoidal in lowest 0.11 m and 49.76-49.87 m. Some graded bedding. Mudstone parting 49.94 m.	2.22	50.36
	Mudstone, black.	0.18	50.54
	Limestone, mid-grey, waulsortian biomicrites and micrites, rare stromatactis, sporadic bryozoa, common coarse rudite crinoid debris. Some pockets of arenite grainstone. Coral 50.90 m. Patchily silicified matrix, stylolitic, some pyrite, mudstone parting at 50.92 m.	1.77	52.31
	Mudstone.	0.17	52.48
	Limestone, mid-grey, wackestone, common rudite crinoid debris, very rare bryozoa, some algal fragments. Some arenite grainstone pockets. Locally grades to coarsely crinoidal packstone. Some silificiation, clayey stylolites, pyritous.	1.70	54.18
	Mudstone.	0.62	54.80

B
SD 75 SW 1


LITHOLOGY
γ log
cps
COLOUR
Etched
Powder
MECHANICAL PROPERTIES
FRACTURE INDEX
(lf/mm)
AIV
INSOLUBLE RESIDUE DATA
%
PURITY
>15%

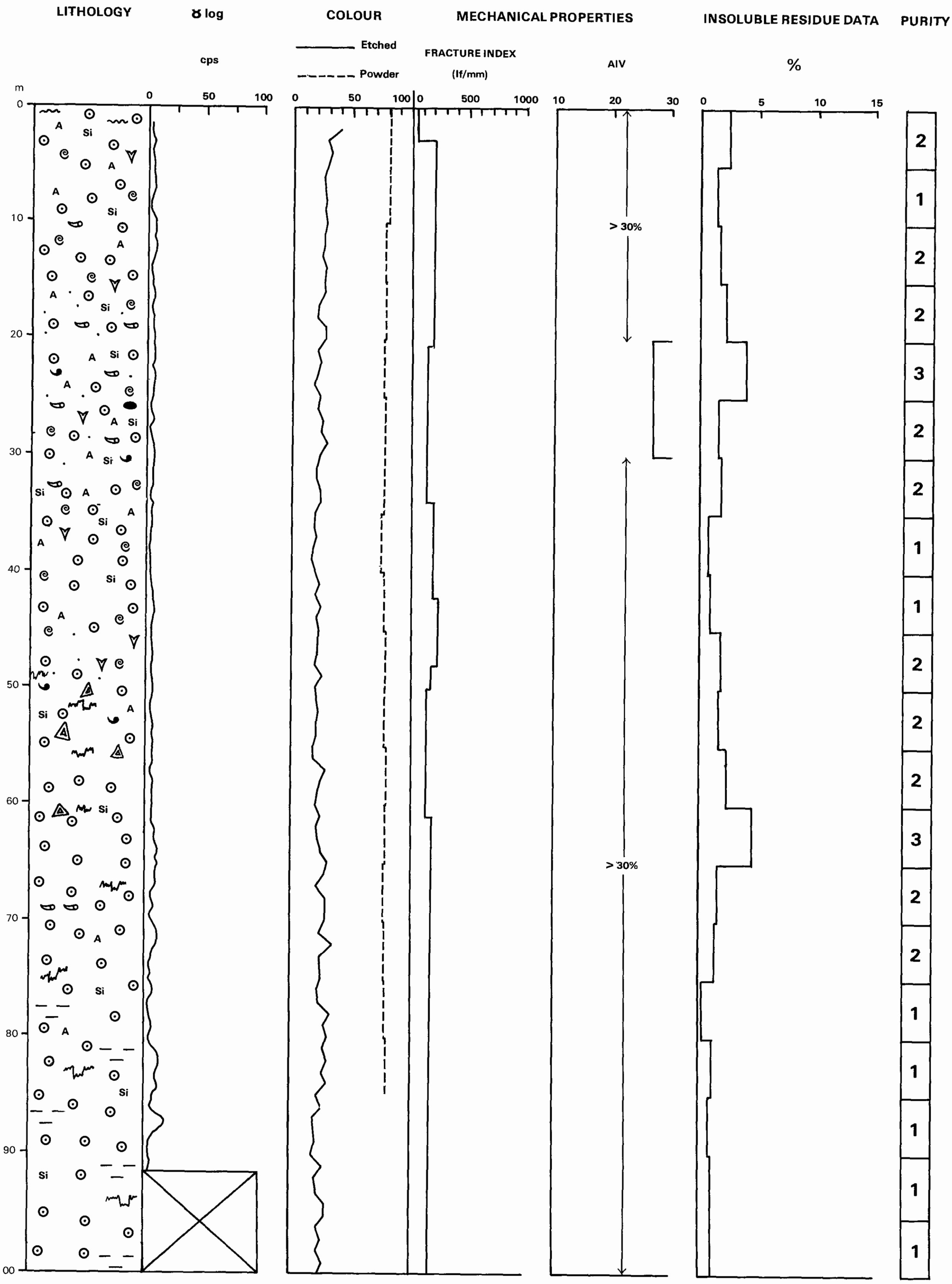
	Limestone, mid-grey, wackestone, waulsortian facies. Patchily silicified and pyritised.	0.24	55.04
	Argillaceous limestone, dark grey, wackestone, scattered rudite crinoid debris, subordinate bryozoa and shell derbris. Locally abundant bryozoa, scattered coral. Laminated (dip 30°-40°). Thin, irregular bands of waulsortian micrites 55.04-55.12 m, 56.15-56.38 m. High level of silicification, scattered irregular silicified patches 57.08-58.65 m, 60.54-61.30 m. Variable clay content. Pyritous. Graded unit 62.89-64.23 m.	9.19	64.23
	Argillaceous limestone/calcareous mudstone, dark grey, wackestone, widely scattered crinoid and bryozoa debris, some shell debris. Locally grades to calcarous mudstone. Laminated (dip 32°). Sporadic fragmented coral 74.60-75.04 m. Pyritous, patchily silicified. Some limonite staining.	24.02	88.25
	Mudstone, dark grey, micaceous, scattered bryozoa and crinoid debris. Pyritous. Sharp base.	8.18	96.43
	Argillaceous limestone, dark grey, wackestone, locally grades to packstone, common coarse arenite and rudite crinoid, coral, bryozoa and shell debris. Laminated (dip 30°).	2.47	98.90

SD 74 SW 7 **7093 4102** **Withgill Knoll** **Block C**

Surface level +99 m
December 1979

		Thickness m	Depth m
	Topsoil and clay	0.36	0.36
Knoll-reef Limestone	Limestone, mid-grey, coarse arenite to coarse rudite, abundant crinoid debris, packstone. Some current sorting. Rare shell, foraminifera, bryozoa and algal debris. Very uniform, monotonous lithology. Minor patchy silicification, patchy limonite staining.	20.73	21.09
	Limestone, mid-grey, coarse rudite packstone, abundant crinoid debris, micrite matrix. Some coral, foraminifera, algae, shelly and bryozoa debris. Rare stromatactis. Some areas of minor brecciation. Some irregular cherty silicification 20.00-25.00 m.	12.93	34.02
	Limestone, mid-grey, coarse rudite packstone, abundant crinoid debris, spar and micrite matrix. Well sorted. Rare foraminifera, bryozoa and algal debris. Rare stromatactis. Patchy silicification and hematite/limonite staining.	12.74	46.76
	Limestone, mid-grey, coarse rudite packstone, abundant crinoid debris, micrite matrix. Rare ostracod, coral, bryozoa and algal debris. Some stromatactis. Patchy silicification, sporadic pyrite.	9.85	56.61
	Limestone, mid-grey, coarse rudite packstone, abundant crinoid debris, micrite matrix. Well sorted. Rare stromatactis.	3.44	60.05
	Limestone, mid-grey, coarse rudite packstone, common crinoid debris, some coral, forminifera and shelly fragments. Common stromatactis. Patchy silicification.	2.52	62.57
	Limestone, mid-grey, arenite and rudite packstone, common crinoid debris, subordinate finer bioclasts, spar and micrite matrix. Well sorted. Some hematite staining, rare disseminated pyrite, some brownish-green clay-grade mineral infilling cavities.	34.98	97.55
	Limestone, mid-grey, arenite and rudite packstone, common crinoid debris, subordinate finer bioclasts, micrite matrix. Well sorted. Patchy silicification, rare pyrite.	10.44	107.99
	Limestone, mid-grey, arenite and rudite crinoidal packstone, well sorted. Scattered finer bioclastic debris. Spar and micrite matrix. Stylolitic. Minor silicification. Some veins with baryte and pyrite. Sporadic clay alteration minerals.	21.01	129.00

C
SD 74 SW 7



LITHOLOGY
γ log
cps
COLOUR
Etched
Powder
MECHANICAL PROPERTIES
FRACTURE INDEX
(lf/mm)
AIV
> 30%
> 30%
INSOLUBLE RESIDUE DATA
%
PURITY
2
1
2
2
3
2
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1
1
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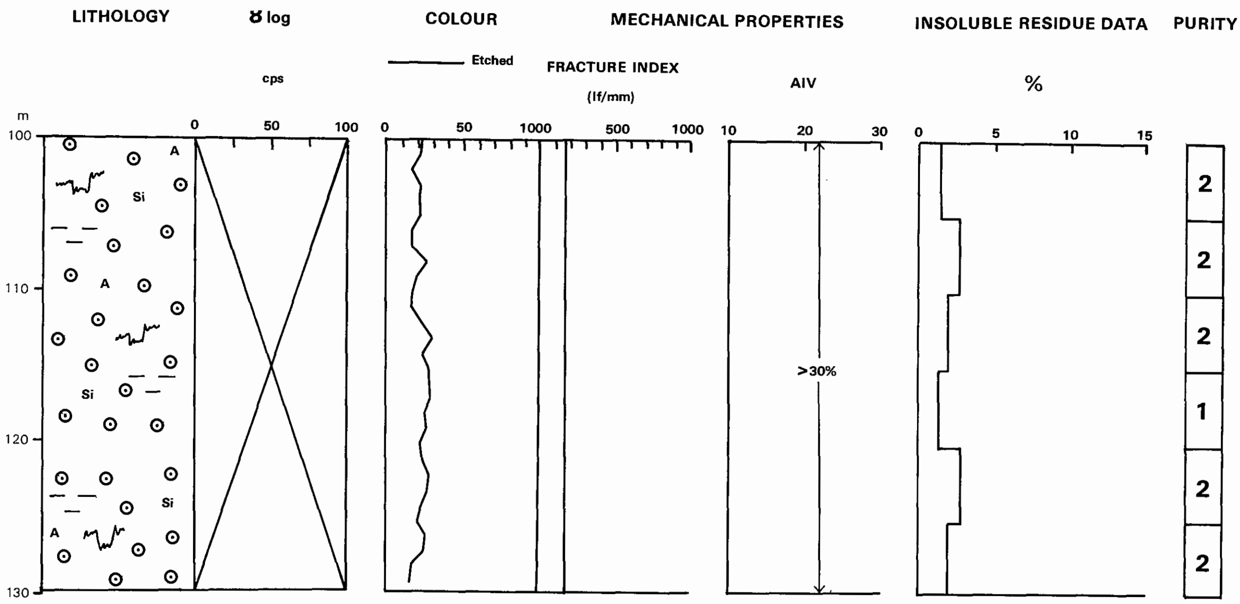
1

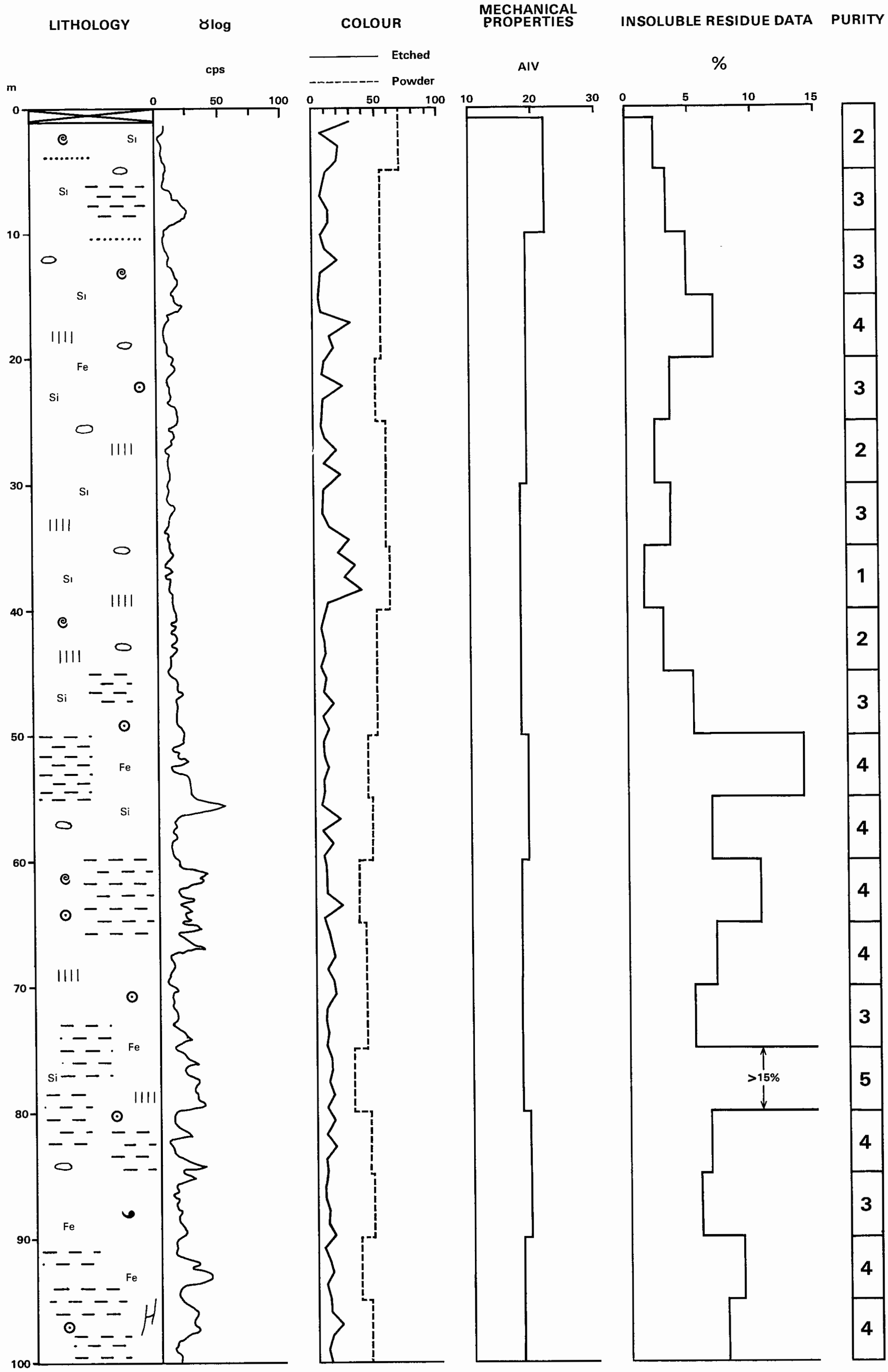


SD 74 SW 8 **7380 4290** **Brungerley Bridge** **Block C**

Surface level +70 m
March 1980

		Thickness m	Depth m
	Made ground	0.98	0.98
Knoll-reef Limestone	Limestone, mid to dark grey, wackestone, fairly uniform lithology throughout. Sparry grainstones locally and patchily developed. Very fine arenite finely comminuted shell debris, foraminifera, peloidal debris and ostracods. Rare pale grey beds with algae-encrusted bioclasts. Scattered patchily silicified rudite crinoid and coral debris. Variable, generally low, clay content. Relatively clay-rich 6.00-9.10 m, 12.78-16.50 m. Patchy dolomitisation, silicification, cherty nodular silicification, and pyritisation throughout.	44.52	45.50
	Limestone, dark grey, wackestone, clay-rich, variable clay-content. Fine arenite ostracods and foraminifera, subordinate peloid, spine and calcisphere debris. Some sparry grainstones at intervals, 49.84-55.79 m, 60.42-66.90 m, 73.50-85.50 m, 91.25-100.60 m. Widely scattered rudite crinoid debris 45.50-66.90 m. Sporadic disseminated dolomite, euhedral quartz and minor silicification. Pyritous. Stiff yellow clay infilling fissure 87.70 m. Fractured, calcite-veined core, fault breccia? 91.25-100.60.	55.10	100.60

C
SD 74 SW 8

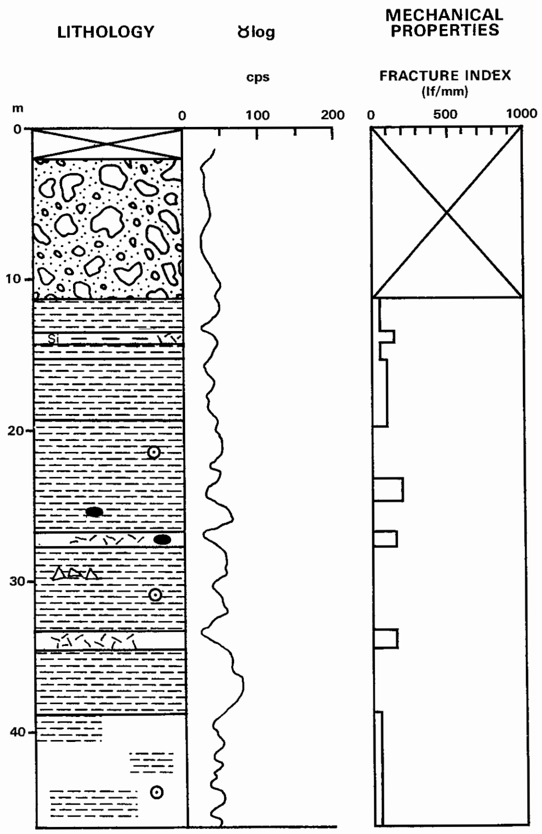

LITHOLOGY
ɣlog
cps
COLOUR
Etched
Powder
MECHANICAL PROPERTIES
AIV
INSOLUBLE RESIDUE DATA
%
PURITY
m
0
10
20
30
40
50
60
70
80
90
100
0
50
100
0
50
100
10
20
30
0
5
10
15
Si
Fe
>15%
2
3
3
4
3
2
3
1
2
3
4
4
4
4
3
5
4
3
4
4

SD 74 SW 9 **7055 4103** **Withgill Farm** **Block C**

Surface level +87 m
January 1980

	Thickness m	Depth m
Topsoil and clay.	2.10	2.10
Boulder clay, stiff grey clay with common pebbles and boulders of limestone, argillaceous limestone, feldspathic sandstone and gritstone.	9.10	11.20
Mudstone, grey, laminated, micaceous. Dip 27°.	2.25	13.45
Argillaceous limestone, dark grey, fine arenite wackestone. Common spines. Some silicification, chert and pyrite.	0.71	14.16
Mudstone, slumped.	1.08	15.24
Mudstone, laminated, calcareous laminae. Locally grades to argillaceous limestone. Locally slumped with erosive sedimentary structures.	4.16	19.40
Mudstone, dark grey, laminated, non-calcareous. Dip 28°. Some thin crinoidal bands. More massive, wavy-bedded, 23.84-25.36 m.	7.47	26.87
Limestone, dark grey, laminated, fine arenite abundant spines and spicules, current orientated. Some thin cherty bands.	0.74	27.61
Mudstone, laminated, some calcareous laminae. Limestone conglomerate 29.51-29.65 m. Non-laminated mudstone 29.65-30.68 m.	3.07	30.68
Limestone, graded unit, common silicified spines, crinoid debris towards base.	0.40	31.08
Mudstone, laminated, slumped.	2.15	33.23
Limestone/Mudstone, dark grey, predominantly limestone with thin mudstones. Common silicified spines.	1.33	34.56
Mudstone, dark grey, laminated and non-laminated. Thin limestone band 36.03-36.24 m. Some slump structures.	4.21	38.77
Mudstone/Limestone, grey, micaceous, wavy-bedded. Thin limestone interbeds, graded units with limestone conglomerates. Some strongly deformed beds. Rare coarsely crinoidal bands.	7.51	46.28

C
SD 74 SW 9

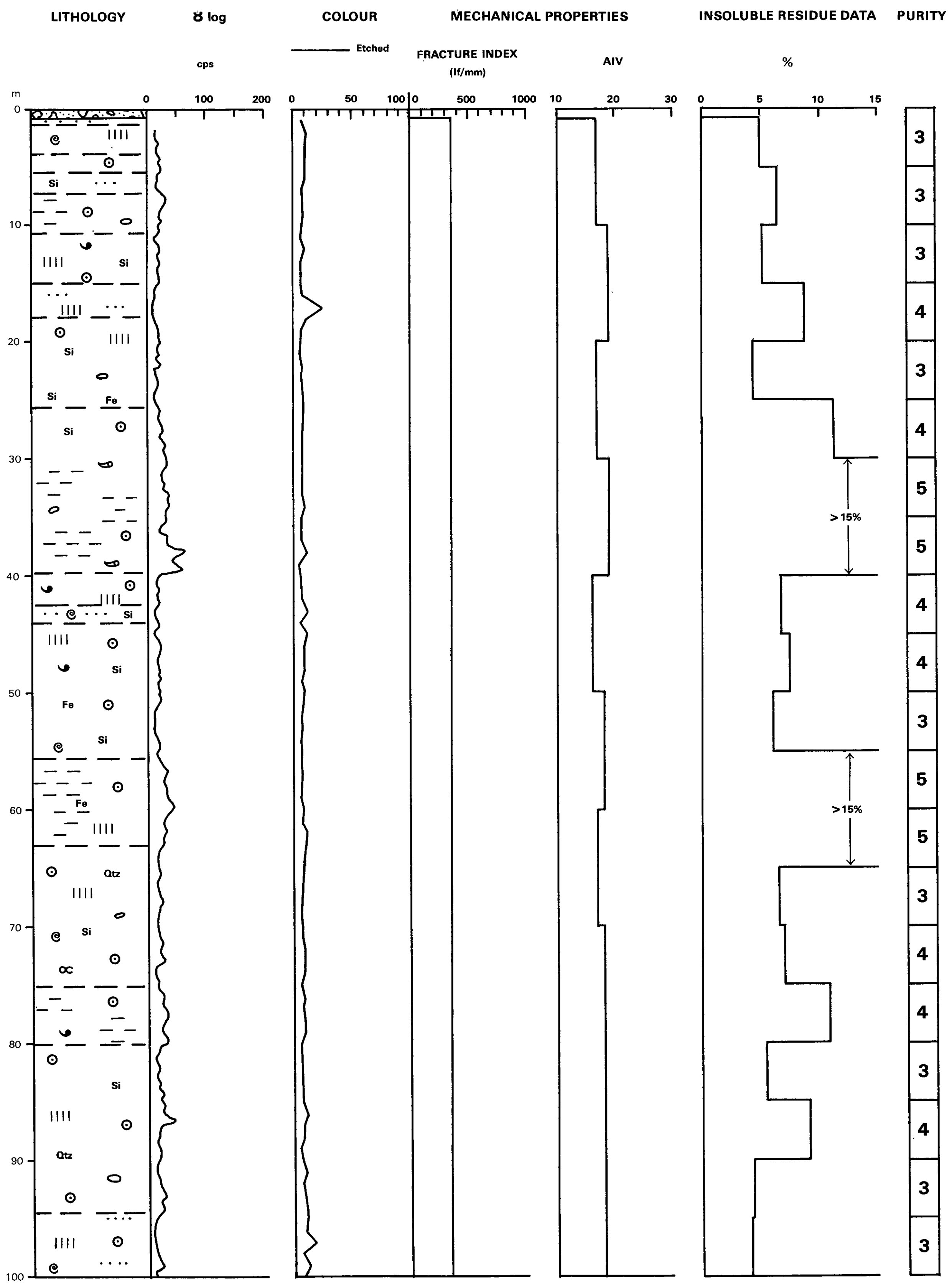

LITHOLOGY
γ log
cps
MECHANICAL PROPERTIES
FRACTURE INDEX (If/mm)
m
0
10
20
30
40
0
100
200
0
500
1000
Sl

SD 74 SE 1 **7893 4450** **Smithfield Farm, Downham** **Block C**

Surface level +158 m
January 1980.

