KARSTIC SEDIMENTS, RESIDUAL AND ALLUVIAL ORE DEPOSITS OF THE PEAK DISTRICT OF DERBYSHIRE

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Leicester.

Statement

The accompanying thesis submitted for the degree of Ph.D. entitled Karstic Sediments, Residual and Alluvial Ore Deposits of the Peak District of Derbyshire is based on work conducted by the author in the Department of Geology of the University of Leicester mainly during the period between 1st. October 1979 and 1st. October 1982.

All the work recorded in this thesis is original unless otherwise acknowledged in the text or by references. None of the work has been submitted for another degree in this or any other university.

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Abstract

Detailed sedimentological studies of both surface and underground karstic sediments from the Peak District have been undertaken.

Mineralogical examination shows that the allochthonous fraction of the sediments have been derived mainly from the Namurian strata which surround, and once overlay, the area. The remainder of the allochthonous fraction has been derived from the Triassic sediments to the south of the area and from superficial loess deposits, many of which were introduced into the area during the Devensian Glaciation.

Many of the deposits contain an autochthonous fraction consisting variably of chert, authigenic quartz, limestone and dolomite, fluorite, baryte, calcite and galena clasts released from the host rocks by phreatic solution and having suffered only limited transport.

Scanning electron microscope (S.E.M.) studies of quartz grain surface textures show that many of the allochthonous sediments have been transported under fluvio-glacial conditions.

A number of sedimentary accumulations in isolated cavities consist of reworked loessic silt which has been carried underground via joints by the mechanism of translatory flow.

Palaeomagnetic studies of sediments in the Matlock area show that they consistently have a reversed remanent magnetism which may indicate that these fluvio-glacial sediments have an age in excess of 690,000 years b.p.

The "ore" fraction of some of the deposits studied may form important sources of fluorspar when other, larger and more easily worked, deposits have been worked out, if the dressing problems can be overcome.

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1. INTRODUCTION

1.1. Aims of the Project

As originally conceived the project was concerned with the study of residual fluorite, baryte and galena deposits in karstic cavities of the Peak District and their evaluation as possible sources of fluorspar.

Once the project had started it was found that the number of "ore" bearing deposits available for study was very limited so the project evolved into a regional study of karstic sediments throughout the Peak District with special reference to residual and alluvial ore deposits. This study would establish which sediments were present in the Peak District karst, where they were derived from and how they were derived. With this information a relative chronology for the sediments, and possibly the caves in which they occur, could be established.

There still remains considerable scope for detailed studies of the sediments in individual caves or whole underground drainage systems especially in the Castleton and Eyam areas.

Towards the end of the project in an attempt to date some of these sediments pilot palaeomagnetic studies were carried out. This work has proved to be exceedingly useful and there is considerable potential for further work in this field.

1.2. Location of the Study Area

The Peak District of Derbyshire is an upland region in central northern England lying at the southern end of the Pennine Hills (fig. 1.2.1.). It ranges in altitude from above 260 metres in the south around Brassington to over 600 metres in the north around Kinderscout. Being an area of outstanding natural beauty and much visited by the populace of the surrounding conurbations the Peak District became one of Britains first national parks in 1951.

1.3. Regional Geology

The Pennines, extending from the Scottish border to the Peak District are a range of broadly uplifted Carboniferous rocks, composed of limestones overlain by shales and sandstones, flanked to the east and west by the Upper Carboniferous Coal Measures (Edwards and Trotter, 1954). These are unconformably overlain by Permian and Triassic strata with a generally more gentle easterly inclination (Edwards and Trotter, 1954) (Fig. 1.3.1.).

1.4. Geographical Setting

The Peak District is geographically divided into to areas, the Dark Peak to the north developed on the Namurian (Millstone Grit series) shales and sandstones and the White Peak to the south developed on the Dinantian (Lower Carboniferous) limestones.

Two rivers permanently flow across the limestone

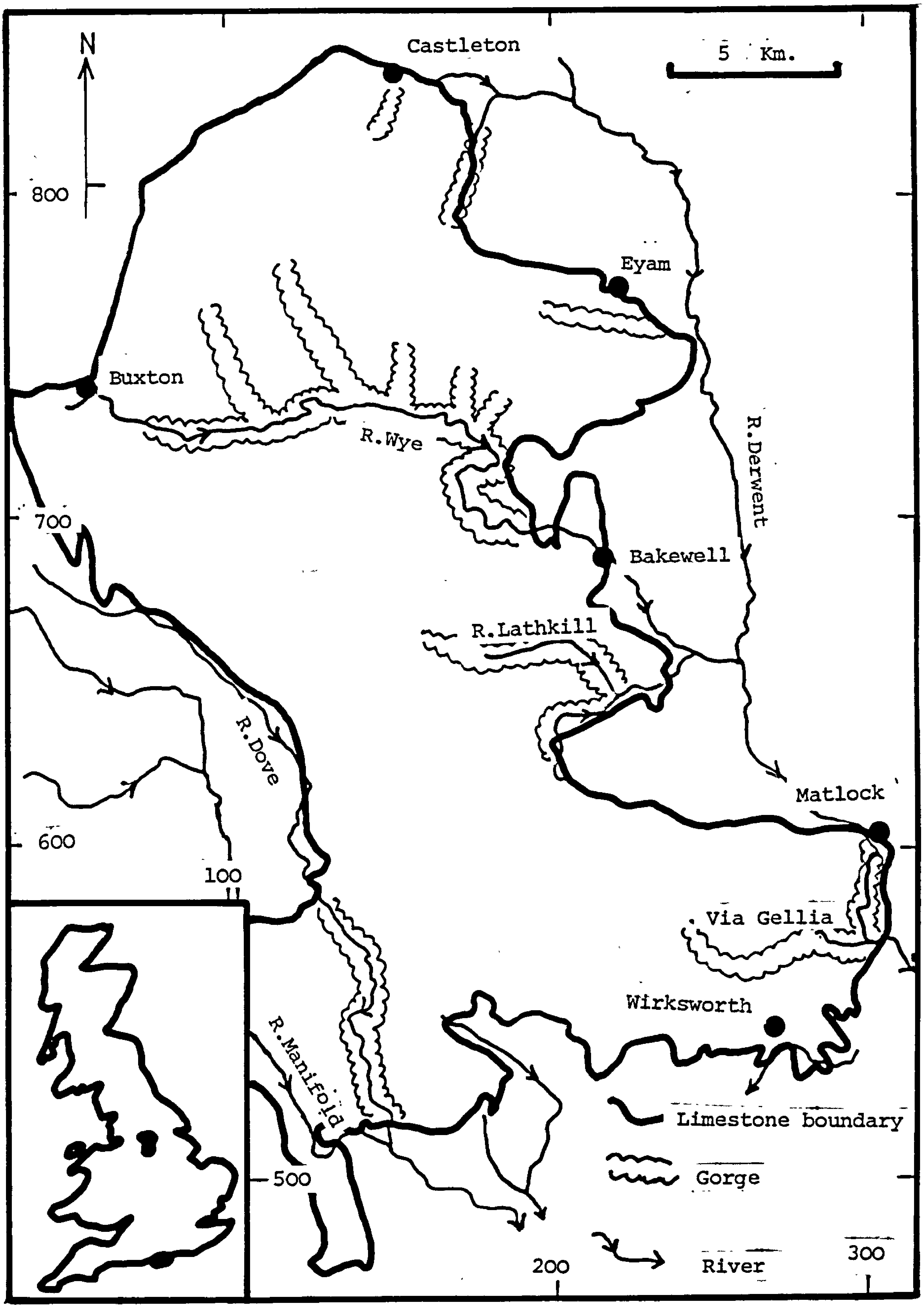


Figure 1.2.1. Physical features of the Peak District.

Figure 1.3.1. Regional geology, after Edwards and Trotter (1954).

outcrop, the Wye from Buxton to Bakewell and the Dove from near Hartington to Ilam (fig. 1.2.1.). The Derwent, which takes most of the limestone drainage to the Trent, traverses the gritstone country to the east, crossing the limestones for only a short distance between Matlock and Cromford. Other major rivers, which flow underground during dry periods, are the Lathkill, Bradford and Manifold. The remainder of the area is normally devoid of surface drainage despite an average annual rainfall of between 35 to 50 inches (Edmunds, 1971).

These rivers, particularly the Derwent and the Wye, cross the limestone in a manner unrelated to its structure. This is regarded as the result of superimposition from overlying strata now removed (Fearnsides, 1932, Linton, 1951, Walsh et al, 1972). Superimposition does not entirely explain the formation of the Matlock Gorge of the Derwent nor a number of other similar gorges.These may have been formed when the mechanism of unilateral shiftdown the limestone dip slope was prevented by reef knolls leading to vertical incision (Ford and Burek, 1976).

The area is traversed by a complex system of dry valleys related to the present river system (Warwick, 1964). It is likely that these valleys formed under periglacial conditions when surface drainage could occur while the limestones were frozen and thus impermeable (Burek, 1977a).

Where allogenic streams flow onto the limestones they are soon engulfed by swallets. These are depressions down which streams sink into the limestone. They are formed by the dissolution of the limestone and may lead to accessible cave systems or may be choked by boulders. Much of the limestone plateau is extensively pitted with dolines many of which represent former swallets. After abandonment most were filled with re-worked loess and other glacial and/or periglacial sediment (Beck, 1980).

1.5. Geology of the Peak District

1.5.1. Carboniferous Limestone

The oldest exposed rocks of the Peak District are the Dinantian Limestones which are developed to a total thickness of over 2000 metres. Approximately 500 metres at the top of the succession is exposed (Mason, 1974). The limestones rest unconformably on a basement of Late PreCambrian and Lower Palaeozoic sediments (Evans and Maroof, 1976). Two boreholes have penetrated this basement. At Eyam they were proved to be mudstones of Ordovician age (Dunham, 1973) while at Woodale the borehole entered dacitic volcanics of questionable age, probably late Precambrian or Lower Palaeozoic (Cope, 1949 and 1973).

The facies of the limestones are highly variable ranging from shaly basinal limestones through reef limestones to massive bedded limestones (Smith et al, 1967, Stevenson and Gaunt, 1971, Ford, 1977, Worley, 1978 and Frost and Smart, 1979). During deposition the area was a stable block surrounded by subsiding basins (Butcher, 1976). The facies of the basin type limestones are well exposed at Ecton, Staffordshire and consist of thinly bedded limestones with shale layers (Critchley, 1979). The margins of the stable block are characterised by extensive algal reefs, as at Treak

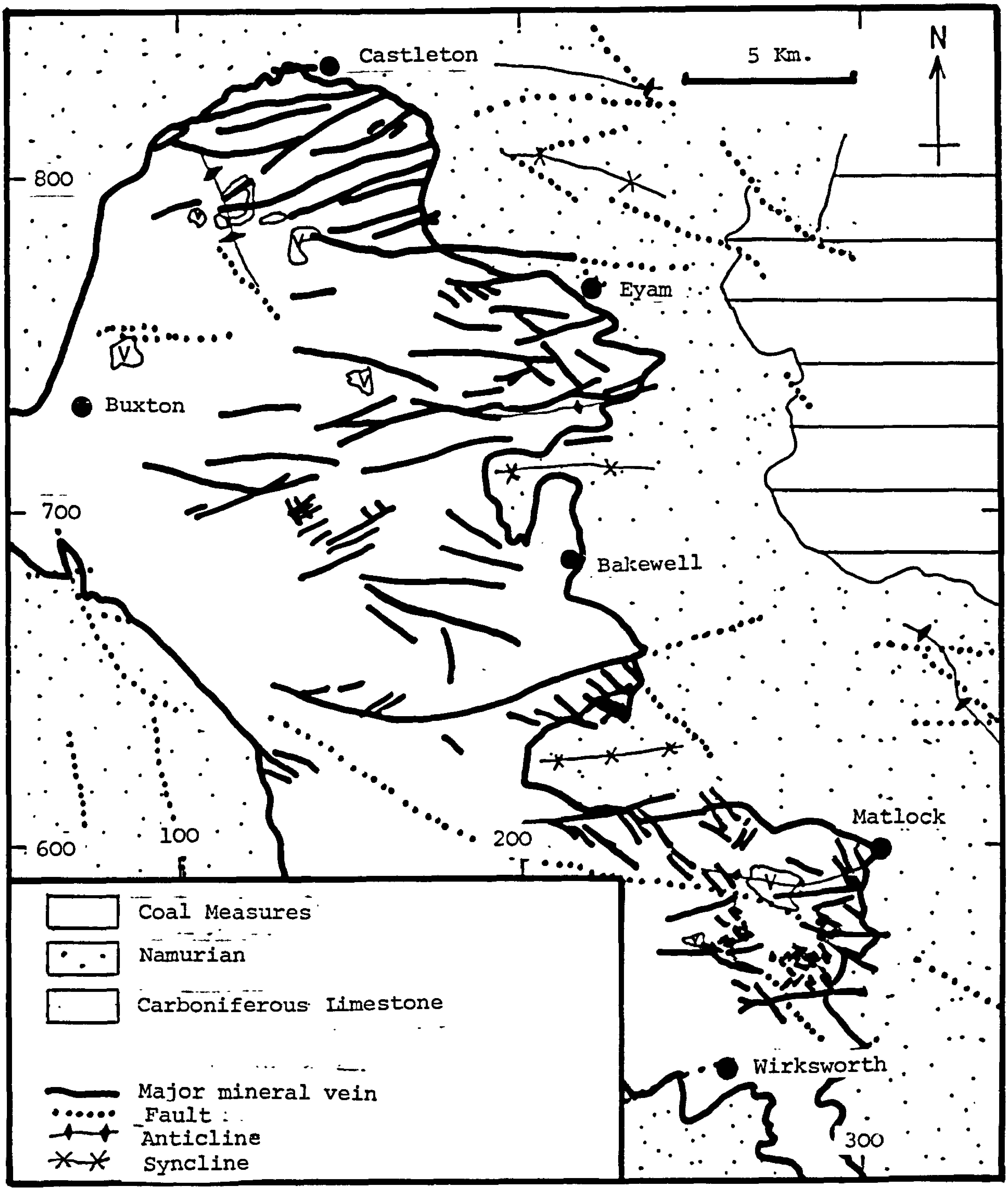


Figure 1.5.1. General geology of the Peak District, After Mason (1974).

Cliff, Castleton and High Tor, Matlock (Biggins, 1969).

The shallow water facies are massive, varied, usually bioclastic limestones varying from pale grey to dark grey bituminous limestones (Ford, 1967).

Silicification of the limestones is widespread throughout the Peak District (Orme, 1974). Three main forms of silica occur: chert, quartzose limestone and silicified fossils (Orme, 1974). Chert usually occurs as small nodules, a few centimetres across, lying parallel to the bedding. Rarely beds of chert reach 3 to 4 metres thick (Ford, 1977) such as those around Bakewell which have been quarried underground mainly for grinding stone for the ceramic and china industries (Critchley and Wilson, 1975).

Much of the limestone contains acicular authigenic quartz needles (Cox and Bridge, 1977, Cox and Harrison, 1980 and Harrison, 1981), in some areas such quartz forms between 50 and 100 percent of the rock (Bemrose, 1898 and Ford, 1967).

Parts of the limestone, particularly around Brassington and Masson Hill, have been dolomitized. This probably occurred during Zechstein (Permian) times by circulating magnesium rich brines (Ford, 1967). The base of the dolomitised areas is highly irregular often crosscutting the bedding (Ford, 1963). The dolomite tends to be a very porous rock with large cavities where calcite has been leached out since dolomitization. Occasionally fossils have survived the dolomitisation process (Ford, 1963).

Interbedded with the limestones over much of the area are various igneous rocks in the form of lava flows, sills vent agglomerates and tuffs. The thickness of these beds vary markedly laterally, from over 30 metres thick to zero in distances of a few tens of metres (Walters and Ineson, 1981).

The lavas, locally known as toadstones, are usually grey-green olivine basalts with calcite and chlorite filled amygdales when fresh (Mason, 1974). These have often been altered, especially near to the top and bottom of the flows, to a greenish clay (toadstone clay) by circulating groundwaters (Walkden, 1972; Ineson and Mitchell, 1973).

The pyroclastic rocks vary from massive, thick agglomerates to thin altered tuffs, locally called wayboards, with much variation in thickness. Wayboards vary from barely more than a bedding plane to several metres in thickness over distances of a few metres. These tuffs are often altered to a stiff yellow clay, either by their marine environment at the time of deposition or by circulating groundwater since burial (Walkden, 1972).

Volcanic vents occur at a number of localities, for instance Bonsall Moor, Moor Lane, Pounder Lane and Ember Lane all of which are in the Bonsall area (Smith et al, 1967)). They generally consist of coarse agglomerate and lapilli tuffs with limestone and volcanic fragments embedded in a greenish matrix (Mason, 1974).

A number of intrusive rocks occur in the form of sills. They are of similar age and composition (olivine dolerite) as the other volcanics (Mason, 1974). Some of the sills contain amygdaloidal layers, such as the Bonsall Sill, while others, such as the Ible Sill, do not (Smith et al, 1967).

A few volcanic pipes are known such as that at Black Hillock Mine (Walters, 1980), representing feeders to the vents and sills.

The end of limestone deposition is marked by regression and a period of erosion, possibly sub-aerial at times, which led to the formation of the boulder bed at Treak Cliff, Castleton (Simpson and Broadhurst, 1969).

1.5.2. Namurian Strata

The limestones are unconformably overlain by Namurian (Millstone Grit series) sediments, a series of alternating shales, siltstones and sandstones, which are 400 metres thick in the south (Frost and Smart, 1979) and 1300 metres thick in the north (Stevenson and Gaunt, 1971). The basal beds, the Edale Shales, are dark grey pyritic shale varying in thickness from 0 to 250 metres, which are overlapped by the overlying strata (Frost and Smart, 1979).

The Edale Shales are overlain by a succession of shales, siltstones and sandstones of varying thickness. The sandstone units become thicker and more dominant in the north. In the north of the area the sediments were derived by rivers draining the north and northeast (Smith et al, 1967; Stevenson and Gaunt, 1971; Jones, 1980). Deltaic sedimentation was preceded by the turbidite deposits of the Mam Tor Sandstones (Allen, 1960). Most of the Namurian sediments in the southern part of the area were derived from the south rather than from the north, being derived from the Wales - Brabant Island, and were transported largely by turbidity currents (Frost and Smart, 1979; Jones, 1980).

The Namurian strata were overlain by the Coal Measures. Including the Coal Measures, over 2 kilometres of strata were removed by erosion before the Triassic sediments were laid down (Frost and Smart, 1979).

Reworked Namurian sediments often form a considerable part of the allochthonous fraction of the karstic sediments examined during this study.

1.5.3. Permo-Triassic

Extensive erosion occurred during Permian times eventually exposing the limestones (Smith et al, 1967). Most of the southern part of the area was then covered by Triassic sediments, the Sherwood Sandstones (Bunter Pebble Beds) being at the base. These beds are now found just to the south of the area of exposed limestone. The source of this material appears to have been to the south and southwest (Matley, 1914; Smith, 1963).

The pebble beds rest on a peneplaned surface which now has a dip of about 3 degrees to the south. If extrapolated this surface would be projected over the areas around Brassington, Wirksworth and Masson Hill noted for dolomitisation of the Dinantian limestones (Frost and Smart, 1979).

1.5.4. Structure

Structurally the limestone area of the Peak District can be described as a dome (Fearnsides, 1972) but in detail it is far more complicated. The eastern side of the area is a series of easterly plunging folds which were active during sedimentation and have been accentuated since, probably during the Hercynian Orogeny (Ford, 1976a). The central area has very gentle doming while in the west folding has a north-south trend (Butcher and Ford, 1977).

Faulting in the limestones is complex and most faults have been mineralized. A northwest-southeast fault set generally shows little displacement except around Bonsall and Cromford when this faulting produces grauben like structures (Ford, 1976a). Most of the faulting has a generally east-west trend. These faults are more persistant and have larger displacements than the northwest-southeast set. Most of the faults are wrench faults with a small east-west movement sometimes with a minor vertical component (Ford, 1976a).

1.6. Ores and Ore Deposits

The ore deposits of Derbyshire have been described in detail by numerous authors including, Wedd and Drabble (1908), Carruthers and Strahan (1923), Schnellmann and Wilson (1947), Dunham (1952), Mueller (1954), Varvill (1959), Ford (1974), Mason (1974), Butcher (1976), Ford (1976a) and Worley (1978). Generally they are described as medium temperature (80^{o} to 140^{o} C) hydrothermal cavity - fill deposits of the Mississippi Valley type.

The main sulphide mineral present in the ore deposits and ubiquitous throughout the orefield is galena. Lesser quantities of pyrite, marcasite, sphalerite and chalcopyrite also occur; the last, with secondary copper minerals, is abundant at the Ecton Copper Mines (Critchley, 1979).

The gangue minerals are fluorite, baryte and calcite with minor quartz, dolomite and smithsonite. There is a crude zonation of the gangue minerals from fluorite in the east, through baryte to calcite in the west (figure 1.6.1.). Various authors have outlined these zones, notably Dunham (1952), Mueller (1954) and Firman and Bagshaw (1974), but these zones are greatly generalized and cannot be followed too closely. A unique variety of fluorite, known as Blue John, occurs in Treak Cliff, Castleton where it occurs as pipe veins between boulders of the Boulder Bed (Ford, 1955 and 1969a).

Four main types of ore body occur in the orefield called, by the lead miners, rakes, scrins, flats and pipes. The first two are fissure fillings, the third stratabound replacement deposits and the fourth cavity filling (figure 1.6.2.).

1.6.1. Rakes

All rakes are developed along major fractures, usually vertical wrench faults (Firman, 1977). Mineralization is often poly-phase (Ineson and Al-Kufaishi, 1970) and associated with repeated fault movement (Ford, 1976a). Some of the rakes have been mined over lengths in excess of 7 kilometres and widths of up to 30 metres though generally they are from 1 to 5 metres wide. The majority of rakes have an east-west trend (Butcher, 1976).

1.6.2. Scrins

Veins smaller than rakes are called scrins. They are generally little more than joints with a mineral fill varying from a few millimetres to about 1 metre in width (the lower limit for rakes and the upper one for scrins is undefined, Hooson (1747) described scrins as "the least or smallest kind

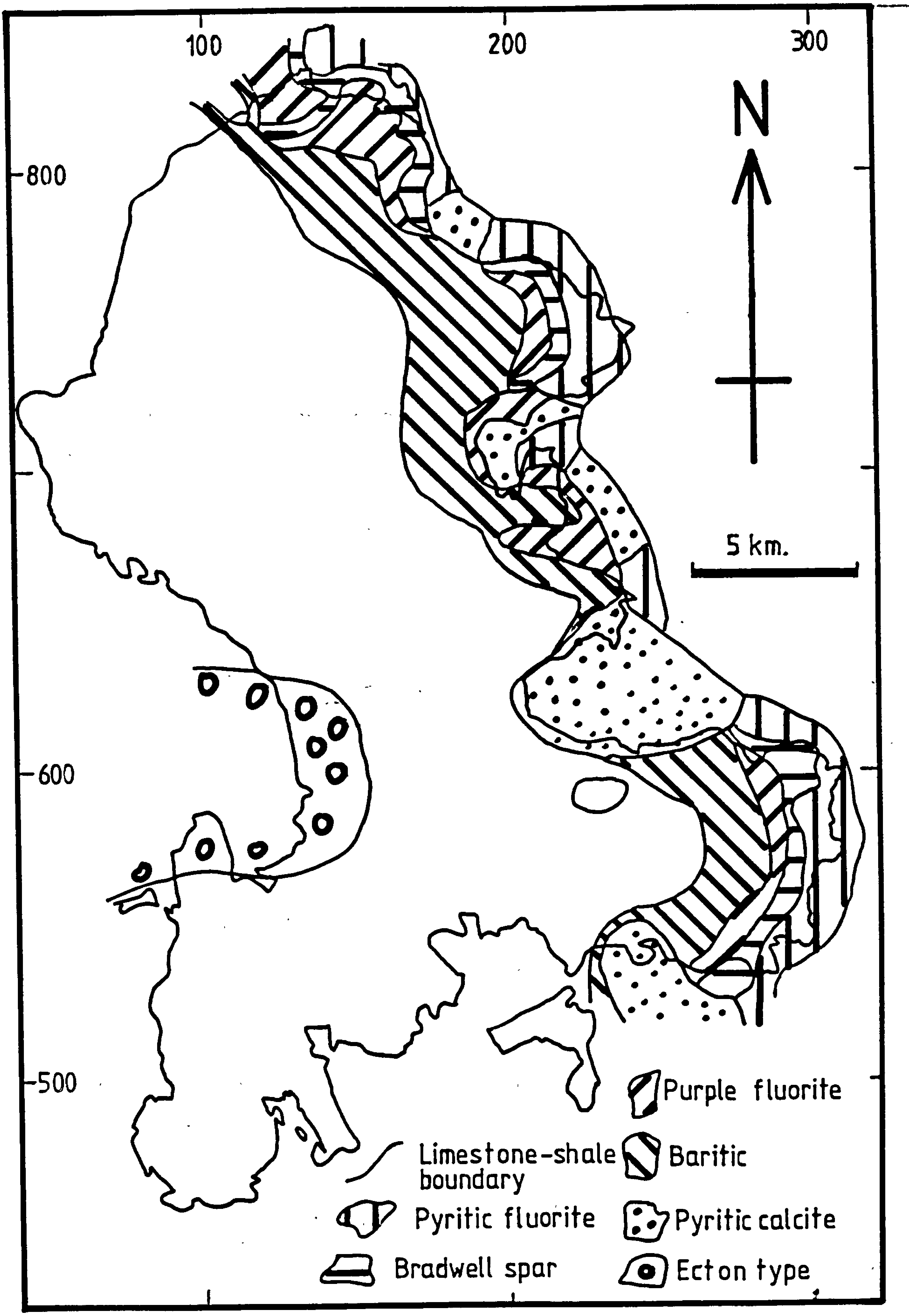


Figure 1.6.1. The zonation of the Derbyshire Orefield. After Mueller (1954).

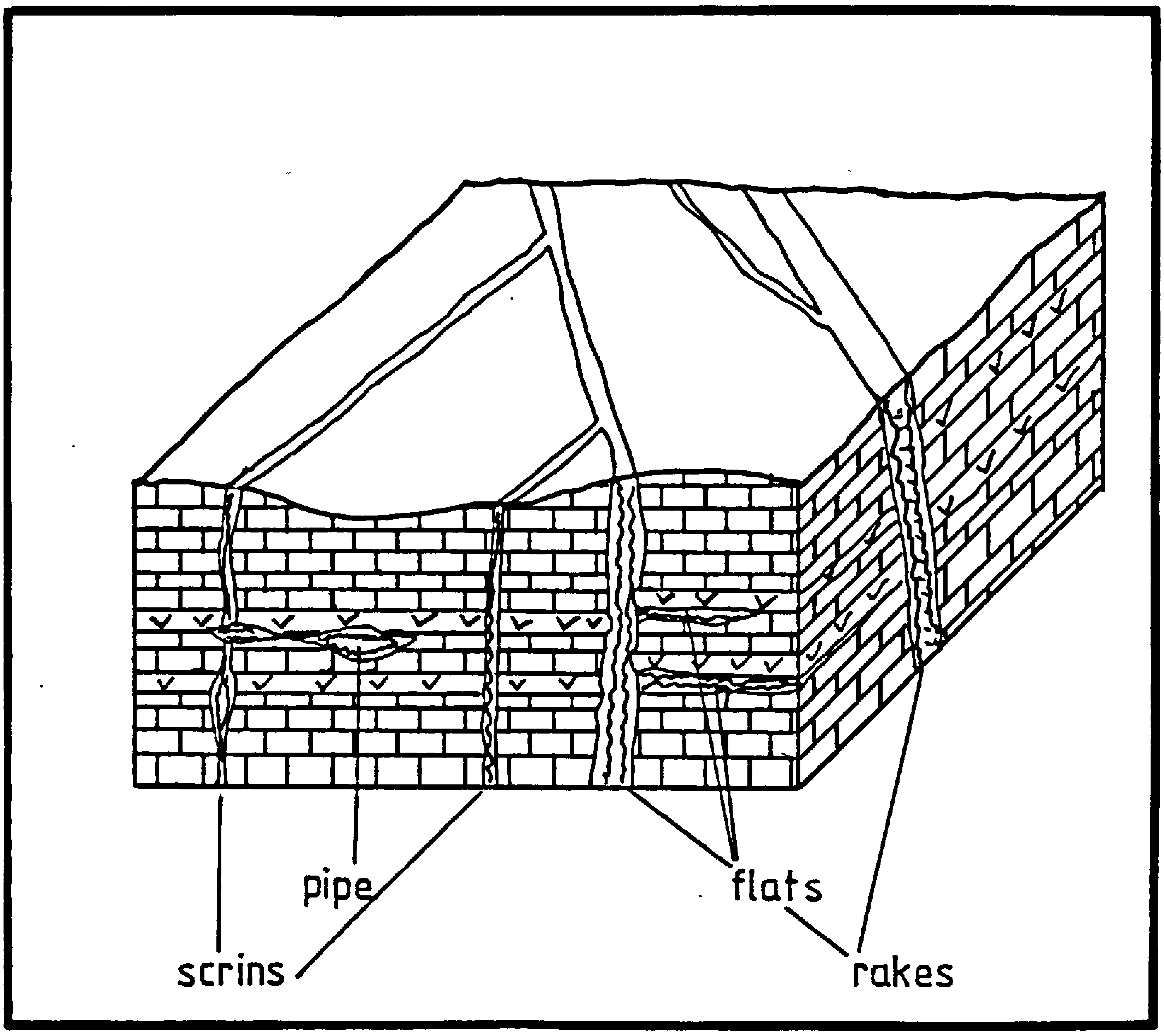


Figure 1.6.2. Types of ore deposits. After Ford and Rieuwerts (1975).

of veins .... if it were not for their ore .... would pass for joynts only"). They were not usually been followed for more than a few hundred metres or to any great depth. The direction of scrins varies from northwest - southeast to northeast-southwest (Butcher, 1976).

1.6.3. Flats

Flats are metasomatic replacement deposits or flat bedding void fills confined to particular beds of limestone and normally associated with impermeable toadstones or wayboards. They have a defined floor and roof but may extend laterally to a greater or lesser extent (Hooson, 1747).

1.6.4. Pipes

Three types of vein were called pipes by the miners, in addition to the Blue John deposits noted above. Firstly linings of cavities existing prior to, or formed during, mineralization. For example, the Blende Vein of Magpie Mine (Worley, 1976) or the deposits at the Golconda Mine (Ford and King, 1965 and 1966). Secondly the near vertical pipes which formed the main ore bodies of the Ecton Copper Mines (Critchley, 1979) and are a distinct type of mineralization. Thirdly cavities formed by circulating groundwaters and associated with, or formed close to, earlier epigenetic mineralization. These may be filled or partly filled with surface and underground derived sediment containing, throughout or as distinct layers, alluvial and residual fragments of the primary mineralization derived from nearby deposits. All pipes have limited width and height but are many times longer than their width.

Wall - rock alteration, though not obvious in the limestones, is present in both limestone and toadstone wall rocks.

In the limestone wall rock alteration may simply be progressive loss of the original textures of the limestone fabric accompanied by an increase in microfracturing (Ineson, 1969 and 1970). In places dolomitisation and silicification occur (Mason, 1974), the latter is more intense in areas of more abundant volcanic horizons (Ford, 1976a). Study of the trace element distribution in wall rock limestones has shown that an aureole, 10 metres or so wide, exists adjacent to rake veins where enrichment of many trace elements has occurred (Ineson, 1969 and 1970).

In the toadstones wall rock alteration consists of often intense bleaching and alteration to a soft clay-rich rock similar to the alteration found at the top and bottom of the toadstones (Garnett, 1923; Walters and Ineson, 1980).

The mineralization has been dated by dating metasomatizing events related to hydrothermal activity affecting the toadstones by the potassium - argon method (Fitch et al, 1970; Ineson and Mitchell, 1973). Primary mineralization started around 290 my. with maxima about 270 and 235 my. (Lower and Upper Permian respectively) with continuing mineralization to 180 my. (Late Triassic) (Ineson and Mitchell, 1973).

1.7. Superficial Deposits

1.7.1. Brassington Formation

Of the superficial deposits present in the Peak District the Brassington Formation pocket deposits are probably the most important and have been described by Yorke (1954 and 1961) and by Walsh et al (1972). The pocket deposits occur only in solution collapse hollows in the southern part of the exposed limestone. The deposits have been divided into three units, Kenslow Member, Bees Nest Member and Kirkham Member (Boulter et al, 1971).

The composition of the deposits has been described by Howe (1920), Scott (1927), Yorke (1954 and 1961), Ford (1969b) and Walsh et al (1972 and 1980). Most of the sediments consist of reworked Triassic (Bunter) material derived from the Triassic scarp to the south (Walsh et al, 1980). Plant remains are abundant in the upper (Kirkham) member indicating an early Pliocene age (Boulter, 1971).

The deposits are thought to have once been a continuous sheet over this part of the Peak District (Ford and King, 1969). These deposits have been preserved by collapse and sagging into large solution cavities in the limestones below, this process probably started during deposition. Glacial and fluvial erosion has removed the rest of the deposits (Ford and King, 1969).

1.7.2. Pleistocene and Recent Deposits

1.7.2.1. Glacial Deposits

Derbyshire lay outside the last (Devensian) glacial advance (fig. 1.7.2.1.1.) and only remnants of till remain from the earlier Anglian and Wolstonian glaciations (Burek, 1977a) though it is likely that much more of the area was covered by till deposits after the retreat of both these

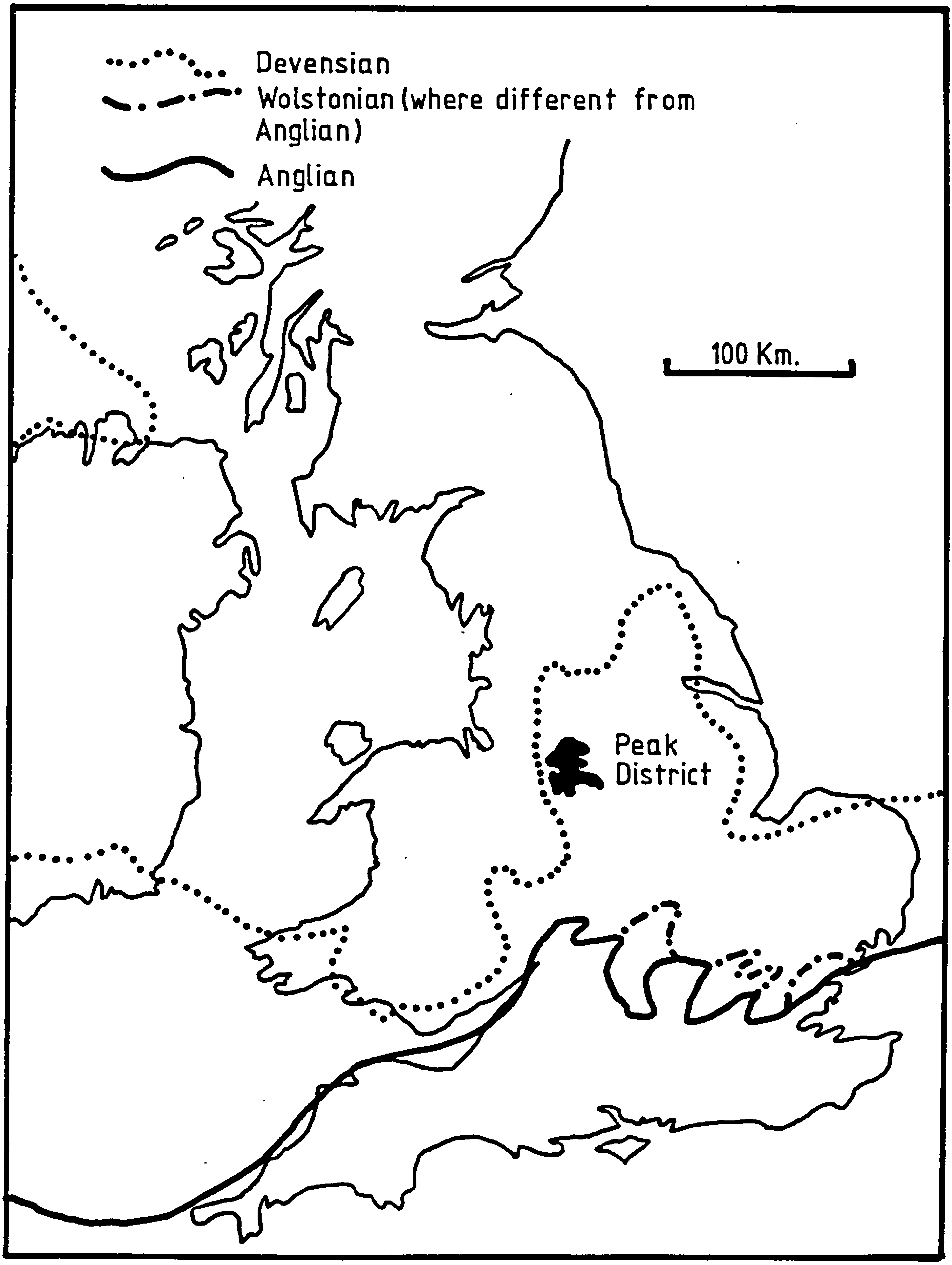


Figure 1.7.2.1.1. Limits of glaciation in Britian, after Boulton et al (1977).

glaciations. Typically the till is a stiff, brown/grey gritty clay containing boulders, up to 2 metres in diameter, mainly of local shale, grit limestone (dolomite also being present in the south of the area) and local volcanics with rare Lake District erratics (Burek, 1977a and 1977b).

Fluvio-glacial deposits are virtually unknown in the White Peak. The only recorded deposit is a block enclosed in till found at Raper Pit (Burek, 1977b). It is thought that this block of unconsolidated sediments is of local derivation being carried in a frozen condition (Burek, 1977b).

In the Derby area to the southeast of the Peak District sands and gravels underlie, overlie and are interbedded with boulder clay and are interpreted as outwash and/or englacial deposits (Frost and Smart, 1979).

1.7.2.2. Periglacial Deposits

During the Devensian glaciation the Peak District lay outside the ice advance and periglacial conditions were prevalent. Much of the area was covered with a loessic drift, characteristically an orange-brown colour. It is fine grained and the mineralogy of the grains shows that the bulk of it is derived from outside the limestone area (Burek, 1977a). In many areas cryoturbation has mixed the loess deposits with the underlying insoluble limestone residue to form a "silty drift" (Pigott, 1962).

Other periglacial deposits include cemented screes, solifluction deposits (head of Dines et al, 1940) and landslip material.

1.7.2.3. Other Superficial Deposits

Tufa deposits occur in a number of localities in the Peak District and at some of these tufa deposition is still continuing (Burek, 1977a). Though still continuing tufa deposition is more active under warmer climatic conditions than prevailing today (Burek, 1977a).

Insoluble residues formed by chemical weathering of the limestones are widespread. They consist primarily of silica, either as chert or as authigenic quartz silt and may contain insoluble minerals from the epigenetic mineral suite (Piggot, 1962).

1.8. Caves and Cave Formation

Cavernization can occur in any water soluble rock but is best known in limestone. In Britain the Carboniferous Limestone is that most noted for cavernization.

Cave formation has been described by many authors including Davis (1930), Bretz (1942), Mack (1948), Warwick (1953, 1971 and 1976), Bogli (1971 and 1980), Ford (D.C.) (1971), Newson (1971), Waltham (1971 and 1981),Ford (1971, 1972 and 1977), Ford and Worley (1977a) and Beck (1980). Cave development is often in two phases, phreatic and vadose. Phreatic cave development occurs below the watertable, mainly by corrosion of the limestone, widening faults, joints and bedding planes or other lines of weakness. The tendency is for a tube to be formed with a roughly circular or elliptical cross section or, if developed along a fault, a vertical fissure may form. Less soluble parts of the limestone, as well as any insoluble material such as chert, shale or mineral veins, may be left protruding into the cavity.

