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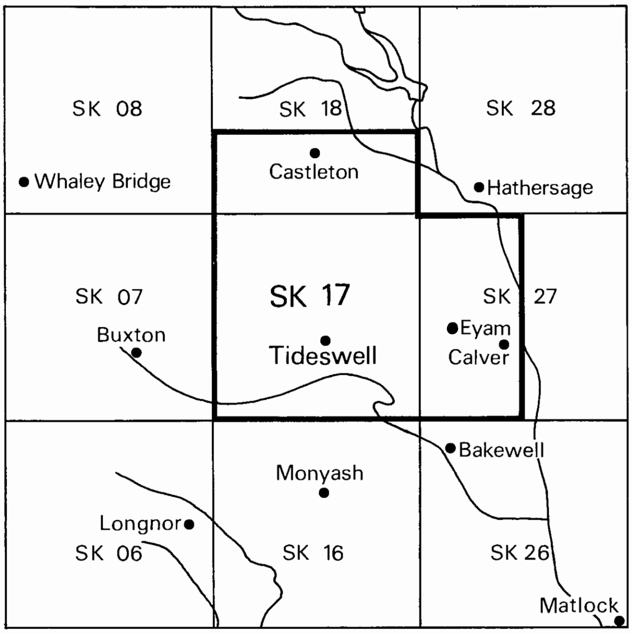

The limestone and dolomite resources of the country around Tideswell, Derbyshire

Description of 1:25 000 sheets SK 17 and parts of SK 18 and 27

R. W. Gatliff

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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 No. 13 and subsequent reports appear as Mineral Assessment Reports of the Institute.

Details of published reports appear at the end of this Report.

Any enquiries concerning this report may be addressed to
Head, Industrial Minerals Assessment Unit,
Institute of Geological Sciences,
Keyworth, Nottingham NG12 5GG.

The asterisk on the cover indicates that parts of sheets adjacent to the one cited are described in this report.

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 was subsequently financed by the Department of the Enviroment and was undertaken with the co-operation of members of the British Quarrying and Slag Federation.

This report describes the limestone and dolomite resources of some 124 km^2 of country around Tideswell, Derbyshire, shown on the accompanying 1:25 000 resource map. The survey was conducted by Mr R. W. Gatliff under the supervision of Mr D. McC. Bridge. Most of the laboratory testing was carried out by members of the Industrial Minerals Assessment Unit.

The work is based on 1:10 560 scale geological surveys by Mr I. P. Stevenson and Mr R. A. Eden; dates of surveys are given on the resource map which is folded into the pocket at the end of this report.

Chemical analyses were carried out by Mr A. Davis and Mr A. N. Morigi of the Institute's Analytical Chemistry Unit. Mr K. S. Siddiqui carried out X-ray diffraction analyses of the insoluble residues. Palaeontological determinations were made by Mr M. Mitchell.

Mr J. W. Gardner, CBE and Mr C. L. Reeves (Land Agents) were responsible for negotiating access to land for drilling. The ready co-operation of land owners, tenants and the quarrying companies in this work is gratefully acknowledged.

G. M. Brown, FRS
Director

28 August 1981

CONTENTS

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SUMMARY

The study of samples from 17 cored boreholes, 50 major sections and 155 scattered localities, together with information from the records and geological maps of the Institute of Geological Sciences, form the basis of the assessment of limestone and dolomite resources in the Tideswell area, Derbyshire. The geology and carbonate resources of each formation are described and the chemical and mechanical properties are presented. The accompanying 1:25 000 resource map shows the variation in purity of the carbonate resources at the surface while horizontal sections constructed from borehole data and from a knowledge of the regional geology indicate the purity categories likely to be encountered at depth. As limestone purity in this district is closely controlled by the stratigraphy, many of the lines on the map delimiting the various categories of limestone coincide with geological boundaries.

The survey has shown that high purity, chemical-grade limestones occur mainly within the Bee Low and Woo Dale limestones which underlie much of the western part of the district, whereas limestones of more variable purity make up the Monsal Dale and Eyam limestones which lie to the east.

Note

All National Grid references in this report fall in 100 km square SK.

Bibliographical reference

GATLIFF, R. W. 1982. The limestone and dolomite resources of the country around Tideswell, Derbyshire: description of 1:25 000 sheet SK 17 and parts of sheets SK 18 and SK 27. **Miner. Assess. Rep. Inst. Geol. Sci.,** No. 98.

Author

R. W. Gatliff, MA, MSc
Institute of Geological Sciences, Keyworth,
Nottingham NG12 5GG

INTRODUCTION

In recent years it has become apparent that more detailed and comprehensive information on limestone resources is required. The information is needed to facilitate land-use and mineral planning by central and local government and to assist in the formulation of national policies to ensure continuing supplies to the many industries for which limestone is an essential raw material. Ideally the information should relate to all the uses of limestone, ranging from its mechanical properties, which determine its suitability for use as an aggregate, to trace element composition, relevant to more specialised uses such as glass and steel manufacture. The provision of such information is particularly important in Derbyshire and north Staffordshire, an area which contributes significantly to the country's industrial economy, and at the same time is of high scenic and amenity value. In 1978 the area produced 17.2 million tonnes of limestone from the Lower Carboniferous outcrop, representing 20 per cent of the total production in the United Kingdom (Institute of Geological Sciences, 1980); the cement, steel and chemical industries accounted for nearly half this tonnage, the remainder being used for constructional purposes. This report describes the resources of the north-eastern part of the limestone crop, centred on the village of Tideswell, and is one of a series of reports covering the region.

The methods of assessment embody the most cost-effective procedures for assessing limestone resources on a regional scale (Cox and others, 1977). The materials for study have been obtained from cored boreholes, natural sections and quarry faces. The petrological, mineralogical, chemical and certain physical properties of the samples have been determined in the laboratory. Conventional geological nomenclature has been used for the technical descriptions, ensuring compatability 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 purity and possible end use may be deduced (Table 1). Whilst detailed results are set out in the report and its appendices, the accompanying resource map gives a more generalised summary of the regional variations in limestone purity. In the horizontal sections, the variation in purity of the limestone at depth is inferred from knowledge of the local geology augmented by the results from boreholes.

DESCRIPTION OF THE DISTRICT*

General

Lying almost entirely within the Peak District National Park (Figure 1), the district is predominantly rural. The largest villages are Tideswell, Castleton and Bradwell; the nearest towns are Buxton, Chapel en le Frith and Bakewell, all of which lie just outside the district. The local economy is based largely on agriculture, tourism and the mineral extractive industries. Limestone has

* The term 'district', as used here, refers to the area covered by the assessment report.

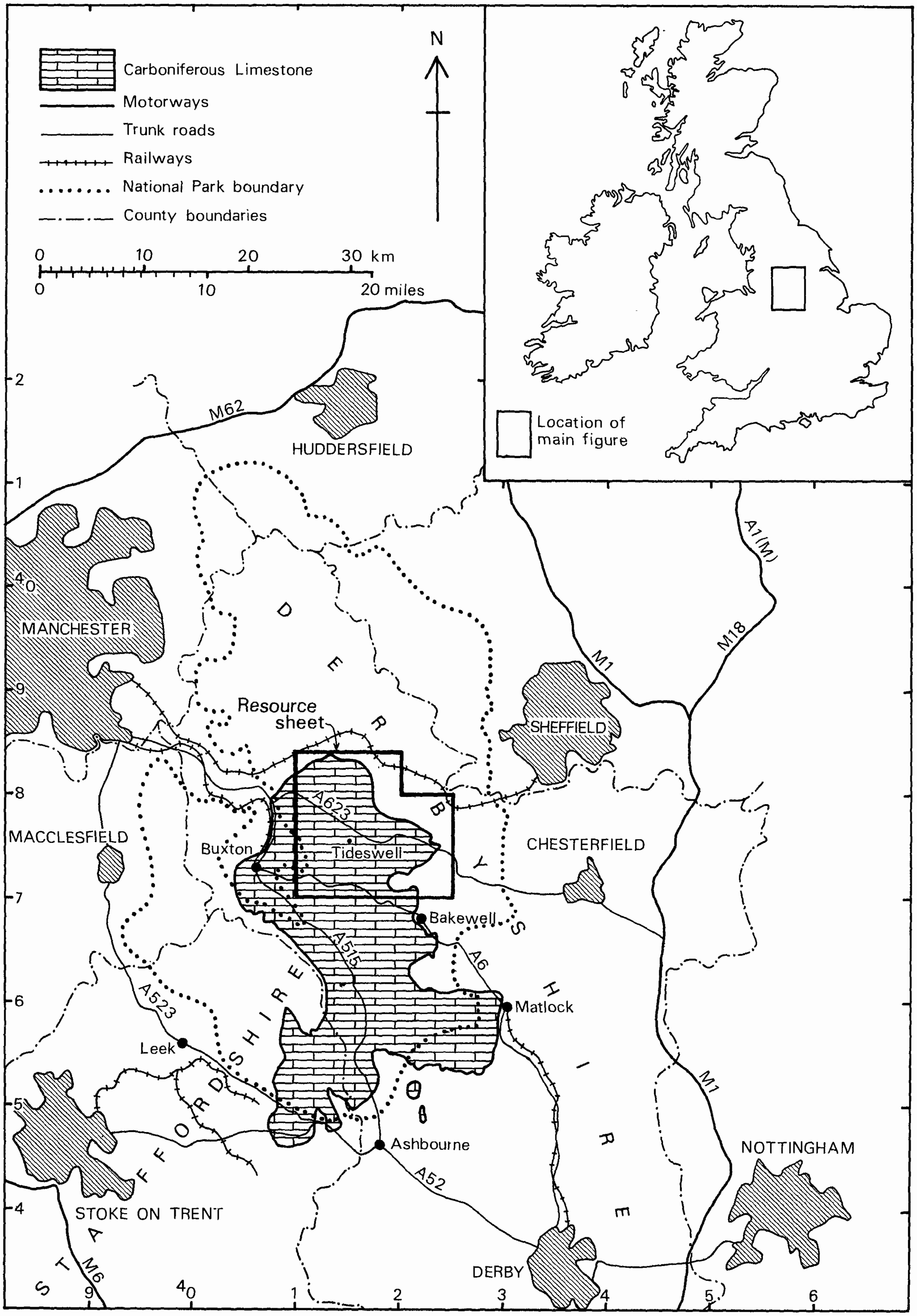


Figure 1 Map showing the location of the district.

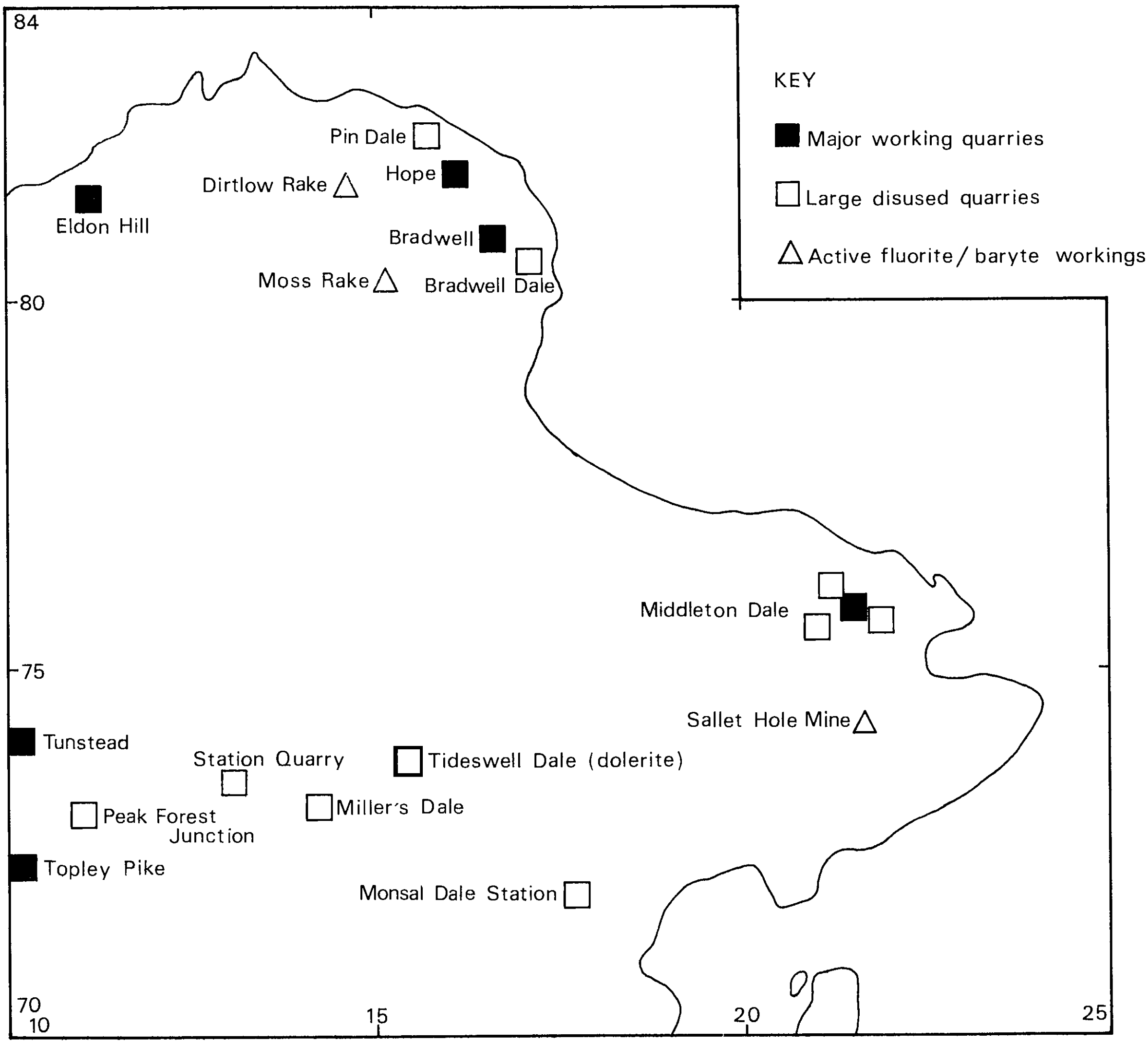


Figure 2 Distribution of the major quarries and active mineral vein workings.

been worked since the seventeenth century for lime burning and walling stone, but, for the most part, quarries were small and numerous and served only local needs. However, today quarrying is one of the most important industries in the district with six large working quarries (Figure 2) producing crushed stone and lime for the construction, chemical, glass and metallurgical industries. Cement is manufactured at Hope and is also produced as a by-product at the Tunstead works.

Dolerite has been quarried in the past at Calton Hill for use as aggregate, but the quarry has now been filled and the area landscaped.

The district is crossed by numerous mineral veins, especially in the north and east, and there are many old lead mines and open workings, some possibly dating back to Roman times. Nowadays the veins are worked primarily to extract fluorite and baryte. The main producer in the district at the present is Laporte Industries Limited, whose Cavendish Mill produces high-grade fluorspar from Sallet Hole Mine and from a number of surface workings.

The 'Blue John' fluorite deposits of Castleton are a popular tourist attraction and the area as a whole is one of high scenic and amenity value.

Buxton and Hope are served by rail and there is a mineral line to Tunstead works. The district is linked with the surrounding conurbations by three main roads, the A6, the A623, and the A625.

Topography

The Carboniferous Limestone outcrop forms an undulating plateau ranging in elevation from about 1000 ft (300 m) to 1500 ft (450 m) at Eldon Hill and Bradwell Moor (Figure 3). It is dissected by the gorge of the River Wye and its several dry tributary valleys, and also by Bradwell Dale and Middleton Dale. These steep-sided valleys are predominantly tree-covered, contrasting with the treeless pastures, dry-stone-wall networks and karst features of the plateau. The northern margin of the limestone outcrop is characterised by an apron-reef forming steep outward-dipping slopes and cut by the narrow gorges of Winnats Pass and Cave Dale. The effects of mineral extraction on the landscape are very evident; numerous spoil heaps and open-cuts mark the position of former lead workings and the lines of many of the larger veins are picked out by the trees which have been planted along their length. At the present day, quarrying of limestone is also producing striking modifications of the landscape.

To the north of the limestone crop, sandstones and shales of the 'Millstone Grit' produce marked dip- and scarp-slope topography; to the east lies the valley of the River Derwent.

Geology

This account is based mainly on geological investigations which are detailed in the Chapel en le Frith memoir (Stevenson and Gaunt, 1971).

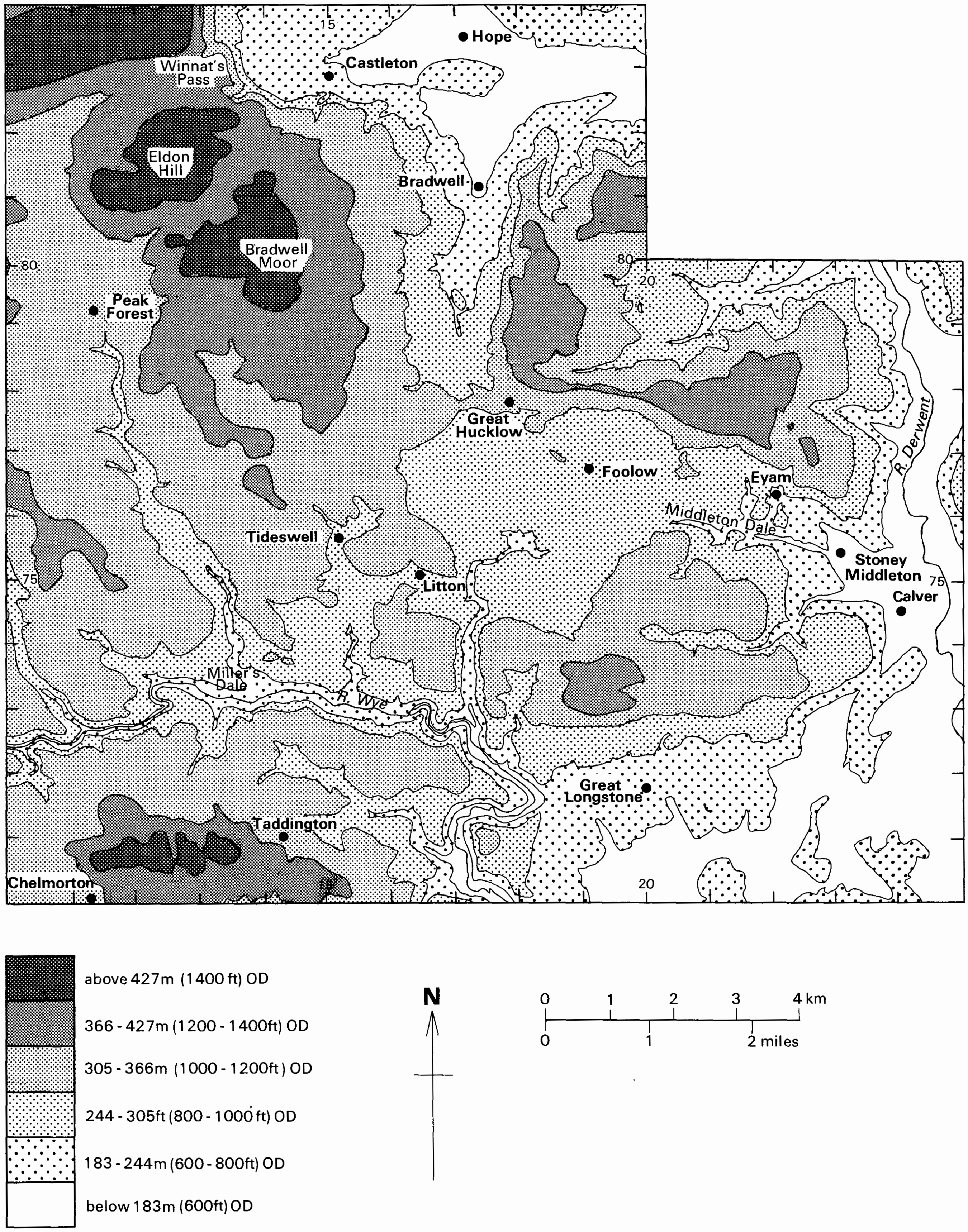


Figure 3 Topography.

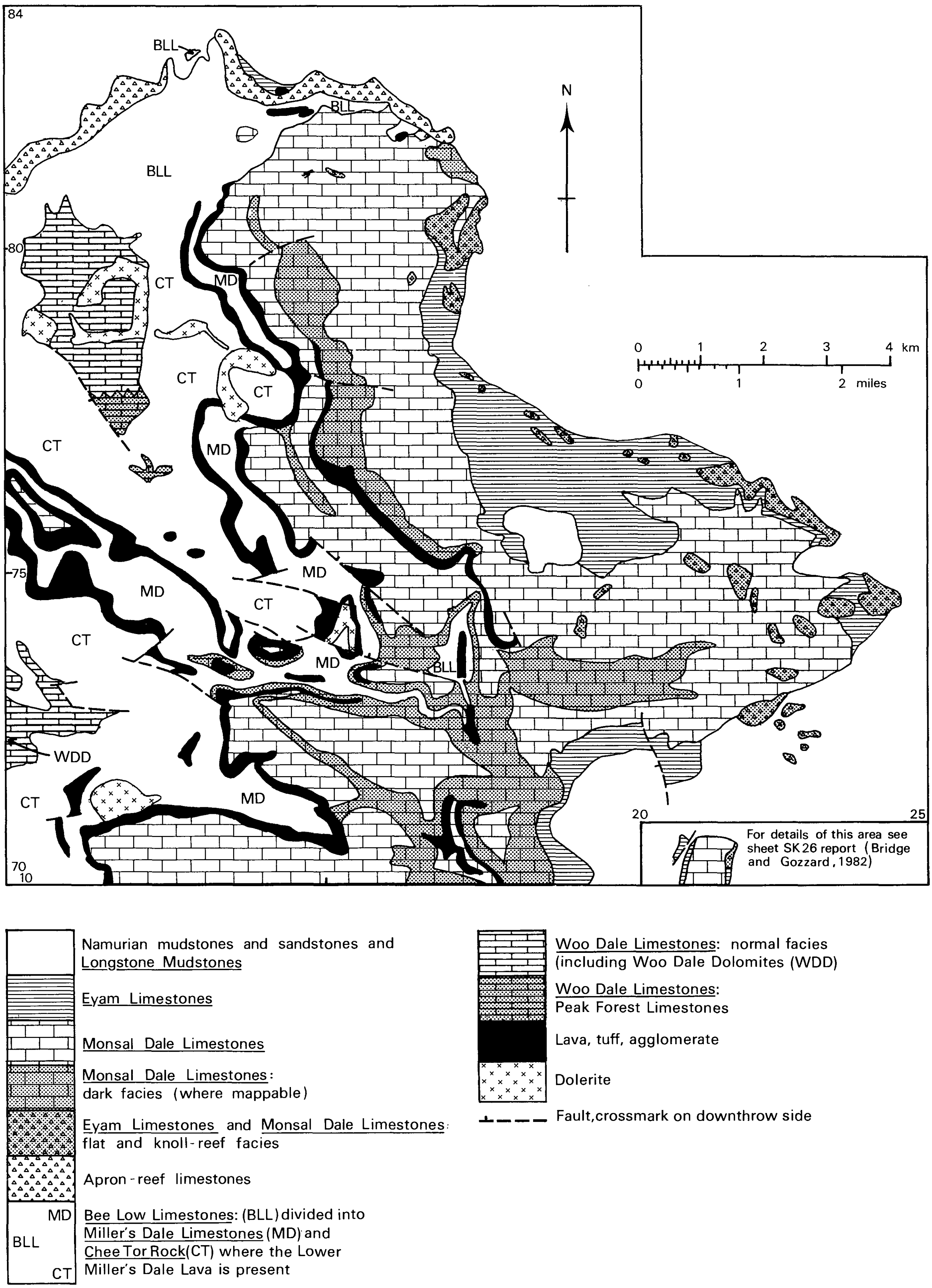


Figure 4 Simplified map of the solid geology.

The exposed Carboniferous limestones of Derbyshire belong to the Viséan Series of the Dinantian. During their deposition an area of slow subsidence, variously called shelf, block or massif, occupied much of the present limestone crop. Flanking it to north, west and south were more rapidly subsiding tracts termed basins or gulfs; where the shelf and basins abut, discontinuous apron-reefs were formed in places. The basins are now largely concealed by later sediments, as is the shelf area to the east.

At intervals throughout the deposition of the limestones, volcanic activity produced local outpourings of lava and associated falls of tuffaceous material.

Limestone deposition was succeeded by that of shales and sandstones, the outcrop of which now surrounds that of the limestones. For the most part these terrigenous sediments belong to the Namurian ('Millstone Grit'), but their lowermost portion is locally of Viséan age. The upward change from limestone to shale is generally marked by an unconformity on or near the block, where even minor uplift led to emergence.

Thin Quaternary deposits cover part of the limestone crop. Head, consisting of reddish brown silt and clay with angular chert debris, is the most widespread deposit and forms sheets up to a few metres thick on Bradwell and Longstone moors. There are also thin post-Glacial deposits of alluvium in the bottoms of the main valleys and of peat above the Head on parts of Bradwell Moor.

Landslips are present at a number of localities but only involve small masses of limestone; slippage occurs on the soft, impermeable clays that are commonly developed at the top of lava or tuff units. The largest slips are at St Peter's Stone [174 753], Cressbrook Dale [172 737] and on the north slope of Fin Cop [176 712].

Dinantian rocks A simplified map of the solid geology is shown in Figure 4 and the succession is summarised in Figure 5. The base of the Carboniferous is not exposed, but has been proved in two deep boreholes; one, drilled at Woo Dale [098 725] (Cope, 1949) to the west of the district, penetrated ?Precambrian pyroclastics at a depth of 212 m, the other at Eyam [210 760] (Dunham, 1973), proved almost 2000 m of Dinantian rocks, mainly limestones, overlying Ordovician mudstones.

The Woo Dale Limestones underlie most of the area at depth but crop out only in the western part of the Wye valley and in the north-west of the district around Peak Forest. A thickness of about 70 m is exposed and the normal facies, seen in the Wye valley and in the southern part of the Peak Forest inlier, consists of thinly-bedded grey and dark grey calcarenites. Around Peak Forest the normal facies passes into pale crinoidal limestones known as the Peak Forest Limestones. A lithologically distinctive group of beds comprising dolomites and dolomitic limestones is exposed in the Wye valley at its western end, and forms a mappable unit known as the Woo Dale Dolomites. The main sections, up to 32 m thick, lie outside the district and are described more fully elsewhere (Harrison, 1982).

The Bee Low Limestones, which overlie the Woo Dale Limestones, are up to 180 m thick and crop out over most of the western half of the district. They are generally thick-bedded, pale and mid-grey calcarenites with sporadic coarser brachiopod and coral bands. Over most of the district they are subdivided into a lower unit, the Chee Tor Rock, about 90 m thick and an upper unit, the Miller's Dale Limestones, about 60 m thick, separated by the Lower Miller's Dale Lava. Where the lava is absent the Bee Low Limestones are lithologically indistinguishable from the separately mapped units. Several thin tuffaceous mudstones ('wayboards') occur within the sequence: a borehole drilled at Litton Dale [160 750] by the Derwent Valley Water Board proved lava or interbedded lava and tuff about 30 m from the top of the Chee Tor Rock and at least 20 m thick; this lava has not been found elsewhere. About 80 m from the top of the Bee Low Limestones around Cressbrook Dale [172 737] there is another tuff about 20 m thick known as the Ravensdale Tuff.

The Lower Miller's Dale Lava is made up of a series of basalt flows and reaches a thickness of about 30 m near Wormhill [125 742] but thins both to the north and south and is developed only locally south of Miller's Dale. It disappears north of borehole 18 SW 47 [132 808], re-appearing near Cave Dale [146 822], where it is less than 10 m thick; east of Cave Dale it dies out and is replaced by the Pindale Tuff.

Along the northern margin of the limestone crop the Bee Low Limestones pass laterally into an apron-reef complex which separates the shelf or block from the basinal deep to the north.

The Bee Low Limestones are overlain in part by the Upper Miller's Dale Lava, an amygdaloidal basalt up to 30 m thick and similar in most respects to the Lower Miller's Dale Lava. It extends from Bradwell Moor in the north to the southern margin of the district, but thins abruptly to the east, a feature well exposed in Litton railway-cutting. North of Tideswell the lava is replaced locally by the Brook Bottom Tuff.

Over much of the district the Monsal Dale Limestones rest directly on the Upper Miller's Dale Lava; where this is absent there is generally a sharp break at the top of the Bee Low Limestones suggesting a non-sequence. Around Miller's Dale there is about 7 m of dark thin-bedded cherty limestones below the Upper Miller's Dale Lava which are included in the Monsal Dale Limestones and are known as the Station Quarry Beds. The Monsal Dale Limestones are about 180 to 200 m thick and lithologically highly variable. North of the Wye valley they can be divided into an upper and a lower unit, separated by the Litton Tuff. The latter extends from Hucklow Moor to Wardlow but only reaches its maximum thickness (about 30 m) at Litton. The sequence below the tuff ranges in thickness from about 50 m in borehole 17 NW 10 to over 100 m in the Eyam Borehole; in most places it consists of pale chert-free limestones with a thin development of dark cherty limestones at the base. An amygdaloidal basalt, the Cressbrook Dale Lava, is present about 15 m below the Litton Tuff and is widely developed at depth in the east of the district. The lava varies in thickness from about 7 m at outcrop, east of Litton, to the 77 m proved in the Eyam Borehole. The sequence above the Litton Tuff is about 100 m thick and consists of dark cherty limestones at the base and pale, generally cherty limestones above.

In the Wye valley and the area to the south, the Monsal Dale Limestones show a progressive easterly passage from predominantly pale limestones to dark thin-bedded, cherty limestones. Thus around Miller's Dale there is only a thin basal development of dark beds but near Fin Cop the whole thickness exposed is made up of the dark facies. To the south of Fin Cop there are two thin lavas (the Lees Bottom Lava and the Shacklow Wood Lava) in the lower part of the sequence.

The Eyam Limestones crop out across the eastern part of the district where they rest with a marked break on the Monsal Dale Limestones. They are up to 40 m thick and generally consist of dark, thinly-bedded cherty limestones. Within the sequence there are localised reef accumulations, known as flat-reefs and knoll-reefs, which are composed of pale shelly or crinoidal limestones. Near Bradwell and Eyam, flat-reefs constitute the total thickness of the formation but elsewhere there are only scattered knoll-reefs, such as those around Foolow. In some areas the unconformity at the base of the Namurian has cut out much of the sequence, and in the Wardlow Mires No. 1 Borehole [185 755] the thickness of the formation is only 10 m.

The limestone sequence is intruded by a number of vents, sills and dykes. The largest bodies are the sills which are intruded into the Bee Low and Woo Dale limestones near Peak Forest. The subsurface extent of these rocks is not well known at present and no attempt

STAGES	CORAL-BRACHIOPOD ZONES	GONIATITE-BIVALVE ZONES	FORMATION/MEMBER
BRIGANTIAN	D_2	P_2	LONGSTONE MUDSTONES
			EYAM LIMESTONES(EyL) with knoll-reefs (K) and flat reefs (Kf)
		?	MONSAL DALE LIMESTONES (Mo) with dark facies (Mo/dk) and knoll-reefs (K). Volcanic horizons are shown in black.
ASBIAN	D_1		BEE LOW LIMESTONES (BLL) divided into MILLER'S DALE LIMESTONES (MD) and CHEE TOR ROCK (CT) when LOWER MILLER'S DALE LAVA is present. Apron-reef limestones (Rap) along northern margin of district
HOLKERIAN	S_2		WOO DALE LIMESTONES (WDL) including Peak Forest Limestones and Woo Dale Dolomites (WDD)

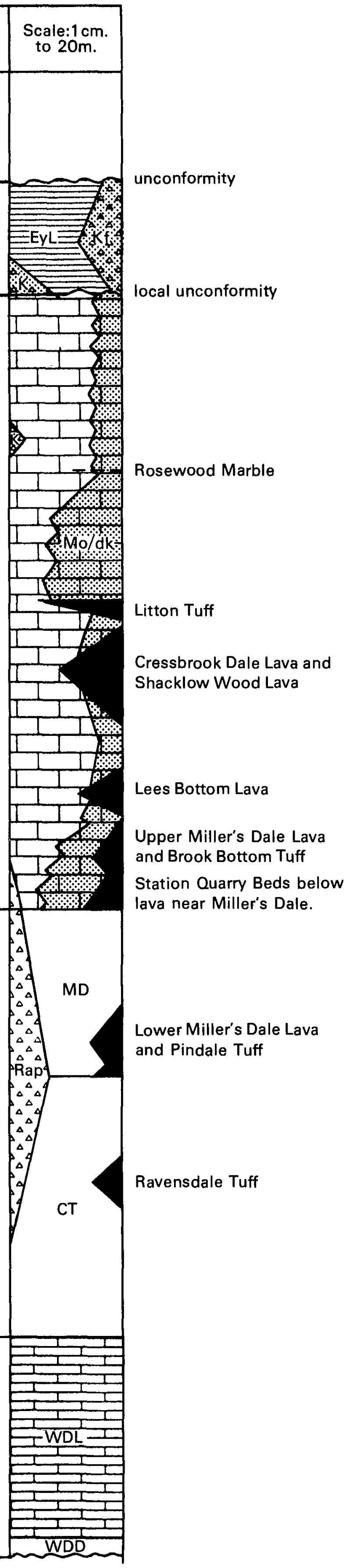


Figure 5 Generalised section of exposed Dinantian rocks.

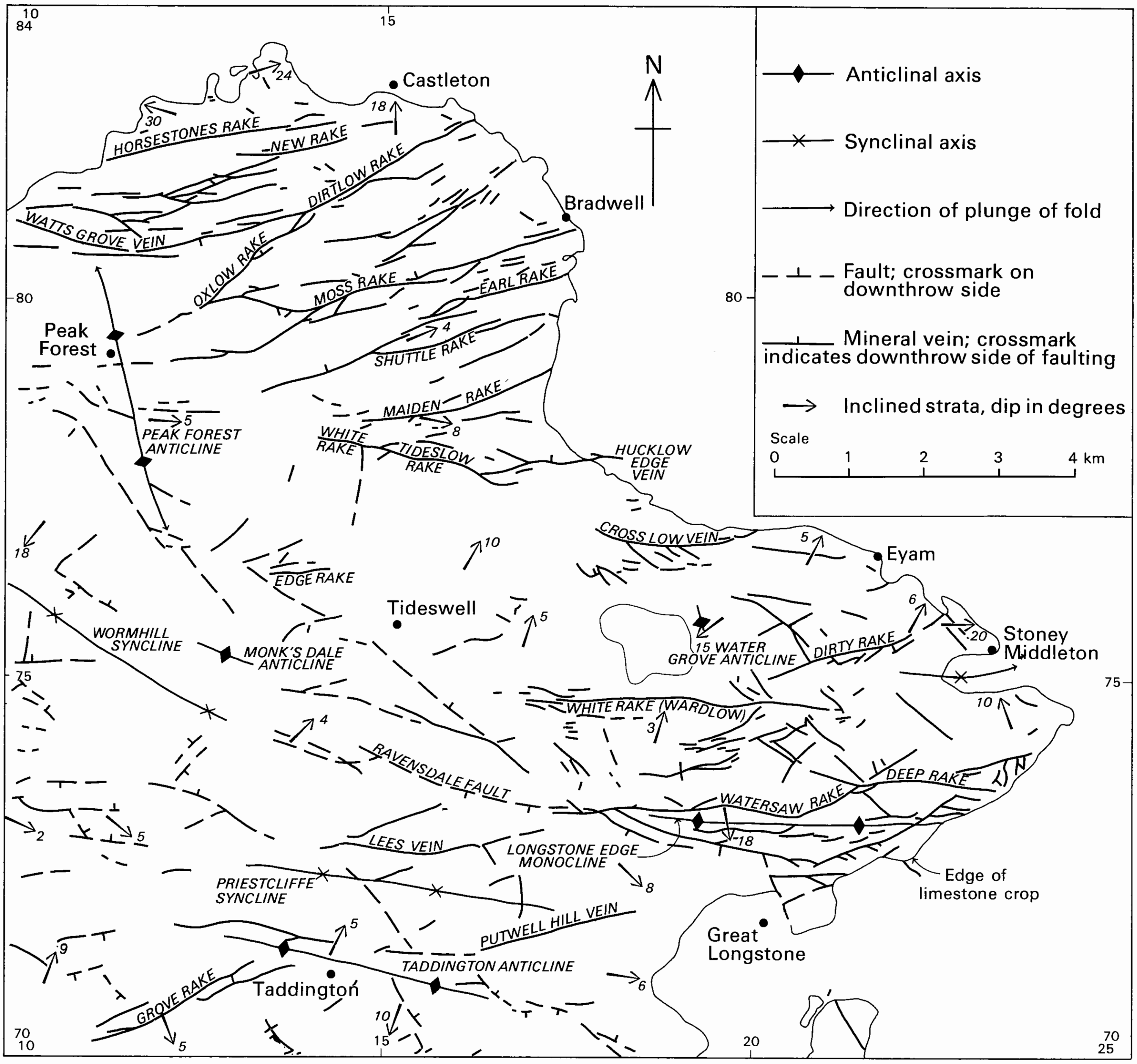


Figure 6 Sketch map indicating main structural features and principal mineral veins of the district.

to delineate their size by drilling has been made during this survey.

Structure The limestones are characterised by open folds with flanking dips of between 5° and 15° (Figure 6). The Peak Forest Anticline in the north-west trends south-south-east for about 4 km, whereas the main folds further south, the Wormhill and Priestcliffe synclines and the Taddington Anticline, have axes aligned generally east-south-east. In the southern part of the district the main structure is the Longstone Edge Monocline which runs east-west with a steeply dipping southerly limb and a gently dipping northern flank. In addition to the broad folds there are small tight folds at Monk's Dale [125 755] (associated with two volcanic vents) and at Water Grove [192 755].

The reef-belt along the northern margin of the crop marks the edge of the block and the dips of about 30° into the basin are depositional. The low dips (5 to 10°) at the eastern edge of the limestone crop suggest that the block margin here lies further east beneath Namurian cover.

Two main sets of faults are recognisable, one running east or east-north-east, the second generally north-west. Many of the faults in the former set are mineralised (Figure 6). The faults with the largest throws are Dirtlow Rake in the north, with a southerly downthrow of about 60 m on Bradwell Moor, and the Ravensdale Fault, which is a westerly extension of the Longstone Edge Monocline and has a southerly downthrow , also of about 60 m, in Cressbrook Dale.

Mineralisation The district falls within the northern part of the extensive Derbyshire orefield. Veins containing the lead and zinc sulphide ores galena and sphalerite, together with the gangue minerals calcite, baryte and fluorite, are found principally east of a line drawn from Perryfoot to Taddington. Although calcite is a ubiquitous vein mineral, Mueller (1954) has shown that the gangue minerals are crudely zoned with fluorite more prevalent in the east of the orefield, baryte in the centre and the calcite at the western extremity. Most of the large veins (termed 'rakes') occupy near-vertical fault or joint fissures up to 20 m wide. The majority trend east-north-east (Figure 6) but some cross-veins are aligned north-west to south-east. A few ore bodies ('pipes' and 'flats') are horizontal and were formed by replacement of limestone along major bedding planes and other discontinuities.

Alteration of the limestone country rock can be detected up to about 10 m from veins, depending on the degree of fracturing in the wall-rock (Ineson, 1969), and commonly involves some degree of silicification. In some cases, the silica may have been derived from within the host rock but, in chert-free areas, it is presumably of hydrothermal origin. A striking example of wholesale silicification adjacent to a vein can be seen along the southern margin of Dirtlow Rake where silica blocks have weathered out and now lie on the surface.

ASSESSMENT OF RESOURCES

Procedures

Following a desk study, a field survey was mounted and representative rocks were sampled for processing in the laboratory.

Field survey As modern 1:10 560-scale geological maps were available, the first phase of the field work involved collecting representative material from the extensive natural exposures and quarries in the district. Most sections were sampled at every metre, but in cherty sequences chert-free samples were collected and the percentage of chert was then estimated by direct measurement on the rock face. Supplementary spot samples were also collected. To provide additional data in areas where information was scanty, 17 boreholes were drilled to depths ranging from 40 to 100 m, and continuous cores of 47-mm diameter were obtained. The first seven boreholes were drilled in 1971-72, as part of an original feasibility study, and a further eight were drilled in 1978. The drilling programme was carried out by contractors using trailer-mounted Reich and Edeco rigs. Drilling was by air- and water-flush methods. Core was also made available from two Land Survey Division boreholes; one (27 NW 15) was a deep borehole drilled near Eyam in 1970-72, and the other (27 SE 14) at Lees Bottom was drilled in 1979, using the Institute's own Edeco Mark 8 rig.

In general the recovery of limestone cores exceeded 90 per cent, but some difficulties were encountered with cherty limestone, and with clay and shale bands. Preliminary lithological logs were prepared on site, and, in addition, the structural homogeneity of the limestone was assessed by measuring the frequency of naturally occurring fractures such as joints and bedding planes (Franklin and others, 1971).

Laboratory programme All core and section material was sawn in half, acid-etched and then lithologically logged. The purity (that is the carbonate content) of samples, each representing 1 metre of strata, was measured by an acid-digestion process (Molinia, 1974), and the mineralogy of the resulting insoluble residues was determined by optical and X-ray diffractometry. Full chemical analyses (Roberts and Davis, 1977) were also performed on selected samples. A simple reflectance spectrophotometer was used to measure the brightness of the limestones after acid-etching and also when finely powdered; information from the etched surface is useful for correlation purposes while the whiteness of the powders is a significant parameter in certain industrial applications (see section on Colour). As an indication of the mechanical strength of the rock, the Aggregate Impact Value Test (British Standards Institution, 1975) was performed on crushed samples of all the borehole core and on some of the material from sections. A summary of these results is given in Appendices C and D but more detailed records may be consulted at the Institute's Keyworth office on application to the Head, Industrial Minerals Assessment Unit.

Classification

Two classifications of limestones have been used in this report, one based on petrology and the other on calcium carbonate ($CaCO_3$) content. The former is used to describe the rocks in lithological terms and the latter is preferred for demonstrating the variation in purity of the resouces. The relationship between the five purity categories adopted, their $CaCO_3$ contents and possible end-uses are shown in Table 1.