		Thickness m	Depth m
	Made ground	0.75	0.75
Chatburn Limestone	Limestone, dark grey, monotonous lithology throughout, fine arenite grainstones and packstones with some wackestones. Thin mudstone partings. Finely comminuted crinoid, shell, peloid, foraminifera and ostracod debris. Some algae-encrusted bioclasts. Variable clay content. 45° dip. Patchily dolomitised throughout. Some silicified bioclasts, patchy silicification and rare chert. Sporadic pyrite. Common *Syringopora* 4.83-5.22 m.	24.89	25.64
	Limestone/Argillaceous limestone, dark grey, wackestone, clay-rich. Bioturbated, scattered crinoid, ostracod and coral debris. Some *Syringopora*. Sporadic silicified bioclasts, some irregular silicified bands. Scattered pyrite.	6.36	32.00
	Argillaceous limestone, dark grey, grades to calcareous mudstone 37.70-39.59 m, rare *Syringopora*.	7.64	39.64
	Limestone, dark grey, fine arenite wackestone with some packstones, scattered rudite crinoid and shell debris. Fine arenite grainstone 42.50-44.00 m. Patchily dolomitised and some patchy silicification. Scattered silicified bioclasts throughout, sporadic flecks of pyrite.	16.03	55.67
	Argillaceous limestone, dark grey, arenite, wackestone, scattered rudite crinoid debris, some disseminated dolomite, pyritous.	7.43	63.10
	Limestone, dark grey, fine arenite wackestone, uniform monotonous lithology. Widely scattered, patchily silicified crinoid, ostracod and foraminifera debris. Rare bioturbation. Rare algae-encrusted shell debris. Some disseminated dolomite, pyritous.	12.16	75.26
	Limestone/Argillaceous limestone, fine arenite, wackestone.	4.84	80.10
	Limestone, dark grey, fine arenite wackestone, locally common ostracods, patchily dolomitsed.	14.40	94.50
	Limestone, dark grey, fine arenite grainstones with some wackestones. Spar matrix. Scattered rudite crinoid and shell debris. Scattered disseminated dolomite throughout. Locally common silicified patches and bands. Rare bioturbation. Some argillaceous limestone 100.24-101.00 m	18.27	112.77
	Limestone, dark grey, wackestone, micrite matrix. Some sparry grainstones and packstones 112.77-123.00 m. Scattered, locally common, rudite crinoid debris, subordinate shell and ostracod debris. Sporadic *Syringopora*, locally concentrated in bands. Disseminated and patchy dolomite throughout. Some argillaceous limestone beds 123 m to 131 m and 139.02-146.50 m. Pyritous thoughout, minor silicification and authigenic quartz throughout.	33.73	146.50

C
SD 74 SE 1


LITHOLOGY
ɤ log
cps
COLOUR
Etched
MECHANICAL PROPERTIES
FRACTURE INDEX
(lf/mm)
AIV
INSOLUBLE RESIDUE DATA
%
PURITY
m
Si
Fe
Qtz
>15%
>15%
3
3
3
4
3
4
5
5
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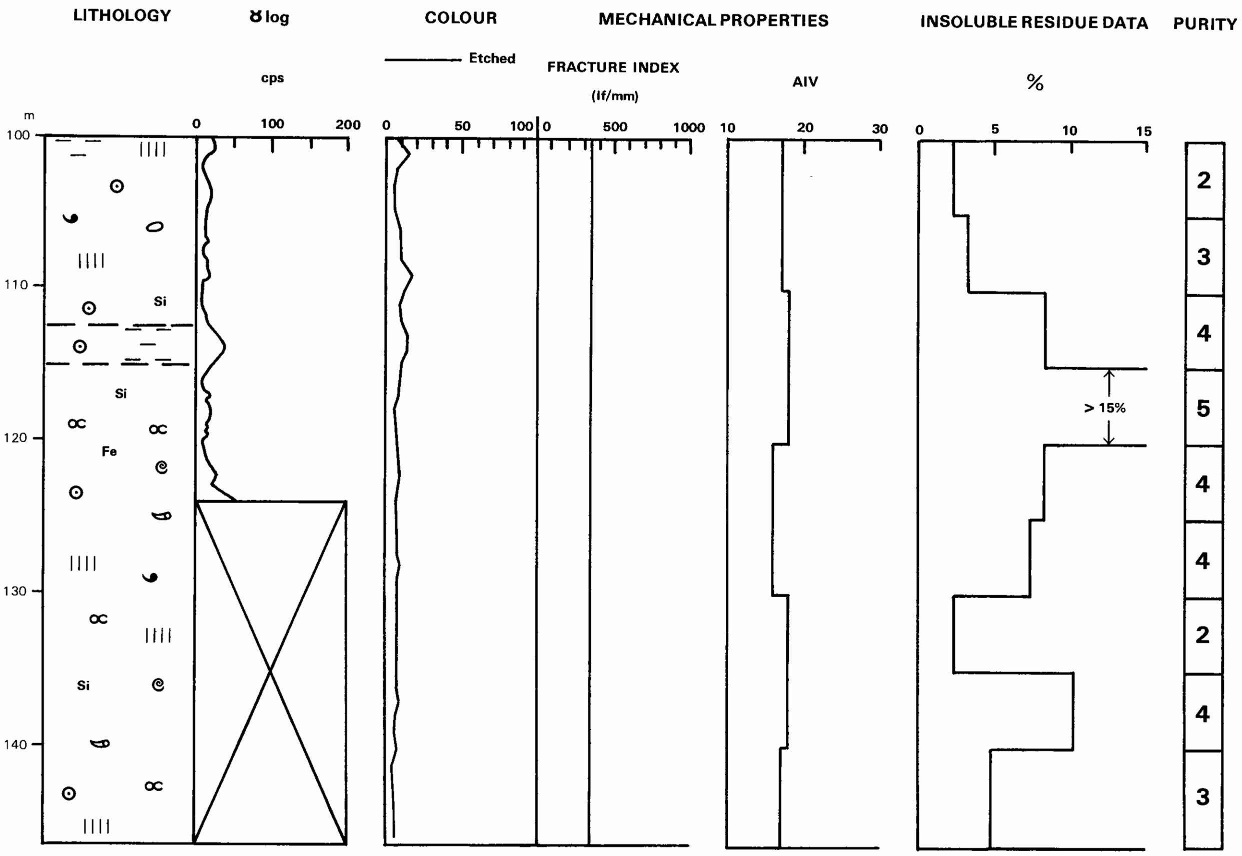
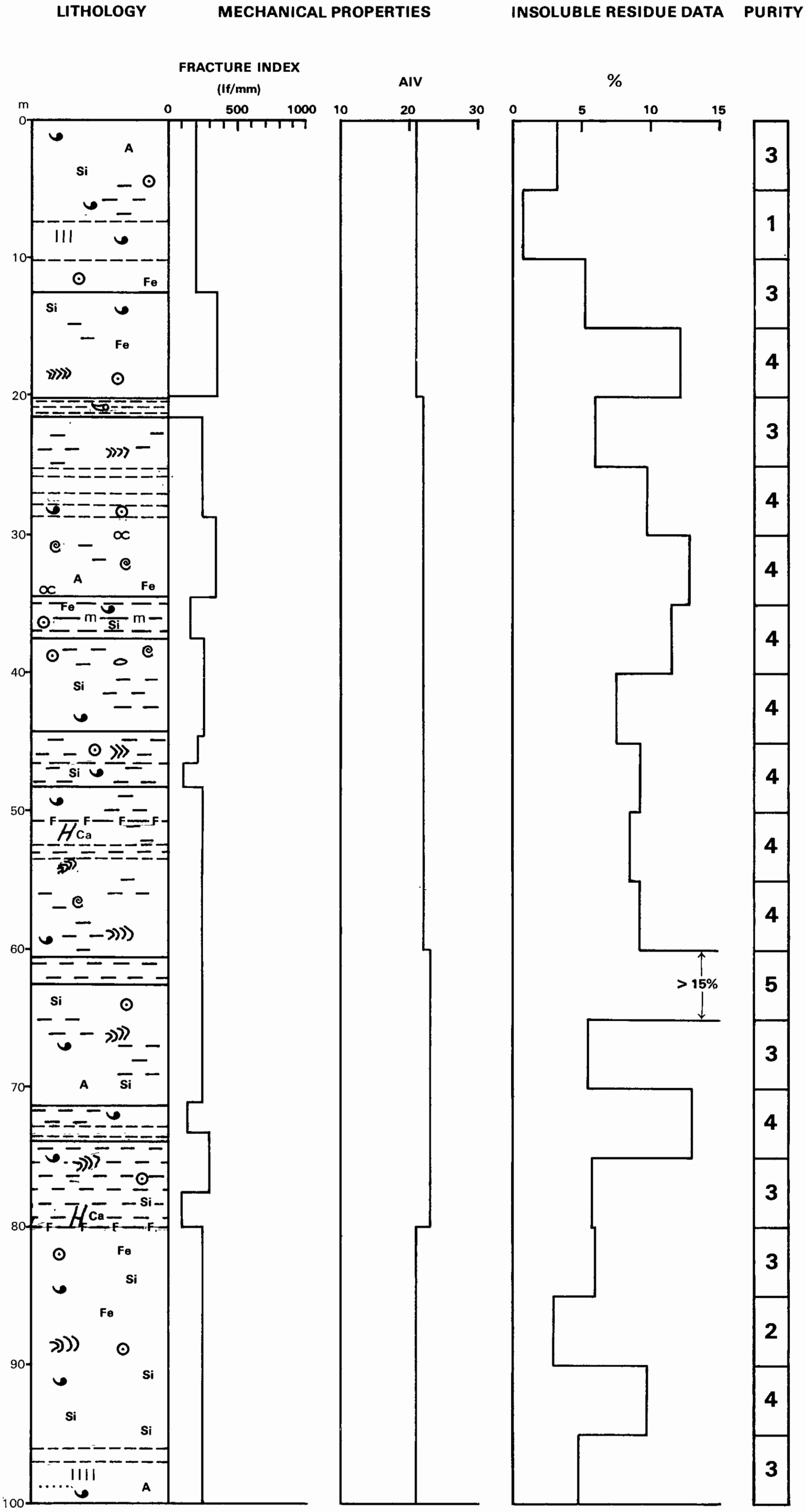


SD 74 SE 1 s **7731 4399** **Chatburn Road-Cutting** **Block C**

Surface level +107 m
August 1979

		Thickness m	Depth m
Chatburn Limestone	Limestone, dark grey, wackestone, scattered arenite shell and crinoid debris rare algae. Some patchy disseminated clay, silicified bioclasts and fine silica. Thin shaly partings 6.80 m, 10.05 m, 10.15 m.	12.50	12.50
	Limestone, dark grey, wackestone, scattered arenite crinoid and shell debris, rare bioturbation. Common shale partings, clay-rich, locally argillaceous. Some silicification and pyrite. Rare current lamination.	7.62	20.12
	Shale, some thin argillaceous limestone interbeds.	1.40	21.52
	Limestone, dark grey, fine arenite wackestone, rare bioclasts. Clay-rich, thin shale partings, shale 25.30-25.42 m, 25.90-27.05 m, 28.10 m, 28.75 m. Common bioclasts, particularly foraminifera, 28.22-34.50 m. Common ostracods, and oncolites 33.50-34.50 m.	12.98	34.50
	Limestone/Shale, dark grey, thin limestones interbedded with micaceous shales.	3.00	37.50
	Limestone, dark grey, arenite wackestone, scattered rudite crinoid and shell debris, some ostracod and foraminifera debris, bioturbated. Some fine silica.	6.80	44.30

C
SD 74 SE 1S


LITHOLOGY
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
FRACTURE INDEX
(lf/mm)
AIV
%
m
0
500
1000
10
20
30
0
5
10
15
> 15%
3
1
3
4
3
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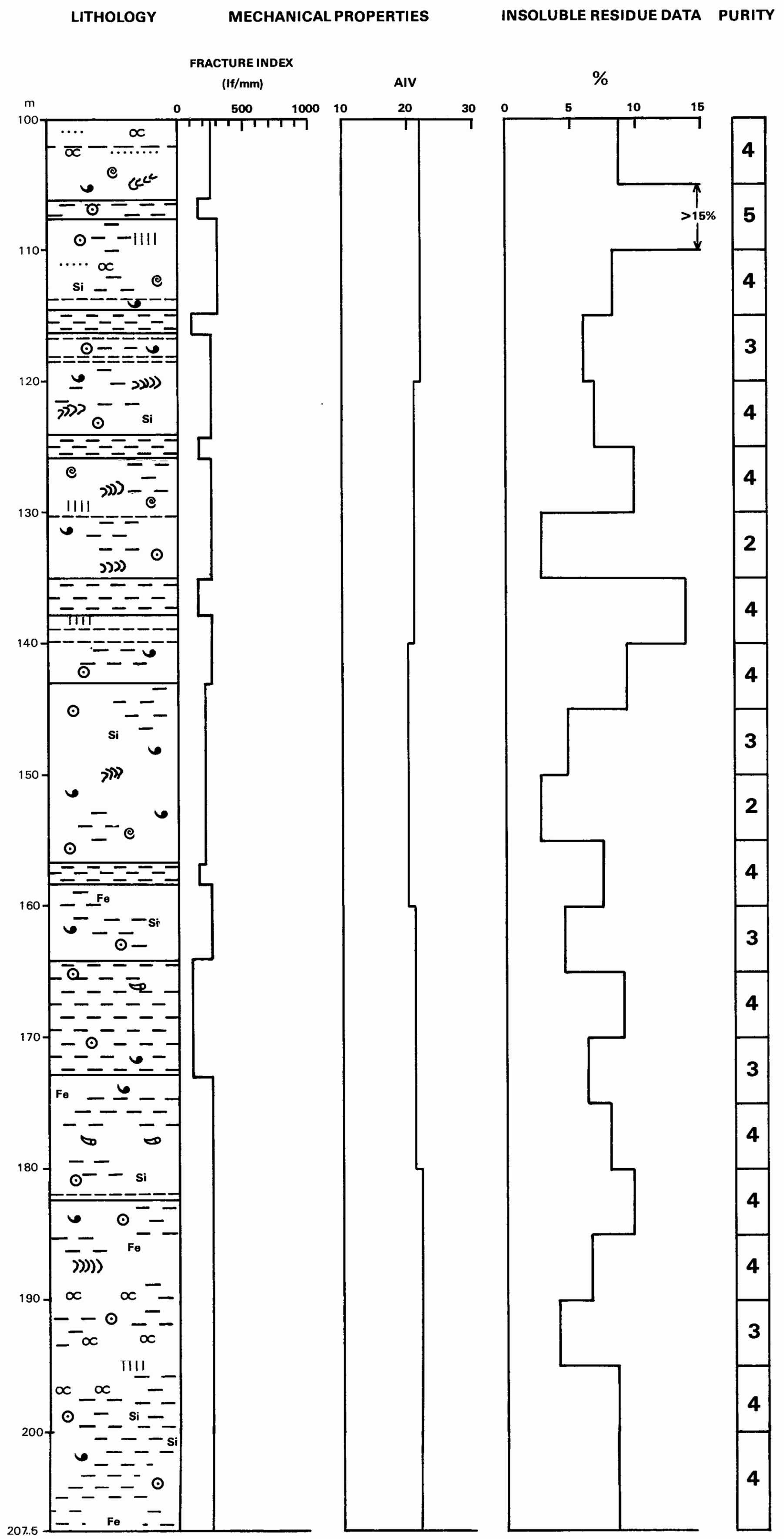
3

Argillaceous limestone, dark grey, arenite wackestone, some bioturbation. Common shale partings, particularyly 46.50-48.20 m. Common silicification and pyrite.	3.90	48.20
Limestone, dark grey, wackestone, clay-rich common pyrite and silica. Reverse fault 50.50 m with common calcite veining. Thin shales 52.30 m, 53.20 m. Common bioturbation 50.50-60.25 m.	12.05	60.25
Argillaceous limestone/shale, dark grey, wackestone, common shale beds and partings	2.00	62.25
Limestone, dark grey, fine arenite wackestone, bioturbated, clay-rich. Some pyrite and silicification.	8.85	71.10
Argillaceous limestone, dark grey, fine arenite wackestone, bioturbated. Common thin shale interbeds. Shale 72.50 m, 72.30 m. Some fine silica, silicified bioclasts and pyrite.	2.25	73.35
Limestone, dark grey, fine arenite wackestones, some shale partings, common calcite veining 77.50-80.00 m. Reverse fault at 80.00 m. Few shale partings 80.00 m to 96.00 m. Some bioturbated beds. Thin shales 96.00 m, 97.00 m. Some patchy dolomitisation 96.00-97.00 m. Rare chert nodules 93.00-95.00 m.	23.65	97.00
Limestone, dark grey, fine arenite packestone, common bioclastic and peloid debris, scattered oncolites, oncolite band 98.50 m. Patchy dolomitisation 98.00-99.00 m. Thin shale 101.80 m. Pale grey grainstone 101.80-102.50 m. Locally bioturbated.	9.20	106.20
Argillaceous limestone, dark grey, coarse arenite, common crinoid debris, common shale interbeds.	1.40	107.60
Limestone, dark grey, wackestone, scattered arenite and rudite crinoid, shell, ostracod, foraminifera and algal-encrusted bioclasts, rare shale interbeds. Thin shale 113.80 m.	7.10	114.70
Limestone/Shale, dark grey, mixed sequence.	1.55	116.25
Limestone, dark grey, wackestone, scattered crinoid and shell debris, bioturbated. Variable clay content, locally clay-rich. Some beds rich in foraminifera. Patchy dolomitisation. Thin shale 130.40 m.	7.80	124.05
Limestone/Shale, dark grey, mixed sequence.	1.80	125.85
Limestone, dark grey, wackestone, scattered crinoid and shell debris, bioturbated. Variable clay content, locally clay-rich. Some beds rich in foraminifera. Patchy dolomitisation. Thin shale 130.40 m.	9.20	135.05
Limestone/Shale, dark grey, mixed sequence.	2.70	137.75
Limestone, dark grey, wackestone, scattered crinoid and shell debris, bioturbated, some argillaceous beds, patchy silicification. Common shale partings 143.00-156.70 m. Thin shale 138.90 m, 139.90 m.	18.95	156.70
Limestone/Shale, dark grey, mixed sequence. Pyritous.	1.55	158.25
Limestone, dark grey, wackestone, common shale partings, patchily silicified, some pyrite.	5.85	164.10
Limestone/Shale, dark grey, mixed sequence. Shales thicken to 0.2 m.	8.80	172.90
Limestone, dark grey, wackestone, scattered arenite crinoid, shell and coral debris, common *Syringopora* 177.80 m. Common shale interbeds and partings. Shale 182.00-182.40 m. Some argillaceous beds. Some bioturbated beds. Common oncolites 190.00 m, 193.00 m, 198.00 m. Patchy silicification, some disseminated dolomite, pyritous.	34.60	207.50

C
SD 74 SE 1S cont.

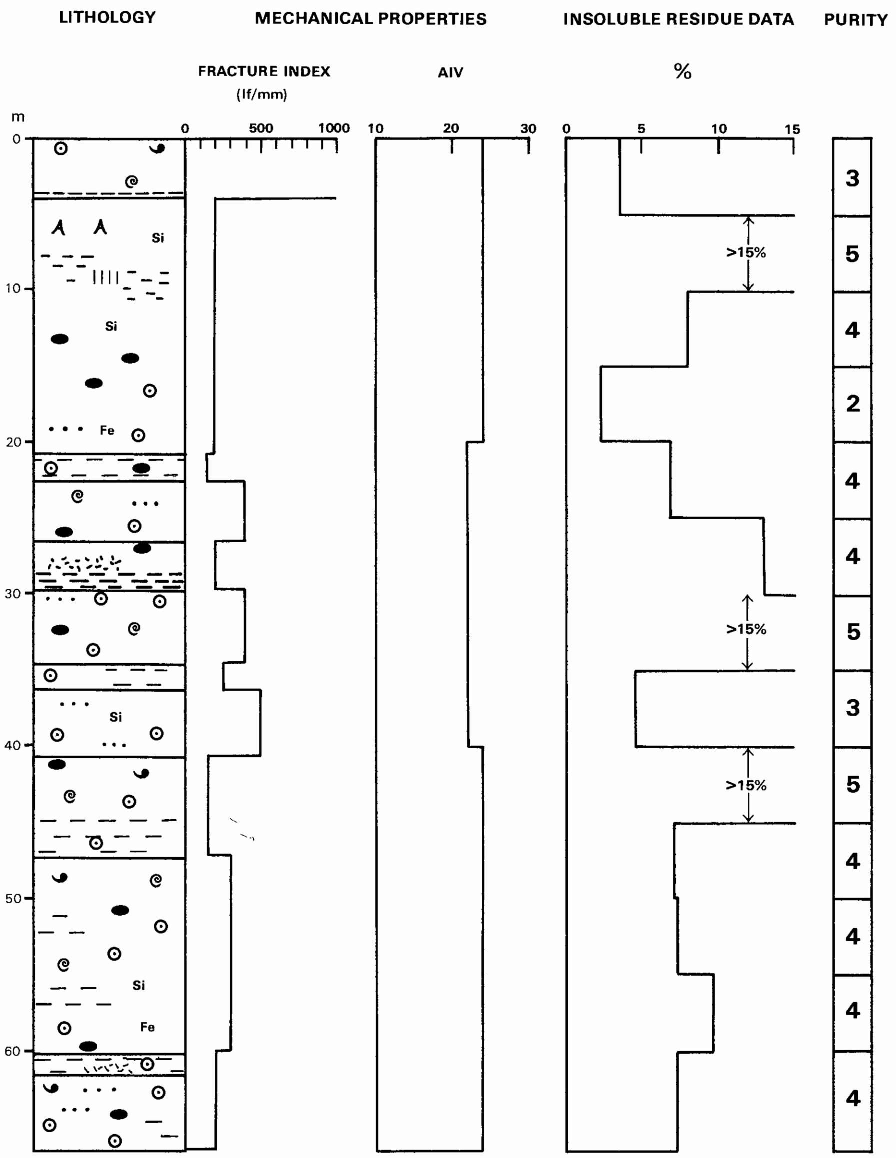


Surface level +177 m
October 1979

		Thickness m	Depth m
Knoll-reef Limestone	Limestone, mid-grey, packstone, some grainstone pockets. Common rudite crinoid and shell debris, in upper 1.50 m. Some foraminifera and spines in sparry pockets. Thin brown shale at base.	4.03	4.03
Peach Quarry Limestone	Limestone, mid-grey, packstone, abundant coarse arenite to fine rudite crinoid, shell, foraminifera and spine debris. Abundant dasycladacean algae in band at 6 m. Some shale interbeds, common thin shales 7.60-10.50 m. Patchily silicified bioclasts, chert 6.00 m, 12.70-16.50 m. Some pyrite and patchy dolomitisation. Some grainstone beds 10.50-20.80 m. Coarsely crinoidal 16.50-18.50 m.	16.77	20.80
	Limestone/Shale, dark grey, mixed sequence, common chert nodules.	1.80	22.60
	Limestone, mid-grey, fine rudite grainstone and packstone, abundant comminuted crinoid, faoraminifera, shell and peloid debris. Some silicification, dolomitisation and disseminated clay. Thin shale partings. Sporadic chert 25.40-26.50.	3.90	26.50
	Limestone, mid-grey, packstone and wackestone, clay-rich, common shale interbeds, particularly 28.50-29.70 m.	3.20	29.70
	Limestone, mid-grey, coarse arenite grainstone 29.70-30.50 m, crinoidal packstone/grainstone 30.50-34.50 m. Common foraminifera. Patchy silicification, thin cherts 32.00-33.00 m.	4.80	34.50
	Limestone, mid-grey, coarsely crinoidal packstone, thin shale partings.	1.70	36.20
	Limestone, mid-grey, arenite grainstone, abundant comminuted bioclastic and peloidal debris, pale grey abundant crinoid debris 38.50-39.50 m. Sporadic silicified bioclasts, some fine silica, rare pyrite.	4.40	40.60
	Limestone, dark grey, packstone, arenite crinoid, foraminifera, spine and shell debris. Common shale partings, increasingly shaly 44.50-47.30 m. Chert 40.60-41.00 m. Some patchy dolomitisation and fine silica.	6.70	47.30
	Limestone, mid-grey, coarse rudite crinoidal grainstone and packstone; some arenite foraminifera, peloid and spine debris; some irregular bands of fine arenite grainstone. Scattered cherts 50.00-52.00 m, 59.50-60.10 m. Thin shales, 52.05-52.20 m, 56.00-57.00 m. Some fine silica and patch bioclastic silicification. Scattered pyrite flecks 58 m.	12.80	60.10
	Limestone, mid-grey, arenite packstone, common spines, clay-rich, common shale partings.	1.40	61.50
	Limestone, mid-grey, fine rudite grainstone, abundant crinoid debris, subordinate shell, peloid and foraminifera debris. Common algae-encrusted bioclasts. Some nodular chert 63.00 m. Clay-rich 65.00 m.	5.00	66.50

C

SD 74 SE 2s


LITHOLOGY
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
FRACTURE INDEX
(lf/mm)
AIV
%
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Si
Si
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Si
Fe
>15%
>15%
>15%
3
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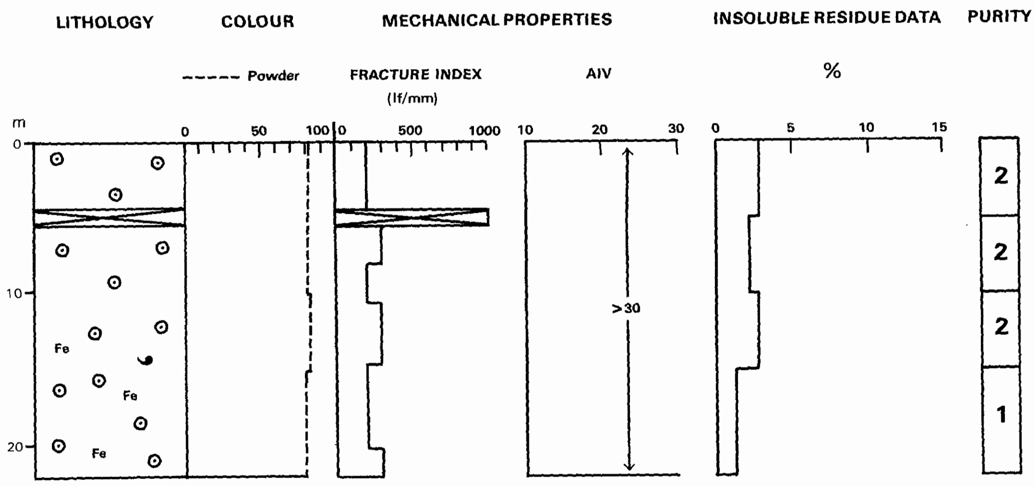
4