Vadose cave development occurs above the local watertable. Vadose caves often develop from a phreatically formed cavity after the watertable has been lowered. This occurs when outlet points are lowered or new, lower resurgences form. Cave development will then proceed with a free air space and a fast flowing stream. Under these conditions mechanical erosion assumes greater importance and caves take on a trench-like form.

On the surface karst cavities may take several forms including:-

1. Widening of joints and other lines of weakness produces enlarged fissures.
2. Differential solution of the limestone at joint intersections can produce much larger surface depressions.
3. Where surface streams flow from an impermeable cover rock onto limestone they often go underground through such joint controlled depressions to form swallow holes and pot holes.
4. Collapse of underground cavities may lead to the formation of a depression on the surface.

1.9. Cave Sediments

Cave sediments initially attracted the attention of early palaeontologists and archaeologists who collected bones and artifacts from them, sometimes using these finds to relate the cave deposits to surface climate (Ely, 1861; Lyell, 1873). More recently the sediments themselves have been studied by archaeologists in order to relate finds to climatic changes and perhaps also to use this information for dating purposes (Kula and Lozek, 1958; Warwick, 1960; Bull, 1981a).

Until recently sedimentological studies of archaeologically barren cave sediments has been lacking but the last two decades has seen much research including that by Warwick (1961), Collier and Flint (1964), Simons (1965), White and White (1968), Reams (1968), Frank (1971 and 1974), Wolfe (1973), Meia and Pochon (1975), Bull (1976a, 1976b, 1976c, 1977, 1978a, 1978b and 1979), Hladnik and Kraje (1977) and Bull and Carpenter (1979).

Phreatic and vadose cave - forming processes will produce different types of sediment. An active vadose cave tends to contain a fast moving stream and therefore largely contains pebbles or boulders along its bed. Where the gradient is less or pools in the stream occur, sand may also be deposited. In times of flood clay and silt may be deposited in backwaters and on ledges. Where roof falls block or partially block passages ponding may occur leading to areas of finer sediment deposition, sometimes building up extensive deposits. Where a vadose stream enters the phreatic zone its velocity is considerably reduced allowing it to drop the finer constituents of its load, producing mud banks and larger accumulations of finer sediments. In the phreatic zone any insoluble material in the walls, when detached, will tend to accumulate on the floor.

Cave sediments are classified into two groups (Ford, 1975 and 1976b). These are:-

Allochthonous (exogenetic) sediments derived from a source outside the cave and then carried in.

Autochthonous (endogenetic) sediments derived by internal processes (such as insoluble residue).

Most sediments found in caves are usually a mixture of both autochthonous and allochthonous material but allochthonous sediments tend to form the larger percentage of material.

Allochthonous sediments can be carried into the cave environment by any combination of wind, water and ice but transport within a cave is usually by water (Ford, 1976b).

Once a cave has ceased being an active system it tends to fill with various deposits. Speleothem deposition, roof falls and occasional flooding bring in large quantities of sediment which slowly fill a cave system.

Many apparently isolated solution and vein cavities are filled or partially filled with surface derived sediments. This can only be satisfactorily explained by the mechanism of translatory flow postulated by Bull (1981b). In this process fine - grained sediments are transported underground via joints and bedding planes by filtering groundwater. If the routes are than 1mm. wide then filter caking will probably occur preventing sediment transport. Where they are greater than this size considerable quantities of sediment may be carried down joints and may then accumulate in any cavities present when further migration is prevented. Cavity formation and infilling with sediments may be carried out by the same groundwater percolation.

Surface depressions may become filled with sediment by a combination of processes including wind, water and ice transport, and slumping of the depression walls. In some instances filling of the depressions and subsidence may be contemporary producing slump structures in the sedimentary fill.

Some of the cave sediments of the Peak District are bone bearing and have been excavated at various times for their contained faunal remains including Dream Mine, Wirksworth (Heath, 1882), Victory Quarry fissure, Dove Holes (Dawkins, 1903; Spencer and Melville, 1974) and Windy Knoll Cave (Dawkins, 1877; Pennington, 1875 and 1877).

1.10. "Ores" in Sediments

Any of the above processes can introduce "ore" minerals into the sediments; some may be derived purely by mechanical erosion of a surface or underground exposure of epigenetic mineralization. In most cases the mineral vein material is left as an insoluble residue when the limestone is removed under phreatic conditions. In some cases the former mineral vein may protrude into the cavity but usually it becomes disaggregated and locally redistributed. If other sediment is present the "ore" minerals may form discrete layers within the deposit or may be more or less uniformly distributed throughout the sediment.

For centuries this type of ore deposit containing easily worked and dressed galena has been worked by Derbyshire lead miners who knew it as "gravel ore". It has been responsible for the "bonanzas" found in some mines in Derbyshire.

1.10.1. Types of "ore" - bearing deposit

The cavities containing ore-bearing sediments can be classified into four categories, namely:-

1. Surface Hollows - Solution hollows are common on the surface in limestone areas and they are frequently partially or completely filled with residual and derived sediment and broken rock. When developed close to or around mineralization they may contain derived or residual "ore" minerals.

2. Cavities/cave systems close to mineralization - frequently cave systems intersect mineralization and material derived from that mineralization is often incorporated into any cave fill present, sometimes some distance from the actual mineral deposit.

3. Cavities/cave systems developed within mineralization. Cave systems may develop in or along mineral veins. The sediment will usually contain derived mineral vein material and may also contain in situ remnants of vein material protruding into the cavity following removal of the surrounding wall rock, particularly if the limestone was removed solutionally. Mineral veins often contain cavities and vein material may accumulate as a boulder pile in the bottom of the cavity, which may be modified by the later invasion of a cave system. Pipe veins often contain a cavity in the centre, which may have been modified and filled with residual and derived sediment at some stage.

4. Cavities/cave systems apparently unrelated to mineralization - Cave systems containing a blocky fill with some fine-grained calamine and secondary copper minerals are known (Shipham, Mendip and Pikedaw, Yorkshire Dales), but have not been found in the Peak District.

A number of mines in Derbyshire are known to have worked alluvial and residual ore deposits, either solely or as part of their normal vein mining operations. The Derbyshire orefield is particularly known for the number of natural caves found by mining operations (Kirkham, 1953).

The deposits in some of these cavities are known to have contained and been worked for their galena content. Cavities containing residual ores associated with primary mineralization with minor phreatic modification occur at Mill Close Mine (Wass, 1880; Parsons, 1896; Varvill, 1962). Sedimentary fills overlying residual deposits and containing reworked primary mineralization are noted in several mine and cave systems and have been worked in many of them including the Masson Mines (Flindall and Hayes, 1976; Ford and Worley, 1977b), Jug Holes (Worley and Nash, 1977), Hubbadale Mines (Worley et al, 1978), Moorfurlong Mine (Worley and Beck, 1976), Mandale Mine (Worley and Ford, 1975), Nicker Grove Mine (Beck and Worley, 1977), Golconda Mine (Ford and King, 1965 and 1966), Winnats Head Cave (Shaw, 1979) and Treak Cliff Cavern (Ford, 1955 and 1969). A number of surface solution hollows also contain this type of deposit including Portway Mine (Dines, 1945; Shaw, 1983a) and Bonsall Moor (Shaw, 1983a). The Brassington Formation pocket deposits have also been noted for their residual ores as well as barytic cementation of the sands and secondary baryte growth (Yorke, 1961).

1.11. Other areas of England and Wales

Similar deposits have been noted in other localities in England and Wales where mineralized Carboniferous Limestone outcrops, including the Mendips, Yorkshire Dales, North

Pennines and North Wales.

In the Mendips lead miners broke into a number of natural cavities, including Lamb Leer (Gough, 1930 and Platten, 1947), Pen Park Hole, Bristol, (Tratman, 1963) and the Charterhouse area (Gough, 1930, Barrington and Stanton, 1977; Stanton, pers. comm.). Unusual calamine deposits occur in the Triassic dolomitic conglomerate in the Shipham area which were once important sources of zinc for brass making.

The Yorkshire Dales are well known for their cave systems but mining is restricted to a few areas, notably the Greenhow, Grassington and Malham areas. The Greenhow and Grassington areas are noted for their "Gulphs", areas of ground intersected by miners following mineral veins filled with gravel, sand and clay containing derived lead ore for which they were sometimes worked (Varvill, 1920, Dunham and Stubblefield, 1945, Anon, 1965a and 1965b, Dickenson, 1970; Finch, 1978). Unusual deposits of calamine occur in the Pikedaw area of Malham Moor where fine-grained calamine and secondary copper minerals (malachite and azurite) occur in the sedimentary fill between boulders in a high level phreatic cave system (Raistrick, 1938 and 1954, Gemmell and Myers, 1952, Simpson, 1967; Binns, 1968).

In the Alston Block of the North Pennine Orefield these deposits are less common. This is mainly due to the thin limestones within the cyclic deposits in these counties which are composed of limestone, shale and sandstone rhythmites often with the limestones omitted, especially towards the top of the succession. Despite this a number of deposits are known, notably at Lune Head (Dunham, 1948), Silverband (Smith and Carruthers, 1923), Huddgill Burn (Sopwith, 1833) and

Ayleburn (Sopwith, 1833; Anon, 1970).

Sediment filled cavities are also present in the Halkyn district of North Wales, many associated with the surface and underground course of the Hesp Alyn (Smith, 1921). The Milwr Sea Level Tunnel, driven to drain the mines, reached a distance of 10 miles from its portal beside the Dee estuary by 1958 (Williams, 1980). On reaching the Cathole Vein in that year it broke into a large cavity filled with "liquid" sand which filled the level for over 100 metres and defied all attempts to clear it (Parry, pers. comm., 1981).

1.12. Rest of World

A number of deposits of similar character have been described from most areas of the world with limestones hosting mineralization. Zuffardi (1976) gave a world wide synopsis of karst deposits, some of the residual and alluvial types, but many of the deposits that he described are primary mineral accumulations rather than a reworking of such deposits.

Lead and/or zinc deposits have or are being worked for their ores in a number of areas. Most are surface residual accumulations, either in solution hollows as in the Yunnan area of China (Searls, 1952) or as the insoluble residue formed as a result of limestone weathering as in East Tennessee (Hawkes and Lakin, 1949) or Northwestern Illinois (Bradbury, 1959). At these localities weathering of the limestones concentrates the primary mineralization in the insoluble fraction. In the Yunnan these accumulations are further concentrated by fluvial action into solutional hollows and swallow holes. The area of Illinois also contains primary fissure vein deposits some of which are modified by post mineralization solution forming collapse breccia, alluvial and residual accumulations (Bradbury, 1959).

Sink hole, cave and residual deposits of baryte reworked from local primary lead-zinc-baryte mineralization occur in Missouri where weathering has concentrated the insoluble vein minerals, some being further concentrated by fluvial action (Tarr, 1919). Similar baryte and/or lead deposits occur in Sardinia (Padalina et al, 1980).

Lacustrine fluorite deposits, currently under evaluation for their fluorite content, occur in the Latium district of Italy. These consist of fine- and ultra-fine grained deposits of fluorite with baryte, calcite and apatite as the main constituents (Carta et al, 1975). Two distinct ores occur, "clayey ore" and "sandy ore", the former overlying the latter. The "clayey ore" is extremely fine-grained (70% less than 2 microns) with an average fluorite content of 55%. The "sandy ore" is mainly coarser grained (40 to 100 microns but consists mainly of calcite with finer grained fluorite (20%) (Hodge, 1978).

2. SAMPLING AND LABORATORY TECHNIQUES

2.1. Sampling Procedure

Because of restricted or difficult access to many of the underground sites the reconnaissance and sampling were carried out on the same visit.

Most sample sites were near vertical faces cut in the sediments by mining and quarrying. At these sites sampling was a simple process of collecting material from each unit or part of a unit using a small trowel after the face had been cleaned to remove possible contamination. Measured sections and, sometimes, photographs were taken at the same time. Samples were related to cave or mine plans where these are available and to measured sections. Pits were sunk in the floor to sample the unexposed parts of some of the sections. Altitudes given on the cave and mine plans showing the sample locations are for the entrance. Where the sample locations have considerably different altitudes this is noted with the sample numbers.

Each sample, normally consisting of between 150 and 200 grams of material was collected into kraft bags with wire ties. Each sample was labelled sequentially for each mine or cave system or part thereof with a prefix representing the name of the cave or mine, using a waterproof felt pen. Sample numbers were used throughout all laboratory analysis to avoid any potential confusion.

Even for wet sediment samples these bags were found to be adequate.

On return to the laboratory the samples were air dried or placed in an oven at $60^{o}C$ for 48 hours to remove any moisture present.

2.2. Size Analysis

A part of each sample weighing approximately 75 grams was used for grain size analysis. For the coarser fraction separation was undertaken mechanically using 12 sieves with meshes between -2.0 and +4.0 phi.

Each sample was carefully disaggregated using a rubber-ended pestle with a standard porcelain mortar. Great care had to be taken not to break up any grains of calcite, fluorite, baryte or galena which were present in many of the samples as these minerals are particularly friable. It was often found necessary to re-process some size fractions after sieving to be able to ensure complete disaggregation.

Dry sieving was undertaken following the methods of Folk (1974). After disaggregation each sample was weighed to 0.01 gram and placed in the top sieve of the stack. A Ro-Tap sieve shaker was used, each sample being sieved on the machine for 15 minutes. After sieving each size fraction was put into previously weighed and labelled envelopes and reweighed to 0.01 gram. Each size fraction was then examined under the binocular microscope to estimate the percentage of aggregates present by counting 100 grains. If more than 25 percent of a fraction consisted of aggregate it was re-disaggregated and re-sieved, the resultant fractions being added to the appropriate initial fractions.

The fine fraction (finer than 4 phi) was analysed by the pipette method of Folk (1974, pp 33-34). Approximately 15 grams of the minus 4.0 phi mesh fraction, dispersed in a 2.5 gm/l solution of Sodium hexametaphosphate to ensure total seperation of the individual mineral grains, was put into a litre cylinder and topped up with dispersant to 1000cc. The sample was left for 24 hours to ensure that it did not flocculate.

It was then stirred vigorously to distribute the sediment thoroughly. Twenty seconds after stirring ceased a sample was pipetted from a depth of 20 cm.. Withdrawals were continued at specific time intervals from specific depths. Each sample of the suspension was put into pre-weighed 50 ml. beakers and the pipette rinsed with distilled water. The beakers were then evaporated to dryness at 120°C for 24 hours. They were then left at room temperature open to the atmosphere enabling the moisture content to reach equilibrium and then weighed to 0.001 gram. These weights were then converted to weights for each size fraction and added to those obtained by sieving for plotting.

Corrected weight, cumulative weight, percent and cumulative percent of each size fraction were calculated and histograms, cumulative frequency and probability plots were generated.

The data is presented in this thesis as multiple cumulative probability plots for each sample site. This enables several plots for a single site to be displayed on the same graph. Figures 2.2.1. to 2.2.3. shows the relationship between the histogram, cumulative frequency and probability curves for the same sample.

Figure 2.2.1. Example of a mesokurtic sediment, Royal Mine.

Figure 2.22. Example of a leptokurtic sediment, Devonshire Cavern.

Figure 2.2 3 Eample of a platykurtic sediment, Wapping Mine.

Using the size analysis data the character of the sediments can be described in terms of the shape of the curve (leptokurtic, mesokurtic or platykurtic), skewness (whether there is a higher relative proportion of finer or coarser grain sizes present in the sample) and the degree of sorting.

A mesokurtic curve (fig. 2.2.1.) indicates that the sediment sample has a close to normal distribution of grain sizes. A true normal distribution plots as a straight line on a cumulative probability plot. A leptokurtic curve (fig. 2.2.2.) shows that a sediment sample has a large proportion of its grains close to the mean grain size. A platykurtic curve (fig. 2.2.3.) indicates that the sediment sample grains have a bimodal distribution and may have been derived from two distinctly different sources.

The character of sediments is an indication of their environmental history. Loessic silts and the sediments derived from them are often well sorted and leptokurtic. Fluvial sediments are usually less well sorted and mesokurtic while mixed sediments show varying degrees of sorting and are often platykurtic.

2.3. Mineralogy

The mineralogical composition of each sample was calculated using a point counter with grain mount thin sections and/or washed sand (<3.5 phi).

From the mineralogy of the sediments it is possible to identify the rocks from which the sediments were derived.

2.4. X-Ray Diffraction

A number of samples were studied using X - Ray Diffraction (X.R.D.) techniques to identify the clay minerals present. The same sample was used as for the pipette size analysis. By the use of this technique it was hoped that possible sources of the clay fraction of the sediments could be distinguished but this did not prove to be so in the majority of cases.

Samples were filtered and then treated with acetic acid (approximately 5 molar) to remove carbonates. The sample was then washed with distilled water. The resulting sample was then stirred into distilled water and left to stand until the silt had settled. A labelled glass microscope slide was then suspended just above the sediment and left to stand while the clays settled on to it. The slides were then carefully removed from the water and allowed to dry slowly.

When dry the slides were mounted in a Philips X-ray diffractometer mounted on a Philips PW 1729 X-Ray generator with the detector scanning at one degree per minute. Paper printout was generated for approximately the first 60^{o}.

From the printouts the minerals present were identified using the data of Brown (1961) and Brindley and Brown (1980). The clay minerals present were distinguished from the other minerals in the sample (mainly quartz but fluorite, baryte, feldspars, muscovite and dolomite were also sometimes present) and their relative proportions were estimated from the relative heights of the major peaks representing the clays.

2.5. Scanning Electron Microscopy

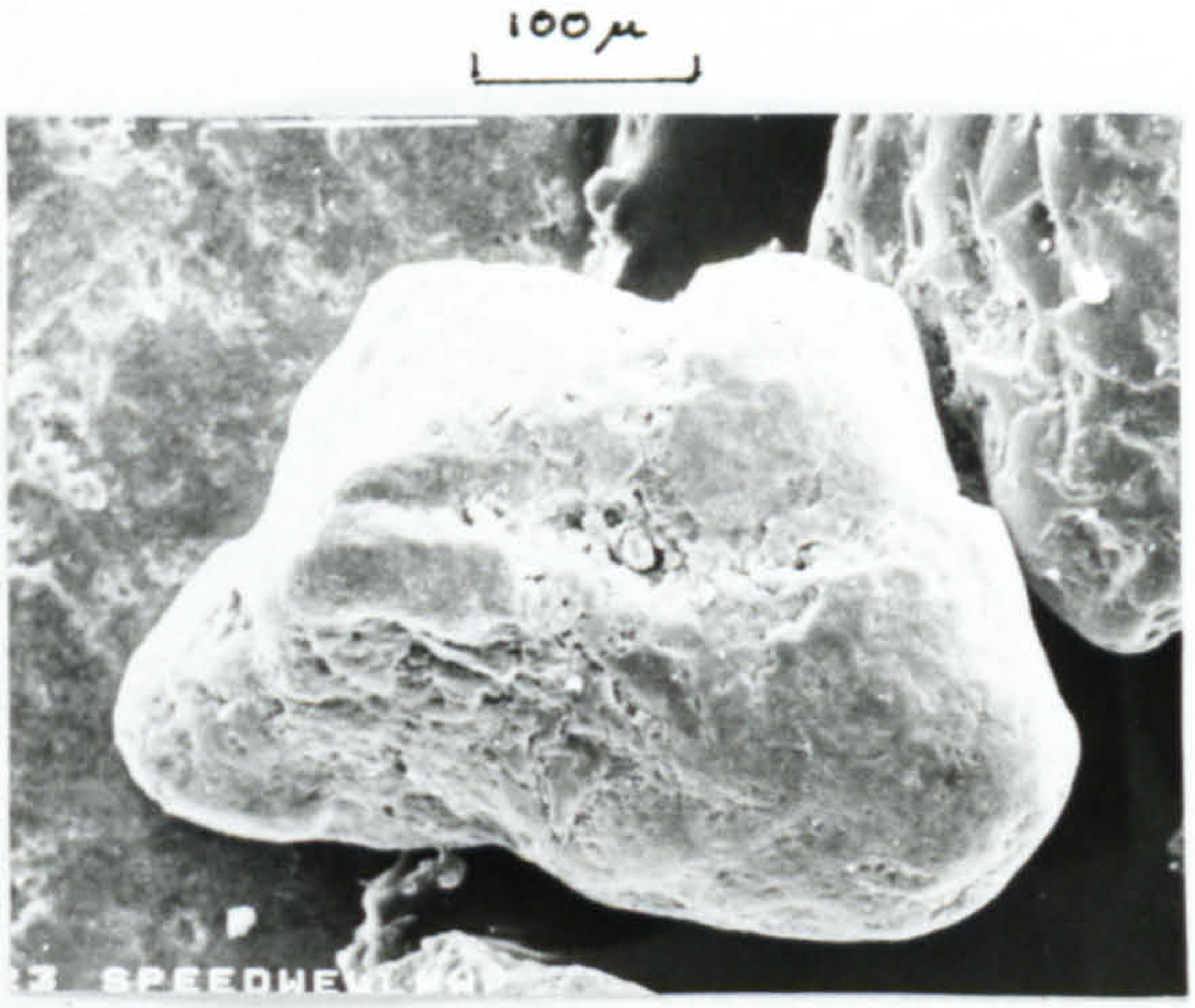
Samples were prepared for scanning electron microscopy (S.E.M.) following the method of Krinsley and Doornkamp (1973, p 3). A small amount of each sample, 5 to 10 grams, was placed in a 50 ml. beaker and boiled, in a sand bath, with concentrated (approximately 10 Molar) hydrochloric acid for ten minutes. The sample was then thoroughly washed several times with distilled water to remove all traces of acid. This preparation was found to be sufficient for all of the samples studied and no further treatment to remove organic coatings was necessary.

After drying approximately 50 quartz grains were taken from each sample and mounted onto aluminium specimen stubs using double sided tape.

Gold was evaporated onto the stubs using a vacuum evaporator with an eccentrically rotating table. An ISI 620 scanning electron microscope was used to view each grain. Details of grain morphology and the presence of a wide range of surface features (plate 2.5.1.) were recorded using a data aquisition sheet (fig. 2.5.1.). Photomicrographs were taken of representative grains and

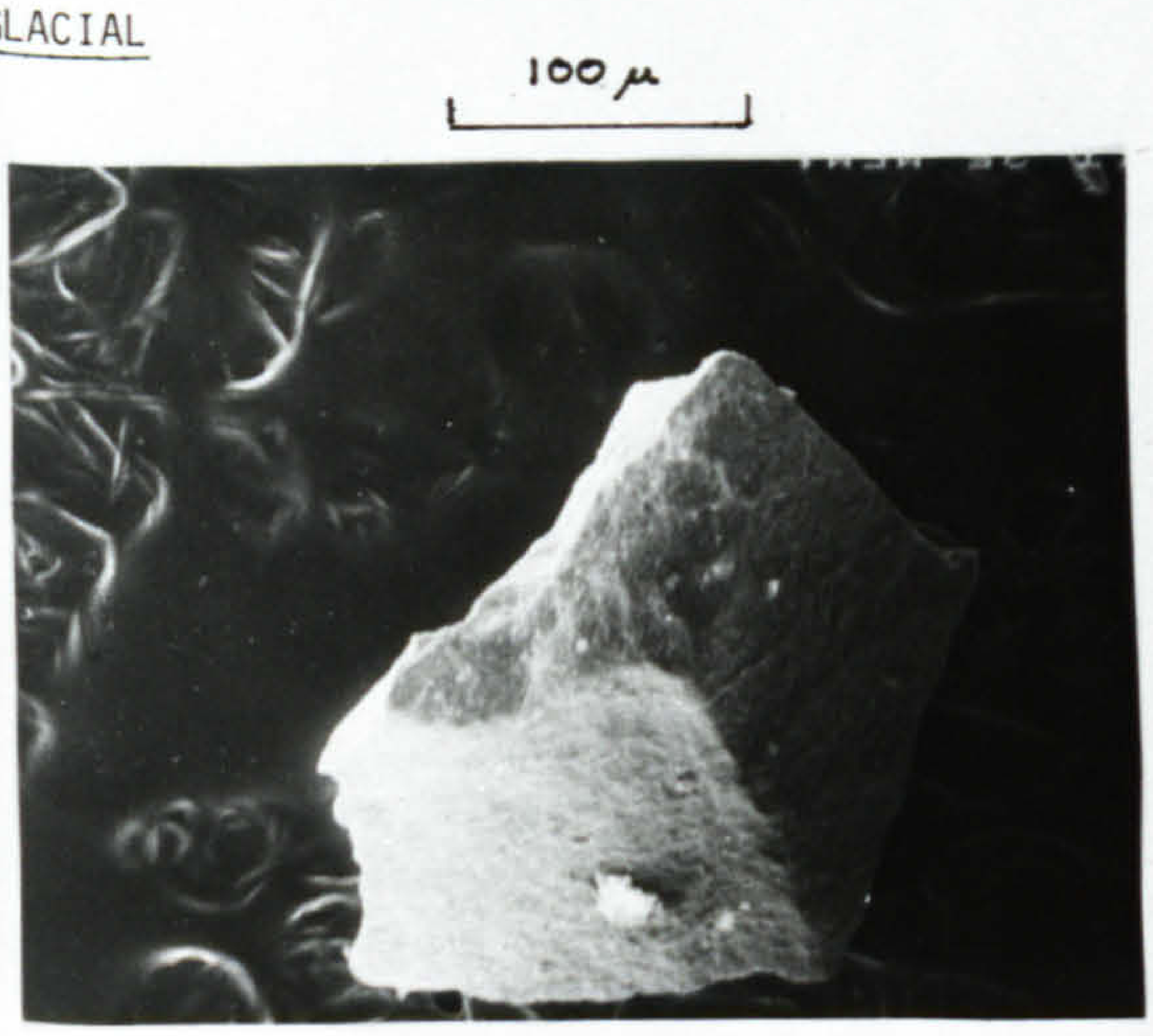
FLUVIAL

(a) Mechanical V. pits.
Temple Mine.

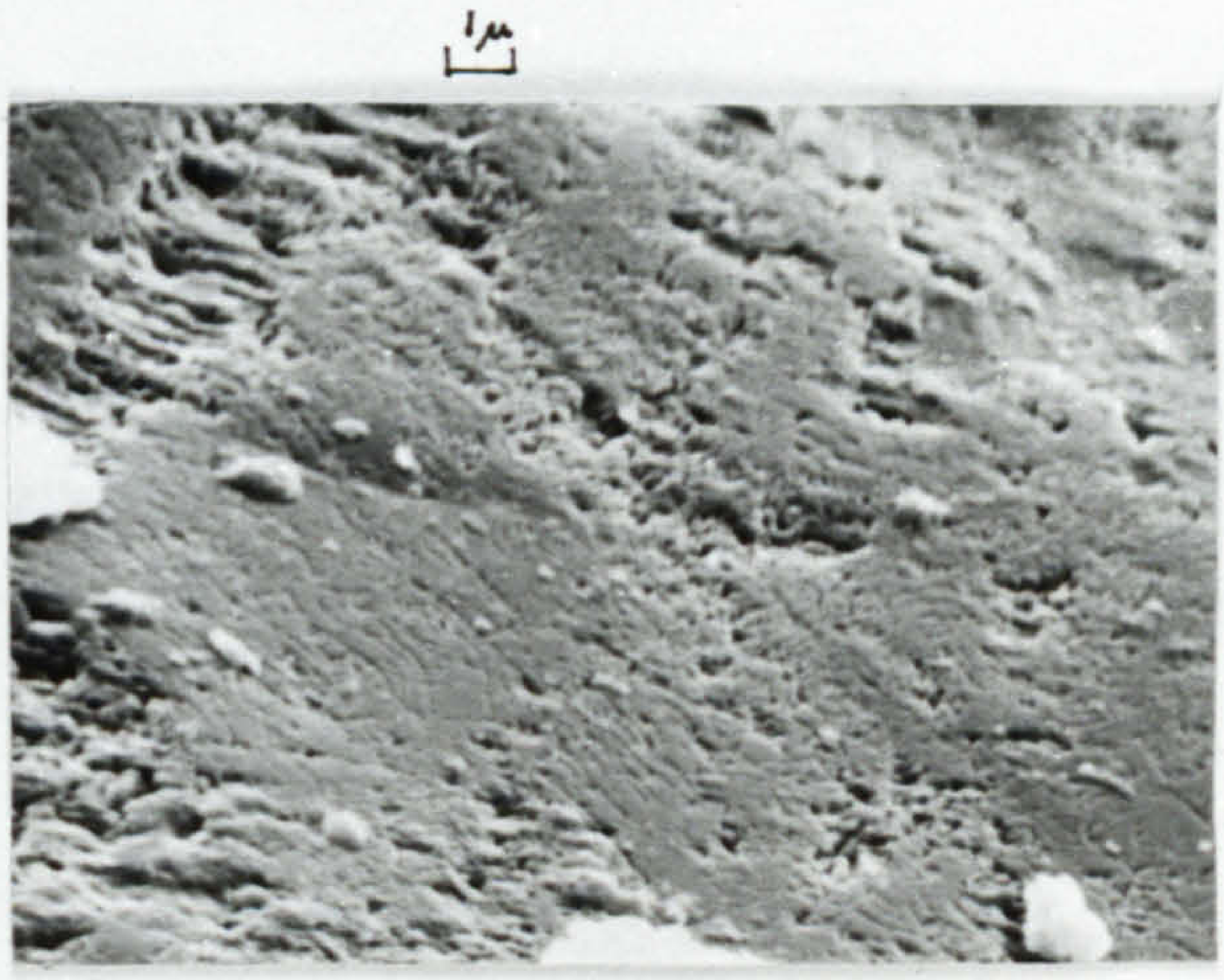


(b) Rounded grain.
Speedwell Cavern.

GLACIAL



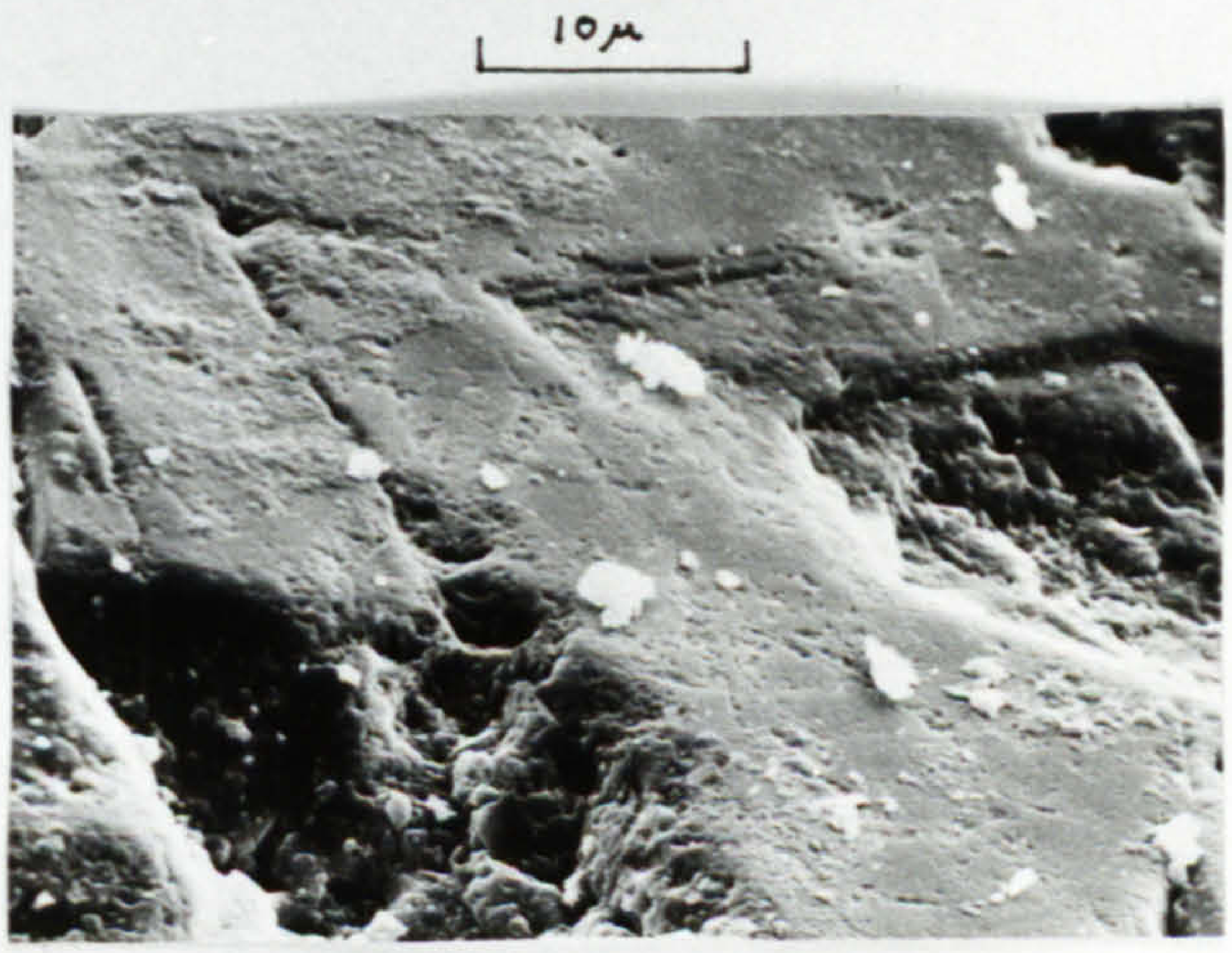
(c) Angular quartz grain.
Moorfurlong Mine.



(d) Chattermarks.
Earle's Quarry.

FLUVIO-GLACIAL

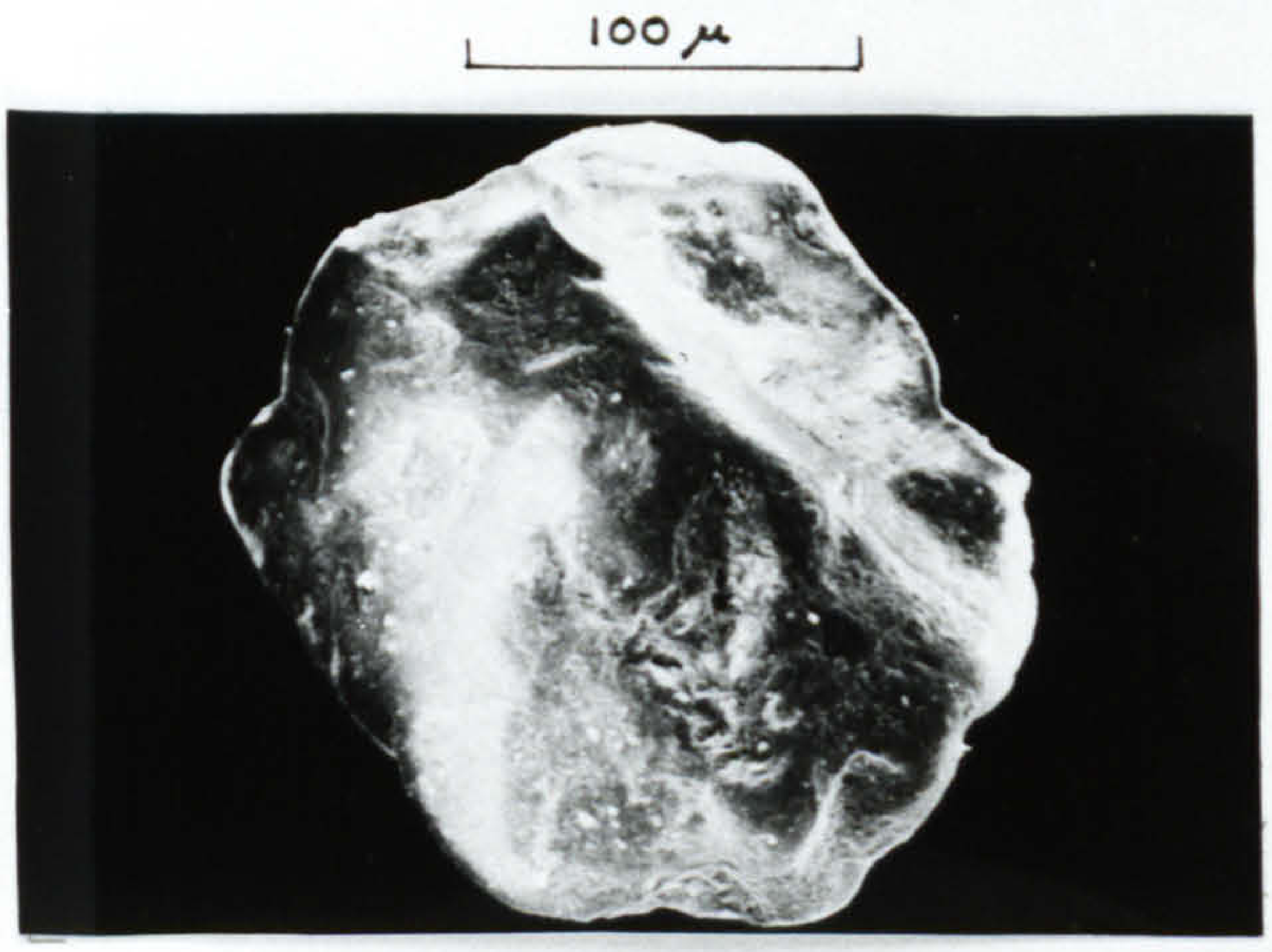
(e) Conchoidal fracture, and edge abrasion.
Masson Mine.



(f) Straight Scratch Marks.
Clay Shaft, Old Jant Mine.