DESCRIPTION OF RESOURCES

As purity is stratigraphically controlled, it is convenient to describe the resources within the district on a formational basis. In the following section, information is given on the types of limestone to be found in each formation, their distribution, and the relationship between their non-carbonate mineralogy and overall purity.

Woo Dale Limestones

The Woo Dale Limestones are divided into a normal facies, seen in the southern part of the district, and the Peak Forest Limestones in the north. The total crop area is about 5 km², of which about 3 km² are Peak Forest Limestones.

The normal facies consists of grey and dark grey, thin-bedded limestones. The dominant lithology is a moderately or poorly sorted, fine- or medium-grained

Table 1 Classification of limestones by purity

Category	Percentages		Possible uses
	$CaCO_3$	Equivalent CaO	
1 Very High purity	>98.5	>55.2	Steel, glass, rubber, plastics, paint, whiting
2 High purity	97.0 to 98.5	54.3 to 55.2	Iron, ceramics, Portland cement, sugar
3 Medium purity	93.5 to 97.0	52.4 to 54.3	Paper, animal feeding stuffs, agriculture
4 Low purity	85.0 to 93.5	47.6 to 52.4	Aggregates
5 Impure	<85.0	<47.6	Natural cement, mineral wool

Note
$CaCO_3$ content is only one of several chemical specifications governing end-use; for example, silica, iron, sulphur and certain trace elements may be as important in some applications.

biosparite; the main allochems are crinoids, foraminifera, brachiopods, algal fragments and pellets, and the matrix is generally fine-grained spar with some micrite. Subordinate lithologies include thin, well sorted biopelsparites and a number of irregular micrite beds, some showing stromatactis and birds-eye structures (Bathurst, 1975). Discrete dolomite rhombs are disseminated throughout the sequence and sometimes form localised concentrations. However, dolomitic rocks, *sensu stricto*, are restricted in their occurrence (see earlier section) and are dealt with in detail in another report (Harrison, 1982).

The Peak Forest Limestones consist of moderately sorted and well sorted, grey and pale grey crinoidal biosparites and biosparrudites, containing very tightly packed crinoidal debris with only a small amount of spar cement. Dolomite has not generally been recorded during this survey but a commercial borehole drilled at Eldon Hill Quarry [113 816] passed through 51 m of Bee Low Limestones and then 69 m of Peak Forest Limestones with a 4-m dolomitic band 14 m from the base.

Collectively the Woo Dale Limestones may be classified as very high purity mineral, although lower carbonate levels have been recorded locally. The main waste products in the succession are shaly partings, present in the normal facies, and dolerite which is restricted to the Peak Forest inlier. Fissure-filling clays are also likely to be encountered.

The insoluble fraction of the limestones consists essentially of clay and quartz. The clay occurs disseminated throughout the rock and also concentrated along stylolites and is more abundant in the normal facies. The quartz is present as scattered euhedral crystals and as microcrystalline replacements of crinoid and shell fragments. Silica, in the latter form, is largely responsible for the reduced purity recorded in the lower part of borehole 18 SW 48, at Peak Forest. The source of the silica is speculative, but it may have been derived from the dolerite sill that underlies part of the inlier. The effect of sills on adjacent limestones is illustrated by a short section at Peak Forest [116 789], where the limestones overlying the sill are strongly marmorised and also show the development of secondary silica and dolomite which can be traced for at least 10 m above the contact. Clearly the limestones in the immediate vicinity of the sills should not be regarded as a source of high purity mineral.

Chee Tor Rock

The Chee Tor Rock is made up of a rather uniform sequence of thick-bedded grey and pale grey limestones, consisting mainly of moderately sorted and poorly sorted medium- and fine-grained biosparites; the dominant allochems are crinoids, foraminifera, brachiopods, algal fragments and pellets. There are several well sorted pelsparite and biopelsparite beds and a few coarse coral, brachiopod and algal bands. The lowest 10 to 15 m are more thinly bedded than the more massive higher beds which are characterised by closely spaced vertical joints.

Overall, the Chee Tor Rock may be classified as very high purity limestone: boreholes 17 SW 55 and 17 SW 56 in the south-west of the district both prove thicknesses in excess of 70 m of the highest grade of limestone. The non-carbonate content is usually low and is composed of approximately equal proportions of euhedral quartz crystals and disseminated clay (Figure 9). Very little silicification has been noted except in the immediate vicinity of the sills that crop out south-east of Peak Forest and south of Tideswell. Pyrite is locally abundant adjacent to the thin tuffaceous clays or wayboards that divide the sequence. The pyritous zones vary in thickness: in borehole 17 NW 9 the limestones are affected for up to 5 m on either side of a wayboard at 55.7 m depth, whereas in boreholes 17 SW 55 and 18 SW 47 the effect is restricted to within one or two metres of the wayboards. Some silicification and pyrite have also been recorded adjacent to the Ravensdale Tuff. Anomalously high insoluble residue values, such as 26.8 per cent recorded near the top of borehole 17 NW 7, are caused by fissure-filling clay and have been excluded from purity calculations.

Miller's Dale Limestones

The Miller's Dale Limestones are lithologically very similar to the Chee Tor Rock, consisting mainly of medium and fine-grained, grey and pale grey biosparites. Thin well sorted biopelsparites form distinctive bands and there are more coarse crinoidal biosparites than in the Chee Tor Rock; coarse coral and brachiopod fragments are locally abundant. A tuff 50 cm thick occurs locally about 20 m from the top of the member; it is exposed in Station Quarry, Miller's Dale (Section 17 SW 2 S).

The non-carbonate content is variable but the limestones generally range from high to very high purity. The level of silicification is slightly higher than in the Chee Tor Rock, and a few thin beds and nodules of chert have been recorded in Blackwell Dale [131 725], Station Quarry [133 735] and in borehole 17 SE 13. Euhedral quartz crystals, and disseminated clay, concentrated along stylolites, also occur. Samples collected from near the tuff in Station Quarry [17 SW 2 S] and from outcrops close to the Upper Miller's Dale Lava at Wormhill [106 753] indicate that there is a deterioration in purity to medium grade in the beds adjacent to the volcanic units.

From the results obtained for the Miller's Dale Limestones it has proved impossible to separate limestone of very high purity from those of high purity and consequently the two categories have been combined and are shown diagrammatically on the resource map.

Bee Low Limestones

The Bee Low Limestones are lithologically very similar to the Chee Tor Rock and Miller's Dale Limestones: they consist primarily of medium- and fine-grained biosparites. Most insoluble residue determinations indicate that the limestones are of very high purity: their generally very low non-carbonate content is dominated by fine euhedral quartz crystals and a trace of disseminated clay. However, evidence from two sections at Pin Dale (18 SE 2 S) and Cressbrook (17 SE 8 S) suggests that the upper beds of the Bee Low Limestones have a similar purity distribution to the Miller's Dale Limestones, that is a mixture of very high and high purity categories. For this reason the sequence has been divided into a lower very high purity division and an upper division of more variable purity, the junction being taken at the estimated horizon of the Lower Miller's Dale Lava.

Apron-reef limestones

Along the northern margin of the limestone crop the block margin is marked by thick apron-reef deposits. These crop out over an area of 2.2 km^2. Various facies within the reef belt have been distinguished (Stevenson and Gaunt, 1971) but for the purposes of this assessment the reef is considered as one unit.

Generally the limestones are massive and only poorly-bedded, consisting primarily of micrites and biomicrites with some poorly sorted biosparites. Bryozoan fragments are much more common than in the 'shelf' limestones and algal limestones are developed locally.

Sections through the different parts of the reef-complex indicate that the apron-reef limestones are of very high purity overall. However, spot samples have shown that some silicification does occur and this may reduce the purity by one grade locally. A section through the apron-reef at Cave Dale (18 SE 4s) produced two samples containing large concentrations of silica and fluorite in an otherwise very high purity sequence.

Monsal Dale Limestones

The Monsal Dale Limestones are much more variable

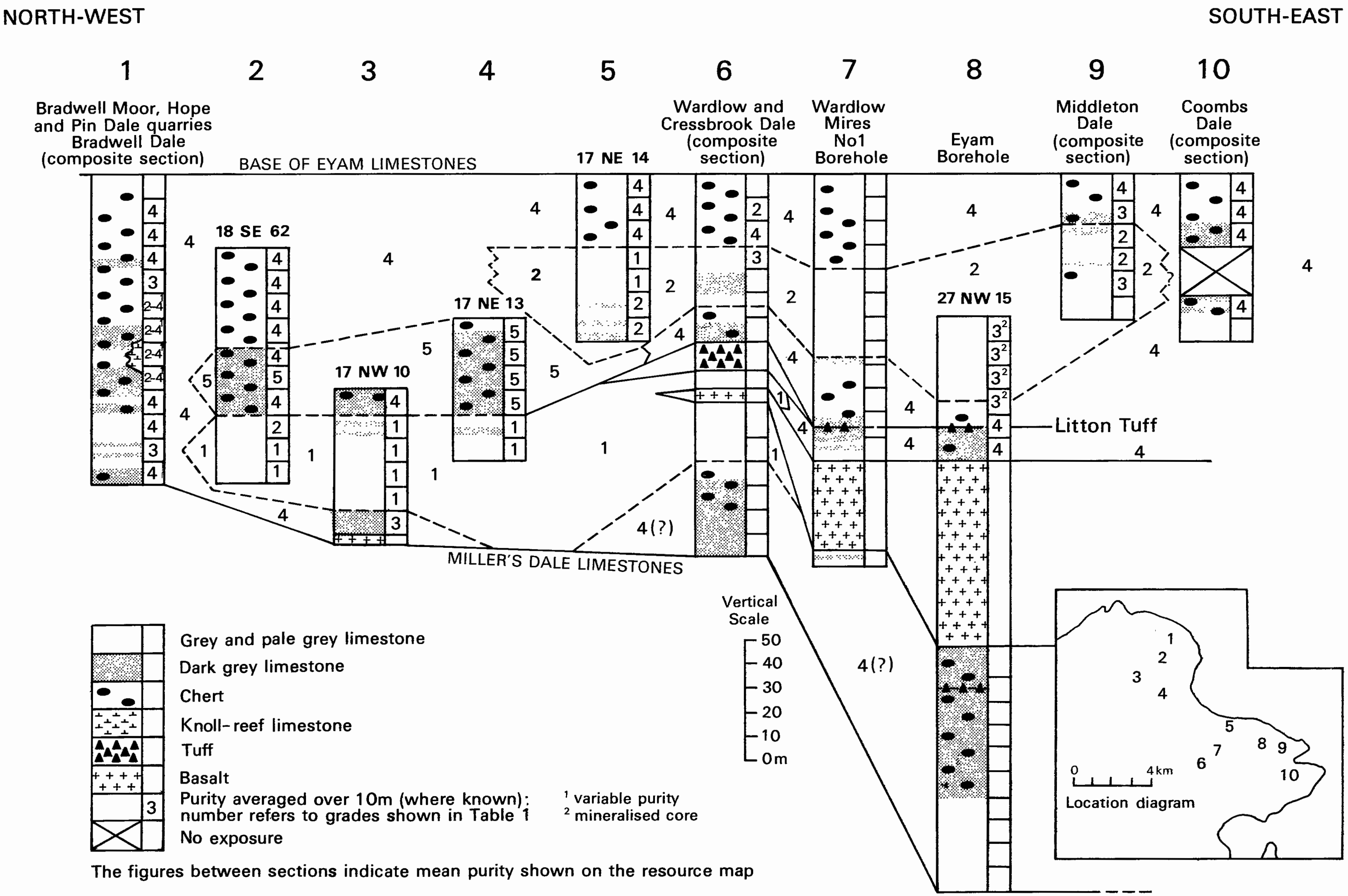


Figure 7 Vertical sections of Monsal Dale Limestones north of the Wye valley.

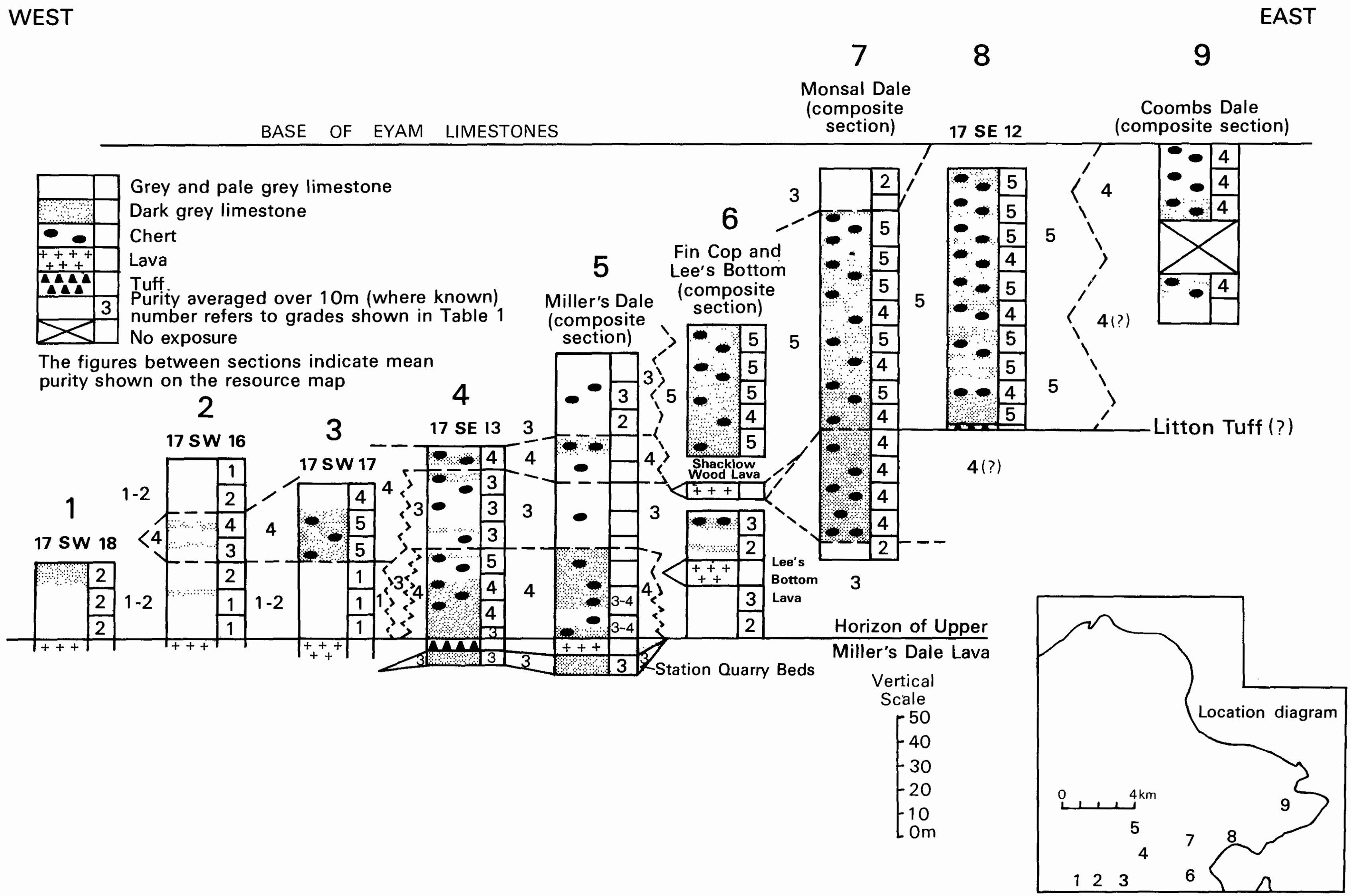


Figure 8 Vertical sections of Monsal Dale Limestones in and south of the Wye valley.

lithologically than either the Woo Dale or the Bee Low limestones. The contrast between pale and mid-grey lithologies on the one hand and dark-coloured beds on the other is striking and has been used as an aid to mapping the formation. Beds of the dark facies have been recorded at various stratigraphical levels, but not all are of sufficient thickness or are laterally persistent enough to be shown on the map. The main developments of the dark facies at the surface are indicated on Figure 4 and are more precisely delineated on the resource map where they are denoted by the symbol Mo/dk.

Both facies contain persistent coral, brachiopod and algal (*Girvanella*) bands, which are useful for correlation. There are also distinctive lithological marker beds, of which the Rosewood Marble is probably the best known. At outcrop in Monsal Dale it forms a 3-m bed comprising convoluted laminae of micrite and dolomite.

All the dark limestones contain disseminated clay, sometimes in amounts in excess of 10 per cent, in which case the limestones are properly classified as argillaceous. Thin mudstones and shaly partings are sometimes present and nodules and beds of chert are abundant. Chert is also common in beds of the pale facies, but it is not so uniformly distributed. Where the pale facies is free of chert the non-carbonate fraction is dominated by euhedral quartz crystals, silicified bioclasts and traces of disseminated clay. Pyrite occurs in both facies but is more common in bituminous dark limestones and both above and below the volcanic units.

The purity of the Monsal Dale Limestones varies according to the distribution of the two facies and whether or not they contain chert. A series of vertical sections (Figures 7 and 8) shows the variations that occur across the outcrop. Figure 7 summarises the distribution north of the Wye valley. The beds above the Litton Tuff may be grouped into an upper pale unit and a lower dark unit. In the north, chert is widespread in the pale unit and the sequence, as proved in Borehole 18 SE 62, is one of low purity. Chert decreases in amount to the south, however, and in the Shining Cliff section (27 NW 1 S) in Middleton Dale equivalent beds are predominantly of medium or high purity. The underlying dark unit, sampled in boreholes 17 NE 10, 17 NE 13 and 18 SE 62 is all impure or of low purity. This facies thins south towards Litton and east towards Eyam. The beds below the Litton Tuff are generally pale with only a basal development of the dark facies. Boreholes 17 NW 10, 17 NE 13 and 18 SE 62 indicate that most of the pale limestones are free of chert and of very high purity; however, in the north-east the carbonate level decreases and in Pin Dale Quarry [18 SE 2 S] the limestones are only of low purity. In the area to the east around Eyam the lower beds are overlain by the Cressbrook Dale Lava.

The sequence developed in the Wye Valley and in the area to the south differs from that described above and is summarised in Figure 8. In the south-west, only the lower beds are preserved and they are predominantly pale and chert-free. Farther north towards the Wye valley and farther east towards Monsal Head, the sequence thickens, dark beds are more common and chert is widespread. The borehole north of Great Longstone (17 SE 12) indicates that the top 100 m of the sequence all belongs to the dark facies and consists mainly of impure-grade limestones.

In general the non-carbonate fraction increases from west to east and the only chemical-grade limestones in this part of the district occur above the Upper Miller's Dale Lava in the extreme south-west.

Eyam Limestones

The Eyam Limestones crop out over an area of about 12 km^2. Typically they consist of thin-bedded, grey or dark grey biosparites and biomicrosparites in which crinoids and brachiopod fragments are the main allochems. The limestones contain variable amounts of nodular and bedded chert and thin shaly partings are common. The chief disseminated impurities are authigenic quartz, clay (often concentrated along stylolites), silicified bioclasts and pyrite. The limestones are shown as impure on the resource map but are known to be variable with areas of higher purity mineral occurring where there is less chert.

Limestones of reef facies cover about 2.5 km^2 of the crop and are mainly poorly bedded and poorly sorted mid-grey biomicrites. Around Bradwell and Eyam the reefs reach a maximum thickness of about 40 m but elsewhere the deposits are considerably thinner. Apart from traces of silicified shell debris, non-carbonate minerals are rare and the limestones are of high purity. A facies developed locally around some of the reefs consists of pale-coloured and highly crinoidal limestones, sometimes containing chert. Where these limestones have been sampled, near Calver [236 747], they are of medium purity. However, this facies is not extensive and has therefore been included for assessment purposes with the more widespread thin-bedded impure facies.

NON-CARBONATE MINERALOGY

The distribution of the chief non-carbonate constituents is known from field observations and from examination of sawn and etched rock surfaces (see preceding section).

Additional information has been gained from studying the residues retained on the filters used for carbonate determination. In nearly all cases the residue is dominated by clay minerals and quartz in differing proportions. Figure 9 demonstrates how the clay:silica ratio varies within each formation. The predominance of silica over clay in the reef limestones is striking, but clay minerals outweigh silica in the dark facies of the Eyam and Monsal Dale limestones. Clay is also proportionately higher in the normal facies of the Woo Dale Limestones; however, the high proportion of clay in the Peak Forest Limestones is anomalous and results from contamination of some samples with fissure-fill clays.

Representative samples of residue material were analysed by X-ray diffraction (Table 2). Of the 92 determinations carried out, over 95 per cent showed the presence of quartz and over 50 per cent proved one or more clay minerals. The majority of the clay minerals were identified as belonging to the illite and kaolinite groups but a number of mixed-layer clays were also recorded. Pyrite, apatite and fluorite were identified from between 5 and 10 per cent of the samples. Traces of several minerals not observed using other methods were recorded from a few samples; these include chalcopyrite, chlorite, feldspar and ?gypsum.

ROCK CHEMISTRY

The results of 200 chemical analyses are given in Appendix D and are summarised in Tables 3 and 4. The distribution of sampling points is shown in Figure 10. The results confirm that the most extensive resources of high purity, chemical-grade limestone are to be found in the Bee Low and Woo Dale limestones and in limestones of reef facies. In these three divisions the CaO levels are generally in excess of 55 per cent (pure $CaCO_3$ contains 56.02% CaO) and apart from small variations in the SiO_2 content the deposits are chemically uniform. A slight increase of MgO concentration in the Woo Dale Limestones (normal facies) is due to the presence of scattered dolomite rhombs. The slightly less pure Miller's Dale Limestones have a higher SiO_2 value, reflecting the higher levels of silicification recorded in this division.

In the pale facies of the Monsal Dale Limestones a distinction is drawn (Table 3) between samples originating from chert-free sequences and those representing beds where chert is a common impurity. The figures show that even in the chert-free areas, the pale facies contains higher levels of SiO_2 than either the Bee Low or Woo Dale limestones.

Samples from the Eyam limestones and the dark facies of the Monsal Dale Limestones are characterised

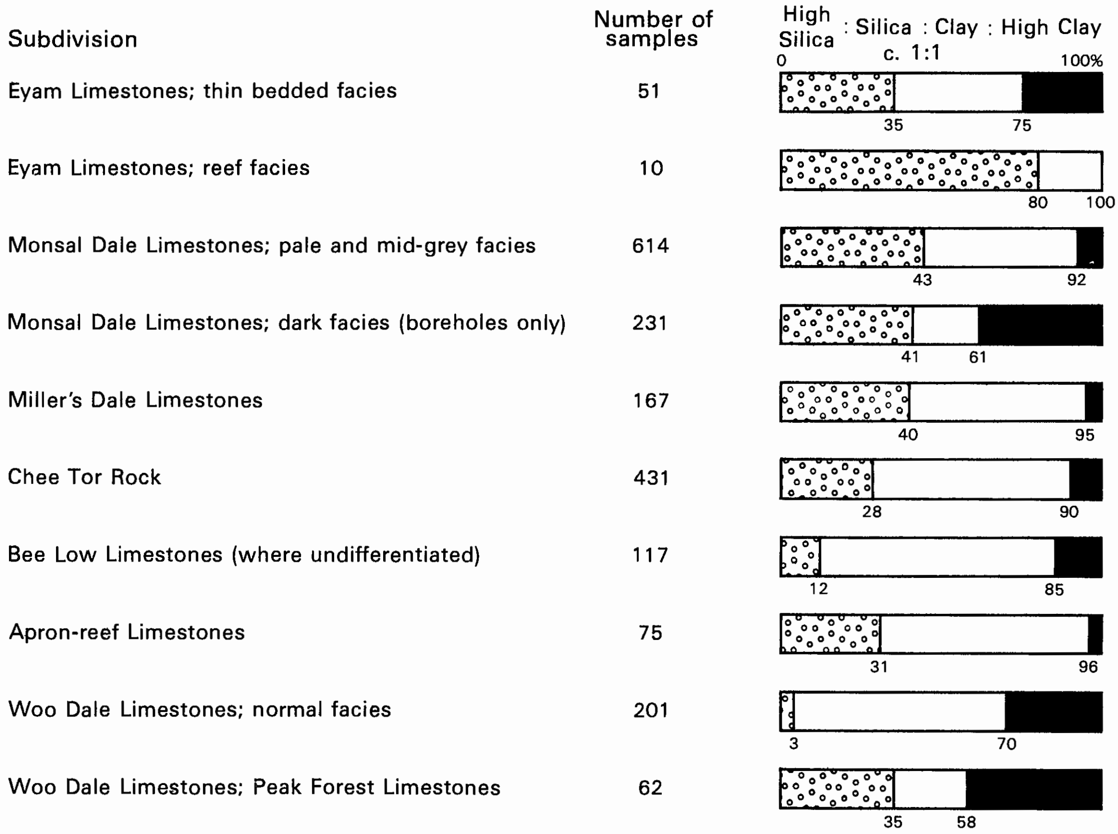


Figure 9 Silica: clay ratios (from optical examination of insoluble residue material)

Table 2 Insoluble residue mineralogy determined by X-ray diffraction analysis.

Mineral(s) identified	Formation					
	Eyam Limestones	Monsal Dale Limestones	Miller's Dale Limestones	Chee Tor Rock	Woo Dale Limestones	Reef Limestones*
Quartz	X	X	X	X	X	X
Illite		X	X	X	X	
Kaolinite	X	X	X	X		X
Mixed-layer clays		X	X			
Chlorite			X	X		
Pyrite		X				
Chalcopyrite		X		X		
Hematite			X			
Apatite		X				
Fluorite		X				X
Feldspar		X				
Gypsum				?		
Number of samples analysed	7	42	8	26	5	4

Notes

Minerals recorded are marked by a cross.

* Reef Limestones include flat-reef and apron-reef limestones.

TABLE 3 Summary of chemical analyses for main limestone divisions: Part 1 - the 'D_2' limestones (Eyam and Monsal Dale limestones).

Lithostratigraphical divisions (with number of analyses)*		Percentages												Parts per million					Limestone category†
		CaO	Loss on ignition	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As	
Eyam Limestones Thin-bedded facies (3;0)	mean	51.08	40.29	6.71	0.46	0.24	0.05	0.14	0.07	0.23	0.04	0.10	0.01	0	0	150	320	-	4
	maximum	52.06	41.66	9.72	0.49	0.35	0.06	0.33	0.09	0.30	0.04	0.13	0.02	0	10	320	450	-	4
	minimum	49.41	38.42	4.73	0.41	0.16	0.04	0.04	0.06	0.18	0.03	0.07	0.01	0	0	40	190	-	4
Reef facies (2;0)	mean	54.24	42.49	2.73	0.24	0.12	0.02	0.04	0.01	0.02	0.03	0.14	0.00	5	0	10	320	-	3
	maximum	54.61	42.65	3.21	0.24	0.13	0.03	0.05	0.01	0.02	0.05	0.14	0.00	5	0	10	330	-	3
	minimum	53.87	42.33	2.24	0.24	0.10	0.02	0.03	0.00	0.01	0.01	0.13	0.00	5	0	10	300	-	3
Monsal Dale Limestones Dark facies (21;0)	mean	49.20	39.53	8.72	1.03	0.53	0.10	0.21	0.12	0.36	0.06	0.06	0.02	5	10	50	250	-	4
	S.D.	2.86	1.96	4.32	0.63	0.52	0.07	0.32	0.05	0.29	0.03	0.04	0.01	10	20	40	130	-	-
	maximum	54.39	43.33	16.29	2.29	2.48	0.34	1.42	0.21	0.97	0.12	0.13	0.04	30	90	170	590	-	1
	minimum	45.50	36.20	1.11	0.41	0.09	0.03	0.03	0.04	0.01	0.01	0.01	0.00	0	0	10	100	-	5
Pale facies (all samples) (48;7)	mean	54.03	42.72	2.15	0.35	0.16	0.04	0.06	0.04	0.10	0.03	0.04	0.01	5	10	40	270	1	2
	S.D.	1.49	1.40	2.63	0.06	0.07	0.01	0.08	0.02	0.12	0.03	0.05	0.01	5	10	50	220	1	-
	maximum	55.45	43.76	12.58	0.52	0.43	0.08	0.50	0.13	0.70	0.11	0.25	0.03	5	70	300	1600	2	1
	minimum	47.81	36.64	0.33	0.25	0.07	0.02	0.02	0.01	0.00	0.00	0.01	0.00	0	0	0	100	0	5
Pale facies (samples from chert-free sequences) (37;7)	mean	54.56	43.18	1.27	0.36	0.15	0.04	0.07	0.03	0.09	0.03	0.04	0.01	5	10	40	290	1	2
	S.D.	0.79	0.78	1.65	0.06	0.06	0.01	0.08	0.01	0.13	0.02	0.05	0.01	5	10	40	250	1	-
	maximum	55.45	43.76	9.17	0.52	0.26	0.06	0.50	0.08	0.70	0.11	0.25	0.03	5	70	230	1600	2	1
	minimum	50.99	39.61	0.33	0.25	0.07	0.02	0.02	0.01	0.00	0.00	0.01	0.00	0	0	0	100	0	4
Pale facies (samples from cherty sequences) (11;0)	mean	52.23	41.17	5.10	0.34	0.20	0.05	0.05	0.07	0.10	0.05	0.04	0.01	5	0	60	220	-	3
	S.D.	1.90	1.90	3.22	0.07	0.09	0.02	0.03	0.03	0.09	0.02	0.02	0.01	0	5	80	50	-	-
	maximum	54.50	43.37	12.58	0.46	0.43	0.08	0.10	0.13	0.31	0.09	0.09	0.02	5	10	300	300	-	1
	minimum	47.81	36.64	1.51	0.27	0.12	0.03	0.02	0.03	0.02	0.02	0.01	0.00	5	0	10	150	-	5

* The first figure denotes the number of samples analysed for all constituents other than As; the second figure denotes the number of samples analysed for As.

S.D. denotes 'Standard deviation'.

† Calculated from loss on ignition

TABLE 4 Summary of chemical analyses for main limestone divisions: Part 2 - the 'D_1/S_2' Limestones (the Bee Low to Peak Forest limestones).

Lithostratigraphical divisions (with number of analyses)*		Percentages												Parts per million					Limestone category
		CaO	Loss on ignition	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As	
Bee Low Limestones	mean	55.49	43.56	0.43	0.36	0.14	0.04	0.07	0.02	0.04	0.02	0.08	0.00	5	10	10	210	1	1
where undivided	S.D.	0.33	0.26	0.20	0.07	0.04	0.01	0.09	0.01	0.04	0.03	0.18	0.00	5	10	10	150	-	-
(15;2)	maximum	55.95	44.00	0.82	0.49	0.23	0.06	0.28	0.05	0.13	0.12	0.65	0.01	10	20	40	570	1	1
	minimum	54.91	42.96	0.21	0.26	0.08	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0	0	0	90	0	2
Miller's Dale Limestones	mean	54.86	43.38	0.97	0.37	0.18	0.05	0.10	0.04	0.08	0.02	0.01	0.00	5	0	20	280	1	1
	S.D.	0.57	0.29	0.43	0.07	0.06	0.01	0.11	0.02	0.07	0.02	0.01	0.01	5	0	10	350	1	-
(18;4)	maximum	56.00	43.83	1.87	0.54	0.33	0.08	0.42	0.07	0.23	0.09	0.03	0.02	15	10	50	1600	1	1
	minimum	53.71	42.73	0.31	0.29	0.09	0.03	0.02	0.01	0.01	0.00	0.01	0.00	0	0	0	100	0	2
Chee Tor Rock	mean	55.15	43.50	0.52	0.36	0.16	0.04	0.05	0.03	0.09	0.02	0.01	0.00	5	0	10	140	1	1
(51;9)	S.D.	0.48	0.22	0.26	0.07	0.07	0.01	0.04	0.01	0.10	0.01	0.00	0.01	0	0	10	50	1	-
	maximum	56.10	43.95	1.33	0.52	0.41	0.08	0.27	0.06	0.47	0.04	0.02	0.02	5	30	20	230	2	1
	minimum	54.25	42.75	0.16	0.25	0.08	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0	0	0	60	0	2
Apron-reef Limestones	mean	55.54	43.56	0.41	0.37	0.09	0.03	0.03	0.01	0.03	0.13	0.09	0.00	5	5	40	320	0	1
	S.D.	0.21	0.56	0.57	0.04	0.01	0.00	0.01	0.01	0.03	0.35	0.06	0.00	0	5	80	100	1	-
(12;3)	maximum	55.89	44.00	1.27	0.44	0.12	0.03	0.05	0.02	0.10	1.24	0.25	0.01	5	10	300	500	1	1
	minimum	55.16	41.88	0.07	0.32	0.07	0.02	0.02	0.00	0.01	0.01	0.04	0.00	5	0	10	220	0	3
Woo Dale Limestones	mean	55.40	43.74	0.23	0.50	0.10	0.03	0.04	0.02	0.05	0.01	0.01	0.00	0	0	10	150	1	1
	S.D.	0.51	0.18	0.23	0.11	0.04	0.01	0.05	0.01	0.03	0.01	0.00	0.00	5	0	10	60	-	-
Normal facies	maximum	56.00	44.00	0.96	0.88	0.25	0.06	0.22	0.04	0.14	0.03	0.01	0.02	5	10	30	220	3	1
(20;4)	minimum	53.84	43.34	0.02	0.38	0.06	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0	0	0	80	0	1
Peak Forest	mean	55.40	43.55	0.71	0.36	0.09	0.03	0.07	0.03	0.21	0.03	0.02	0.01	5	0	10	210	1	1
Limestones	S.D.	0.47	0.45	0.88	0.03	0.05	0.00	0.09	0.01	0.26	0.02	0.00	0.01	0	0	10	30	-	-
(10;2)	maximum	56.10	43.99	2.27	0.43	0.22	0.04	0.32	0.05	0.30	0.06	0.02	0.02	5	10	30	250	1	1
	minimum	54.54	42.56	0.01	0.32	0.07	0.03	0.02	0.01	0.14	0.01	0.02	0.00	5	0	10	150	0	3

* The first figure denotes the number of samples analysed for all constituents other than As; the second figure denotes the number of samples analysed for As.

S.D. denotes 'Standard deviation'.

† Calculated from loss on ignition

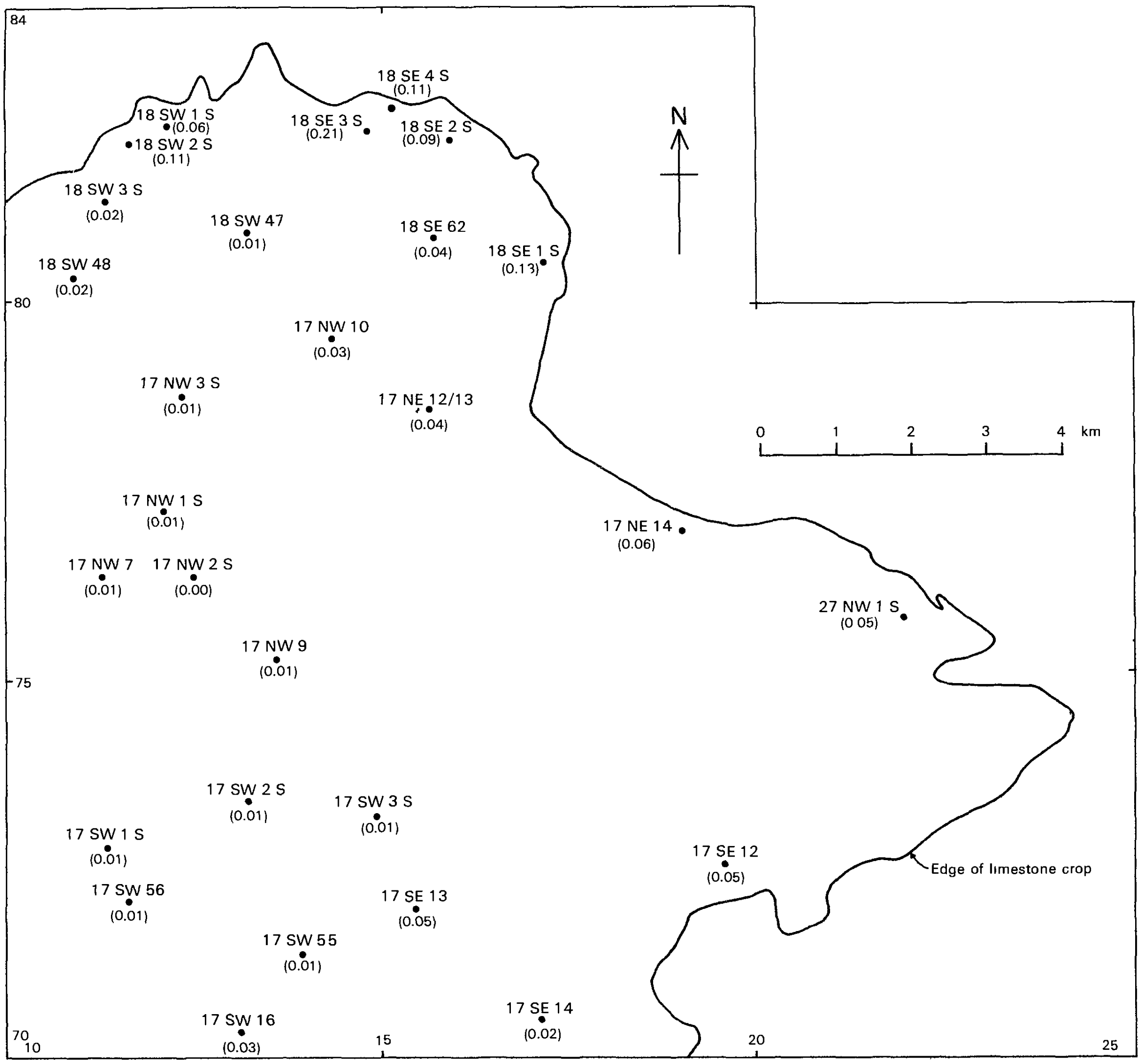


Figure 10 Map showing locations for which analytical data are available.

by high mean SiO_2, Al_2O_3 and K_2O values, reflecting high percentages of chert and clay.

In most analyses Fe_2O_3 and SrO values follow those of Al_2O_3, K_2O and MgO, indicating the occurrence of some iron and strontium in the clay minerals. High values of Fe_2O_3 (greater than 0.2 per cent) can be correlated with occurrences of pyrite, hematite and limonite.

Nearly all values of SO_3 can also be correlated with recorded occurrences of pyrite. However, several samples within the dark facies of the Monsal Dale Limestones contain low Fe_2O_3 and a very high (greater than 0.4 per cent) SO_3 content (see for example, borehole 17 SE 12). Although pyrite has been recorded from these samples, it is not present in sufficient amounts to account for all the sulphur, and the likelihood is that some sulphur is contained in bituminous material.

A plot of the mean P_2O_5 percentages for each sample point (Figure 10) shows that, in general, the highest concentrations occur around the edge of the limestone crop, particularly in the reef limestones.

Trace amounts of fluorine, zinc, copper and manganese have been recorded at all stratigraphical levels, whereas lead and arsenic are more restricted in occurrence. There is a tendency for trace element concentrations to increase from west to east across the district as the influence of the main orefield is felt more strongly but, in general, the mean trace element values approximate to background levels since the sampling programme was designed specifically to avoid known mineralisation. One exception is the anomalously high fluorine content (0.13%) indicated for the apron-reef limestones; this was caused by sampling a mineralised reef section at Cave Dale (18 SE 8 S).

Table 5 Limiting reflectance percentages used to define rock colour

Colour	Limiting reflectance percentages		
	660 nm	520 nm	470 nm
Pale grey	>35	>26	>24
Mid-grey	35 to 15	26 to 12	24 to 11
Dark grey	<15	<12	<11

COLOUR

In order to compare the colour of the limestones objectively, tri-colour reflectance measurements were made using an EEL reflectance spectrophotometer. Readings were taken every metre on sawn and acid-etched surfaces of the borehole cores and section

Table 6 Distribution of rock colour

Formation/facies	Colour distribution (percentage)		
	Pale grey	Mid-grey	Dark grey
Eyam Limestones			
Thin-bedded facies	0	49	51
Reef facies	0	100	0
Monsal Dale Limestones			
Pale facies	8	79	13
Dark facies	0	25	75
Miller's Dale Limestones	17	77	6
Chee Tor Rock	6	85	9
Bee Low Limestones	11	87	2
Apron-reef Limestones	0	94	6
Woo Dale Limestones			
Normal facies	0	46	54
Peak Forest Limestones	10	90	0

samples. Three colours, pale grey, mid-grey and dark grey are defined (Table 5) by reference to three filters (wavelengths 660, 520, and 470 nm respectively) and a white $MgCO_3$ standard. The dark grey shade is particularly distinctive and corresponds approximately to the shade 'Dark Grey, N3' as defined in the Munsell Rock-Color Chart. Limestones of this colour are well represented in the dark facies of the Monsal Dale Limestones, in the Eyam Limestones and in the normal facies of the Woo Dale Limestones. Throughout the remainder of the sequence mid-grey limestones predominate (Table 6). Pale grey limestones are not well represented in the district, which is surprising in view of the fact that much of the western part of the district is underlain by the chemically pure Bee Low and Woo Dale limestones. The lower limit of the pale grey reflectance band equates approximately with 'Light Grey, N7' on the Munsell Rock-Color Chart; samples assigned to this category normally contain a high percentage of micritised allochems and it is these which impart the whiteness to the rock. It would appear from the data that these highly micritised lithologies are not as widely distributed in the Tideswell district as they are in adjacent areas (see, for example, Cox and Bridge, 1977).

The colour of a rock powder is important where it is to be used as a whiting agent, or in an end-use where the colour of the manufactured product is critical. Hence tri-colour reflectance values were determined for powdered samples (<63 micrometres particle size) of the very high purity limestones in each formation. The results are detailed in Appendix C and summarised in Table 7 and Figure 11. The formations tested all produced comparable results with the exception of the normal facies of the Woo Dale Limestones. The latter, although very pure chemically, produced powders of relatively low whiteness, and thus constitutes an exception to the generalisation that the paler the colour, the purer the limestone (Anon., 1966; Cox and Bridge, 1977).