SD 74 SE 4 s **7607 4265** **Bellmanpark Quarry** **Block C**

Surface level +105 m
April 1980

		Thickness m	Depth m
Knoll-reef Limestone	Limestone, pale grey, packstone, abundant coarse rudite crinoid debris, graded bedding. Sporadic fragmented bryozoa 12 m, 20 m, 21 m. Scattered flecks of pyriteand some disseminated dolomits. Pyrite and limonite staining common 13.00-22.00 m.	22.00	22.00

C
SD 74 SE 4s


LITHOLOGY
COLOUR
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
Powder
FRACTURE INDEX
(lf/mm)
AIV
%
m
0
10
20
0
50
100
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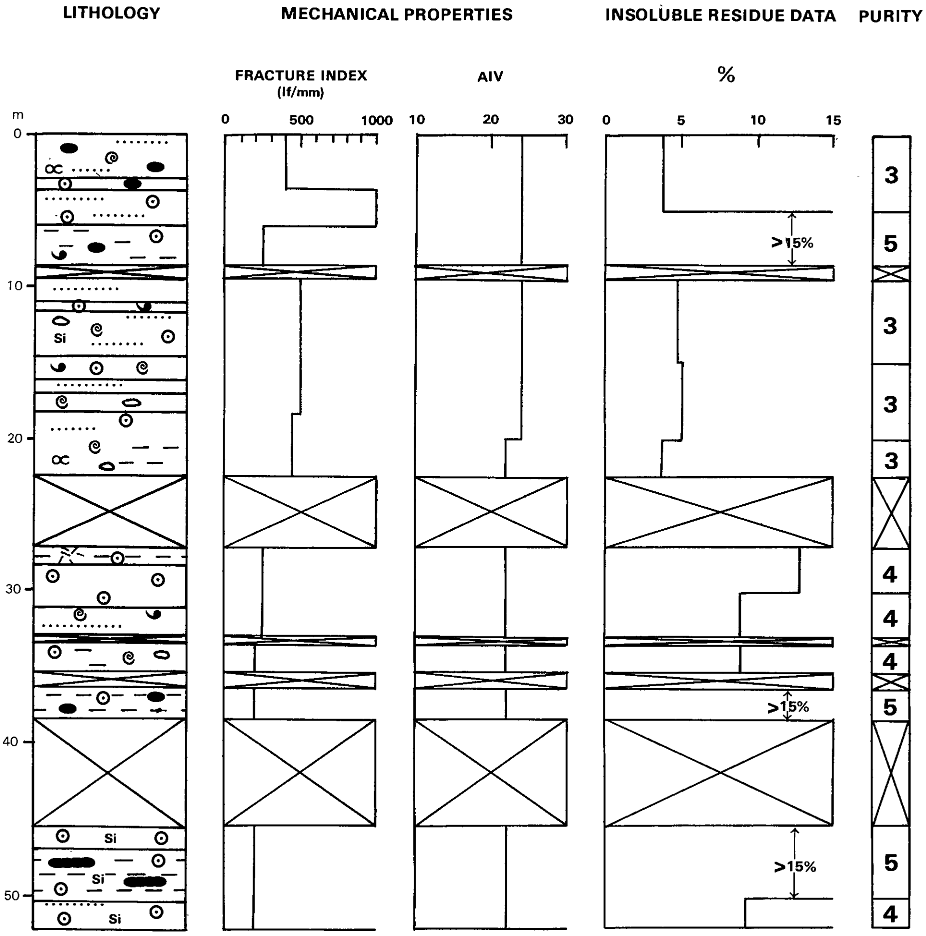
500
1000
10
20
30
0
5
10
15
Fe
Fe
Fe
>30
2
2
2
1

SD 74 SE 5s **7641 4322** **Peach Quarry** **Block C**

Surface level +103 m
April 1980

		Thickness m	Depth m
Peach Quarry Limestone	Limestone, mid-grey, grainstone, scattered rudite crinoid debris, rare oncolites, well sorted. Common large chert nodules.	3.00	3.00
	Limestone, dark grey, packstone, common rudite crinoid debris with some peloid and shell debris. Some cherts.	0.70	3.70
	Limestone, mid-grey, medium arenite grainstone, abundant peloid debris, some rudite crinoid debris, common foraminifera. Well sorted.	2.30	6.00
	Limestone, mid-grey, wackestone, scattered rudite crinoid, shell and coral debris, some oncolites, sporadic ostracods and foraminifera. Clay-rich, locally argillaceous, some shale partings. Scattered chert nodules.	2.60	8.60
	Gap.	0.90	9.50
	Limestone, mid-grey, medium arenite grainstone, rare intraclasts.	1.50	11.00
	Limestone, mid-grey, coarse arenite packstone.	0.60	11.60
	Limestone, mid-grey, medium arenite grainstone, some irregular, patchy silicification.	2.90	14.50
	Limestone, mid-grey to dark grey, packstone, coarse arenite.	1.65	16.15
	Limestone, mid-grey to dark grey, coarse arenite grainstone	0.85	17.00
	Limestone, mid-grey, fine arenite wackestone, scattered foraminifera, shell, ostracod and spine debris.	1.15	18.15
	Limestone, mid-grey, coarse arenite packstone passing locally into coarse arenite grainstone, common algae-encrusted bioclasts 21.50 m. Common shales 20.05-20.75 m. Some patchy bioclastic silicification. Some channelling.	4.33	22.48
	Gap.	4.50	26.98
	Limestone, mid-grey, fine arenite packstone, common spines, common shale interbeds.	1.26	28.24
	Limestone, mid-grey, some pale grey beds, rudite packstone, abundant rudite crinoid debris, subordinate brachiopod debris.	2.76	31.00
	Limestone, mid-grey, fine arenite wackestone passing below 32.00 m to medium arenite grainstone.	1.90	32.90
	Gap.	0.50	33.40
	Limestone, mid-grey, coarse arenite wackestone and packstone, some shale partings and disseminated clay.	1.80	35.20
	Gap.	1.00	36.20
	Limestone, dark grey, wackestone, common shale partings, some bedded chert.	2.10	38.30
	Gap.	7.00	45.30
	Limestone, mid-grey packstone, common rudite crinoid debris.	1.60	46.90
	Limestone, mid-grey, wackestone, common pockets of coarse rudite crinoid debris, abundant silicification, very common bedded chert, some shale partings.	3.40	50.30
	Limestone, mid-grey wackestone with some grainstones and packstones, some patchy silicification.	1.75	52.05

C
SD 74 SE 5s



LITHOLOGY
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
FRACTURE INDEX
(lf/mm)
AIV
%
m
0
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30
40
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500
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15
Si
>15%
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3
3
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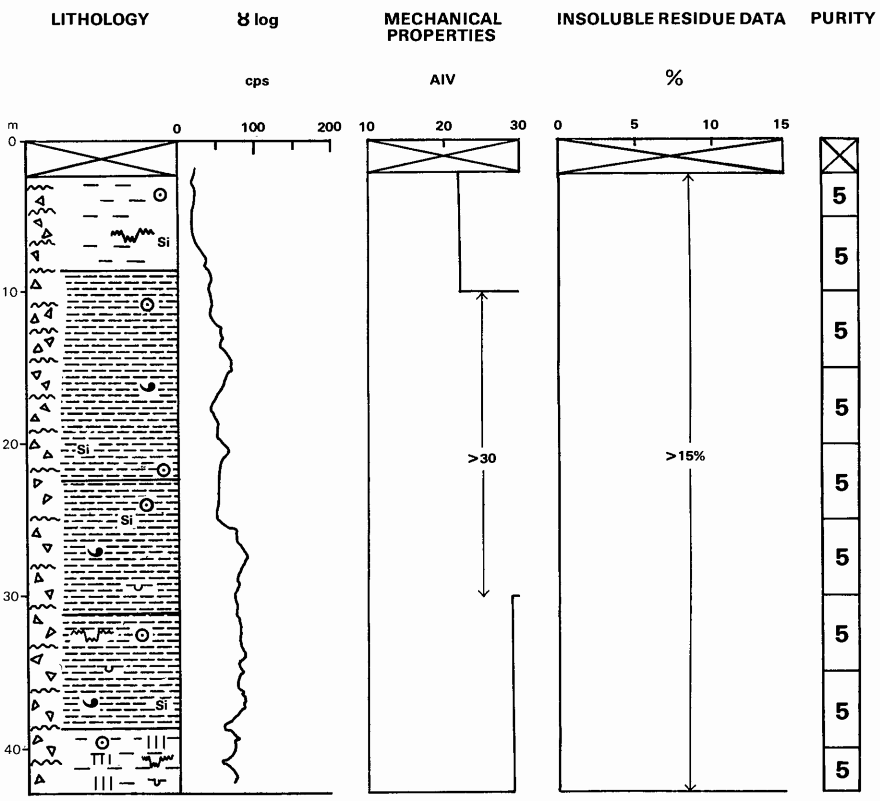
4

SD 74 NE 3 **7992 4676** **Cowgill Farm** **Block D**

Surface level +151 m
January 1980

		Thickness m	Depth m
	Soil and clay	2.30	2.30
Chatburn Limestone	Argillaceous limestone, dark grey, wackestone, rare bioclasts, crinoid and shell debris. Fractured, broken, brecciated, calcite-veined. Common pyrite, some silicified patches.	6.20	8.50
	Mudstone, dark grey, extremely disturbed, common pyrite, micaceous. Rare shelly debris. Some limestone fragments.	9.50	18.00
	Argillaceous limestone, dark grey, heavily fractured and calcite veined.	0.30	18.30
	Mudstone, dark grey, extremely disturbed, fractured, some fragmental argillaceous limestone. Micaceous. Sporadic rudite crinoid debris. Pyritous.	4.00	22.30
	Mudstone, dark grey, some argillaceous limestone. Fractured, broken, calcite veined. Rare crinoid and shell debris. Bioturbated 26.90 m. Pyritous, patchy silicification.	8.70	31.00
	Mudstone/Argillaceous limestone, less severe fracturing, dark grey wackestone and mudstone. Vertical bedding. Common rudite crinoid and shell debris, some finer bioclasts. Sporadic bioturbation. Some calcite veining and patchy silicification.	7.50	38.50
	Argillaceous limestone, dark grey, disturbed and fractured beds, some inter-bedded mudstones. Wackestone, common shell and crinoid debris, some finer bioclasts. Some bioturbation. Common calcite veining, patchy dolomitisation.	4.18	42.68

D
SD 74 NE 3


LITHOLOGY
ɣ log
cps
MECHANICAL PROPERTIES
AIV
INSOLUBLE RESIDUE DATA
%
PURITY
m
0
10
20
30
40
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100
200
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0
5
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15
Si
>30
>15%
5
5
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5
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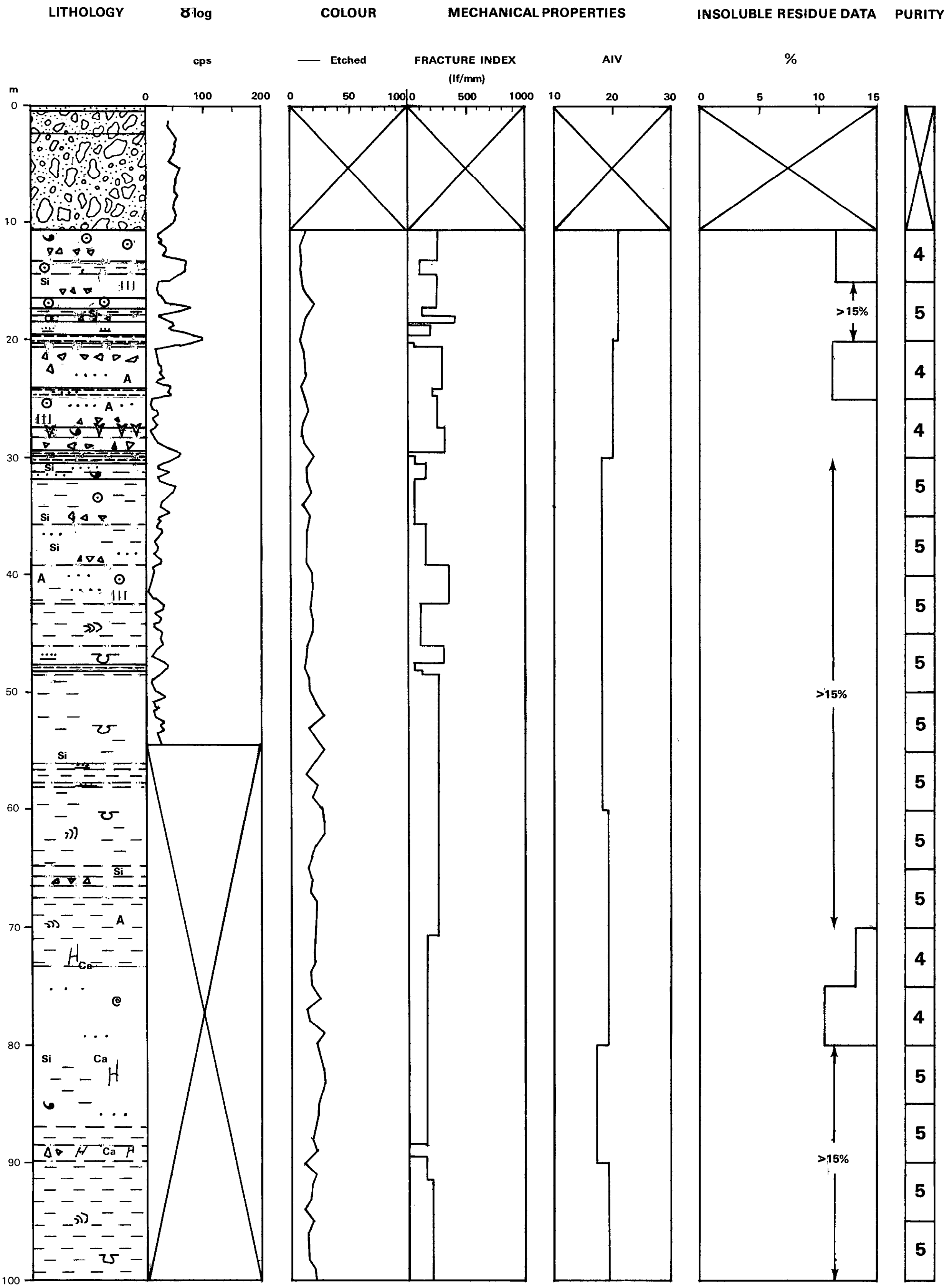
5
5

SD 75 NE 12 **7794 5661** **Snape House** **Block E**

Surface level +232 m
February 1980

		Thickness m	Depth m
	Topsoil	0.45	0.45
	Boulder clay, stiff grey clay.	1.95	2.40
	Boulder clay, grey clay with common angular and subrounded clasts of sandstone, grit, and limestone.	8.28	10.68
Pendleside Limestone	Limestone, grey, packstone. Abundant coarse arenite to fine rudite crinoid and brachiopod debris, subordinate lithoclastic debris. Some silicified bioclasts and disseminated dolomite.	2.66	13.34
	Argillaceous limestone, dark grey, wackestone. Locally grades to mudstone.	1.10	14.44
	Limestone, grey, packstones and grainstones, graded bedding. Fine arenite to coarse rudite, some ooids and algae-encrusted bioclasts. Chert 14.61-14.68 m, disseminated dolomite 15.34-15.58 m.	2.05	16.49
	Limestone, grey, medium arenite grainstone. Sharp base.	0.79	17.28
	Argillaceous limestone, dark grey, fine arenite wackestone.	0.63	17.91
	Limestone, mid-grey, graded units, medium arenite packstone grading to coarse rudite packstone. Mudstone interbeds. Some silicified bioclasts and cherty silicification.	1.78	19.69
	Mudstone, dark grey.	0.57	20.26
	Argillaceous limestone, dark grey, wackestone.	0.30	20.56
	Limestone, mid-grey, packstone, fine to coarse arenite, coarse rudite lithoclast bands 20.56-22.16 m, 26.38-26.60 m, 27.26-27.52, 28.31-29.56 m. Abundant bioclastic debris, some algal-encrusted bioclasts, *Koninckopora* and peloid debris. Locally grades to grainstone. Thin mudstones 24.14 m and 24.70 m. Some silicified bioclasts, patchy silicification and cherty silicified bands. Patchy disseminated dolomite. Abundant bryozoa 27.52-28.31 m.	9.00	29.56
	Mudstone, dark grey, thin limestone interbeds.	0.93	30.49
	Limestone, mid-grey, grainstone locally grading to packstone. Medium arenite to rudite commuted bioclasts and peloid debris. Some silicified patches, chert, pyrite and disseminated dolomite. Thin mudstone 31.15-31.31 m.	1.35	31.84
	Mudstone/Argillaceous limestone, dark grey, mudstone bands interbedded with very fine arenite, wackestone argillaceous limestones and coarse arenite to fine rudite, packstone limestone bands. Some cherty silicification. Brecciated, silicified, calcite-veined zone 34.80-35.35 m.	3.87	35.71
	Limestone/Argillaceous limestone, mixed sequence variable clay content. Fine arenite wackestone and grainstone. Some extensive bioturbation. Some silicification, thin chert bands, pyrite. Brecciated in lowest 0.5 m.	3.43	39.14
	Limestone, mid-grey, arenite and rudite grainstones and packstones, graded. Patchy silicification throughout, scattered pyrite. Disseminated dolomite 40.90-41.25 m. Bioturbated in lowest, clay-rich, 0.5 m.	3.36	42.50
	Mudstone/Argillaceous limestone, laminated and banded clay-rich division. Sporadic bioturbation. Rare thin cherty bands.	3.62	46.12
	Limestone, mid-grey, coarse arenite packstone, graded.	1.59	47.71
	Mudstone.	0.47	48.18
	Limestone, mid-grey, fine arenite, packstone. Some chert and mudstone.	0.34	48.52
	Argillaceous limestone, mid-to-dark grey, graded units with common mudstones. Rare mudstones, grainstone 64.87-67.50 m, 73.30-87.00 m. Coarse rudite lithoclast conglomerate 65.85-66.50 m. Locally bioturbated 60.00-100.26 m. Some patchy and cherty silicification throughout. Sporadic pyrite. Broken, brecciated, calcite-veined core 88.50-89.83 m.	51.74	100.26

E
SD 75 NE 12



LITHOLOGY
γ log
cps
COLOUR
— Etched
MECHANICAL PROPERTIES
FRACTURE INDEX
(lf/mm)
AIV
INSOLUBLE RESIDUE DATA
%
PURITY
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Si
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Ca
>15%
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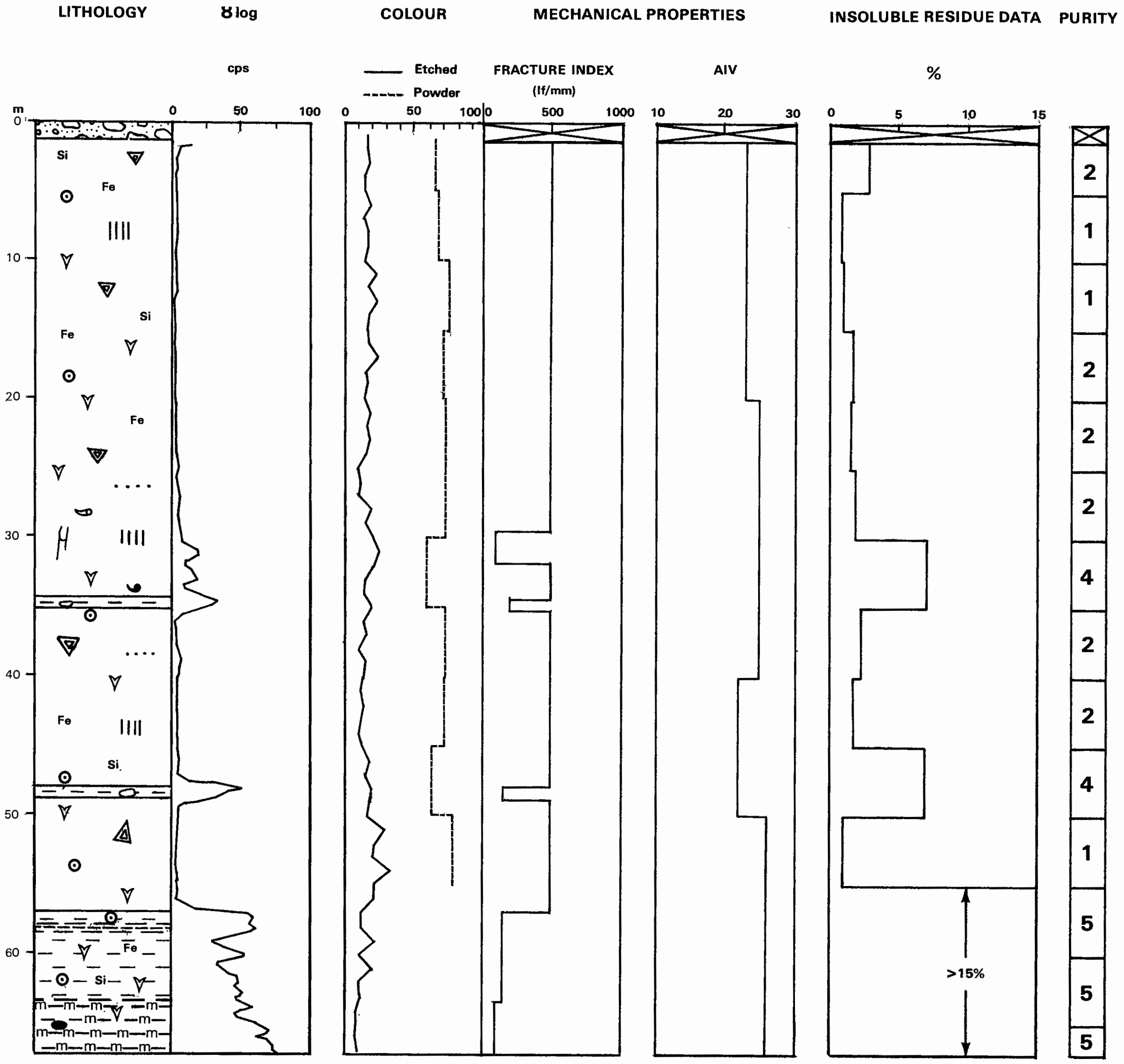
5

Surface level +152 m
November 1979

		Thickness m	Depth m
	Topsoil	0.50	0.50
	Clayey soil	0.50	1.00
	Clay	0.15	1.15
Knoll-reef Limestone	Limestone, mid-grey, mottled, wackestone, waulsortian biomicrites and micrites. Widely scattered crinoid, shell and ostracod debris. Some bryozoa below 9.50 m, locally common 11.42-34.41 m, grades to boundstone. Common stromatactis. Numerous iron-rich dolomite filled cavities, commonly weathered to limonite. Patchy disseminated dolomite, patchy silicification throughout. Disturbed, brecciated reef limestone 29.64-31.70 m. Grainstone pockets, common crinoid and shell debris, rare bryozoa in lowest 1.00 m. Common medium rudite intraclasts in thin band 34.31 m. Clay-rich in lowest 0.15 m.	33.26	34.41
	Argillaceous limestone, dark grey, wackestone, scattered rudite crinoid debris, some thin bands of micrite intraclasts. Laminated (dip 30°). Pyritous.	0.78	35.19
	Limestone, mid-grey, waulsortian facies as above. Some grainstone pockets with ostracod and foraminifera debris. Scattered coral. Scattered rudite crinoid debris 39.69-41.55 m. Widely scattered dolomite rhombs and patches of silicification. Patchy limonite staining.	12.68	47.87
	Mudstone, black, pyritous.	0.10	47.97
	Limestone, dark grey, common rudite crinoid debris, waulsortian facies. Pyritous. Common microstylolites.	0.10	48.07
	Argillaceous limestone, dark grey, scattered rudite crinoid debris and micrite intraclasts, laminated (dip 20°). Pyritous. Passing into mudstone in lowest 0.05 m.	0.68	48.75
	Limestone, mid-grey, waulsortian facies, wackestone, common bryozoa, rare gastropods and cephalopods, some thin-shelled bivalves and rudite crinoid debris. Stromatactis. Some silicification in top 0.24 m and lowest 0.7 m. Unaltered.	8.15	56.90
	Argillaceous limestone, dark grey, laminated (dip 30°), scattered crinoid debris. Pyritous.	1.10	58.00
	Mudstone, black, calcareous.	0.39	58.39
	Argillaceous limestone, dark grey, wackestone, scattered rudite patchily silicified crinoid debris, locally common bryozoa, shell debris, and chambered algae. Rare coral.Pyritous.	5.01	63.40
	Argillaceous limestone/Calcareous mudstone, dark grey, micaceous, bryozoa rare below 65.24 m. Thin chert 65.15 m.	4.00	67.40