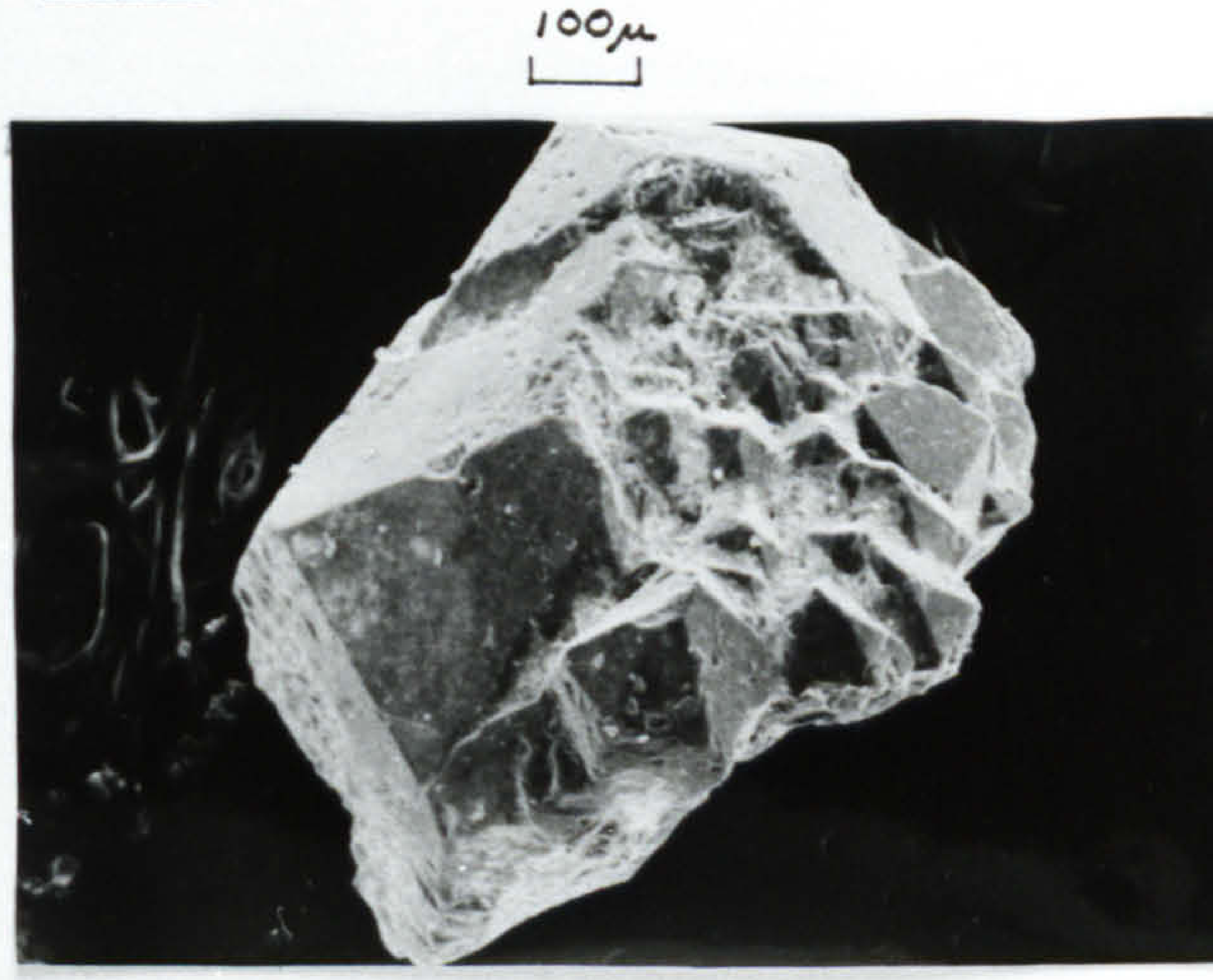
PLATE 2 1(a) Examples of S.E.M. surface textures indicative of certain environments

LOESSIC



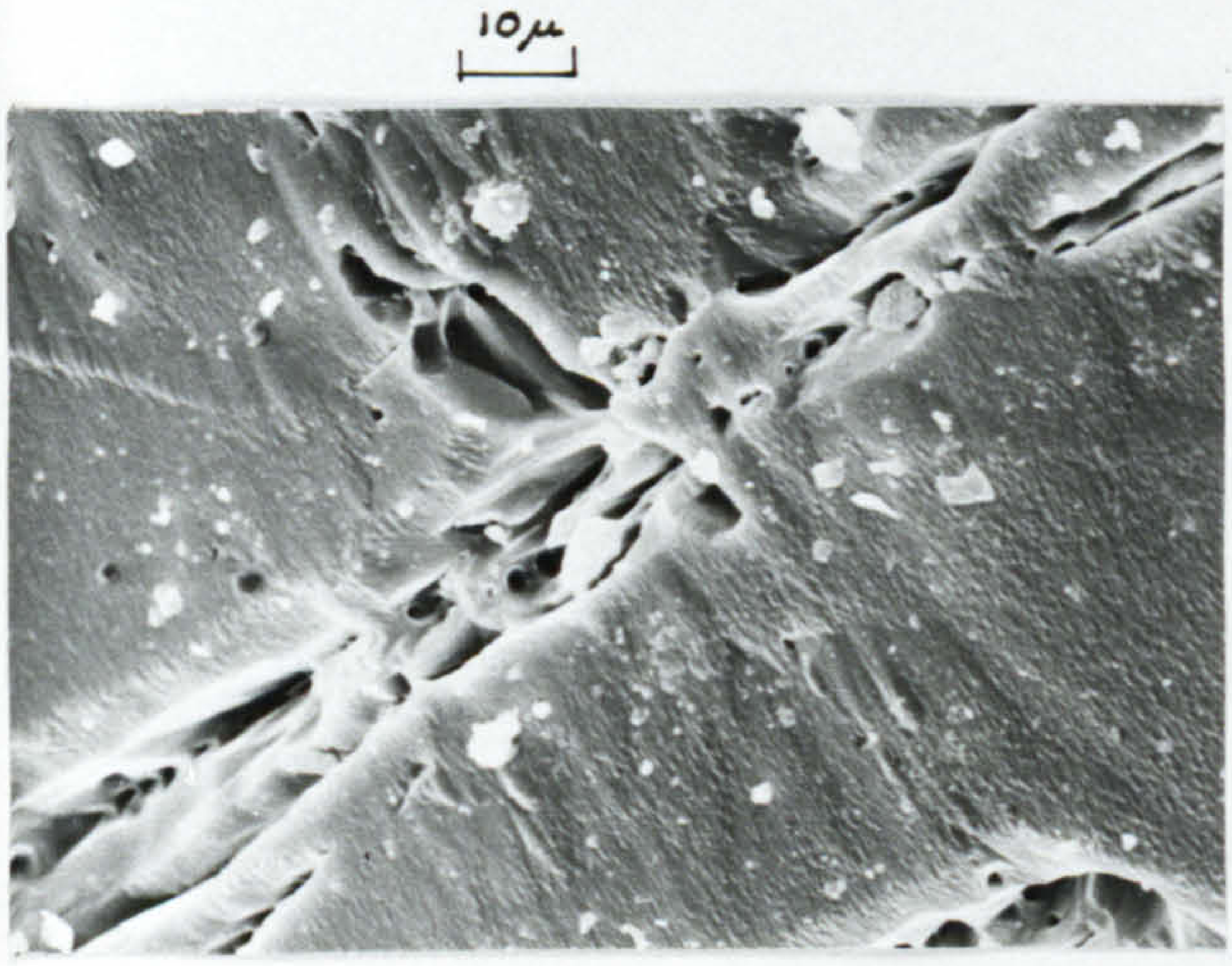
(g) Well rounded grain with disc shaped hollows.
Treak Cliff Cavern

PRIMARY

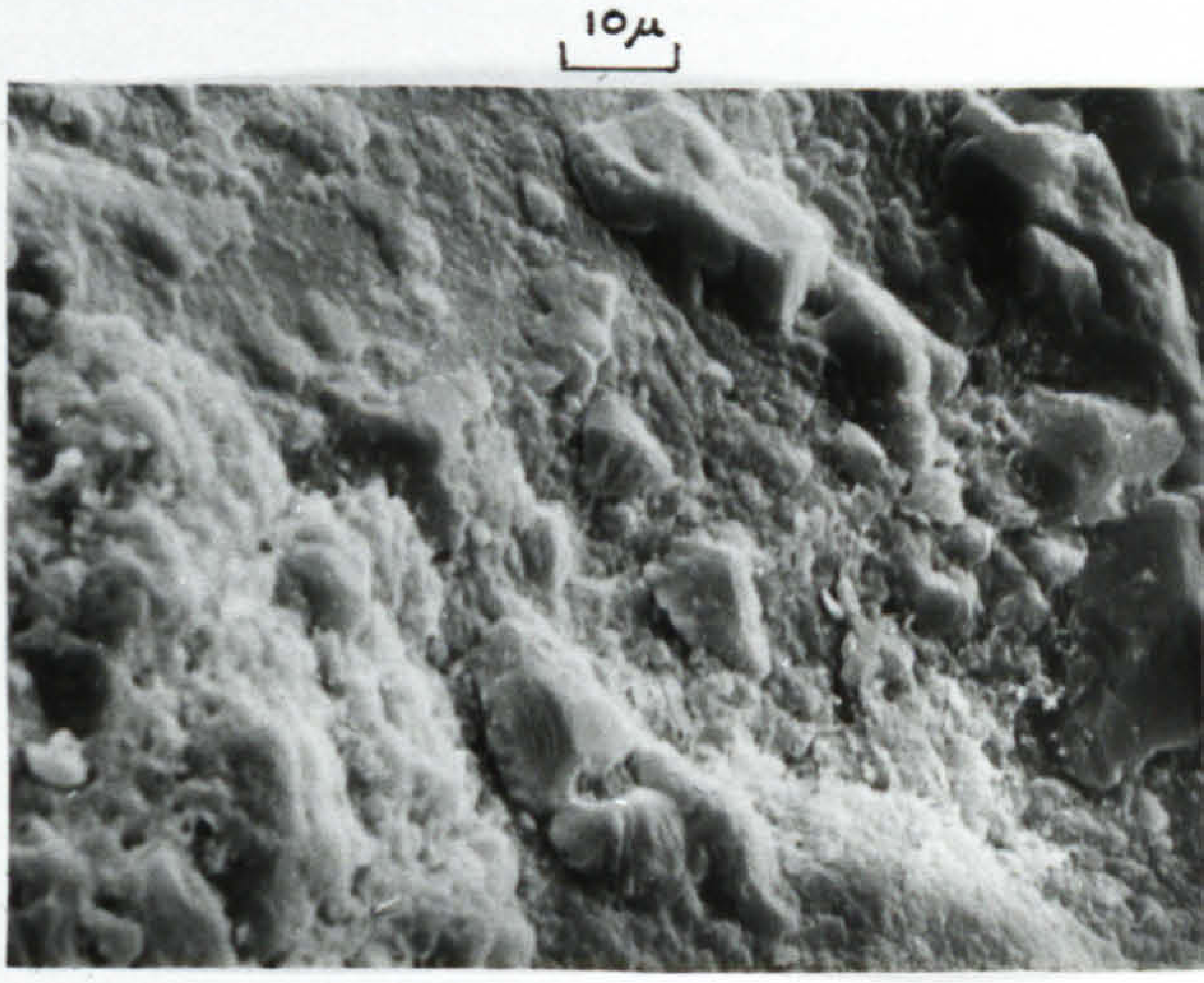


(h) primary quartz grain with quartz overgrowth.
Giants Hole

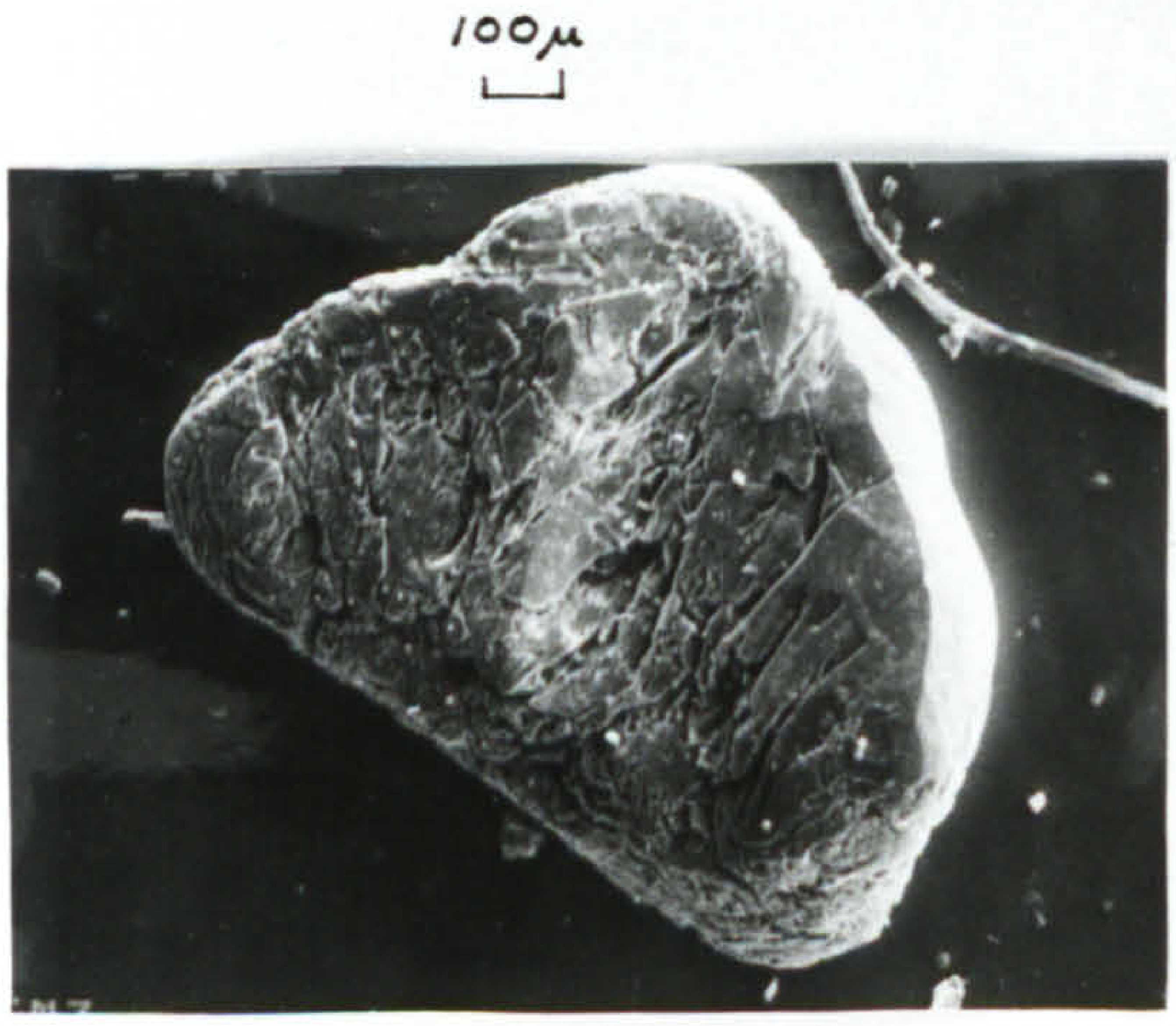
CHEMICAL



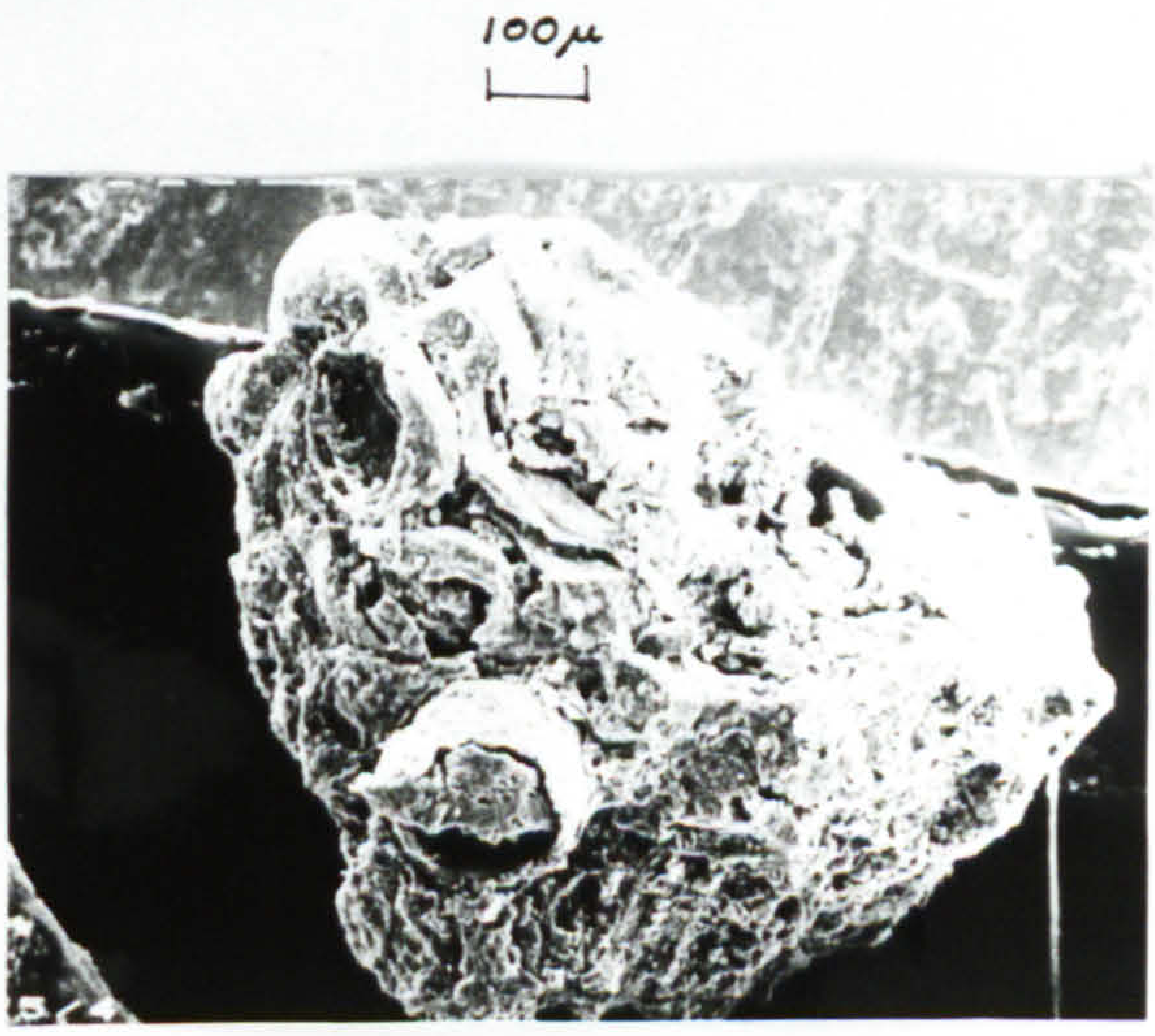
(i) Oriented etch pits (probably along quartz grain cleavages).
Middleton Mine.



(j) Amorphous silica overgrowth.
Temple Mine.



(k) Solution crevasses.
Temple Mine.



(l) Manganiferous coating on unprocessed quartz grain.
Speedwell Cavern

PLATE 2 1(b) Examples of S.E.M. surface textures indicative of certain environments (continued)

SAMPLE Nº	Nº GRAINS	TOT.	%
ROUNDED			
SUB ROUNDED			
SUB ANGULAR			
ANGULAR			
EUHEDRAL QTZ			
HIGH RELIEF			
MEDIUM "			
LOW "			
GRAIN BREAKAGE			
DULLED SURFACE			
SMOOTH "			
EUHEDRAL Si O/G			
AMORPHOUS Si O/G			
DISH SHAPED PITS			
SOLUTION "			
ORIENTED ETCH "			
MECHANICAL V "			
ADHERING PARTICLES			
CONCOIDALS >10µ			
" <10µ			
SCALING			
STRAIGHT STEPS			
ARCUATE STEPS			
EDGE ABRASION			
CURVED SCRATCHES			
STRAIGHT "			
CHATTER MARKS			
IMBRICATE GRINDING			
PARALLEL STRIATIONS			
FRACTURE PLATES			
BREAKAGE BLOCKS >10µ			
" " <10µ			
MEANDERING RIDGES			
SOLUTION CREV.			

Figure 2.5.1. S.E.M. data aquisiton form.

surface textures.

The raw data were converted to percentages and then plotted on a composite data chart for each locality. These charts group morphological and surface features into classes, based on distinctive environments, of which they are broadly characteristic according to Krinsley and Doornkamp (1973) (fig. 2.5.2.). These charts can then be used visually (a high density of black squares and triangles) to establish whether the sediments of a deposit are likely to have been derived fluvially, glacially, fluvio - glacially or as wind bourne silt.

2.6. Palaeomagnetic Measurement

Some palaeomagnetic work has been carried out in the Matlock/Matlock Bath and Castleton areas.

Cave sediments are ideally suited to palaeomagnetic studies of the Earth's magnetic field since they are usually preserved under conditions of constant temperature, high humidity and negligible bioturbation. Consequently, the minerals responsible for natural magnetisation are relatively undisturbed mechanically and unaltered chemically, when compared, for example, with sediments from lakes or the deep ocean (Noel, 1983). Furthermore, cave sediments are formed under conditions which are similar to those produced artificially in laboratory flumes intended to study the magnetisation processes in sediments (Rees, 1961). Consequently, it is possible to apply laboratory-determined criteria to the

Surface Features																							
Chemical	Euhedral silica																						
	Amorphous silica																						
	Solution crevasses																						
	Solution pits																						
	Oriented etch pits																						
Loessic	Dulled surface																						
	Smooth surface																						
	Rounded																						
	Dish-shaped pits																						
Fluvial	Subangular																						
	Subrounded																						
	Mechanical V-pits																						
	Curved scratches																						
	Straight scratches																						
Glacial	Chattermarks																						
	Angular																						
	Fracture plates																						
	Adhering particles																						
	Imbricate grinding																						
	Parallel striations																						
	Conchoidals >10µ																						
	Conchoidals <10µ																						
	Breakage blocks>10µ																						
	Breakage blocks<10µ																						
General	Euhedral quartz																						
	Scaling																						
	High relief																						
	Medium relief																						
	Low relief																						
	Meandering ridges																						
	Arcuate steps																						
	Straight steps																						
	Edge abrasion																						
	Grain breakage																						
	Sample number																						

■ Abundant — 75%
◩ Common 25-75%
● Present 1-25%
☐ Absent — 1%

Figure 2.5.2. Example S.E.M. data chart.

magnetic results from these natural materials (Noel, 1983).

The palaeomagnetism of cave sediments have been reported for sites in Spain (Creer and Kopper, 1974; Kopper and Creer, 1973 and 1976), the Lebanon (Creer and Kopper, 1976), Sarawak (Noel and Bull, 1982), the U.S.A. (Schmidt, 1982), Norway and Britain (Noel,1983; Stober, 1978). A stable magnetisation of geomagnetic origin has been found to exist in stalagmite (Latham et al, 1979).

The majority of unlithified cave sediments have acquired their magnetisation during deposition because of a systematic alignment of suspended magnetic particles by the Earth's magnetic field. This alignment is largely maintained by the magnetic grains when they settle and become incorporated in the sediment matrix. The resulting deposit thus retains a weak depositional remanent magnetisation (King, 1955).

The presence of water flow during deposition causes the magnetic particles to rotate slightly away from their geomagnetic alignment as they pass through the laminar fluid shear layer immediately above the bed. This phenomenon can be detected in a sediment by comparing the direction of magnetisation (mainly controlled by the magnetic field) with the linear lineation direction of the magnetic grains (mainly controlled by the flow). The latter is measured in terms of the anisotropy of magnetic susceptibility in the sediment. The principle of this flow measuring technique was outlined by Rees (1961) and applied successfully to cave sediments by Noel (1983).

This note describes both the palaeomagnetism and susceptibility anisotropy of the cave sediments. The results have important implications concerning the age of deposition and indicate the palaeoflow direction through part of the cave system.

Samples were obtained by pressing 5 by 5 cm. plastic cylinders into the sediment by hand or by using a hydraulic jack. The orientation of each cylinder was recorded with a spirit level and magnetic (Silva) compass. The orientation is considered accurate to $\pm 1^{\circ}$ in inclination and $\pm 2^{\circ}$ in declination (Noel, 1983).

The natural remanant magnetisation of all specimens was measured using a Digico fluxgate spinner magnetometer. The results were then corrected for the field orientation and local magnetic variation. The remanence vector direction is recorded in terms of the horizontal declination and the vertical inclination.

In order to study the stability of the magnetisation, pilot samples of typical lithology were selected and partially demagnetised in alternating magnetic fields up to a peak intensity of 500 Oe. The change in the remanence vector direction at each stage in the demagnetisation was measured. From a inspection of the results it was decided to partly demagnetise the remaining samples in an alternating field of 150 Oe. This field was the optimum level required for the removal of secondary components of magnetisation acquired since deposition. The remanence of the samples was then remeasured in the spinner magnetometer.

3. MATLOCK AREA

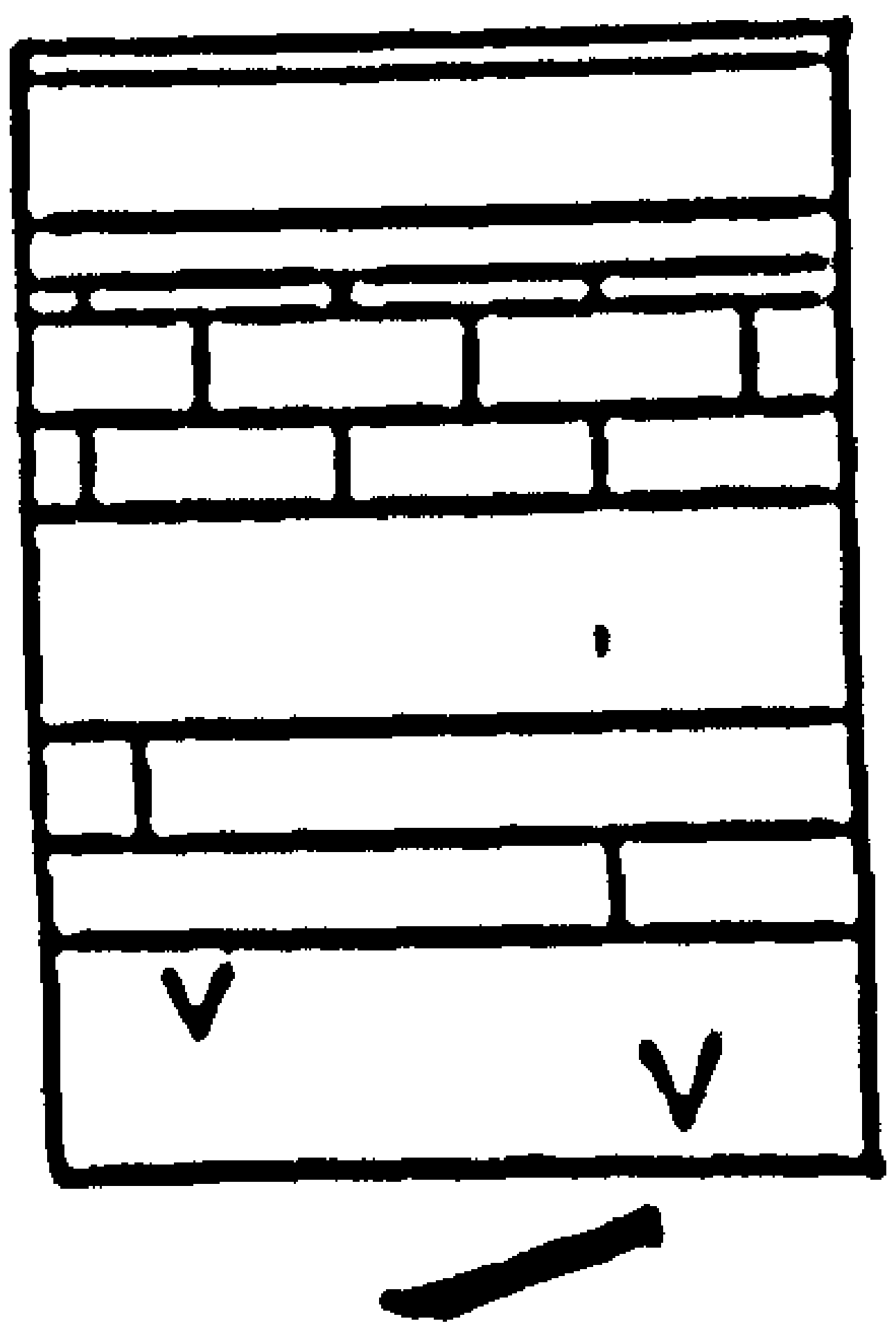
3.1. Introduction

The Matlock - Bonsall area (fig. 3.1.1.) is separated from the Wirksworth area by the Via Gellia. This is a deeply incised valley, now carrying a small stream, draining into the River Derwent downstream of the Matlock Gorge. It probably formed a major topographic break throughout most of the Pleistocene. Boulder clay deposits only 50 metres above the valley floor, southwest of Black Rocks (SK 294,557), show that the Via Gellia existed before the last glaciation of this area (Smith et al, 1967).

The area contains numerous disused lead and fluorspar mines as well as a number of working and abandoned limestone quarries. Many of these operations have intersected a variety of cavities often filled or partly filled with layered sediment. The close association of these cavities with the epigenetic mineralization in the area sometimes led to their sediments containing alluvial galena for which they were prized by the lead miners as they were easily worked (Mawe, 1802).

No caves or sediment - filled cavities have been found in the limestones on the east side of the Matlock Gorge. This may be due to the lack of a catchment area for surface drainage and therefore a lack of cave development.

Figure 3.1.1. Geological sketch map of the Matlock Area.



Namurian sandstones and shales

Cawdor Limestone

Matlock Limestone

Hoptonwood Limestone

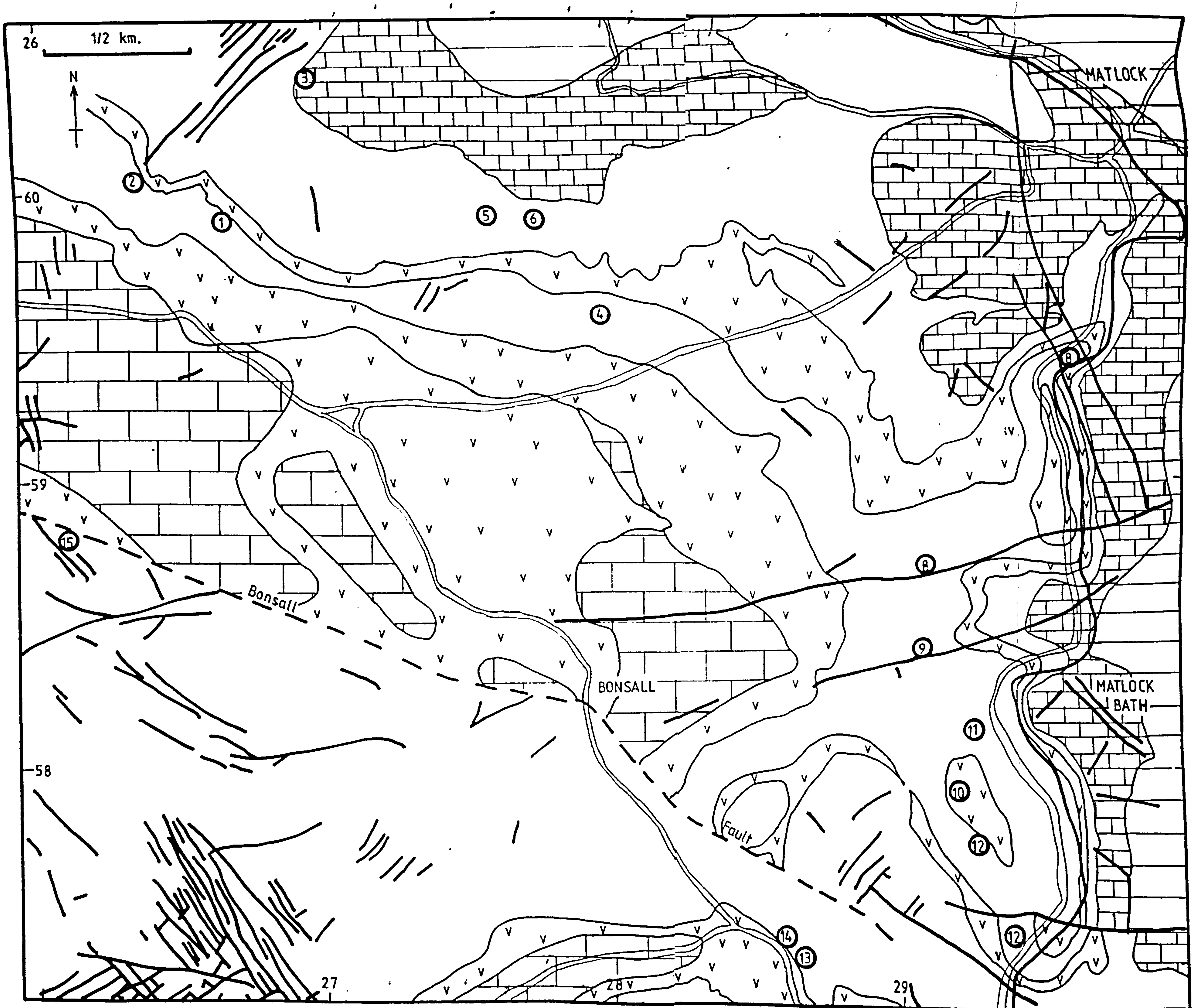
Cawdor, Matlock and Hoptonwood Limestone } Carboniferous Limestone

Volcanics

Mineral veins

Key to localities

1 Brightgate Cave
2 Tearsall Pit
3 Old Ash Mine
4 Jugholes
5 Oxclose Mine
6 Leawood Pipe
7 Millclose Mine
8 Masson Cavern/Youds Level
9 Devonshire Mine
10 Royal Mine
11 Temple Mine
12 Cumberland Cavern/Wapping Mine
13 Ball Eye Mine
14 Houghton Pipe
15 Bonsall Moor Pit


26
1/2 km.
N
MATLOCK
60
59
58
27
28
29
Bonsall
Fault
BONSALL
MATLOCK BATH
①
②
③
④
⑤
⑥
⑧
⑧
⑨
⑩
⑪
⑫
⑫
⑬
⑭
⑮

3.2. Geological Setting

The area is situated on the east side of the Carboniferous Limestone massif of Derbyshire. It consists typically of varied Carboniferous Limestone of the Griffe Grange, Hopton Wood, Matlock and Cawdor Groups (fig. 3.2.1.) (Smith et al, 1967) here dipping eastwards under the overlying shales.

Only the top of the Griffe Grange Limestones is exposed, in the western end of the Via Gellia. They consist of a pale porcellaneous limestone of Holkerian (S2) age (Smith et al, 1967).

The Hopton Wood Group Limestones are extensively exposed west of the Gulf Fault, being about 75 metres thick and consisting of pale grey coarse to medium grained massive limestones and are of Asbian (D1) age (Smith et al, 1967).

The Matlock Group Limestones, of Brigantian (D2) age, again approximately 75 metres thick, consist predominently of massive grey limestones (Smith et al, 1967).

The Cawdor Group consists of approximately 25 metres of varied limestones and shales. The basal biohermal reef knolls are overlain by dark limestones in turn overlain by dark shales with interbedded dark limestones (Smith et al, 1967).

Interbedded with the limestones are a number of volcanic horizons including sills, tuffs and two lava flows (Gibson and Wedd, 1913; Smith et al, 1967), called the Upper and Lower Matlock Lavas.

The Matlock Limestones on the top of Masson Hill have been dolomitized (Smith et al, 1967), probably during Zechstein times, producing a very porous dolomite.

Structurally Masson Hill is a plunging anticline with dips to the north, east and south. To the north the limestone dips beneath the shale cover of the Snitterton area. To the east the anticline plunges across the Matlock Gorge which was incised into the limestone when protruding reef masses prevented down dip unilateral shift (Ford and Burek, 1976). To the south the limestone dips gently towards Cromford with a subsidiary syncline at Matlock Bath.

The area has been intensely mineralized resulting in a large number of near vertical veins (rakes and scrins). These veins generally have an east-west trend and contain mainly banded fluorite, baryte, calcite and galena. There is also a system of northwest - southeast scrins and joints.

Between the Upper and Lower Matlock Lavas there has been extensive development of pipe veins and flats (Dunham, 1952; Ixer, 1974; Ford, 1974). These consist of a series of either pre-existing or hydrothermally produced cavities in the limestones filled or lined with any combination of the fluorite, galena, baryte, calcite and sphalerite epigenetic mineral suite.

The voids left by the mineralization and controlled by the impermeable Lower Lava were later utilised by circulating ground water. Once the shale cover had been removed, the development of underground drainage eastwards from a catchment area to the west of the Matlock Gorge occurred.

Most of these cave systems eventually became filled with both surface and underground derived material. Many contained clasts of galena and other insoluble minerals, especially near to the bottom of the sedimentary fill. These deposits were so easily worked for their lead content by simple sieving and hand - sorting that the miners often left lead ore adhering to the walls as too hard to work. Later miners picked out part of the linings of the voids.

3.3. Types of deposit

The intense mineralisation of this area resulted in the production of a series of partly interconnecting pipe vein cavities which were never totally filled with epigenetic minerals. This resulted in a pre-existing "plumbing" system. In Mio-Pliocene times this area probably had low relief (Walsh et al, 1972) and it is only since then that the gorges have been incised.

Until Masson Hill was exposed little or no surface water would have found its way underground because of the impermeable cover rocks. Once the limestone was exposed, and an outlet established at a lower level, intergrated underground drainage could occur. This occurred by the solutional enlargement of the pre-existing vein cavities. As the Matlock Gorge deepened, lower outlets to the underground drainage network became available leading to the extension of the cave systems further down dip towards the River Derwent.

These cave systems were in limestones controlled by the impervious Lower Matlock Lava and partially capped by the Upper Matlock Lava. As the Lower and Upper Matlock Lavas dip below the present valley floor, cave development between these lavas appears to have been mainly phreatic, i.e. below the local water table, following the pipe vein network until a point of weakness, generally on a rake vein, enabled the water to well upwards through the capping Upper Matlock Lava to resurge at the surface.

This process led to the formation of a complex system of interconnecting enlarged pipe vein cavities and non-vein orientated passages, probably with a number of input and resurgence points. The majority of these cavities, including many small and apparently isolated vein cavities, have been almost totally filled with mainly surface derived - sediment.

As the sediment was not washed through the system a trap preventing the free flow of the groundwater is required. This trap may have been a section of restricted passage or, perhaps, passage restricted by roof falls as proposed by Ford and Worley (1977b). Sluggish water movement through the phreatic system would enable the deposition of any suspended sediment load as would ponding during flooding in vadose parts of the system. Ice damming in the gorge during glacial and periglacial conditions could also cause ponding.

As a result of centuries of lead and, more recently, fluorspar mining this complex system of sediment - filled passages has been extensively modified. In places the fill has been totally extracted. Much of the rest has been processed for galena and is therefore well mixed. This means that only small, isolated pockets of sediment with occasional larger accumulations remain with their relationships to each other difficult or impossible to evaluate.

Many small vein cavities, unrelated to the larger sediment - filled voids are filled with fine - grained silt and clay, sometimes showing fine lamination. The complete filling of these isolated pockets may be explained by diffuse sedimentation via cracks and fissures from the surface and controlled by the translatory-flow mechanism as postulated by Bull (1981b).

3.4. Sites Studied

3.4.1. Brightgate Cave

Situated at the head of Northern Dale at (SK 265,599) this cave system was re-entered by cavers in 1965 (Hurt, 1968) but inscriptions testify to visits made between 1536 and 1798, probably by miners prospecting for lead ores (Ryder, 1979).

The cave is a labyrinth of phreatic tubes, enlarged joints and larger chambers (fig. 3.4.1.1.) developed in dolomitized Matlock Group limestones between the Upper and Lower Matlock Lavas. The dip of the limestones here varies between 25 and 30^{o} to the north.

A number of the passages are filled to the roof with a poorly - sorted fill consisting of angular limestone, dolomite and toadstone blocks in a clayey matrix probably

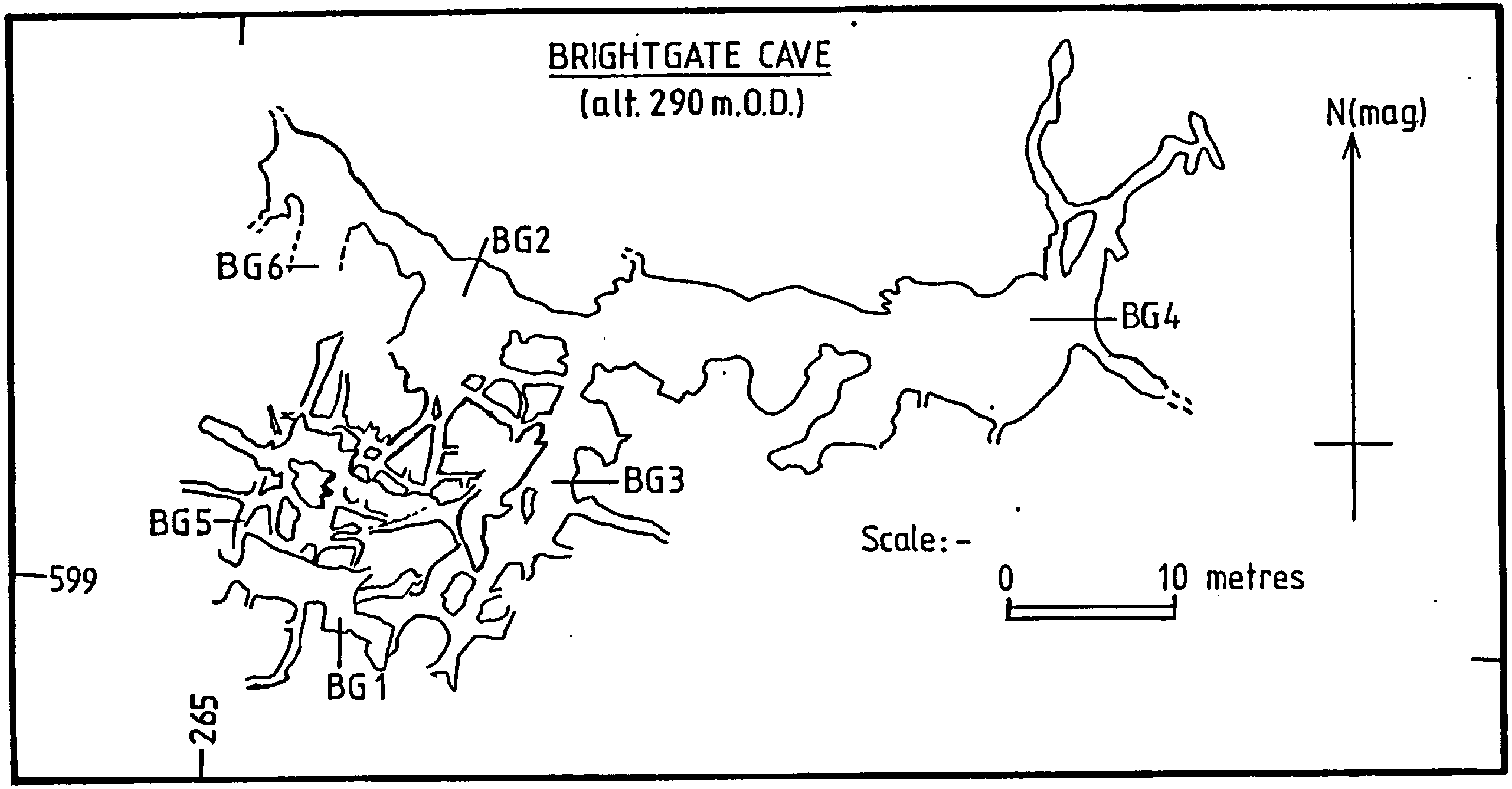


Figure 3.4.1.1. Plan of Brighgate Cave, Snitterton, showing location of samples. After Ryder (1979).

of solifluction origin. The composition of the matrix of this deposit is given in figure 3.4.1.2..