Table 7 Summary of mean powder reflectance results for very high purity limestones

Formation	Mean reflectance percentage		
	660 nm	520 nm	470 nm
Monsal Dale Limestones	80	75	72
Miller's Dale Limestones	83	80	76
Chee Tor Rock	83	77	76
Apron-reef limestones	84	69	78
Woo Dale Limestones			
Normal facies	70	62	59
Peak Forest Limestones	80	73	70

MECHANICAL AND ENGINEERING PROPERTIES

Aggregate Impact Value As an indication of the strength of the limestones the Aggregate Impact Value test (British Standards Institution, 1975) was performed on samples from most boreholes and two sections. The Aggregate Impact Values (AIV) are recorded graphically in Appendix C and summarised in Figure 12. The AIVs are generally independent of facies or formation and a mean result of 21-23 was obtained for most limestone units.

The slightly higher value of 25 obtained for all of the reef limestones suggests that a slight weakening occurs in rocks containing a substantial micrite component. The Peak Forest Limestones are the least durable member with a mean value of 28, making them unsatisfactory for use as an aggregate. This low rating is due mainly to the brittle nature of the tightly packed crinoid fragments that dominate these rocks.

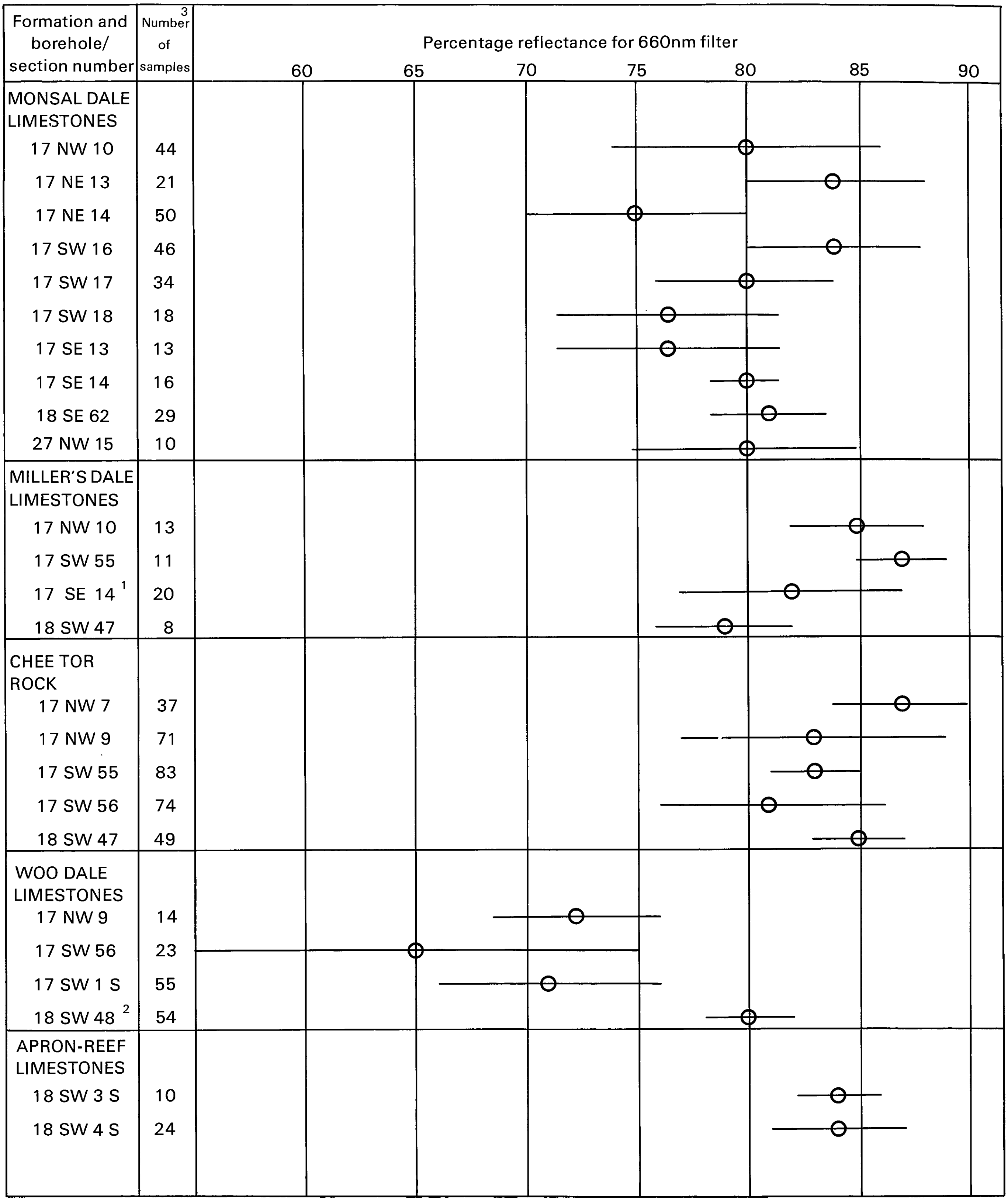
A test was carried out on samples of the Lower Miller's Dale Lava recovered from Borehole 17 SW 55 and a value of 27 was obtained. Generally, the tops and bottoms of all the lavas have been altered to clays rendering the thinnner lavas unsuitable as aggregate material.

The aggregate impact test, when carried out in accordance with the British Standard, requires that the method of crushing used produces at least 15% by weight of chips in the range 10-14 mm for the test to be a valid reflection of the strength of the rock as a whole. The laboratory crusher used in this survey generally produced between 13 and 23 per cent of chips in the required size range. One sample, however, in borehole 17 SE 13 (between 51 and 60 m), produced only 4.5 per cent of the required size of chips; it yielded an AIV of 21.

Fracture spacing Details of fracture spacing (Franklin and others, 1971) are shown graphically for some sections in Appendix C. Fracture indices for all limestones are generally in the range 100 to 1000 mm. Although the results are very variable, the thicker-bedded limestones, found predominantly in the Chee Tor Rock, Miller's Dale Limestones, Bee Low Limestones and the pale facies of the Monsal Dale Limestones, give values of 500 or higher. The thin-bedded limestones, typical of the dark facies of the Monsal Dale Limestones, the Eyam Limestones and the Woo Dale Limestones, give values of less than 500. The reef limestones are generally massive and tend to give very high values.

THE RESOURCE MAP

Carbonate resource information The limestone and dolomite resource map is folded into the pocket at the end of this report. The base map is the Ordnance Survey 1:25 000 outline edition in grey. For cartographic reasons, geological data are restricted to those most

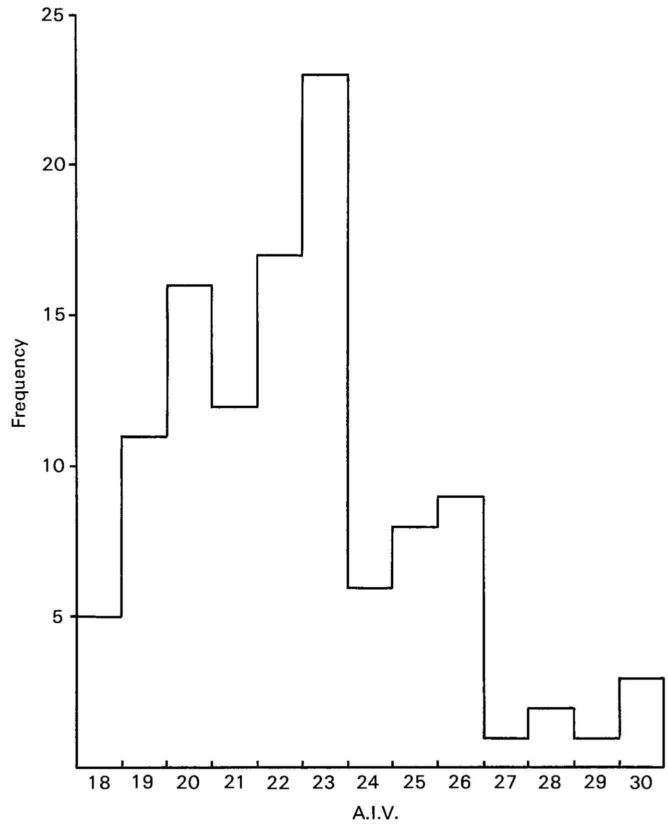


[1] Top 20m of Bee Low Limestones

[2] Peak Forest Limestones

[3] For details of sampling see graphical logs in Appendix C

Figure 11 Reflectance values for powder samples of dominantly very high purity limestones.



FORMATION	NUMBER OF SAMPLES	MINIMUM A.I.V.	MAXIMUM A.I.V.	MEAN A.I.V.	STANDARD DEVIATION
WOO DALE LIMESTONES					
Normal Facies	4	19	27	22	3.4
Peak Forest Limestones	6	26	30	28	1.8
CHEE TOR ROCK	36	18	25	22	1.8
MILLER'S DALE LIMESTONES	10	20	28	23	2.8
MONSAL DALE LIMESTONES					
Pale Facies	32	18	30	23	2.7
Dark Facies	20	18	24	21	1.8
EYAM LIMESTONES	3	18	20	19	1.2
Reef Limestones	3	23	25	24	1.0
TOTAL	114	18	30	22	2.7

Figure 12 Distribution of Aggregate Impact Values.

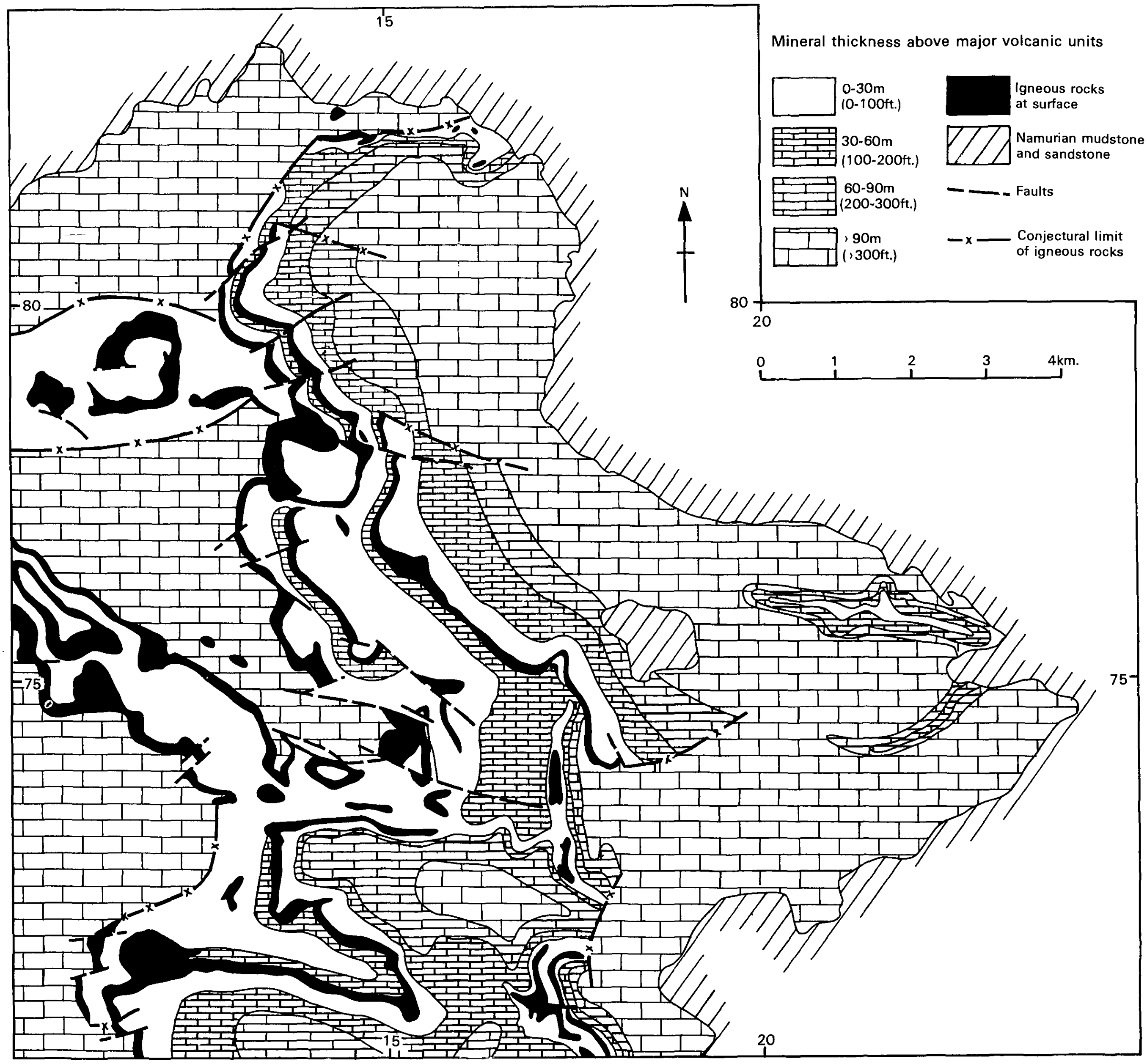


Figure 13 Sketch map indicating variation in thickness of limestone above volcanic horizons.

likely to have a bearing on the extraction of limestone and dolomite: these include faults, mineral veins and other structural information, which are shown in red, and major geological boundaries, in green. Drift is shown in yellow.

Carbonate resource information is shown in blue: the different shades shown on the map indicate the purity of limestone likely to be found at or near the surface. Purity values were determined at sample points as follows: the measurements of insoluble residue (that is, the non-carbonate fraction) were grouped into successive 10-m sets. For each group the mean, standard deviation, and confidence limits were calculated at the 95 per cent probability level, assuming the Student's 't' distribution. The mean and the positive confidence limit were summed to give a value which, when subtracted from 100, gave a conservative (worst) estimate of the calcium carbonate percentage for each thickness increment. This value then determined the category of limestone according to the classification in Table 1. In sections containing chert, the limestone category was adjusted by adding the precentage of chert measured in the section to the insoluble residue value obtained for the chert-free material in the laboratory.

Areas of dolomite or dolomitisation are indicated in green; no attempt has been made to divide the dolomite quantitatively because of the lack of data.

IMAU site data At the site of each borehole or extensive natural section, the stratigraphical sequence is summarised in a tablet and the purity of the limestones is indicated. The right half of the tables shows the mean

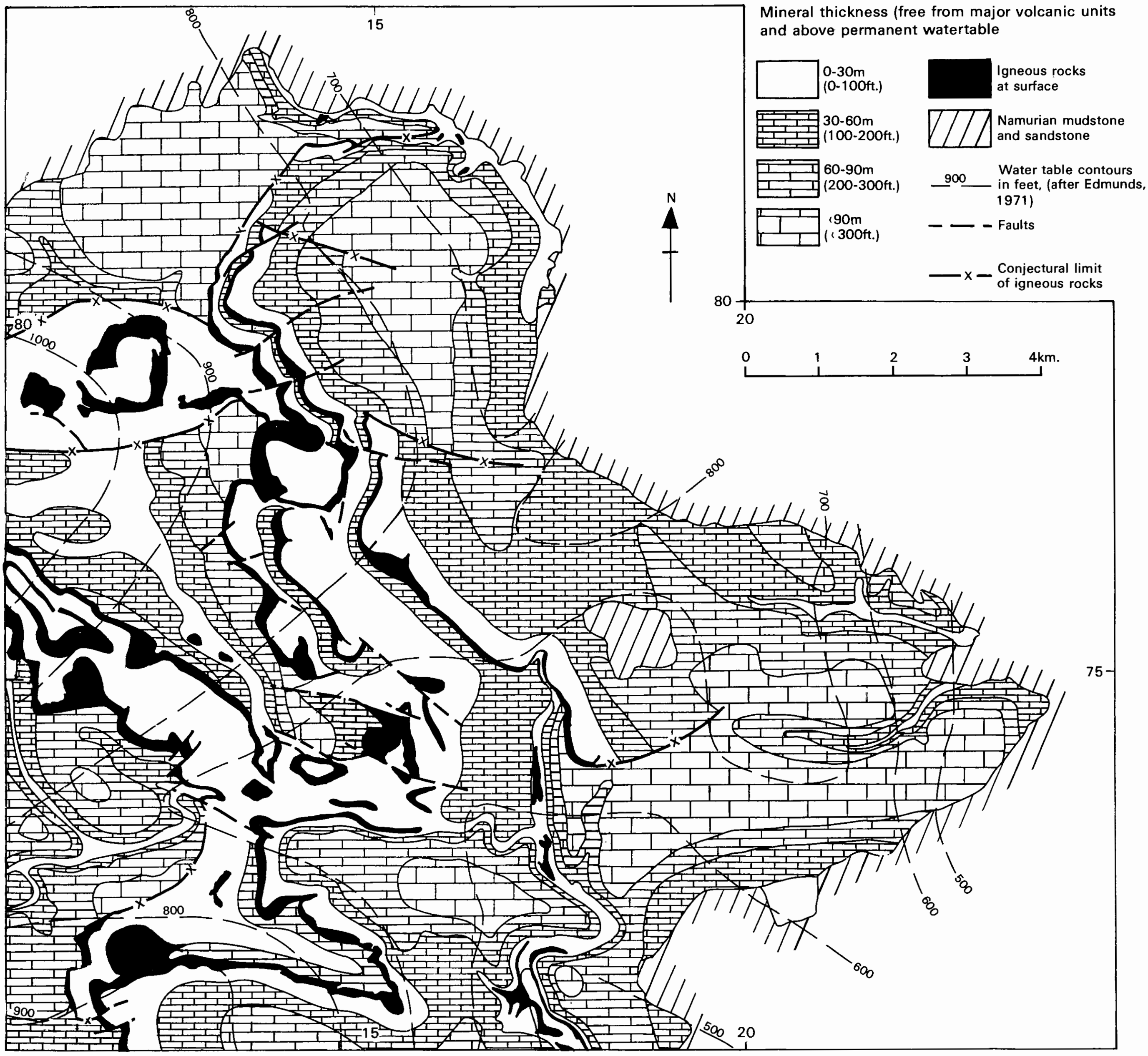


Figure 14 Sketch map indicating variation in thickness of limestone above volcanic horizons and above the permanent water table.

insoluble residue value up to a maximum of 10 per cent for each 10-m increment of thickness.

Horizontal sections Hortizontal sections have been drawn to show the relationship of the various limestone categories at depth. These sections are based directly upon borehole information, the structure as determined from field evidence, and the relationship of the various categories of limestone to the known stratigraphical sequence. They represent, therefore, an interpretation based upon all the available data and should be treated only as a guide to the likely distribution of purity at depth. Zig-zag lines have been used diagrammatically to indicate the approximate position of a change in limestone category.

NOTES ON CARBONATE RESOURCES

In addition to the overall purity distribution discussed in the preceding sections there are a number of other geological constraints that would affect mineral working. These are summarised below.

Overburden The mean overburden thickness for the boreholes drilled in this district is 1.9 m. These include two boreholes drilled on made ground where the overburden was 5.5 m (17 NW 9) and 3.4 m (17 SW 56] thick respectively. In borehole 17 SE 14, drilled in the Wye valley just below the level of the Lees Bottom Lava, the top 4.9 m consisted mainly of sand. The mean for the remaining boreholes of about 1.2 m is probably more representative of the normal overburden thickness. The small areas of drift outlined on the map are not thought to exceed a few metres in thickness at their maximum development.

The outlier of Namurian sediments around Wardlow Mires reaches thicknesses of 25 m and 20 m proved in the two Wardlow Mires boreholes (Stevenson and Gaunt, 1971, p. 208).

Igneous rocks Over much of the district igneous rocks occur at the surface or at depth within the limestone sequence. Their distribution is summarised in the Geology section and is shown on the resource map. The thickness of mineral that is likely to be present above the igneous rocks is shown diagrammatically in Figure 13. The 30-, 60- and 90-m isopachs have been drawn using all the available data, but it must be emphasised that the subsurface distribution of the lavas and sills, particularly those that are developed only locally, cannot be predicted with certainty. Consequently the diagram should be used only as a guide to mineral thickness. Igneous rocks less than 2 m thick have been excluded from the figure.

Clays, known locally as 'wayboards', up to about 1 m thick, are interbedded with the limestones. These may be removed by high-pressure water jets during quarrying or at a later stage in washing units and do not constitute a serious contaminant, although disposal of the slurry may pose a problem.

Water table Generalised water-table data are available (Edmunds, 1971) and have been used in compiling Figure 14, which shows the thickness of mineral that is potentially workable above the permanent water table and free from igneous rocks.

SUMMARY OF ASSESSMENT

1 The greatest thicknesses (over 100 m) of very high purity limestones occur in the Woo Dale Limestones, in the Chee Tor Rock (and equivalent beds in the Bee Low Limestones), and in the apron-reef limestones. These members are generally free of volcanics, the only known occurrences being the Ravensdale Tuff in Cressbrook Dale and the lava and tuff proved in a borehole drilled through the Chee Tor Rock at Litton Dale (Stevenson and Gaunt, 1971). In the Peak Forest area dolerite sills restrict the workable thickness of mineral and are a source of local contamination.

2 The Miller's Dale Limestones and the pale facies of the Monsal Dale Limestones contain thicknesses of up to 50 m of high and very high purity mineral. However, the presence of volcanic units at the base of both divisions limits the extent and workable thickness of mineral of these grades.

3 The Eyam Limestones and the dark facies of the Monsal Dale Limestone consists predominantly of low purity or impure limestones, but the locally developed reef facies contains limited resources, generally less than 30 m thick, of high purity limestone.

4 The beds at the base of the Woo Dale Limestones, which crop out only at the western edge of the district but probably underlie the whole area at depth, contain the only thick dolomitic sequences in the area.

5 Data from the Aggregate Impact Value test suggest that, with the exception of the Peak Forest Limestones and limestones of reef facies, the limestones are all of similar durability.

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APPENDIX A

CLASSIFICATION, TERMINOLOGY AND GLOSSARY

Classification

The petrographic classification of limestones proposed by Folk (1959; 1961) is widely accepted and is used in this report in a slightly modified form. The full classification is summarised in Table 8.

Clastic limestones consist of two basic components, namely allochem grains and matrix. The former are discrete bodies which have been subjected to some degree of transport; they include fossils and fossil fragments, oolites, intraclasts and pellets. The matrix is subdivided on grain size into microcrystalline ooze (less than 4 microns) termed micrite, a slightly coarser crystalline fabric (4 to 16 microns) termed microspar and crystalline calcite cement termed spar (greater than 16 micro-metres).

Limestones are also classified by reference to the mean grain size of the allochems into calcirudites (greater than 1 mm), calcarenites (1 to 0.062 mm) and calcilutites (less than 0.062 mm).

The pure mineral dolomite (Ca Mg $(CO_3)_2$) contains 21.9 per cent MgO and 30.4 per cent CaO (or 54.3 per cent $CaCO^3$). Rocks containing dolomite are classified as follows:

10 to 50 per cent	Dolomitic limestones
50 to 90 per cent	Calcitic dolomite
>90 per cent	Dolomite rock (usually referred to simply as 'dolomite').

Limestones containing 10 to 50 per cent detrital clay are classified as argillaceous limestones.

Terminology

In this district most of the limestones are biosparites, biomicrosparites, biomicrites, pelsparites or biopelsparites (Table 8). Pelsparites and biopelsparites have not been differentiated in the descriptive logs and all are shown as pelsparites. Very few 'micrites' occur. Grain size is described using the terms calcirudite, calcarenite (subdivided into coarse, medium and fine), and calcilutite. Diagnostic allochems may also precede the main grain size term for example, crinoid brachiopod calcirudite.

Glossary

Allochem A collective term for one of several varieties of discrete and organised carbonate aggregates, such as fossil fragments, oolites and pellets that serve as the coarser framework grains in most mechanically deposited limestones.

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

Argillaceous Applied to rocks containing large quantities of clay minerals.

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

Bird's eye fabric Irregular patches of sparry calcite commonly found infilling cavities in fine-grained limestones and resulting from localised disturbances such as escaping gas bubbles.

Calcarenite A limestone consisting predominantly (more than 50 per cent) of detrital calcite particles of sand size (0.062 to 1 mm).

Calcilutite A limestone consisting predominantly (more than 50 per cent) of detrital particles of silt and/or clay size (less than 0.062 mm).

Calcirudite A limestone consisting predominantly (more than 50 per cent) of detrital calcite particles larger than sand size (greater than 1 mm) and often also cemented with calcareous material.

Clastic Refers to a rock or sediment composed principally of particles of either fragmental or chemical origin that have been transported individually for some distance from their places of origin.

Conformable A sequence of beds are said to be conformable when they represent an unbroken period of deposition.

Table 8 Classification of limestone rocks (based on Folk, 1959).

				LIMESTONES			
				>10% Allochems Allochemical Rocks		<10% Allochems Microcrystalline Rocks	
				Sparry calcite cement > microcrystalline ooze	Microcrystalline ooze > sparry calcite cement	1-10% allochems	<1% allochems
Volumetric Allochem Composition	>25% Intraclasts			Intrasparite	Intramicrite(rare)	Most abundant allochem — Intraclasts: Intraclastic micrite(rare)	Micrite
	<25% Intraclasts	>25% oolites		Oosparite	Oomicrite(rare)	Oolites: Oolitic micrite (rare)	
		<25% oolites	Volume ratio of Fossils: Pellets >3:1	Biosparite	Biomicrite	Fossils: Fossiliferous Micrite	
			3:1 to 1:3	Biopelsparite	Biopelmicrite	Pellets: Pelletiferous Micrite	
			<1:3	Pelsparite	Pelmicrite		

Disconformity An erosion surface separating two parallel series of beds and indicating an interruption in the stratigraphical succession representing a period of geological time.
Epigenetic A term used to describe mineral deposits of later origin than the enclosing rocks.
Euhedral A term used to describe crystals which have well developed crystal boundaries or faces.
Facies The group of features of a sedimentary rock type which characterise a particular environment of deposition.
Formation The fundamental unit of lithostratigraphical classification; a body of strata having one or more unifying lithological features.
Gangue A mineral in a vein, other than an ore mineral.
Inlier An area or group of rocks surrounded by younger rocks.
Intraclast Material created by penecontemporaneous erosion within a basin of deposition.
Marmorise The process of recrystallisation of limestone by heat to form marble.
Member A lithostratigraphical unit; a subdivision of a formation.
Monocline A unit of strata that dips or flexes from the horizontal in one direction only and is not part of an anticline or syncline. It is generally a large feature of gentle dip.
Outlier An area or group of rocks surrounded by older rocks.
Oolite or Ooid A spherical or subspherical accretionary grain generally less than 2.00 mm in diameter. In section, oolites display concentric structure and may also exhibit radial structure.
Stromatactis A sedimentary structure characterised by a horizontal bottom, up to 10 cm in diameter, and an irregular or convex upwards supper surface, infilled by sparry calcite cement.
Stylolite An irreguar suture-like boundary development in some limestones; caused by the dissolution of limestone, often leaving a concentration of insoluble material along the stylolite surface.
Syncline A trough fold, the core of which contains stratigraphically younger rocks.
Unconformable Describes strata which do not succeed the underlying rocks in immediate order of age. It indicates a substantial break or gap in the geological record.
Wayboard An old mining term used commonly in Derbyshire to describe a discrete and deleterious thin rock bed, usually clay.

APPENDIX B
EXPLANATION OF FORMAT FOR BOREHOLE LOGS

The following list is arranged in the same order as data in 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:

a) The number of the 1:25 000 sheet on which the borehole lies, for example, SK 17.
b) The quarter of the borehhole lies and its number in a series for that quarter, for example, NW 7.

Thus the full Registration Number is SK 17 NW 7. This is abbreviated to 17 NW 7 in the text.

Collected sections are registered in a similar manner using a separate series of numbers, suffixed by the letter s, for example, SK 17 NW 2 s.

2 The National Grid Reference
All National Grid References in this publication lie within the 100 km square SK, unless otherwise stated. Grid references for borehole sites and section limits are given to eight figures (that is accurate to within 10^2 m). In the text, six-figure references are used for more approximate locations.

3 Location
Generally the borehole and section locations are referred to the nearest named locality on the 1:25 000 base-map.

4 Surface level
The surface level at the borehole site is given in metres above Ordnance Datum.

5 Type of drill and date of drilling
The type of machine, diameter of core produced and the date of completion of the borehole are given.

6 Descriptive borehole log
The major rock types are listed, for example, Limestone, Basalt.

7 Each major rock type is subdivided where possible and followed by a brief description. The classification and terminology used to describe the carbonate rocks is explained in Appendix A.

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

9 Graphical borehole log
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 15.

10 Energy (Sorting) Index
In the column representing energy (sorting) index; the shaded intervals highlight carbonate lithologies which exhibit textural and compositional properties characteristic of strongly agitated water conditions at the time of deposition.

11 Colour
The percentage reflectances of red light (peak wavelength of 660 mm) from flat, acid-etched rock surfaces, and also from prepared powder tablets are shown graphically. The powder has been tested only for borehole samples dominantly of very high purity limestone. Three sections, 17 SW 1s, 18 SW 1s 18 SW 2s and were also tested. A white magnesium cabonate standard with a reflectance value of 100 per cent was used to calibrate the spectrophotometer.

12 Mechanical properties
For most boreholes (and a few sections) the results of the Aggregate Impact Value test (British Standards Institution, 1975) are reported for each 10 m of core.

For certain sections the fracture spacing index (If) is measured in millimetres and plotted on a logarithmic scale (see for example, 17 SE 1s).

13 Insoluble residue data
Residue values are expressed as weight percentages.

14 Residue mineralogy is summarised.

15 Classification into categories by purity
The overall purity of a limestone, averaged over consecutive 10-m intervals of depth, is stated, using the following system (see also Table 1).

		Composition (per cent $CaCO_3$)
1	Very high purity	>98.5
2	High purity	97.0 - 98.5
3	Medium purity	93.5 - 97.0
4	Low purity	85.0 - 93.5
5	Impure	<85.0

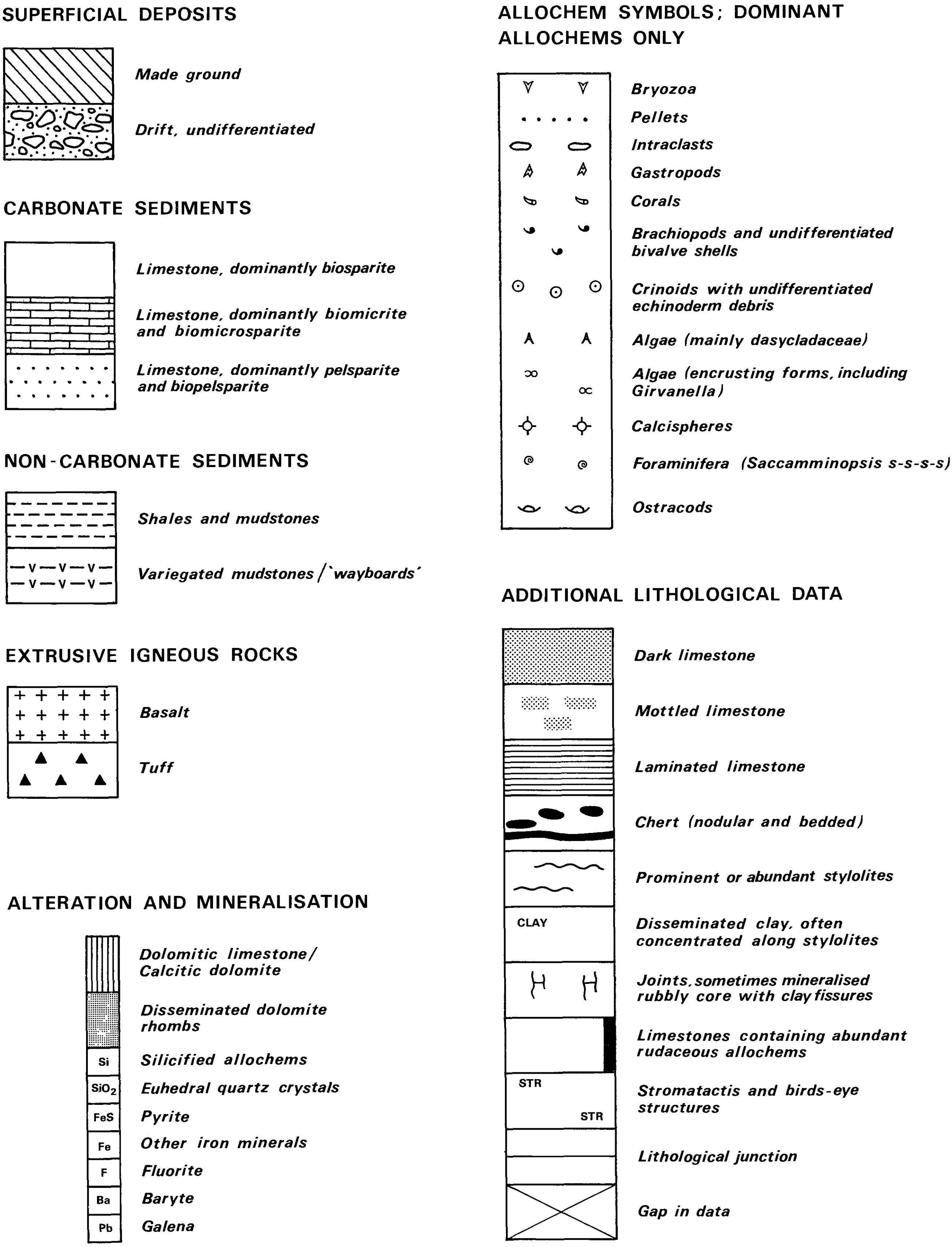


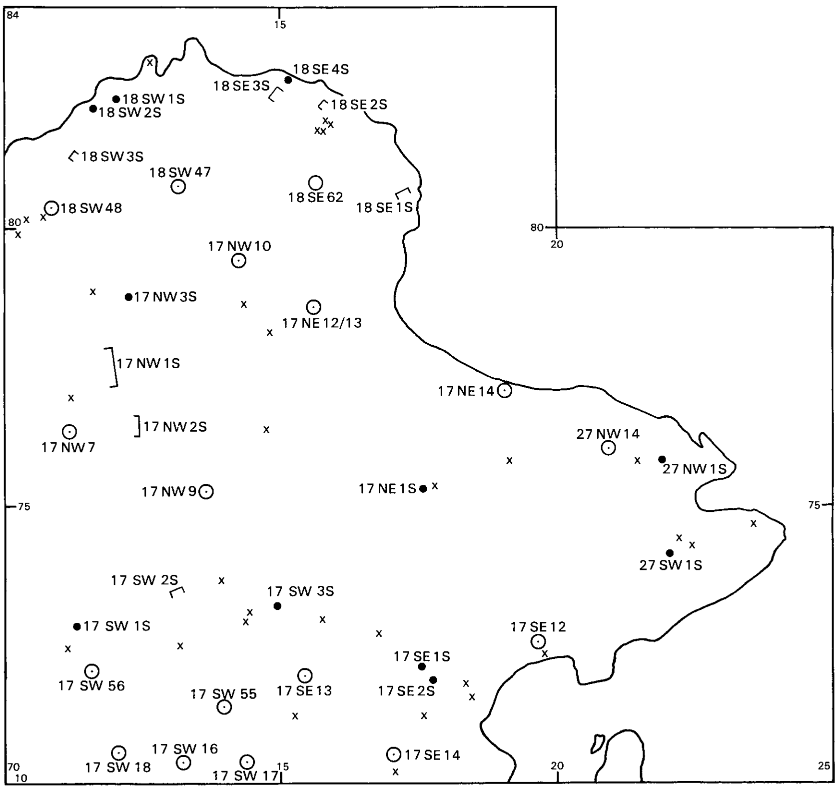
Figure 15 Explanation of symbols used on the graphical logs.

APPENDIX C
RECORDS OF BOREHOLES AND SECTIONS

Borehole number	Grid reference	Section number	Grid* reference
17 NW 7†	1120 7633	17 NW 1 S†	1197 7714
17 NW 9†	1366 7526	17 NW 2 S†	1253 7630
17 NW 10	1428 7942	17 NW 3 S†	1227 7877
17 NE 12	1560 7858	17 NE 1 S	1763 7527
17 NE 13	1559 7858	17 SW 1 S†	1134 7283
17 NE 14†	1905 7708	17 SW 2 S†	1327 7348
17 SW 16†	1324 7038	17 SW 3 S†	1494 7316
17 SW 17	1440 7037	17 SE 1 S	1752 7202
17 SW 18	1206 7053	17 SE 2 S	1773 7178
17 SW 55†	1399 7138	18 SW 1 S†	1208 8235
17 SW 56†	1158 7203	18 SW 2 S†	1166 8217
17 SE 12†	1969 7253	18 SW 3 S†	1132 8142
17 SE 13†	1545 7192	18 SE 1 S†	1713 8055
17 SE 14†	1705 7050	18 SE 2 S†	1575 8215
18 SW 47†	1316 8079	18 SE 3 S†	1489 8230
18 SW 48†	1086 8038	18 SE 4 S†	1511 8267
18 SE 62†	1563 8081	27 NW 1 S†	2190 7588
27 NW 15	2096 7603	27 SW 1 S	2210 7413

Logs of additional collected sections (See Figure 16) may be consulted on application to Head, Industrial Minerals Assessment Unit, Institute of Geological Sciences, Keyworth, Nottingham NG12 5GG.

* Of the top of the section.
† Chemical analyses are reported in Appendix D.



○ Boreholes used in assessment
•⌐ Collected sections(bracket indicates extent)
x Additional collected sections

Additional Collected Sections

GRID REFERENCE (TOP OF SECTION)		FORMATIONS SAMPLED
17 NW 4S	1125 7696	CHEE TOR
5S	1478 7636	MONSAL DALE(P+D)
6S	1481 7815	MONSAL DALE(P)
7S	1434 7862	MONSAL DALE(P)
8S	1162 7886	WOO DALE(PFL)
9S	1022 7992	CHEE TOR
17 NE 2S	1774 7538	MONSAL DALE(P)
3S	1914 7581	EYAM
17 SW 4S	1440 7297	MONSAL DALE(P)
5S	1445 7302	MONSAL DALE(P)
6S	1393 7365	MILLER'S DALE
7S	1115 7244	CHEE TOR & WOO DALE
8S	1315 7252	MILLER'S DALE
17 SE 3S	1834 7177	MONSAL DALE(D)
4S	1846 7159	MONSAL DALE(D)
5S	1757 7121	MONSAL DALE(D)
6S	1708 7021	MONSAL DALE(P)
7S	1523 7121	MONSAL DALE(P)
8S	1678 7271	BEE LOW
9S	1571 7298	MONSAL DALE(D)
10S	1975 7235	EYAM
18 SW 4S	1078 8025	WOO DALE(PFL)
5S	1261 8300	BEE LOW
6S	1040 8020	WOO DALE(PFL)
18 SE 5S	1578 8177	MONSAL DALE(P)
6S	1585 8189	MONSAL DALE(P)
7S	1588 8190	MONSAL DALE(P)
8S	1570 8175	MONSAL DALE(P+D)
27 NW 2S	2141 7584	MONSAL DALE(P)
27 SW 2S	2358 7466	EYAM
3S	2222 7440	MONSAL DALE(P)
4S	2246 7429	EYAM (REEF) & MONSAL DALE(P)

P:PALE FACIES
D:DARK FACIES
PFL:PEAK FOREST LIMESTONES

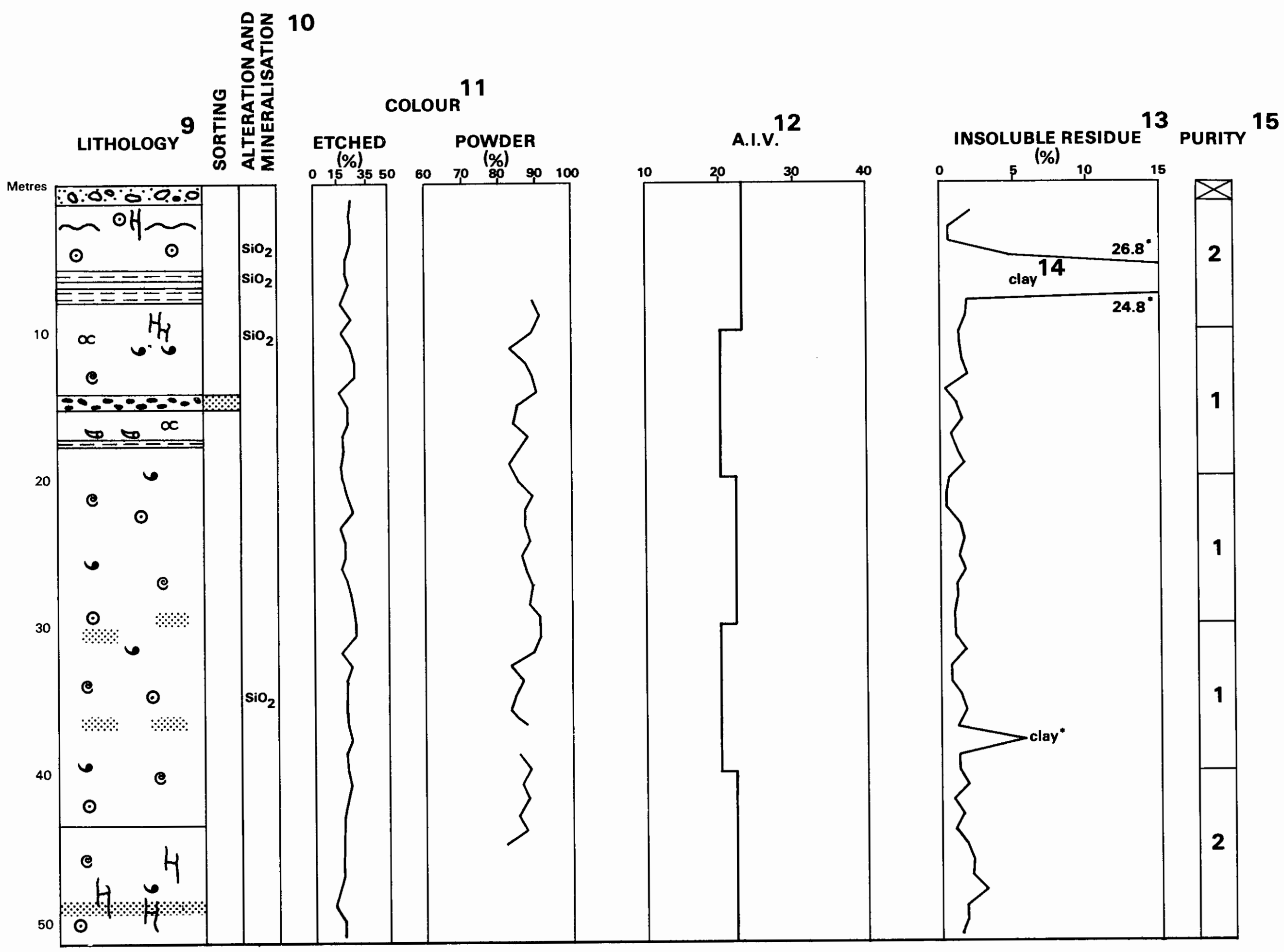
Figure 16 Distribution of sample points.