F
SD 85 SW 5



LITHOLOGY
γ log
COLOUR
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
cps
Etched
Powder
FRACTURE INDEX
(lf/mm)
AIV
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Si
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>15%
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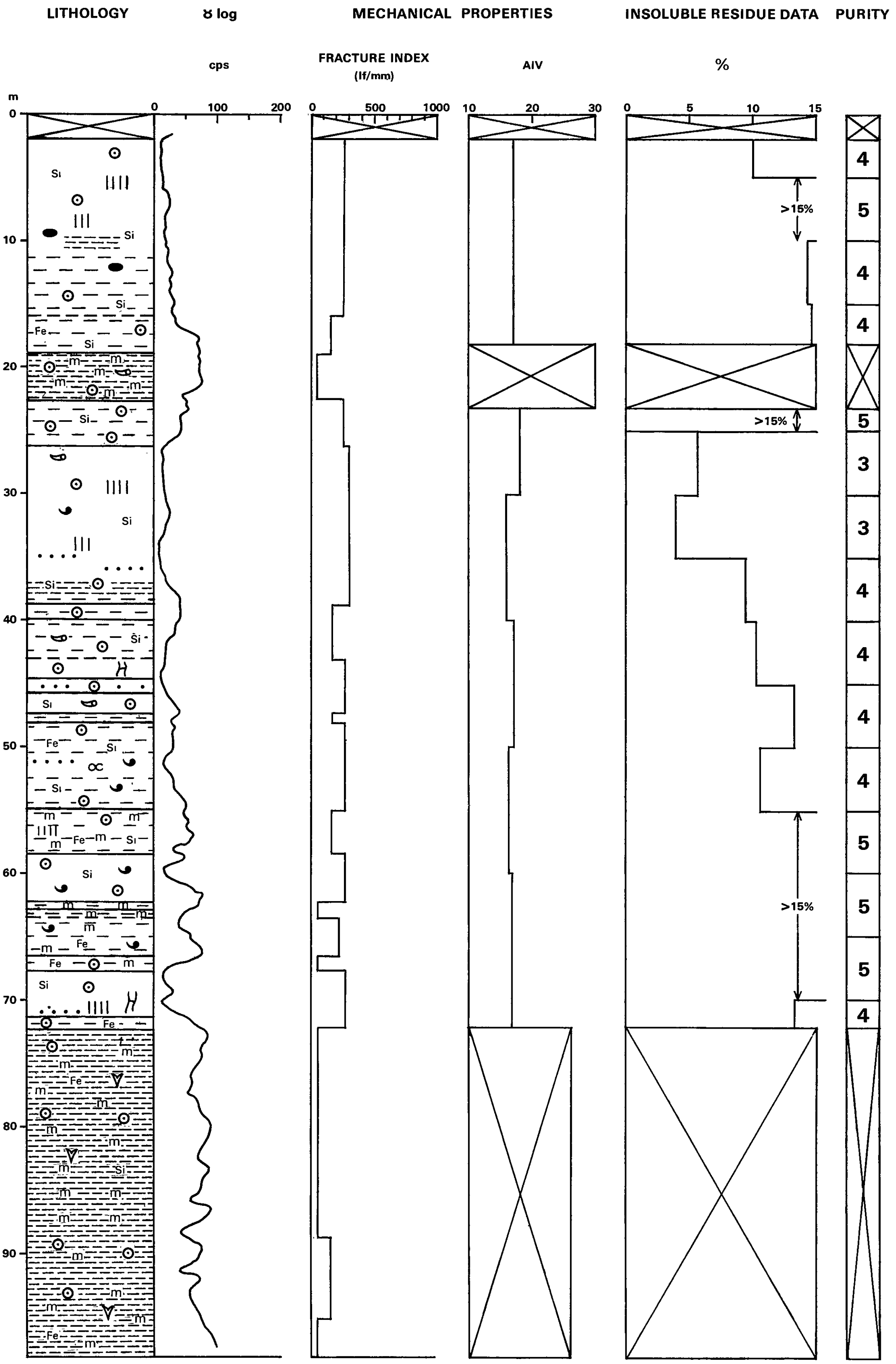
Surface level +168 m
November 1979

		Thickness m	Depth m
	Topsoil	0.51	0.51
	Soil and clay	1.05	1.56
	Dark clay	0.34	1.90
	Pale grey clay	0.20	2.10
Thornton Limestone	Limestone, dark grey to mid-grey, wackestone locally passing into packstone. Scattered arenite and rudite crinoid and shell debris, subordinate spines and foraminifera. Rare grainstones with algal-encrusted bioclasts developed. Common irregular silicified patches, and silicified bioclasts. Patchy disseminated dolomite. Common chert 8.68-10.00 m, 12.15-12.20 m. Some disseminated clay and common microstylolites below 9.95 m, clay-rich below 12.20 m.	13.85	15.95
	Argillaceous limestone, dark grey, wackestone, grades locally to calcareous mudstone below 17.73 m. Scattered rudite crinoid debris. Pyritous.	2.97	18.92
	Mudstone, black, calcareous, micaceous, pyritous.	3.62	22.54
	Limestone, dark grey, wackestone, scattered rudite silicified crinoid debris. Common fine arenite, foraminifera, spines, ostracod and peloid debris. Fine arenite grainstone 34.23-36.25 m. Coral 26.8 m. Some algae-encrusted bioclasts in grainstones. Patchily silicified and dolomitised throughout. Sporadic pyrite. Variable clay content, locally argillaceous in top 2.55 m.	15.91	38.45
	Mudstone, black.	0.05	38.50
	Argillaceous limestone, dark grey, laminated (dip 30°), wackestone, widely-scattered bioclasts, bioturbated.	1.27	39.77
	Mudstone.	0.23	40.00
	Argillaceous limestone, dark grey, wackestone, scattered rudite crinoid and shell debris. Patchily silicified, some disseminated dolomite.	3.03	43.03
	Limestone, mid-grey, wackestone, fine arenite, scattered rudite crinoid debris. Some calcite veining with trace pyrite.	1.62	44.65
	Limestone, mid-grey, fine arenite grainstone, some rudite crinoid and brachipod debris. Patchy silicification and dolomitisation.	1.14	45.79
	Limestone, mid-grey to dark grey, packstone grading to wackestone below 46.45 m. Fine arenite to rudite bioclasts. Some colonial corals. Patchy silicification and disseminated dolomite.	1.61	47.40
	Argillaceous limestone, dark grey, wackestone, mudstone interbeds, common disseminated dolomite.	0.64	48.04
	Limestone, mid-grey, wackestone, arenite bioclasts some rudite, patchily silicified crinoid and shell debris. Variable clay content, relatively clay-rich 48.42-48.77 m, 49.00-50.65 m, 52.00-54.88 m. Clay-free grainstone with algal-encrusted bioclasts 51.24-51.50 m. Patchy silicification, scattered flecks of pyrite.	6.84	54.88
	Argillaceous limestone, dark grey, wackestone, micaceous, pyritous.	3.36	58.24
	Limestone, mid-grey to dark grey, wackestone and packstone, arenite to rudite bioclasts, common ostracods. Variable clay content.	4.03	62.27
	Argillaceous limestone, dark grey wackestone, grades to mudstone 62.87-63.48 m, 66.50-67.61 m. Micaceous, pyritous, some silicified bioclastic debris. Locally bioturbated.	5.34	67.61

F
SD 85 SE 16



LITHOLOGY
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cps
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FRACTURE INDEX
(lf/mm)
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INSOLUBLE RESIDUE DATA
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PURITY
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70
80
90
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200
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1000
5
15
>15%

		Thickness m	Depth m
	Limestone, dark grey packstone; wackestone 69.12-70.40 m, grainstone 70.45-71.18 m. Arenite bioclasts, scattered rudite crinoid debris. Variable clay content, muddy below 69.12 m. Patchily silicified, some disseminated dolomite and pyrite.	3.61	71.22
	Argillaceous limestone, dark grey, wackestone, sporadic silicified rudite crinoid debris and arenite ostracods. Pyritous.	1.09	72.31
	Mudstone, dark grey, micaceous, common fine arenite bioclasts, scattered, locally common, rudite crinoid debris. Common bryozoa, some ostracods. Passes into crinoidal argillaceous limestone 88.65-89.25 m. Patchily silicified rare disseminated dolomite.	25.75	98.06

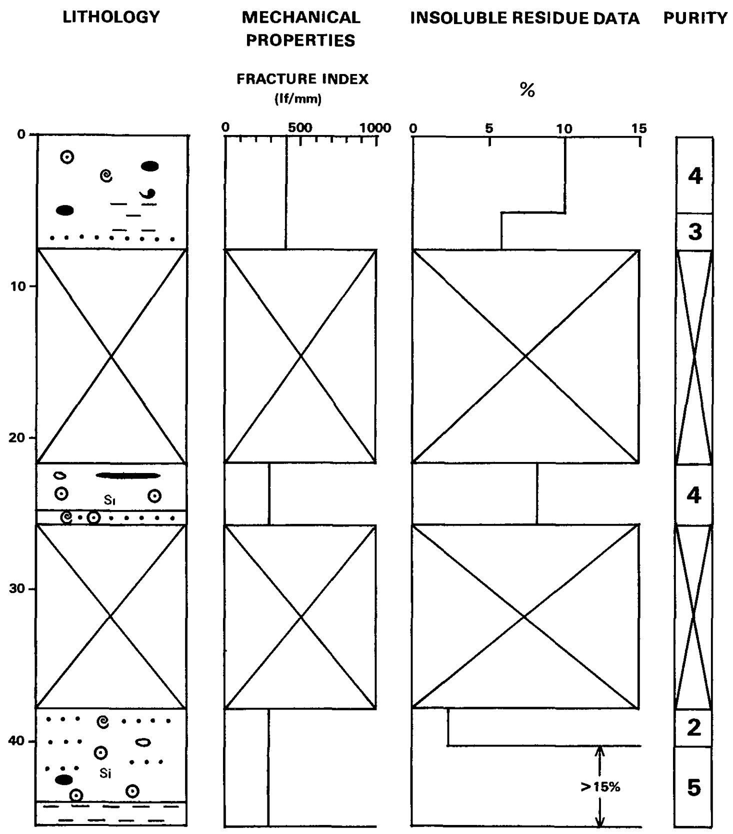
SD 85 SE 2s **8818 5161** **Marton Scar** **Block F**

Surface level +211 m
October 1979

		Thickness m	Depth m
Chatburn Limestone	Limestone, mid-grey to dark grey, fine arenite wackestone, scattered rudite crinoid debris, some ostracod, peloid and foraminifera debris. Patchy silicification, some nodular and bedded chert. Shaly and flaggy 5 m to 6 m. Passing to medium arenite grainstone 6.50-7.50 m.	7.50	7.50
	Gap.	14.00	21.50
	Limestone, mid-grey, wackestone, scattered ostracods, some patchy silicification.	0.70	22.20
	Chert.	0.20	22.40
	Limestone, mid-grey packstone, abundant rudite crinoid debris.	2.10	24.50
	Limestone, mid-grey, fine arenite grainstone. Some silicification.	1.00	25.50
	Gap.	12.00	37.50
	Limestone, mid-grey, medium arenite grainstone, abundant peloid, foraminifera, ostracod and shell debris. Some patchy silicification and dolomite. Some nodular chert 42 m and 43 m. Passing to crinoidal packstone below 42 m.	6.00	43.50
	Argillaceous limestone, mid-grey, wackestone, laminated, sporadic rudite crinoid and ostracod debris. Patchy silicification, some chert.	2.00	45.50

F

SD 85 SE 2S



LITHOLOGY
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INSOLUBLE RESIDUE DATA
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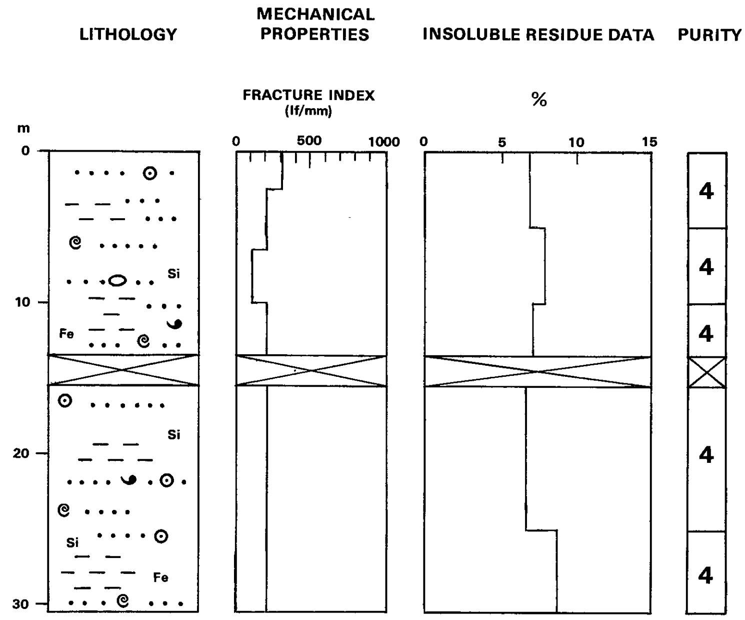
>15%

SD 94 NW 1s **9417 4529** **Lothersdale Quarry** **Block G**

Surface level +256 m
October 1979

		Thickness m	Depth m
Limestone (Worston Shale Group)	Limestone, dark grey, fine arenite grainstone, some scattered rudite crinoid debris. Well sorted. Laminated, current sorted, locally graded. Sporadic foraminifera and ostracods. Shale partings, some disseminated clay, some patchy silicification. Sporadic pyrite.	30.50	30.50

G
SD 94NW1S


LITHOLOGY
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
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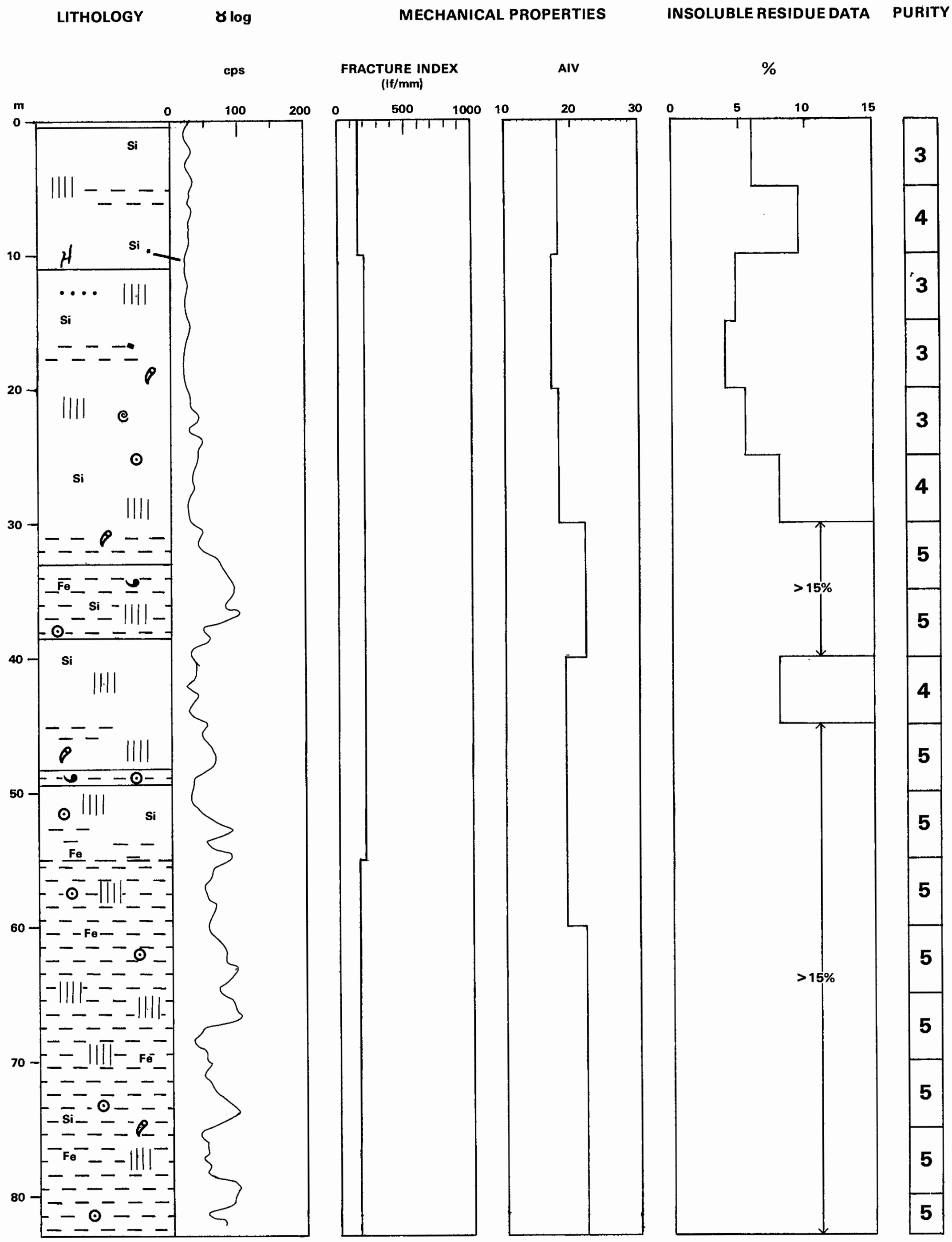
SD 95 SW 29 **9250 5077** **Brows Hill Quarry** **Block H**

Surface level +161 m

October 1979

		Thickness m	Depth m
	Topsoil	0.25	0.25
	Clay and broken limestone	0.16	0.41
Chatburn Limestone	Limestone, dark grey, wackestone, scattered arenite ostracods, locally bioturbated. Variable clay content, locally argillaceous, sporadic silicified bioclasts and quartz euhedra, some pyrite. Common disseminated dolomite. Patchily silicified 9.96-10.11 m. Fractured, clay-infill 10.30-10.80 m.	10.39	10.80
	Limestone, dark grey, fine arenite packstone locally passing to grainstone; some patchily silicified, rudite *Syringopora* and crinoid debris; some pockets of foraminifera; rare oncolites. Common disseminated dolomite and dolomitsed bands. Some patchy silicification, pyrite and microstylolite swarms. Passing to wackestone below 22.90 m.	22.30	33.10
	Argillaceous limestone, dark grey, wackestone, some rudite crinoid and shell debris, rare bioturbation. Locally passes into calcareous mudstone.	5.37	38.47
	Limestone, dark grey, wackestone, some rudite *Syringopora*, rare bioturbation. Some disseminated dolomite, rare pyrite, variable clay content, locally grades to argillaceous limestone.	9.69	48.16
	Argillaceous limestone, dark grey, wackestone.	1.19	49.35
	Limestone, dark grey, wackestone, clay-rich, locally passing into argillaceous limestone. Some dolomitised patches.	5.75	55.10
	Argillaceous limestone, dark grey, wackestone, laminated, rare bioturbation, scattered rudite crinoid debris. Patchy dolomitisation, sporadic pyrite, variable clay-content.	28.27	83.37

H
SD 95SW29



LITHOLOGY
ɣ log
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
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FRACTURE INDEX
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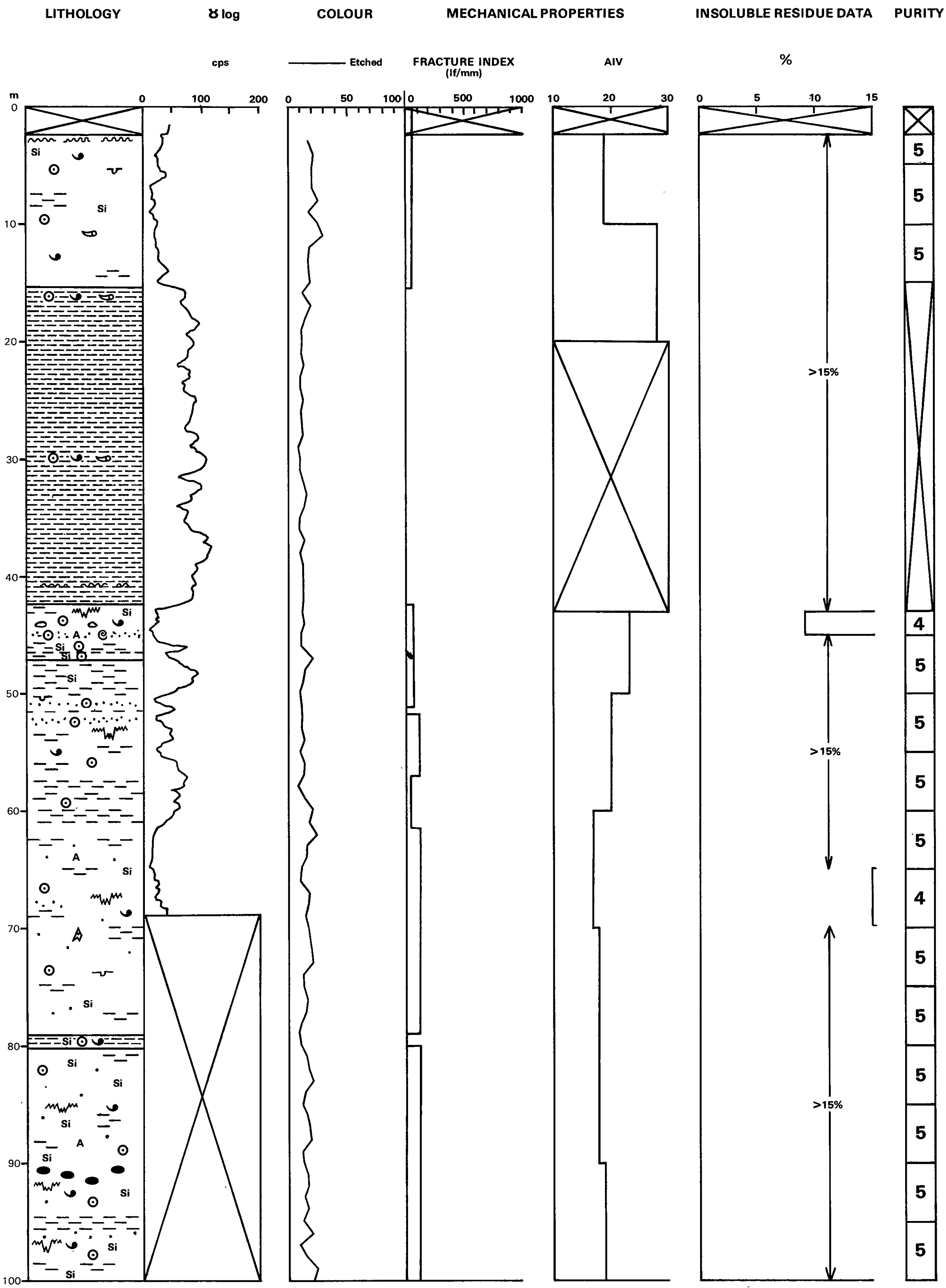
SD 95 SW 30 **9346 5259** **Butterhaw** **Block H**

Surface level +169 m
October 1979

		Thickness m	Depth m
	Topsoil and Boulder Clay	2.39	2.39
Limestone	Limestone, mid-grey to dark grey, packstone, common arenite and rudite crinoid debris, bioturbated. Some pyrite, rare silicification.	3.87	6.26
	Limestone, mid-grey to dark grey, packstone, arenite and rudite crinoid, coral and shell debris, bioturbated. Variable clay content, common micro-stylolites and clay seams, locally passes to argillaceous limestone. Some bioclastic and nodular silicification. Pyritous. Some disseminated dolomite.	9.13	15.39
	Mudstone, dark grey, calcareous, micaceous, pyritous. Some patchily silicified bioclastic debris.	26.94	42.33
Thornton Limestone	Limestone, dark grey, packstone and wackestone, arenite and rudite crinoid and shell debris, some intraclasts. Common microstylolites and clay seams, pyritous, patchily silicified.	2.16	44.49
	Limestone, dark grey, grainstone and packstone, common peloid, crinoid, algae and foraminifera debris. Patchily silicified, pyritous.	1.00	45.49
	Limestone, dark grey, wackestone with some thin packstones and grainstones, variable clay-content, locally argillaceous. Mudstones with thin limestones 46.16-46.46 m, 47.13-50.72 m, 51.17-51.86 m, 56.84-61.47 m. Locally common rudite crinoid debris, locally peloidal, some bioturbation. Patchy bioclastic and matrix silicification, pyritous.	17.01	62.50
	Limestone, dark grey, grainstone, some packstone, calcarenite, some rudite crinoid debris, patchy bioclastic and matrix silicification.	4.73	67.23
	Limestone, dark grey, wackestone, some packstone, variable, generally high, clay content, locally argillaceous. Passes into mudstone with thin argillaceous limestone 77.18-80.12 m. Some rudite crinoid and shell debris, locally bioturbated. Patchy, irregular silicification, some bioclastic silicification. Some pyrite. Some fine silicification.	32.66	99.89