Many of the passages have a fine - grained silt coating the floor and loose boulders the composition of which is given in figure 3.4.1.3..

The results of X.R.D. analysis of the clay fraction of these deposits (fig. 3.4.1.3.) indicate that part of the source was probably the altered volcanic horizons (toadstones and wayboards) in the immediate vicinity (a number of wayboards are seen in the cave where bedding planes have been washed out).

The results of S.E.M. study of the quartz grains from the silts indicates that most of the quartz present in the sediment has been derived from the loess deposits which once covered much of the area (fig. 3.4.1.4., BG 1 - 4). The results of size analysis of the silts shows that they are moderately well sorted, fine - skewed, mesokurtic silts (fig. 3.4.1.5., BG 1 - 4). The nature of the sorting is probably a reflection of their loessic origin while their mesokurtic nature indicates that the silt was derived from only one source. This is supported by the composition of the silts.

The source of these silts is in the former loess cover.

The phreatic development of the cave system represents an early phase of cavernisation in this area because the cave system is now a considerable distance above the water table. The cavernisation probably pre-dates the formation of Northern Dale because the system appears to be truncated by the dale for which a

Sample Numbers BG 5-6		
		%
1	Limestone	0 — 38
	Dolomite	
	Volcanics	0 — 35
	Chert	0 — 6·5
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	10 — 25
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	25 — 50

1 Autochthonous 2 Allochthonous

Figure 3 4.1.2 Summary of sediment composition, solifluctin deposits, Brightgate Cave.

Sample Numbers BG 1–4		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	24 — 52
	Sandstone	
	Feldspar	0 — 2·5
	Mica	0 — 1·5
	Shale	
	Quartzite	
	Balance (mainly clay)	25 — 70

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	30 — 70
Kaolinite	8 — 17
Chlorite	12 — 16
Mixed layer smectites	3 — 7

Figure 3.4.1.3 Summary of sediment composition, silts, Brightgate Cave.

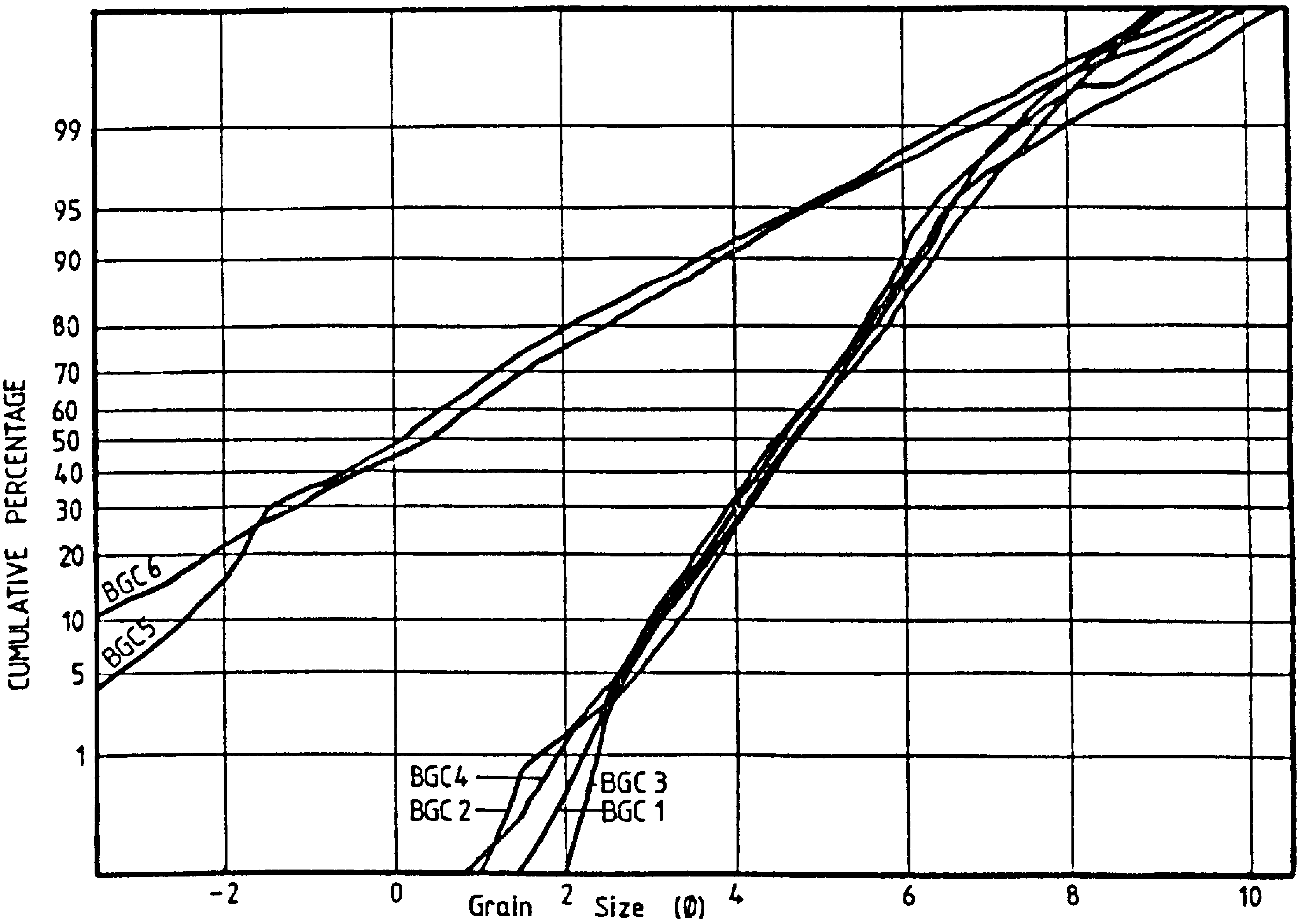
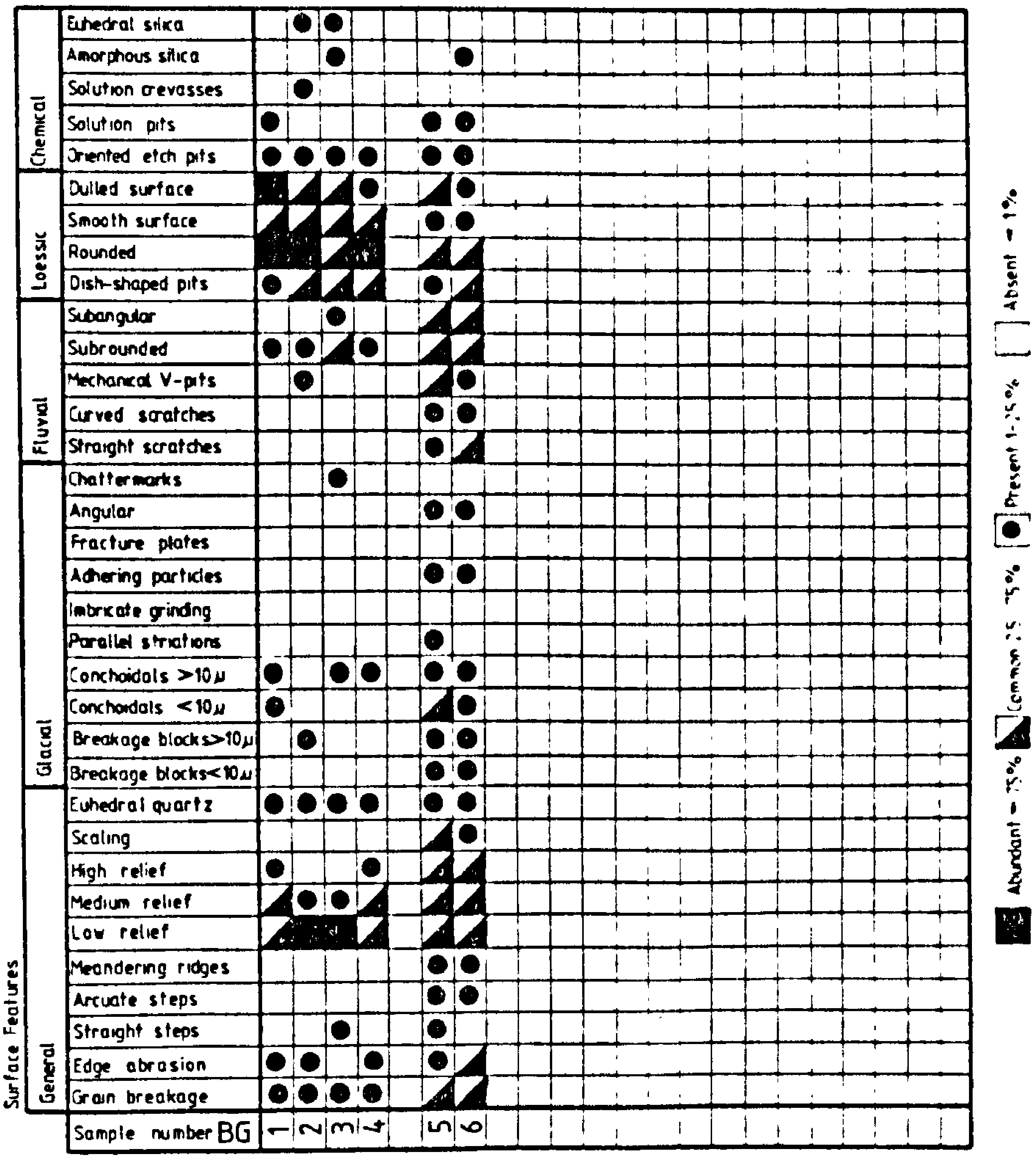


Figure 3.4.1.4. Sediment Size Analysis. Brightgate Cave.



	Chemical	Euhedral silica		●	●				
		Amorphous silica			●				●
		Solution crevasses		●					
		Solution pits	●					●	●
		Oriented etch pits	●	●	●	●		●	●
	Loessic	Dulled surface	■	◩	◩	●		◩	●
		Smooth surface	◩	◩	◩	◩		●	●
		Rounded	■	■	◩	■		◩	◩
		Dish-shaped pits	●	◩	◩	◩		●	◩
	Fluvial	Subangular			●			◩	◩
		Subrounded	●	●	◩	●		◩	◩
		Mechanical V-pits		●				◩	●
		Curved scratches						●	●
		Straight scratches						●	◩
Surface Features	Glacial	Chattermarks			●				
		Angular						●	●
		Fracture plates							
		Adhering particles						●	●
		Imbricate grinding							
		Parallel striations						●	
		Conchoidals >10μ	●		●	●		●	●
		Conchoidals <10μ	●					◩	●
		Breakage blocks>10μ		●				●	●
		Breakage blocks<10μ						●	●
	General	Euhedral quartz	●	●	●	●		●	●
		Scaling						◩	●
		High relief	●			●		◩	◩
		Medium relief	◩	●	●	◩		◩	◩
		Low relief	◩	■	■	◩		◩	◩
		Meandering ridges						●	●
		Arcuate steps						●	●
		Straight steps			●			●	
		Edge abrasion	●	●		●		●	◩
		Grain breakage	●	●	●	●		◩	◩
		Sample number BG	1	2	3	4		5	6

■ Abundant = 75% ◩ Common 25-75% ● Present 1-25% ☐ Absent = 1%

Figure 3.4.1.5. Summary of quartz grain surface textures, Brightgate Cave.

periglacial origin under permafrost conditions was postulated by Smith et al (1967). The solifluction material may have been introduced at the time of the formation of Northern Dale or during a subsequent cold period. The fine silt deposits post - date the introduction of the solifluction debris but are not as recent as speleothem development which has occurred on top of them in some places.

There are no ore minerals present in the sediments of this system and no mineral veins have been exposed in the cave walls. The miners appear to have entered the cave system purely for exploration purposes and not to have found any ore.

3.4.2. Tearsall Mine and Open Pit

Situated to the west of the head of Northern Dale (centred at SK 263,601), Tearsall Pipe consists of a pipe vein modified by later cavernisation (fig. 3.4.2.1.). The systems have been described by Kirkham (1962) and Flindall (1974). The pipe vein is developed within the Matlock Lower Limestone just above the Lower Matlock Lava (Worley, 1978). A number of clay wayboards are exposed in the underground workings and the open pit. In recent years open pit working for fluorspar has been carried out in part of the pipe, destroying some of the underground workings.

An examination of the underground workings shows that some of the cavities were filled with sediment, probably containing galena, fluorite and baryte derived

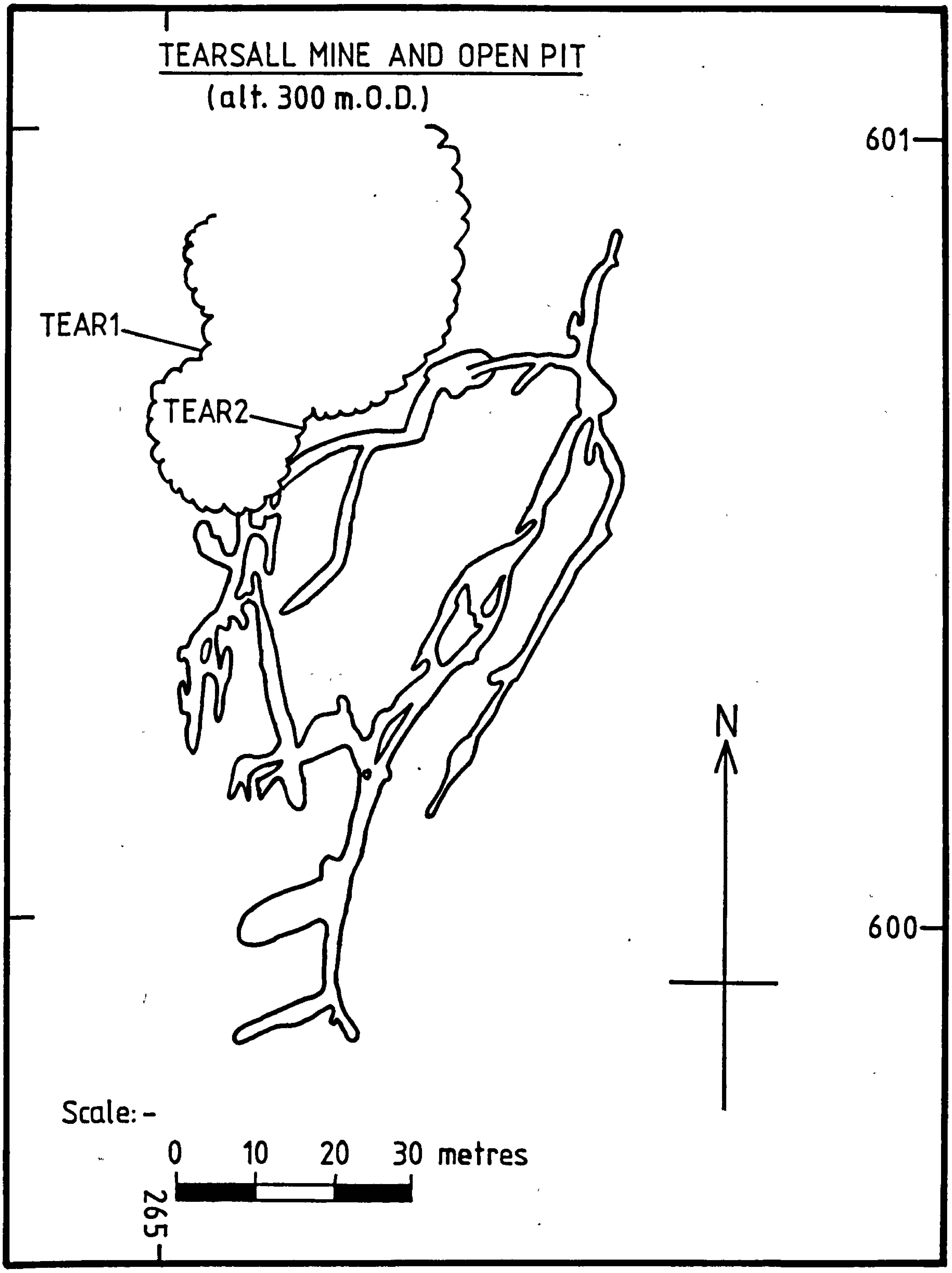


Figure 3.4.2.1. Plan of Tearsall Mine and Open Pit (November 1979), Wensley, showing sample locations. Mine plan after Ford et al (1977).

from the pipe vein. These deposits have been totally removed by mining. Two small cavities containing sediment were exposed in the open pit but these have now (1982) been removed by the mining operation.

Each cavity (fig. 3.4.2.2.), was approximately 0.7 metre in diameter and consisted of a lining of primary mineralisation with the centre filled with surface derived sediment, situated close to the top of the pit face, about 2 metres from ground level. Both cavities were developed in dolomitized limestones which, close to the cavity walls, were extensively replaced with fluorite. The cavity linings consisted of banded baryte, fluorite, galena and calcite. Being close to the surface.the calcites were deeply etched by groundwater.

The composition of the sediments is given in figure 3.4.2.3.. The results of X.R.D. analysis indicate that part of the clay fraction was derived locally from the clay wayboards.

The results of S.E.M. study of quartz grains from the sediments indicates a loessic source for most of the quartz probably with a minor fluvial contribution (fig. 3.4.2.4.).

Size analysis of the sediments shows that they are well - sorted, slightly fine - skewed, platykurtic, clayey silts (fig. 3.4.2.5.). The good sorting is probably the result of the mechanism of introduction of the sediment into the cavities by filtering down cracks and joints and of the loessic origin of much of the finer fraction. The platykurtic nature of the sediments indicates at least two sources, being the loess, thought to cover this area, the

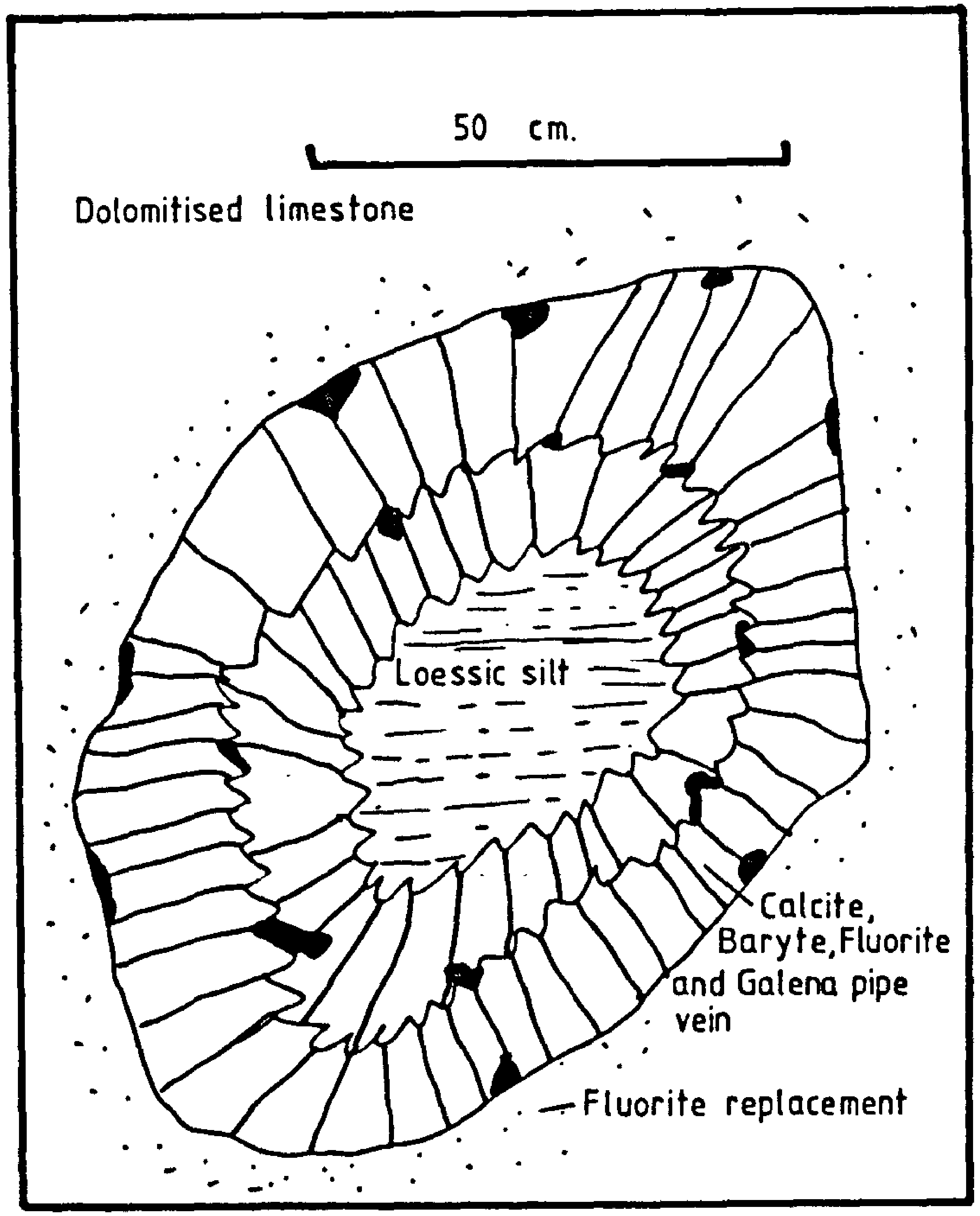


Figure 3.4.2.2. Pipe vein, Tearsall Open Pit.

Sample Numbers TEAR 1–2

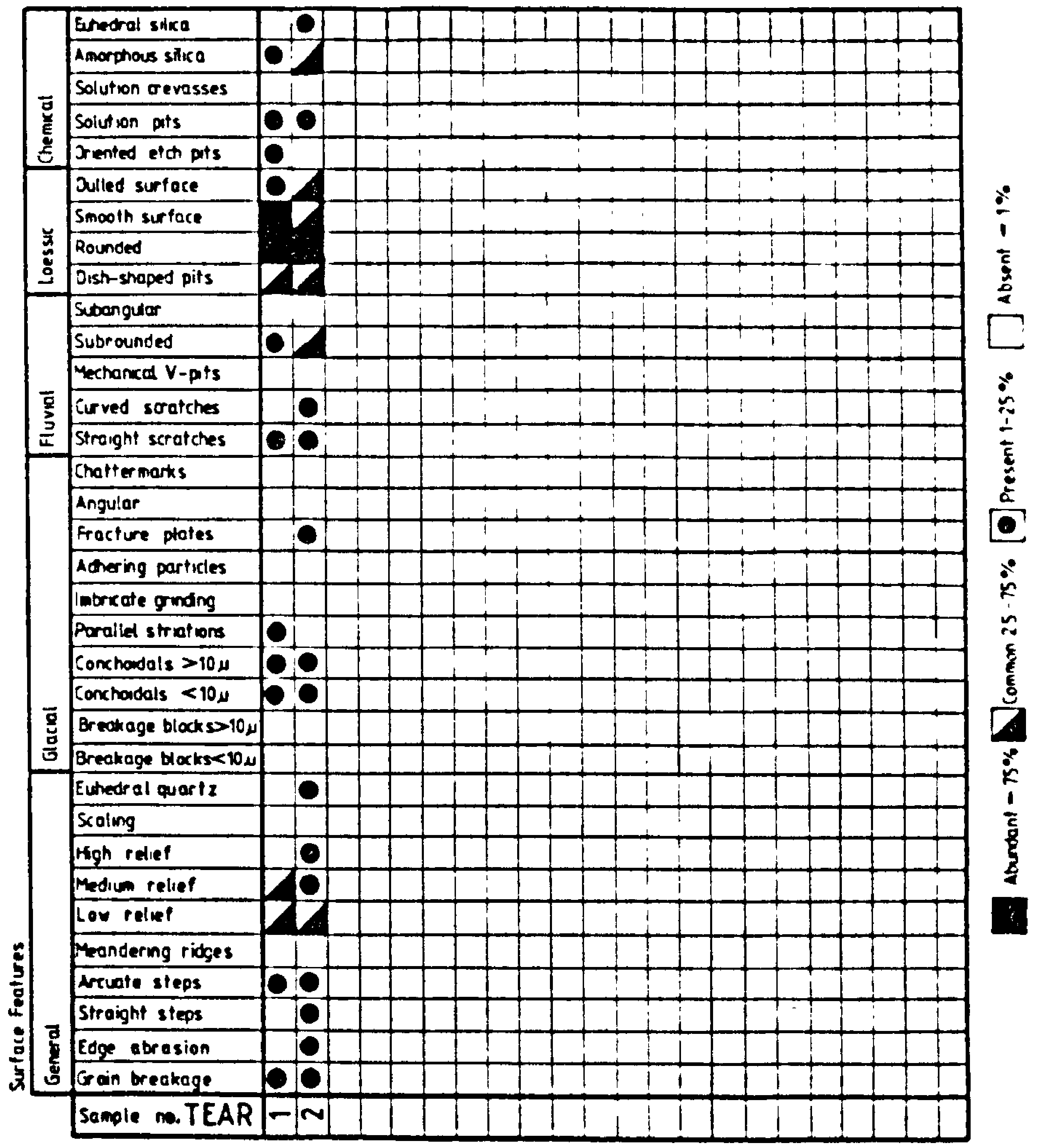
		%
1	Limestone	
	Dolomite	15 — 18
	Volcanics	1 — 4
	Chert	
	Silicified fossils	1 — 2·5
	Authigenic quartz	
	Galena	1 — 3
	Fluorite	4 — 5
	Baryte	1 — 2
	Calcite	6 — 8
2	Quartz	25 — 29
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	39 — 48

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	56 — 62
Kaolinite	18 — 21
Chlorite	14 — 16
Mixed layer smectites	1 — 6·5

Figure 3.4.2.3. Summary of sediment composition, Tearsall Open Pit.



Surface Features			
Chemical	Euhedral silica		●
	Amorphous silica	●	◢
	Solution crevasses		
	Solution pits	●	●
	Oriented etch pits	●	
Loessic	Dulled surface	●	◢
	Smooth surface	■	◢
	Rounded	■	■
	Dish-shaped pits	◢	◢
Fluvial	Subangular		
	Subrounded	●	◢
	Mechanical V-pits		
	Curved scratches		●
	Straight scratches	●	●
Glacial	Chattermarks		
	Angular		
	Fracture plates		●
	Adhering particles		
	Imbricate grinding		
	Parallel striations	●	
	Conchoidals >10µ	●	●
	Conchoidals <10µ	●	●
	Breakage blocks>10µ		
	Breakage blocks<10µ		
General	Euhedral quartz		●
	Scaling		
	High relief		●
	Medium relief	◢	●
	Low relief	◢	◢
	Meandering ridges		
	Arcuate steps	●	●
	Straight steps		●
	Edge abrasion		●
	Grain breakage	●	●
	Sample no. TEAR	1	2

■ Abundant – 75%
◢ Common 25 - 75%
● Present 1-25%
☐ Absent – 1%

Figure 3.4.2.4. Summary of quartz grain surface textures, Tearsall Open Pit.

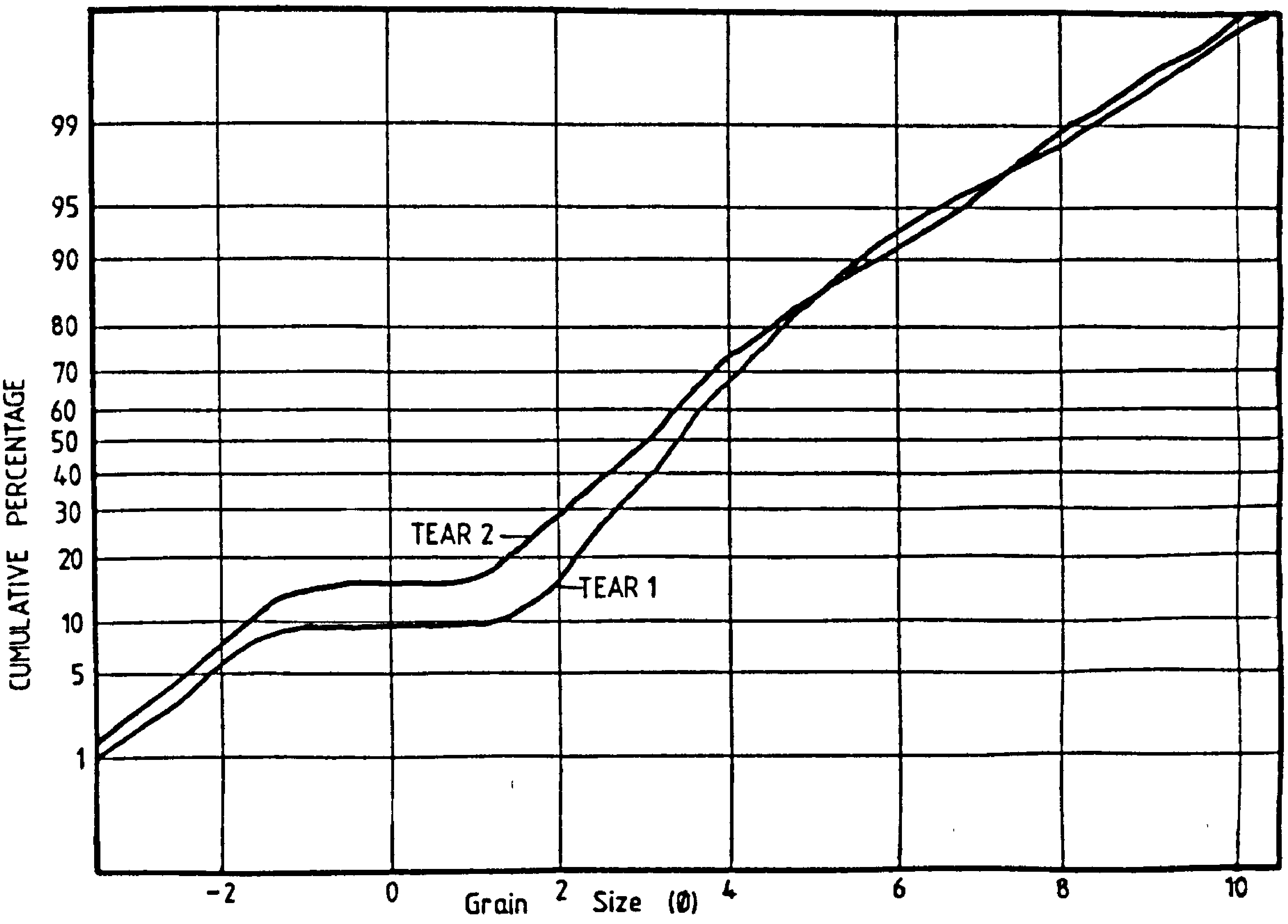


Figure 3.4.2.5. Sediment Size Analysis. Tearsall Open Pit.

surface weathering of the dolomitized limestones and local volcanics, and clasts of epigenetic minerals derived from the pipe vein walls. This conclusion is supported by the composition of the sediments.

The "ore" minerals present are locally derived probably by solutional stoping of the cavity walls causing the insoluble baryte, fluorite and galena to collapse. These minerals are distributed throughout the deposits, indicating that their introduction was a continuous process during sedimentation.

3.4.3. Old Ash Pipe

Situated on the western side of Northern Dale towards its northerly (downstream) end at SK 269,605 (fig. 3.4.3.1.). The pipe is developed in reef facies Cawdor Limestones which are partly dolomitized (Worley, 1978). The pipe vein consists of a number of small cavities (1 to 1.5m in diameter) linked by small joints which are sometimes mineralised. The mineralisation of the cavities consists of galena, fluorite, baryte and calcite and in places there has been extensive fluoritization of the wall rocks, sometimes accompanied with baryte.

Post - mineralization cavernization has occurred with the development of a number of phreatic tubes, up to 1 metre in diameter. These tubes, variously developed within the limestone and the pipe veins, are partially or totally filled with brown gritty clays sometimes containing large fluorite clasts derived from the replacement deposits. These sedimentary deposits have been

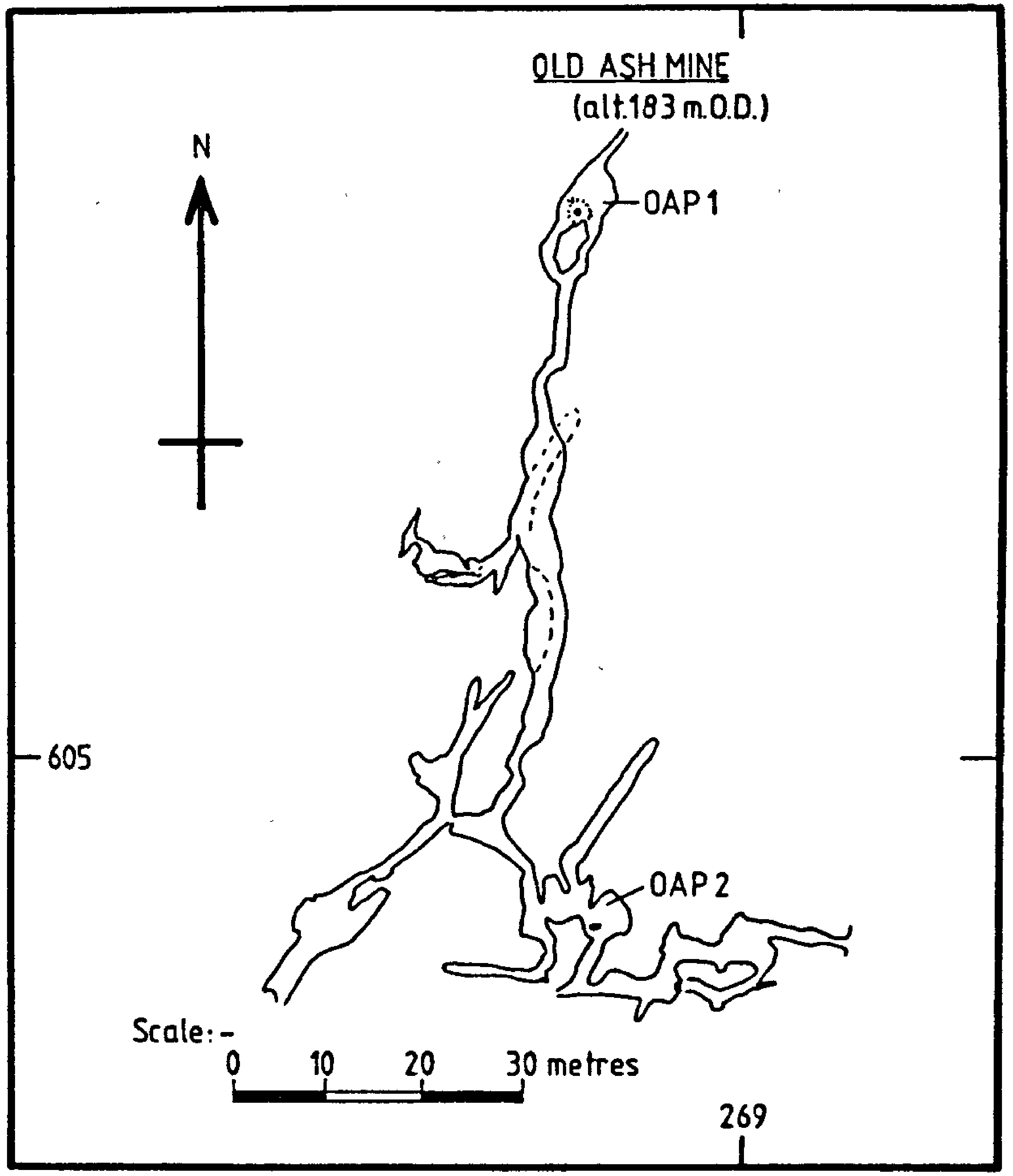


Figure 3.4.3.1. Plan of Old Ash Mine, Northern Dale, showing sample locations. After Ford et al (1977).

Sample Numbers OAP 1−2		
		%
1	Limestone	12 — 19
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	0 — 3·5
	Fluorite	27 — 81
	Baryte	0 — 2·5
	Calcite	4 — 9
2	Quartz	8 — 13
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	5 — 49
1 Autochthonous 2 Allochthonous		
Clay Mineralogy		
		%
	Illite	31 — 52
	Kaolinite	14 — 43
	Chlorite	4 — 9
	Mixed layer smectites	31 — 48

Figure 3.4.3.2. Summary of sediment composition, Old Ash Pipe.

extensively disturbed by the old lead miners in their search for lead ores.

The composition and the results of X.R.D. analysis of the sediments is given in figure 3.4.3.2..

The sediments are poorly sorted, slightly fine - skewed and, being bimodal, very platykurtic silty sands (fig. 3.4.3.3.). The results of S.E.M. studies of quartz grain surface textures show that the quartz is probably of loessic origin (fig. 3.4.3.4.).

Their bimodal nature suggests two or more sources for the sediments, one being the autochthonously derived fluorite, baryte, galena, calcite and limestone/dolomite and the other being the quartz and clay fractions which have been derived from former surface deposits of loess. Some of the clay fraction may be derived from the weathering of wayboards and toadstones which outcrop further up the hill.

Old Ash Pipe has been truncated by the incision of Northern Dale, its continuation on the east side of the valley being known as Lords and Ladies Mine (Ford et al, 1977).