SK 17 NW 7[1] **1120 7620**[2] **Peacock Meadow, near Wheston**[3]
Surface level +338.6 m[4]
Reich (airflush) 74 mm diameter[5]
January 1971

	Thickness m	Depth[8] m
Topsoil, broken limestone and clayey soil	1.20	1.20
Chee Tor Rock		
[6]Limestone (biosparite)[7] fine crinoid calcarenite; many stylolites 2.7-2.75 m, clay-lined fractures 3.8-3.9 m, scattered euhedral quartz crystals at 4.5 m	4.58	5.78
Clay, reddish brown with limestone pebbles; fissure filling	0.64	6.42
Limestone (biosparite), fine calcarenite with scattered large brachiopods	0.40	6.82
Clay, yellow-buff; fissure-filling	1.18	8.00
Limestone (biosparite), moderately sorted medium and fine calcarenites, encrusting algae at 10.95 m and below 15.2 m, shelly band at 11.6 m, well-sorted pelsparite 14.2-15.2 m, more algal fragments towards base, coral band at 17.1 m. Much broken limestone with clay-filled fissures in upper part, scattered euhedral quartz crystalls, locally stylolitic	9.18	17.18
Clay, brownish yellow with limestone pebbles; fissure filling	0.59	17.77
Limestone (biosparite), moderately sorted medium calcarenites, dominantly fine spar cement with subordinate micrite, many foraminifera, scattered large crinoids and brachiopods, some mottling between 29 and 37 m due to variations in spar-micrite ratio; several stylolites, abundant euhedral quartz crystals at 34.5 and 35.5 m. Clay-lined fissure at 38.3 m. Much broken limestone with clay-lined fractures below 44 m	33.79	51.56

The annotations are explained in Appendix B

SK 17 NW 7



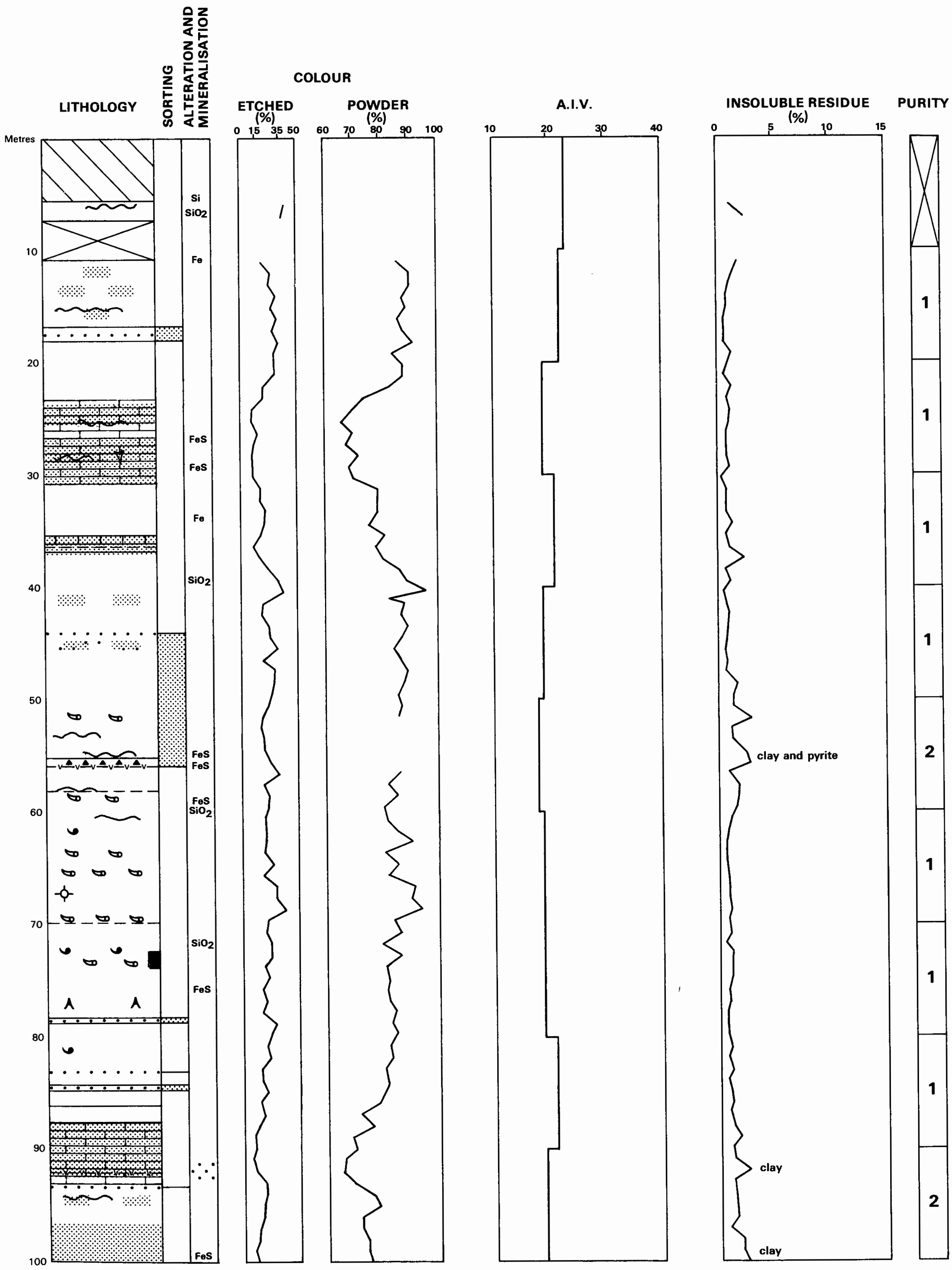
* Fissure filling clay excluded from purity calculations

SK 17 NW 9 **1366 7526** **Monksdale House**

Edeco Stratadrill (waterflush) 47 mm diameter
Spring 1978.

	Thickness m	Depth m
Made ground	5.55	5.55
Chee Tor Rock		
Limestone (biosparite), pale grey, moderately sorted calcarenite, trace silicifications; rare euhedral quartz crystals, several silicified stylolites	1.85	7.40
Gap A few limestone and igneous rock fragments recovered	3.20	10.60
Limestone (biosparite), moderately sorted medium calcarenites, generally fine spar cement with some micrite, well sorted laminated pelsparite 16.8-18.0 m; many stylolites, no silicification	12.59	23.19
Biomicrosparite, dark grey, poorly sorted medium and fine calcarenites, fine spar cement some micrite; many stylolites, trace of pyrite	7.50	30.69
Biosparite, poorly sorted medium calcarenite; trace of limonite	5.57	36.26
Clay, yellowish brown, poor recovery, probably fissure filling	0.54	36.75
Limestone (biosparite), mid to pale grey, moderately and well sorted medium calcarenites, dominantly clear spar cement, more micritic towards base, well sorted cross-laminated pelsparite 44.1-44.2 m: few stylolites, rare euhedral quartz crystals. Green volcanic 'bomb' showing chilled margin in thin grey clay at base	18.94	55.74
Biosparite, moderately sorted medium calcarenites with several thin well sorted pelsaparites, scattered colonial corals; several stylolites, rare euhedral quartz crystals, traces of pyrite at 56 m and 76 m	30.31	86.05
Woo Dale Limestones		
Limestone (biosparite), dark grey, poorly sorted fine and medium calcarenites; fine spar cement with some micrite; irregularly laminated micrite 92.63-92.66 m, well sorted pelsparite 92.66-92.73 m; several stylolites, rare quartz crystals, scattered dolomite rhombs 91.1-92.2 m,some disseminated clay and limonite 92.1-92.4 m above brownish yellow clay 'wayboard' at 92.4 m, trace pyrite near base	13.95	100.00

SK 17 NW 9

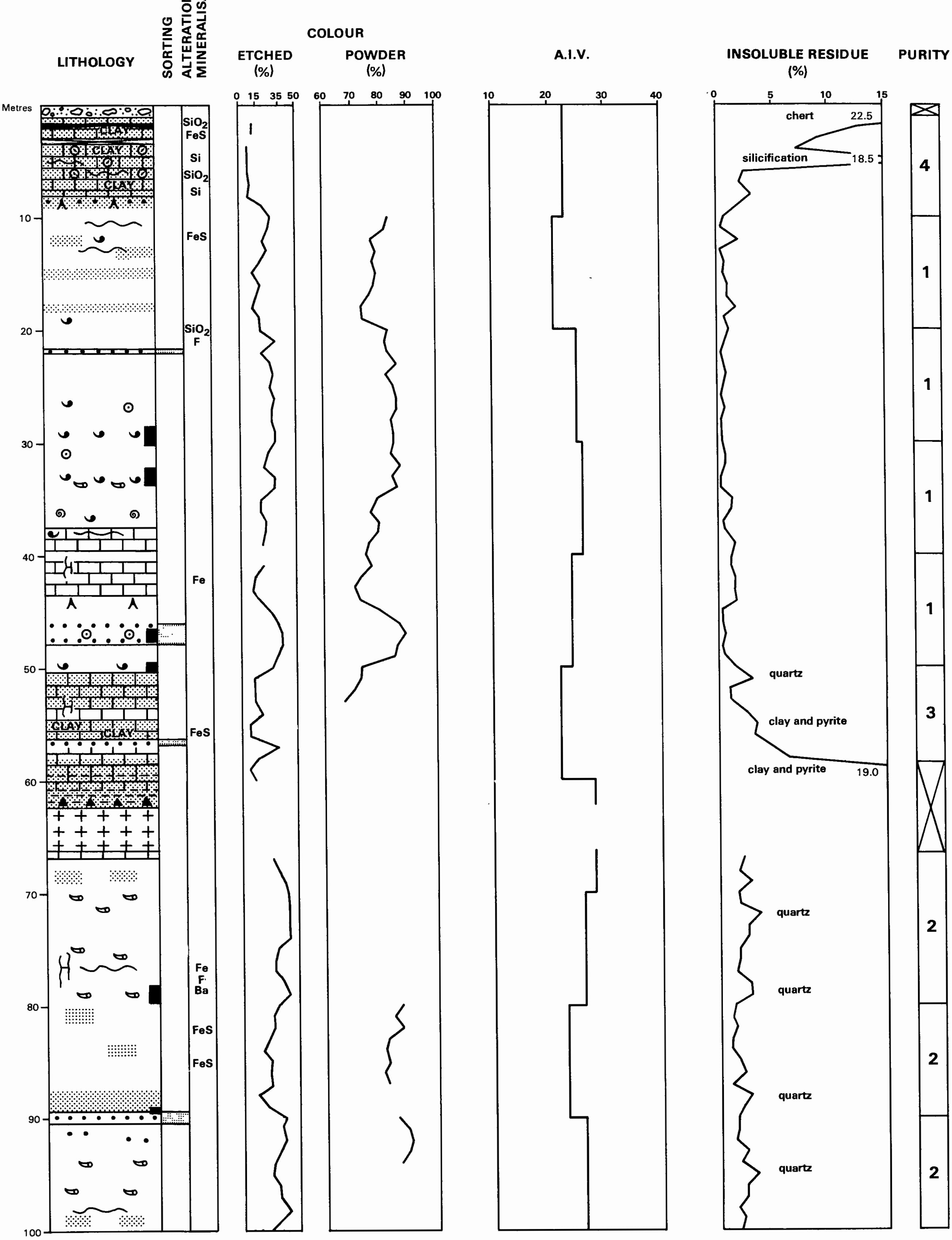


LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR
ETCHED (%)
POWDER (%)
A.I.V.
INSOLUBLE RESIDUE (%)
PURITY
Metres
0 15 35 50
60 70 80 90 100
10 20 30 40
0 5 10 15
10
20
30
40
50
60
70
80
90
100
Si
SiO2
Fe
FeS
FeS
Fe
SiO2
FeS
FeS
FeS
SiO2
SiO2
FeS
FeS
clay and pyrite
clay
clay
1
1
1
1
2
1
1
1
2

SK 17 NW 10 1428 7942 The Holmes
Edeco Stratadrill (waterflush) 47 mm diameter
October 1978

	Thickness m	Depth m
Topsoil	1.00	1.00
Monsal Dale Limestones (dark facies)		
Limestone (biomicrosparite), dark grey, poorly sorted medium and coarse crinoid calcarenites, mixed fine spar and micrite, many algal fragments 8.0-8.2 m; much disseminated clay, many clayey stylolites, chert 1.84-1.86 m, few silicified allochems, traces euhedral quartz crystals, haematite, limonite and pyrite	8.00	9.00
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), mid to pale grey, moderately sorted medium and coarse calcarenites; locally micritic, well sorted pelsparites 21.85-22.0 m, 46.15-46.30 m and 46.95-47.57 m; coarse brachiopod beds 28.65-29.06 m, 32.41-33.00 m and 33.70-33.78 m; trace silicification, stylolites common in top 3 m	41.46	50.46
Monsal Dale Limestone (dark facies)		
Limestone (biomicrosparite), dark grey, poorly sorted medium calcarenites, dominantly very fine microspar cement; well sorted pelsparite 56.3-56.5 m; much dark grey clay in matrix below 54.3 m; some silicified allochems, trace euhedral quartz crystals, more pyrite towards the base	8.17	58.63
Argillaceous Limestone, dark grey fine-grained with scattered partly pyritised crinoid and brachiopod fragments		
Limestone/Mudstone, interbedded, tuffaceous and pyritic; breccia/conglomerate below 62 m with basalt and limestone fragments. Poor recovery	3.77	62.40
Upper Miller's Dale Lava		
Basalt, dark green, amygdaloidal	3.60	66.00
Clay, green, pyritic	0.29	66.29
Miller's Dale Limestone		
Limestone (biomicrite), poorly sorted medium calcarenite; some spar cement; trace limonite, few stylolites	0.44	66.73
Biosparite, moderately sorted, medium and coarse calcarenite, dominantly fine spar cement with patches of micrite, colonial corals 70.08-70.86 m, 71.03-71.44 m *Cheatetes depressus*, 75.66-76.30 m *Lithostrotion junceum*, 96.35-96.46 m *Lithostrotion martini*, rudaceous shell beds 78.18-79.69 m and 89.27-89.42 m, well sorted pelsparite 89.42-90.50 m; trace silicification above 89 m, rare stylolites, trace limonite, haematite and pyrite; fluorite and barytes in calcite vein at 78.20 m	33.32	100.05

SK 17 NW 10



[1]Grade 4 if insoluble residue for 59m of 19 per cent is included

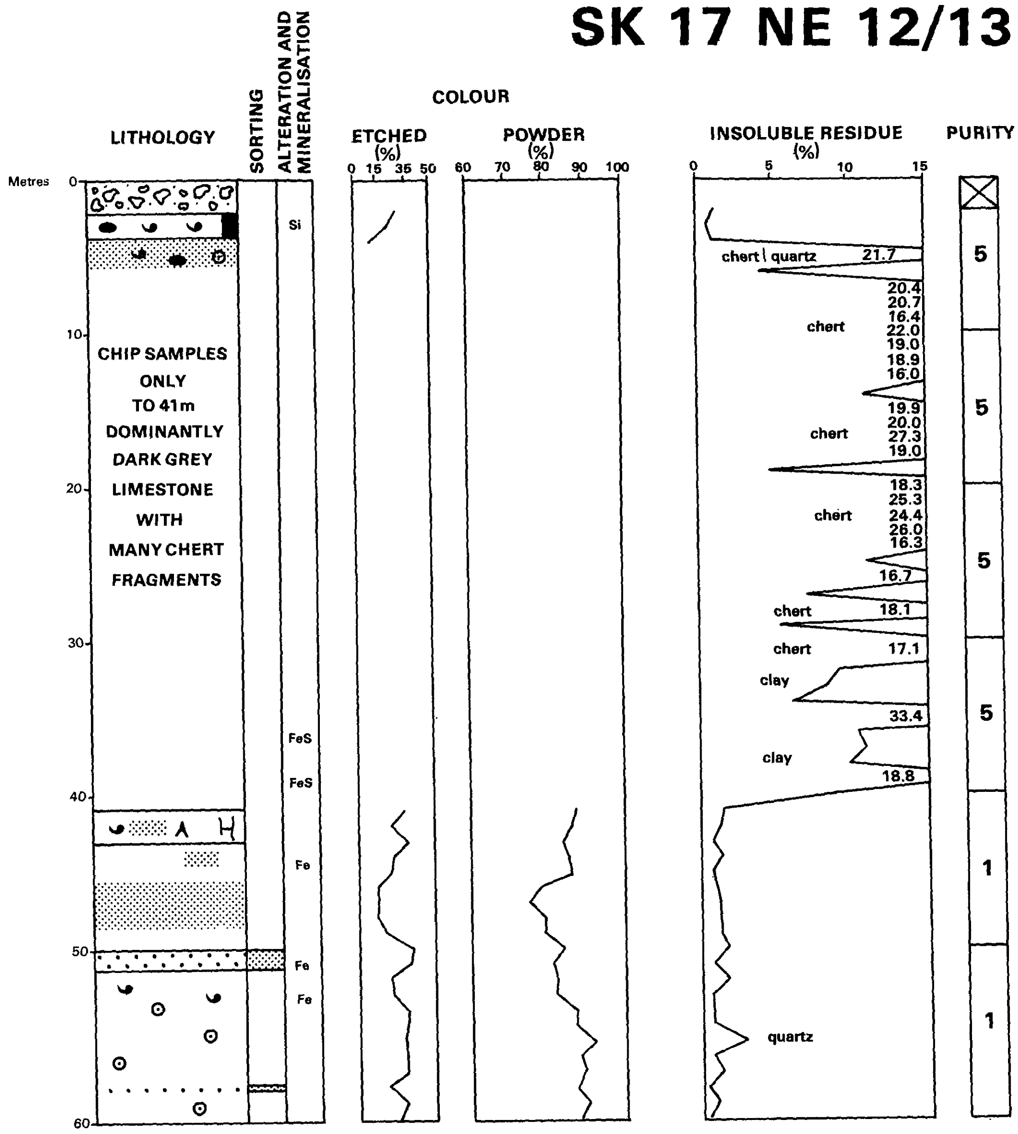
SK 17 NE 12/13† 1560 7858/1559 7858 Little Hucklow

Surface level +348.4 m/+348.1 m
Reich (airflush) 76 mm diameter
January 1971

	Thickness m	Depth m
Topsoil, clayey soil with limestone pebbles	2.10	2.10
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), poorly sorted calcarenite with many large brachiopods, some micrite, thin chert at 2.8 m	1.71	3.81
Monsal Dale Limestones (dark facies)		
Limestone (biomicrosparite), dark grey, poorly sorted coarse crinoid calcarenite, mixed spar and micrite matrix, lowest 0.2 m laminated; chert at 4.13 m and from 4.30 to 4.36 m	0.57	4.38
Limestone (chippings), dark grey, fine calcarenites and calcilutites, much chert, some disseminated clay	36.63	41.01
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), poorly sorted medium and coarse calcarenites, scattered large brachiopods with micrite rims; some fissure-filling clay below 42 m	1.99	43.00
Biosparite, mid to dark grey, poorly sorted medium and coarse clacarenites; dominantly spar cement with some micrite, well sorted pelsparites 50.02–51.30 m and 58.98–59.07 m; trace silicification, few styolites, fluorite at 55.9 m	18.20	61.20

†Composite log

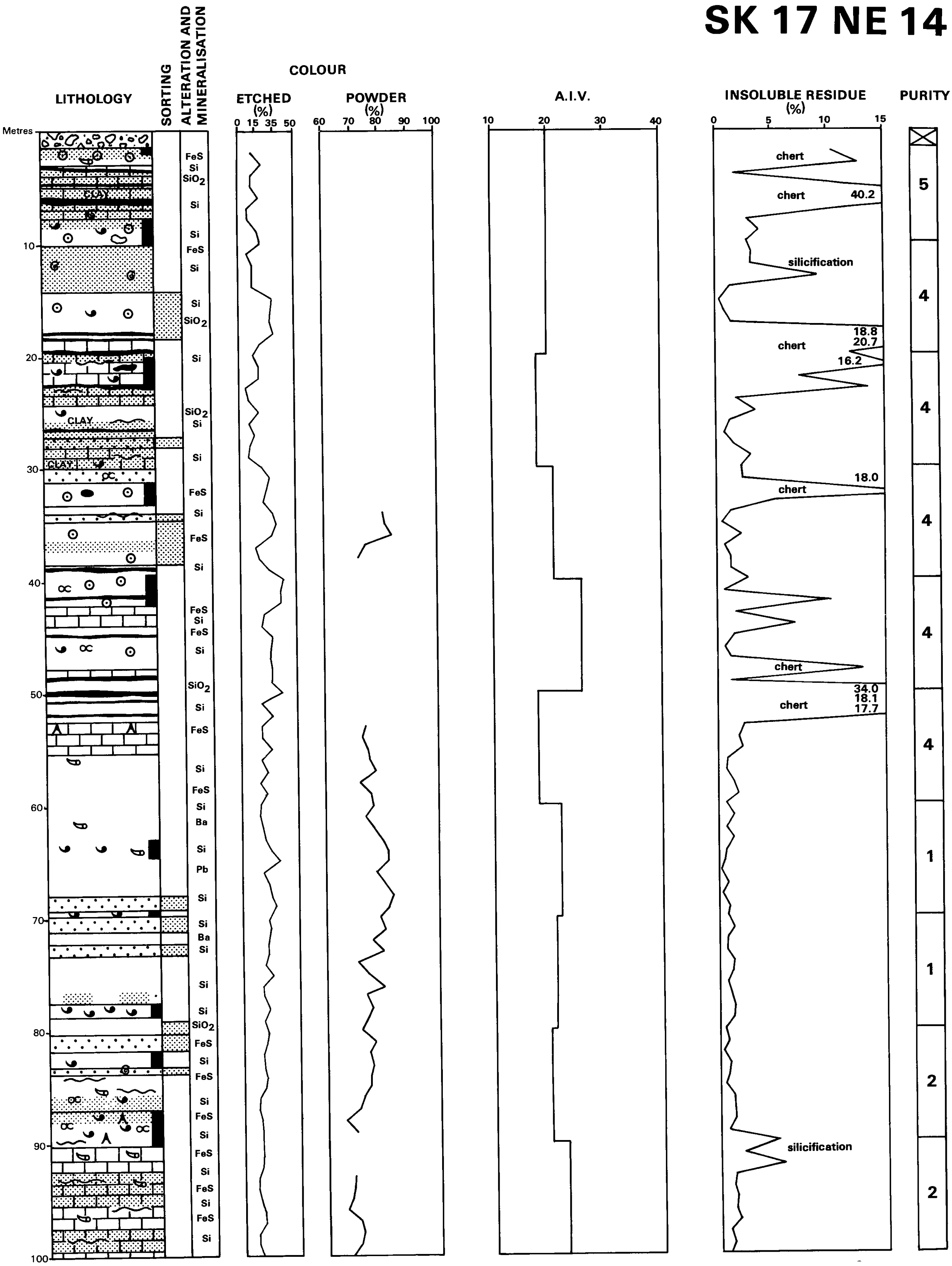
SK 17 NE 12/13


LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR
ETCHED (%)
POWDER (%)
INSOLUBLE RESIDUE (%)
PURITY
Metres
CHIP SAMPLES ONLY TO 41m DOMINANTLY DARK GREY LIMESTONE WITH MANY CHERT FRAGMENTS
Si
FeS
FeS
Fe
Fe
Fe
chert | quartz
21.7
chert
20.4
20.7
16.4
22.0
19.0
18.9
16.0
19.9
20.0
27.3
19.0
18.3
25.3
24.4
26.0
16.3
16.7
chert
18.1
chert
17.1
clay
33.4
clay
18.8
quartz
5
5
5
5
1
1

SK 17 NE 14 1905 7708 Foolow
Edeco Stratadrill (waterflush) 47 mm diameter
Spring 1978

	Thickness m	Depth m
Topsoil	1.50	1.50
Eyam Limestones		
Limestone (biosparite), grey to dark grey, moderately sorted calcarenites with some calcirudite bands; dominantly fine spar cement with some micrite; some allochems silicified; chert beds 3.2-3.4 m, 4.5-4.7 m and 5.9-6.5 m; black clayey stylolites below 4.4 m, some disseminated clay 6.5-7.9 m; trace pyrite	12.85	14.35
Biosparite, well sorted coarse crinoid calcarenite; chert nodules at 18 m and 18.5 m, scattered euhedral quartz crystals and silicified allochems	4.15	18.50
Biomicrosparite, grey and dark grey, moderately sorted medium and fine calcarenites; mixed fine spar and micrite cement, scattered large brachiopods throughout, locally laminated and bioturbated; some allochems silicified, scattered quartz crystal, several cherts above 24.4 m and at 26.55 m, bituminous shell-infilling at 26 m	11.50	30.00
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), moderately sorted crinoid calcarenites with calcirudite bands 31.2-32.2 m and 39.4-42.3 m; generally fine spar cement with micrite 42.3-42.9 m; well sorted pelsparite 34.1-34.7 m; irregular spar-filled tubes 31.8-32.0 m and 47.9-48.3 m; corals at 41.65 m *Lithostrotion portlocki*, 43.3 m *Lithostrotion pauciradiale* and 50.85 m *Lithostrotion junceum;* several chert bands, some allochems silicified, clayey stylolites and patches of pyrite	21.90	51.90
Biosparite, moderately sorted medium and fine calcarenites; dominantly fine spar cement with some micrite; large brachiopods 63.2-64.4 m, rare spar-filled tubes, coral 55.5 m *Palaeosmilia regia*, 62 m *Syringopora;* no chert, some silicified allochems; clay-coated stylolites and patches of pyrite	16.14	68.04
Biosparite, moderately sorted calcarenites and calcirudites interbedded with well sorted pelsparites; mainly fine spar with some micrite; large brachiopods 69.2-69.4 m, 77.5-78.6 m and 87.0-90.3 m, below 87 m brachiopods are encrusted, coral 86.5 m *Lithostrotion martini;* some silicified allochems, rare euhedral quartz crystals (78.6-80.3 m); several stylolites; some pyrite below 87 m	22.60	90.30
Biomicrite, dark grey, moderately sorted coarse calcarenites; mixed micrite and fine spar matrix, locally mottled with patches of clear spar; many bryozoa, corals 90.3-90.7 m, 91.5-91.8 m and 93.8-94.6 m *Lithostrotion junceum;* some silicified allochems; stylolites common and are often associated with pyrite	10.00	100.30

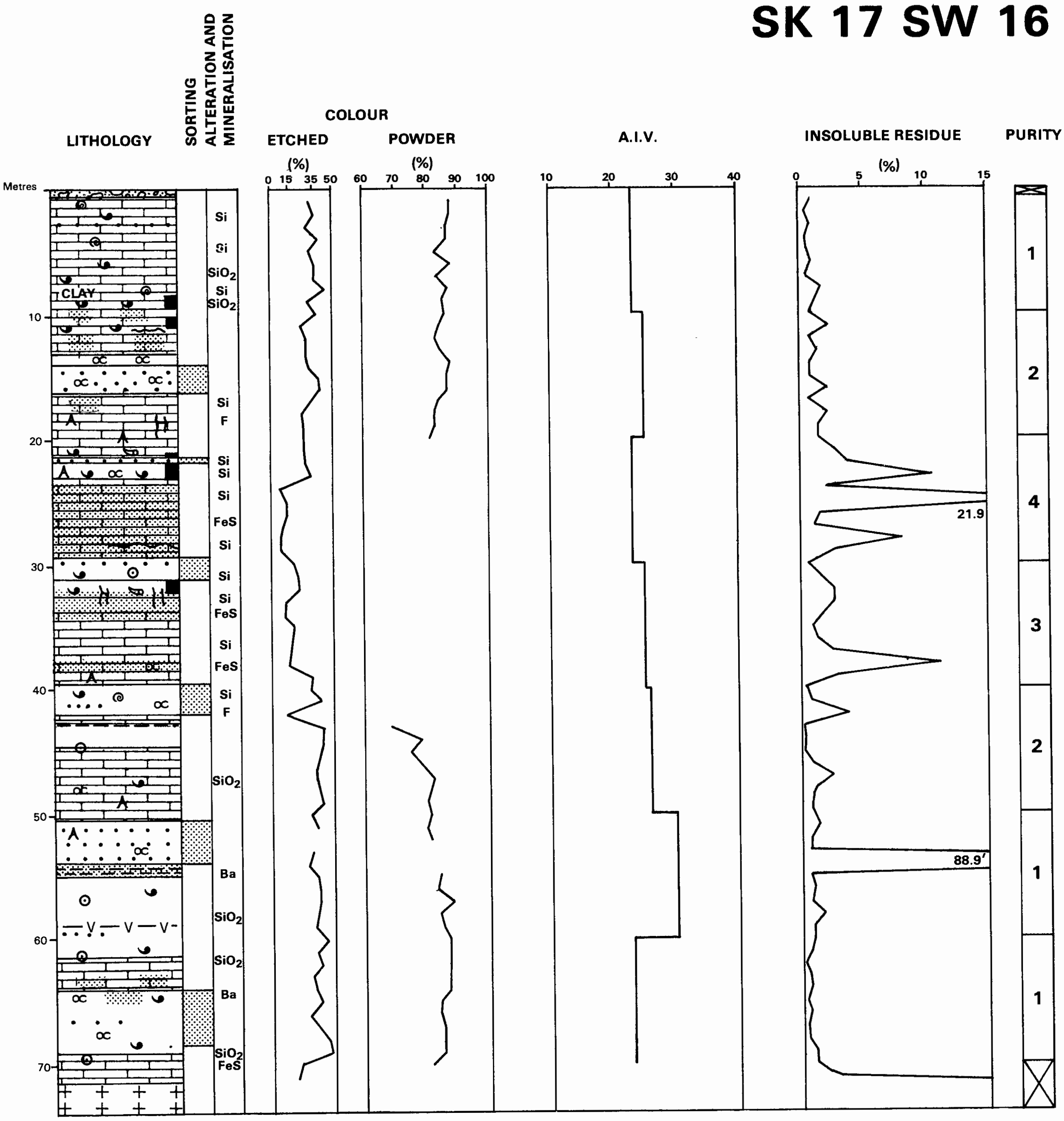
SK 17 NE 14


LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR
ETCHED (%)
POWDER (%)
A.I.V.
INSOLUBLE RESIDUE (%)
PURITY
Metres
CLAY
FeS
Si
SiO2
Ba
Pb
chert
40.2
silicification
18.8
20.7
16.2
18.0
34.0
18.1
17.7
5
4
1
2

SK 17 SW 16 1324 7038 Moor Grange Farm, Taddington
Surface level +406.6 m
Reich (airflush) 76 mm diameter
March 1971

	Thickness m	Depth m
Topsoil		0.50
Monsal Dale Limestones (pale facies)		
Limestone (biomicrosparite), pale grey, moderately and poorly sorted medium and fine calcarenites; rudite sized shell clusters common; spar in mottles from 8.8-10.25 m and 11.45-13.6 m; encrusting algal rims common from 13.6-14.0 m; some silicified allochems, trace euhedral quartz, abundant stylolites at 11.3 m with associated brown iron-staining	13.50	14.00
Pelsparite, well sorted medium calcarenite with scattered rudite shell fragments; many allochems are algally-corroded; some lamination and grading; some silicification	2.30	16.30
Biomicrosparite, poorly sorted medium and fine calcarenites with well sorted fine pelsparite 21.4-21.8 m; brachiopod calcirudite 21.8-23.05 m; scattered silicified allochems, trace euhedral quartz crystals	7.56	23.86
Monsal Dale Limestones (dark facies)		
Limestone (biomicrite), dark grey, poorly sorted medium and fine calcarenites; scattered pyrite and hematite flecks throughout; abundant stylolites with clayey concentrations	5.9	29.35
Monsal Dale Limestones (pale facies)		
Limestone (biosparite and pelsparite), well sorted calcarenites, more crinoidal in lower part with scattered shell clusters; some silicification	1.75	31.10
Biomicrosparite, grey and dark grey, poorly sorted medium calcarenites; mixed micrite and microspar matrix; paler limestones contain more spar and are better sorted; scattered large corals and brachiopods, many foraminifera and peloids; abundant clay-rich stylolites, disseminated pyrite above 38.5 m; scattered silicification; thin brown clay seams (joint infill) 31.33-31.40 m and 42.60-42.61 m	11.54	42.64
Biomicrite, pale grey, moderately and poorly sorted medium and fine crinoid calcarenites; bioturbated and mottled 42.6-43.0 m and 48.65-50.0 m; some brachiopods with algal encrustations	7.76	50.40
Pelsparite, pale grey, well sorted medium calcarenite; many algal fragments	3.40	53.80
Clay, yellowish brown, with limestone and barytes rubble	1.00	54.80
Limestone (biomicrosparite), pale grey, moderately sorted medium and coarse brachiopod crinoid calcarenites; mixed micrite and spar matrix; abundant quartz above 61.05 m; light olive-grey clay 'wayboard' 58.57-58.60 m	9.10	63.90
Biosparite, pale grey, well sorted medium and fine calcarenites; less well sorted and more micritic below 68.3 m; many peloids, *Girvanella* and *Koninckopora* fragments; scattered large shell and crinoidal debris; mottled near base; pyritic below 70 m	7.40	71.30
Upper Miller's Dale Lava		
Basalt, dark grey, with red and green mottling, amygdaloidal, some calcite veining, pyritic, upper part altered	2.64	73.94

SK 17 SW 16



'Fissure filling clay excluded from purity calculations

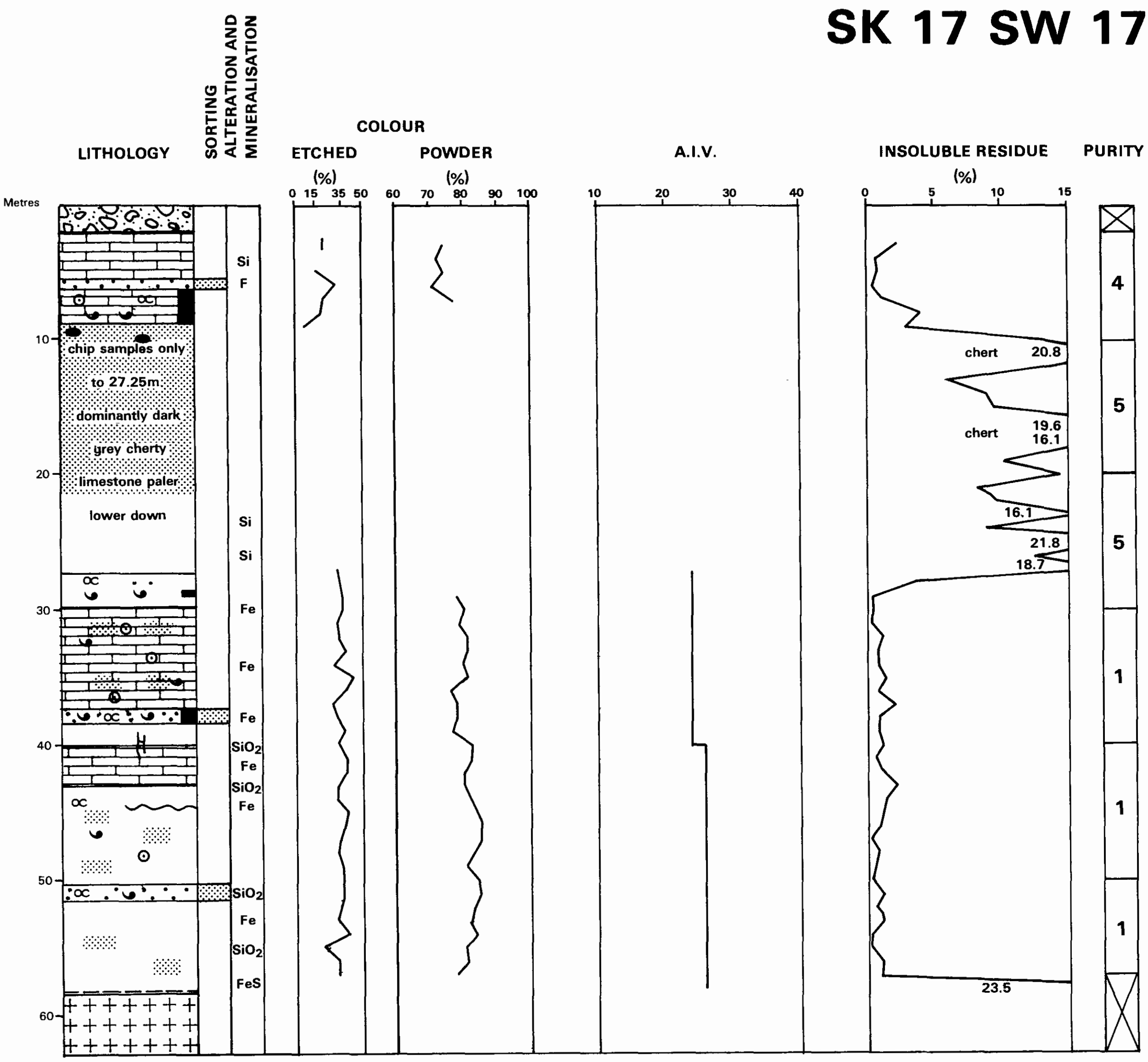
SK 17 SW 17 1440 7037 High Mere, Taddington
Surface level +380.7 m
Reich J082 (airflush) 76 mm diameter
March 1971

	Thickness m	Depth m
Topsoil	c 2.00	c 2.00
Monsal Dale Limestones (pale facies)		
Limestone (biomicrosparite), poorly sorted calcarenites; some allochems silicified; very poor recovery	c 3.50	c 5.50
Pelsparite, well sorted fine calcarenites	0.75	6.25
Biomicrosparite, moderately sorted crinoid calcirudites; mixed micrite and spar matrix; graded-bedding 6.25-7.90 m	2.47	8.72
Monsal Dale Limestones (dark facies)		
Limestone (chippings), dark grey with black chert fragments; less chert in lower part	18.53	27.25
Monsal Dale Limestones (pale facies)		
Limestone (biomicrosparite), pale grey, moderately sorted medium and coarse calcarenites; mixed micrite and spar matrix; many stylolites with iron-ore and clay fillings	12.12	37.37
Pelsparite, well sorted fine calcarenite with coarse shell clusters, encrusting algae 37.8-38.0 m	1.08	38.45
Biomicrosparite, poorly sorted calcarenites with mixed micrite and microspar matrix; encrusting algae throughout; locally bioturbated, clay (joint infilling) at 39.5 m	11.90	50.35
Biosparite, moderately and well sorted fine and medium calcarenites; pelsparite at top; some encrusting algae; thin graded units 53.7-54.5 m; abundant pyrite below 58.3 m	7.97	58.32
Mudstone, grey, pyritic	0.20	58.34
Upper Miller's Dale Lava		
Basalt, greenish black, amygdaloidal in upper part, pyritic	4.51	62.85

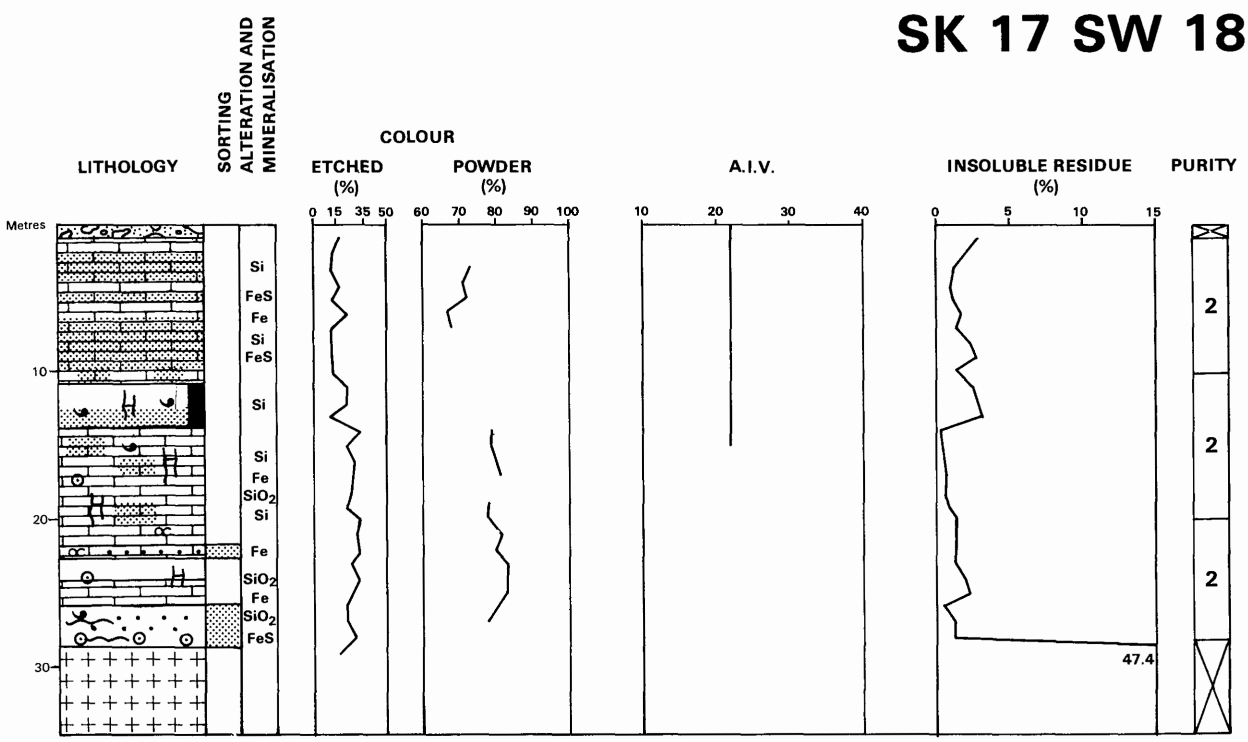
SK 17 SW 18 1206 7053 Pillwell Lane
Surface level +418.8 m
Reich J082 (airflush) 76 mm diameter
March 1971