H
SD 95 SW 30



LITHOLOGY
ɣ log
COLOUR
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
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Etched
FRACTURE INDEX (lf/mm)
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SD 95 SW 1s **9281 5077** **Micklethorn Quarry** **Block H**

Surface level +158 m
October 1979

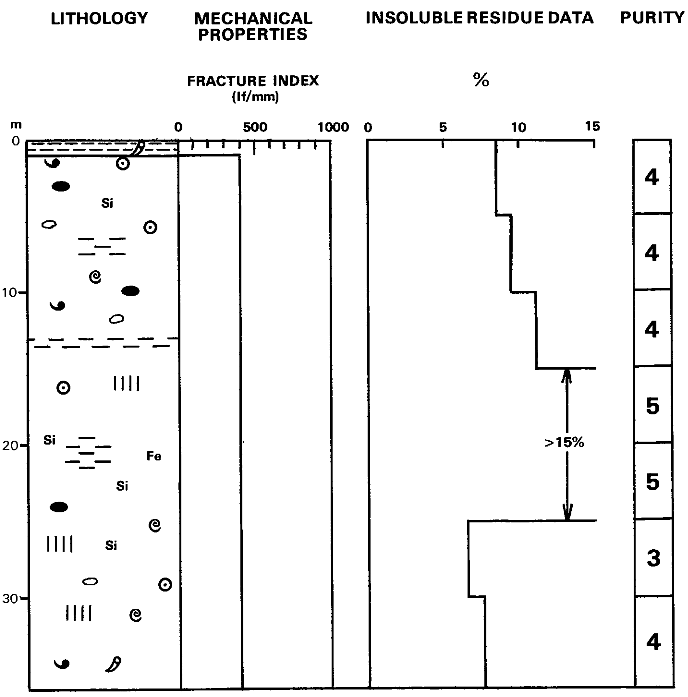
		Thickness m	Depth m
Chatburn Limestone	Shale, some limestone interbeds, common *Syringopora*.	1.00	1.00
	Limestone, dark grey, arenite wackestone, scattered rudite crinoid debris, some foraminifera, ostracods and fragmented coral. Variable clay-content, locally argillaceous, some patchy silicification and dolomitisation. Nodular chert 3.20 m, 10.00 m, 24.00 m. Sporadic pyrite. *Syringopora* 28.50 m, 34.00 m.	35.00	36.00

SD 95 SW 2s **9232 5066** **Broughton Fields** **Block H**

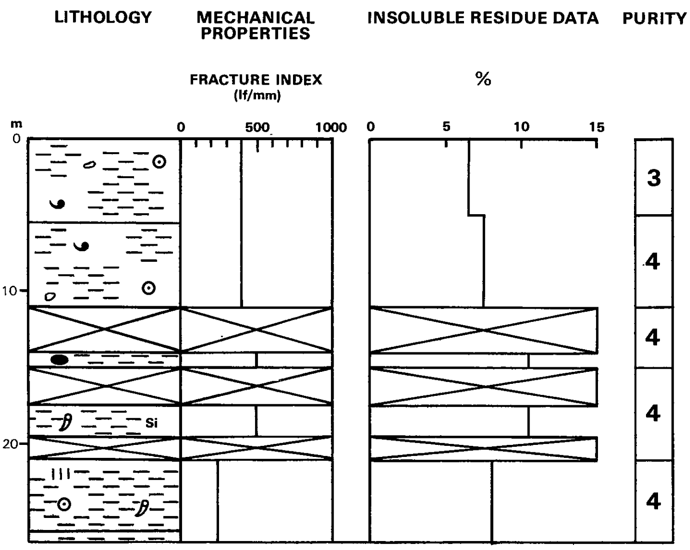
Surface level +153 m
October 1979

		Thickness m	Depth m
Chatburn Limestone	Limestone, dark grey, wackestone and packstone, calcarenite, widely scattered rudite crinoid debris, locally common ostracods. Variable clay content, some argillaceous beds, common shale partings. Some disseminated dolomite 6.5 m and 7.5 m, patchy silicification, locally common authigenic quartz. Chert 14.50 m. Scattered pyrite. Scattered fragmented *Syringopora*. Gap 11.00-14.00 m, 15.00-17.50 m, 19.60-21.00 m.	26.50	26.50

H
SD 95 SW 1S



H
SD 95 SW 2S



SD 95 SW 3s **9249 5076** **Brows Hill Quarry** **Block H**

Surface level +161 m
October 1979

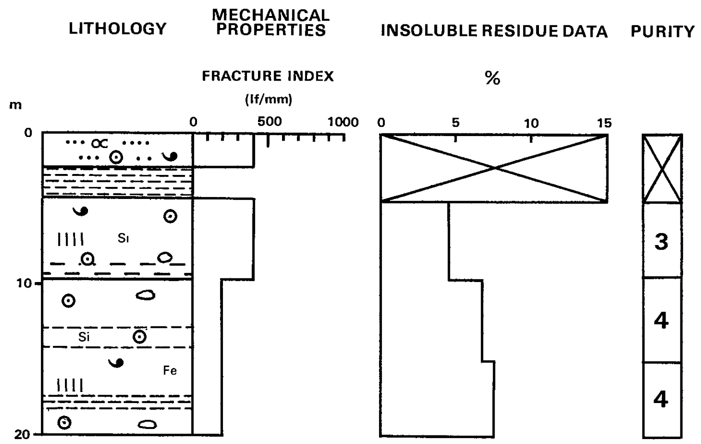
		Thickness m	Depth m
Chatburn Limestone	Limestone, dark grey, medium arenite grainstone, scattered rudite crinoid debris, some algal-encrusted bioclasts.	2.20	2.20
	Shale, dark grey, some thin limestones.	2.05	4.25
	Limestone, dark grey, calcarenite, wackestone, packstone and grainstone beds. Some disseminated clay, shaly 9.00-9.75 m. Some patchy dolomitisation, sporadic silicified bioclasts.	5.50	9.75
	Limestone, dark grey, wackestone, scattered rudite crinoid and ostracod debris. Common disseminated clay, shale partings; thin shales 12.75 m, 14.00-14.30 m, 17.60 m, 18.00 m, 18.30 m. Some bioclastic silicification, sporadic flecks of pyrite.	10.25	20.00

SD 95 SW 6s **9292 5178** **Clints Delf Quarry** **Block H**

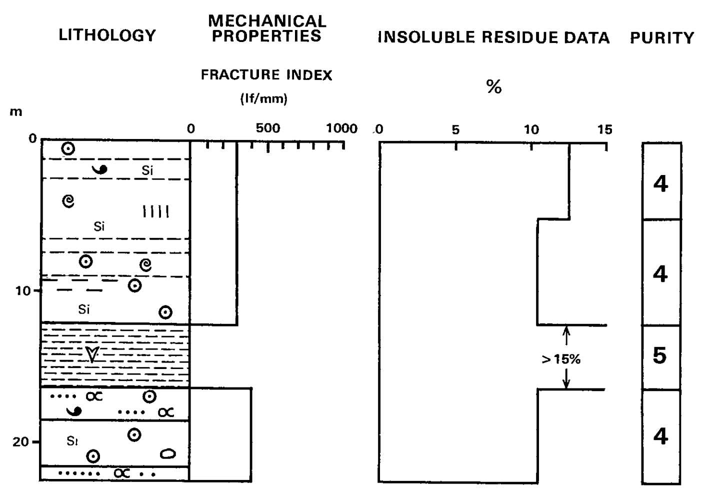
Surface level +160 m
October 1979

		Thickness m	Depth m
Thornton Limestone	Limestone, mid-grey to dark grey packstone, some wackestone. Abundant rudite crinoid debris, common foraminifera, subordinate brachiopod and spine debris. Thin shale partings 1.10 m, 2.75 m, 2.90 m, 6.50 m, 7.50 m, 9.00 m. Patchy, locally intense, silicification, some patchy dolomitisation.	12.20	12.20
	Shale, some thin, coarsely crinoidal, limestone interbeds with bryozoa and arenite brachiopods.	4.10	16.30
	Limestone, mid-grey, grainstone, calcarenite, some algal-encrusted bioclasts, common foraminifera, crinoid, shell and spine debris.	2.20	18.50
	Limestone, dark grey, packstone and wackestone, coarse rudite crinoid debris, common pockets of ostracods. Patchy silicification.	3.00	21.50
	Limestone, mid-grey, grainstone, common algal-encrusted grains.	0.90	22.40

H
SD 95 SW 3S



H
SD 95 SW 6S



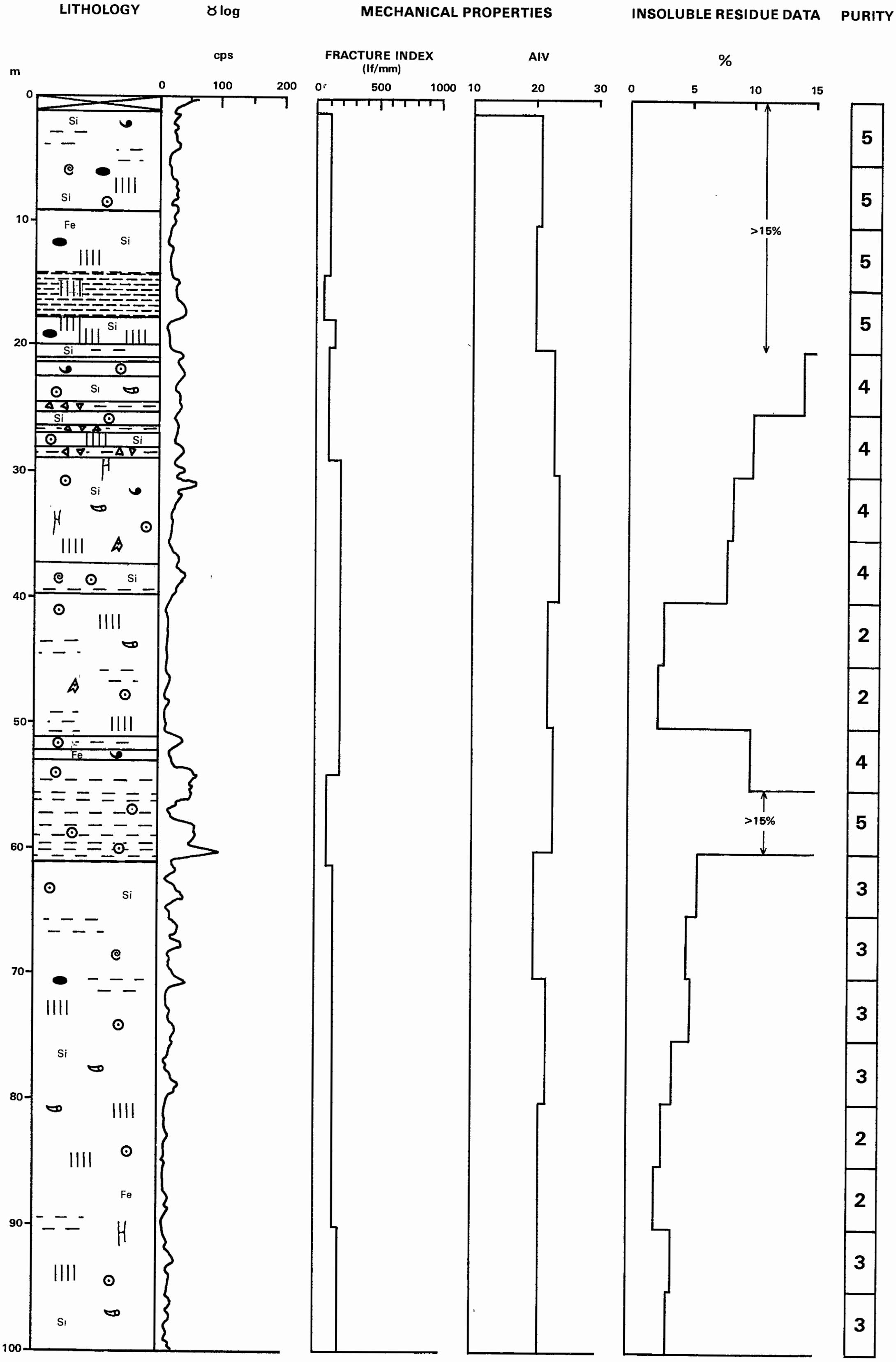
SD 95 NW 7 **9166 5660** **Throstle Nest** **Block I**

Surface level +197 m
March 1979

		Thickness m	Depth m
	Openhole	1.20	1.20
Bell Busk Limestone with Mudstone	Limestone, dark grey, laminated, coarse and finely bioclastic bands, interbedded with silty mudstones and argillaceous limestones. Packstone, sporadic pockets of rudite crinoid and shell debris, some foraminifera. Locally bioturbated. Scattered intraclasts 8.95-9.24 m. Some chert, patchy bioclastic silicification, patchy dolomitisation.	8.04	9.24
	Argillaceous limestone, mid-grey, laminated, graded bedding, slumped, some mudstone laminae. Bioturbated. Silicified bioclasts, patchy dolomitisation, some pyrite.	4.86	14.10
	Mudstone, mid-grey, laminated, dolomitic.	3.60	17.70
	Dolomitic limestone, mid-grey, fine grained, patchily silicified, some chert.	2.17	19.87
Haw Crag Boulder Bed	Limestone, dark grey, fine arenite packstone/wackestone, bioturbated, mudstone partings, some disseminated clay. Some patchily silicified rudite crinoid and shell debris. Locally grades to mudstone and argillaceous limestone. Some angular intraclasts. Some dolomitised joints.	8.93	28.80
Hetton Limestone	Limestone, dark grey, fine arenite wackestone, some rudite crinoid, shell and *Syringopora* debris. Variable clay content, locally grades to mudstone. Locally bioturbated. Rare *Caninia*. Some broken and jointed core. Patchy bioclastic silicification and dolomitisation.	11.00	39.80
	Limestone, dark grey, wackestone, local packstones and rare pockets of grainstone, fine arenite scattered rudite crinoid and coral debris. Bioturbated. Common stylolites and clay seams. Patchy dolomitisation.	11.26	51.06
	Limestone, dark grey, wackestone, clay rich.	1.16	52.22
	Limestone, dark grey, fine arenite packstone and wackestone, patchy dolomitisation and pyrite.	0.81	53.03
	Limestone, dark grey, wackestone, widely scattered rudite crinoid debris. Clay-rich locally, passing into argillaceous limestone and mudstone. Locally bioturbated.	8.16	61.19

Continued

I
SD 95 NW 7



LITHOLOGY
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MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
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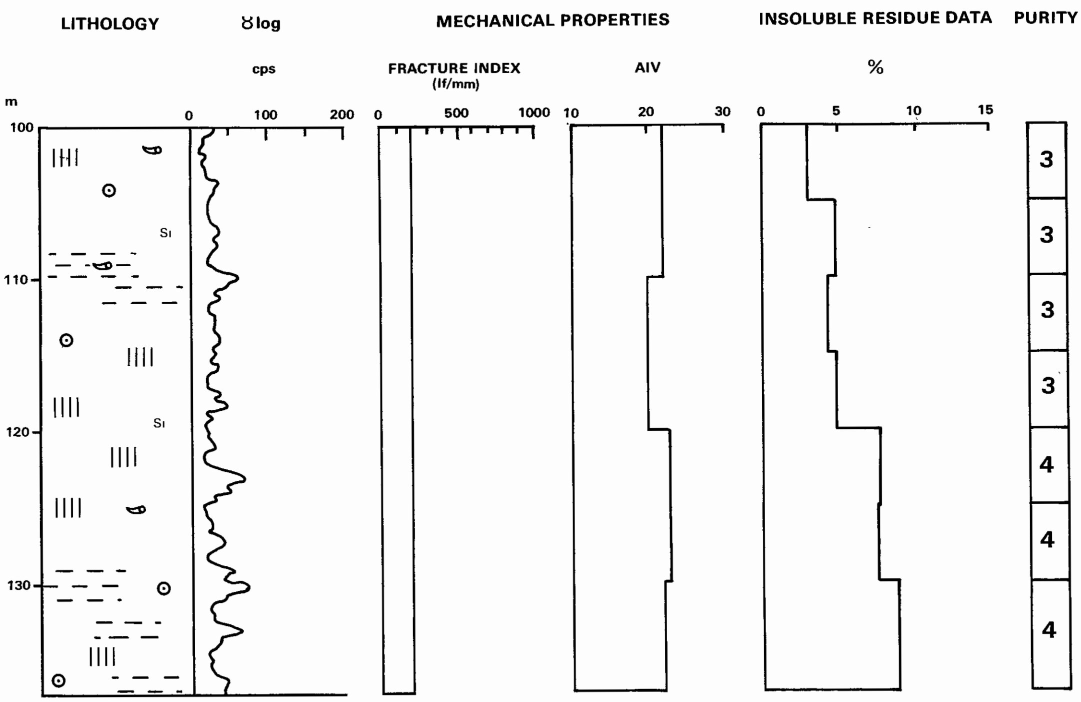
Limestone, dark grey, wackestone, fine arenite foraminifera and spines, rare dasycladacean algae, widely scattered locally concentrated rudite crinoid and *Syringopora* debris. Some microstylolites, microstylolite swarms; more argillaceous 66.37-66.67 m, 67.76-68.25 m, 70.95-71.26 m, 129.00-130.36 m, 133.17-133.69 m, 136.36-137.27 m, passing to mudstone 130.36-130.58 m. Patchily bioturbated. Disseminated dolomite throughout, particularly below 72.22 m.	76.08	137.27

I
SD 95 NW 7 cont.



SD 95 NE 1 **9629 5813** **Park Laithe** **Block I**

Surface level +191 m
December 1978

		Thickness m	Depth m
	Topsoil and clay	2.70	2.70
Rylstone Limestone	Limestone, dark grey, wackestone, common fine arenite comminuted bioclasts, some foraminifera, sporadic rudite crinoid debris and colonial coral. Clay-rich locally passing to argillaceous limestone; mudstone partings. Bioturbated. Abundant fine grained silica, some disseminated dolomite. Some pyrite.	10.59	13.29
Bell Busk Limestone with Mudstone	Limestone, dark grey, very fine arenite, scattered rudite crinoid and coral debris, bioturbated. Some patchy silicification, some cherts, locally dolomitised adjacent to fissures. Passes to dolomite 15.80-16.25 m. Variable clay content.	7.37	20.66
	Argillaceous limestone/calcareous mudstone, dark grey, wackestone, minor silicification and dolomitisation.	2.16	22.82
	Limestone, dark grey, fine arenite wackestone, rare rudite crinoid debris, bioturbated, clay rich.	2.79	25.61
	Mudstone, black, calcareous pyritous.	0.54	26.15
	Argillaceous limestone/calcareous mudstone, dark grey, scattered rudite crinoid and shell debris, bioturbated, rare intraclasts of fine grained limestone. Patchy bioclastic silicification and pyritisation. Some disseminated dolomite and fine silica.	23.05	49.20
Hetton Beck Limestone	Limestone, dark grey, fine arenite wackestone, mudstone partings, common patchy dolomitisation and fine silicification. Some bioturbation. Scattered rudite crinoid and shell debris.	23.67	72.87

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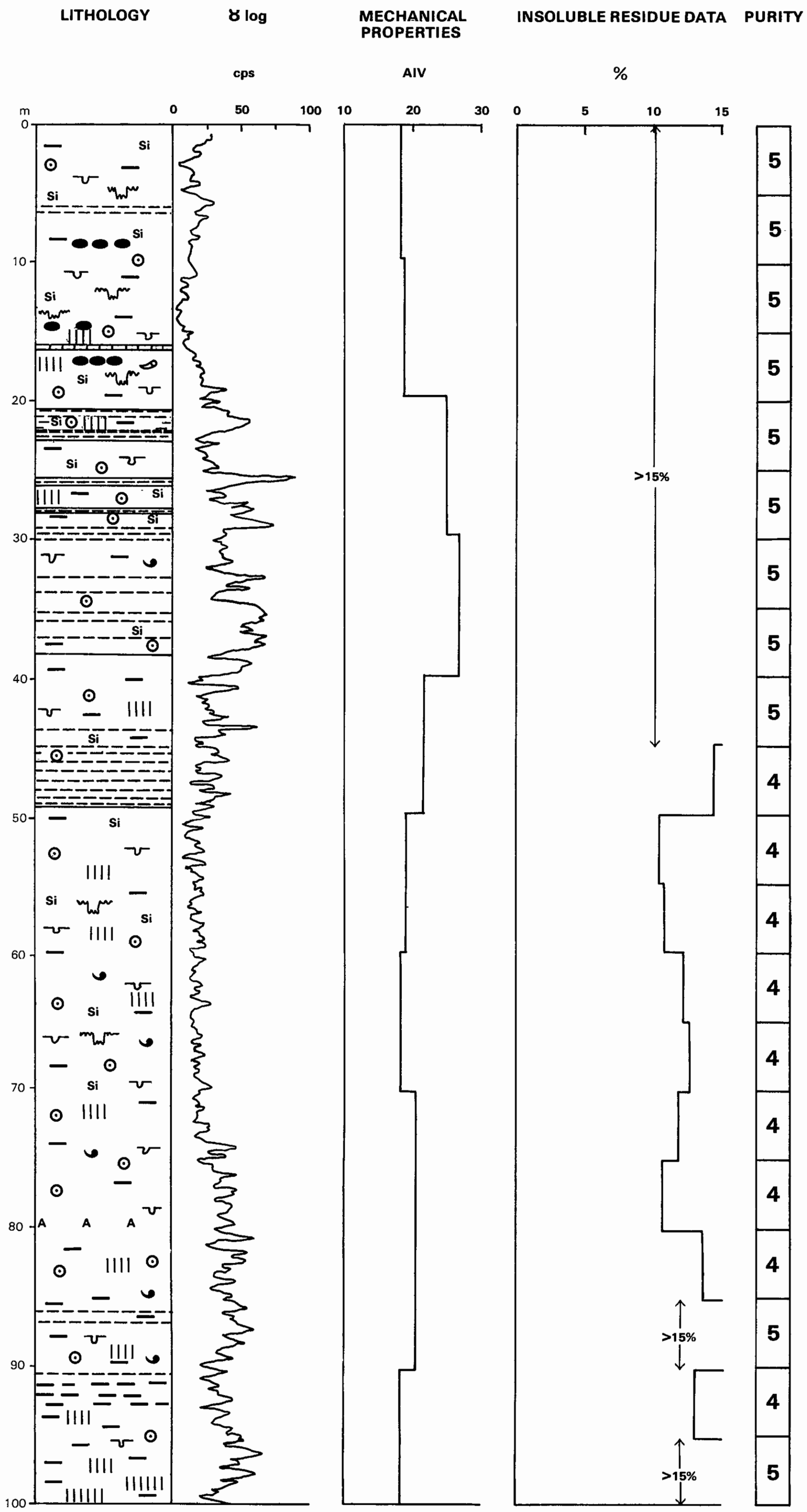
I
SD 95 NE 1