3.4.4. Jugholes and Calf Tail Pipe

Jugholes Pipe has a north - south trend and now consists of two systems of interconnecting mine workings and natural chambers which were probably connected underground in mining days (Nash, 1957). Jugholes is entered via a collapsed natural cavern at SK 279,596 or by a lower adit entrance which is now almost blocked by

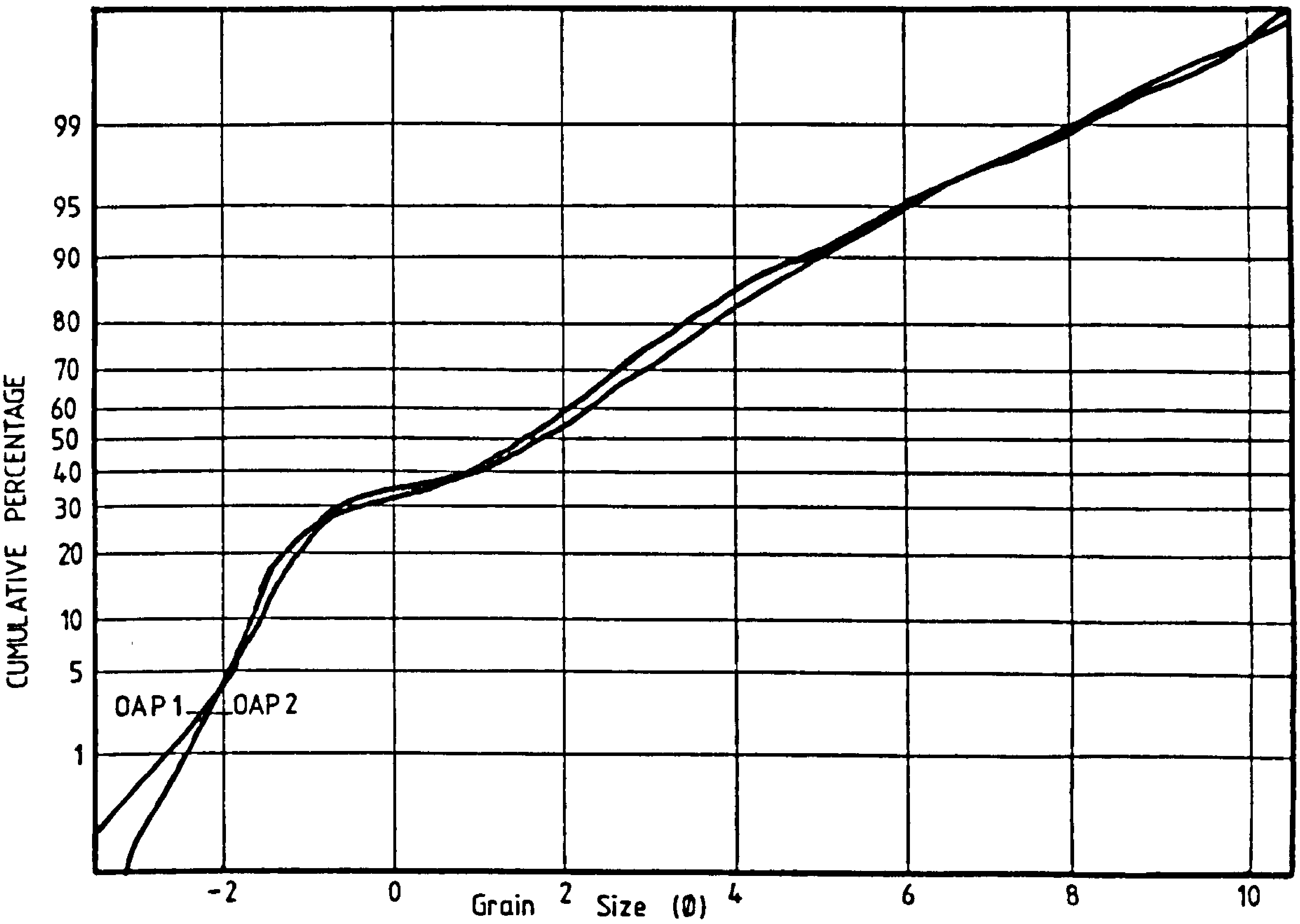
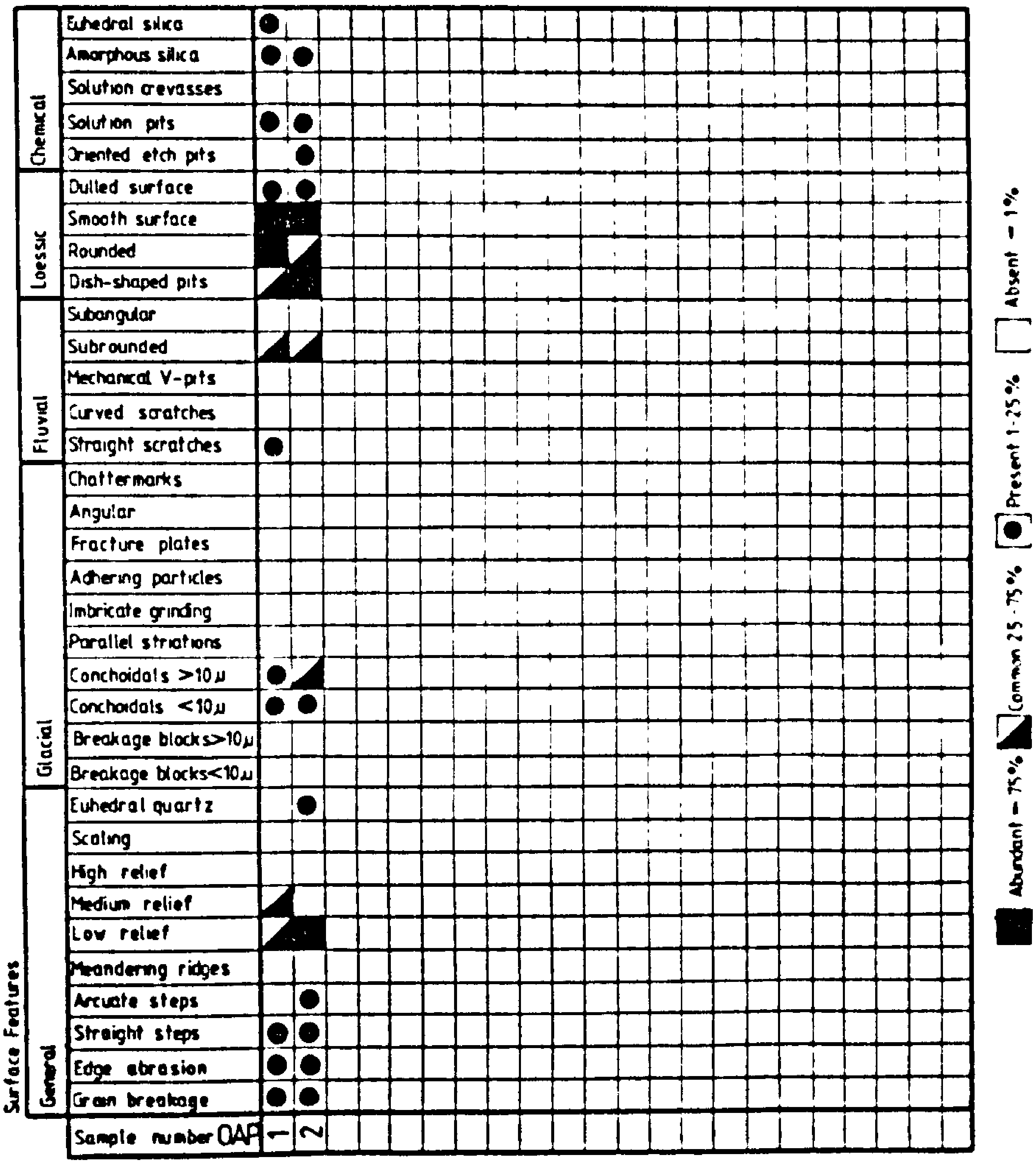


Figure 3.4.3.3. Sediment Size Analysis. Old Ash Pipe.



Chemical	Euhedral silica	●	
	Amorphous silica	●	●
	Solution crevasses		
	Solution pits	●	●
	Oriented etch pits		●
Loessic	Dulled surface	●	●
	Smooth surface	■	■
	Rounded	■	◢
	Dish-shaped pits	◢	■
Fluvial	Subangular		
	Subrounded	◢	◢
	Mechanical V-pits		
	Curved scratches		
	Straight scratches	●	
Glacial	Chattermarks		
	Angular		
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10μ	●	◢
	Conchoidals <10μ	●	●
	Breakage blocks>10μ		
	Breakage blocks<10μ		
Surface Features General	Euhedral quartz		●
	Scaling		
	High relief		
	Medium relief	◢	
	Low relief	◢	■
	Meandering ridges		
	Arcuate steps		●
	Straight steps	●	●
	Edge abrasion	●	●
	Grain breakage	●	●
	Sample number OAP	1	2

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 3.4.3.4. Summary of quartz grain surface textures, Old Ash Pipe.

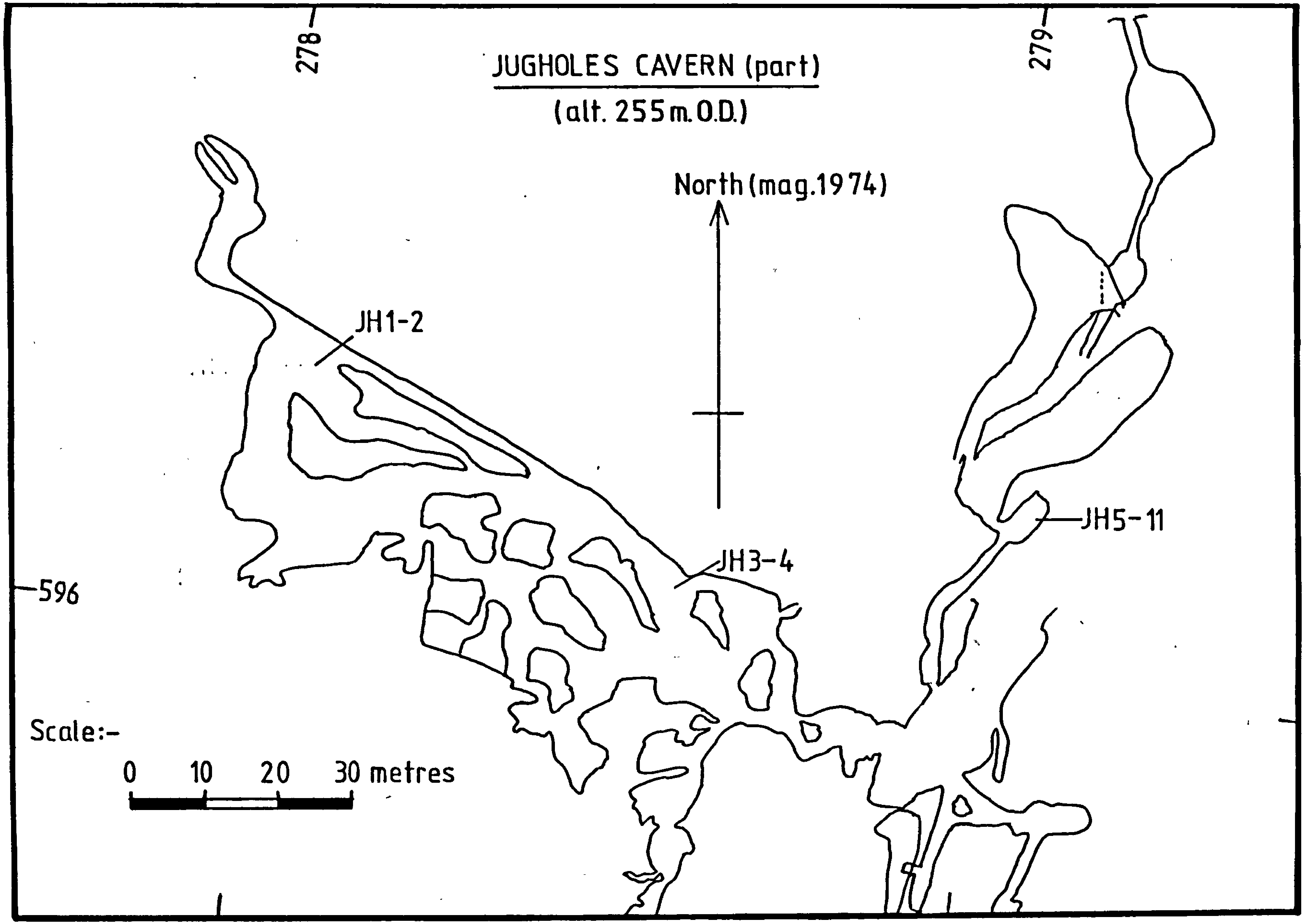


Figure 3.4.4.1. Plan of part of Jugholes Cavern, Snitterton, showing sample locations. After Worley and Nash (1977).

collapse (1982). The further continuation of the pipe, known as Calf Tail Pipe is entered via a shaft approximately 15 metres deep about 30 metres to the north of the adit entrance.

The system of caves and mine workings has been described by Nash (1957) and Worley and Nash (1977) (fig. 3.4.4.1.). The pipe is developed between the Upper and Lower Matlock Lavas within the Matlock Lower Limestone which here is 28 metres thick (Worley and Nash, 1977) and has a northerly dip of between 25 and 30°. The mineralization consists of replacement fluorite flats and void - fillings consisting of fluorite, baryte, calcite and galena.

The Jugholes cave system can conveniently be described in two sections (fig. 3.4.4.1), that to the northwest of the upper entrance (the Upper Series) and that to the northeast (the Lower Series). The continuation of Jugholes Pipe (as Calf Tail Pipe) in this direction is sometimes known as Lower Jugholes.

The Upper Series of Jugholes consists of a succession of partially collapsed natural chambers leading to a small stream which flows in the bottom of a large bedding plane cavern. The floor of this cavern is developed in the highly altered top of the Matlock Lower Lava into which the small stream has incised a small vadose trench. Much of the southwest side of this cavern is covered in stalagmite deposits which normally overlie a clayey gravel deposit resting upon the lava floor of the chamber. This part of the cave and mine system has not been modified by mining but rather in recent decades has been extensively disturbed by visiting cavers.

The composition of the sediments below the stalagmite floor is given in figure 3.4.4.2..

The dolomite and limestone clasts show evidence of solutional rounding since burial with a de-calcified limestone coating. The lava clasts are small and well - rounded due to their friable nature and were probably derived from the floor of the chamber by vadose stream erosion. The fluorite and galena, being locally derived from Jugholes Pipe, are sub-angular, the galena having a coating, about 1 mm. thick, of cerussite. The high kaolinite content of the clay fraction (fig. 3.4.4.2.) reflects the contribution to the deposit derived from the Matlock Lower Lava.

The sediments are moderately well sorted, strongly fine - skewed, very platykurtic gritty sands (fig. 3.4.4.3.). The platykurtic nature of the sediments indicate two sources, one being the coarse - grained locally derived limestone, lava and epigenetic minerals and the other the finer - grained quartz and some of the clay fraction.

Between the boulders resulting from roof collapse in the first part of the Upper Series is a similar deposit. It has been so disturbed by mining activity and the passage of cavers that no undisturbed deposits have been found. In the roof of the entrance chamber, but unfortunately well out of reach, is a cavity containing frost shatter debris overlain by brown sediments which have not penetrated between the boulders.

The Lower Series of Jugholes is an interconnecting

Sample Numbers JH 1-3

		%
1	Limestone Dolomite	3 — 8
	Volcanics	28 — 41
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	0 — 15
	Fluorite	5 — 19
	Baryte	2 — 8
	Calcite	
2	Quartz	5 — 12
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	43 — 62

1 Autochthonous 2 Allochthonous

<u>Clay Mineralogy</u>

	%
Illite	12 — 37
Kaolinite	36 — 74
Chlorite	3 — 9
Mixed layer smectites	12 — 16

Figure 3.4.4.2. Summary of sediment composition, Jugholes.

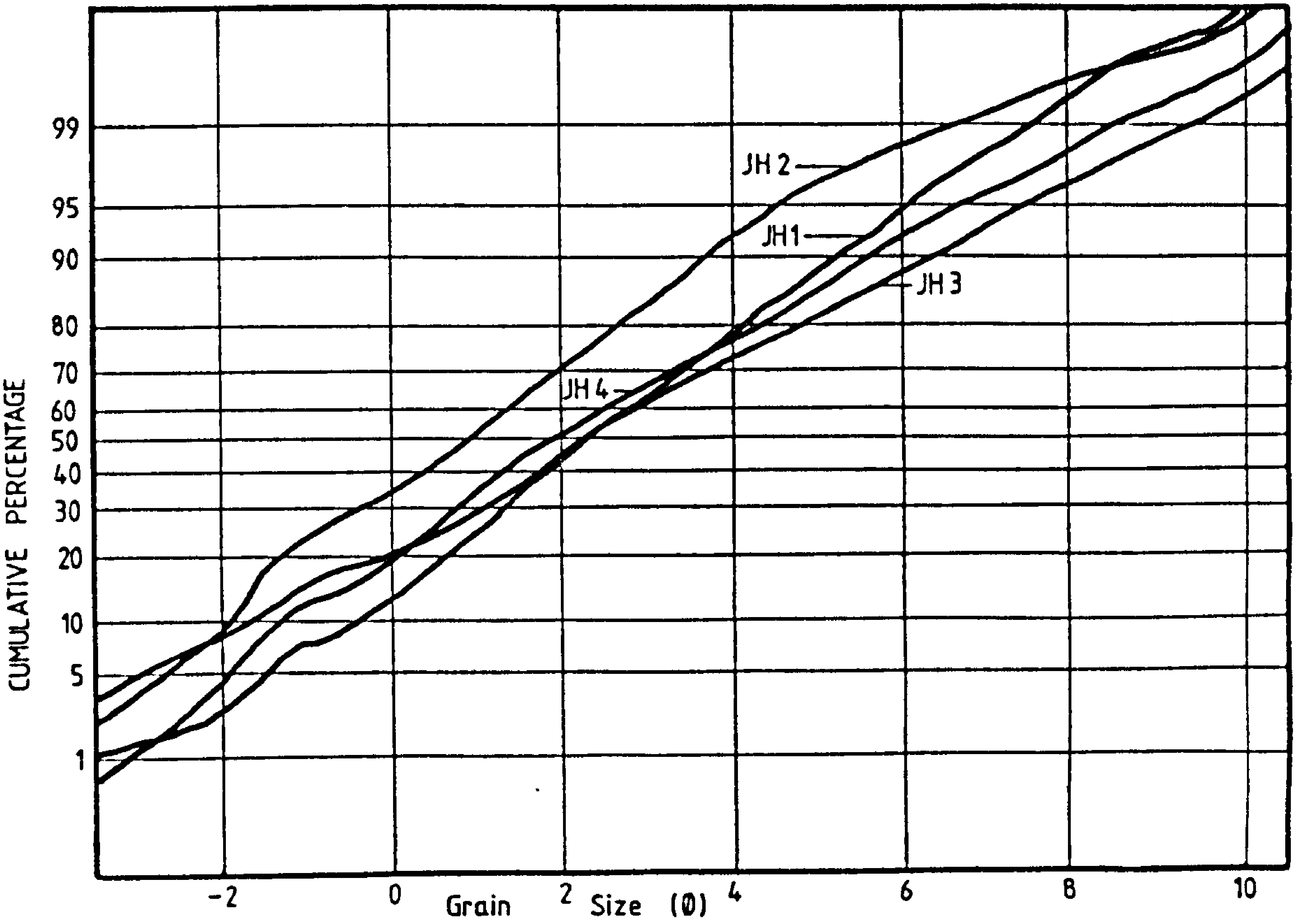


Figure 3.4.4.3. Sediment Size Analysis. Jugholes.

series of phreatic caverns and associated pipe vein and other mine workings. Calf Tail Pipe consists of a series of phreatic caverns and pipe vein workings entered via a 15 metre deep shaft. Here the pipe veins have been extensively modified by cavernization. These solution caverns were largely filled with sediment before mining took place. The upper end of the Calf Tail Pipe workings is very close to the lowest workings in Jugholes and probably once connected.

All of these caverns contain sedimentary fills, to varying extent removed by the miners for their galena and/or fluorite content. In places speleothem development has occurred since mining ceased. The sediments in all the caverns are similar and attain thicknesses up to 6.5 metres (fig. 3.4.4.4) often with a thick speleothem floor above them. In places a speleothem layer occurs within the sediments.

The sediments vary from poorly bedded, poorly sorted red-brown silts and clays to very coarse, angular to sub-angular, clayey gravels. Their composition is given in figure 3.4.4.5.. All gravel - sized and larger clasts are angular to sub-angular, locally derived wall rock and primary mineralization material. The limestone and calcite clasts sometimes show deep solutional corrosion which has occurred since deposition. Galena clasts, which are up to 20 cm. in diameter, have a coating of cerussite about 1 mm. thick.

The sediments are moderately well sorted, strongly fine - skewed and, being slightly bimodal, very platykurtic gravelly silts (fig. 3.4.4.6.). These results

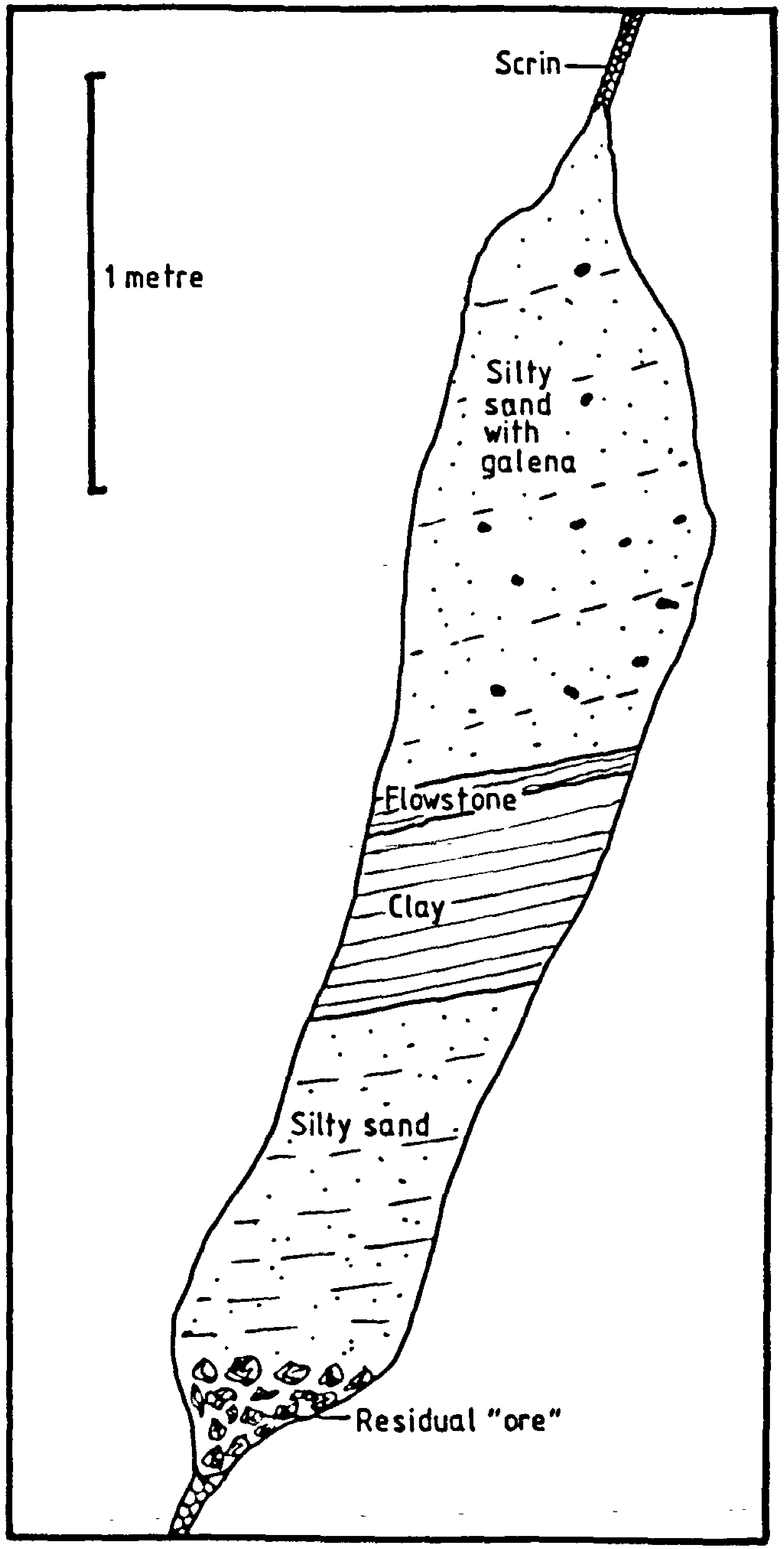


Figure 3.4.4.4 Scrin-controlled cavity, Jugholes.

Sample Numbers JH 4-11

		%
1	Limestone Dolomite	20 — 47
	Volcanics	1 — 3
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	1 — 35
	Fluorite	4 — 29
	Baryte	0·5 — 13
	Calcite	2·5 — 11
2	Quartz	7 — 16
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	19 — 68

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	33 — 67
Kaolinite	16 — 35
Chlorite	3 — 7
Mixed layer smectites	11 — 14

Figure 3.4.4.5. Summary of sediment composition, Jugholes.

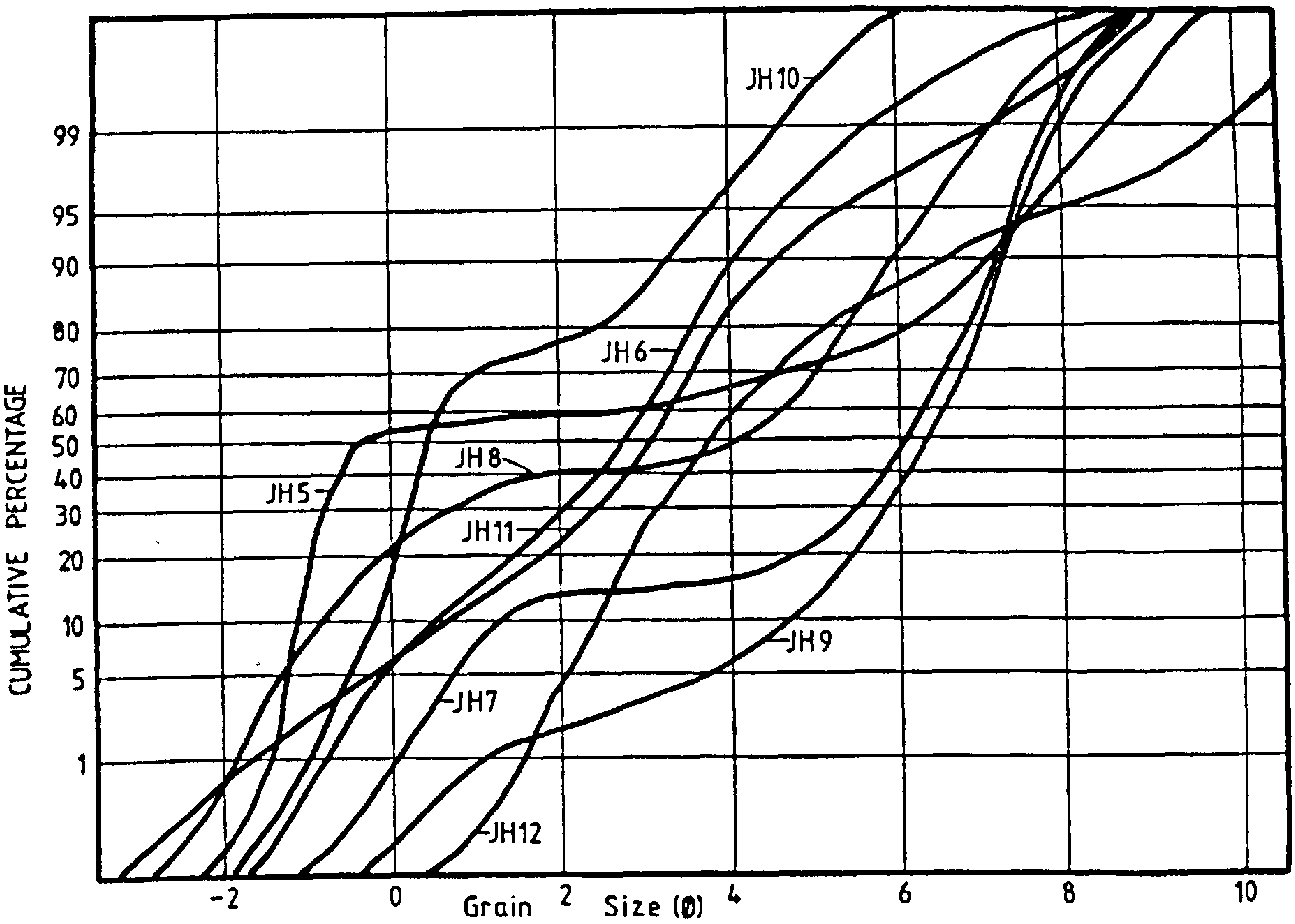
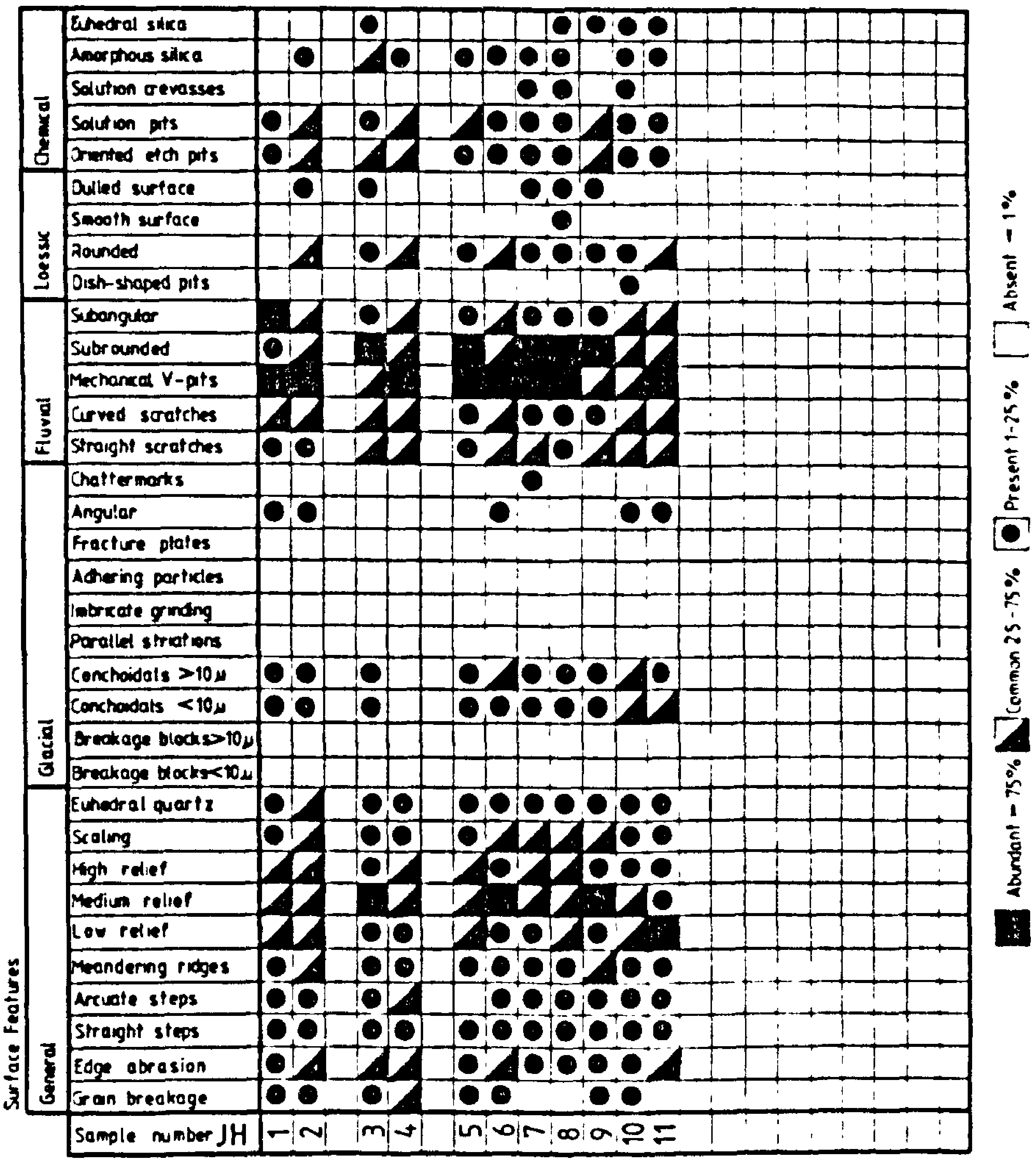


Figure 3.4.4.6. Sediment Size Analysis. Jugholes.



		1	2	3	4	5	6	7	8	9	10	11
Chemical	Euhedral silica			●					●	●	●	●
	Amorphous silica		●	◢	●	●	●	●	●		●	●
	Solution crevasses							●	●		●	
	Solution pits	●	◢	●	◢	◢	●	●	●	◢	●	●
	Oriented etch pits	●	◢	◢	◢	●	●	●	●	◢	●	●
Loessic	Dulled surface		●	●				●	●	●		
	Smooth surface								●			
	Rounded		◢	●	◢	●	◢	●	●	●	●	◢
	Dish-shaped pits										●	
Fluvial	Subangular	■	◢	●	◢	●	◢	●	●	●	◢	◢
	Subrounded	●	◢	■	◢	■	◢	■	■	■	◢	◢
	Mechanical V-pits	■	■	◢	■	■	■	■	■	◢	◢	■
	Curved scratches	◢	◢	◢	◢	●	◢	●	●	●	◢	◢
	Straight scratches	●	●	◢	◢	●	◢	◢	●	◢	◢	◢
Glacial	Chattermarks							●				
	Angular	●	●				●				●	●
	Fracture plates											
	Adhering particles											
	Imbricate grinding											
	Parallel striations											
	Conchoidals >10μ	●	●	●		●	◢	●	●	●	◢	●
	Conchoidals <10μ	●	●	●		●	●	●	●	●	◢	◢
	Breakage blocks>10μ											
	Breakage blocks<10μ											
Surface Features General	Euhedral quartz	●	◢	●	●	●	●	●	●	●	●	●
	Scaling	●	◢	●	●	●	◢	◢	◢	◢	●	●
	High relief	◢	◢	●	◢	◢	●	◢	◢	●	●	●
	Medium relief	◢	◢	■	◢	◢	■	◢	◢	■	◢	●
	Low relief	◢	◢	●	●	◢	●	●	◢	●	◢	■
	Meandering ridges	●	◢	●	●	●	●	●	●	◢	●	●
	Arcuate steps	●	●	●	◢		●	●	●	●	●	●
	Straight steps	●	●	●	●	●	●	●	●	●	●	●
	Edge abrasion	●	◢	◢	◢	●	◢	●	●	●	●	◢
	Grain breakage	●	●	●	◢	●	●			●	●	
	Sample number JH	1	2	3	4	5	6	7	8	9	10	11

■ Abundant – 75% ◢ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 3.4.4.7. Summary of quartz grain surface textures, Jugholes.

are similar to those obtained by Worley (see Worley and Nash, 1977).

The results of S.E.M. studies of quartz grain surface textures show no evidence for a glacial or loessic derivation and only limited evidence of a fluvial environment, extensive solution and re-precipitation of silica having occurred (fig. 3.4.4.7.).

The platykurtic nature of the sediments suggests that the sediment was derived from two or more sources, firstly the locally derived limestone, dolomite, lava and the minerals of the epigenetic mineral suite and, secondly, from further afield but still fairly local surface erosion of the limestones and lavas. This conclusion is supported by the composition of the sediments. The S.E.M. study shows that this derivation was by fluvial processes.

Speleothem layers intercalated between the sedimentary units indicate periods when the cave system was abandoned, as most of it is now, by the streams which formed the caverns and introduced the sediments.

These sediments contain derived galena, particularly in Calf Tail Pipe, and were obviously important to the lead miners as sources of lead ore which was easily worked and dressed. The miners have left little of the deposits unworked and much of the ore dressing was carried out underground in the larger caverns leaving the waste which closely resembles the original sediments.

3.4.5. Oxclose Mine

Situated one kilometre south of the village of Snitterton at SK 275,597. The mine has been worked, firstly for lead ores and more recently for fluorspar, into the 1950's. The mine consists of a complex series of interconnecting pipe vein, scrin, rake and replacement deposit workings and natural caverns.

The deposits are developed in the Matlock Lower Limestone sandwiched between the Upper and Lower Matlock Lavas dipping at approximately 20^{o} to the north. The mineralization is not known to penetrate the Matlock Upper Lava and has not been explored below the Matlock Lower Lava (Dunham, 1952). The limestones are dark shelly limestones grading into pale grey thick - bedded biomicrites. Seven wayboards occur in the limestone sequence and these have had a controlling effect on the location of the mineralization (Worley, 1978).

Primary mineralization consists of fluorite, baryte, marcasite, galena and sphalerite with secondary cerussite, smithsonite and minor malachite. It occurs as a series of pipe vein cavities connected by widened joints, flats and scrins with associated replacement deposits.

Post - mineralization cavernization within the pipe vein system has eroded and corroded the primary mineral deposits the insoluble residue from this process has accumulated on the floor of the cavities. Allochthonously derived sand and clay is mixed with these residual accumulations. The sedimentary deposits generally do not fill the caverns to the roof allowing the formation of flowstone floors 1 to 7 cm thick on top. Early mining consisted of breaking through these floors and removing the sediments below for their galena content. Much of the material that once nearly filled much of the cave system has been removed in this way leaving limited sections of undisturbed material.

The sediments vary from coarse angular gravels with large blocks in a silty clay matrix to finely laminated silts which form the higher horizons. The bulk of the material has an autochthonous origin, often barely more than falling to the floor of a cavity when solution has removed the limestone wall rocks and calcite present within the mineralization. The composition of the deposits is given in figure 3.4.5.1..

Limonite is also present and has been derived from the decomposition of the substantial quantities of marcasite present in the primary mineralization. Size analysis of the sediments shows them to be poorly sorted, strongly coarse - skewed, platykurtic silty gravels with little sand - sized material (fig. 3.4.5.2.).

The platykurtic nature of the sediments again reflects the two source origin of these sediments, the bulk of the material being autochthonously derived from the primary mineral deposits with a smaller allochthonous contribution of quartz sand and clay.

3.4.6. Leawood Pipe

Located about 200 metres east of Oxclose Mine at SK 276,599 this mine was not visited during the present

Sample Numbers OX 3, 5-6

		%
1	Limestone	
	Dolomite	
	Volcanics	0 — 3
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena (cerussite coated)	0 — 5
	Fluorite	31 — 90
	Baryte	2 — 8
	Calcite	
2	Quartz	1 — 14
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	4 — 38

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	14 — 34
Kaolinite	22 — 52
Chlorite	15 — 28
Mixed layer smectites	4 — 15

Figure 3.4.5.1. Summary of sediment composition, Oxclose Mine.