	Thickness m	Depth m
Topsoil	0.80	0.80
Monsal Dale Limestones (pale facies)		
Limestone (biomicrosparite), moderately and poorly sorted fine calcarenites; dominantly micritic with patches of clear spar; some allochems silicified, pyrite and iron-staining throughout; poor recovery	10.00	10.80
Biosparite, poorly sorted fine calcirudites; some micrite and microspar, many large brachiopods, encrusting algae at 12 m, *Coelosporella* 11.5-13.79 m; many of the coarser allochems silicified; much jointing	2.99	13.79
Biomicrosparite, poorly sorted medium calcarenites; patches of spar; dominantly brachiopod and crinoid debris; encrusting algae common near base; some clay in joints throughout	7.17	21.96
Pelsparite, very well sorted medium calcarenites; coarse shell clusters with encrusting algae	0.72	22.68
Biomicrosparite, poorly sorted coarse crinoid calcarenites and fine calcirudites; more micritic towards base; abundant euhedral quartz crystals at 25 m; some jointing and rubbly core	3.12	25.85
Pelsparite and biosparite, well sorted medium and fine calcarenites becoming more crinoidal towards base; some coarse shell clusters; much pyrite below 27 m; many stylolites and thin calcite veins	1.59	28.86
Upper Miller's Dale Lava		
Basalt, dark greenish grey, pyritic, calcite-veined, amygdaloidal	5.75	34.61

SK 17 SW 17



SK 17 SW 18

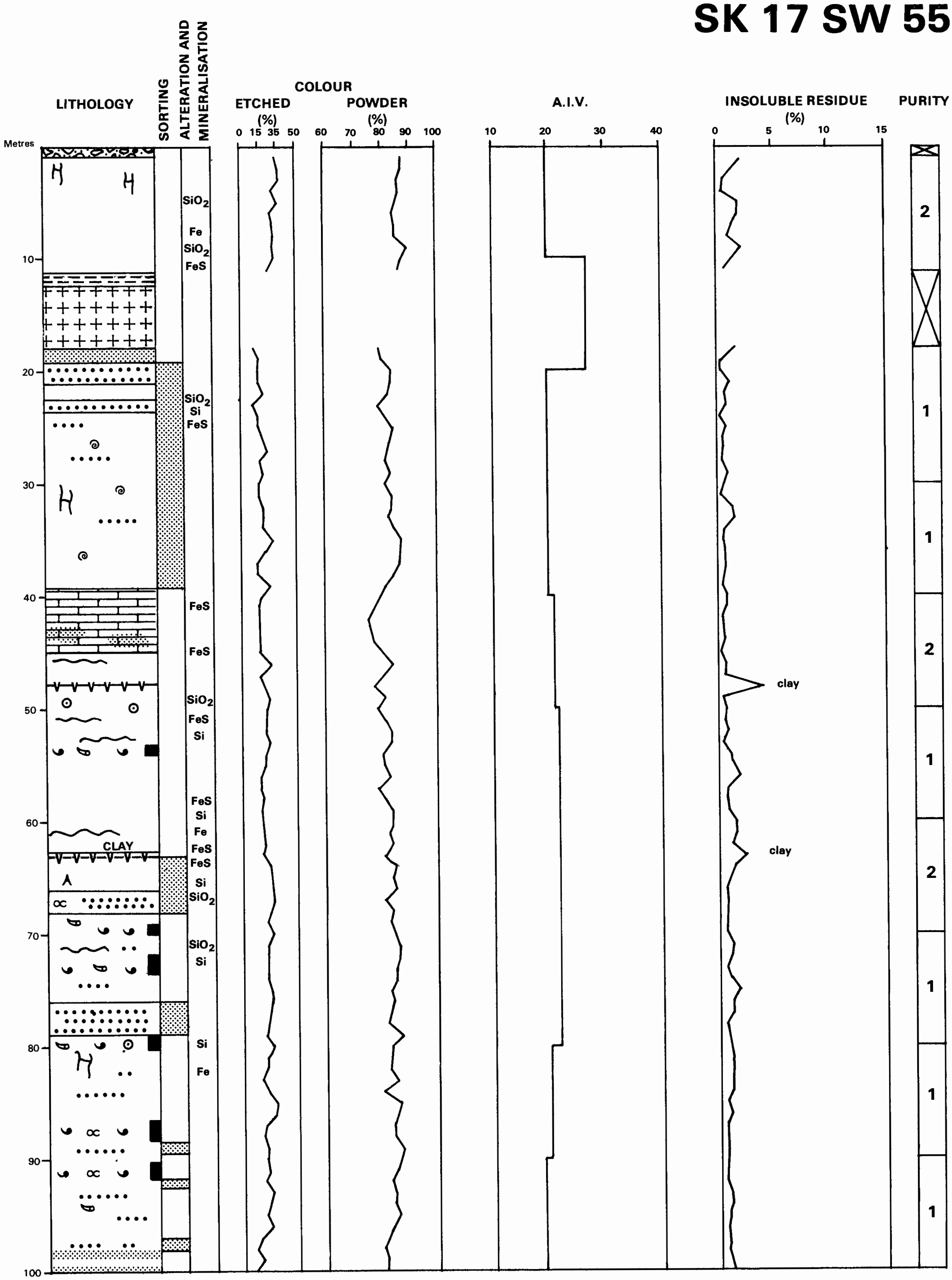


SK 17 SW 55 1399 7138 Taddington

Surface level +342.8 m
Edeco Stratadrill (waterflush) 47 mm diameter
Spring 1978

	Thickness m	Depth m
Topsoil	0.8	0.8
Miller's Dale Limestones		
Limestone (biosparite), pale grey, moderately sorted medium calcarenites; some bioturbation; euhedral quaryz crystals common; mineralised fissures 1.93-2.42 and 3.10-3.65 m; large pyrite mass 10.9 m	10.50	11.30
Clay, brown	1.10	12.40
Lower Miller's Dale Lava		
Basalt, green, abundant calcite and chlorite filled amygdales above 14.65 m, altered to clay below 17.7 m	5.57	18.03
Chee Tor Rock		
Limestone (biosparite), well sorted medium and fine calcarenites, locally bioturbated, pelsparites 19.15-20.73 m and 22.5-23.56 m; euhedral quartz crystals common; fine silicification 22.98-23.47 m; trace of pyrite	21.27	39.30
Biomicrite, moderately sorted fine calcarenite; mottled with patches of spar; locally abundant spar-filled tubes; some allochems pyritised	5.61	44.9?
Biosparite, moderately and well sorted fine calcarenite, many peloid grains; abundant spar-filled tubes 47.85-48.48 m; rudite brachiopods and coral bands 53.69 m; many clayey stylolites with some pyrite and silicification; thin greenish grey clay 'wayboard' 47.8 m; pyrite flecks and clay partings common below 62.50 m	17.93	62.84
Clay, 'wayboard', greenish with masses of pyrite	0.16	63.00
Limestone (biosparite), moderately and well sorted medium calcarenites interbedded with coarse brachiopod coral calcirudites at 69.15-69.90 m, 71.87-73.55 m, 78.32-80.12 m, 86.61-88.28 m, and 90.23-91.66 m; spar-filled tubes common above 68.1 m; pyrite flecks 63.0-63.9 m; some silicified allochems 66.18-66.32 m; clayey and partially silicified stylolites 72.0-76.0 m; mineralised fissure 81.26-82.46 m. The basal 3 m are darker grey and may represent the top of the Woo Dale Limestones	37.00	100.00

SK 17 SW 55

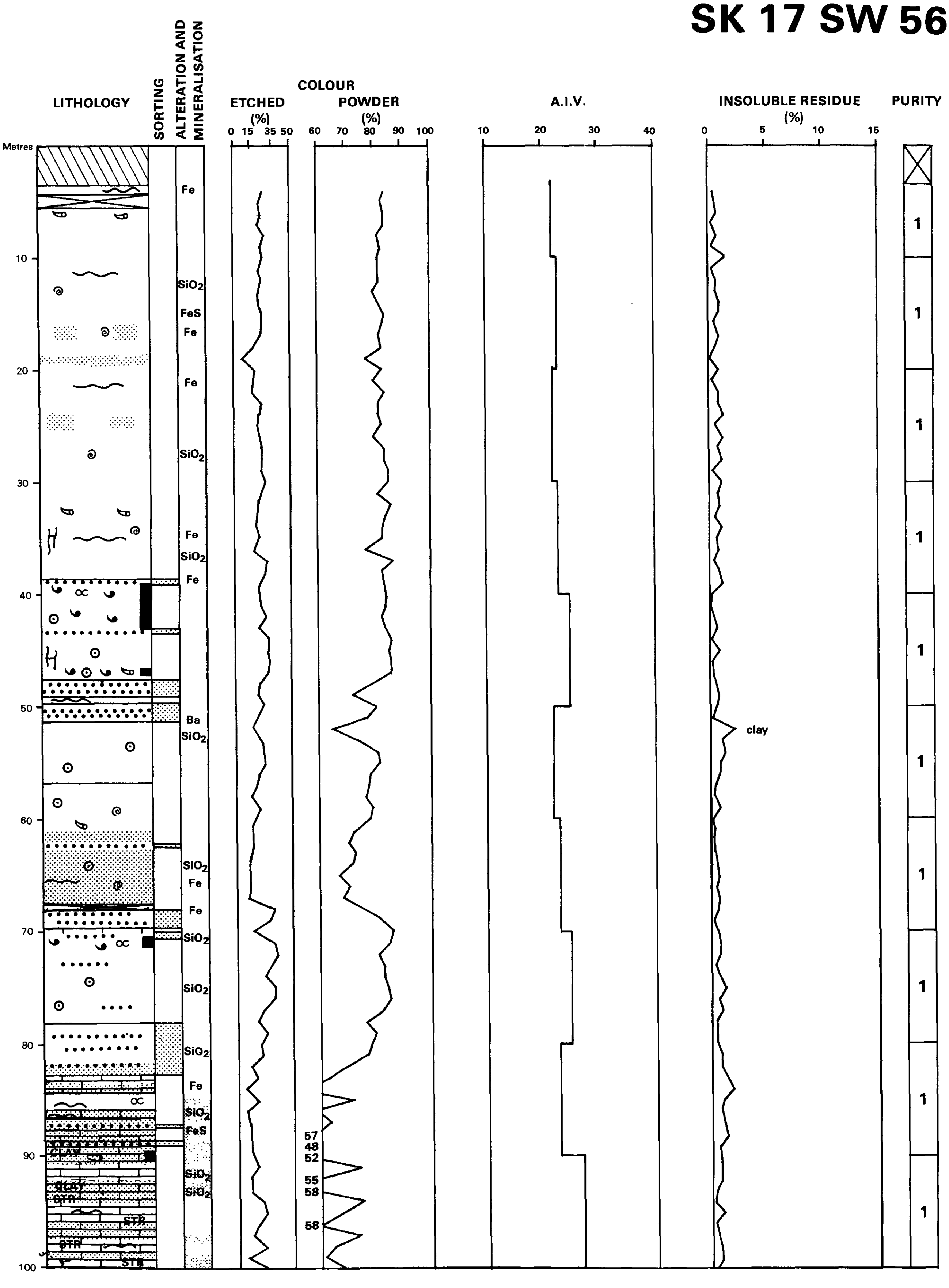

LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR
ETCHED (%)
POWDER (%)
A.I.V.
INSOLUBLE RESIDUE (%)
PURITY
Metres
CLAY
clay
clay

SK 17 SW 56 **1158 7203** **Calton Farm**

Edeco Stratadrill (waterflush) 47 mm diameter
October 1978

	Thickness m	Depth m
Made ground	3.40	3.40
Chee Tor Rock		
Limestone (biosparite), moderately sorted medium calcarenites with scattered large brachiopods and corals	1.00	4.40
Gap Poor recovery	1.06	5.46
Limestone (biosparite), moderately sorted medium and coarse calcarenites; many foraminifera, few colonial corals; trace pyrite 15 m, fractured core 35.22-35.55 m	33.07	38.53
Biosparate, moderately and well sorted medium and coarse calcarenites with rudite brachiopods 38.7-43.04 m (with micrite envelopes) and 46.73-47.10 m: pelsparites 38.5-38.7 m, 43.04-43.35 m, 47.54-48.98 m and 49.55-51.22 m; some mottling 47.1-47.54 m; fractured core with calcite veins 45.68-46.11 m; clayey bituminous stylolities 48.98-49.55 m; many quartz crystals at 49.54 m;	18.17	56.70
Biosparite, grey and dark grey, moderately sorted calcarenites; some microspar, well sorted pelsparite 62.21-62.45 m; scattered quartz crystals, siderite at 66.09 m	10.70	67.40
Gap, poor recovery - some limestone fragments and (?) fissure-filling clay	0.45	67.95
Limestone (biosparite), grey and dark grey moderately and well sorted medium calcarenites; micritic matrix 69.73-69.83 m; many peloid grains throughout; rudite brachiopods with micrite envelopes 70.48 m-71.24 m; several thinly bedded (70-100 mm) units 72.75-73.20 m with large crinoids concentrated at bases; scattered euhedral quartz crystals	10.10	78.05
Woo Dale Limestones		
Limestone (pelsparite), grey and dark grey well sorted medium calcarenites; locally micritic, scattered euhedral quartz crystals	4.68	82.73
Biomicrite, poorly sorted calcarenites; mixed micrite and microspar matrix; partially silicified calcite veins 82.75-83.08 m	1.57	84.30
Biosparite, moderately sorted medium and coarse crinoid calcarenites; scattered quartz crystals; dolomite rhombs in stylolites at 85.8 m	1.51	85.81
Biomicrite, moderately and poorly sorted medium calcarenites with well sorted pelsparites 87.34-88.00 m and 88.94-89.13 m; coral colonies 89.70-89.90 m, many rudite (?) intraclasts of micrite 89.94-90.10 m; clayey stylolites in upper 300 mm; scattered dolomite rhombs throughout; some disseminated clay 89.13-89.94 m and at base; shale parting at 91.72 m	7.71	92.98
Biomicrite, fine calcarenites and calcilutites with scattered coarser allochems; some microspar cement; 'birds eye' structures 92.98-93.45 m; 'stromatactis' structures 93.45-96.50 m, 97.78-97.93 m and 99.95-100.05 m, faint laminations 93.20-93.45 m; some mottling; coral colonies 99.16-99.23 m and 99.58-99.63 m; scattered euhedral quartz crystals above 93.45 m; many dolomite rhombs 97.09-97.11 m, 97.30-97.51 m and 98.75-99.53 m	7.07	100.05

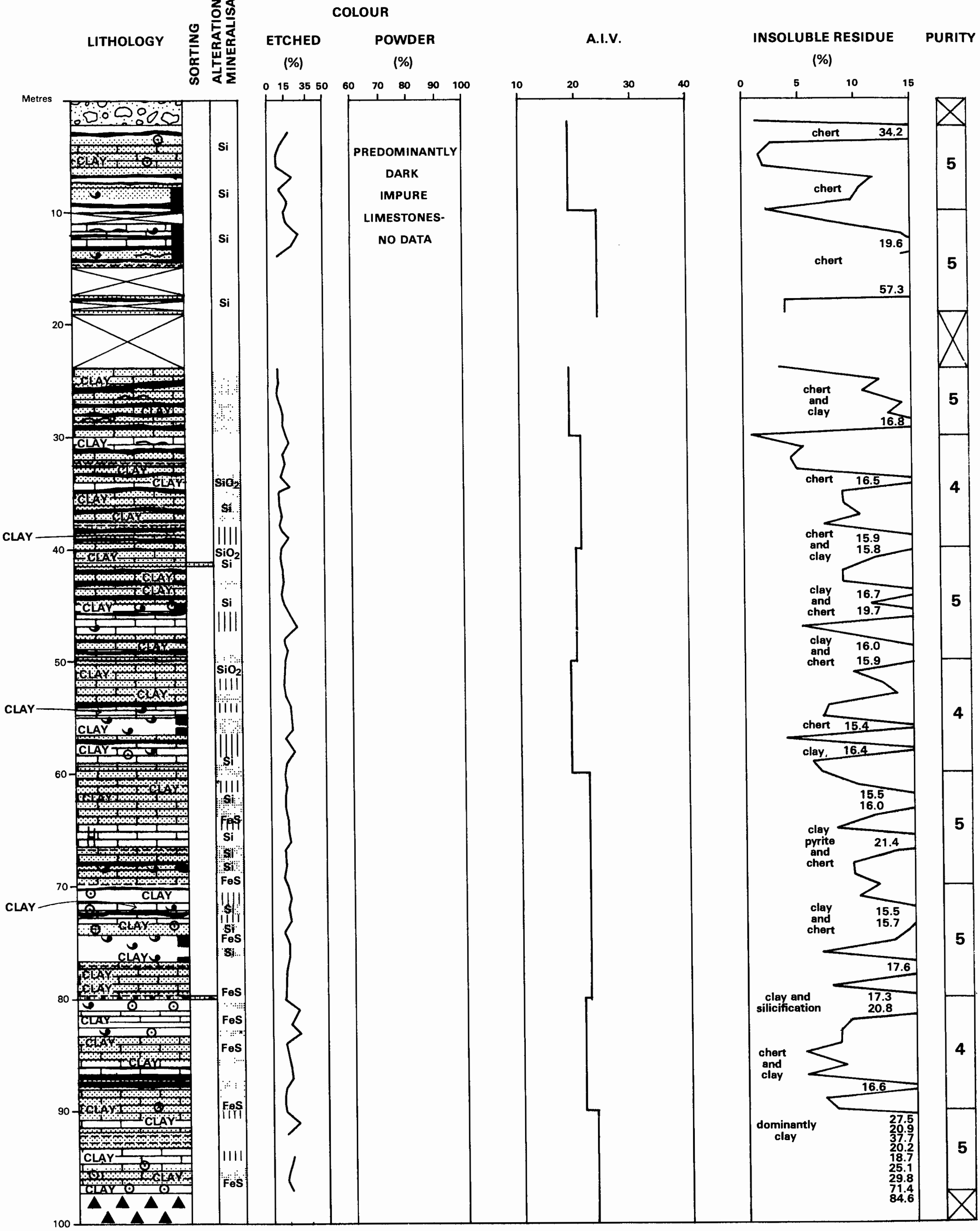
SK 17 SW 56


LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
ETCHED (%)
COLOUR
POWDER (%)
A.I.V.
INSOLUBLE RESIDUE (%)
PURITY
Metres
10
20
30
40
50
60
70
80
90
100
0 15 35 50
60 70 80 90 100
10 20 30 40
0 5 10 15
Fe
SiO2
FeS
Ba
57
48
52
55
58
58
clay
CLAY
STR
1

SK 17 SE 12 1969 7253 Great Longstone
Edeco Stratadrill (waterflush) 47 mm diameter
April 1978

	Thickness m	Depth m
Topsoil	2.30	2.30
Monsal Dale Limestones (dark facies)		
Limestone (biomicrosparite), moderately and poorly sorted medium and coarse calcarenites; mixed spar and micrite matrix, chert beds 2.98-3.10 m, 6.67-6.72 m and 7.37-7.46 m; some fine silicification, disseminated clay and bituminous debris 5.46-6.67 m; no core recovery 2.80-2.98 m, 3.10-3.55 m and 4.92-5.18 m	5.55	7.85
Biosparite, poorly sorted calcarenite with many large brachiopods; fine spar with some micrite, many thin cherts, some fine silicification; no core recovery 10.07-11.19 m	6.50	14.35
Clay, (?) fissure filling	0.20	14.55
Gap, a few limestone fragments recovered	2.90	17.45
Limestone (biosparite), poorly sorted coarse crinoid calcarenite; locally micritic; no core recovery 17.72-18.72 m apart from some brown clay fragments	1.56	19.01
Gap, a few limestone fragments recovered	4.93	23.94
Limestone (biomicrosparite), fine calcarenites and calciluties, mixed fine spar and micrite matrix, bioturbated and mottled; about 10 % chert; many clayey partings and much disseminated clay above 29.35 m; dolomite rhombs locally abundant	8.11	32.05
Clay, poor recovery, some limestone and chert fragments	0.50	32.55
Limestone and argillaceous limestone dark grey calcilutites, mixed micrite and spar matrix; some bioturbation; much disseminated clay throughout; many thin cherts (10 % of total rock); some fine silicification and euhedral quartz crystals; locally abundant dolomite rhombs	4.96	37.51
Mudstone, dark grey, calcareous, poor recovery	0.14	37.65
Limestone and argillaceous limestone, dark grey calcilutites and fine calcarenites; mixed micrite and fine spar matrix, bioturbated, large crinoids and brachiopods scattered throughout; coarse crinoid calcarenite 41.25-41.31 m and brachiopod calcirudites 54.86-55.50 m and 55.89-56.55 m; much disseminated clay and many thin clay laminae; many thin cherts above 51 m (about 8 % of total rock) becoming less common in lower part of unit; abundant dolomite rhombs; some fine silicification and scattered quartz crystals	21.54	59.19
Limestone (Rosewood Marble), laminated micrite and dolomite; rare scattered crinoid fragments; some micro-faulting	0.41	59.60
Limestone and argillaceous limestone (biomicrite); calcilutites and fine calcarenites with scattered coarse allochems; some fine spar; several thin brachiopod calcirudites, calcareous mudstones 60.32-60.66 m, 76.58-78.69 m and 79.68-79.76 m; much disseminated clay; many dolomite rhombs; some fine silification, thin cherts 68.0-72.5 m and at 86.88 m (10 % of total rock), pyrite scattered througout	32.19	91.79
Mudstone, grey, calcareous, interbedded with very clayey limestone	1.52	93.31
Limestone and argillaceous limestone, dark grey calcilutite with thin crinoid calcarenites; mixed micrite and spar matrix; many dolomite rhombs; much pyrite below 96.6 m	3.95	97.26
(?) Litton Tuff		
Tuffaceous mudstone, green calcareous, with a few shell fragments; some calcite veining near top	2.74	100.00

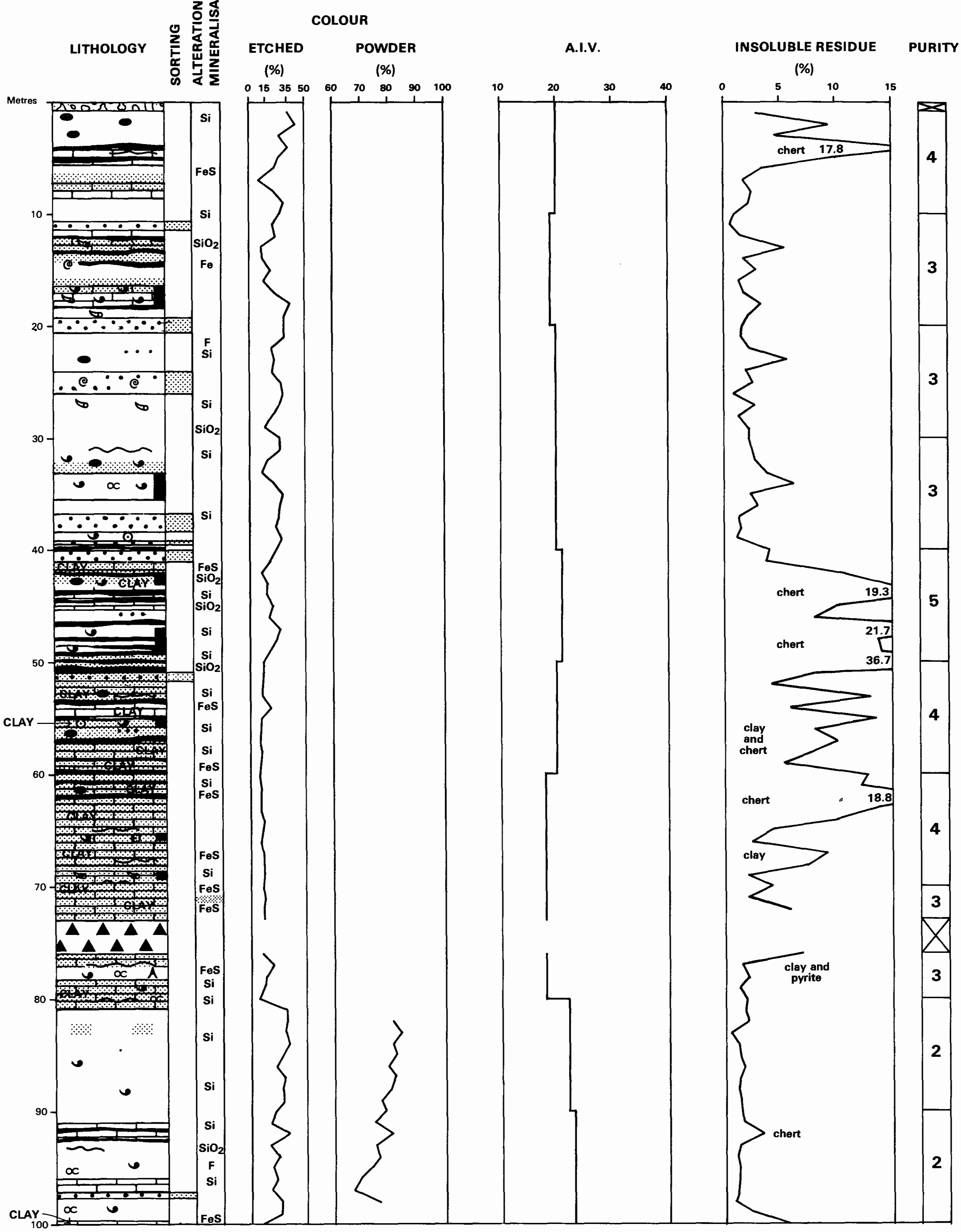
SK 17 SE 12


LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR
ETCHED (%)
POWDER (%)
A.I.V.
INSOLUBLE RESIDUE (%)
PURITY
Metres
PREDOMINANTLY DARK IMPURE LIMESTONES- NO DATA
CLAY
Si
SiO2
FeS
chert
chert and clay
clay and chert
clay pyrite and chert
clay and silicification
dominantly clay
34.2
19.6
57.3
16.8
16.5
15.9
15.8
16.7
19.7
16.0
15.9
15.4
16.4
15.5
16.0
21.4
15.5
15.7
17.6
17.3
20.8
16.6
27.5
20.9
37.7
20.2
18.7
25.1
29.8
71.4
84.6
5
5
5
4
5
4
5
5
4
5

SK 17 SE 13 **1545 7192** **Brushfield**
Edeco Stratadrill (waterflush) 47 mm diameter
September 1978

	Thickness m	Depth m
Topsoil	0.65	0.65
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), pale grey, poorly sorted medium and coarse calcarenites; some micrite; many chert nodules, some silicified allochems, many stylolites below 4.75 m	4.87	5.52
Biosparite, poorly sorted medium calcarenites; some micrite; well sorted fine pelsparite 10.7-11.4 m; some silicified allochems; many clayey stylolites above 8.5 m	5.90	11.42
Biosparite, moderately sorted medium clacarenites; some microspar; several thin brachiopod calcirudites with micritic matrices 16.5-18.4 m; corals at 12.5 m *Diphyphyllum lateseptatum* and 16.5 m *Lithostrotion pauciradiale;* a few thin cherts, scattered euhedral quartz crystals above 13.5 m	6.98	18.40
Biosparite, moderately and poorly sorted calcarenites with several well sorted pelsparites; corals at 18.5 m *Palaeosmilia murchisoni* and 27 m *Lithostrotion portlocki;* brachiopod calcirudite with encrusting algae 33.1-35.1 m; some silicified allochems; rare chert nodules, clayey stylolites common 31.9-32.05 m	22.55	40.95
Monsal Dale Limestones (dark facies)		
Limestone and argillaceous limestone, dark grey, poorly sorted calcarenites and calcirudites with mixed spar and micrite matrix, local lamination; much disseminated and stylolitic clay; chert nodules and silification throughout	2.84	43.79
Limestone (biomicrosparite), moderately sorted calcarenites and calcirudites; mixed fine spar and micrite matrix; brachiopod calcirudite 46.89-49.00 m; well sorted pelsparite 50.83-51.40 m; at least 10 % chert; many quartz crystals above 47 m; poor recovery (mainly chert fragments) 46.35-46.75 m and 50.15-51.60 m	8.13	52.10
Limestone and argillaceous limestones (biomicrosparite), dark grey, poorly sorted calcarenites and calcilutites; fine spar and micrite matrix; large brachiopods and crinoids 55.04-55.51 m and 65.26-65.11 m; graded bed 65.00-65.11 m; much disseminated and stylolitic clay; many thin cherts above 63 m, silicified allochems throughout; dolomite rhombs 69.9-71.1 m	20.72	72.82
Upper Miller's Dale Lava		
Tuffaceous mudstone, greenish grey, pyritic, many calcite veins; poor recoverey	2.98	75.80
Station Quarry Beds (within Monsal Dale Limestones)		
Limestone (biomicrosparite), dark grey, poorly sorted calcarenites; fine spar cement with some microspar; well sorted pelsparite 97.09-97.53 m; trace silicification throughout; thin chert 91.5-92.5 m	19.02	99.80
Biosparite, dark grey, fine calcarenite; mixed spar and micrite matrix; many thin clay laminae and much disseminated clay; pyrite	0.23	100.03

SK 17 SE 13


LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR
ETCHED
POWDER
(%)
(%)
0 15 35 50
60 70 80 90 100
A.I.V.
10 20 30 40
INSOLUBLE RESIDUE
(%)
0 5 10 15
PURITY
Metres
10
20
30
40
50
60
70
80
90
100
CLAY
CLAY
Si
FeS
Si
SiO2
Fe
F
Si
Si
SiO2
Si
Si
FeS
SiO2
Si
SiO2
Si
Si
SiO2
Si
FeS
Si
Si
FeS
Si
FeS
FeS
Si
FeS
FeS
FeS
Si
Si
Si
Si
Si
SiO2
F
Si
FeS
chert 17.8
chert 19.3
chert 21.7
36.7
clay and chert
chert 18.8
clay
clay and pyrite
chert
4
3
3
3
5
4
4
3
3
2
2

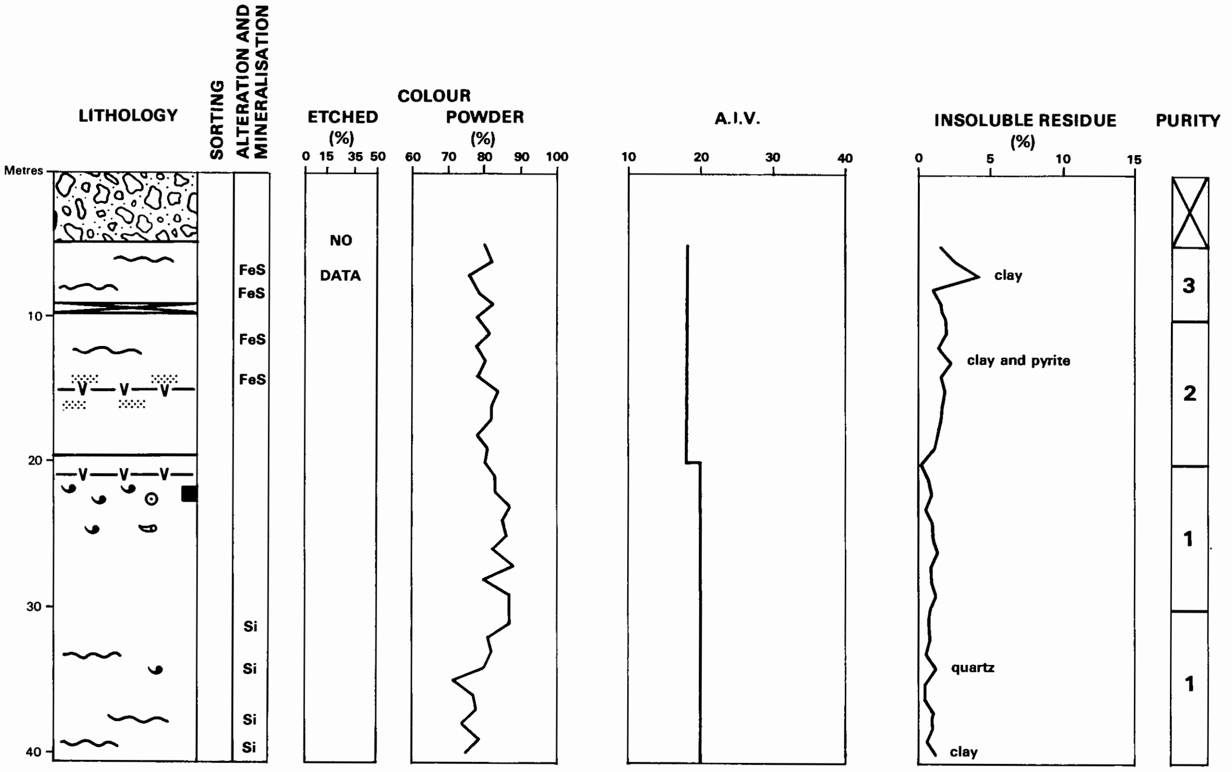
SK 17 SE 14 1705 7050 Lees Bottom
Surface Level +164.3 m
Edeco Stratadrill (waterflush) 30 mm diameter
Summer 1979

	Thickness m	Depth m
Sand, quartz and dolomite grains, fining towards base	4.90	4.90
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), poorly sorted medium and fine calcarenites; find spar cement with some micrite; several thin brown laminated and mottled micrites (pedogenic horizons?); many clayey stylolites; pyrite common above 15 m; greenish grey clay 'wayboard' 15.16 -15.17 m; no core recovered 9.2-9.5 m	15.96	20.86
Clay, greenish grey 'wayboard', pyritic. Horizon of **Lower Miller's Dale Lava**	0.06	20.92
Bee Low Limestones		
Limestone (biosparite), pale grey, poorly sorted calcarenites; several brown mottled horizons above 34 m; many stylolites	19.74	40.66

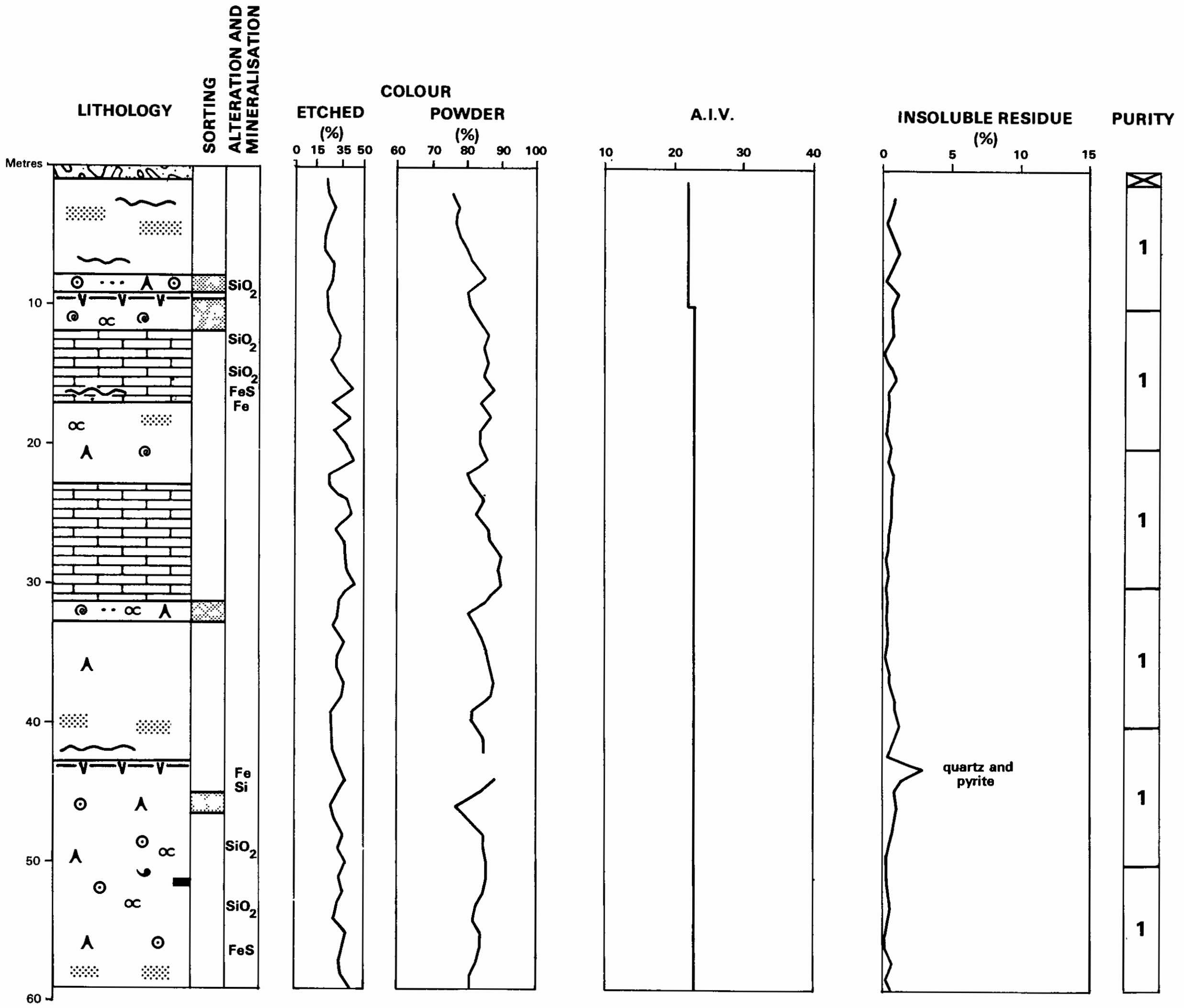
SK 18 SW 47 1316 8079 Oxlow Rake
Surface level +411.5 m
Reich (airflush) 79 mm diameter
March 1971

	Thickness m	Depth m
Topsoil, yellow-brown clay with limestone fragments	1.00	1.00
Miller's Dale Limestones		
Limestone (biosparite), moderately and well sorted fine and medium calcarenites; many crinoids, foraminiferas and dasycladacean algal fragments towards base	8.20	9.20
Clay, greenish brown 'wayboard'. Horizon of **Lower Miller's Dale Lava**	0.31	9.51
Chee Tor Rock		
Limestone (biosparite), well sorted foraminifera calcarenite	2.41	11.92
Biosparite, moderately sorted medium calcarenites; tightly packed allochems with few patches of micrite and spar cement; quartz crystals common at 12.7 m and 14.5-15.0 m; abundant stylolites with hematite and pyrite concentrations 15.00-17.56 m	19.43	31.35
Biosparite, well sorted medium calcarenites; many foraminifera and encrusting algae; some bioturbation	1.42	32.77
Biosparite, moderately sorted tightly packed medium calcarenites; many stylolites below 41.25 m	9.94	42.71
Clay, grey-brown 'wayboard', tuffaceous, with limestone fragments	0.15	42.86
Limestone (biosparite), moderately sorted medium calcarenites tightly packed with crinoids and dasycladacean algal fragments; scattered large brachiopods with encrusting algae; trace hematite and pyrite; abundant quartz crystals associated with encrusting algal masses	16.15	59.01

SK 17 SE 14



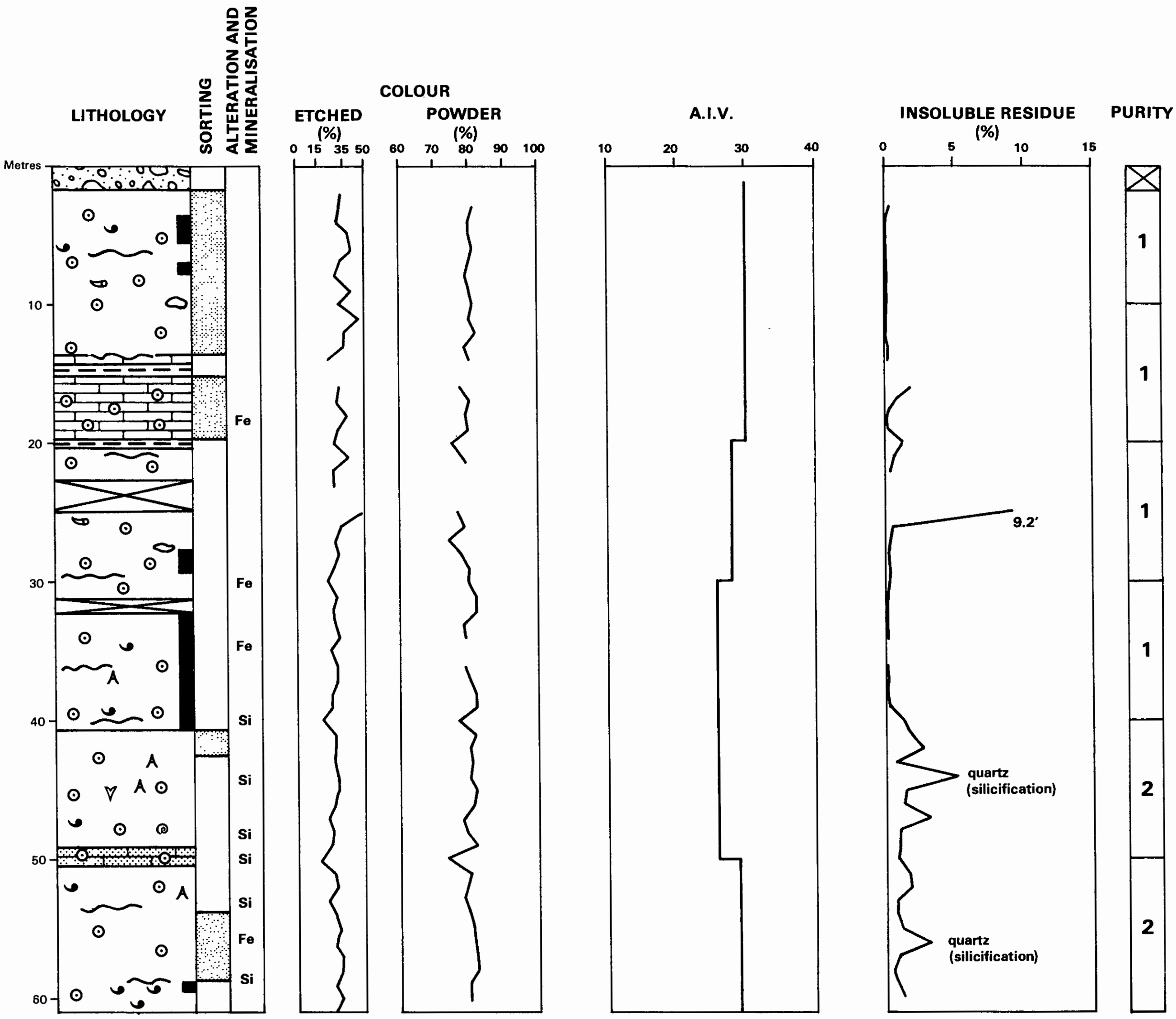
SK 18 SW 47



SK 18 SW 48 **1086 8038** **Peak Forest**
Reich (airflush) 76 mm diameter
January 1971