LITHOLOGY
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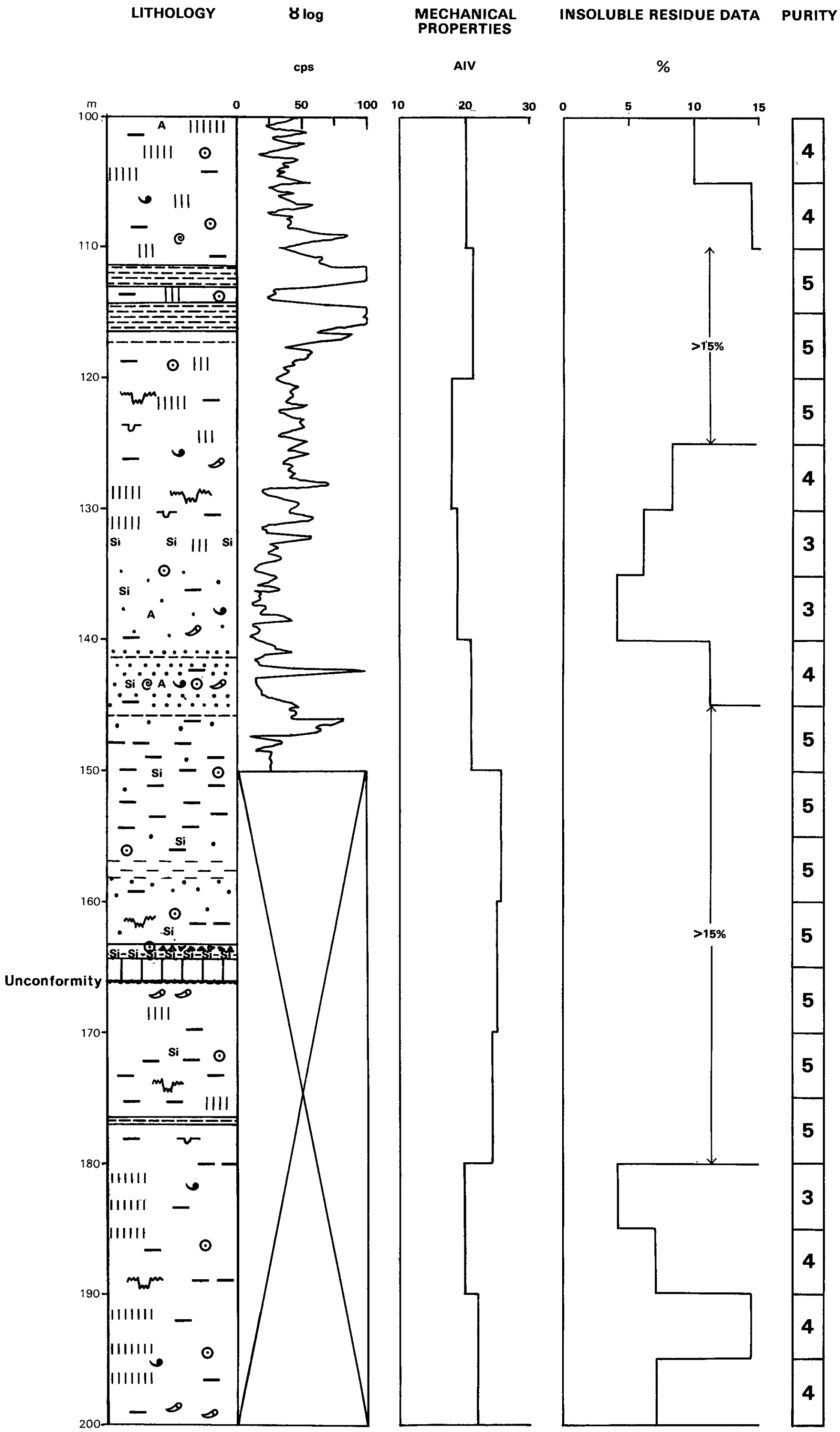
	Limestone, dark grey, fine arenite wackestone, scattered rudite crinoid debris and shell debris, rare algae, some bioturbation. Some fine silicification, rare patchy dolomite, locally pyritous. Clay-rich below 80 m. Scattered ostracods and foraminifera.	38.56	111.43
	Argillaceous limestone, dark grey, wackestone, interbedded mudstones. Bioclasts patchily silicified, some disseminated dolomite. Some pyrite, rare chert.	22.08	133.51
	Limestone, dark grey, fine arenite wackestone and grainstones, common peloid debris, common thin calcareous mudstones, clay-rich below 144.03 m. Some fine silicification and pyrite.	13.69	147.20
	Argillaceous limestone, dark grey, wackestone, interbedded mudstones, scattered rudite patchily silicified crinoid debris, locally peloidal. Pyritous, patchily silicified.	16.03	163.23
	Limestone, dark grey, wackestone, abundant rudite intraclasts, common stylolites, breccia. Silicified breccia 164.30–164.38 m. Unconformity at base.	1.15	164.38
Hetton Limestone	Dolomite, coarsely crystalline, vuggy.	1.72	166.10
	Argillaceous limestone, dark grey, wackestone, some silicified *Syringopora*, common mudstone interbeds, locally abundant microstylolites and clay seams. Common pyrite. Some calcite veining.	11.39	177.49
	Argillaceous limestone, dark grey, wackestone, some silicified rudite crinoid and *Syringopora*, common disseminated dolomite and bands of dolomite. Rare bioturbation. Common microstylolites and clay seams, pyritous.	22.47	199.96

I
SD 95 NE 1 cont



Surface level +254 m
February 1979

		Thickness m	Depth m
	Topsoil	1.08	1.08
Hetton Limestone	Dolomite, mid-grey, sporadic bioclastic fragments, locally dedolomitised, rare partially altered grainstone patches. Patchily silicified throughout, some iron-staining, vuggy.	22.22	23.30
	Limestone, mid-grey, fine arenite grainstone, dolomite bands, sporadic disseminated dolomite. Some silicified bioclasts, patchy silicification, chert nodule 27.30 m.	8.05	31.35
	Limestone, dark grey, fine arenite grainstone and packstone, dolomite bands and disseminated dolomite. Scattered peloid, algae, coral, foraminifera and shelly debris. Patchy silicification.	1.35	32.70
	Argillaceous limestone, dark grey, packstone with grainstones, arenite patchily silicified bioclasts, common pyrite and hematite staining.	4.80	37.50
	Limestone, mid-grey to dark grey, fine to medium arenite, grainstones and packstones, commonly dolomitic; dolomite bands and disseminated dolomite. Rare, patchy silicification, some bioclastic silicification, some pyrite and hematite staining. Variable clay content, stylolitic.	60.44	97.94

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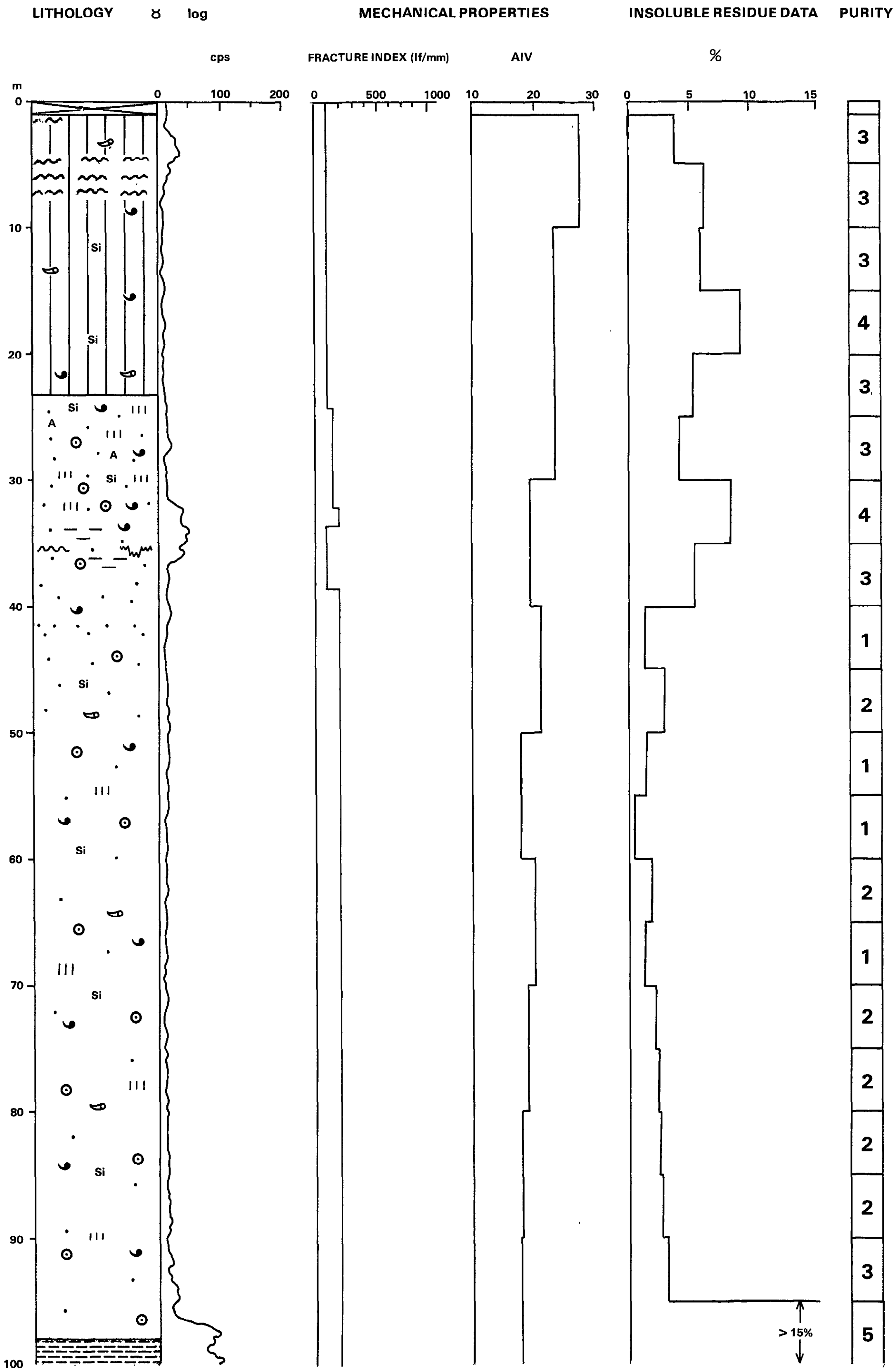
J
SE 86 SE 8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INSOLUBLE RESIDUE DATA
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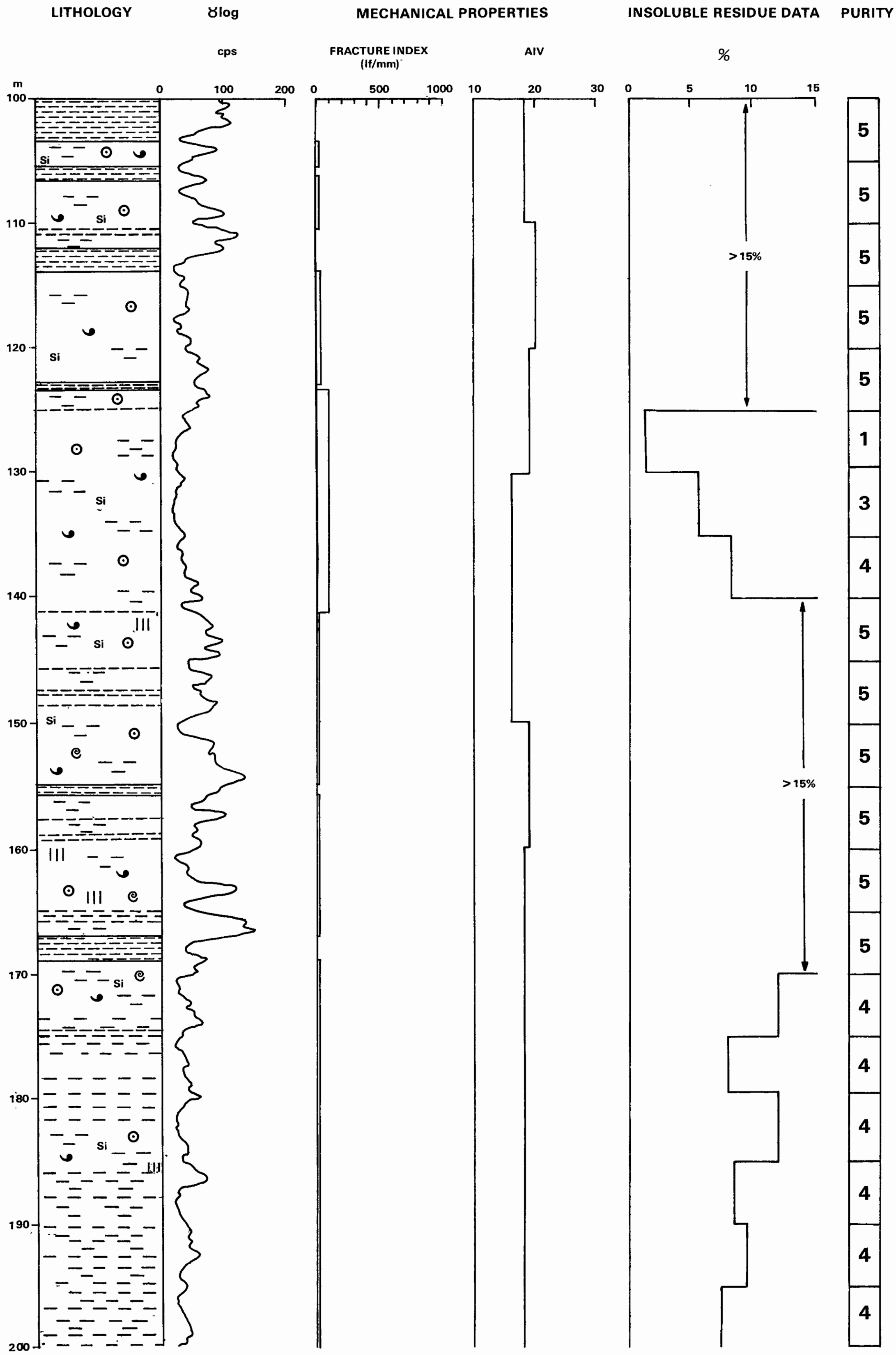
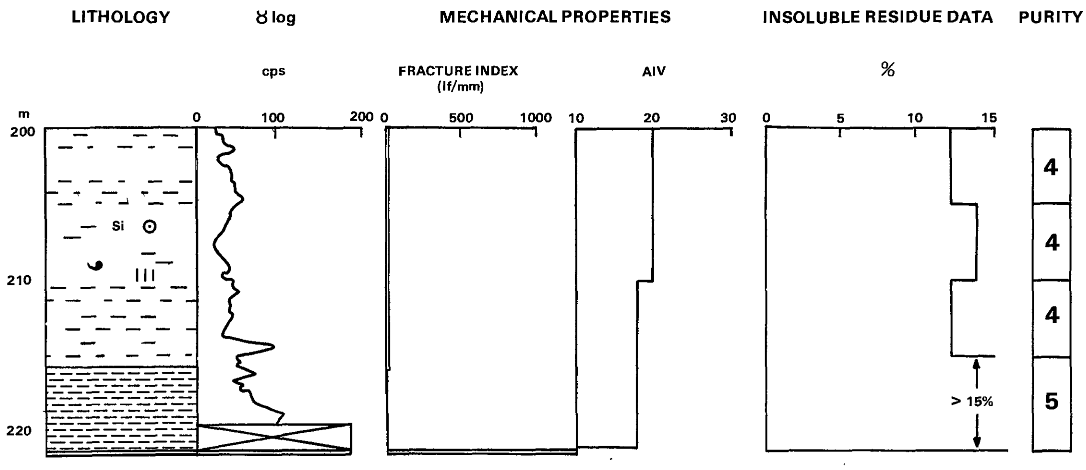
3
5

Argillaceous limestone/mudstone, mixed sequence; mudstone 97.94-103.64 m, 105.43-106.56 m, 110.40-110.91 m, 112.14-113.80 m, micaceous, crinoidal, pyritous. Wackestone, some packstone. Bioturbated. Common rudite crinoid debris. Patchy disseminated dolomite, some bioclastic silicification, pyritous.	15.86	113.80
Argillaceous limestone, dark grey, wackestone, rare packstone. Locally passes into mudstone. Bioturbated. Scattered rudite crinoid and coral debris. Dolomitic.	27.39	141.19
Argillaceous limestone/mudstone, mixed sequence. Dark grey, wackestone, arenite to rudite crinoid, shell, coral, peloid and foraminifera debris. Bioturbated. Common mudstone interbeds. Some pyrite, silicification. Locally dolomitic 162.93-163.90 m.	33.01	174.20
Limestone, dark grey, wackestone, arenite and rudite crinoid, shell and *Syringopora* debris, very bioturbated. Variable clay content, common microstylolites and clay-seams. Patchy silicification, disseminated dolomite and pyrite.	41.36	215.56
Mudstone, dark grey, some dolomite and silicification.	5.64	221.20

J
SD 86 SE 8 cont.



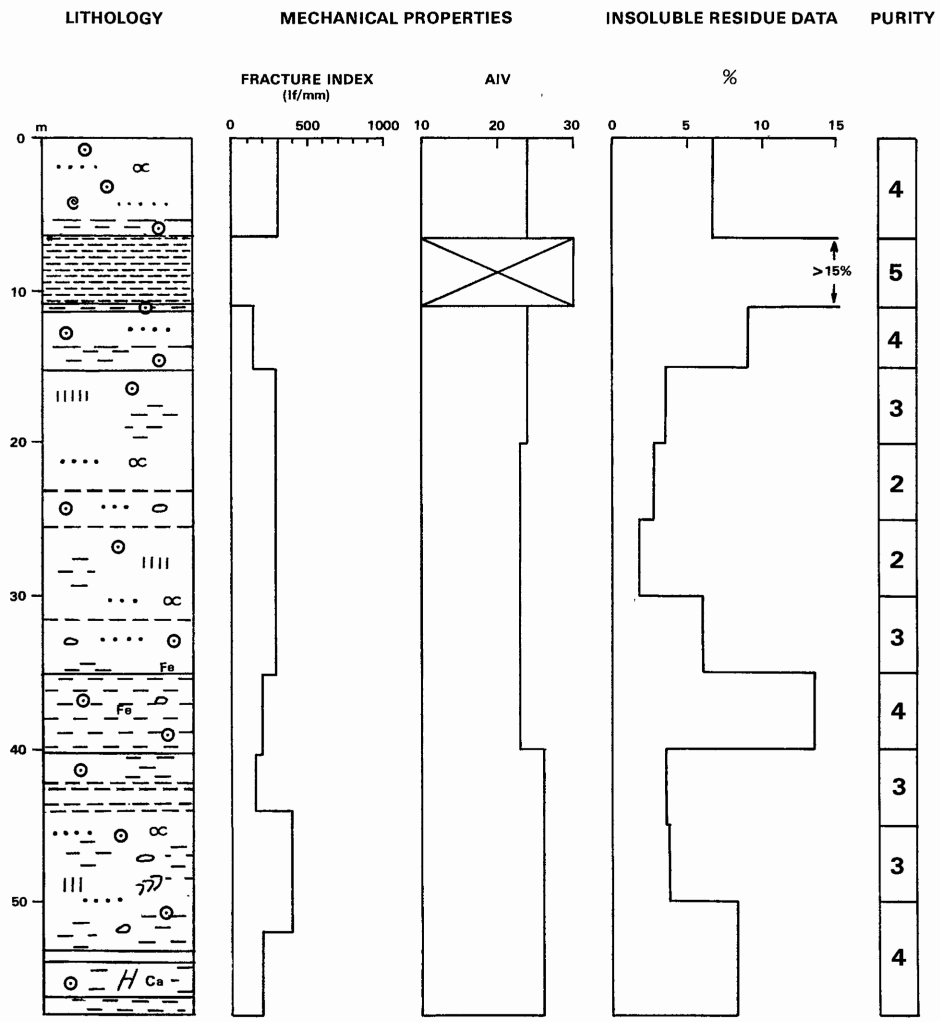


SE 05 SW 2s **0162 5286** **Skibeden Quarry** **Block K**

Surface level +195 m
October 1979

		Thickness m	Depth m
Haw Bank Limestone	Limestone, mid-grey, wackestone and packstone some bioturbated grainstone beds; common arenite crinoid and comminuted bioclastic debris, some oncolites and foraminifera. Scattered authigenic quartz.	5.50	5.50
	Limestone, dark grey, wackestone, clay-rich.	1.00	6.50
	Shale, black, some thin limestone interbeds.	4.50	11.00
	Limestone, dark grey, wackestone, clay-rich.	0.50	11.50
	Limestone, dark grey, lithology variable between grainstone and clay-rich wackestone. Medium arenite ostracods and crinoid debris, some algal-encrusted bioclasts. Shaly 13.70-15.20 m, thin shales 23.10 m, 25.5 m, 31.6 m. Patchy silicification and dolomitisation, scattered pyrite. Common authigenic quartz 34 m.	23.60	35.10
	Argillaceous limestone, dark grey, wackestone, scattered rudite crinoid debris, subordinate ostracod and shell debris. Common thin shale interbeds. Pyritous.	5.30	40.40
	Limestone, dark grey, locally mid-grey, fine arenite, wackestone. Scattered rudite crinoid, shell and ostracod debris, peloidal with algal-encrusted bioclasts 45.00-46.00 m, 50 m. Some shaly partings, clay-rich 50.50-57.50 m; shales 53.10-53.30 m, 54.10-54.40 m, 56.25-56.55 m. Patchy disseminated dolomite. Locally pyritous. Disturbed, faulted beds 53.10-57.50 m.	17.10	57.50

K
SE 05 SW 2s

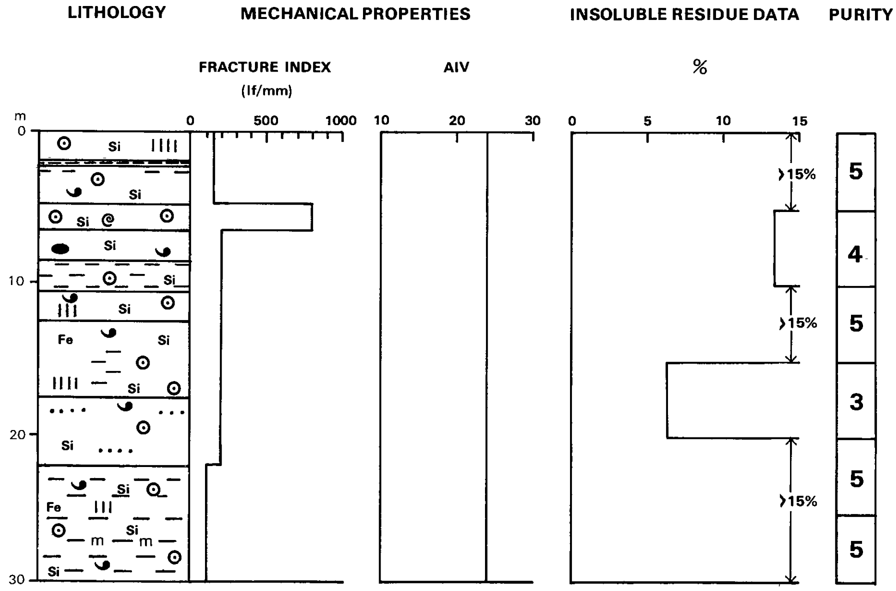

LITHOLOGY
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
FRACTURE INDEX
(lf/mm)
AIV
%
m
0
10
20
30
40
50
0
500
1000
10
20
30
0
5
10
15
>15%
Fe
Ca
4
5
4
3
2
2
3
4
3
3
4

SE 05 SW 3s **0142 5278** **Skibeden Quarry** **Block K**

Surface level +191 m
October 1979

		Thickness m	Depth m
Haw Bank Limestone	Limestone, dark grey, packstone. Patchy silicification.	1.90	1.90
	Mudstone, thin argillaceous limestone interbeds.	0.40	2.30
	Limestone, dark grey, wackestone, arenite and rudite bioclasts.	2.50	4.80
	Limestone, mid-grey, packstone and grainstone, abundant rudite crinoid debris. Some patchy silicification.	1.70	6.50
	Limestone, mid-grey, wackestone, some patchy silicification and chert. Argillaceous below 8.50 m.	4.00	10.50
	Limestone, mid-grey, abundant rudite crinoid and brachipod debris, packstone.	2.00	12.50
	Limestone, dark grey, wackestone, some shaly partings, some argillaceous beds. Sporadic disseminated dolomite. Some irregular cherty silicification.	5.00	17.50
	Limestone, dark grey, coarse arenite grainstone, scattered rudite brachiopod and crinoid debris, common peloid debris. Some patchy silicification.	4.40	21.90
	Limestone, dark grey, wackestone, common shale interbeds. Sporadic crinoid, shell and coral debris. Some bioclastic and cherty silicification, and disseminated dolomite.	7.60	29.50

K
SE 05 SW 3s

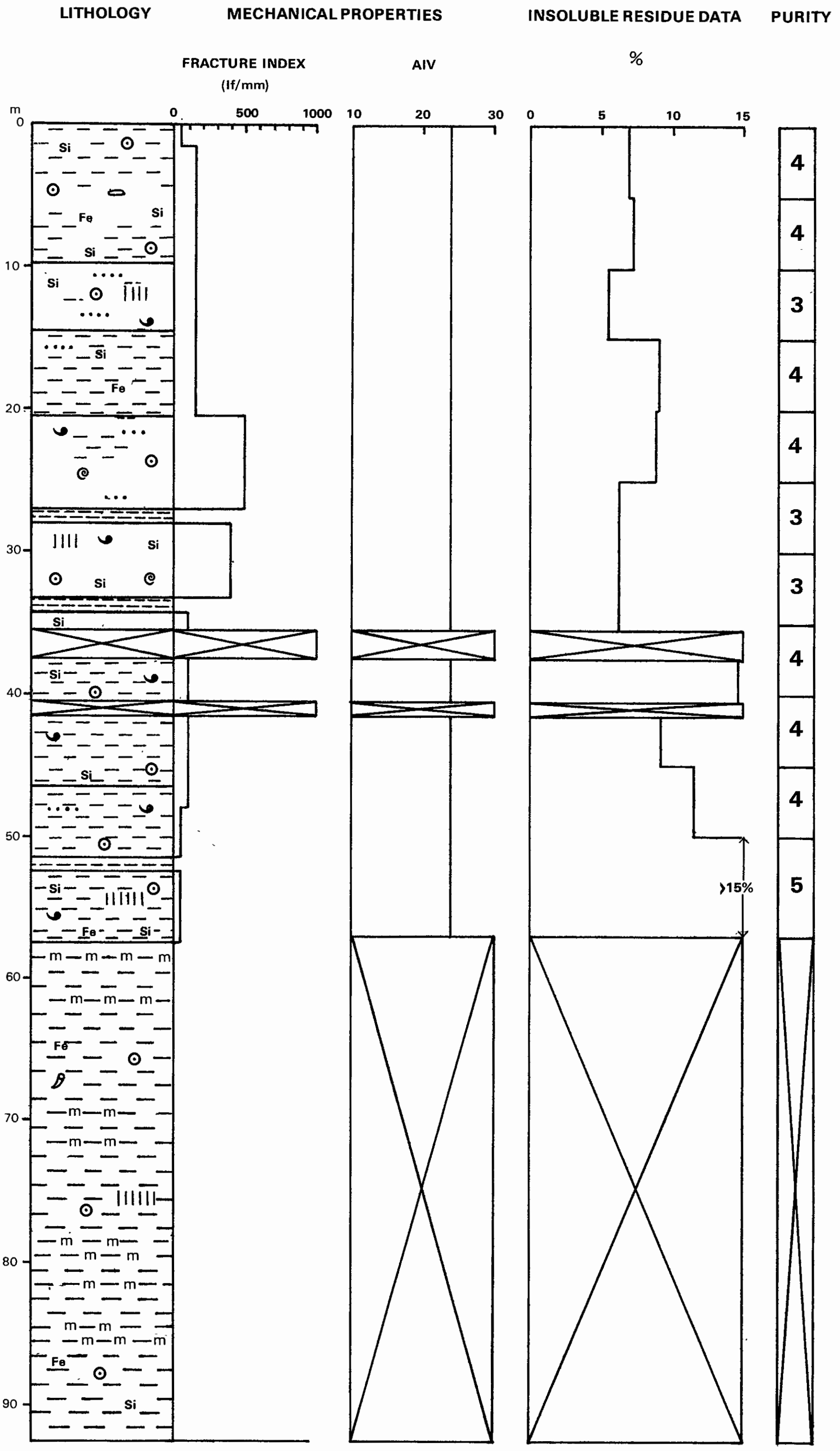


LITHOLOGY
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
FRACTURE INDEX
(lf/mm)
AIV
%
m
0
10
20
30
500
1000
5
15
>15%
4
3
Si
Fe