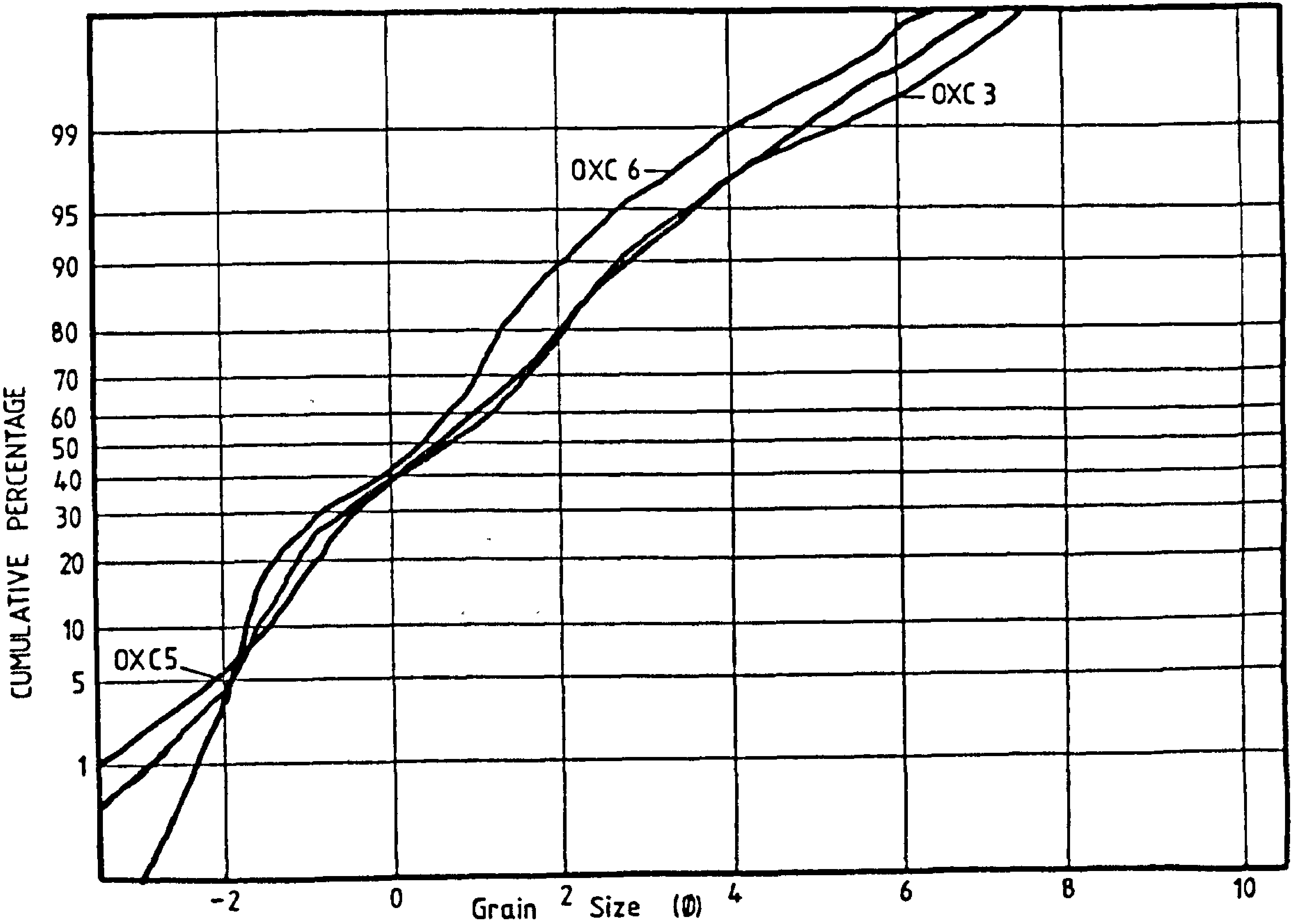


Figure 3.4.5.2. Sediment Size Analysis. Oxclose Mine.

study. Worley (1978) noted that the pipe, which attained a maximum width of 10 metres and height of 12 metres, was developed in the upper part of the Matlock Lower Limestone below a thick clay wayboard and consisted of an interconnecting series of pipe vein cavities, up to two metres in diameter, infilled with columnar calcite with sphalerite, sometimes altered to calamine, and galena. Up dip the pipe contained a laminated brown fluorite up to 2 metres thick.

Post - mineralization cavernization of the wall rocks and pipe veins has occurred, the cavities produced being completely filled with red - brown sediments consisting mainly of fluorite. The old miners excavated this fill for its contained galena, making little attempt to work the deposits still attached to the walls.

3.4.7. Millclose Mine

Worked until 1939, Millclose Mine was the last successfully worked lead mine in the Peak District (Ford and Rieuwerts, 1983). The centre of the mine is at SK 259,265 and the site is now occupied by a scrap lead processing plant.

From the limestone outcrop south of the mine where limited mineralization was first worked the mine was worked northwards below the shale cover for a distance of nearly 5 kilometres attaining a depth of 350 metres below the shaft collars. The history and workings of the mine have been described by several authors including Wass (1881), Stuckey (1917), Anon (1936), Raistrick (1938) and

Taylor (1959).

Since abandonment the mine has been flooded to sough level (about 20 metres below shaft collar). The geology and mineralization of the mine has to be extracted from contemporary accounts, notably Parsons (1897), Stuckey (1917), Varvill (1937 and 1959), Traill (1939 and 1940) and Shirley (1950). An extensive geological account has been produced by Worley (1978).

Mineralization at Millclose occurs mainly within the Matlock Limestones ascending in a stepped pattern, from the north to south, climbing through weaknesses in the toadstone and tuff horizons which prevented fluid migration directly to the base of the shale. It consists of strong fissure veins, small joint controlled scrins with associated flat, pipe vein and "wing" deposits. These associated deposits were generally developed immediately beneath shale, wayboard and toadstone horizons adjacent to fissure veins and were variably replacement and cavity fill deposits.

Post - mineralization cavernization, often along pre-existing pipe vein cavity systems and fissure veins, has reportedly caused the pipe vein mineralization to be removed from the roof and walls and to be concentrated on the floor by the solutional removal of the soluble gangue and wall rock minerals. The ore left in the cavities was mixed with surface and underground (shale and wayboard) derived clays. From Traill's (1939 and 1940) accounts it is apparent that these deposits were generally only found in the shallow parts of the mine (between 93 and 103 fathom levels (approximately 180 and 200 metres)).

From his experience in the Millclose Mine, Varvill (1962) postulated that the lead deposits were of secondary origin being re-deposited galena derived by mechanical erosion of fissure veins and scrins. He further postulated that the fine - grained galena was transported by meteoric waters in a form of natural froth flotation and that deposition occurred when sufficient depth had been obtained for the air bubbles to collapse, releasing the galena. From his own accounts of the mineralization at Millclose this is not likely. He states that the galena of Millclose Mine is coarsely crystalline which would not be the case if this process had operated. Concentration of the "gravel" ore by circulating groundwater has concentrated the galena in some cavities in this mine which then formed workable deposits, but most of the ore produced from Millclose came from primary deposits.

3.4.8. Masson Mine/Youds Level

This is a complex of interconnected mines, underlying the eastern side and slopes of Masson Hill (Warriner et al, 1981; Flindall et al, 1981) (fig. 3.4.8.1). The entrance to Masson Cavern is at SK 292,586, to Youds Level at SK 295,294 and Masson Open pit at SK 285,593.

Underground lead mining dates back to at least 1470 (Ford and Rieuwerts, 1983) and fluorspar mining was carried out underground in older lead workings until the 1950's. Since then surface open pit working has been conducted, resulting in the destruction of a large part of

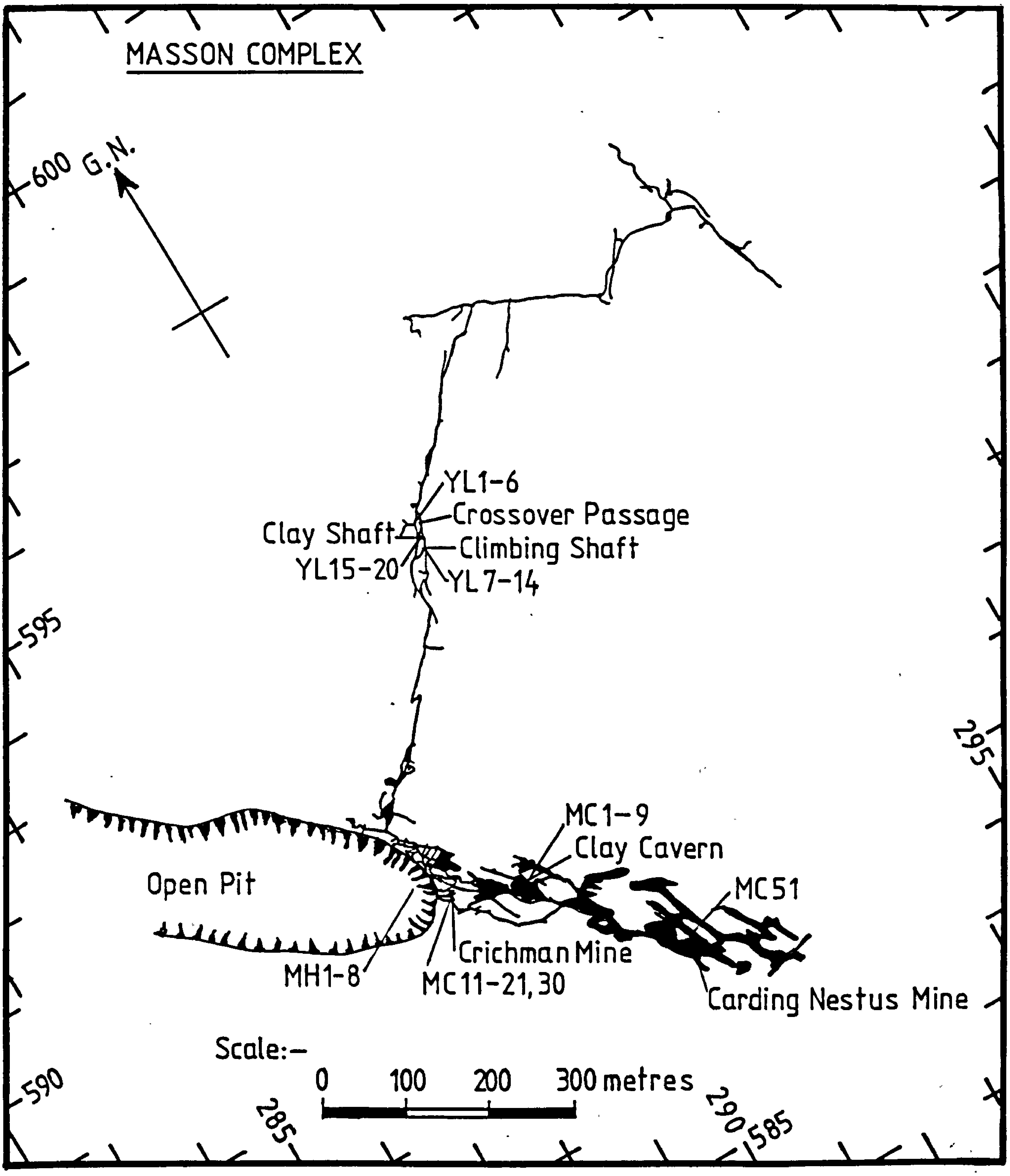


Figure 3.4.8.1. Plan of the Masson Complex showing sample locations. After Flindall et al (1981) and Warriner et al (1981).

the older underground workings. Throughout the system there are numerous sediment filled cavities, many others have probably been removed by the underground and open pit mining operations.

Accounts of the history and recent exploration of this complex mine system are given by Flindall and Hayes (1976) and Warriner et al (1981).

Detailed descriptions of the geology and mineralization of the Masson Mine have been given by numerous authors including Dunham (1952), Ford (1968), Ixer (1974), Butcher (1976) and Worley (1978). Mineralization is restricted to the Matlock Lower Limestone between the Upper and Lower Matlock Lavas. The Upper Matlock Lava apparently capping the mineralization and the Lower Matlock Lava forming its floor.

The limestones are typically pale grey biosparites but are often dolomitized to form a porous, poorly bedded dolomite, especially close to the crest of Masson Hill (fig. 3.4.8.2.). Generally the contact between the limestone and dolomite is highly irregular, crosscutting the bedding and penetrating into the limestone further along bedding planes and joints. Within the limestones and dolomites between the two Matlock Lavas are four clay wayboards which have had controlling effects upon the mineralization (Worley, 1978).

The limestones and dolomites associated with the mineralization are patchily silicified with the development of large (2 to 3 mm. or more) euhedral quartz crystals (both clear and amethystine).

The mineralization consists of a fissure vein (Great

Figure 3.4.8.2. Idealised section through the north-east slope of Masson Hill. Adapted from Warriner et al (1981).

Rake) and associated joint orientated scrins which have controlled the location of flats (both cavity fill and replacement) and pipe veins. The most important minerals in these deposits being fluorite, calcite, baryte and galena. The paragenetic sequence is complex and multiphase mineralization has occurred (Ixer, 1974).

Two main sets of pipe vein systems are present, Masson Pipe which extends some 850 metres along a northwest - southeast strike attaining a maximum width of 240 metres; and Gentlewoman's Pipe, which joins Masson Pipe and extends away from it for some 350 metres with widths of up to 40 metres (fig. 3.4.8.1.) down dip to the northeast. The area where these two pipes meet has now (1982) been removed by open pit fluorspar mining.

Post mineralization cavernization and modification of the primary mineral deposits is extensive. Much of the pipe veins have been solutionally enlarged and filled with sediment. These deposits will be described under the following sections:-

Nestus (Rutland) and Carding's Nestus Mines and
Masson Cavern
High Loft (Black Ox) Mine
Crichman Mine
Masson Open Pit
Gentlewoman's Pipe and Old Jant Mine

3.4.8.1. Nestus (Rutland) and Carding's Nestus Mines and Masson Cavern

Parts of both Masson Cavern and Nestus Mine (as Rutland Cavern) are open to the public as show caves. Both are close to the surface and have been worked for their lead ores for a long period of time, possibly since the Roman occupation. Hurt (1968b) and Flindall and Hayes (1976) describe the history and exploration of these mines. Much of the lead ore was won by working sedimentary deposits and no undisturbed sediments remain in this part of the Masson complex. Outside the entrance to Masson Cavern a recent excavation (1982) through a mine dump has revealed layered silts, similar to those exposed in situ in other parts of the mine. These occur in what was the tailings pond and indicate that some of the sedimentary deposits were of sufficient grade to bring to the surface for dressing.

In Masson Cavern pipe vein cavities contain a pre - mineralization sediment consisting of quartz and minor limonite and showing limited lamination (fig. 3.4.8.1.1.). This represents the insoluble component from the limestones and dolomites concentrated by the hydrothermal solutions which formed the pipe vein cavities. Thin sections show that the quartz is extensively lithified with the development of secondary quartz overgrowths.

Carding's Nestus Mine is free from post - mineralization cavernization being an area of complex pipe vein and scrin mineralization. Close to Black Ox Shaft an underground chamber has been utilized for underground ore

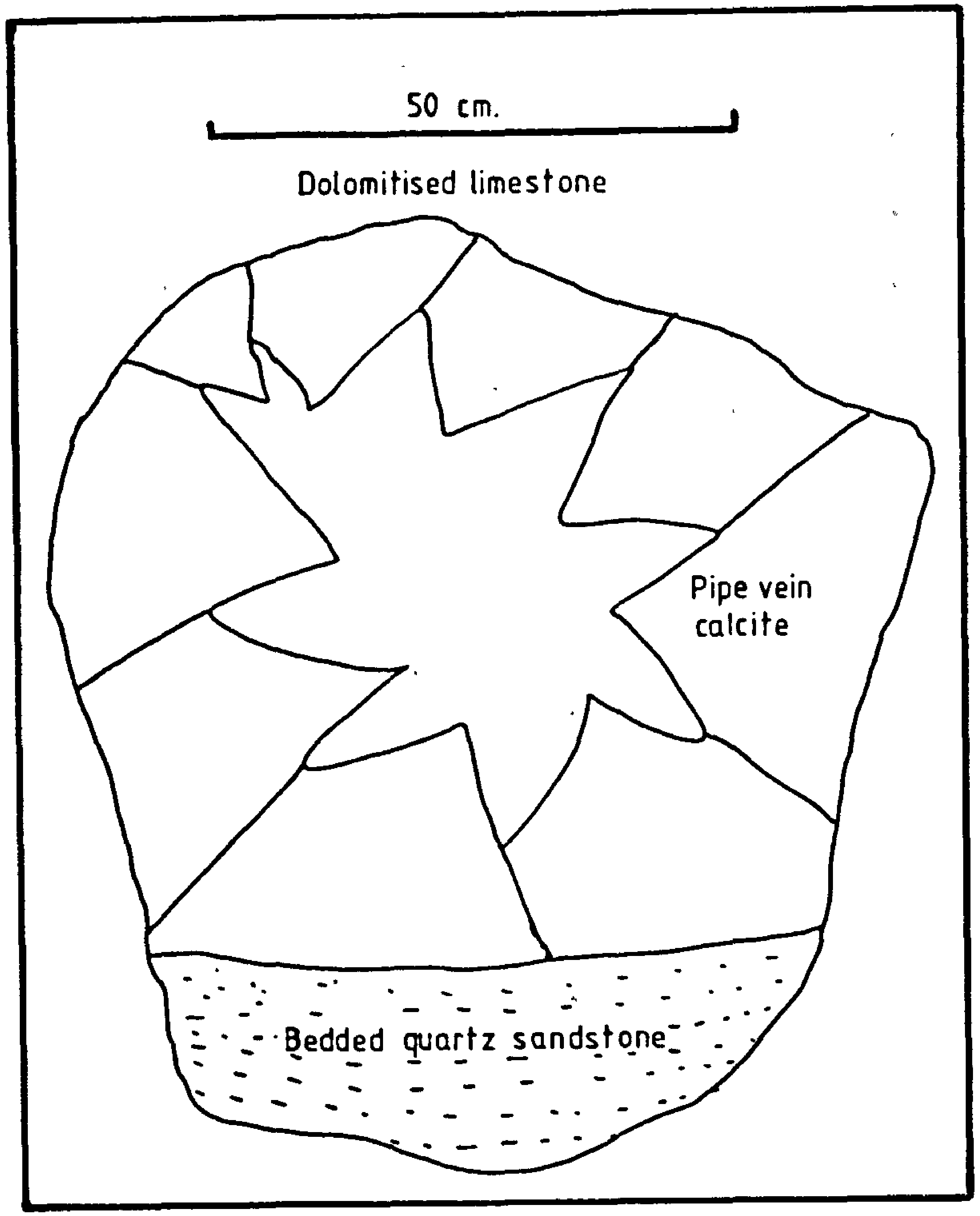


Figure 3.4.8.1.1. Pipe vein, Great Masson Cavern.

Sample Numbers MC 51		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	75
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	25
1 Autochthonous 2 Allochthonous		

Figure 3.4.8.1.2. Summary of sediment composition,
Cardings Nestus Mine, Masson Complex.

dressing, the waste from which forms a layered, coarse - to fine - grained but poorly sorted bedded material consisting solely of gangue minerals and wall rocks.

Some of the vein cavities have been filled with fine - grained silty clay which has been introduced by the mechanism of translatory flow (Bull, 1981b). The composition of these sediments is given in figure 3.4.8.1.2.. The sediments are well sorted, slightly fine - skewed, mesokurtic silty clays (fig. 3.4.8.1.3.). The results of S.E.M. study of the quartz grain surface textures shows that the quartz is of loessic origin (fig. 3.4.8.1.4.). Most of the clay fraction has been derived from the clay wayboards and the Upper Matlock Lava.

The translatory flow mechanism of transport for this material can operate in this section of the Masson Complex because it is one of the few parts of the mine which is not capped by the Matlock Upper Lava. This has been removed by erosion allowing the joint system to be continuous from the surface downwards.

3.4.8.2. High Loft (Black Ox) Mine

Several sedimentary deposits were found in High Loft Mine by the lead miners, some of which remain intact for sampling. Near Dale (High Loft) Shaft a large cavern, nearly 20 metres high, showing phreatic solutional features, cuts across the pipe vein mineralization. The original floor level of this cavern is some 15 metres above the present floor, its sedimentary fill having been removed by the lead miners. The chamber was later used for

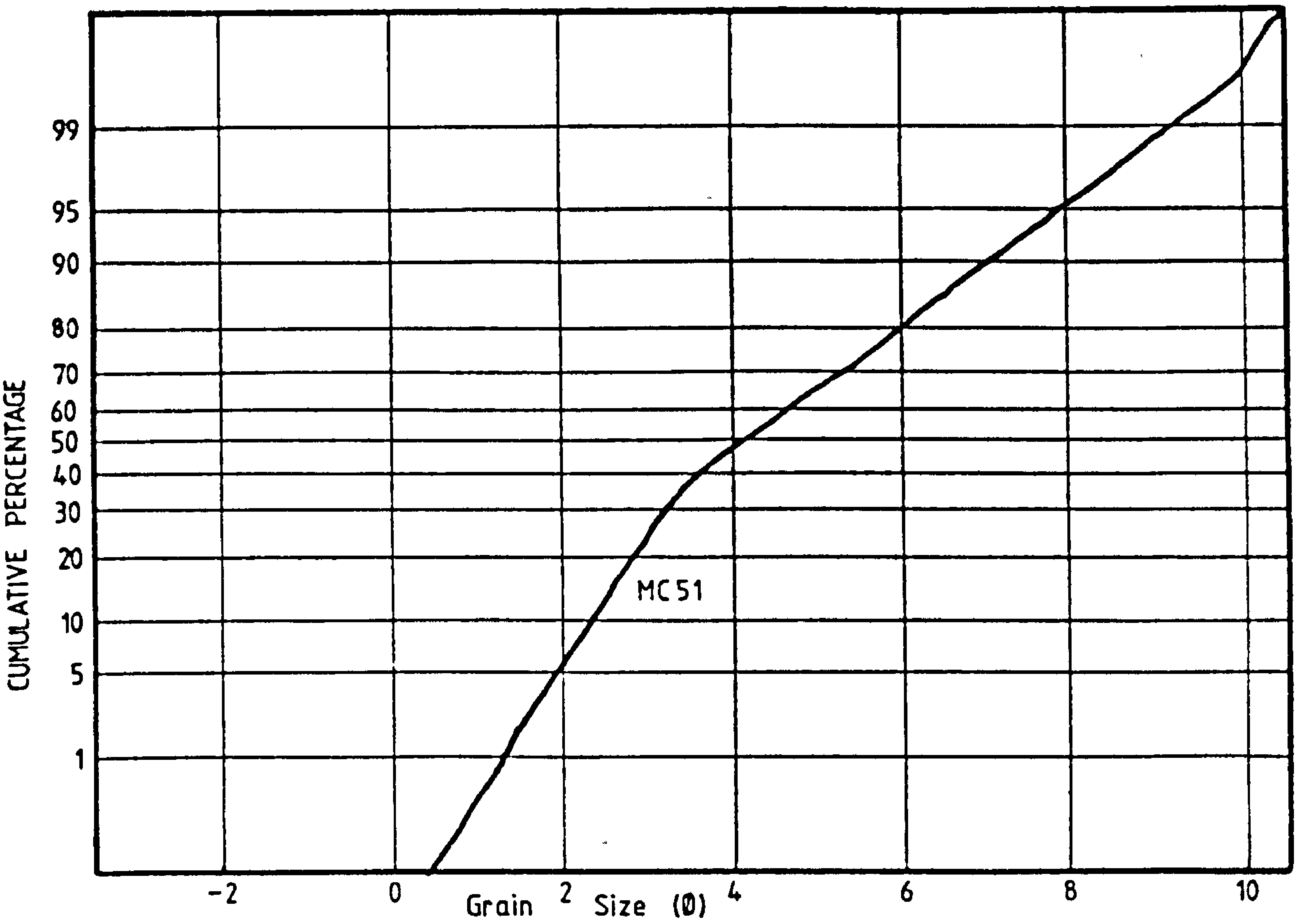


Figure 3.4.8.1.3. Sediment Size Analysis. Carding Nestus Mine.

Surface Features	Chemical	Euhedral silica	
		Amorphous silica	◢
		Solution crevasses	
		Solution pits	●
		Oriented etch pits	
	Loessic	Dulled surface	◢
		Smooth surface	■
		Rounded	■
		Dish-shaped pits	◢
	Fluvial	Subangular	
		Subrounded	◢
		Mechanical V-pits	
		Curved scratches	
		Straight scratches	●
	Glacial	Chattermarks	
		Angular	
		Fracture plates	
		Adhering particles	
		Imbricate grinding	
		Parallel striations	
		Conchoidals >10μ	●
		Conchoidals <10μ	●
		Breakage blocks>10μ	
		Breakage blocks<10μ	
	General	Euhedral quartz	●
		Scaling	
		High relief	
		Medium relief	●
		Low relief	■
		Meandering ridges	
		Arcuate steps	
		Straight steps	
		Edge abrasion	●
		Grain breakage	◢
		Sample number MC	51

■ Abundant – 75%
◢ Common 25 - 75%
● Present 1-25%
□ Absent – 1%

Figure 3.4.8.1.4. Summary of quartz grain surface textures, Cardings Nestus Mine, Masson Complex.

fluorspar dressing until the 1950's.

To the northwest of Dale Shaft a large chamber, Clay Cavern, 30 metres in diameter and up to 4 metres high was found by the miners (fig. 3.4.8.1.). When discovered it was filled with sediment but now only a few remnants are present.

The section remaining (fig. 3.4.8.2.1.) shows a bottom layer of limonitic silts containing large residual clasts of galena, baryte and fluorite in a matrix of altered lavas and clay wayboards with a small contribution from the insoluble content of the limestone.

Overlying this is a succession, 1.1 metres thick, of alternating dark sandy and light brown silty horizons of a varved nature totalling 17 couplets (plates 3.4.8.2.1. and 3.4.8.2.2.). This is overlain by poorly sorted coarse, medium - brown sediments containing lumps of fluorite detached from the roof of the cavern.

The composition of the basal limonitic layer is given in figure 3.4.8.2.2.. Size analysis of the sediment shows two distinct populations, one being the large clasts derived from the epigenetic mineral suite, from coarse sand to large cobble in size and the other being the clay and euhedral quartz fraction which is the insoluble residue of the limestone.

All units from the rhythmite sequence above this basal layer are of similar composition, mainly of autochthonous origin. Their composition is given in figure 3.4.8.2.3..

Size analysis of the coarse units shows them to be moderately well sorted, slightly coarse - skewed, slightly

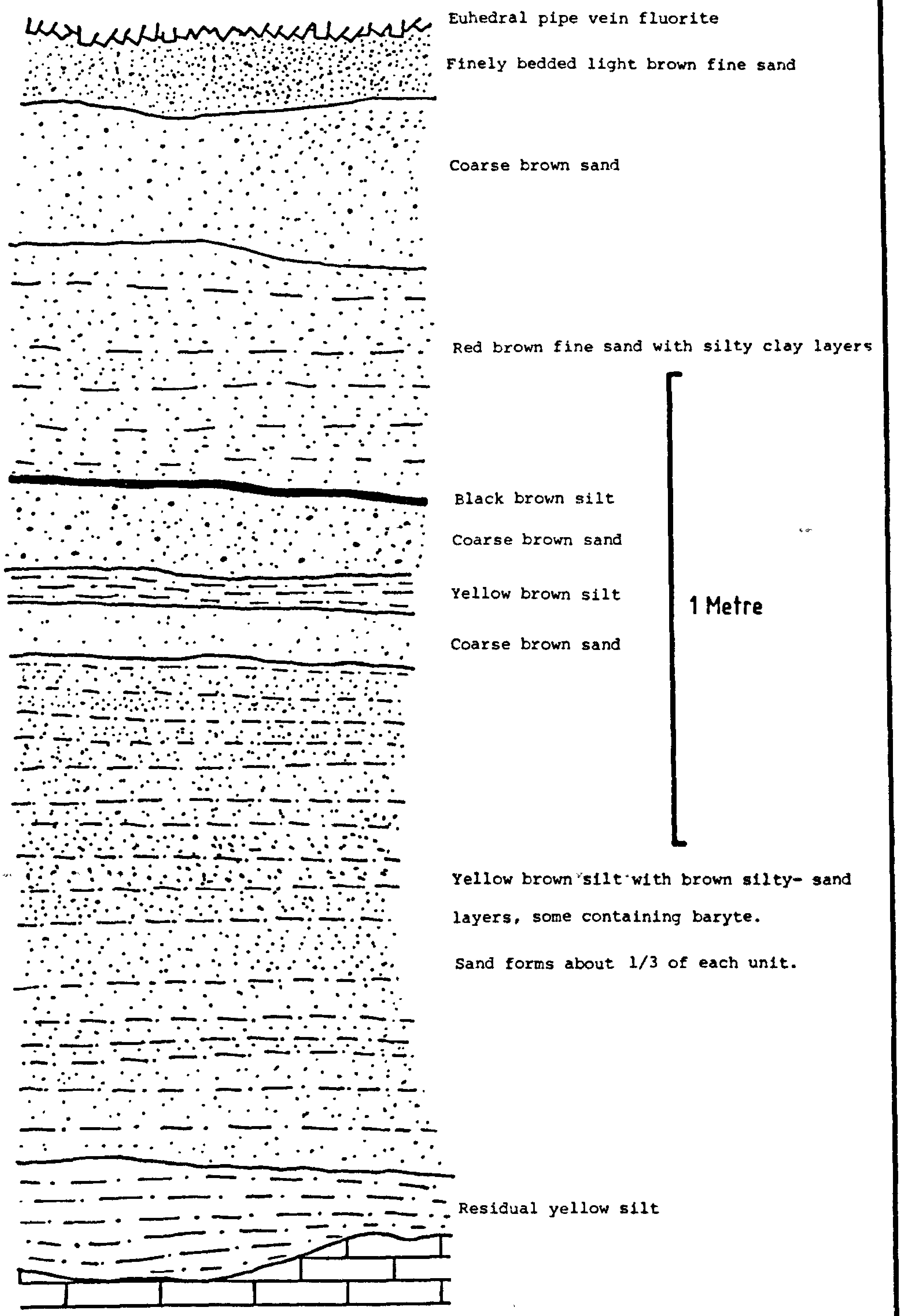


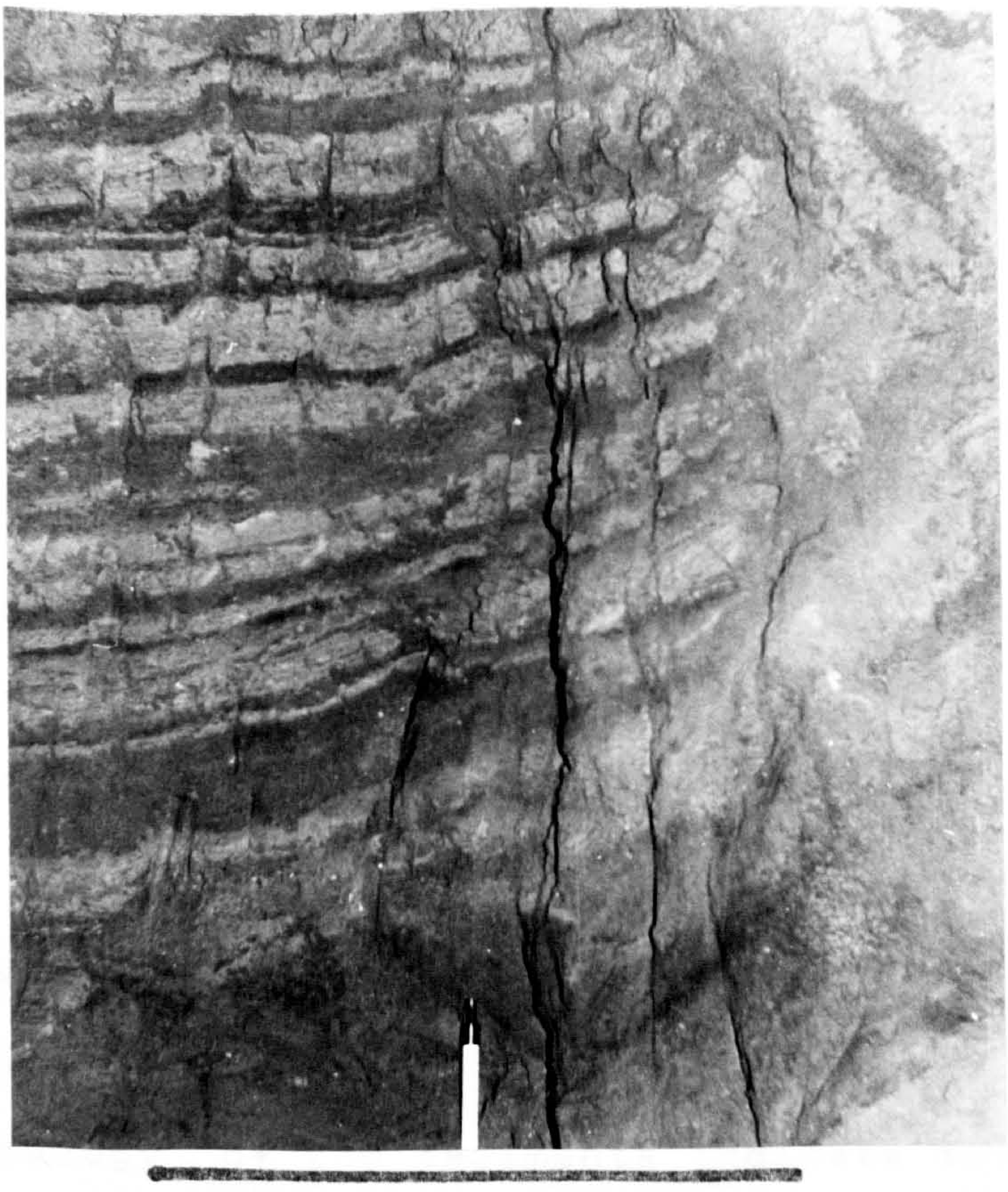
Figure 3.4.8.2.1. The sediment sequence exposed in Clay Cavern, Masson Complex.

Sample Numbers MC 2 − 5		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	1 — 2·5
	Galena	3 — 8
	Fluorite	17 — 45
	Baryte	0 — 3
	Calcite	
2	Quartz	
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	52 — 84
1 Autochthonous 2 Allochthonous		
Clay Mineralogy		
		%
	Illite	17 — 37
	Kaolinite	71 — 89
	Chlorite	5 — 14
	Mixed layer smectites	

Figure 3.4.8.2.2 Summary of sediment composition, Clay Cavern, Masson Complex

Sample Numbers MC 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	1·5
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	85
	Sandstone	3
	Feldspar	1·5
	Mica	1
	Shale	1
	Quartzite	
	Balance (mainly clay)	7
1 Autochthonous 2 Allochthonous		
Clay Mineralogy		
		%
	Illite	68
	Kaolinite	17
	Chlorite	3
	Mixed layer smectites	12

Figure 3 4 8 2 3 Summary of sediment composition, Clay Cavern, Masson Complex



1/2 metre

3.4.8.2.1. Rythmic sediments, Clay Cavern, Masson Cavern.

5 cm.

3.4.8.2.2. Detail of section in previous plate.

platykurtic, coarse sands (fig. 3.4.8.2.4.). The fine units are well sorted, mesokurtic silts (fig. 3.4.8.2.4.). The platykurtic nature of the coarse units reflects their autochthonous content in the form of angular fluorite, baryte and galena clasts. The mesokurtic nature of the fine units indicates that they only contain a limited autochthonous contribution.

The results of S.E.M. study of quartz grain surface textures shows them to be of fluvial origin, with minimal evidence of a glacial history (fig. 3.4.8.2.5., MC 1 - 5, plates 3.4.8.2.3., 3.4.8.2.4. and 3.4.8.2.5.).

The mineralogy of the sediments indicate that most of the allochthonous material has a Namurian sandstone origin, perhaps being derived from the north and east before the Matlock Gorge had been incised and from outliers on the limestone.

Preliminary palaeomagnetic studies of this "varved" sequence show a reversed direction of magnetization characterised by shallow inclination and reversed declination. There is more scatter in samples taken from the coarser units. Demagnetization shows excellent stability. From these results it is reasonable to conclude that these sediments were deposited during a field reversal.

Overlying the "varved" unit is a less well bedded succession of silty clays and sands approximately 1 metre thick (fig. 3.4.8.2.1.). The composition of these sediments is given in figure 3.4.8.2.6.. Some of the fluorite, baryte and galena has been derived by the collapse of the mineral lining on the roof of the cavity,

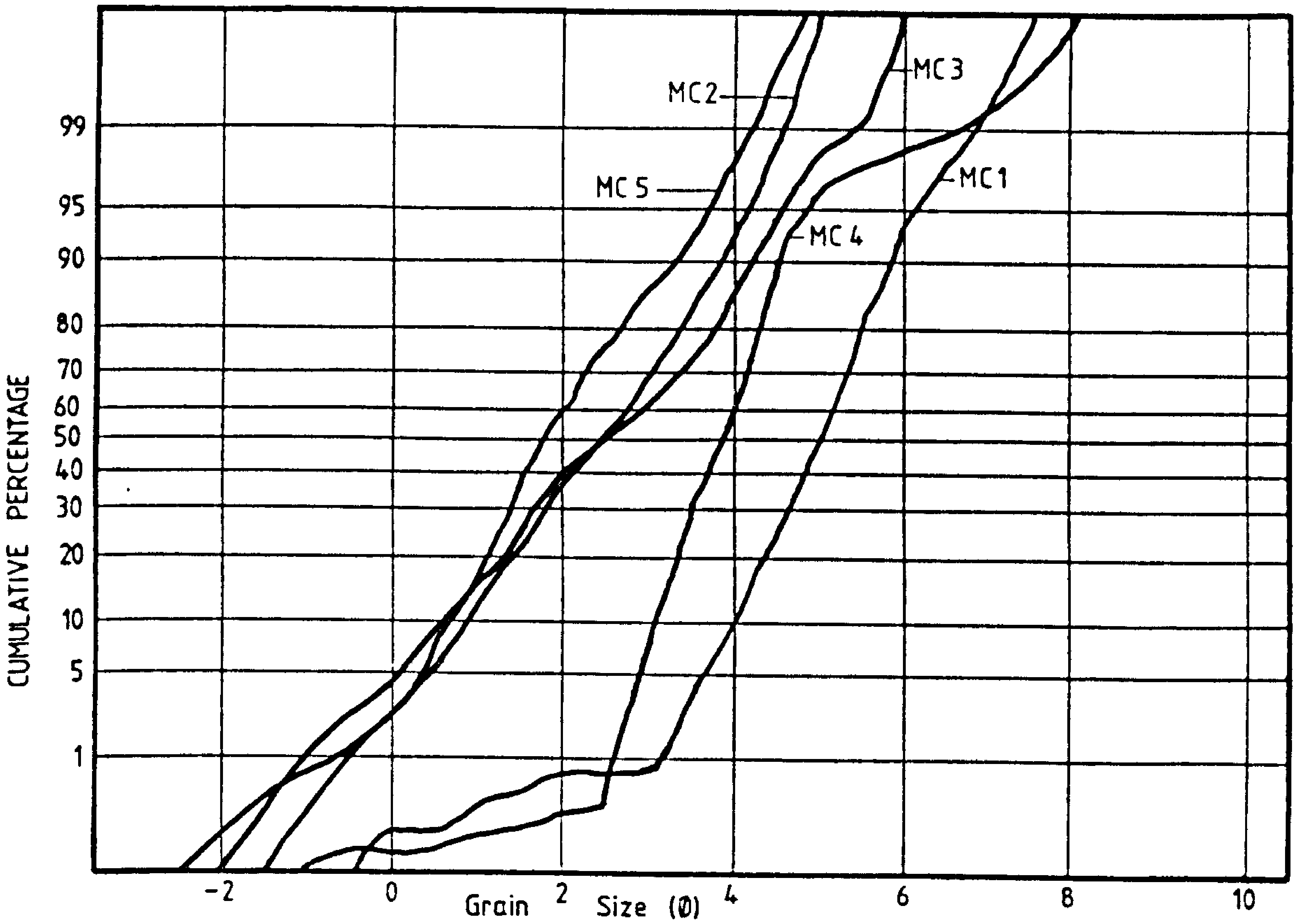
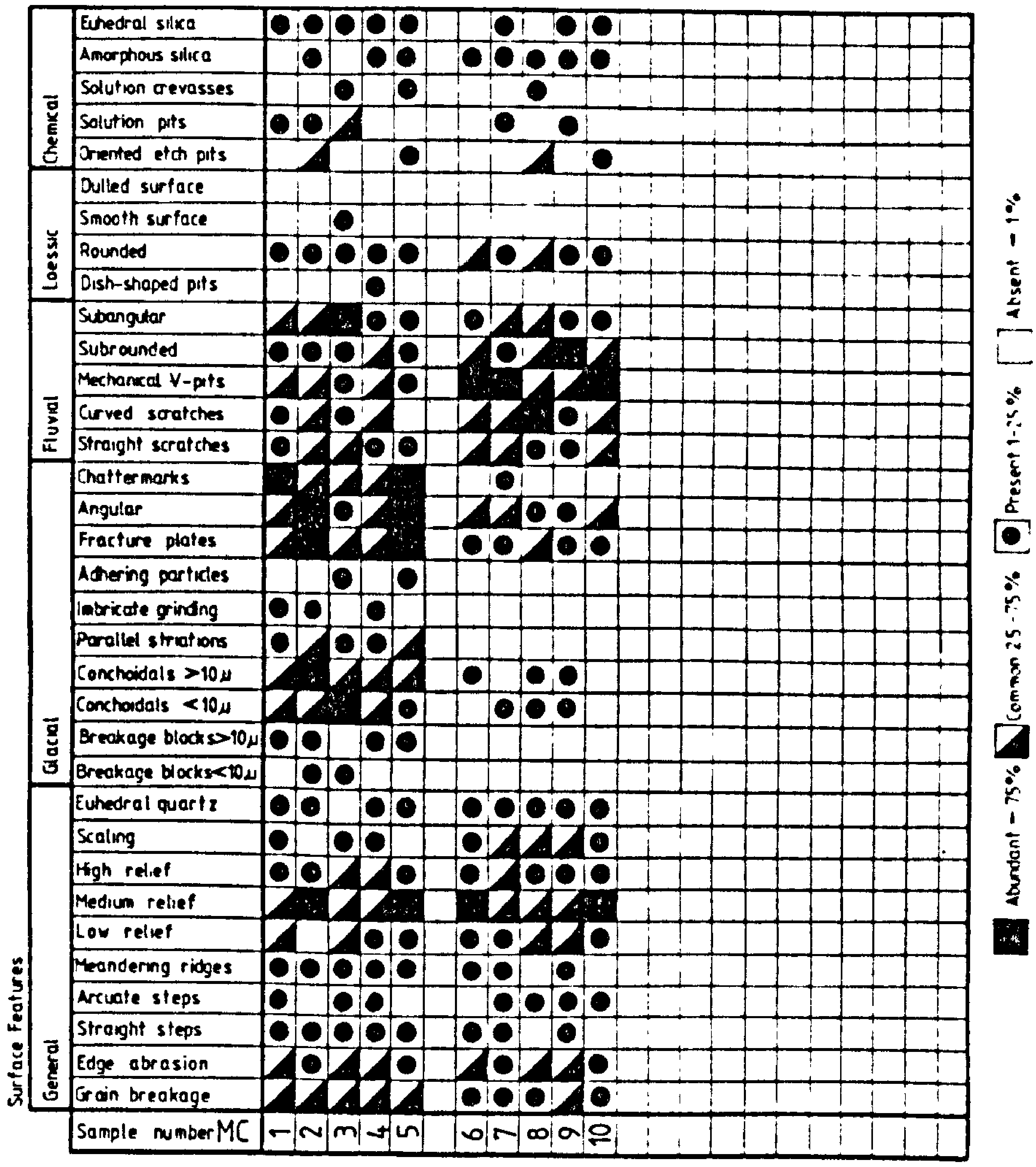


Figure 3.4.8.2.4. Sediment Size Analysis. Clay Cavern, lower part of section.