	Thickness m	Depth m
Topsoil, dark brown, sandy towards base with limestone fragments	1.75	1.75
Woo Dale Limestones (Peak Forest Limestones)		
Limestone (biosparite), moderately and well sorted coarse crinoid calcarenites with thin calcirudites; tighly packed allochems with some spar and microspar cement; some iron-staining below 15.35 m; clay-filled vertical joints common in upper part; poor recovery with some fissure-filling clay 14.33-15.36 m and 19.84-20.50 m	20.96	22.71
Gap. Core loss	2.25	24.96
Limestone (biosparite), moderately sorted medium crinoid calcarenites with coarse calcarenites and clacirudites 27.8-29.3 m; locally intraclastic at 27.5 m	6.40	31.36
Gap. Core loss		
Limestone (biosparite), moderately sorted calcarenites and fine calcirudites; some micrite and microspar; mainly crinoid fragments but with more algal fragments in the finer grained lithologies; some iron-staining and mineralisation; much silicification at 39.7 m and 40.55 m	8.47	40.68
Biosparite, moderately and well sorted crinoid calcarenites, tightly packed bioclasts; more foraminifera and bryozoa than above; some silicification	8.51	49.19
Biomicrosparite, dark grey, poorly sorted medium crinoid calcarenite; scattered rudite-sized allochems, some silicified	1.28	50.47
Biosparite, moderately sorted coarse crinoid calcarenites with some brachiopod crinoid calcirudites; some silicification	10.54	61.01

SK 18 SW 48

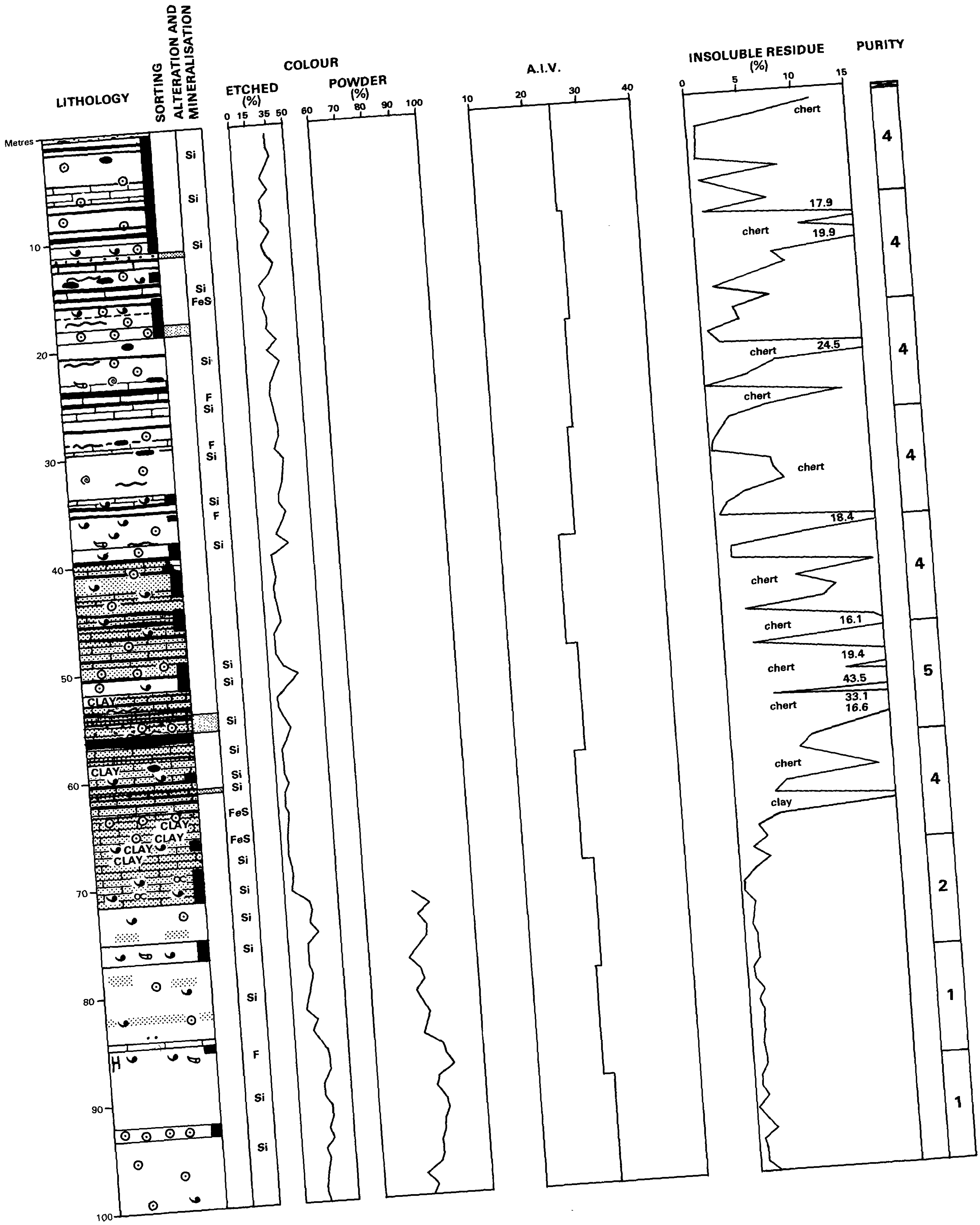


'Predominantly fissure-filling clay; not used in purity calculation

SK 18 SE 62 1563 8081 Potter Barn
Surface level +361.0 m
Edeco Stratadrill (waterflush) 47 mm diameter

	Thickness m	Depth m
Topsoil	0.50	0.50
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), poorly sorted coarse crinoidal calcarenites and calcirudites; some micrite; brachiopod band 10.11-11.33 m; many thin cherts above 1.75 m, also from 6.75-7.20 m and from 9.0-10.0 m; some allochems silicified	10.83	11.33
Biosparite, moderately and poorly sorted medium and coarse crinoidal calcarenites, brachiopod calcirudites and crinoidal calcarenites; patches of fine grained clear spar with some micrite and microspar; several well sorted pelsparites 11.3-11.7 m; many thin cherts; some allochems silicified; thin calcareous mudstone 16.83-16.89 m	28.58	39.91
Monsal Dale Limestones (dark facies)		
Limestone (biomicrosparite), dark grey poorly sorted crinoidal calcarenites; mixed spar, microspar and micrite matrix; scattered rudite brachiopods, fragments of coral at 49.87 m; many cherts (10 % of rock) and stylolitic clays	10.74	50.65
Biosparite, moderately sorted fine calcirudites with crinoid and brachiopod debris predominant; many shells partially silicified	1.30	51.95
Biomicrosparite, dark grey, poorly sorted fine calcarenites and calcilutites; scattered coarse crinoids and brachiopods; many thin cherts (about 15 % of total rock); disseminated clay and clayey stylolites throughout	2.25	54.20
Pelsparite, well sorted medium calcarenites; many crinoid fragments; some stylolitic clay, chert 54.69-54.77 m	1.63	55.83
Chert, some calcareous allochems included	0.94	56.77
Biosparite, dark grey, dominantly poorly sorted calcarenites; mixed fine spar, microspar and micrite matrix; well sorted pelsparite 61.05 m; large brachiopods with *Girvanella* encrustations 59.50-59.69 m, 59.90-60.03 m, 65.75-66.50 m and below 68.46 m; many thin cherts above 64 m (greater than 10 % of total rock); some disseminated and stylolitic clay throughout; scattered silicified allochems; trace pyrite 63.5-67.5 m	14.83	71.60
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), moderately and poorly sorted calcarenites and fine calcirudites; some microspar; many crinoids and brachiopods	12.79	84.39
Biomicrite, poorly sorted calcilutites and fine calcarenites	0.44	84.83
Biosparite, moderately sorted coarse calcarenites and calcirudites; many crinoids and brachiopods throughout	15.17	100.00

SK 18 SE 62



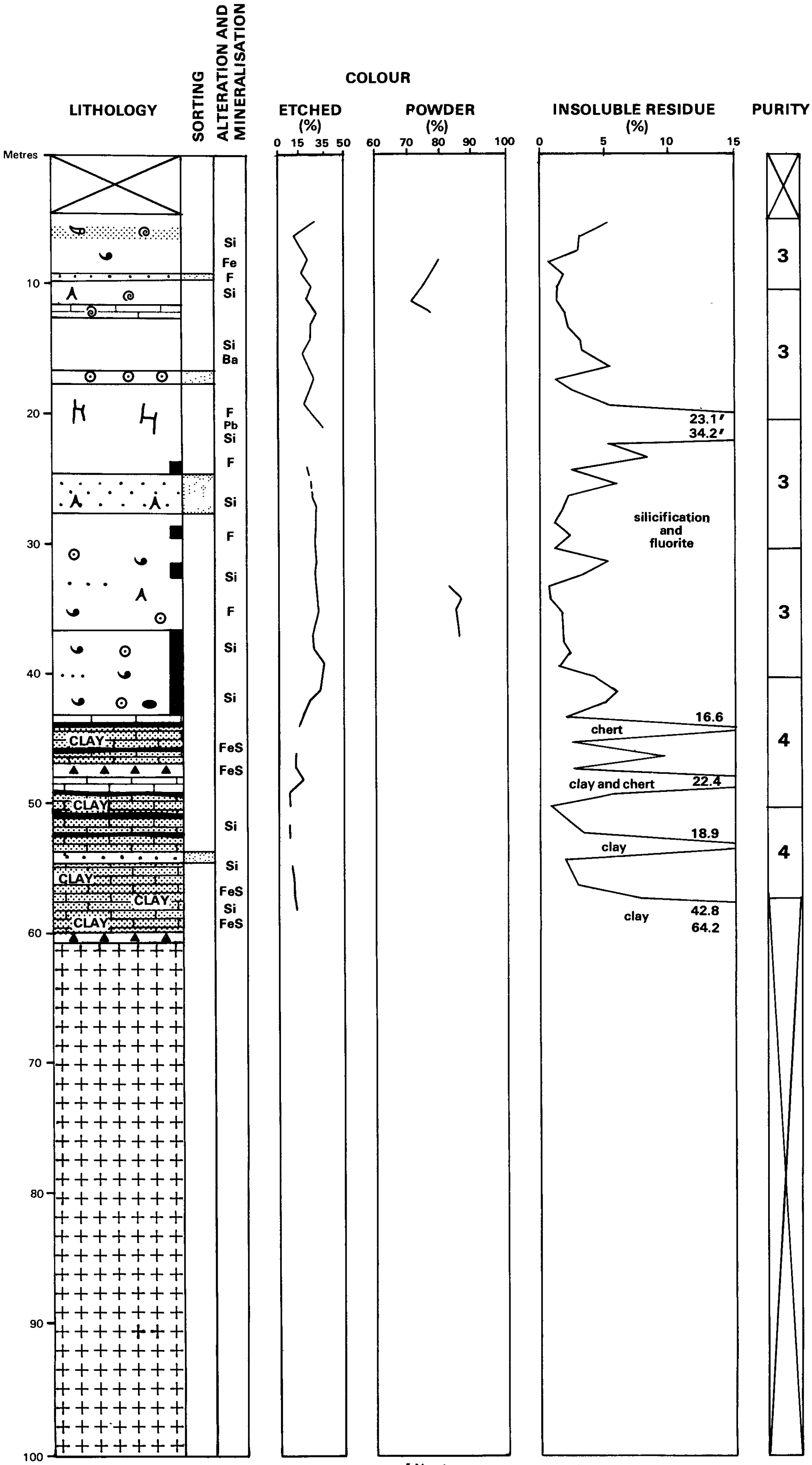
LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR
ETCHED (%)
POWDER (%)
A.I.V.
INSOLUBLE RESIDUE (%)
PURITY
Metres
chert
17.9
19.9
24.5
18.4
16.1
19.4
43.5
33.1
16.6
clay
CLAY

SK 27 NW 15 2096 7603 Eyam
Surface level c.+230 m
1972

	Thickness m	Depth m
Gap. No core	c. 4.50	c. 4.50
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), moderately and poorly sorted calcarenites; some micrite and microspar; well sorted pelsparite at 9 m; some silicification throughout; trace limonite, baryte and chlorite	12.00	16.50
Biosparite, moderately sorted coarse calcarenites and fine calcirudites; dominantly crinoidal; well sorted encrinite at 17 m, pelsparite at 25 m and cross-laminated algal pelsparite at 27 m; fluorite and calcite veining throughout becoming intense 20.0-20.8 m; trace silicification, limonite and galena	20.00	36.50
Biosparite, poorly sorted medium and coarse calcirudites with brachiopods, crinoids and algal fragments (brachiopods are partially silicified); less veining than above; sporadic thin cherts below 42.8 m	7.00	43.50
Monsal Dale Limestones (dark facies)		
Limestone (biomicrosparite), dark grey, poorly sorted calcarenites; fine spar and microspar cement; some large brachiopods and crinoids; thin cherts, pyrite, stylolites and disseminated clay throughout	3.22	46.72
Litton Tuff		
Tuff, grey-green, pyritic	1.08	47.80
Monsal Dale Limestones (dark facies)		
Limestone (biomicrosparite), dark grey generally poorly sorted medium and fine calcarenites, well sorted pelsparite at 54 m; some silicification; thin cherts above 53 m disseminate clay throughout increasing towards base; fluorite and pyrite below tuff; much pyrite below 57 m	12.00	59.80
Cressbrook Dale Lava		
Tuff, pale green, pyritic	0.75	60.55
Basalt, green	75.84	136.39

Borehole continues to 1803 m

SK 27 NW 15



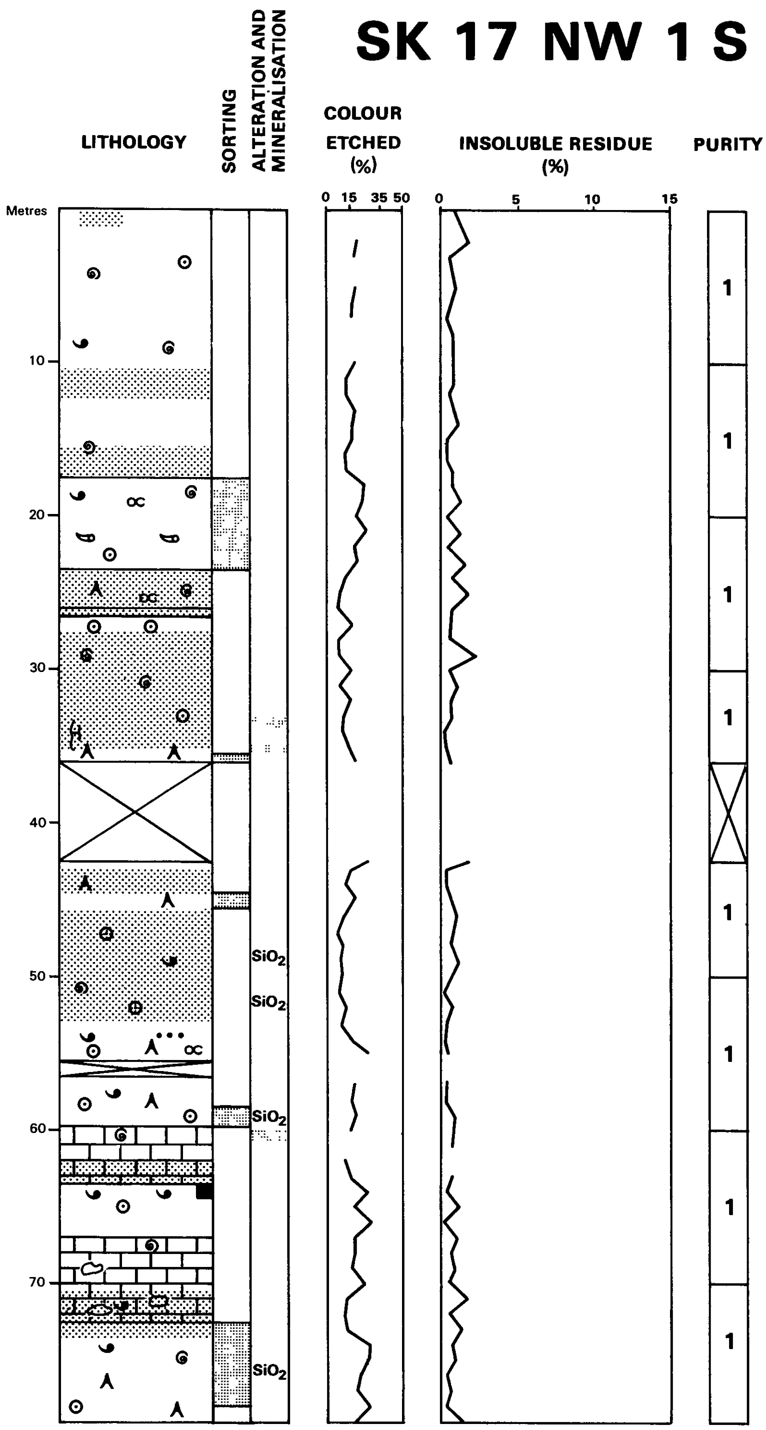
′ Not included in purity calculations; very poor core recovery, predominantly fluorite and quartz

SK 17 NW 1 S Hay Dale/Dam Dale

Section sampled from 1197 7714 (top) to 1187 7782 (base)

	Thickness m	Depth m
Chee Tor Rock		
Limestone (biosparite), thickly bedded, moderately and poorly sorted fine calcarenites; many foraminifera; some mottling	17.0	17.0
Biosparite, thickly bedded, moderately and well sorted medium and coarse calcarenites; coral band 21.5-23.0 m	6.0	23.0
Biosparite, dark grey, medium calcarenites, laminated at base, many dasycladacean algae, some micrite envelopes; locally bituminous	3.5	26.5
Woo Dale Limestones		
Limestone (biosparite), thinly bedded, dark grey, moderately and poorly sorted medium and coarse calcarenites, many foraminifera, well sorted algal bed at base; trace of dolomite associated with thin calcite veins 33-35 m	9.5	36.0
Gap. No exposure	6.6	42.6
Limestone (biosparite), grey and dark grey, moderately sorted medium and coarse calcarenites, well sorted beds at 45 and 59 m, laminated at 55 m; many dasycladacean algal fragments; trace bituminous material, quartz crystals at 47.53 m and at 59 m; no exposure 55.6-56.7 m	17.2	59.8
Biomicrosparite, thinly bedded fine calcarenites; mixed spar and micrite matrix; rudite brachiopods at 64 m; micrite intraclasts (pseudo-breccia?) 68-72.5 m; trace of dolomite at 60.5 m	12.7	72.5
Biosparite, moderately and well sorted fine and coarse calcarenites; dispersed euhedral quartz crystals	6.5	79.0

SK 17 NW 1 S



LITHOLOGY
SORTING
ALTERATION AND MINERALISATION
COLOUR ETCHED (%)
INSOLUBLE RESIDUE (%)
PURITY
Metres
10
20
30
40
50
60
70
0 15 35 50
0 5 10 15
SiO2
SiO2
SiO2
SiO2
1
1
1
1
1
1
1
1

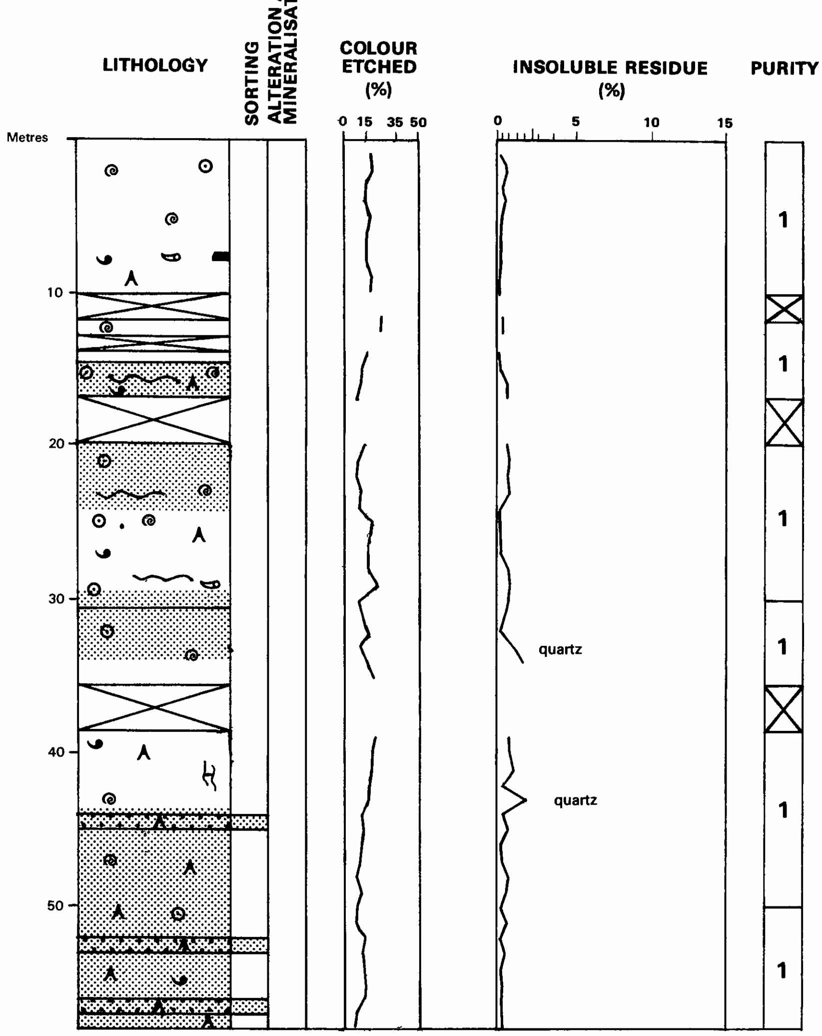
SK 17 NW 2 S **Dale Head**
Section sampled from 1253 7630 (top) to 1233 7662 (base)

	Thickness m	Depth m
Chee Tor Rock		
Limestone (biosparite), thickly bedded, moderately and poorly sorted medium calcarenites; many foraminifera, more algal fragments towards base; calcirudite containing coral and brachiopod debris at 7.8 m. Gaps in section 10.0-11.7 m and 12.7-13.7 m	14.5	14.5
Biosparite, thinner bedded, dark grey, moderately and poorly sorted medium and fine calcarenites	2.3	16.8
Gap		
Biosparite, grey and dark grey, moderately and poorly sorted medium and coarse calcarenites; many foraminifers locally crinoidal	10.7	30.5
Biosparite, thinly bedded, grey and dark grey, moderate and poorly sorted medium and fine calcarenites; some mottling; gap in section 35.5-38.5 m	13.5	44.0
Woo Dale Limestones		
Limestone (biosparite), thinly bedded, dark grey, moderately sorted medium and fine calcarenites; many algal fragments; well sorted pelsparites at 44 m (cross-laminated), 52.5 m and 56.5 m	14.0	58.0

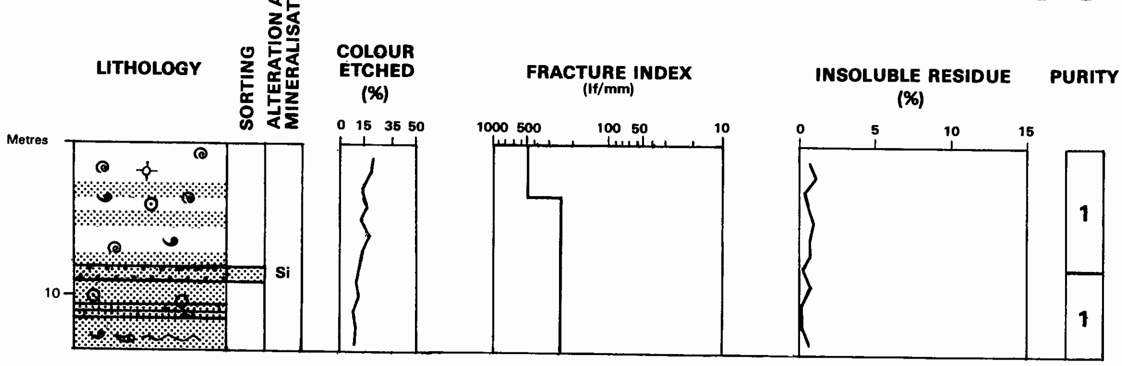
SK 17 NW 3 S **Peak Forest**
Section sampled from 1227 7877 (top) to 1222 7877 (base)

	Thickness m	Depth m
Chee Tor Rock		
Limestone (biosparite), thickly bedded, moderately sorted medium calcarenites; many forminifers; some calcispheres	8.0	8.0
Woo Dale Limestones		
Limestone (biosparite), dark grey, poorly sorted coarse calcarenites, some microspar; many crinoid, brachiopod and coral fragments; well sorted pelsparite at top; many clayey stylolites towards base	5.5	13.5

SK17NW2 S



SK17NW3 S



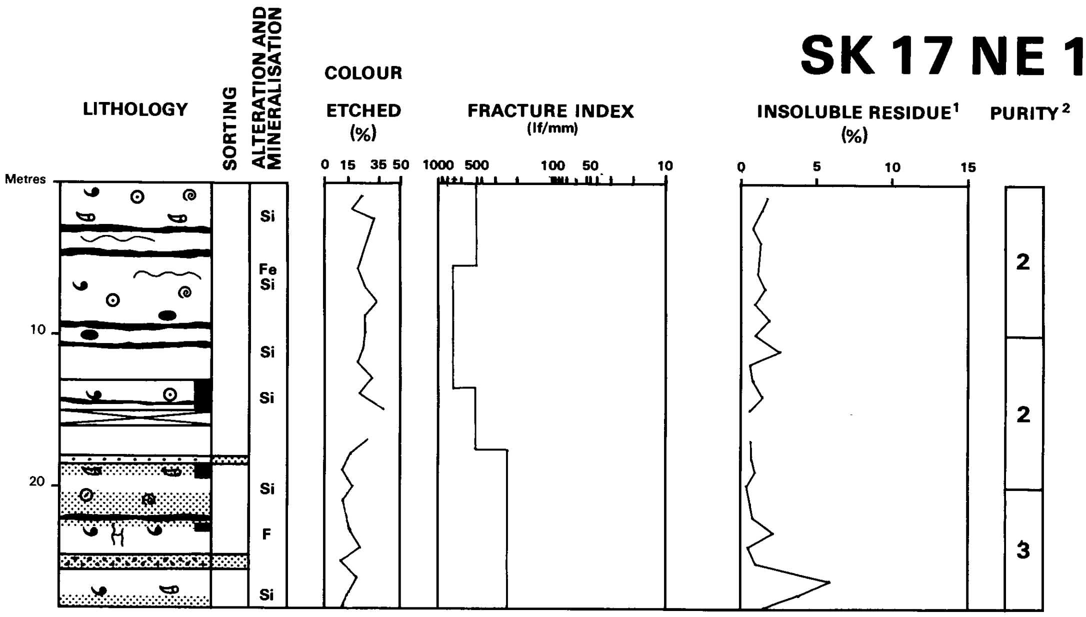
SK 17 NE 1 S **Wardlow Mires**
Section sampled from 1763 7527 (top) to 1751 7535 (base)

	Thickness m	Depth m
Mosal Dale Limestones (pale facies)		
Limestone (biosparite), thickly bedded poorly sorted medium and fine calcarenites; fine spar cement with some micrite; many brachiopod and crinoid fragments; coral band at 2.5 m; sporadic chert (less than 5 % of total rock); some coarser allochems are silicified	13.0	13.0
Biosparite, thickly bedded, moderately sorted coarse calcarenite containing brachiopod and crinoid debris; clear spar cement; some chert and silification	2.0	15.0
Gap. No exposure	1.0	16.0
Biosparite, thinner bedded than above, poorly sorted medium and fine calcarenites; fine spar cement with some micrite; many foraminifera; crinoids and brachiopods occur throughout; well sorted pelsparites at 18 m and 25 m; coral bed 18-19 m; brachiopod calcirudite 22.5-23 m; chert bed at 22.2 m; trace silicification	12.0	28.0

SK 17 SW 1 S **South of Great Rocks Dale**
Section sampled from 1134 7283 (top) to 1125 7277 (base)

	Thickness m	Depth m
Woo Dale Limestones		
Limestone (biosparite), dark grey, moderately sorted medium calcarenites; much rounded shell debris; well sorted algal pelsparite at 7 m	9.0	9.0
Biomicrite, interbedded fine calcarenites and calcilutites; coarser beds tend to contain more spar cement; dominantly fine shell debris with subordinate foraminifera, calcispheres and algal fragments, rare brachipods and corals; much of the micrite shows stromatactis-like structures and commonly has a nodular texture	20.0	29.0
Biosparite, dark grey, medium and fine calcarenites; some micrite in the matrix; foraminifera dominant with subordinate calcispheres and algal fragments; coarse oncolitic beds with pelsparite matrix at 34 m, 39.75 m and 45 m; thin dolomite lens at top, scattered dolomite rhombs below 39 m; some of the rhombs are dedolomitised	18.0	47.0
Gap. No exposure	3.0	50.0
Biosparite, grey and dark grey, moderately sorted medium calcarenites; well sorted pelsparite at 50.5 m	8.0	58.0

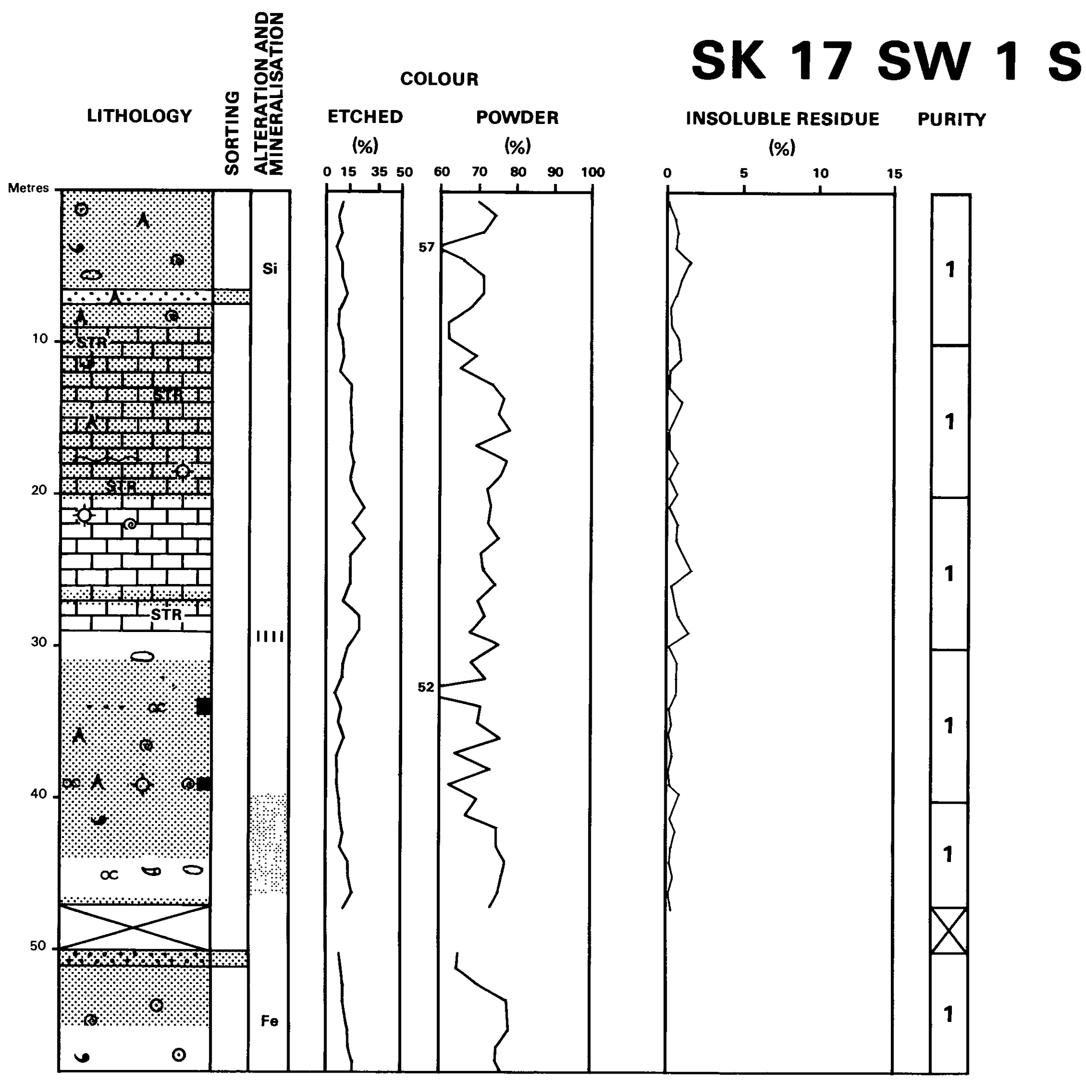
SK 17 NE 1 S



1 Samples chert free

2 Purity adjusted to allow for chert recorded at outcrop

SK 17 SW 1 S



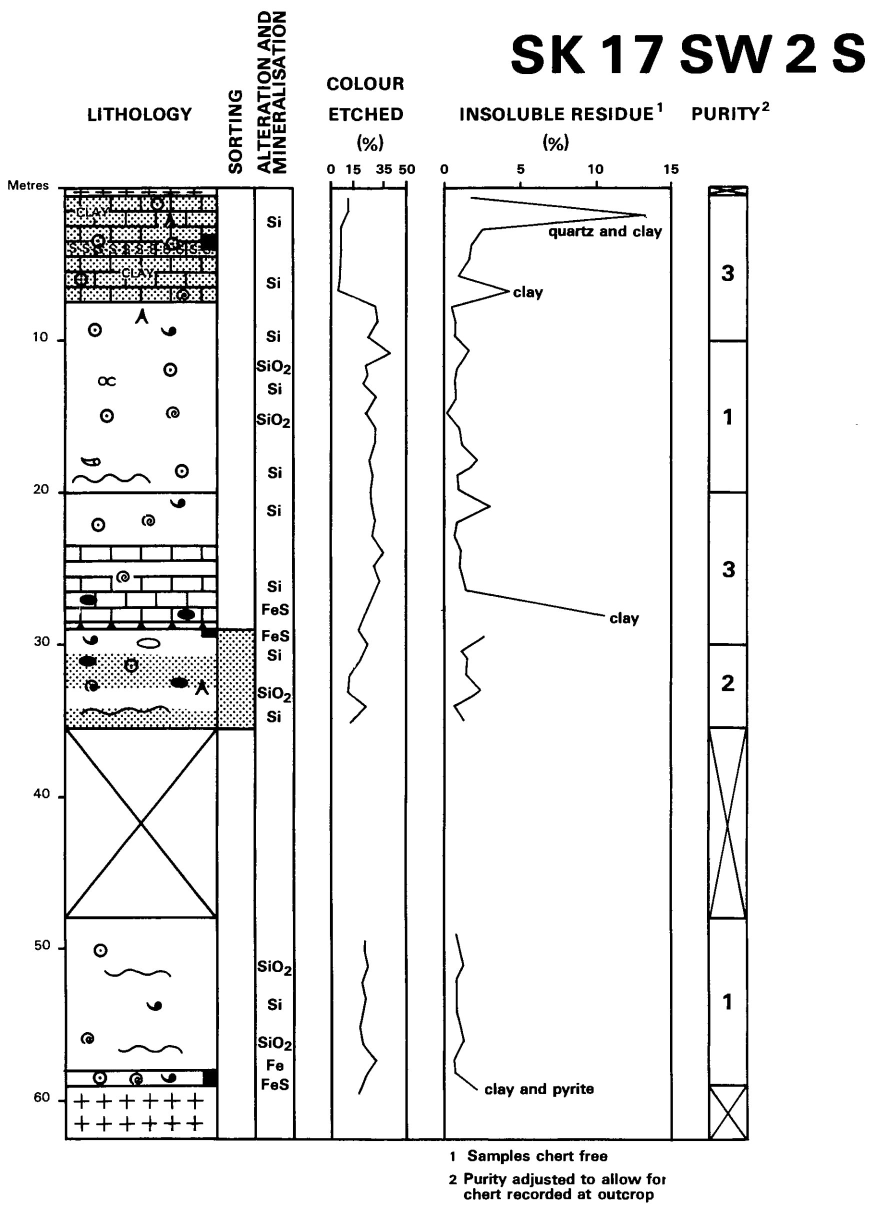
SK 17 SW 2 S Station Quarry
Section sampled from 1327 7348 (top) to 1301 7339 (base)

	Thickness m	Depth m
Upper Miller's Dale Lava	-	-
Monsal Dale Limestones (Station Quarry Beds)		
Limestone (biomicrite), thinly bedded, dark grey, medium and coarse calcarenites; crinoidal calcirudite 3.0-4.0 m; some spar cement present locally; many crinoids throughout with some corals and foraminifera; *Saccamminopsis* at 4.0 m; some disseminated clay; locally bituminous	7.00	7.00
Miller's Dale Limestones		
Limestone (biosparite), thickly bedded, moderately sorted medium and fine crinoidal calcarenites; many brachiopods and algal fragments above 10 m; some micrite envelopes, corals at 18 m; clayey stylolites near base	13.00	20.00
Biosparite, fine calcarenites; fine spar cement with patches of micrite; cherty below 26.5 m with much fine silicification; pyrite and tuff fragments in basal 2 m	8.65	28.65
Tuff, grey, pyritised	0.50	29.15
Limestone (biosparite), well sorted fine calcirudite; many brachiopods and intraclasts; patchy silicification and pyrite traces	0.35	29.50
Biosparite, well sorted fine calcarenites; chert nodules above 33 m; patchy silicification, some euhedral quartz crystals and bituminous streaks	6.30	35.80
Gap. No exposure	12.50	48.30
Biosparite, thickly bedded, poorly sorted fine calcarenites; quartz crystals throughout; many stylolites	10.00	58.30
Biosparite, poorly sorted coarse calcarenite with many large brachiopods and crinoids; some silicification	1.00	59.30
Lower Miller's Dale Lava	-	-

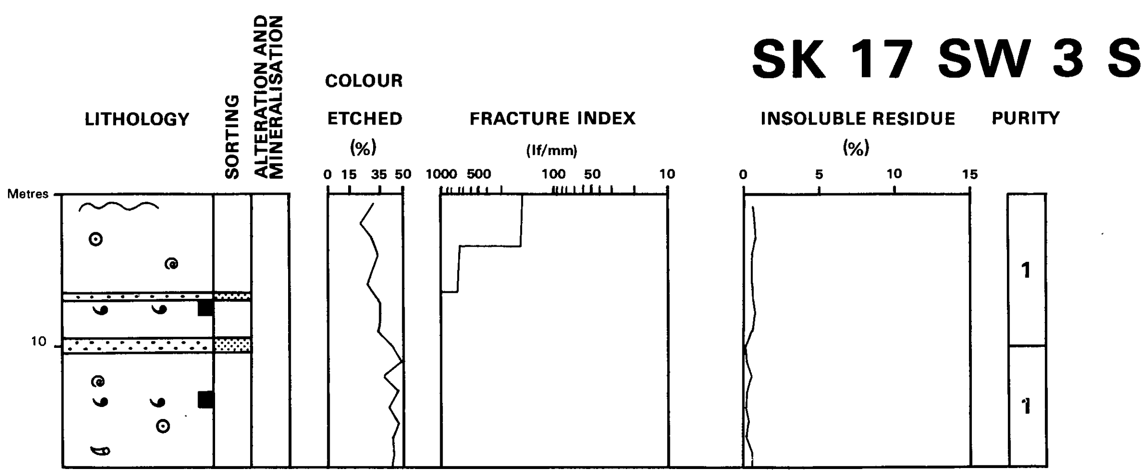
SK 17 SW 3 S Railway cuttings east of Miller's Dale
Section sampled from 1494 7316 (top) to 1477 7322 (base)

	Thickness m	Depth m
Miller's Dale Limestones		
Limestone (biosparite), thickly bedded, mainly poorly sorted medium calcarenites with well sorted pelsparites at 7 m and 10 m; stylolites near top	18.00	18.00

SK 17 SW 2 S



SK 17 SW 3 S



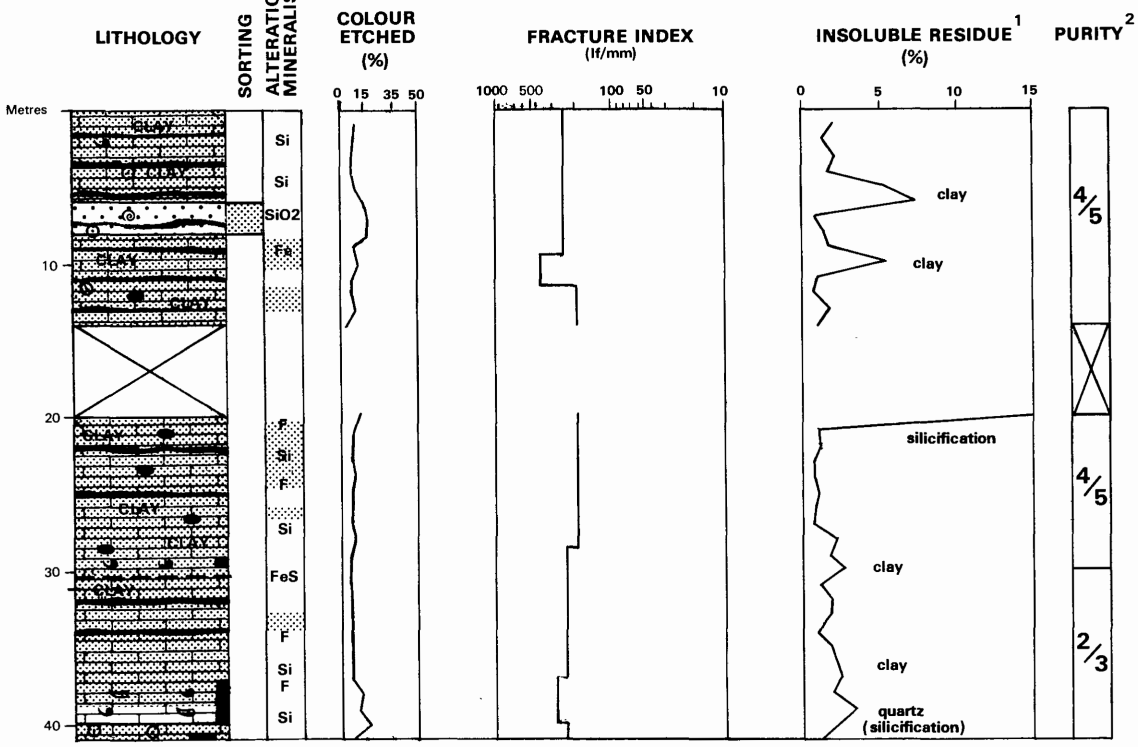
SK 17 SE 1 S **Monsal Dale Station**
Section sampled from 1752 7202 (top) to 1759 7208 (base)

	Thickness m	Depth m
Monsale Dale Limestones (dark facies)		
Limestone (biomicrite), dark grey, fine calcarenites and calcilutites, thin chert beds and nodules; some fine silicification and much disseminated clay	6.0	6.0
Pelsparite, well sorted medium and fine calcarenites, becoming less pelletal lower down; many euhedral quartz crystals	2.0	8.0
Biomicrite, dark grey, thinly bedded calcilutites, mixed spar and micrite matrix; chert (10 % of total rock); some disseminated clay; dolomite rhombs patchily developed	6.0	14.0
Gap. Poor exposure	6.0	20.0
Biomicrosparite, dark grey, thinly bedded calcilutites; mixed micrite and microspar matrix; some disseminated clay; many chert beds (5-10 % of total rock); locally dolomitic	9.0	29.0
Biomicrite, dark grey, brachiopod calcirudite grading up into laminated clayey micrite at top	0.7	29.7
Biomicrite, dark grey, thinly bedded calcilutites; thin shaley partings at 30 m and 30.4 m; less chert than above; traces of dolomite and fluorite; some disseminated clay	7.3	37.0
Upperdale Coral Band. Biomicrosparite, dark grey, poorly sorted calcarenites with many rudite sized crinoids, corals and brachiopods; fine spar cement with some micrite; partially silicified	4.0	41.0

SK 17 SE 2 S **Quarry behind Monsal Dale Station**
Section sampled at 1773 7178

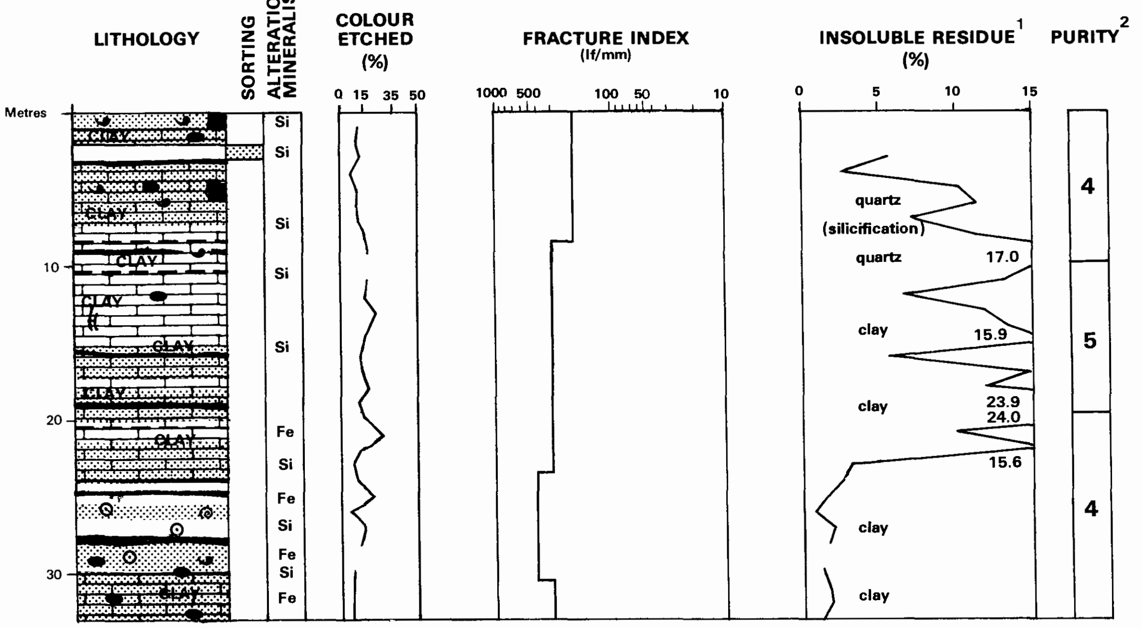
	Thickness m	Depth m
Monsal Dale Limestones (dark facies)		
Limestone (biomicrite), dark grey, poorly sorted medium calcarenite with many rudite-sized brachiopods; some silicification	1.0	1.0
Biomicrosparite, dark grey, fine calcarenite; chert nodules and dissiminated clay	1.0	2.0
Pelsparite, well sorted medium calcarenite; laminated; some silicification	1.0	3.0
Argillaceous limestone (biomicrite), dark grey, dominantly calcilutites and fine calcarenites; mixed microspar and micrite matrix; scattered large brachiopods, much disseminated clay throughout; some chert and partial silicification of larger allochems; thin shales at 8.5, 10.5 and 20.5 m	19.0	22.0
Limestone (biomicrosparite), dark grey, poorly sorted medium and fine calcarenites; fine spar cement, more micritic below 30 m; crinoids, brachiopods and foraminifera dominant; some chert and partial silicification; clayey and bituminous below 30 m	11.0	33.0

SK 17 SE 1 S



1) Samples chert free
2) Purity adjusted to allow for chert recorded at outcrop

SK 17 SE 2 S



1) Samples chert free
2) Purity adjusted to allow for chert recorded at outcrop

SK 18 SW 1 S **Middle Hill**
Section sampled at 1208 8235

	Thickness m	Depth m
Bee Low Limestones (Apron-reef)		
Limestone (biosparite); medium and fine calcarenites, dominantly fine spar cement with some micrite; locally many foraminifera and algal fragments with crinoids, brachiopods, bryozoa, ostracods and calcspheres; many irregular laminated, spar-filled 'voids' throughout; no silicification	10.0	10.0

This section represents the back-reef facies of the apron-reef.