Surface level +191 m
October 1979

		Thickness m	Depth m
Haw Bank Limestone	Argillaceous limestone, dark grey, wackestone, thin shale partings, some bioclastic silicification and fine silica.	9.75	9.75
	Limestone, dark grey, fine arenite packstone, common fine silica, some dolomite.	4.75	14.50
	Argillaceous limestone, dark grey, wackestone, pyritous.	6.00	20.50
	Limestone, dark grey, arenite packstone. Some shale interbeds.	6.00	26.50
	Limestone, dark grey, fine arenite wackestone, common fine silica, some dolomite. Thick shale 27.10-27.80 m.	3.00	29.50
	Limestone, dark grey, fine arenite wackestone, some disseminated clay, common fine silica, scattered disseminated dolomite. Thick shale 33.20-34.30 m.	7.00	36.50
	Argillaceous limestone, fine arenite wackestone. Scattered rudite crinoid and shell debris, rare peloids. Sporadic disseminated dolomite, some patchy silicification.	21.00	57.50
Haw Bank Limestone with Shale	Mudstone, some thin flaggy limestones.	35.00	92.50

K
SE 05 SW 4s


LITHOLOGY
MECHANICAL PROPERTIES
INSOLUBLE RESIDUE DATA
PURITY
FRACTURE INDEX
(lf/mm)
AIV
%
m
0
10
20
30
40
50
60
70
80
90
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500
1000
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20
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0
5
10
15
Si
Fe
m
›15%
4
4
3
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4
3
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4
4
5

SE 05 SW 5s **0181 5298** **Far Skibeden Quarry** **Block K**

Surface level +202 m
October 1979

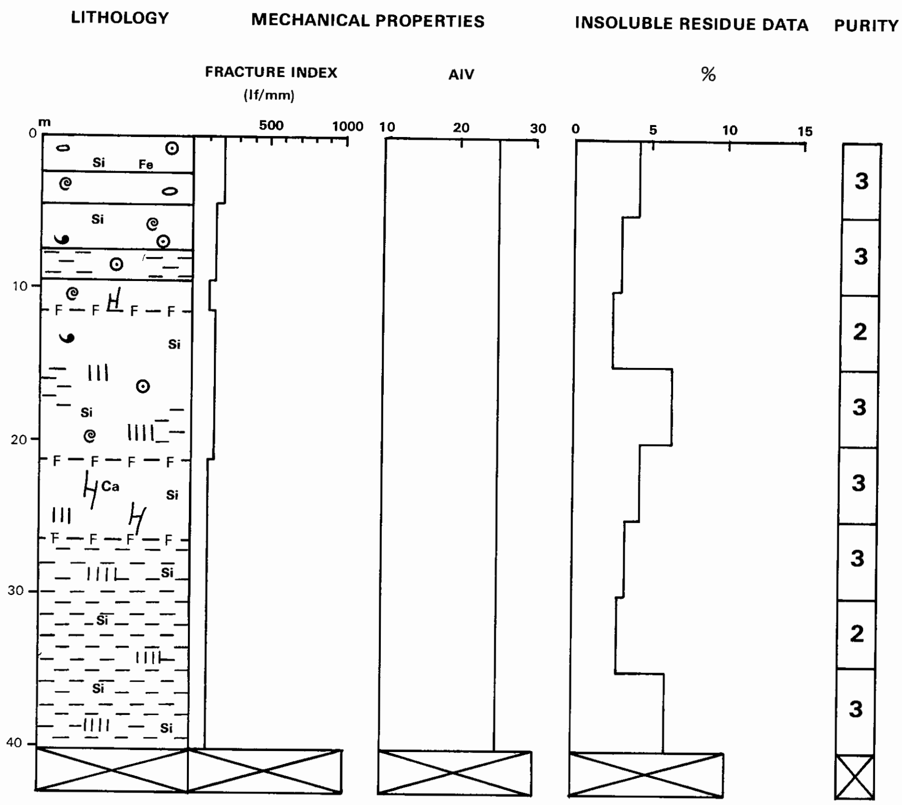
		Thickness m	Depth m
Haw Bank Limestone	Limestone, dark grey, fine to medium arenite ostracod, and foraminifera debris, wackestone. Some fine silica and pyrite.	2.50	2.50
	Limestone, mid-grey, packstone, common ostracod foraminifera, shell, crinoid and peloid debris. Some silicification and dolomitisation.	2.00	4.50
	Limestone, dark grey, fine arenite, wackestone, patchily silicified.	3.00	7.50
	Limestone, dark grey, medium arenite packstone.	1.00	8.50
	Argillaceous limestone, wackestone, some pyrite.	1.00	9.50
	Limestone, mid-grey packstone, common ostracod, crinoid, foraminifera and peloid debris. Strike fault at 11.50 m.	2.05	11.55
	Limestone, mid-grey to dark grey, medium arenite wackestone, some disseminated clay and dolomite, sporadic fine silica. Fault at 21.20 m.	9.65	21.20
	Limestone, dark grey, wackestone, abundant calcite veining, some silica, dolomite and pyrite. Fault at 26.50 m.	5.30	26.50
	Argillaceous limestone, dark grey, fine arenite wackestone, common disseminated dolomite and fine silica.	12.00	38.50

SE 05 SW 6s **0318 5385** **Halton East Quarries** **Block K**

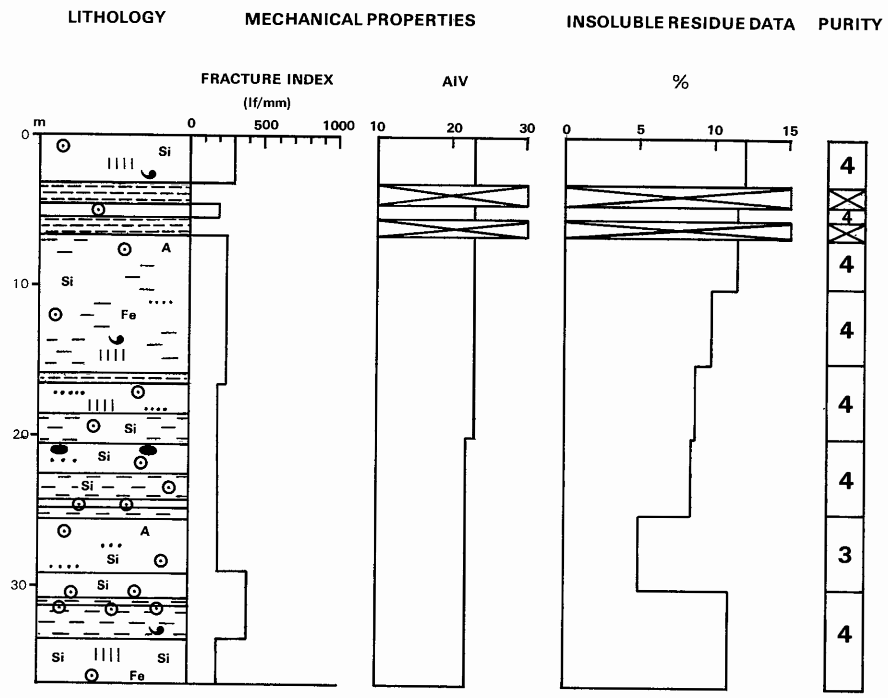
Surface level +197 m
October 1979

		Thickness m	Depth m
Embsay Limestone	Limestone, mid-grey, fine arenite wackestone, abundant fine silica, some dolomite and pyrite.	3.20	3.20
	Shale, some thin limestone interbeds.	1.50	4.70
	Limestone, mid-grey, to dark grey, coarse arenite packstone, some fine silicification.	0.80	5.50
	Shale, some thin limestone interbeds.	1.10	6.60
	Limestone, mid-grey to dark grey, coarse arenite packstone and grainstone, some argillaceous wackestone. Common crinoid, algae, peloid and shell debris. Some thin shaly interbeds and sporadic thick shale lenses in wavy-bedding. Some fine silica, dolomite and pyrite.	9.90	16.50
	Limestone, dark grey, medium arenite packstone and grainstone, some fine silica and dolomite.	2.00	18.50
	Argillaceous limestone, dark grey, wackestone.	2.00	20.50
	Limestone, dark grey, packstone, common crinoid and peloid debris.	2.00	22.50
	Argillaceous limestone, dark grey, wackestone, crinoidal, some silica, partially silicified 23.50-25.50 m. Abundant rudite crinoid debris, 24.40-24.60 m.	3.00	25.50
	Limestone, dark grey, fine arenite packstone and grainstone, common fine silica.	3.60	29.10
	Limestone, dark grey, fine arenite wackestone, some fine silica, dolomite and pyrite. Coarsely crinoidal 30.40-30.80 m, 31.20-31.40 m.	2.70	31.80
	Argillaceous limestone, dark grey, packstone, common crinoid debris.	1.70	33.50
	Limestone, dark grey, medium to coarse arenite wackestone and packstone. Some fine silica, dolomite and pyrite. Some interbedded shales.	3.00	36.50

K
SE 05 SW 5s



K
SE 05 SW 6S



SE 05 SW 7s	0319 5214	Wheelam Rock Quarries		Block K

Surface level +225 m
November 1979

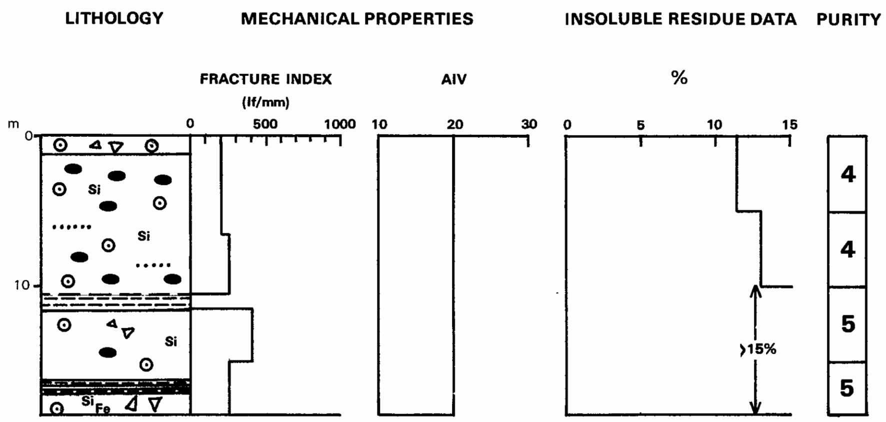
		Thickness m	Depth m
Draughton Limestone	Limestone, mid-grey, packstone, abundant crinoid and lithoclastic debris.	1.20	1.20
	Limestone, mid-grey, variable lithology, sparry peloidal beds, coarsely crinoidal packstone and wackestone beds. Some nodular chert 1.20-6.00 m, 8.20-9.30 m; common fine silica and patchy bioclastic silicification throughout. Scattered pyrite.	9.20	10.40
	Shale, variable thickness 2 to 10 cm.	0.10	10.50
	Shale, interbedded limestones.	1.00	11.50
	Limestone, dark grey, wackestones and packstones, arenite and rudite crinoid debris, some lithoclasts. Scattered chert nodules. Thin shale 15.50 m. Current laminated 16.00 m. Some pyrite.	4.60	16.10
	Shale.	0.30	16.40
	Limestone, dark grey, wackestone.	0.30	16.70
	Shale.	0.20	16.90
	Limestone, dark grey, arenite wackestone, common quartz euhedra and silicified bioclasts. Scattered pyrite.	0.60	17.50
	Limestone, dark grey, packstone, abundant rudite crinoid debris and lithoclasts, current sorted. Patchy silicification, some pyrite and chalcopyrite.	0.90	18.40

SE 05 SE 1s	0565 5325	Hambleton Quarry		Block K

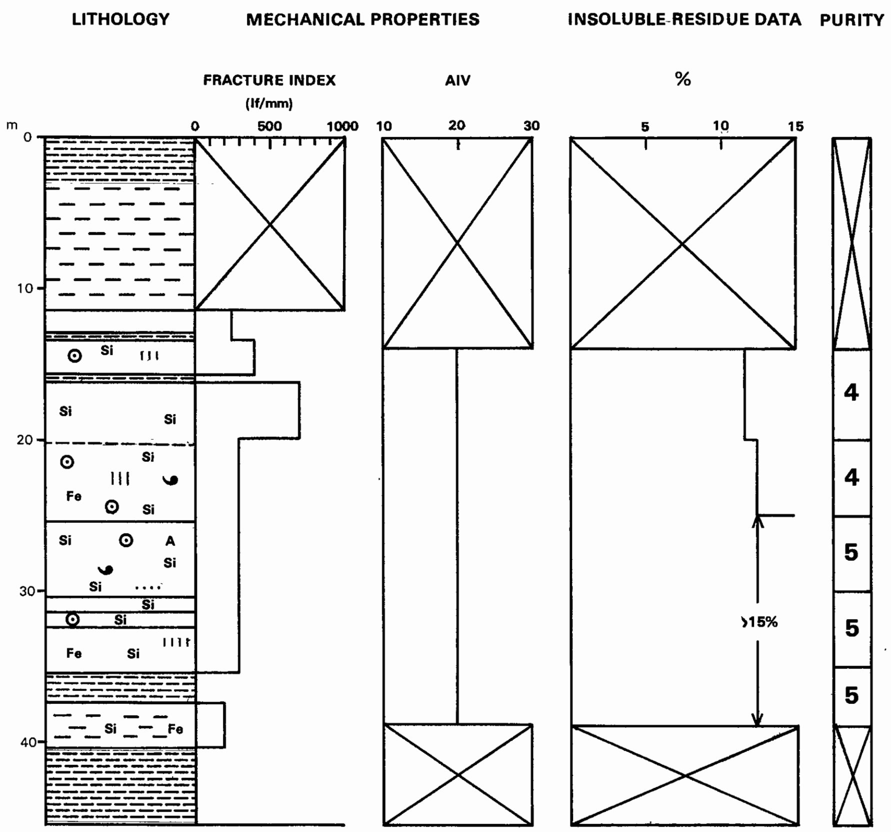
Surface level +170 m
October 1979

		Thickness m	Depth m
	Shale, black, rare thin limestone interbeds.	3.00	3.00
Draughton Limestone	Limestone, dark grey, thinly-bedded, common thin black shales.	8.50	11.50
	Limestone, dark grey.	1.50	13.00
	Shale.	0.50	13.50
	Limestone, mid-grey to dark grey, coarse arenite packstone, common crinoid, peloid, spine and foraminifera debris. Some fine silica and dolomite.	2.30	15.80
	Shale, thin interbedded argillaceous limestones.	0.60	16.40
	Limestone, dark grey, fine arenite packstone, some intraclasts. Some fine silica and common bioclastic silicification.	3.70	20.10
	Limestone, dark grey, wackestone, common crinoid, peloid and foraminifera debris. Common silicification, some dolomite and pyrite.	5.40	25.50
	Limestone, dark grey, wackestone to packstone, some current lamination. Very silicified, some altered pyrite. Some flaggy beds, some disseminated dolomite.	10.00	35.50
	Shale, brown.	2.00	37.50
	Limestone, dark grey, wackestone, common silicification, pyritous, some dolomite. Bioturbated, current laminated. Nodular bedding. Common shale interbeds.	3.00	40.50
	Shale.	5.00	45.50

K
SE 05 SW 7S



K
SE 05 SE 1S



APPENDIX D
CHEMICAL ANALYSES.

Rapid instrumental and chemical methods of analysis were used. The table below shows estimated 95 per cent confidence limits for results on the very high, high and medium purity (>93.5 % $CaCO_3$) limestones, together with the determination limits below which the accuracy is uncertain. The detection limits, which are also shown, are the concentrations of each element reproducibly measurable above the instrumental background signal. For impure limestones, the accuracy is uncertain due to inter-element interference effects. Some results may therefore lie outside the tolerances obtainable using standard or referee chemical methods of analysis.

	Estimated 95% confidence limits ±	Lower Determination Limit	Detection Limit
CaO	0.8%	50%	-
SO_3	0.10%	0.10%	0.01%
Na_2O	0.02%	0.02%	0.02%
F	0.10%	0.05%	0.03%
SiO_2	0.10%	0.10%	0.02%
MgO	0.14%	0.10%	0.02%
Al_2O_3	0.10%	0.10%	0.01%
K_2O	0.02%	0.02%	0.01%
Fe_2O_3	0.12%	0.10%	0.05%
SrO	0.04%	0.20%	0.10%
P_2O_5	0.02%	0.05%	0.02%
Loss at 1050°C	0.15%	-	-
Cu	10 ppm	3 ppm	1 ppm
PB	10 ppm	3 ppm	1 ppm
Zn	20 ppm	5 ppm	2 ppm
Acid-soluble MnO	20 ppm	10 ppm	3 ppm
Acid-soluble Fe_2O_3	20 ppm	10 ppm	3 ppm
As	2 ppm	2 ppm	1 ppm

CHEMICAL ANALYSES.

Depth	Percentage by weight												Parts per million				
	CaO	SO_3	Na_2O	F	SiO_2	MgO	Al_2O_3	K_2O	SrO	P_2O_5	Fe_2O_3	Loss†	Cu	Pb	Zn	MnO	As
SD 64 NE 12	**6930 4809 Ashnott**													**Block B**			
1-10	54.24	0.18	0.02	0.02	1.46	0.47	0.64	0.10	0.03	0.03	0.46	42.82	10	10	90	290	
10-20	52.33	0.09	0.03	0.01	4.87	0.40	0.97	0.12	0.05	0.03	0.59	40.97	10	30	350	310	
20-30	49.98	0.41	0.03	0.03	7.44	0.45	1.84	0.21	0.08	0.03	0.56	39.61	5	20	180	330	
30-40	53.23	0.50	0.02	0.03	2.44	0.45	1.35	0.17	0.04	0.03	0.51	42.18	5	10	210	280	
40-50	54.52	0.19	0.02	0.03	1.56	0.48	0.47	0.08	0.03	0.02	0.34	42.81	5	0	60	280	
50-60	54.64	0.16	0.03	0.01	1.23	0.55	0.47	0.09	0.03	0.02	0.31	42.98	5	0	40	250	
60-70	53.51	0.24	0.03	0.02	1.91	0.59	0.94	0.15	0.04	0.02	0.41	42.46	5	10	40	200	
70-80	54.17	0.21	0.02	0.01	1.72	0.43	0.66	0.10	0.04	0.02	0.34	42.59	5	10	80	320	
80-90	54.57	0.19	0.03	0.02	1.46	0.45	0.67	0.11	0.02	0.02	0.34	42.78	5	0	40	290	
90-100	53.62	0.29	0.02	0.02	1.77	0.50	0.73	0.10	0.03	0.02	0.39	42.57	5	10	80	410	
100-110	53.61	0.18	0.02	0.01	2.11	0.70	0.54	0.08	0.02	0.02	0.66	42.64	5	10	20	800	
110-120	51.99	0.37	0.02	0.03	3.99	0.68	1.20	0.21	0.05	0.02	0.64	41.27	5	10	70	500	
SK 75 SW 1	**7029 5123 Blue Butts Farm**													**Block B**			
2-5	53.69	0.14	0.02	0.01	2.95	0.45	0.30	0.06	0.02	0.02	0.48	42.15	5	0	10	460	
5-10	54.35	0.04	0.02	0.01	2.01	0.52	0.25	0.06	0.02	0.02	0.38	42.49	5	0	10	400	1
10-15	54.20	0.10	0.02	0.01	2.19	0.54	0.36	0.08	0.02	0.02	0.31	42.11	0	0	10	400	
15-20	54.01	0.10	0.02	0.01	2.31	0.54	0.42	0.09	0.02	0.02	0.43	42.12	5	0	10	470	
20-25	53.80	0.14	0.02	0.01	2.10	0.84	0.37	0.08	0.02	0.02	0.45	42.69	0	0	10	500	
25-30	52.38	0.12	0.06	0.01	3.80	0.81	0.95	0.19	0.03	0.02	0.65	41.18	0	0	90	470	
30-35	53.50	0.19	0.07	0.01	2.34	1.00	0.70	0.15	0.03	0.02	0.54	41.84	5	0	20	400	
35-40	49.44	0.53	0.13	0.07	6.92	0.95	2.31	0.47	0.08	0.03	1.02	38.63	5	0	60	600	
42-45	52.34	0.47	0.12	0.02	3.60	0.79	1.16	0.24	0.04	0.02	0.72	40.75	0	0	20	500	
45-50	44.65	1.33	0.22	0.10	11.80	1.29	4.06	0.81	0.13	0.03	1.54	35.43	0	0	70	510	
50-55	45.61	1.11	0.11	0.08	12.67	0.95	3.26	0.66	0.12	0.05	1.27	35.35	0	0	50	950	
55-60	38.79	1.06	0.08	0.06	26.21	1.07	2.76	0.56	0.21	0.04	1.22	30.43	5	10	110	1000	
60-65	37.25	1.35	0.13	0.08	26.34	1.07	4.09	0.80	0.24	0.04	1.67	30.44	5	10	100	920	
65-80	29.21	1.51	0.27	0.10	34.13	1.78	7.22	1.30	0.30	0.05	2.89	26.55	5	10	90	740	
80-90	29.98	1.52	0.27	0.10	31.11	1.93	7.14	1.26	0.31	0.06	3.14	26.83	5	20	70	760	
90-99	20.43	1.33	0.51	0.13	37.33	2.72	13.53	2.10	0.38	0.08	5.19	20.37	15	20	90	720	
SD 74 SW 7	**7093 4102 Withgill Knoll**													**Block C**			
1-10	54.38	0.06	0.03	0.02	1.84	0.41	0.31	0.05	0.01	0.02	0.35	42.73	5	0	20	180	
10-20	54.72	0.09	0.04	0.04	1.60	0.43	0.29	0.05	0.01	0.02	0.37	42.35	5	0	10	180	
20-30	54.55	0.08	0.03	0.07	2.39	0.38	0.23	0.04	0.02	0.02	0.28	42.49	5	0	20	210	
30-40	55.04	0.12	0.08	0.01	1.02	0.47	0.24	0.05	0.00	0.01	0.30	43.03	0	0	10	160	0
40-50	55.23	0.24	0.04	0.03	0.74	0.38	0.26	0.04	0.01	0.02	0.33	42.91	0	0	10	170	
50-60	54.63	0.19	0.06	0.07	1.71	0.36	0.22	0.04	0.00	0.02	0.34	42.40	0	0	10	190	
60-70	54.66	0.35	0.07	0.00	2.10	0.36	0.27	0.05	0.00	0.01	0.47	42.11	5	0	10	200	
70-80	55.39	0.28	0.07	0.00	0.47	0.37	0.32	0.05	0.00	0.01	0.40	42.86	0	0	10	200	
80-90	55.57	0.16	0.05	0.00	0.44	0.34	0.20	0.04	0.00	0.01	0.32	43.07	5	0	20	200	
90-100	55.49	0.18	0.04	0.00	0.53	0.34	0.22	0.04	0.00	0.01	0.34	43.06	5	10	10	200	1
100-110	54.86	0.27	0.04	0.00	1.09	0.39	0.37	0.06	0.00	0.02	0.43	42.63	5	0	10	200	
110-120	54.76	0.16	0.05	0.00	0.99	0.40	0.50	0.07	0.00	0.03	0.37	42.88	5	0	10	180	
120-129	54.64	0.70	0.05	0.01	1.21	0.44	0.52	0.08	0.01	0.03	0.63	41.91	0	0	10	220	
SK 74 SW 8	**73 80 4290 Brungerley Bridge**													**Block C**			
1-10	53.81	0.12	0.03	0.06	3.00	0.49	0.22	0.05	0.08	0.01	0.26	42.49	5	0	20	320	
10-20	51.03	0.28	0.03	0.09	4.82	1.98	0.15	0.04	0.10	0.01	0.39	41.76	5	0	20	270	
20-30	53.47	0.17	0.03	0.07	2.35	1.22	0.19	0.05	0.09	0.01	0.25	43.00	10	0	20	230	
30-40	51.89	0.12	0.02	0.10	2.11	2.28	0.15	0.04	0.09	0.01	0.29	43.44	5	0	10	220	
40-50	53.05	0.19	0.02	0.10	3.17	1.07	0.22	0.05	0.08	0.01	0.08	42.75	5	0	10	100	
50-60	49.10	0.59	0.03	0.07	8.59	1.19	1.02	0.18	0.12	0.01	0.51	39.81	5	10	50	125	
60-70	49.63	0.78	0.04	0.11	6.36	1.53	1.31	0.22	0.10	0.01	0.57	40.56	5	0	20	100	
70-80	48.11	1.08	0.04	0.08	7.47	1.52	2.01	0.32	0.12	0.01	0.82	39.20	5	10	20	300	
80-90	51.78	0.51	0.02	0.05	4.66	1.04	0.83	0.14	0.10	0.01	0.47	41.47	5	10	50	240	
90-100	49.85	0.60	0.03	0.07	6.53	1.38	0.98	0.17	0.09	0.01	0.63	40.84	5	10	230	380	

APPENDIX D continued

CHEMICAL ANALYSES.