Chemical	Euhedral silica	●	●	●	●	●			●		●	●
	Amorphous silica		●		●	●		●	●	●	●	●
	Solution crevasses			●		●				●		
	Solution pits	●	●	◢					●		●	
	Oriented etch pits		◢			●				◢		●
Loessic	Dulled surface											
	Smooth surface			●								
	Rounded	●	●	●	●	●		◢	●	◢	●	●
	Dish-shaped pits				●							
Fluvial	Subangular	◢	◢	■	●	●		●	◢	◢	●	●
	Subrounded	●	●	●	◢	●		◢	●	◢	■	◢
	Mechanical V-pits	◢	◢	●	◢	●		■	■	◢	◢	■
	Curved scratches	●	◢	●	◢			◢	◢	■	●	◢
	Straight scratches	●	◢	◢	●	●		◢	◢	●	●	◢
Glacial	Chattermarks	■	◢	◢	◢	■			●			
	Angular	◢	■	●	◢	■		◢	◢	●	●	◢
	Fracture plates	◢	■	◢	◢	■		●	●	◢	●	●
	Adhering particles			●		●						
	Imbricate grinding	●	●		●							
	Parallel striations	●	◢	●	●	◢						
	Conchoidals >10µ	◢	■	◢	◢	◢		●		●	●	
	Conchoidals <10µ	◢	◢	■	◢	●			●	●	●	
	Breakage blocks>10µ	●	●		●	●						
	Breakage blocks<10µ		●	●								
Surface Features General	Euhedral quartz	●	●		●	●		●	●	●	●	●
	Scaling	●		●	●			●	◢	◢	◢	●
	High relief	●	●	◢	◢	●		●	◢	●	●	●
	Medium relief	◢	■	◢	◢	■		■	◢	◢	◢	■
	Low relief	◢		◢	●	●		●	●	◢	◢	●
	Meandering ridges	●	●	●	●	●		●	●		●	
	Arcuate steps	●		●	●				●	●	●	●
	Straight steps	●	●	●	●	●		●	●		●	
	Edge abrasion	◢	●	◢	◢	●		◢	●	◢	◢	●
	Grain breakage	◢	◢	◢	◢	◢		●	●	●	◢	●
	Sample number MC	1	2	3	4	5		6	7	8	9	10

■ Abundant – 75%
◢ Common 25 - 75%
● Present 1-25%
☐ Absent – 1%

Figure 3.4.8.2.5. Summary of quartz grain surface textures, Clay Cavern, Masson Complex.

Sample Numbers MC 6−9		
		%
1	Limestone	
	Dolomite	
	Volcanics	3 — 5·5
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	0 — 2·5
	Fluorite	2 — 12
	Baryte	0 — 3
	Calcite	
2	Quartz	37 — 72
	Sandstone	3 — 6
	Feldspar	0 — 0·5
	Mica	1 — 2·5
	Shale	0 — 1·5
	Quartzite	1 — 4·5
	Balance (mainly clay)	27 — 46

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	29 — 71
Kaolinite	28 — 43
Chlorite	4 — 8
Mixed layer smectites	8 11

Figure 3.4.8.2.6. Summary of sediment composition, Clay Cavern, Masson Complex.

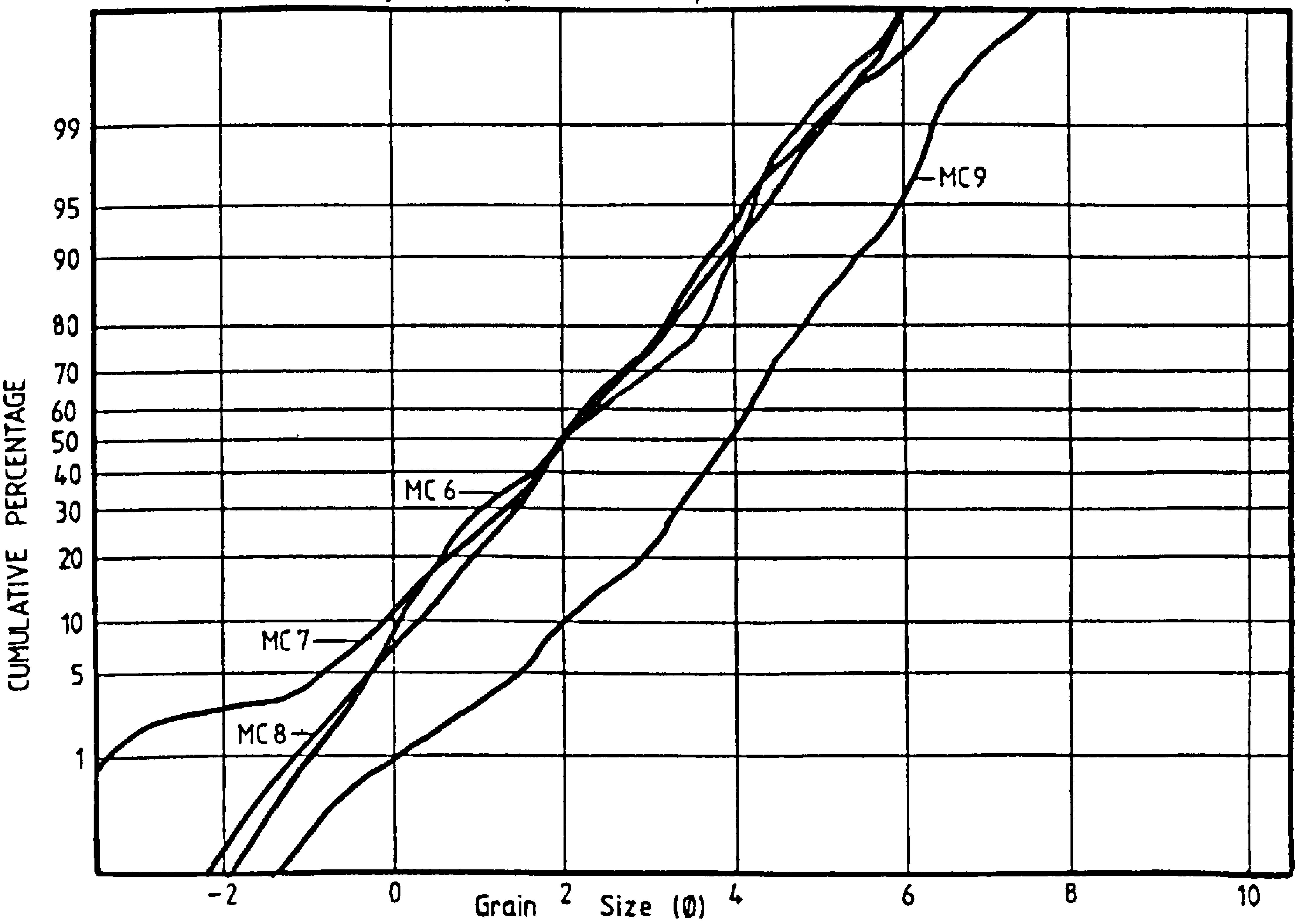
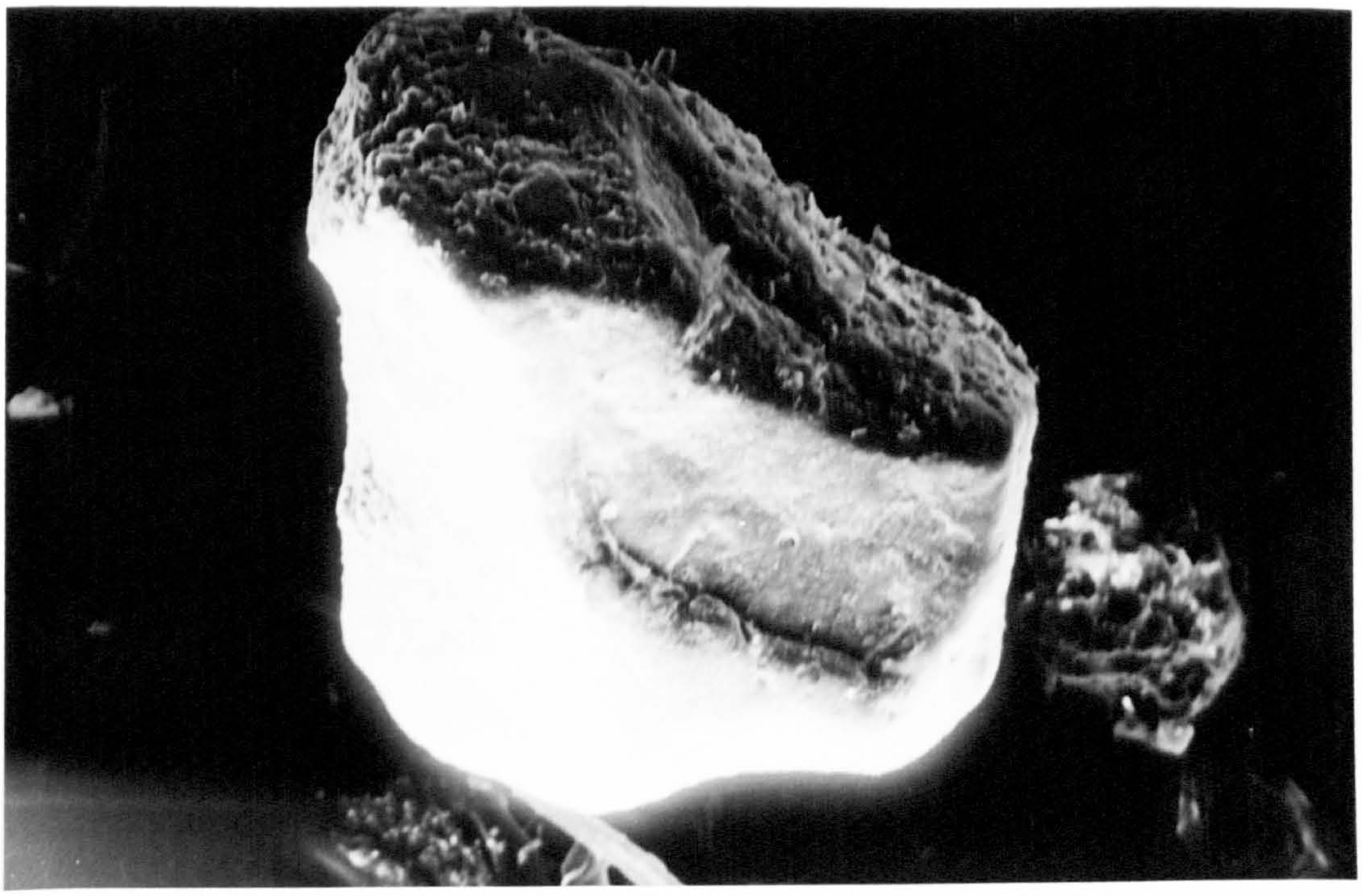
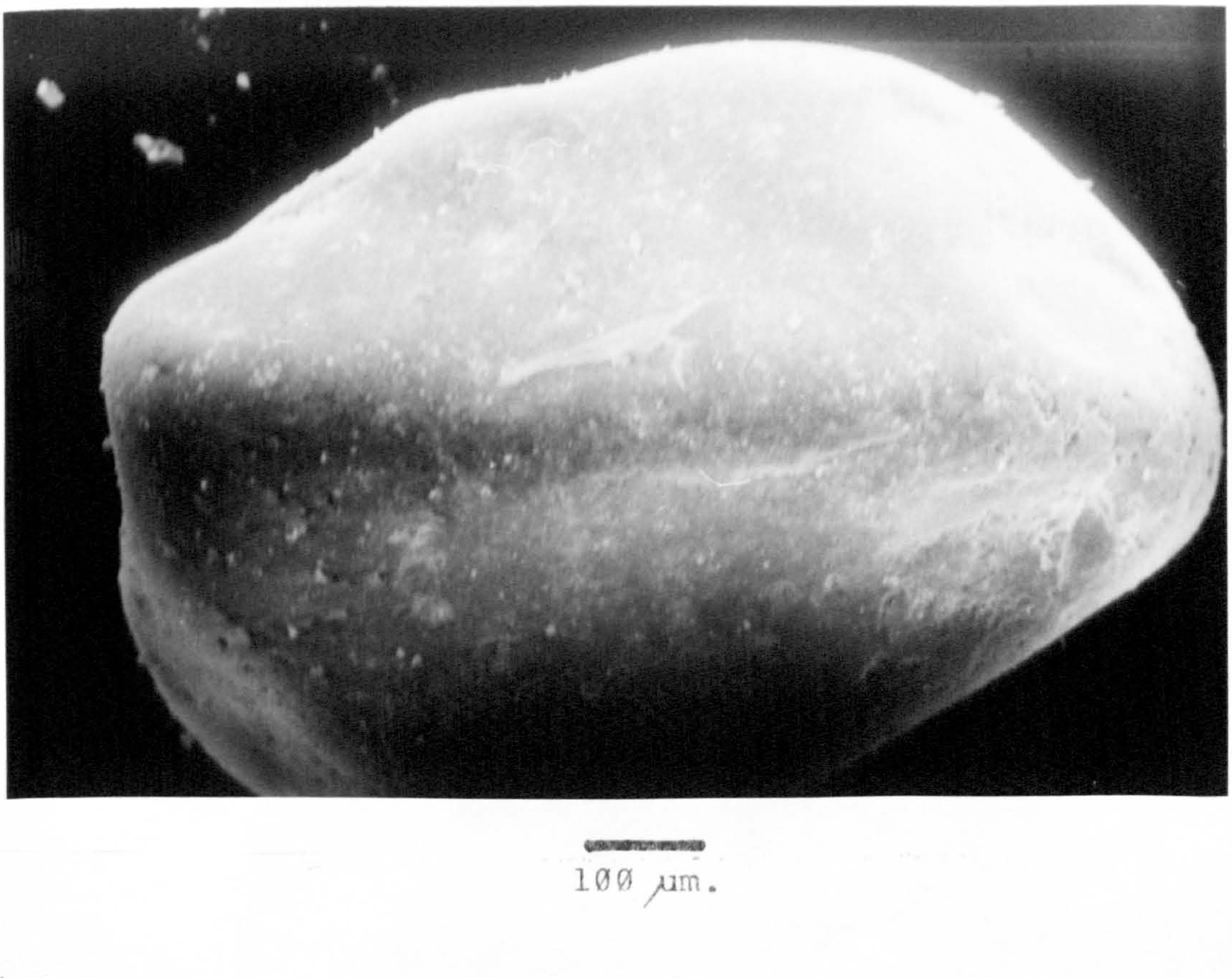


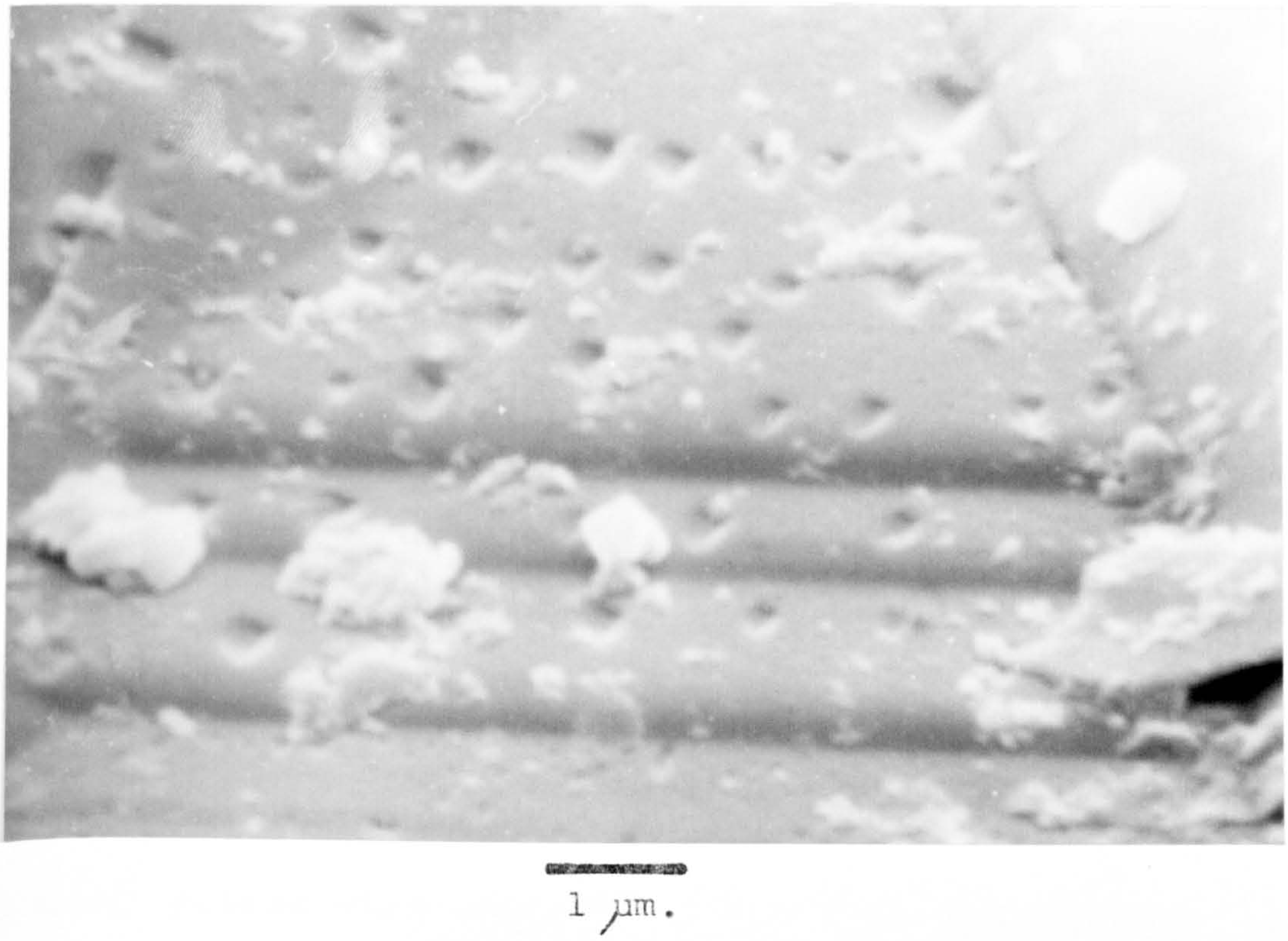
Figure 3.4.8.2.7. Sediment Size Analysis. Clay Cavern, upper partof section.



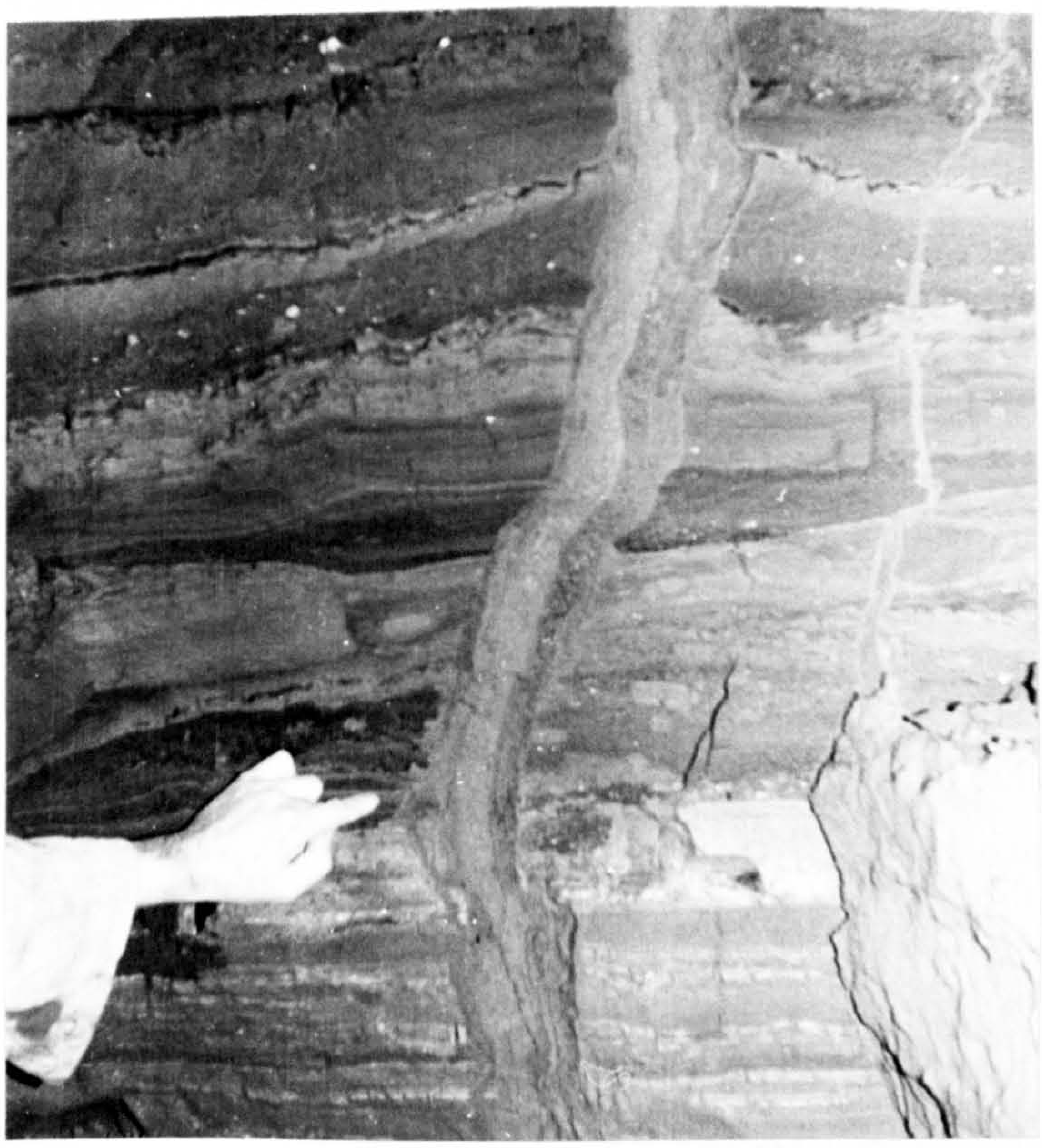
3.4.8.2.3. S.E.M. photomicrograph of a fluvio - glacial quartz grain.



3.4.8.2.4. S.E.M. photomicrograph of a loessic quartz grain, Clay Cavern, Masson Cavern.



3.4.8.2.5. S.E.M. photomicrograph showing detail of a concoidal fracture surface on a quartz grain, Clay Cavern, Masson Cavern.



3.4.8.3.1. Bedded sands and silts cut by a sediment filled ice wedge, Crichman Mine, Masson Cavern.

the rest being angular clasts of local origin.

Size analysis of these sediments show them to be moderately well sorted, mesokurtic sandy silts (fig. 3.4.8.2.7.). The results of S.E.M. studies show that the quartz grains are of fluvial origin (fig. 3.4.8.2.5, MC 6 - 10).

The mineralogy of the sediments indicates two sources, autochthonous epigenetic mineralization and lava and the allochthonous material derived from the Namurian sediments.

Cutting through this sedimentary sequence is a trench filled with angular limestone blocks at the bottom and a poorly sorted muddy gravel containing sub - angular, equidimensional mud flakes derived from earlier deposits. The square, vertical sides of the trench, the limestone blocks and the soft, fresh appearence of the deposits indicate that this deposit is the result of underground ore washing filling a passage cut by the miners.

3.4.8.3. Crichman Mine

At the presently accessible western end of the Masson complex, close to Crichman Old Founder Shaft a thick succession of sediments has been revealed by a collapse caused by recent open pit fluorspar mining operations. The sequence is at least 6 metres thick (fig. 3.4.8.3.1.).

The lowest unit of the sequence is the residual yellow silt, 0.4 metre thick containing large residual clasts of fluorite, baryte and galena in a matrix of

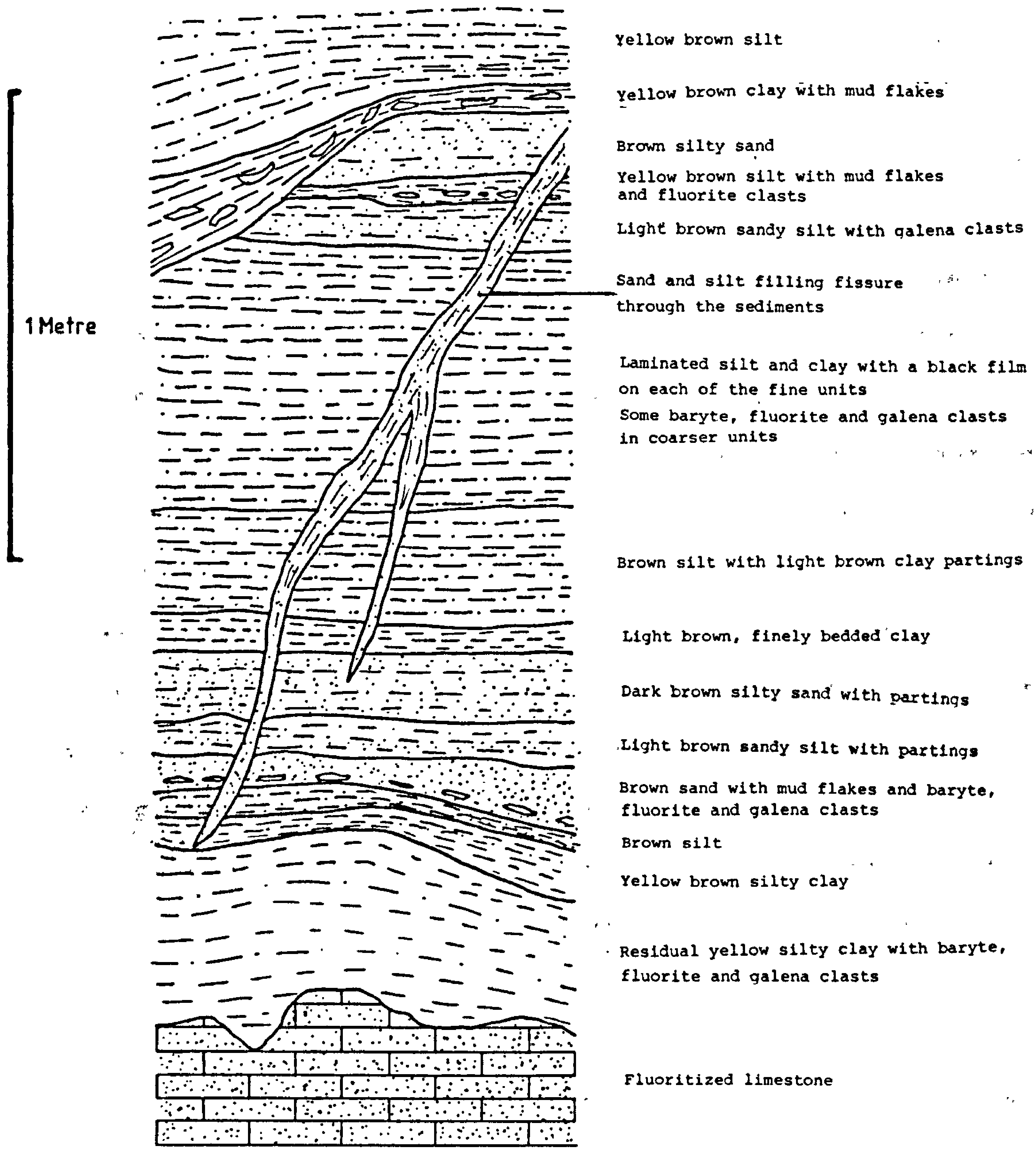


Figure 3.4.8.3.1. The sediment sequence exposed in Crichman Mine, Masson Complex.

limonitic silt. All the sediment is of autochthonous origin being derived from the altered lavas, wayboards, mineralization and the insoluble component of the dolomitised limestone.

The next two metres of the sequence consist of limonitic sands and silts with several mud flake breccia horizons and infilled channels.

The composition of these sediments is given in figure 3.4.8.3.2..

The results of S.E.M. studies shows that the quartz grains are of fluvial origin, with some evidence of a prior glacial history (fig. 3.4.8.3.3.).

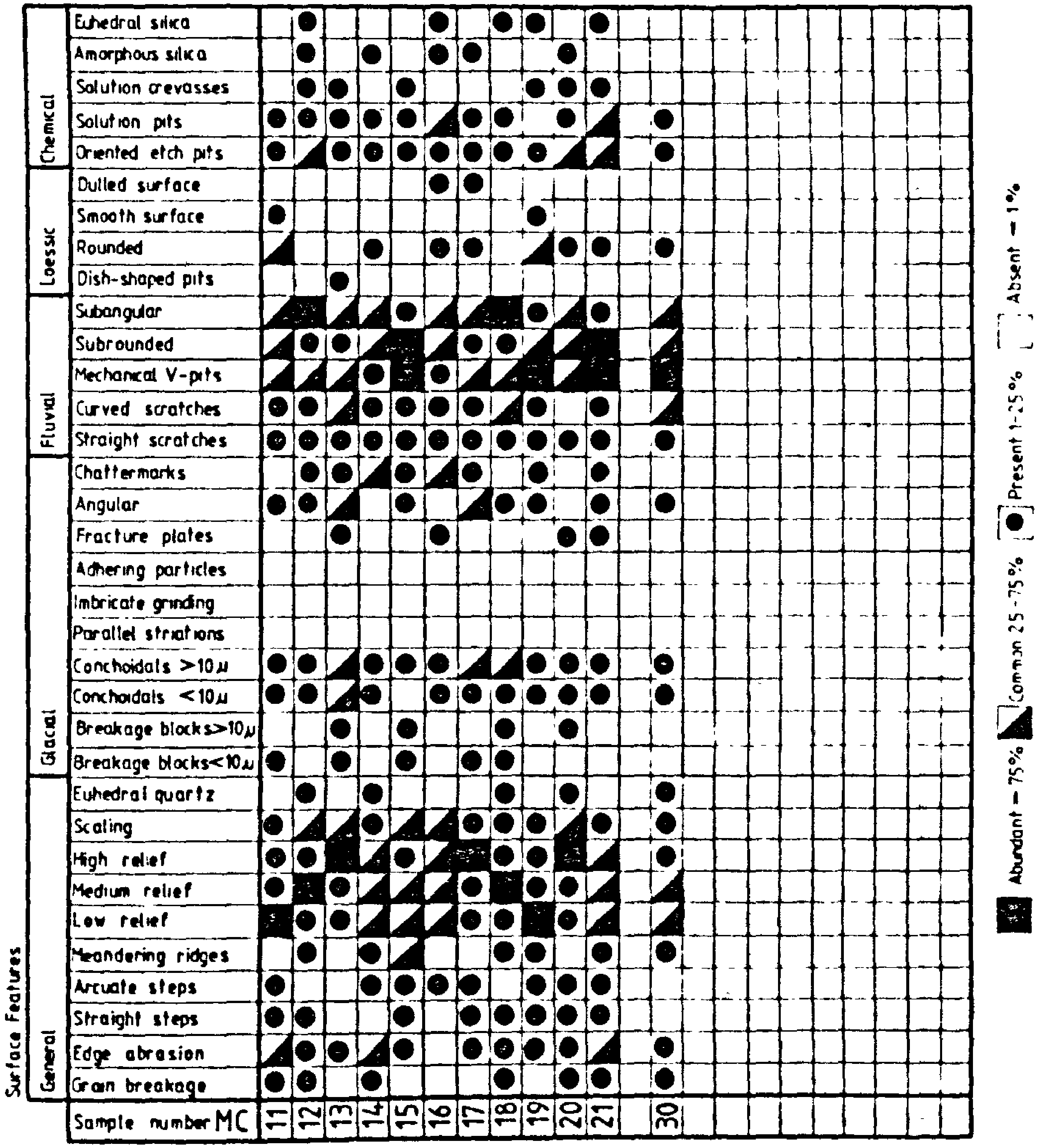
Size analysis of these sediments shows them to be poorly sorted, generally slightly coarse - skewed, platykurtic silty sands though some horizons are fine - skewed, mesokurtic sandy silts (fig. 3.4.8.3.4.). The mineralogy of these sediments and their platykurtic nature show that they have been derived from two sources, one being the allochthonous Namurian sediments the other the autochthonous fluorite, baryte, galena and some chert.

This sequence of sediments is cut by a number of sediment - filled cracks (plate 3.4.8.3.1.) up to 15 cm. wide. The fill in these cracks is parallel to the crack walls and of similar character to the enclosing sediments. They may have been formed by ice wedges, here at a depth of about 30 metres below the present day surface, or by settling of the floor. The latter is unlikely as the floor is composed of solid, in situ limestone and the cracks reduce in size downwards.

Another exposure a few metres away shows sediments

Sample Numbers MC 11 – 21		
		%
1	Limestone	3 — 7
	Dolomite	
	Volcanics	
	Chert	1 — 4
	Silicified fossils	0 — 2
	Authigenic quartz	
	Galena	
	Fluorite	3 — 9
	Baryte	
	Calcite	
2	Quartz	32 — 81
	Sandstone	2 — 35
	Feldspar	
	Mica	
	Shale	
	Quartzite	1 — 3·5
	Balance (mainly clay)	
1 Autochthonous 2 Allochthonous		

Figure 3.4.8.3.2. Summary of sediment composition, Crichman Mine, Masson Complex.



Surface Features	Sample number MC	11	12	13	14	15	16	17	18	19	20	21		30
Chemical	Euhedral silica		●				●		●	●		●		
	Amorphous silica		●		●		●	●			●			
	Solution crevasses		●	●		●				●	●	●		
	Solution pits	●	●	●	●	●	◢	●	●		●	◢		●
	Oriented etch pits	●	◢	●	●	●	●	●	●	●	◢	◢		●
Loessic	Dulled surface						●	●						
	Smooth surface	●								●				
	Rounded	◢			●		●	●		◢	●	●		●
	Dish-shaped pits			●										
Fluvial	Subangular	◢	■	◢	◢	●	◢	◢	■	●	◢	●		◢
	Subrounded	◢	●	●	◢	■	◢	●	●	◢	◢	■		◢
	Mechanical V-pits	◢	◢	◢	●	■	●	◢	◢	■	◢	■		■
	Curved scratches	●	●	◢	●	●	●	●	◢	●		●		◢
	Straight scratches	●	●	●	●	●	●	●	●	●	●	●		●
Glacial	Chattermarks		●	●	◢	●	◢	●		●		●		
	Angular	●	●	◢		●		◢	●	●		●		●
	Fracture plates			●			●				●	●		
	Adhering particles													
	Imbricate grinding													
	Parallel striations													
	Conchoidals >10µ	●	●	◢	●	●	●	◢	◢	●	●	●		●
	Conchoidals <10µ	●	●	◢	●		●	●	●	●	●	●		●
	Breakage blocks>10µ			●		●			●		●			
	Breakage blocks<10µ	●		●		●		●	●					
General	Euhedral quartz		●		●				●		●			●
	Scaling	●	◢	◢	●	◢	◢	●	●	●	◢	●		●
	High relief	●	●	■	◢	●	◢	■	●	●	■	◢		●
	Medium relief	●	■	●	◢	◢	◢	●	■	●	●	◢		◢
	Low relief	■	●	●	◢	◢	◢	●	●	■	●	◢		◢
	Meandering ridges		●		●	◢			●	●		●		●
	Arcuate steps	●			●	●	●	●		●	●	●		
	Straight steps	●	●			●		●	●	●	●	●		
	Edge abrasion	◢	●	●	◢	●		●	●	●	●	◢		●
	Grain breakage	●	●		●				●		●	●		●

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 3.4.8.3.3. Summary of quartz grain surface textures, Crichman Mine, Masson Complex.

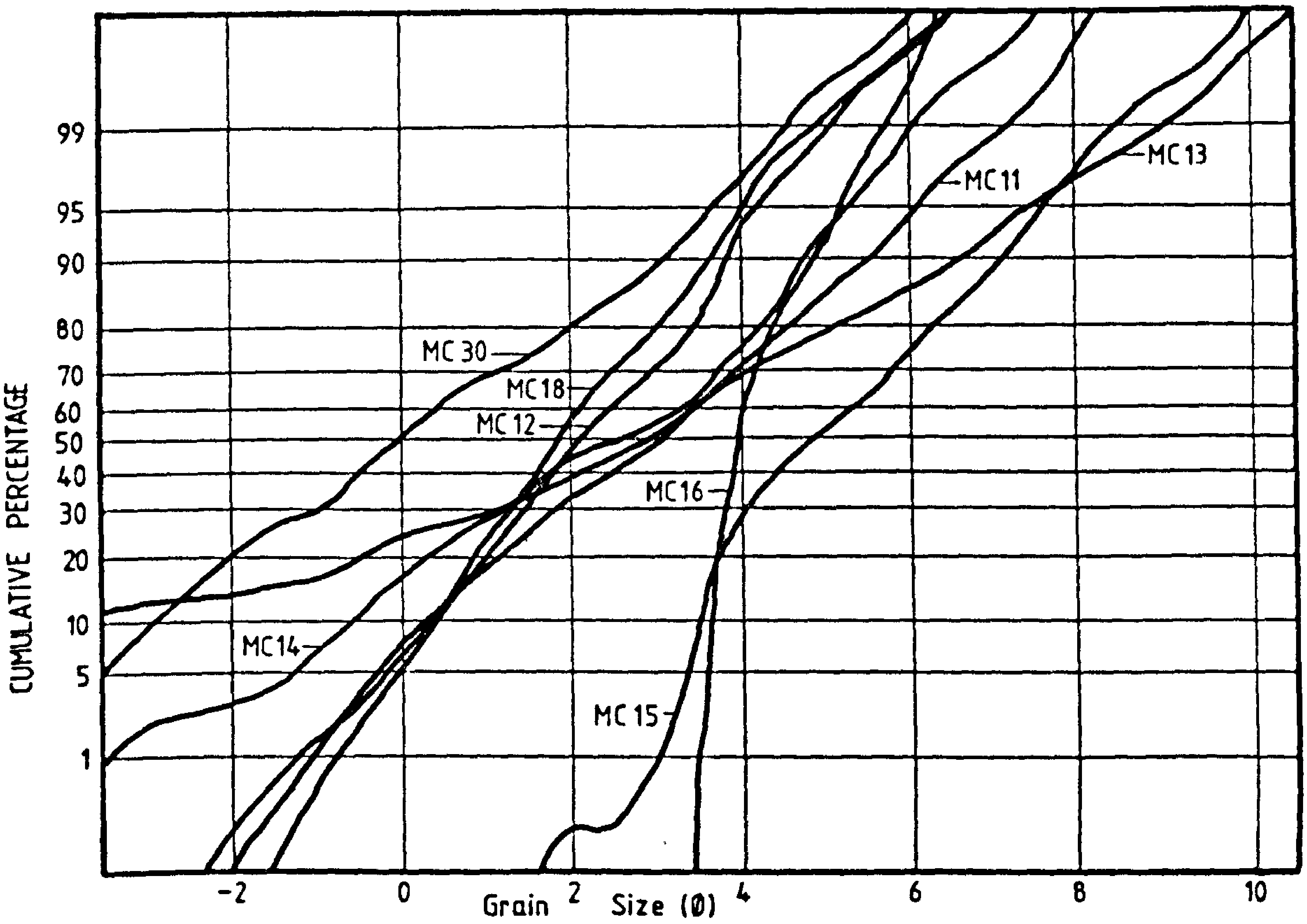


Figure 3.4.8.3.4. Sediment Size Analysis. Crichman Mine.