SK 18 SW 2 S **Middle Hill West**
Section sampled from 1166 8217 (top) to 1166 8214 (base)

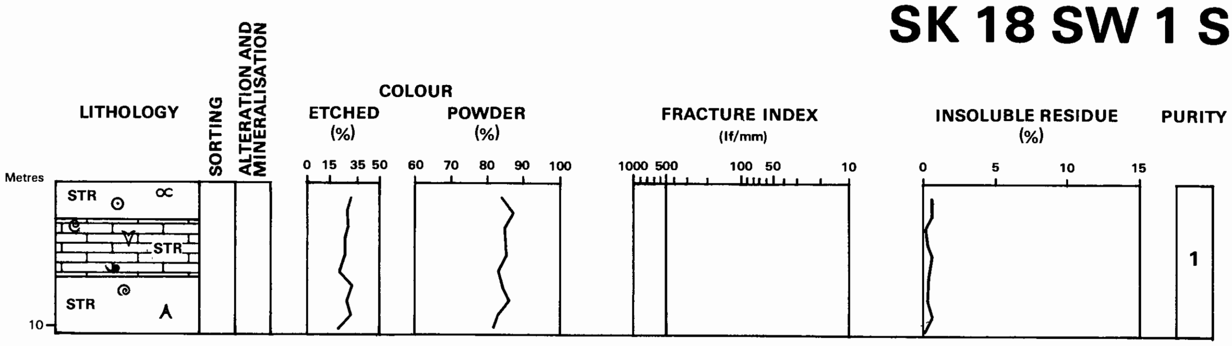
	Thickness m	Depth m
Apron-Reef Limestones		
Limestone (pelsparite), well sorted medium calcarenite with foraminifera, brachiopods, crinoids, bryozoa and algal fragments; thin calcite veins	2.0	2.0
Biomicrite, dominantly calcilutite with scattered larger allochems; some patches of spar cement; geopetal structures in large shells; many large irregular, sometimes flat-based voids lined with laminated calcite (up to 100 mm) often with a centre of clear spar	24.0	26.0

SK 18 SW 3 S **Eldon Hill Quarry**
Section sampled at 1132 8142

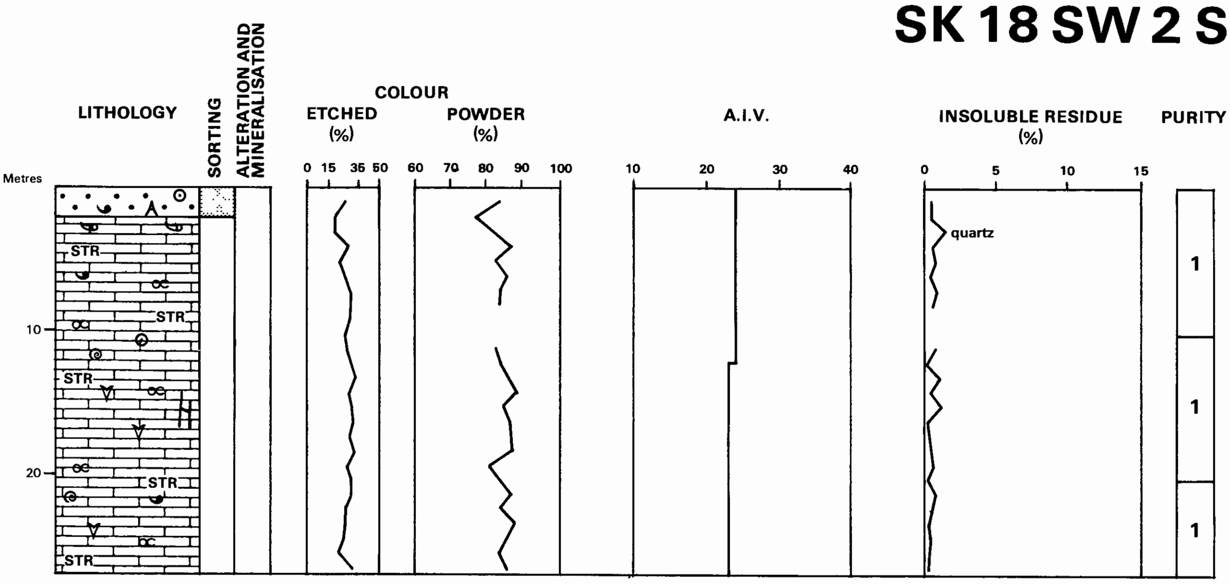
	Thickness m	Depth m
Bee Low Limestone		
Limestone (biosparite), thickly bedded, moderately and well sorted medium and coarse calcarenites; dominantly crinoidal with several well sorted pelsparites; foraminifera, algal and coral fraagments common; scattered large brachiopods and coral colonies; some quartz crystals; thin grey clay at 33 m	37.0	37.0

This section does not represent the complete working thickness of the quarry.

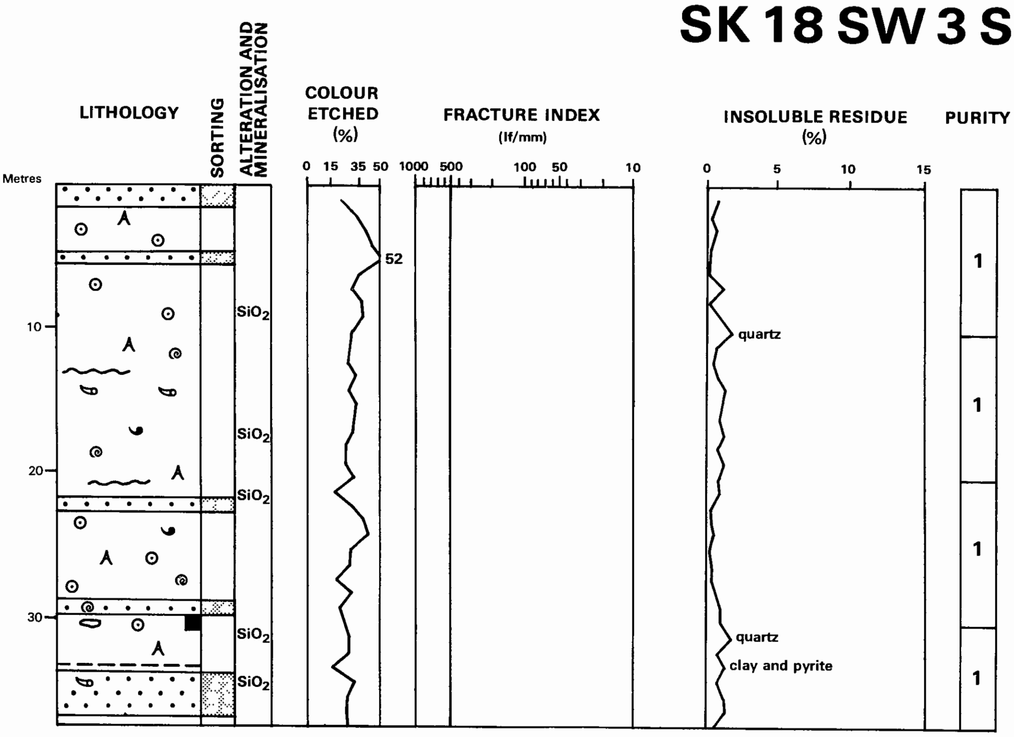
SK 18 SW 1 S



SK 18 SW 2 S



SK 18 SW 3 S



SK 18 SE 1 S **Bradwell Dale**
Section sampled at 1713 8055

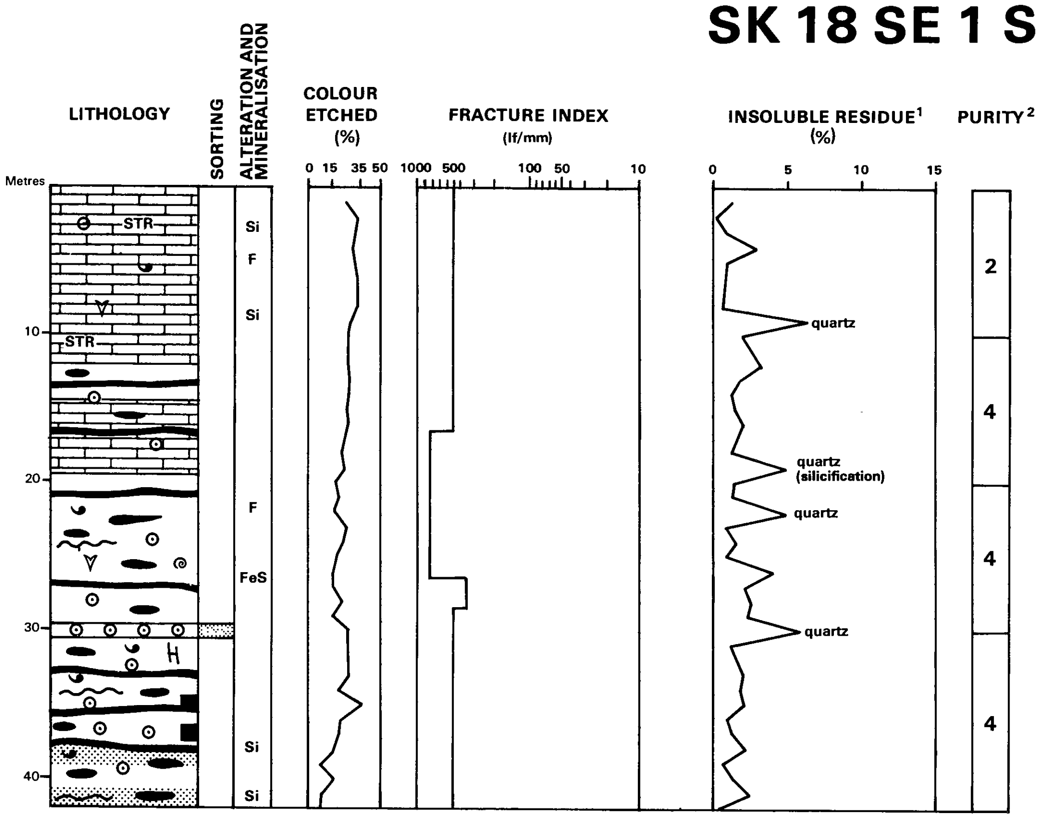
	Thickness m	Depth m
Eyam Limestones (flat-reef)		
Limestone (biomicrite), very poorly sorted calcarenites; dominantly micrite with irregular patches of clear spar cement; scattered crinoids, brachiopods and bryozoa; some irregular silicification; fluorite vein at 5 m	12.0	12.0
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), generally poorly sorted calcarenites with thin calcirudites; some micrite and microspar; dominatly crinoidal with well sorted coarse encrinite at 30 m; many thin cherts (5-10 % of total rock); some of the larger allochems are silicified; fluorite vein at 22 m	30.0	42.0

SK 18 SE 2 S **Pin Dale Quarry**
Section sampled from 1575 8215 (top) to 1594 8227 (base)

	Thickness m	Depth m
Monsal Dale Limestonse (pale facies)		
Limestone (biosparite), generally poorly sorted coarse crinoidal calcarenites with some calcirudites; dominantly fine spar cement with some micrite; some large brachiopods with algal encrustations; chert in upper 4 m; euhedral quartz crystals common; silicification below 7 m	10.0	10.0
Biosparite, moderately and well sorted coarse calcarenites and calcirudites; many crinoids and scattered large brachiopods; some silicification and quartz crystals; trace bituminous material	14.0	24.0
Biomicrosparite, dark grey, very poorly sorted fine crinoidal calcarenite, mixed fine spar and micrite matrix; much disseminated and stylolitic clay; some silicification	1.0	25.0
Pelsparite, well sorted fine calcarenite	1.0	26.0
Biomicrite, calcilutite with scattered large crinoid fragments; bituminous; some fluorite	1.0	27.0
Biosparite, moderately sorted coarse calcarenites and calcirudites; many crinoids, some very large brachiopods and intraclasts; some silicification	5.0	32.0
Biosparite, dark grey, thinly bedded poorly sorted fine calcarenites; mixed spar and micrite matrix; oncolitic with *Girvanella* at 34 m; some nodular chert 34.35 m; many shaley partings	4.0	36.0
Bee Low Limestones		
Limestone (biosparite), thickly bedded, generally poorly sorted medium and fine calcarenites with some coarser beds; fine spar cement with some micrite, less silicification than above, trace of limonite and pyrite; many stylolites below 39 m	12.0	48.0

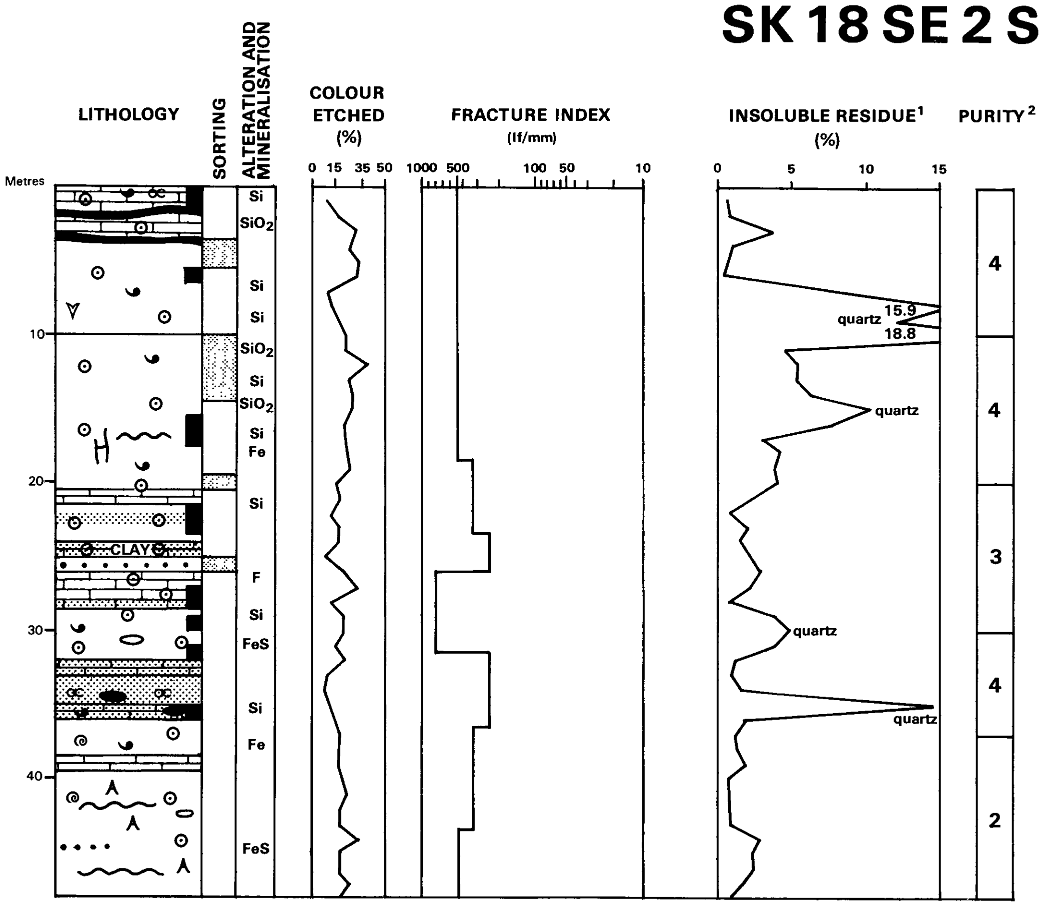
Section completed at main quarry floor; below the quarry a short continuation shows some pale nodular chert within the Bee Low Limestones.

SK 18 SE 1 S



1. Samples chert free
2. Purity adjusted to allow for chert recorded at outcrop

SK 18 SE 2 S



1. Samples chert free
2. Purity adjusted to allow for chert recorded at outcrop.

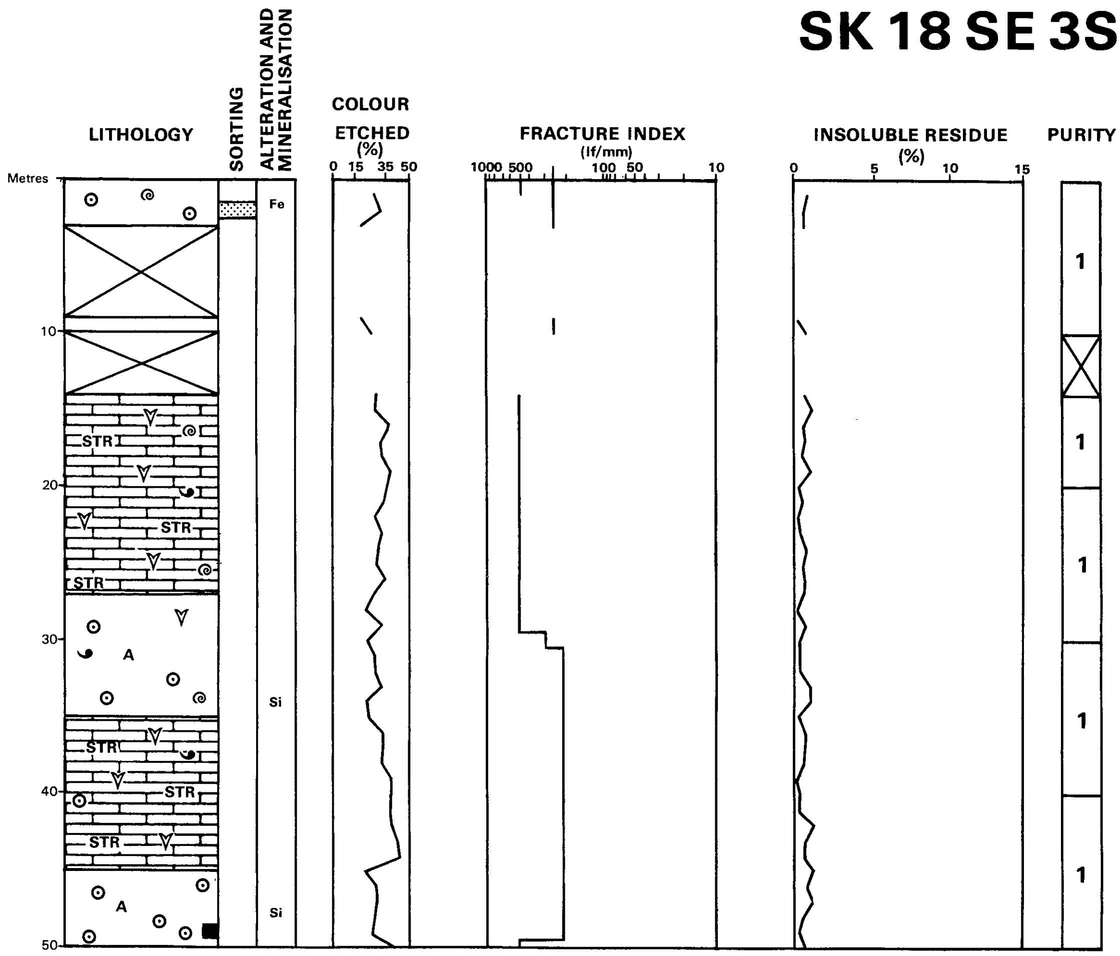
SK 18 SE 3 S Cave Dale (1)
Section sampled from 1489 8230 (top) to 1501 8250 (base)

	Thickness m	Depth m
Bee Low Limestones		
Limestone (biosparite), moderately and well sorted medium and coarse crinoidal calcarenites; trace of limonite	3.0	3.0
Gap. No exposure	6.0	9.0
Limestone (biosparite), poorly sorted medium calcarenite	1.0	10.0
Gap. No exposure	4.0	14.0
Apron-Reef Limestones		
Limestone (biomicrite), calcilutite with scattered bryozoans, foraminifera and shell fragments; irregular patches of clear spar cement	13.0	27.0
Bee Low Limestones		
Limestone (biosparite), poorly sorted medium and fine crinoidal calcarenites; fine spar cement with some micrite	8.0	35.0
Apron-Reef Limestone		
Limestone (biomicrite), calcilutite with scattered bryozoans, brachiopods and crinoids; irregular patches of clear spar cement	10.0	45.0
Bee Low Limestones		
Limestone (biosparite), poorly sorted medium and coarse calcarenites and calcirudites; fine spar cement; many crinoids	5.0	50.0

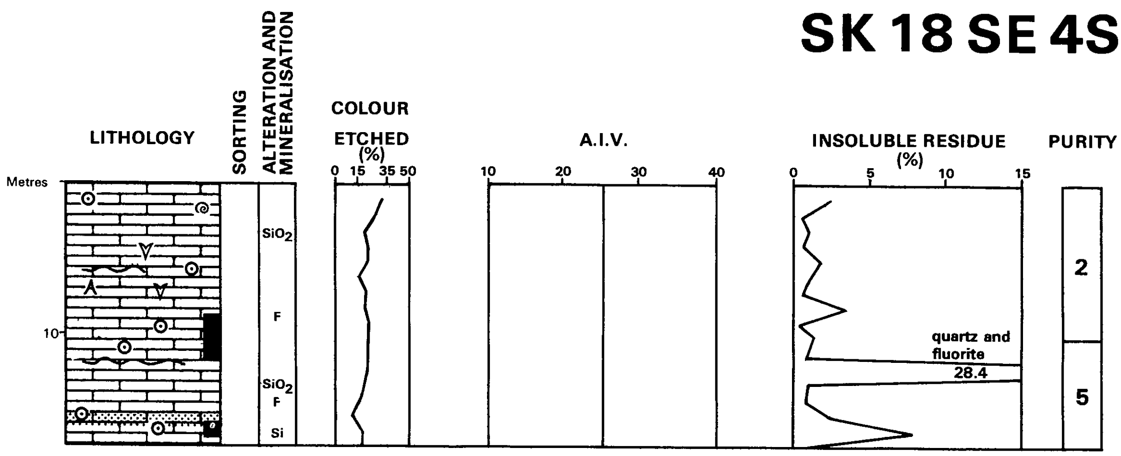
SK 18 SE 4 S Cave Dale (2)
Section sampled at 1511 8267

	Thickness m	Depth m
Apron-Reef Limestones		
Limestone (biomicrite), generally calcilutite with very shelly patches containing large crinoids, brachiopods, bryozoa, algal fragments and foraminifera; many irregular areas of radial calcite lining spar-filled 'voids', trace silicification throughout, locally abundant where associated with fluorite mineralisation; some bituminous material at 13 m	17.0	17.0

SK 18 SE 3S



SK 18 SE 4S



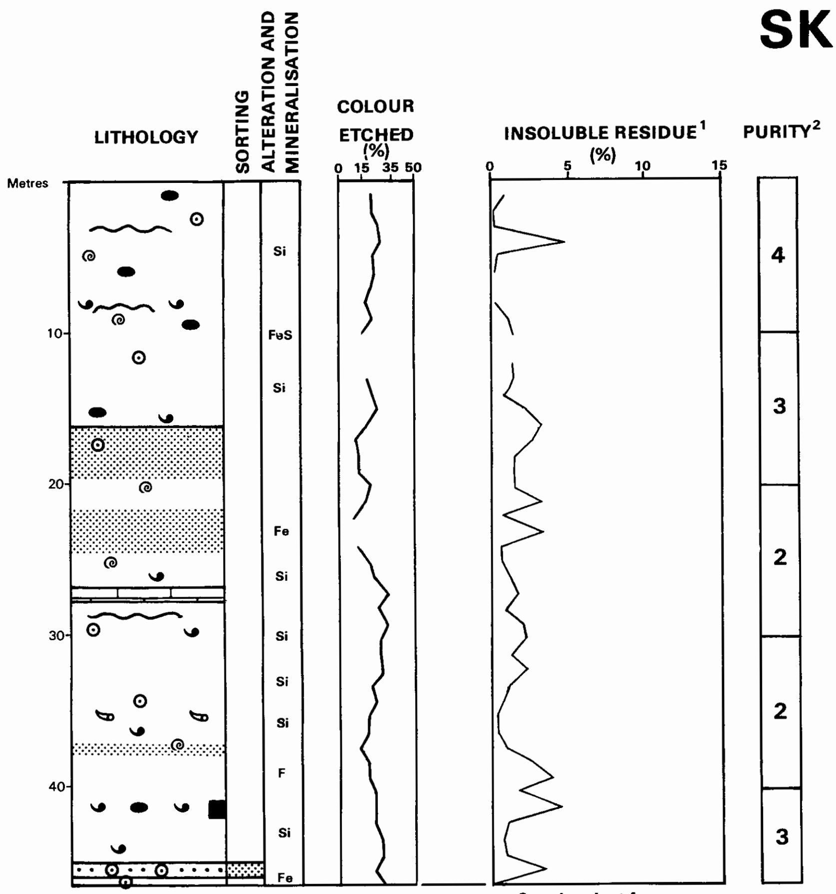
SK 27 NW 1 S   Shining Cliff
Section sampled from 2190 7588 (top) ato 2187 7583 (base)

	Thickness m	Depth m
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), poorly sorted medium and fine calcarenites; fine spar cement; large brachiopods scattered throughout; thin beds and nodules of chert (about 5 % of total rock); trace silicification, pyrite at 10 m	16.0	16.0
Biosparite, thicker bedded than above, moderately sorted medium and coarse calcarenites: many crinoids, brachiopods and foraminifera; coral band at 35 m brachiopods with chert nodules at 41 m, well sorted pelsparite at 45 m; some silicification throughout, generally chert free; trace of fluorite	30.0	46.0

SK 27 SW 1 S   Sallet Hole, Coombs Dale
Section sampled at 2210 7413

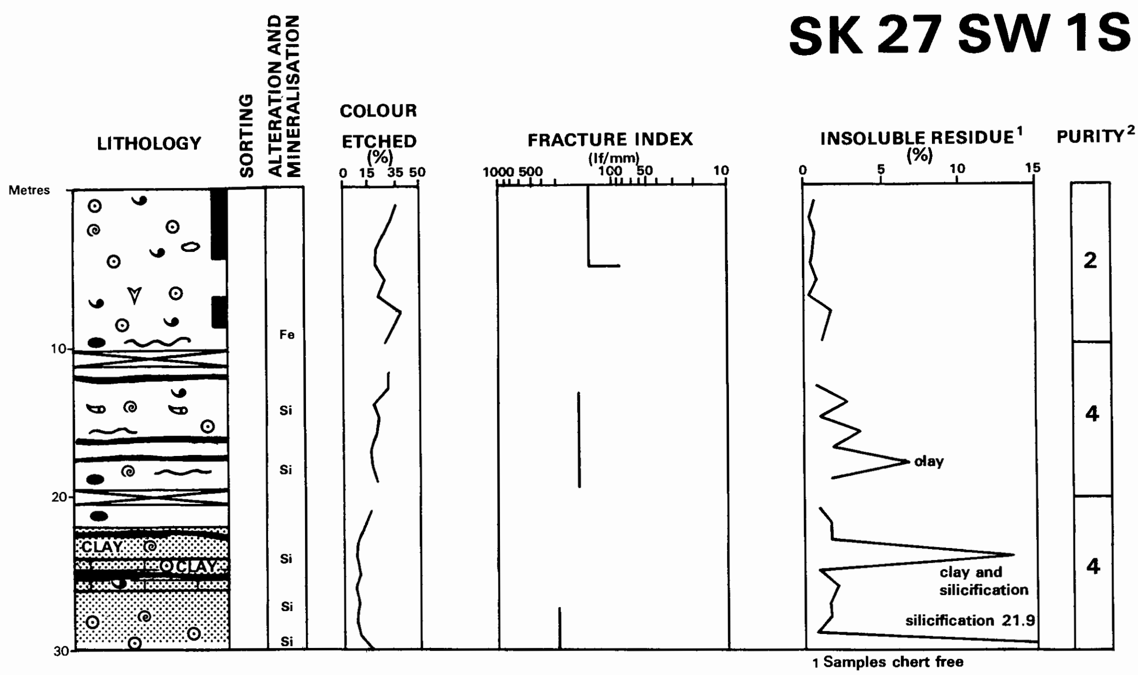
	Thickness m	Depth m
Monsal Dale Limestones (pale facies)		
Limestone (biosparite), thinly bedded calcarenites and calcirudites containing many crinoids and brachiopods; chert nodules at 10 m; trace silicification; stylolites near base	10.5	10.5
Gap. No exposure	1.0	11.5
Biosparite, thinly bedded medium and fine calcarenites; more foraminifera than above; coral bed 14-15 m; thin chert beds and nodules (about 5 % of total rock); some large silicified allochems; no exposure 19.5-20.5 m	10.5	22.0
Monsal Dale Limestones (dark facies)		
Limestone (biomicrosparite), poor exposure, dark grey, poorly sorted fine and medium calcarenites; fine spar and micrite matrix; much disseminated brown clay; chert nodules and beds throughout (about 5 % of total rock); some fine silicification	4.0	26.0
Biosparite, dark grey, thicker bedded than above, coarse crinoidal calcarenites; trace silicification throughout; disseminated clay in upper part; trace (?) dolomite at 27 m; no chert although base of sections is silicified	4.0	30.0

SK 27 NW 1S



1 Samples chert free
2 Purity adjusted to allow for chert recorded at outcrop

SK 27 SW 1S



1 Samples chert free
2 Purity adjusted to allow for chert recorded at outcrop

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 $\pm$	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

Borehole/section number and formation	Interval sampled (m)		Percentages by weight												Parts per million				
	Top	Base	CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As
SK 17 NW 7																			
Chee Tor Rock	1.5	5.5	54.88	43.17	1.27	0.30	0.37	0.07	0.27	0.02	0.27	0.01	0.01	0.00	5	0	10	150	
	7.5	15.5	55.36	43.40	0.66	0.29	0.20	0.04	0.18	0.02	0.25	0.02	0.01	0.00	5	0	10	110	
	15.5	20.5	55.50	43.36	0.57	0.30	0.18	0.05	0.07	0.02	0.24	0.03	0.01	0.00	5	0	10	110	
	20.5	25.5	55.20	43.15	0.67	0.32	0.21	0.06	0.04	0.03	0.22	0.01	0.01	0.00	5	0	10	120	
	25.5	30.5	55.14	43.04	0.85	0.34	0.23	0.06	0.04	0.02	0.18	0.01	0.01	0.00	5	0	10	120	
	30.5	37.5	55.57	43.50	0.68	0.34	0.14	0.04	0.04	0.03	0.15	0.03	0.01	0.01	5	0	10	140	0
	38.5	45.5	55.23	43.54	0.73	0.38	0.22	0.06	0.06	0.03	0.24	0.03	0.01	0.01	5	0	10	130	
	45.5	51.5	55.00	42.25	1.33	0.38	0.26	0.06	0.10	0.04	0.23	0.03	0.01	0.01	5	10	20	170	
SK 17 NW 9																			
Chee Tor Rock	10.5	20.5	55.02	43.41	0.57	0.29	0.13	0.03	0.04	0.03	0.03	0.02	0.01	0.00	0	0	0	250	
	20.5	30.5	54.63	43.74	0.49	0.52	0.16	0.05	0.06	0.05	0.11	0.02	0.01	0.01	5	0	10	280	
	30.5	40.5	55.05	43.71	0.40	0.38	0.17	0.04	0.07	0.05	0.06	0.02	0.01	0.00	5	0	10	250	
	40.5	50.5	55.00	43.37	0.33	0.30	0.14	0.04	0.04	0.02	0.02	0.01	0.01	0.00	0	0	0	130	
	50.5	60.5	52.83	42.75	1.31	0.48	0.41	0.08	0.04	0.05	0.47	0.03	0.01	0.00	0	0	0	190	
	60.5	70.5	54.90	43.45	0.53	0.36	0.14	0.03	0.04	0.03	0.06	0.02	0.01	0.00	5	0	0	170	
	70.5	80.5	54.68	43.66	0.47	0.39	0.13	0.03	0.04	0.04	0.06	0.02	0.01	0.00	0	0	0	150	0
	80.5	90.5	54.53	43.60	0.49	0.47	0.14	0.04	0.05	0.04	0.08	0.02	0.01	0.00	5	0	0	140	
Woo Dale Limestones	90.5	100.0	53.84	43.37	0.96	0.53	0.25	0.06	0.08	0.04	0.14	0.02	0.01	0.00	5	0	10	240	
SK 17 NW 10																			
Monsal Dale Limestones																			
dark facies	1.0	8.5	51.68	41.14	5.41	0.59	0.35	0.07	0.29	0.08	0.09	0.06	0.12	0.00	5	0	20	330	
	8.5	20.5	54.83	43.70	0.49	0.37	0.14	0.04	0.04	0.03	0.04	0.02	0.02	0.00	0	0	20	110	1
pale facies	20.5	30.5	55.04	43.53	0.33	0.30	0.11	0.03	0.03	0.03	0.01	0.02	0.02	0.00	0	0	20	100	
	30.5	40.5	54.86	43.51	0.49	0.33	0.10	0.03	0.04	0.04	0.00	0.02	0.01	0.00	5	0	20	100	
	40.5	50.5	54.66	43.22	0.84	0.35	0.11	0.03	0.04	0.04	0.00	0.01	0.01	0.00	0	0	20	220	
dark facies	50.5	58.5	53.24	42.24	1.68	0.62	0.43	0.09	0.50	0.04	0.65	0.03	0.02	0.00	0	0	60	320	
Miller's Dale Limestones																			
	66.5	70.5	53.71	43.01	1.36	0.32	0.15	0.04	0.42	0.03	0.01	0.01	0.01	0.00	5	0	40	1600	
	70.5	80.5	54.23	42.91	1.64	0.33	0.17	0.05	0.24	0.05	0.01	0.09	0.02	0.00	5	0	40	350	
	80.5	90.5	54.14	43.23	0.90	0.44	0.26	0.07	0.07	0.07	0.12	0.01	0.03	0.00	5	0	20	320	1
	90.5	100.0	54.43	43.12	1.42	0.29	0.18	0.04	0.06	0.05	0.01	0.00	0.01	0.00	5	0	20	170	

APPENDIX D: *continued*

Borehole/section number and formation	Interval sampled (m)		Percentages by weight												Parts per million				
	Top	Base	CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As
SK 17 NE 13																			
Monsal Dale Limestones	2.1	10.5	49.55	38.90	10.07	0.53	0.26	0.05	0.27	0.13	0.15	0.04	0.02	0.03	5	20	50	100	
dark facies	10.5	20.5	45.50	36.20	16.29	0.99	0.33	0.06	0.30	0.21	0.18	0.06	0.03	0.02	5	20	70	120	
	20.5	30.5	47.34	37.39	12.93	0.94	0.51	0.10	0.38	0.17	0.19	0.08	0.05	0.04	10	20	90	150	
	30.5	40.5	48.17	38.48	7.69	0.87	2.48	0.34	1.42	0.11	0.97	0.12	0.15	0.03	10	90	170	470	
pale facies	40.5	45.5	55.09	43.64	0.66	0.39	0.21	0.05	0.09	0.05	0.07	0.02	0.02	0.02	5	20	40	220	
	45.5	50.5	54.72	43.52	0.80	0.52	0.23	0.05	0.27	0.04	0.10	0.03	0.05	0.02	5	10	50	160	
	50.5	55.5	55.38	43.68	0.58	0.35	0.12	0.03	0.08	0.03	0.06	0.02	0.01	0.01	5	20	30	200	1
	55.5	61.2	55.33	43.76	0.46	0.29	0.09	0.03	0.08	0.03	0.04	0.09	0.02	0.01	5	70	40	220	
SK 17 NE 14																			
Eyam Limestones	1.5	10.5	49.41	38.42	9.72	0.49	0.35	0.06	0.33	0.09	0.30	0.04	0.33	0.02	0	0	320	450	
	10.5	20.5	51.76	40.80	5.68	0.41	0.21	0.04	0.05	0.06	0.21	0.05	0.05	0.01	0	0	40	310	
	20.5	30.5	52.06	41.66	4.73	0.48	0.16	0.04	0.04	0.07	0.18	0.03	0.04	0.01	0	10	80	190	
Monsal Dale Limestones																			
pale facies	30.5	40.5	53.28	42.18	2.82	0.30	0.25	0.05	0.09	0.03	0.31	0.06	0.09	0.01	5	0	300	280	
	40.5	52.5	52.13	40.87	5.54	0.30	0.15	0.04	0.04	0.07	0.07	0.04	0.04	0.01	5	0	40	280	
	52.5	60.5	54.43	43.33	0.80	0.38	0.23	0.05	0.03	0.03	0.15	0.02	0.03	0.01	5	0	20	240	
	60.5	70.5	54.81	43.57	0.36	0.29	0.11	0.03	0.03	0.03	0.08	0.03	0.03	0.01	5	0	230	310	
	70.5	80.5	54.53	43.36	0.58	0.34	0.15	0.04	0.03	0.03	0.12	0.02	0.03	0.01	0	0	60	400	
	80.5	90.5	54.64	43.65	0.52	0.37	0.12	0.04	0.02	0.02	0.12	0.02	0.02	0.01	0	0	20	470	2
	90.5	100.0	53.94	43.17	1.23	0.43	0.13	0.03	0.03	0.04	0.15	0.01	0.03	0.01	0	0	60	1600	
SK 17 SW 16																			
Monsal Dale Limestones	0.5	10.5	54.83	43.49	0.58	0.29	0.12	0.03	0.02	0.03	0.00	0.00	0.01	0.00	5	0	10	140	
	10.5	20.5	54.63	43.40	0.81	0.34	0.18	0.04	0.05	0.04	0.00	0.02	0.05	0.00	5	20	20	180	
	20.5	30.5	54.42	43.48	0.69	0.46	0.18	0.04	0.03	0.04	0.09	0.01	0.04	0.00	0	10	80	140	
	30.5	40.5	54.31	43.25	1.07	0.52	0.24	0.06	0.06	0.05	0.13	0.03	0.07	0.00	5	10	40	240	
	40.5	50.5	54.70	43.55	0.70	0.31	0.16	0.04	0.08	0.04	0.05	0.02	0.02	0.00	5	10	40	230	
	50.5	60.5	54.73	43.45	0.77	0.25	0.10	0.03	0.05	0.02	0.00	0.00	0.01	0.00	0	40	20	330	
	60.5	70.5	54.94	43.54	0.34	0.26	0.16	0.03	0.03	0.02	0.02	0.00	0.01	0.00	0	0	10	430	0