Depth	CaO	SO_3	Na_2O	F	SiO_2	MgO	Al_2O_3	K_2O	SrO	P_2O_5	Fe_2O_3	Loss†	Cu	Pb	Zn	MnO	As
	Percentage by weight												Parts per million				
SD 74 SE 1	**7893 4450**	**Smithfield Farm, Downham**											**Block C**				
1-10	51.92	0.28	0.03	0.14	5.13	1.31	0.42	0.08	0.11	0.01	0.45	41.71	0	0	30	420	
10-20	50.23	0.21	0.04	0.09	4.38	2.99	0.20	0.05	0.10	0.01	1.01	42.33	0	10	50	600	
20-30	51.84	0.51	0.00	0.09	6.12	1.08	0.41	0.04	0.22	0.00	0.39	41.18	0	10	40	300	
30-40	44.27	1.42	0.07	0.17	14.08	1.71	2.86	0.47	0.20	0.01	1.02	36.27	5	10	20	180	
40-50	49.92	0.53	0.04	0.12	5.34	2.48	0.90	0.16	0.12	0.01	0.53	41.65	0	10	40	120	
50-60	48.17	1.19	0.07	0.16	7.90	1.63	2.33	0.38	0.15	0.01	0.87	39.49	0	0	10	130	
60-70	48.37	1.05	0.05	0.16	7.16	2.06	1.89	0.31	0.14	0.01	0.80	39.87	0	10	20	160	
70-80	48.76	1.00	0.04	0.15	6.12	1.90	1.56	0.25	0.11	0.01	0.09	40.66	0	10	15	80	
80-90	52.09	0.61	0.04	0.14	3.03	1.55	0.79	0.12	0.09	0.01	0.41	42.49	0	0	15	130	
90-100	51.40	0.22	0.03	0.13	3.29	2.46	0.29	0.06	0.10	0.00	0.27	42.70	0	0	30	200	
100-110	51.63	0.23	0.03	0.14	2.49	2.85	0.18	0.04	0.08	0.00	0.35	43.31	5	0	40	310	0
110-120	51.25	0.74	0.07	0.18	3.90	1.86	0.42	0.09	0.12	0.00	0.45	42.01	5	0	50	340	
120-130	49.88	1.13	0.04	0.19	5.51	1.72	1.82	0.26	0.13	0.01	0.68	40.37	0	10	10	90	
130-146	51.45	0.84	0.07	0.17	3.54	1.72	1.23	0.20	0.10	0.01	0.54	41.92	0	0	10	120	
SD 74 SE 1 s	**7731 4399**	**Chatburn Road Cutting**											**Block C**				
1-20	51.18	0.12	0.02	0.02	5.29	0.82	0.33	0.06	0.13	0.01	0.04	41.62	5	0	20	110	
20-40	49.35	0.61	0.03	0.07	6.75	1.00	1.41	0.23	0.13	0.01	0.67	40.24	5	10	10	110	
40-60	50.28	0.37	0.02	0.05	5.90	0.89	1.10	0.17	0.12	0.01	0.54	40.82	5	10	20	160	
60-80	49.96	0.52	0.03	0.05	5.34	1.12	1.10	0.17	0.10	0.01	0.49	40.94	5	10	20	120	
80-100	51.21	0.28	0.01	0.00	3.62	1.48	0.41	0.06	0.10	0.01	0.05	42.24	5	10	10	170	
110-120	50.01	0.33	0.01	0.04	5.03	1.69	0.64	0.10	0.10	0.01	0.42	41.54	5	0	30	300	
120-140	50.56	0.57	0.01	0.00	3.32	1.72	0.88	0.13	0.10	0.01	0.07	42.21	5	10	10	120	
140-160	50.98	0.49	0.02	0.04	3.45	1.56	0.68	0.11	0.10	0.01	0.05	42.31	5	0	10	110	
160-180	50.47	0.58	0.03	0.04	4.55	1.23	0.79	0.12	0.14	0.01	0.08	41.91	5	0	10	80	
180-201	49.51	0.56	0.02	0.03	4.76	2.12	0.93	0.14	0.10	0.01	0.08	41.77	5	0	30	140	
SD 74 SE 2 s	**7678 4320**	**Chatburn Road Cutting**											**Block C**				
1-20	49.90	0.03	0.01	0.00	10.64	0.41	0.52	0.09	0.07	0.02	0.44	39.80	5	0	30	540	
20-40	49.57	0.01	0.00	0.00	9.48	0.41	0.55	0.09	0.09	0.02	0.39	39.49	5	0	30	500	
40-66	49.38	0.05	0.01	0.00	9.00	0.51	0.67	0.11	0.09	0.02	0.42	39.75	5	0	40	660	
SD 74 SE 3 s	**7674 4289**	**Chatburn Road Cutting**											**Block C**				
1-16	53.43	0.03	0.03	0.03	1.72	0.46	0.77	0.14	0.02	0.03	0.45	42.08	5	0	20	500	
SD 74 SE 4 s	**7607 4265**	**Bellmanpark Quarry**											**Block C**				
1-10	53.37	0.11	0.02	0.00	1.74	0.43	0.50	0.09	0.03	0.02	0.52	42.35	5	0	20	240	
10-21	54.34	0.09	0.02	0.00	0.57	0.30	0.34	0.07	0.01	0.02	0.81	43.05	5	0	30	200	
SD 74 SE 5 s	**7641 4322**	**Peach Quarry**											**Block C**				
1-20	51.03	0.02	0.02	0.00	6.86	0.50	0.29	0.06	0.07	0.02	0.09	40.65	5	0	30	520	
20-37	48.55	0.06	0.01	0.00	11.49	0.53	0.43	0.07	0.12	0.02	0.62	38.57	5	0	50	520	
46-53	42.74	0.00	0.03	0.00	23.17	0.48	0.53	0.07	0.19	0.02	0.42	33.40	5	0	40	600	
SD 74 SE 7 s	**7990 4397**	**Clay House Quarry**											**Block C**				
1-8	52.27	0.39	0.02	0.00	2.47	0.51	0.92	0.14	0.04	0.03	0.63	41.83	5	0	60	270	
SD 84 SW 1 s	**8084 4435**	**Twiston Mill Quarry**											**Block C**				
1-5	53.06	0.01	0.01	0.01	1.55	0.48	0.76	0.13	0.02	0.04	1.03	42.34	5	0	20	830	
5-10	53.91	0.01	0.01	0.02	1.02	0.44	0.59	0.10	0.03	0.03	0.09	42.66	5	0	20	370	
10-13	53.81	0.01	0.00	0.00	1.16	0.43	0.65	0.11	0.02	0.03	0.08	42.82	5	0	20	500	
SD 84 SW 2 s	**8116 4415**	**Hill Top Quarry**											**Block C**				
1-5	53.95	0.02	0.00	0.00	0.95	0.48	0.47	0.07	0.01	0.02	0.33	42.90	5	0	10	220	
5-10	54.39	0.00	0.01	0.00	0.40	0.33	0.22	0.04	0.01	0.03	0.08	43.09	5	0	10	390	
10-13	53.81	0.04	0.00	0.00	1.00	0.49	0.62	0.10	0.02	0.05	0.50	42.73	5	0	30	460	

APPENDIX D continued

CHEMICAL ANALYSES.

Depth	Percentage by weight												Parts per million				
	CaO	SO_3	Na_2O	F	SiO_2	MgO	Al_2O_3	K_2O	SrO	P_2O_5	Fe_2O_3	Losst	Cu	Pb	Zn	MnO	As
SD 75 NE 12	**7794 5661**	**Snape House**												**Block E**			
10-15	47.84	1.26	0.04	0.05	9.95	1.19	1.73	0.28	0.14	0.16	1.01	37.64	5	10	180	1880	
15-20	42.40	1.32	0.08	0.06	16.15	1.70	3.05	0.47	0.19	0.20	1.22	34.34	0	20	200	4600	
20-30	48.95	0.64	0.03	0.02	9.05	1.00	1.41	0.25	0.13	0.04	0.72	38.34	0	0	60	1070	
30-40	41.85	1.00	0.10	0.03	20.26	1.27	2.13	0.37	0.24	0.05	1.21	33.46	0	10	70	1240	
40-50	40.98	0.27	0.06	0.03	23.23	1.24	1.74	0.31	0.24	0.04	0.92	32.84	0	10	110	1100	
50-65	36.35	0.87	0.09	0.04	31.83	1.15	2.19	0.37	0.28	0.04	1.08	28.56	0	0	50	1780	
65-80	46.89	0.43	0.04	0.00	41.08	1.13	0.75	0.13	0.16	0.03	0.71	37.39	0	0	10	1220	
80-90	45.54	0.45	0.04	0.01	16.83	0.85	0.89	0.16	0.17	0.03	0.78	35.94	5	0	10	960	
90-100	43.93	0.73	0.09	0.03	18.55	1.02	1.66	0.29	0.23	0.03	0.74	34.50	0	10	70	490	
SD 85 SW 5	**8471 5194**	**Dobbers Quarry**												**Block F**			
1-5	53.51	0.03	0.01	0.00	1.94	0.91	0.19	0.05	0.01	0.02	0.99	42.47	5	0	10	1700	
5-10	54.81	0.03	0.00	0.00	0.37	0.46	0.18	0.05	0.00	0.02	0.88	43.25	0	0	10	1400	0
10-15	55.47	0.03	0.01	0.00	0.59	0.33	0.13	0.04	0.00	0.02	0.54	43.25	0	0	0	1030	
15-20	54.91	0.03	0.00	0.00	1.13	0.43	0.12	0.04	0.00	0.02	0.76	42.89	0	0	0	1230	
20-25	54.52	0.03	0.01	0.00	0.66	0.59	0.14	0.04	0.00	0.03	0.75	43.14	0	0	0	1100	
25-30	55.00	0.04	0.01	0.00	0.58	0.49	0.34	0.06	0.01	0.03	0.68	42.91	0	0	10	880	
30-35	52.05	0.27	0.05	0.01	5.28	0.60	1.00	0.17	0.05	0.03	0.54	40.63	0	0	30	580	
35-40	54.20	0.11	0.02	0.00	1.29	0.63	0.57	0.10	0.03	0.02	0.57	42.80	0	0	0	550	
40-45	54.53	0.09	0.02	0.00	0.91	0.60	0.46	0.08	0.01	0.02	0.54	42.88	0	0	0	590	
45-50	51.64	0.37	0.02	0.02	5.09	0.73	1.30	0.22	0.06	0.03	0.65	40.67	0	0	10	660	
50-55	55.21	0.04	0.01	0.00	0.56	0.36	0.37	0.06	0.01	0.02	0.50	43.27	0	0	10	530	1
55-60	39.30	1.36	0.06	0.06	21.96	1.22	4.30	0.68	0.19	0.03	1.67	31.62	0	20	90	600	
60-70	27.26	2.12	0.45	0.06	34.40	1.66	8.50	1.13	0.33	0.06	0.68	25.47	0	10	60	500	
SD 85 SE 16	**8606 5301**	**High Laithe**												**Block F**			
2-10	47.94	0.04	0.03	0.05	14.26	0.90	0.17	0.04	0.13	0.01	0.25	37.18	0	10	40	200	
10-20	47.63	0.52	0.06	0.07	12.51	0.86	1.14	0.19	0.16	0.01	0.61	38.26	5	10	100	160	
20-30	47.20	0.81	0.08	0.11	8.75	2.15	1.80	0.35	0.13	0.02	0.82	39.60	5	10	50	240	
30-40	50.81	0.27	0.03	0.17	5.83	1.71	0.37	0.07	0.10	0.01	0.39	41.99	5	0	50	400	
40-50	48.68	0.34	0.07	0.14	10.64	1.21	0.62	0.13	0.13	0.02	0.39	39.57	5	0	50	290	
50-60	45.03	1.17	0.13	0.20	13.75	1.57	2.39	0.41	0.17	0.02	1.00	36.73	0	10	50	150	
60-72	42.90	1.17	0.26	0.03	13.71	2.14	2.71	0.49	0.19	0.03	1.90	36.51	0	10	60	400	
SD 85 SE 2 s	**8818 5161**	**Marton Scar**												**Block F**			
1-7	50.41	0.02	0.00	0.00	7.71	0.59	0.13	0.03	0.11	0.01	0.07	39.98	5	0	30	700	
22-25	50.62	0.00	0.01	0.00	6.96	0.70	0.18	0.03	0.11	0.02	0.04	40.68	5	0	50	240	
38-45	45.78	0.00	0.02	0.00	14.68	1.54	0.29	0.05	0.16	0.02	0.46	37.33	5	0	30	220	
SD 95 SW 29	**9250 5077**	**Brows Hill Quarry**												**Block H**			
1-10	51.03	0.27	0.03	0.08	6.56	1.46	0.45	0.08	0.08	0.00	0.44	41.34	5	0	470	330	
10-20	53.02	0.19	0.05	0.09	3.87	1.10	0.19	0.05	0.08	0.00	0.10	42.36	0	0	60	180	
20-30	50.89	0.36	0.04	0.12	6.31	1.57	0.64	0.12	0.10	0.00	0.44	41.19	5	10	50	130	
30-40	38.18	1.98	0.21	0.61	18.88	1.81	5.95	0.94	0.21	0.02	2.10	31.83	5	10	50	230	
40-50	47.52	0.91	0.09	0.11	9.95	1.24	2.17	0.38	0.15	0.00	1.02	38.51	0	0	40	120	
50-60	44.12	1.58	0.09	0.11	13.65	1.26	3.65	0.58	0.17	0.01	1.43	35.76	0	10	50	130	
60-70	32.79	2.34	0.26	0.16	22.67	2.82	8.17	1.18	0.30	0.02	3.14	30.41	0	0	30	230	
70-83	41.64	2.03	0.11	0.11	15.02	1.29	4.78	0.73	0.17	0.02	1.93	34.80	0	0	40	200	
SD 95 SW 30	**9346 5259**	**Butterhaw**												**Block H**			
3-15	39.50	0.57	0.18	0.09	24.67	1.03	2.81	0.55	0.22	0.04	1.51	31.58	5	0	40	430	
43-45	50.23	0.83	0.08	0.05	5.98	1.41	1.07	0.24	0.11	0.02	0.83	39.82	0	0	30	320	
50-55	46.12	1.10	0.17	0.12	10.96	1.52	2.61	0.54	0.17	0.02	1.14	37.15	0	10	20	220	
60-70	45.51	0.74	0.09	0.10	14.80	1.51	1.48	0.32	0.17	0.02	0.71	36.32	0	0	30	270	
86-100	45.52	0.52	0.05	0.09	15.35	1.81	0.99	0.21	0.17	0.02	0.09	36.25	0	0	70	300	

APPENDIX D continued

CHEMICAL ANALYSES.

Depth	Percentage by weight												Parts per million				
	CaO	SO_3	Na_2O	F	SiO_2	MgO	Al_2O_3	K_2O	SrO	P_2O_5	Fe_2O_3	Loss†	Cu	Pb	Zn	MnO	As
SD 95 NW 7	**9166 5660 Throstle Nest**												**Block I**				
20-30	50.09	0.60	0.09	0.07	6.85	0.94	1.86	0.37	0.11	0.01	0.80	39.51	5	10	10	150	
30-40	51.41	0.30	0.07	0.14	5.54	0.80	1.30	0.25	0.08	0.01	0.65	40.88	5	0	70	150	
40-50	54.33	0.10	0.02	0.07	1.74	0.86	0.29	0.07	0.08	0.01	0.10	43.20	5	10	40	120	1
50-60	47.48	1.30	0.08	0.16	8.78	1.12	3.13	0.56	0.12	0.02	1.15	37.69	5	0	60	170	
60-70	52.51	0.42	0.06	0.07	2.96	1.22	0.74	0.17	0.09	0.01	0.09	42.23	5	0	30	80	
70-80	53.79	0.26	0.03	0.10	2.48	0.85	0.46	0.11	0.08	0.01	0.04	42.63	5	0	40	80	
80-90	53.44	0.13	0.06	0.16	1.22	1.55	0.24	0.08	0.09	0.01	0.07	43.88	5	0	30	130	1
90-100	53.57	0.27	0.10	0.13	2.00	1.25	0.37	0.12	0.08	0.01	0.03	43.00	0	0	30	70	
100-110	52.87	0.39	0.05	0.21	2.30	1.71	0.58	0.14	0.07	0.01	0.05	42.74	0	10	30	130	
110-120	52.20	0.43	0.05	0.17	2.54	1.79	0.68	0.16	0.08	0.01	0.06	42.56	5	0	30	140	
120-130	50.30	0.80	0.04	0.18	4.91	1.87	1.47	0.31	0.09	0.01	0.60	40.90	5	10	30	150	
SD 95 NE 1	**9629 5813 Park Laithe**												**Block I**				
2-20	41.57	0.22	0.25	0.08	23.73	0.93	1.77	0.40	0.24	0.02	0.76	32.94	5	10	60	230	
20-40	35.33	0.99	0.21	0.12	26.84	1.66	5.00	0.95	0.27	0.05	1.83	29.19	5	0	60	230	
40-50	46.16	0.73	0.16	0.11	12.39	1.19	2.46	0.52	0.15	0.06	0.93	36.91	5	10	60	400	
50-60	48.49	0.29	0.03	0.04	9.34	2.04	0.84	0.19	0.10	0.05	0.49	39.60	0	0	60	430	
60-70	48.61	0.31	0.02	0.09	10.93	1.23	0.76	0.18	0.12	0.06	0.37	38.83	0	10	40	290	
70-80	49.57	0.49	0.05	0.13	8.83	1.16	1.02	0.24	0.11	0.04	0.54	39.29	5	0	60	420	
80-90	47.65	0.62	0.08	0.13	11.44	1.18	1.59	0.37	0.14	0.04	0.64	38.07	5	0	70	210	
90-100	47.09	0.53	0.05	0.11	13.07	1.36	1.05	0.23	0.14	0.02	0.45	37.99	5	0	40	230	
100-120	44.48	1.39	0.09	0.19	13.20	1.69	3.27	0.69	0.18	0.03	1.18	36.02	5	10	40	240	
120-130	48.78	0.77	0.06	0.14	8.76	1.35	1.41	0.31	0.12	0.02	0.10	39.40	0	10	50	230	
130-140	52.25	0.35	0.04	0.12	3.74	1.48	0.64	0.15	0.07	0.01	0.04	42.06	5	10	30	110	
140-160	44.29	1.39	0.10	0.13	14.35	1.48	3.09	0.66	0.15	0.03	1.25	34.95	0	10	20	280	
160-180	41.31	2.17	0.12	0.14	14.77	2.68	4.28	0.89	0.17	0.02	1.74	33.91	0	10	100	430	
180-200	48.98	0.51	0.04	0.09	6.07	2.70	0.69	0.16	0.09	0.01	0.75	40.88	5	0	360	1480	
SD 86 SE 8	**8867 6031 High Ings Barn**												**Block J**				
1-10	35.61	0.00	0.00	0.01	2.79	15.50	0.18	0.03	0.07	0.00	3.35	44.25	60	0	160	7800	1
10-20	36.04	0.00	0.00	0.01	4.25	13.31	0.13	0.00	0.09	0.00	4.99	42.73	50	0	70	12000	
20-30	43.35	0.00	0.00	0.01	2.74	8.52	0.14	0.00	0.05	0.00	2.84	43.36	5	10	140	7350	
30-40	53.25	0.17	0.00	0.05	4.18	0.82	0.98	0.21	0.04	0.00	0.54	41.41	5	10	70	300	
40-50	54.31	0.04	0.00	0.01	1.98	1.12	0.19	0.03	0.02	0.00	0.27	42.98	5	10	50	400	
50-60	55.91	0.05	0.00	0.01	0.93	0.54	0.18	0.03	0.01	0.00	0.08	43.37	0	0	30	200	
60-70	55.76	0.02	0.00	0.02	1.05	0.71	0.10	0.00	0.01	0.00	0.28	43.58	0	10	40	470	0
70-80	55.59	0.08	0.00	0.02	1.61	0.53	0.13	0.01	0.02	0.01	0.26	43.03	0	0	40	340	
80-90	55.41	0.11	0.00	0.06	1.67	0.65	0.18	0.03	0.03	0.00	0.07	42.94	0	0	50	190	
90-100	49.17	1.12	0.02	0.10	8.33	1.29	2.21	0.48	0.09	0.01	0.89	37.92	0	10	40	180	
100-125	39.34	2.29	0.09	0.15	18.59	2.33	4.82	1.01	0.18	0.03	1.88	31.22	0	10	20	190	
125-140	52.69	0.60	0.00	0.06	4.50	1.17	0.86	0.17	0.08	0.00	0.09	41.33	0	10	20	100	
140-160	39.86	2.72	0.29	0.14	17.84	1.77	5.35	1.01	0.22	0.03	2.19	30.81	0	10	20	260	
160-180	44.44	1.76	0.00	0.11	12.60	1.97	3.51	0.71	0.15	0.02	1.45	35.20	0	10	30	200	
180-200	50.63	0.66	0.00	0.08	6.60	1.91	0.98	0.19	0.07	0.00	0.03	40.82	0	10	10	60	
200-221	46.95	1.33	0.00	0.10	10.47	1.62	2.60	0.51	0.12	0.01	0.98	37.25	0	0	20	120	

APPENDIX D continued

CHEMICAL ANALYSES.

Depth	Percentage by weight												Parts per million				
	CaO	SO_3	Na_2O	F	SiO_2	MgO	Al_2O_3	K_2O	SrO	P_2O_5	Fe_2O_3	Loss†	Cu	Pb	Zn	MnO	As
SE 05 SW 2 s	**0162 5286 Skibeden Quarry**													**Block K**			
1-6.5	51.82	0.03	0.02	0.00	4.89	0.45	0.62	0.12	0.06	0.01	0.49	41.15	5	0	20	550	
10-35	52.08	0.46	0.01	0.00	2.69	0.95	0.64	0.12	0.06	0.01	0.09	41.92	5	0	50	300	
35-57.5	50.53	0.61	0.03	0.02	4.16	1.11	1.26	0.24	0.06	0.01	0.60	40.90	5	0	20	360	
SE 05 SW 3 s	**0142 5278 Skibeden Quarry**													**Block K**			
1-20	47.98	0.33	0.03	0.00	11.47	0.72	0.88	0.16	0.12	0.01	0.07	38.14	5	0	30	270	
20-29	43.52	0.68	0.08	0.04	15.13	1.07	2.87	0.55	0.17	0.02	1.20	35.17	5	0	80	500	
SE 05 SW 6 s	**0318 5385 Halton East Quarries**													**Block K**			
6-15	48.99	0.35	0.07	0.01	9.04	0.86	0.82	0.13	0.10	0.08	0.59	39.20	5	0	30	160	
15-36	50.60	0.25	0.05	0.00	6.51	0.69	0.64	0.09	0.09	0.14	0.48	40.47	5	0	50	180	
SE 05 SW 7 s	**0319 5214 Wheelam Rock Quarries**													**Block K**			
1-10	48.09	0.11	0.01	0.00	11.50	0.60	0.52	0.08	0.13	0.05	0.77	38.29	5	0	30	900	
10-18	41.08	0.48	0.11	0.01	23.03	0.75	1.67	0.22	0.22	0.11	1.25	32.62	5	10	60	520	
SE 05 SE 1 s	**0565 5325 Hambleton Quarry**													**Block K**			
14-25	47.54	0.25	0.02	0.00	11.94	0.62	0.54	0.08	0.15	0.07	0.81	38.32	5	0	30	670	
25-35	40.91	0.75	0.12	0.00	23.23	0.75	1.70	0.20	0.23	0.13	1.24	32.14	5	10	60	800	

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