APPENDIX D: *continued*

Borehole/section number and formation	Interval sampled (m)		Percentages by weight												Parts per million				
	Top	Base	CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As
SK 17 SW 55																			
Miller's Dale Limestones	0.8	10.5	54.26	43.41	1.10	0.29	0.18	0.05	0.24	0.05	0.04	0.02	0.02	0.00	5	10	10	350	
Chee Tor Rock	18.5	30.5	55.32	43.57	0.48	0.32	0.14	0.04	0.03	0.03	0.04	0.04	0.01	0.02	0	0	0	270	1
	30.5	40.5	54.54	43.49	0.58	0.39	0.17	0.05	0.04	0.03	0.02	0.01	0.01	0.00	5	0	0	230	
	40.5	50.5	54.65	43.52	0.55	0.43	0.27	0.06	0.03	0.04	0.05	0.02	0.02	0.00	5	0	0	180	
	50.5	60.5	54.67	43.53	0.57	0.40	0.21	0.05	0.02	0.04	0.06	0.02	0.01	0.00	5	0	0	160	
	60.5	70.5	54.44	43.50	0.72	0.37	0.19	0.04	0.04	0.06	0.06	0.02	0.01	0.00	5	0	0	160	
	70.5	80.5	54.25	43.53	0.64	0.37	0.14	0.04	0.02	0.04	0.03	0.01	0.01	0.00	5	0	0	160	
	80.5	90.5	54.56	43.40	0.46	0.38	0.13	0.03	0.02	0.03	0.03	0.02	0.01	0.00	5	30	0	130	
	90.5	100.0	54.36	43.66	0.46	0.40	0.18	0.05	0.03	0.04	0.05	0.01	0.01	0.01	5	0	0	120	1
SK 17 SW 56																			
Chee Tor Rock	5.5	10.5	54.93	43.45	0.36	0.28	0.11	0.03	0.03	0.01	0.01	0.00	0.01	0.00	0	0	0	120	
	10.5	20.5	55.21	43.55	0.34	0.34	0.15	0.04	0.03	0.03	0.00	0.01	0.01	0.00	0	0	0	130	
	20.5	30.5	55.16	43.45	0.39	0.32	0.13	0.04	0.03	0.03	0.00	0.00	0.00	0.00	5	0	10	130	
	30.5	40.5	55.07	43.31	0.34	0.34	0.12	0.03	0.03	0.03	0.00	0.00	0.01	0.00	0	0	0	140	
	40.5	50.5	55.16	43.58	0.24	0.32	0.10	0.03	0.03	0.02	0.00	0.01	0.01	0.00	0	0	10	150	1
	50.5	60.5	54.80	43.55	0.57	0.39	0.15	0.05	0.05	0.02	0.00	0.02	0.01	0.00	0	0	20	160	
	60.5	70.5	55.05	43.63	0.37	0.38	0.10	0.03	0.03	0.01	0.01	0.01	0.01	0.00	5	0	10	120	
	70.5	77.5	54.93	43.65	0.26	0.29	0.09	0.04	0.03	0.01	0.00	0.00	0.01	0.00	0	0	10	160	
Woo Dale Limestones	77.5	83.5	55.02	43.70	0.19	0.42	0.08	0.02	0.03	0.01	0.03	0.01	0.01	0.00	0	0	20	140	
	83.5	89.5	54.93	43.91	0.13	0.53	0.09	0.02	0.03	0.01	0.09	0.01	0.01	0.01	0	0	20	120	1
	89.5	95.5	54.88	43.82	0.18	0.56	0.11	0.04	0.03	0.01	0.07	0.01	0.01	0.00	0	0	30	170	
	95.5	100.0	54.95	43.92	0.13	0.88	0.13	0.22	0.04	0.02	0.05	0.01	0.01	0.00	0	0	30	320	
SK 17 SE 12																			
Monsal Dale Limestones	3.5	14.5	50.57	40.10	7.67	0.49	0.16	0.03	0.06	0.11	0.08	0.04	0.03	0.01	20	10	40	180	
dark facies	23.5	40.5	47.07	38.00	12.30	1.42	0.18	0.04	0.04	0.15	0.12	0.08	0.02	0.02	5	10	10	190	
	40.5	50.5	45.77	38.23	12.03	2.29	0.50	0.09	0.04	0.15	0.43	0.10	0.04	0.03	20	0	40	160	
	50.5	60.5	46.13	38.81	10.98	2.26	0.72	0.13	0.04	0.15	0.54	0.09	0.05	0.02	30	0	20	210	
	60.5	70.5	46.57	38.53	10.66	1.54	1.28	0.24	0.09	0.16	0.86	0.12	0.10	0.03	5	0	20	400	
	70.5	80.5	46.25	38.50	11.47	1.93	0.66	0.13	0.03	0.17	0.56	0.06	0.06	0.03	0	0	40	400	
	80.5	90.5	47.62	40.12	8.64	2.03	0.56	0.11	0.03	0.14	0.54	0.06	0.07	0.03	0	10	60	220	

APPENDIX D: *continued*

Borehole/section number and formation	Interval sampled (m) Top	Base	Percentages by weight CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Parts per million Cu	Pb	Zn	MnO	As
SK 17 SE 13																			
Monsal Dale Limestones	0.6	10.5	52.14	41.12	5.15	0.45	0.25	0.06	0.10	0.09	0.10	0.03	0.09	0.01	5	10	70	210	
pale facies	10.5	20.5	53.93	42.97	2.12	0.41	0.14	0.04	0.03	0.06	0.08	0.03	0.02	0.01	5	0	30	150	
	20.5	30.5	54.50	43.37	1.51	0.35	0.13	0.04	0.04	0.05	0.06	0.09	0.01	0.01	5	0	50	210	
	30.5	40.5	53.82	42.76	2.50	0.37	0.17	0.04	0.06	0.07	0.06	0.04	0.02	0.02	5	0	60	200	
	40.5	50.5	47.81	36.64	12.58	0.46	0.43	0.08	0.08	0.13	0.22	0.07	0.04	0.01	5	0	90	250	
dark facies	50.5	60.5	50.11	39.67	8.32	0.62	0.41	0.09	0.10	0.11	0.28	0.06	0.05	0.03	5	10	90	170	
	60.5	66.5	49.56	39.27	8.19	0.75	0.66	0.13	0.05	0.13	0.64	0.07	0.13	0.02	5	20	100	240	
	66.5	72.8	52.49	41.85	3.15	1.16	0.55	0.11	0.59	0.09	0.60	0.05	0.08	0.03	5	0	80	590	
	76.5	83.5	54.39	43.33	1.11	0.49	0.21	0.05	0.07	0.05	0.17	0.01	0.02	0.01	5	10	20	270	
Miller's Dale Limestones	83.5	90.5	54.90	43.38	0.98	0.39	0.14	0.04	0.05	0.06	0.07	0.03	0.01	0.01	0	0	30	150	0
	90.5	100.0	54.46	43.22	1.34	0.48	0.20	0.05	0.07	0.07	0.15	0.06	0.03	0.02	5	0	50	220	
SK 17 SE 14																			
Monsal Dale Limestones	4.5	10.5	54.77	42.93	0.95	0.43	0.26	0.06	0.50	0.04	0.49	0.03	0.05	0.01	5	5	10	480	
pale facies	10.5	15.5	54.25	42.62	0.72	0.38	0.26	0.06	0.09	0.06	0.70	0.01	0.01	0.00	5	0	0	240	
	15.5	20.5	55.20	43.62	0.55	0.40	0.16	0.04	0.03	0.03	0.10	0.00	0.01	0.00	5	0	0	180	
Bee Low Limestones	20.5	25.5	55.54	43.83	0.23	0.32	0.08	0.02	0.01	0.02	0.03	0.04	0.01	0.00	5	0	0	110	
	25.5	30.5	55.33	43.73	0.52	0.37	0.13	0.03	0.02	0.05	0.03	0.02	0.01	0.00	0	0	0	120	
	30.5	35.5	55.38	43.86	0.32	0.49	0.13	0.03	0.03	0.04	0.05	0.02	0.01	0.00	0	0	0	140	0
	35.5	40.0	55.44	43.70	0.35	0.47	0.12	0.03	0.03	0.04	0.08	0.00	0.01	0.00	5	0	0	120	
SK 18 SW 47																			
Miller's Dale Limestone	1.0	5.5	55.02	43.50	0.71	0.45	0.22	0.06	0.04	0.04	0.09	0.02	0.01	0.01	5	0	20	100	
	5.5	10.5	54.90	43.54	0.64	0.39	0.23	0.05	0.05	0.04	0.08	0.00	0.01	0.01	5	0	20	110	
Chee Tor Rock	10.5	15.5	55.22	43.22	0.55	0.25	0.12	0.04	0.03	0.02	0.04	0.00	0.01	0.01	5	0	10	90	1
	15.5	20.5	55.44	43.53	0.20	0.25	0.10	0.03	0.04	0.02	0.04	0.00	0.01	0.00	0	0	10	90	
	20.5	25.5	55.65	43.12	0.37	0.29	0.12	0.04	0.03	0.03	0.03	0.00	0.00	0.00	5	0	10	90	
	25.5	30.5	55.84	43.39	0.22	0.27	0.12	0.04	0.04	0.02	0.06	0.01	0.01	0.00	5	0	10	130	
	30.5	35.5	55.78	43.44	0.19	0.26	0.13	0.04	0.03	0.02	0.12	0.02	0.00	0.00	0	0	10	110	
	35.5	40.5	55.61	43.43	0.39	0.29	0.18	0.05	0.03	0.01	0.14	0.00	0.00	0.00	5	0	10	90	
	40.5	45.5	55.20	43.36	0.93	0.34	0.19	0.05	0.10	0.03	0.20	0.01	0.01	0.01	5	0	10	130	
	45.5	50.5	55.97	43.62	0.39	0.28	0.10	0.04	0.06	0.02	0.32	0.02	0.01	0.01	0	0	10	100	
	50.5	55.5	56.10	43.59	0.30	0.30	0.10	0.03	0.03	0.03	0.24	0.03	0.01	0.00	5	0	10	110	
	55.5	59.0	55.89	43.37	0.41	0.29	0.10	0.03	0.03	0.02	0.19	0.02	0.01	0.00	5	0	10	110	

APPENDIX D: *continued*

Borehole/section number and formation	Interval sampled (m)		Percentages by weight												Parts per million				
	Top	Base	CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As
SK 18 SW 48																			
Woo Dale Limestones	2.5	8.5	55.38	43.52	0.01	0.32	0.08	0.02	0.04	0.01	0.17	0.01	0.02	0.00	5	0	10	210	
(Peak Forest	8.5	14.5	55.52	43.39	0.01	0.35	0.07	0.03	0.03	0.02	0.19	0.01	0.02	0.01	5	0	10	200	1
Limestones)	15.5	22.5	55.36	43.51	0.46	0.43	0.22	0.04	0.32	0.04	0.17	0.02	0.02	0.01	5	10	30	250	
	25.5	29.5	55.51	43.77	0.11	0.37	0.10	0.03	0.05	0.03	0.14	0.01	0.02	0.01	5	10	10	200	
	29.5	34.5	55.84	43.99	0.01	0.37	0.07	0.03	0.06	0.03	0.28	0.03	0.02	0.02	5	0	10	200	
	35.5	39.5	55.70	43.73	0.08	0.37	0.07	0.03	0.05	0.03	0.03	0.02	0.02	0.01	5	0	10	200	
	39.5	45.5	54.75	42.79	2.12	0.39	0.08	0.03	0.04	0.05	0.28	0.04	0.02	0.02	5	0	10	180	
	45.5	50.5	54.54	42.56	2.27	0.36	0.09	0.03	0.05	0.03	0.24	0.02	0.02	0.01	5	0	10	220	
	50.5	55.5	55.30	43.21	1.29	0.37	0.07	0.03	0.03	0.04	0.21	0.06	0.02	0.01	5	10	10	210	
	55.5	60.5	55.10	43.01	0.70	0.32	0.07	0.03	0.02	0.04	0.18	0.04	0.02	0.02	5	0	10	150	0
SK 18 SE 62																			
Monsal Dale Limestones																			
(pale facies)	0.5	10.5	52.88	41.67	4.15	0.27	0.18	0.04	0.04	0.05	0.04	0.03	0.04	0.00	5	0	10	300	
	10.5	20.5	50.18	39.51	8.13	0.33	0.28	0.06	0.03	0.07	0.09	0.02	0.07	0.01	5	0	20	260	
	20.5	30.5	51.60	40.33	6.92	0.27	0.14	0.03	0.02	0.07	0.03	0.04	0.04	0.00	5	0	20	170	
	30.5	40.5	52.35	41.41	4.69	0.28	0.12	0.03	0.03	0.05	0.02	0.08	0.01	0.01	5	0	20	160	
(dark facies)	40.5	50.5	49.34	38.92	10.17	0.42	0.20	0.04	0.05	0.09	0.04	0.02	0.03	0.01	5	0	20	210	
	50.5	60.5	46.23	36.61	16.09	0.41	0.17	0.04	0.04	0.13	0.06	0.04	0.03	0.01	5	0	20	120	
	60.5	70.5	51.35	40.93	5.55	0.61	0.43	0.09	0.03	0.07	0.01	0.08	0.13	0.02	5	0	40	250	
(pale facies)	70.5	80.5	54.57	43.53	0.68	0.34	0.13	0.04	0.04	0.01	0.06	0.02	0.03	0.01	0	0	20	120	
	80.5	90.5	54.61	43.51	0.62	0.31	0.11	0.03	0.04	0.02	0.03	0.03	0.02	0.00	0	0	20	130	1
	90.5	100.0	54.42	43.56	0.40	0.29	0.09	0.03	0.09	0.03	0.07	0.02	0.02	0.01	0	10	30	150	
SK 17 NW 1 S																			
Chee Tor Rock	0.5	10.5	55.32	43.66	0.53	0.44	0.17	0.04	0.04	0.03	0.02	0.02	0.01	0.02	5	0	0	100	
	10.5	17.5	55.30	43.81	0.39	0.48	0.14	0.04	0.03	0.04	0.03	0.01	0.01	0.02	0	0	0	100	
	17.5	26.5	55.45	43.66	0.38	0.41	0.10	0.03	0.02	0.02	0.04	0.02	0.01	0.00	5	10	0	130	
Woo Dale Limestones	26.5	31.5	55.50	43.71	0.50	0.46	0.13	0.04	0.03	0.02	0.04	0.02	0.01	0.02	5	0	0	120	
	31.5	36.5	55.61	43.92	0.24	0.48	0.08	0.02	0.02	0.03	0.03	0.01	0.01	0.00	0	0	10	120	1
	42.5	50.5	55.25	43.73	0.41	0.50	0.09	0.03	0.02	0.03	0.06	0.01	0.01	0.00	5	10	10	120	
	50.5	60.5	55.76	43.80	0.17	0.47	0.07	0.02	0.01	0.02	0.04	0.02	0.01	0.00	0	0	0	110	
	60.5	70.5	55.72	43.83	0.24	0.44	0.11	0.03	0.03	0.01	0.05	0.02	0.01	0.00	5	0	10	210	
	70.5	79.5	56.00	43.77	0.14	0.38	0.09	0.03	0.02	0.01	0.03	0.01	0.01	0.00	5	0	0	170	

APPENDIX D: *continued*

Borehole/section number and formation	Interval sampled (m)		Percentages by weight												Parts per million				
	Top	Base	CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As
SK 17 NW 2 S																			
Chee Tor Rock	0.5	10.5	55.47	43.86	0.29	0.40	0.11	0.03	0.04	0.03	0.03	0.02	0.01	0.01	5	0	0	100	
	11.5	16.8	55.56	43.95	0.16	0.50	0.08	0.02	0.02	0.03	0.06	0.01	0.00	0.00	0	0	0	60	
	19.5	29.5	55.39	43.90	0.26	0.46	0.09	0.02	0.03	0.02	0.04	0.02	0.00	0.00	0	0	0	80	1
	29.5	35.5	55.71	43.65	0.53	0.41	0.12	0.03	0.03	0.03	0.02	0.01	0.00	0.00	5	0	0	70	
	38.5	42.5	55.71	43.69	0.56	0.39	0.09	0.02	0.02	0.01	0.02	0.03	0.00	0.00	5	0	0	70	
Woo Dale Limestones	42.5	50.5	55.86	43.68	0.55	0.39	0.09	0.03	0.02	0.02	0.02	0.03	0.00	0.00	0	0	0	80	
	50.5	58.5	55.84	43.96	0.12	0.46	0.06	0.02	0.01	0.01	0.04	0.02	0.00	0.00	5	0	0	100	
SK 17 NW 3 S																			
Chee Tor Rock	0.5	8.5	55.50	43.75	0.57	0.47	0.15	0.04	0.05	0.03	0.04	0.03	0.01	0.00	5	0	10	140	
Woo Dale Limestones	8.5	13.5	55.45	44.00	0.20	0.62	0.11	0.03	0.03	0.03	0.09	0.03	0.00	0.00	5	0	10	130	3
SK 17 SW 1 S																			
Woo Dale Limestones	0.5	10.5	55.21	43.61	0.32	0.51	0.08	0.02	0.02	0.01	0.06	0.01	0.01	0.00	5	10	0	80	
	10.5	20.5	55.75	43.76	0.09	0.43	0.12	0.03	0.04	0.02	0.05	0.02	0.01	0.00	0	0	0	160	
	20.5	30.5	55.43	43.82	0.04	0.47	0.10	0.03	0.03	0.02	0.04	0.00	0.01	0.00	5	0	20	230	0
	30.5	40.5	55.39	43.63	0.12	0.53	0.08	0.02	0.02	0.01	0.07	0.00	0.01	0.00	0	0	0	120	
	40.5	47.5	55.74	43.34	0.08	0.41	0.07	0.02	0.04	0.02	0.02	0.01	0.01	0.00	0	0	0	210	
	49.5	58.5	55.92	43.54	0.04	0.44	0.07	0.03	0.01	0.02	0.04	0.01	0.01	0.01	0	0	0	80	
SK 17 SW 2 S																			
Monsal Dale Limestones (dark)	0.5	7.5	54.20	42.91	2.65	0.61	0.09	0.03	0.03	0.05	0.10	0.02	0.01	0.00	5	10	40	250	
Miller's Dale Limestones																			
	7.5	15.5	55.20	43.66	0.73	0.36	0.16	0.04	0.04	0.02	0.10	0.02	0.01	0.00	5	0	20	150	1
	15.5	20.5	55.13	43.47	0.85	0.34	0.11	0.03	0.04	0.02	0.03	0.01	0.01	0.00	5	0	15	140	
	20.5	28.5	54.71	42.73	1.87	0.43	0.33	0.08	0.06	0.04	0.23	0.02	0.02	0.00	5	0	10	160	
	29.5	35.5	54.92	43.42	1.09	0.54	0.23	0.05	0.29	0.06	0.21	0.03	0.01	0.01	15	0	30	110	
	48.5	54.5	55.43	43.53	0.80	0.37	0.15	0.04	0.04	0.01	0.02	0.02	0.01	0.00	5	0	0	190	
	54.5	59.5	55.18	43.42	0.87	0.39	0.22	0.06	0.09	0.03	0.13	0.02	0.01	0.00	10	0	0	490	
SK 17 SW 3 S																			
Miller's Dale Limestones																			
	0.5	6.5	55.18	43.67	0.57	0.37	0.17	0.04	0.03	0.03	0.03	0.01	0.01	0.00	5	10	10	180	
	6.5	12.5	55.61	43.83	0.31	0.27	0.09	0.03	0.02	0.02	0.02	0.01	0.01	0.00	5	0	0	150	0
	12.5	18.5	56.00	43.71	0.33	0.27	0.10	0.04	0.02	0.03	0.01	0.02	0.01	0.02	5	0	0	130	

APPENDIX D: *continued*

Borehole/section number and formation	Interval sampled (m)		Percentages by weight													Parts per million				
	Top	Base	CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Cu	Pb	Zn	MnO	As
SK 18 SW 1 S																			
Apron-reef limestones	0.5	5.5	55.70	43.94	0.12	0.41	0.09	0.03	0.03	0.02	0.03	0.02	0.05	0.01	5	0	20	220	0
	5.5	10.5	55.51	43.88	0.15	0.42	0.11	0.03	0.03	0.01	0.02	0.01	0.07	0.00	5	0	20	250	
SK 18 SW 2 S																			
Apron-reef limestones	0.5	8.5	55.44	43.72	0.25	0.39	0.12	0.03	0.03	0.02	0.03	0.03	0.25	0.00	5	0	20	290	
	10.5	15.5	55.63	43.85	0.29	0.33	0.08	0.02	0.02	0.01	0.02	0.01	0.06	0.00	5	0	20	260	
	15.5	20.5	55.89	43.85	0.02	0.38	0.07	0.02	0.02	0.01	0.03	0.03	0.07	0.00	5	0	10	260	
	20.5	27.5	55.64	44.00	0.07	0.37	0.09	0.02	0.03	0.00	0.03	0.00	0.05	0.00	5	0	10	300	0
SK 18 SW 3 S																			
Bee Low Limestones	0.5	5.5	55.91	43.47	0.21	0.26	0.10	0.04	0.03	0.01	0.00	0.01	0.01	0.00	0	10	0	220	
	5.5	10.5	55.84	43.33	0.44	0.27	0.11	0.03	0.01	0.02	0.01	0.02	0.05	0.00	0	0	0	90	
	10.5	15.5	55.81	44.00	0.32	0.27	0.11	0.03	0.02	0.00	0.01	0.01	0.01	0.00	0	10	10	120	1
	15.5	20.5	55.31	43.52	0.69	0.36	0.17	0.04	0.03	0.03	0.01	0.01	0.01	0.00	5	10	10	120	
	20.5	25.5	55.92	43.62	0.21	0.29	0.12	0.03	0.03	0.01	0.03	0.01	0.01	0.00	5	0	10	140	
	25.5	30.5	55.95	43.69	0.28	0.33	0.16	0.04	0.09	0.01	0.03	0.01	0.01	0.01	10	10	20	150	
	30.5	37.5	55.02	43.47	0.68	0.33	0.14	0.03	0.03	0.02	0.02	0.00	0.01	0.00	5	0	10	140	
SK 18 SE 1 S																			
Eyam Limestones																			
(flat reef)	0.5	6.5	53.87	42.33	3.21	0.24	0.13	0.03	0.05	0.00	0.01	0.05	0.13	0.00	5	0	10	300	
	6.5	12.5	54.61	42.65	2.24	0.24	0.10	0.02	0.03	0.01	0.02	0.01	0.14	0.00	5	0	10	330	
SK 18 SE 2 S																			
Monsal Dale Limestones																			
(pale facies)	4.5	10.5	50.99	39.61	9.17	0.32	0.15	0.04	0.08	0.08	0.02	0.04	0.04	0.01	5	30	30	280	
	10.5	18.5	52.59	41.23	5.48	0.29	0.14	0.03	0.08	0.05	0.00	0.01	0.05	0.00	5	20	40	430	
	18.5	24.5	54.82	42.79	1.73	0.39	0.15	0.04	0.06	0.01	0.14	0.02	0.18	0.02	5	0	30	370	
	24.5	30.5	54.63	42.67	1.91	0.38	0.24	0.05	0.38	0.03	0.08	0.11	0.25	0.01	5	20	110	480	
	30.5	35.5	53.54	42.11	3.62	0.39	0.14	0.03	0.09	0.04	0.04	0.01	0.04	0.00	5	10	30	550	
Bee Low Limestones	35.5	40.5	54.91	43.40	0.64	0.45	0.20	0.05	0.28	0.03	0.12	0.02	0.08	0.00	5	10	20	570	
	40.5	48.5	55.25	43.33	0.82	0.41	0.23	0.06	0.28	0.03	0.13	0.02	0.02	0.00	5	0	10	300	

APPENDIX D: *continued*

Borehole/section number and formation	Interval sampled (m) Top	Base	Percentages by weight CaO	loss at 1050°c	SiO_2	MgO	Al_2O_3	K_2O	Fe_2O_3	SrO	SO_3	F	P_2O_5	Na_2O	Parts per million Cu	Pb	Zn	MnO	As
SK 18 SE 3 S																			
Apron-reef limestones	14.5	20.5	55.36	43.69	0.46	0.33	0.10	0.03	0.04	0.00	0.01	0.01	0.11	0.00	5	5	10	300	
	20.5	27.5	55.46	43.42	0.36	0.35	0.09	0.03	0.04	0.02	0.02	0.02	0.07	0.00	5	0	30	440	
Bee Low Limestones	27.5	35.5	55.41	43.51	0.28	0.35	0.13	0.04	0.04	0.00	0.03	0.04	0.36	0.00	5	10	30	370	
Apron-reef limestones	35.5	40.5	55.76	43.61	0.40	0.32	0.09	0.03	0.04	0.01	0.01	0.02	0.05	0.00	5	0	10	230	1
	40.5	45.5	55.29	43.49	0.95	0.32	0.08	0.02	0.02	0.02	0.02	0.01	0.04	0.00	5	5	10	330	
Bee Low Limestones	45.5	50.0	55.34	42.96	0.43	0.38	0.18	0.05	0.05	0.02	0.03	0.12	0.65	0.00	5	20	40	480	
SK 18 SE 4 S																			
Apron-reef limestones	0.5	9.5	55.58	43.63	0.55	0.38	0.10	0.03	0.05	0.00	0.06	0.13	0.12	0.00	5	0	30	470	
	9.5	17.5	55.16	41.88	1.27	0.44	0.11	0.03	0.05	0.00	0.10	1.24	0.10	0.00	5	10	300	500	
SK 27 NW 1 S																			
Monsal Dale Limestones (pale facies)	16.5	20.5	54.74	43.14	1.13	0.43	0.26	0.06	0.08	0.03	0.17	0.03	0.20	0.03	5	30	50	260	
	20.5	25.5	54.60	42.93	1.64	0.39	0.14	0.02	0.03	0.03	0.20	0.06	0.03	0.00	5	20	30	230	
	25.5	30.5	54.65	43.03	1.93	0.32	0.10	0.04	0.02	0.02	0.05	0.00	0.02	0.03	5	10	10	210	
	30.5	35.5	55.45	43.54	0.95	0.33	0.07	0.02	0.02	0.02	0.03	0.03	0.01	0.00	0	20	10	160	0
	35.5	40.5	54.98	43.36	1.57	0.36	0.10	0.02	0.02	0.02	0.04	0.03	0.01	0.00	5	0	10	190	
	40.5	46.5	55.26	43.57	0.87	0.31	0.09	0.02	0.05	0.01	0.05	0.08	0.01	0.00	5	20	20	170	

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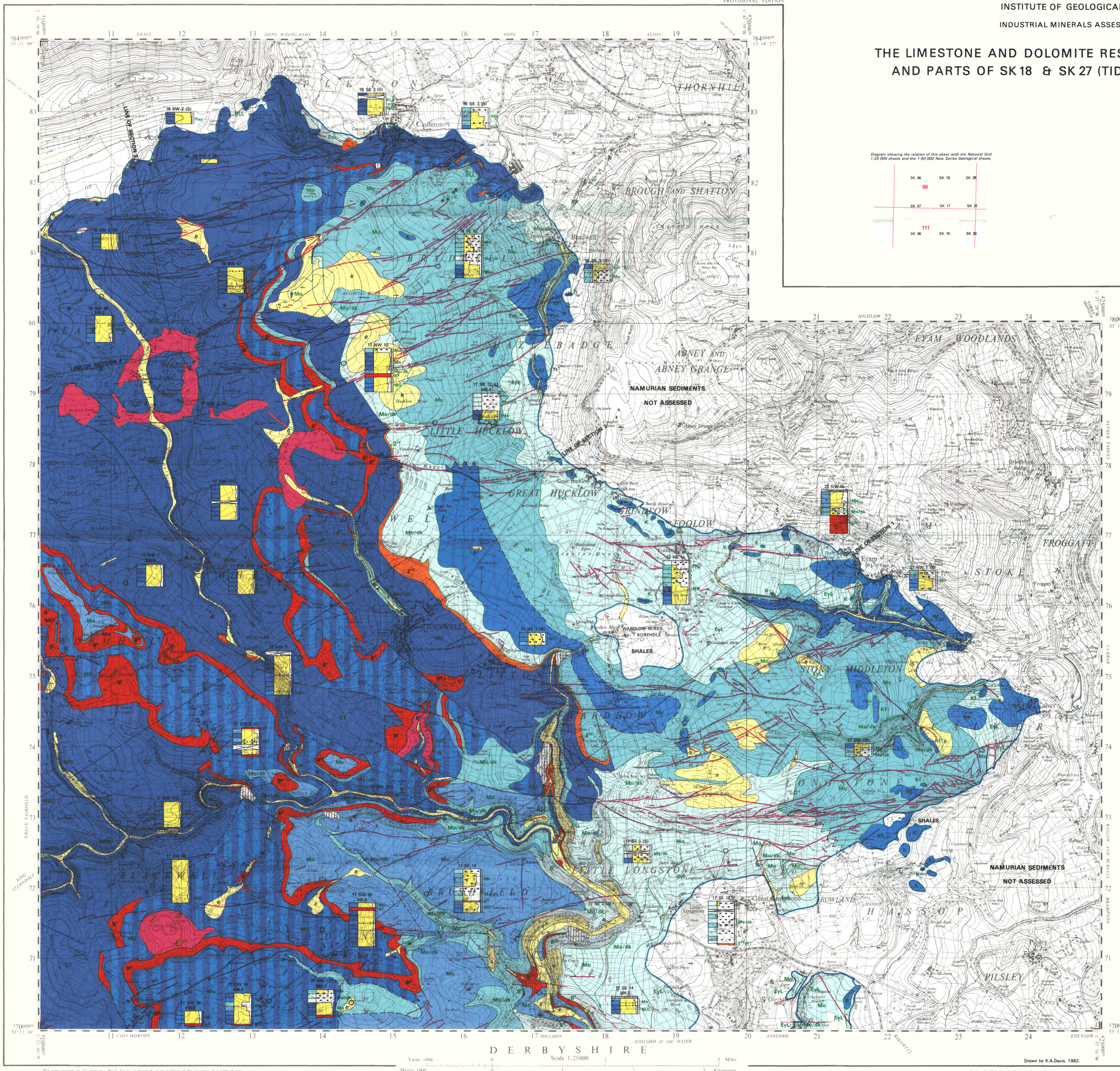

INSTITUTE OF GEOLOGICAL SCIENCES

INDUSTRIAL MINERALS ASSESSMENT UNIT

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

EXPLANATION OF SYMBOLS AND ABBREVIATIONS

Shades of blue on the face of the map are used to indicate regional variation in limestone purity at the surface; at data points the purity is shown averaged over 10m intervals.

CATEGORIES OF ROCK

LIMESTONE

		Composition (%CaCO₃)	
Very high purity	CAT-L9	>98.5	
High purity	CAT-L18	97.0-98.5	
Medium purity	CAT-L19	93.5-97.0	
Low purity	CAT-L20	85.0-93.5	
Impure	CAT-L21	<85.0	
Intermixed very high and high purity		>97.0	CAT-L22

Interbedded dolomite and limestone DOL-4

IGNEOUS ROCKS

- Basalt IGR-2
- Tuff IGR-3
- Dolerite IGR-4
- Agglomerate IGR-5

DRIFT

- Alluvium
- Head
- Peat IGNORE DRIFT
- Scree
- Till

LANDSLIP L-1

CAPTURE ✓

BOUNDARY LINES

- ✓ Boundary between categories for boundaries not coincident with geological boundaries
- ✓ Geological boundary, Solid (broken lines on horizontal sections denote uncertainty) (CAPTURE ONLY WHERE CATEGORY BOUNDARY ("Category + Geo Bdy"))
- Geological boundary, Drift
- ✓ Boundary of assessed area

STRUCTURAL SYMBOLS

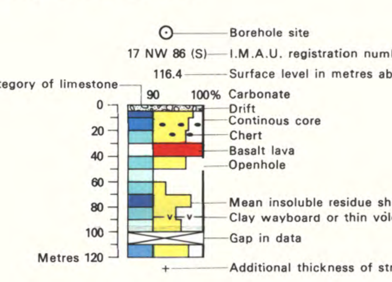
- Inclined strata, dip in degrees
- Anticlinal axis
- ✓ Fault at surface, crossmark indicates downthrow side
- ✓ Mineral vein, where veins are also faults crossmark indicates downthrow side.
- ✓ Pipe vein
- ✓ Mineral flat

BOREHOLE AND SECTION DATA

SITE LOCATIONS

- Industrial Minerals Assessment Unit (I.M.A.U.) boreholes
- Other boreholes
- Collected section (bracket indicates limits)
- Additional collected section

FORMAT (fictitious example)



Detailed records may be consulted on application to the Head of the Industrial Minerals Assessment Unit, Institute of Geological Sciences, Keyworth, Nottingham.

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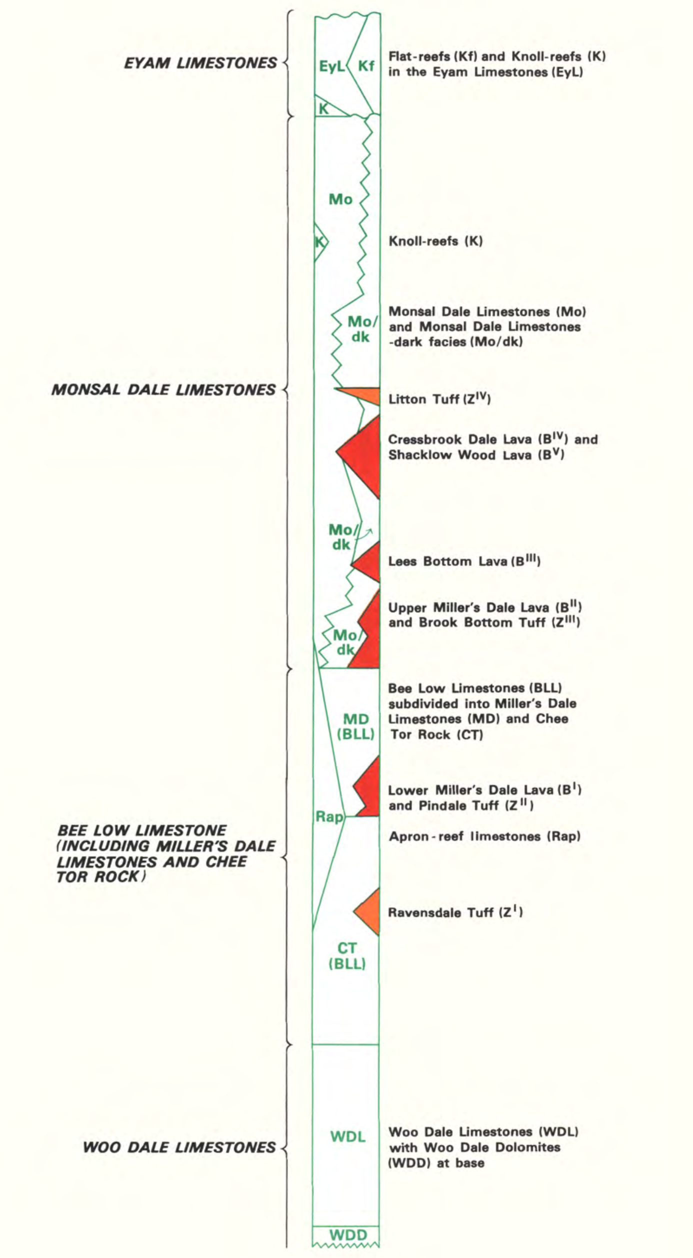
GENERALISED VERTICAL SECTION AND EXPLANATION OF STRATIGRAPHICAL SYMBOLS

Scale 1:2 000 (1cm to 20 m)



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1100/82

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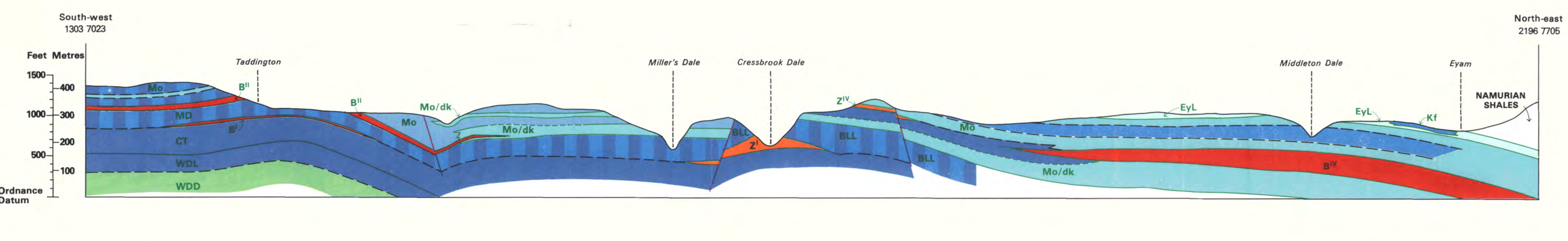
HORIZONTAL SECTIONS SHOWING GENERALISED LIMESTONE CATEGORIES AT DEPTH

SECTION 1



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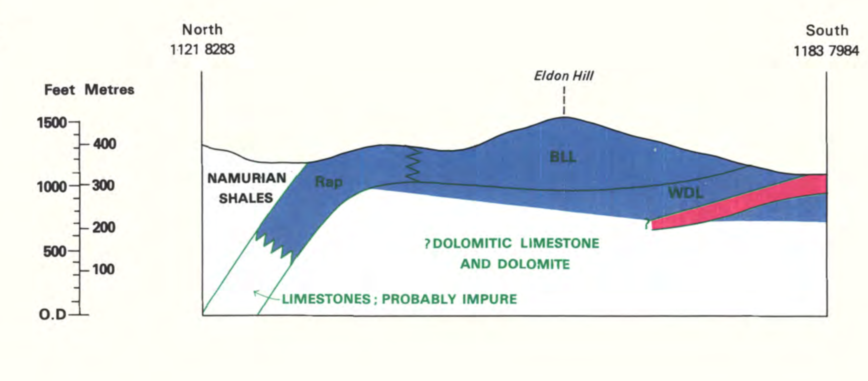

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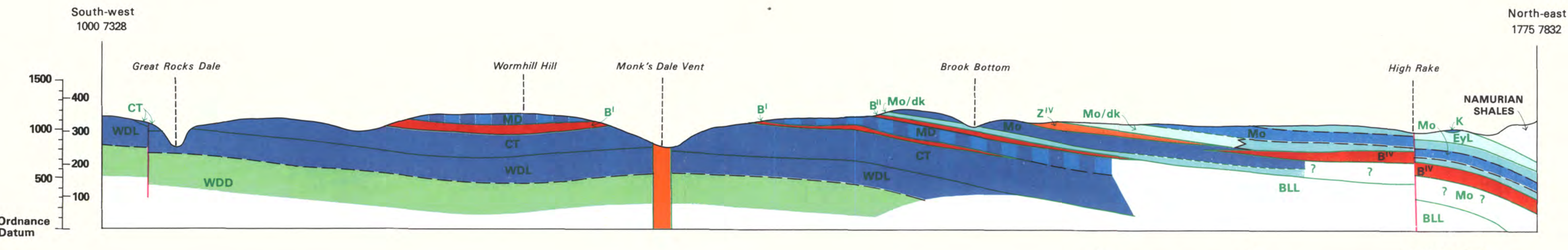

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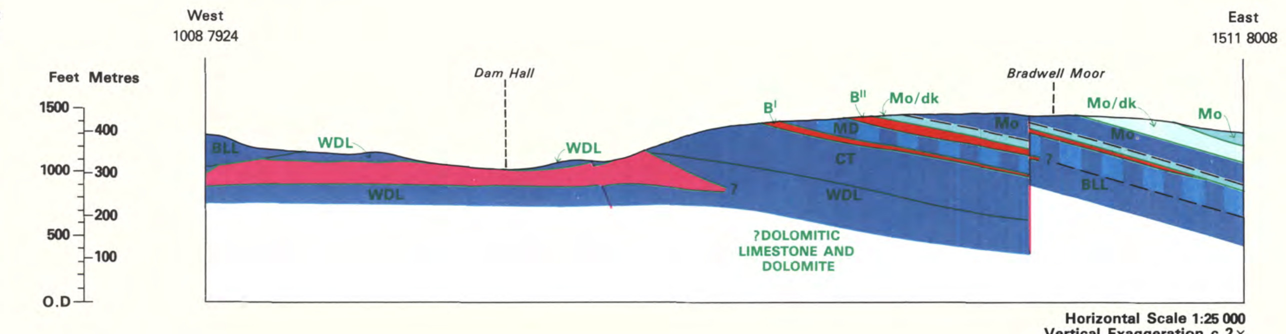

2 KILOMETRES
7000 FEET

Horizontal Scale 1:25 000
Vertical Exaggeration c.2×