Sample Numbers MC 30		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0·5
	Silicified fossils	
	Authigenic quartz	
	Galena	2
	Fluorite	7
	Baryte	2·5
	Calcite	
2	Quartz	68
	Sandstone	5
	Feldspar	1
	Mica	3
	Shale	2
	Quartzite	1
	Balance (mainly clay)	8
1 Autochthonous 2 Allochthonous		

Figure 3.4.8.3.5. Summary of sediment composition, Crichman Mine, Masson Complex.

which probably overlie the above sequence (the top is not exposed in the first section). This exposure reveals clean washed bedded sand and gravels, the composition of which is given in figure 3.4.8.3.5.. The results of S.E.M. studies of the surface textures of the quartz grains show that these sediments are of fluvio - glacial origin (fig. 3.4.8.3.3.) with a locally derived limestone, chert and fluorite component.

Size analysis shows that the sediments are poorly sorted, fine - skewed, platykurtic gravels (fig. 3.4.8.3.4.).

A nearby section, no longer accessible due to roof collapse caused by open pit mining before 1980, displayed a silty sediment sequence containing a number of secondary baryte "rosettes" which had grown in situ.

3.4.8.4. Masson Open Pit

The open pit operations on Masson Hill have removed part of the Masson fluorite flats formerly worked underground. Unfortunately the old (pre 1975) open pit has been back - filled during this operation and a number of exposures lost. Cavities containing sediments are exposed in the pit walls from time to time but the nature of the operation and the unstable nature of the pit walls generally precludes examination.

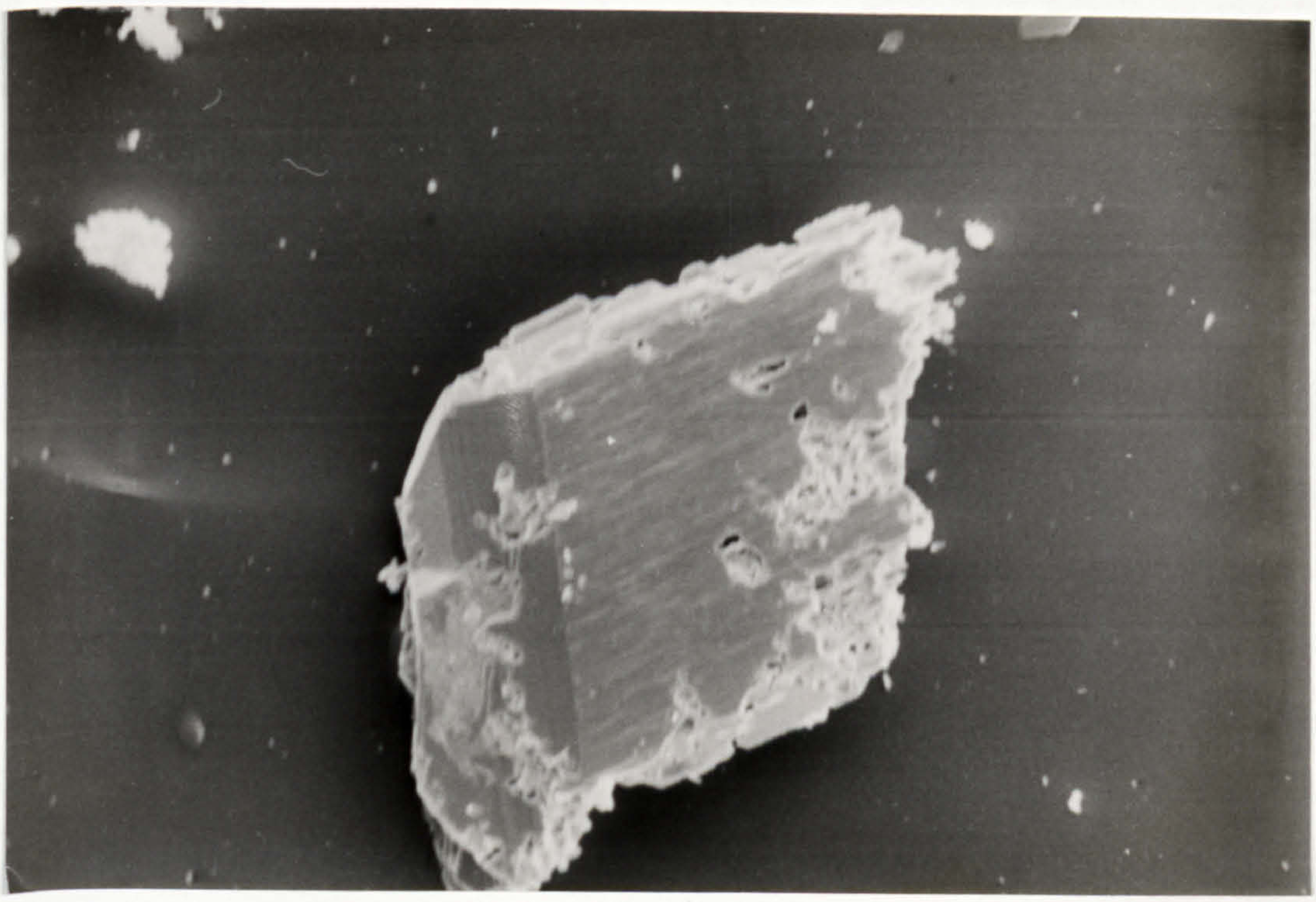
The sections examined have been substantially affected by blasting and/or ore excavation. The sediments are of similar nature to those described in Crichman Mine but in places contain up to 11 percent of local baryte clasts (plate 3.4.8.4.1.) and up to 3.5 percent authigenic quartz grains (plate 3.4.8.4.2.).

Ford (1968) noted that some of these fills, exposed in the pre 1975 open pit, showed cryoturbation structures and that one pocket in the southwest flank of the pit had a sand fill containing nodules and linings of grey baryte in a pseudo - stalactitic form.

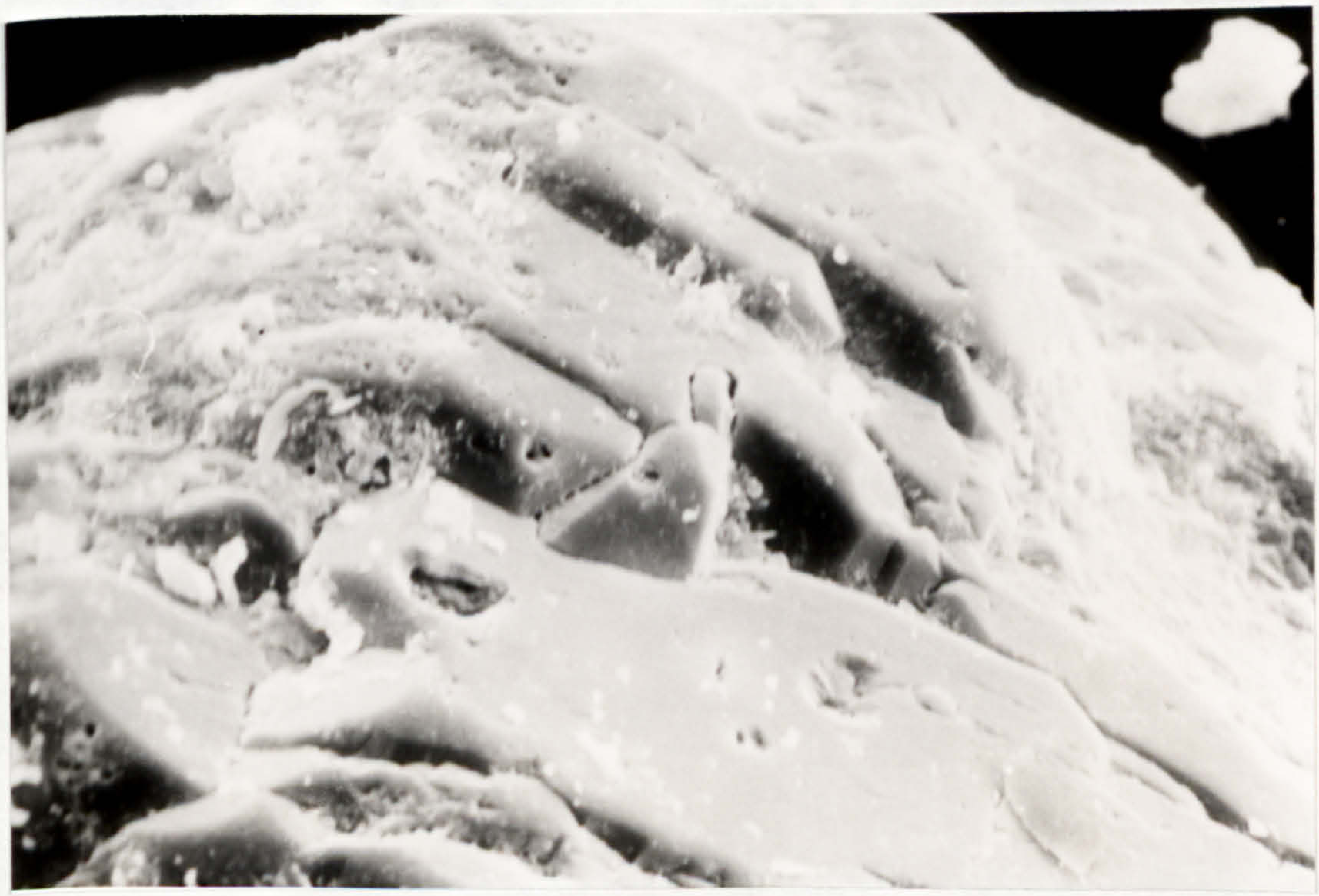
3.4.8.5. Gentlewoman's Pipe and Old Jant Mine

Before the recent open pit operation commenced the top section of Gentlewoman's Pipe was accessible from workings in the Crichman Title of the Masson complex. In 1977 the rediscovery of Ringing Rake and Masson Sough followed by much digging through blockages led to the discovery of sustantial pipe vein workings down dip of the previously known section of Gentlewoman's Pipe with which they are now connected (Warriner et al, 1981).

The drainage level, also known as Youds Level after the owner of the garden through which entry was first gained, was driven in the early years of the eighteenth century to drain the down dip extension of Gentlewoman's Pipe which was discovered around 1690 (Warriner et al, 1981). The sough, generally a crosscut drainage level, was driven from the River Derwent some 600 metres through gradually older strata commencing close to the base of the Matlock Upper Lava and finishing in the pipe vein close to the top of the Matlock Lower Lava having crossed a thickness of some 70 metres of the Matlock Lower



3.4.8.4.1. S.E.M. photomicrograph of a detrital baryte grain, Masson Open Pit.



3.4.8.4.2. S.E.M. photomicrograph of part of a derived Namurian sandstone quartz grain, Masson Open Pit.

Limestones.

The top of Gentlewoman's Pipe is now generally dry and contains no undisturbed sediments. The Old Jant Mine section of the workings, between Forefield Shaft and Upper Close Shaft (fig. 3.4.8.5.1) shows pipe and fissure vein mineralization. The former generally of calcite and galena and the latter generally of fluorite, baryte and galena in biosparitic host limestones.

Post - mineralization cavernization in this part of the mine consists of phreatic enlargement of the pipe veins and the development of new cavities along joints. These have now been drained to sough level (approximately 95 metres O.D.) which forms the present water table. The cavity system continues below the sough level and is now silted up with fines from ore washing. Present day percolation drainage, which is minimal as most of the mine is capped by the Matlock Upper Lava, follows this old phreatic route with only minor diversion by mining, and thence to the Derwent via the sough.

No sedimentary deposits have been found below 150 metres O.D. in Old Jant Mine. Three sections of sediment fills occur within a distance of 40 metres of each other (fig. 3.4.8.5.1.) but apart from the bottom residual horizon no correlation can be made.

3.4.8.5.1. Crossover Passage

This is a hand - picked level driven through the base of a sediment - filled cavern exposing the residual sediments at its base and silty sands above (fig.

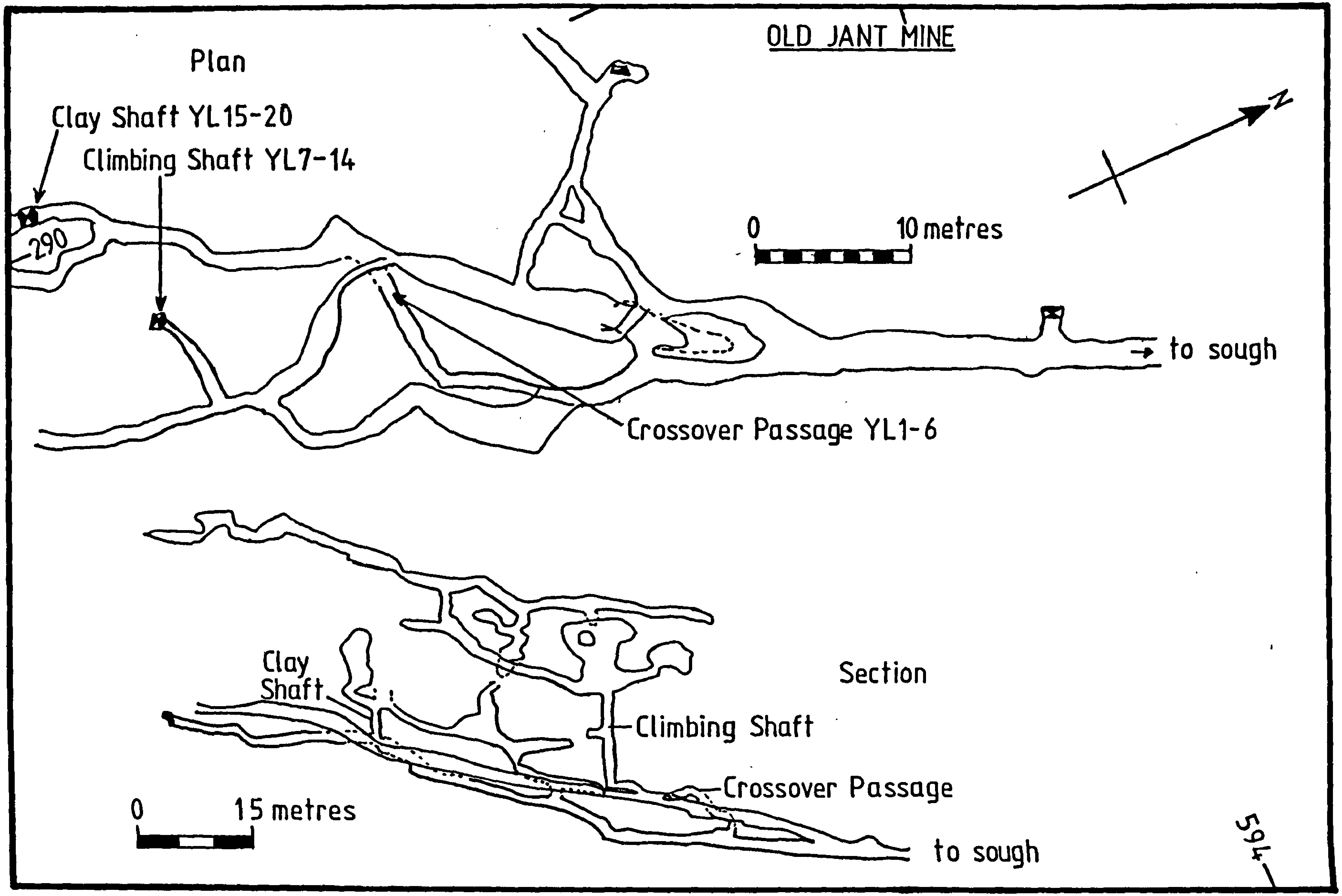


Figure 3.4.8.5.1. Plan of Old Jant Mine, part of the Masson Complex showing sample locations. After Warriner et al (1981).

3.4.8.5.1.1.).

The composition of the basal sediments is given in figure 3.4.8.5.1.2.. Sediment size analysis shows that the sediments are strongly coarse - skewed, very platykurtic, silty gravels (fig. 3.4.8.5.1.3.).

The size analysis and the mineralogy of the sediments shows that it has two sources, one being the epigenetic mineralization and the other being the clay derived from the Matlock Lower Lava and clay wayboard horizons.

The overlying sediment varies from clayey sands to clays, the composition of which is given in figure 3.4.8.5.1.4..

The results of S.E.M. study of the quartz grain surface textures shows them to have a fluvial origin (fig. 3.4.8.5.1.5.). Size analysis shows that the sediments are moderately well sorted, slightly fine - skewed, platykurtic sandy silts (fig. 3.4.8.5.1.3.). Their platykurtic nature indicates two sources for the sediment, firstly the autochthonous limestone, fluorite, baryte and calcite and, secondly, the allochthonous quartz, muscovite and clay which has been derived from the Namurian strata.

3.4.8.5.2. <u>Clay Shaft</u>

Clay Shaft is a small shaft sunk through sediments nearly 5 metres thick in a calcite - lined pipe vein cavity. The sediments are well bedded and vary from coarse sands to clays which have a horizontal or slightly inclined bedding (see fig. 3.4.8.5.2.1.).

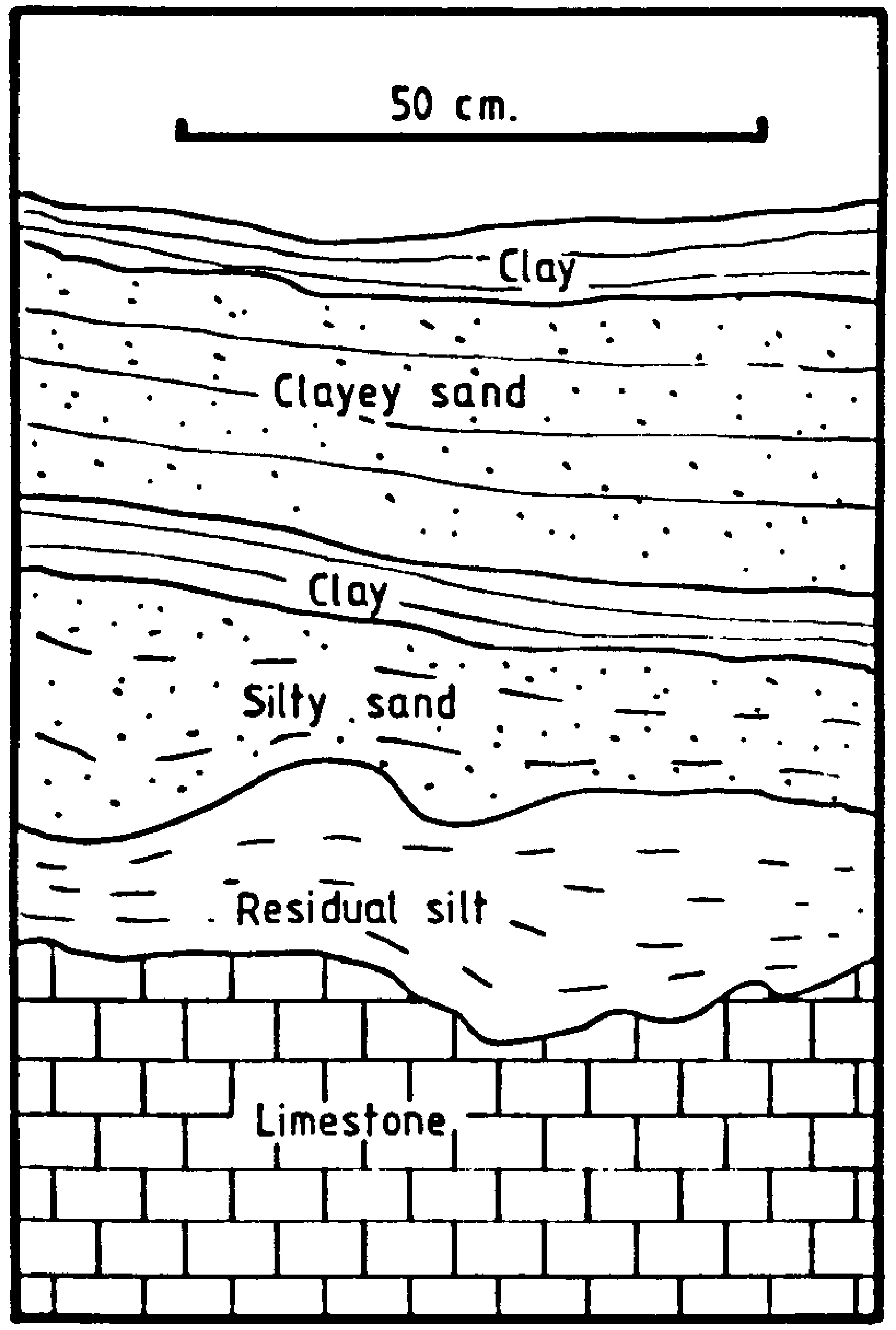


Figure 3.4.8.5.1.1. Sediment section, Crossover Passage, Old Jant Mine.

Sample Numbers YL 1-2		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	10 — 21
	Calcite	15 — 26
2	Quartz	
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	47 — 67

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	
Kaolinite	79 — 93
Chlorite	7 — 21
Mixed layer smectites	

Figure 3.4.8.5.1.2. Summary of sediment composition, Crossover Passage, Old Jant Mine.

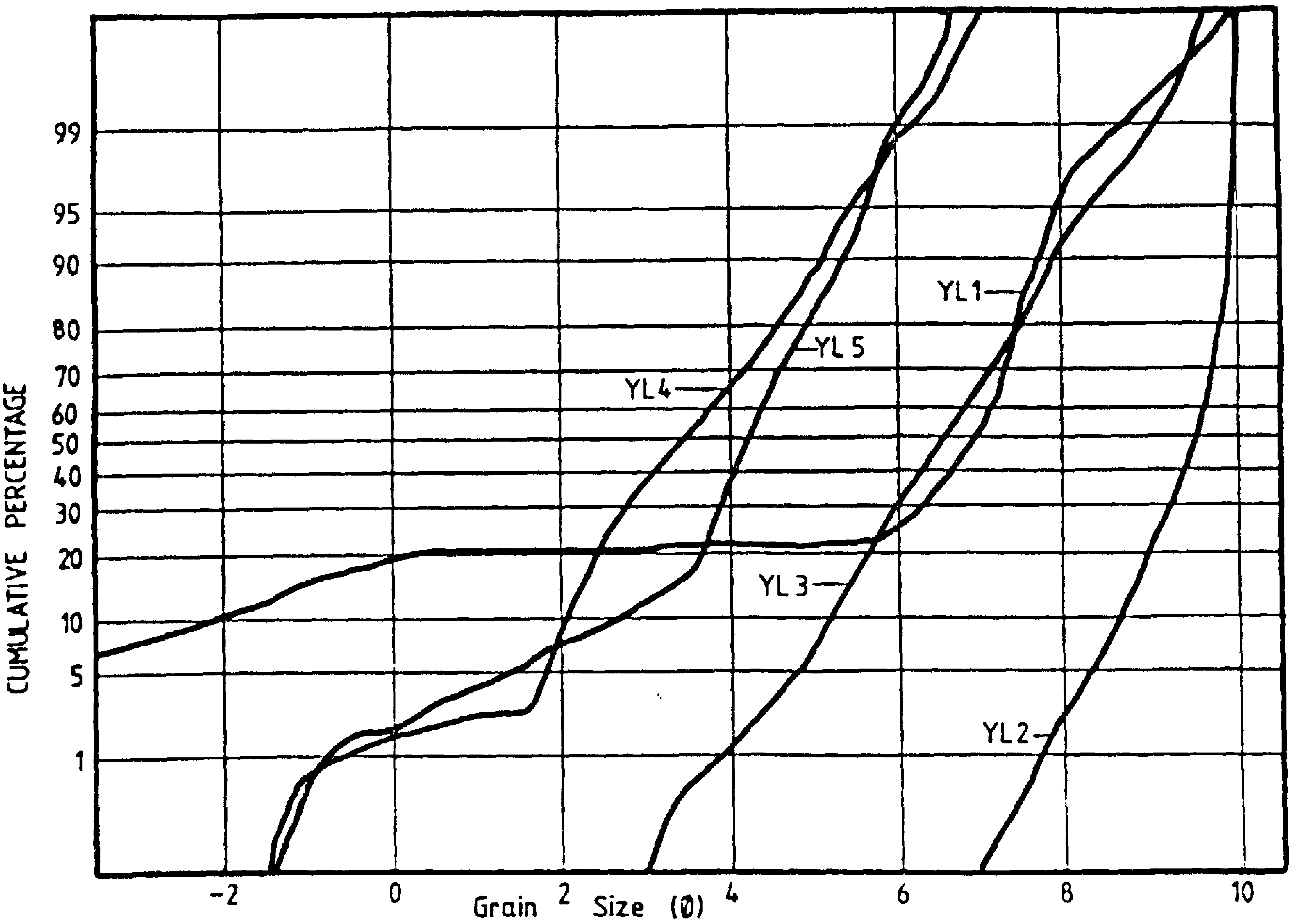


Figure 3.4.8.5.1.3. Sediment Size Analysis. Crossover Passage.

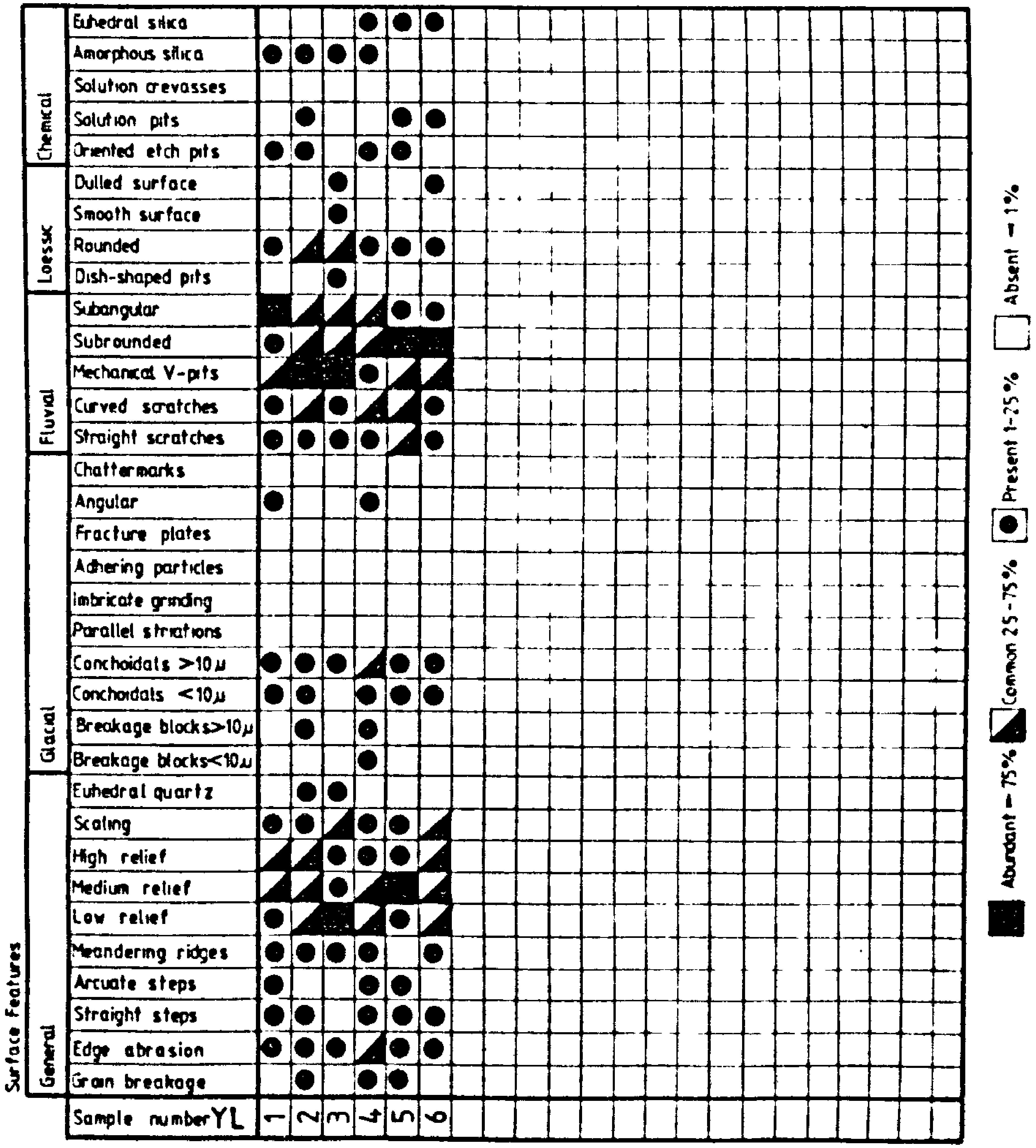
Sample Numbers YL 3-6		
		%
1	Limestone(partly de-calcified in situ)	0 — 2
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0 — 8
	Baryte	0 — 35
	Calcite	0 — 3
2	Quartz	38 — 63
	Sandstone	
	Feldspar	
	Mica	1 — 6
	Shale	
	Quartzite	0 — 2
	Balance (mainly clay)	31 — 59

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	36 — 53
Kaolinite	7 — 25
Chlorite	1 — 3
Mixed layer smectites	3 — 7

Figure 3.4.8.5.1.4. Summary of sediment composition, Crossover Passage, Old Jant Mine.



Surface Features		1	2	3	4	5	6
Chemical	Euhedral silica				●	●	●
	Amorphous silica	●	●	●	●		
	Solution crevasses						
	Solution pits		●			●	●
	Oriented etch pits	●	●		●	●	
Loessic	Dulled surface			●			●
	Smooth surface			●			
	Rounded	●	◩	◩	●	●	●
	Dish-shaped pits			●			
Fluvial	Subangular	■	◩	◩	◩	●	●
	Subrounded	●	◩	◩	◩	■	■
	Mechanical V-pits	◩	■	■	●	◩	◩
	Curved scratches	●	◩	●	◩	◩	●
	Straight scratches	●	●	●	●	◩	●
Glacial	Chattermarks						
	Angular	●			●		
	Fracture plates						
	Adhering particles						
	Imbricate grinding						
	Parallel striations						
	Conchoidals >10μ	●	●	●	◩	●	●
	Conchoidals <10μ	●	●		●	●	●
	Breakage blocks>10μ		●		●		
	Breakage blocks<10μ				●		
General	Euhedral quartz		●	●			
	Scaling	●	●	◩	●	●	◩
	High relief	◩	◩	●	●	●	◩
	Medium relief	◩	◩	●	◩	■	◩
	Low relief	●	◩	■	◩	●	◩
	Meandering ridges	●	●	●	●		●
	Arcuate steps	●			●	●	
	Straight steps	●	●		●	●	●
	Edge abrasion	●	●	●	◩	●	●
	Grain breakage		●		●	●	
	Sample number YL	1	2	3	4	5	6

■ Abundant – 75% ◩ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 3.4.8.5.1.5. Summary of quartz grain surface textures, Crossover Passage, Old Jant Mine.

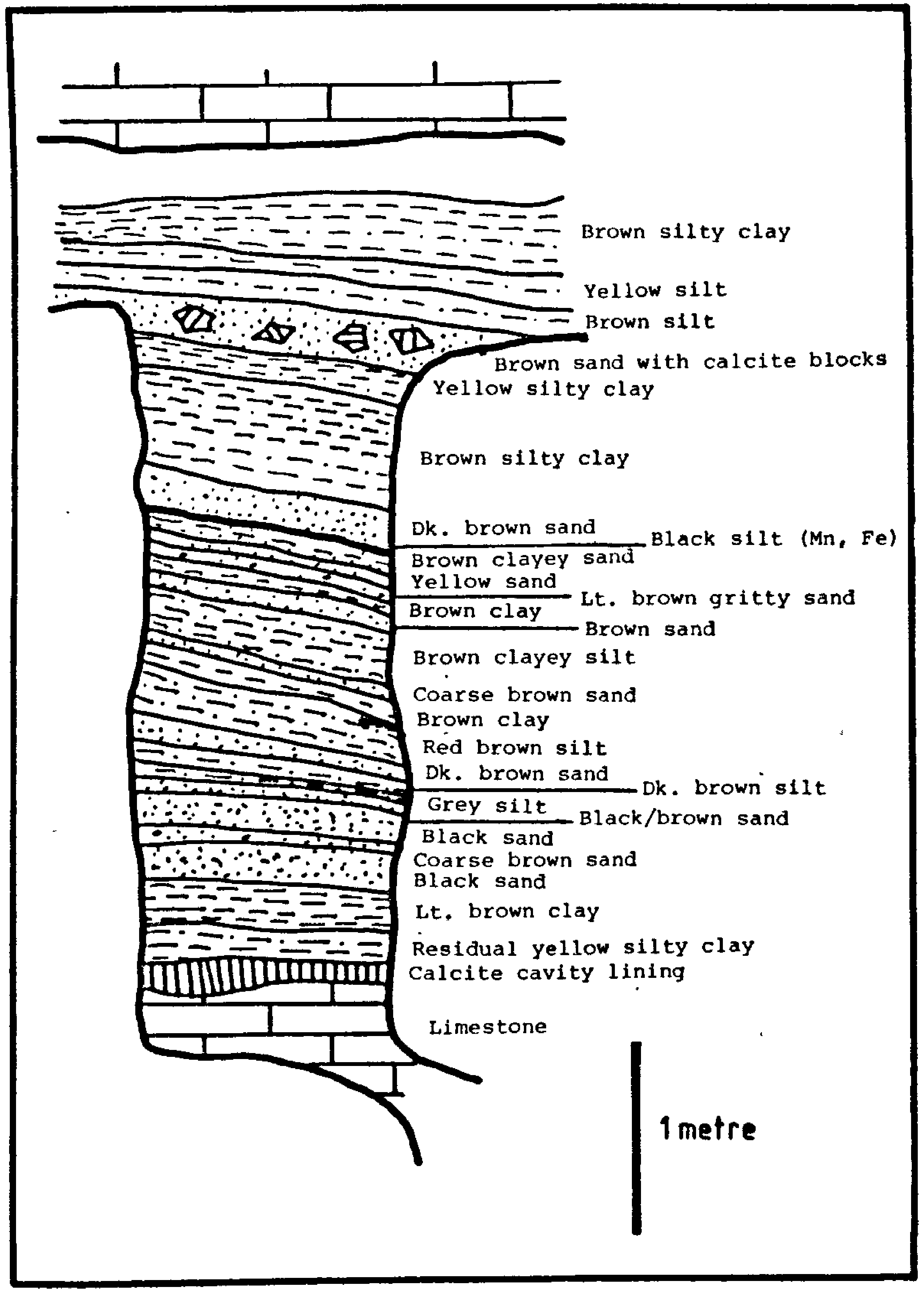


Figure 3.4.8.5.2.1. The sedimentry sequence exposed in Clay Shaft, Old Jant Mine.

The basal layer consists of a residual limonitic silty clay, the composition of which is given in figure 3.4.8.5.2.2.. The sediment is derived from the insoluble content of the limestone and the underground erosion of toadstone and wayboard horizons.

The composition of the overlying sediment is given in figure 3.4.8.5.2.3..

The results of S.E.M. studies of the quartz grain surface textures show that the sediments have a fluvial origin (fig. 3.4.8.5.2.4.). Size analysis shows that the sediments are moderately well sorted, slightly fine skewed, mesokurtic silty sands (fig. 3.4.8.5.2.5.).

Apart from the small amount of limestone and calcite present in some of the layers most of the sediment has an allochthonous source, being derived from the Namurian sediments.

Samples for palaeomagnetic study were obtained from a closely spaced vertical profile of the sediments exposed in the shaft. The results (fig. 3.4.8.5.2.6.) show that a reversal to normal remnant magnetism occurs approximately one metre from the top of the exposed sediments. This reversal can be tentatively correlated with the reversion to normal magnetic polarity between the Matuyama and Brunhes polarity epochs at 690,000 yrs. B.P. (LaBrecque et al, 1977). It may possibly be correlated with the end of other, shorter, reversals during the Brunhes palaeomagnetic epoch (Rampino, 1981) though the consistant reversed remnant magnetism of the sediments close to the top of Masson Hill makes this less likely.

There is no sedimentological evidence to suggest

Sample Numbers YL 15 - 16		
		%
1	Limestone	4 — 9
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	5 — 11
	Galena	2 — 23
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	63 — 83

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	
Kaolinite	66 — 83
Chlorite	6 — 11
Mixed layer smectites	

Figure3.4.85.22.Summary of sediment composition, Clay Shaft, Old Jant Mine.

Sample Numbers YL 17 - 21		
		%
1	Limestone	0 — 1
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	0 — 23
2	Quartz	34 — 64
	Sandstone	
	Feldspar	
	Mica	1 — 8
	Shale	
	Quartzite	
	Balance (mainly clay)	36 — 57

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	35 — 58
Kaolinite	10 — 21
Chlorite	2 — 4
Mixed layer smectites	2 — 5

Figure3.4.8.5.2.3.Summary of sediment composition, Clay Shaft, Old Jant Mine.

Chemical	Euhedral silica	●				●	●
	Amorphous silica	●					●
	Solution crevasses		●	●			
	Solution pits			●	●	●	
	Oriented etch pits	●	●		●	●	●
Loessic	Dulled surface					●	
	Smooth surface					●	
	Rounded	●				◪	●
	Dish-shaped pits					●	
Fluvial	Subangular	◪	●	●	■	◪	●
	Subrounded	◪	■	■	●	◪	■
	Mechanical V-pits	●	◪	■	●	◪	■
	Curved scratches	●	●	●	●	●	●
	Straight scratches	●	●	◪	●	●	●
Glacial	Chattermarks	◪	●		●	◪	
	Angular	◪	●		●	●	
	Fracture plates	◪				●	
	Adhering particles	●				●	
	Imbricate grinding					●	
	Parallel striations	●					
	Conchoidals >10µ	●		●	●	●	●
	Conchoidals <10µ	●		●	●		●
	Breakage blocks>10µ	●				●	●
	Breakage blocks<10µ	●	●			●	●
General	Euhedral quartz			●			
	Scaling	●	●		●	●	●
	High relief	■	●	●	◪	●	◪
	Medium relief	●	◪	●	◪	●	◪
	Low relief	●	◪	■	●	■	◪
	Meandering ridges	●		●	●		
	Arcuate steps	●	●		●	●	●
	Straight steps	●		●		●	●
	Edge abrasion	◪	●	●		●	●
	Grain breakage	◪	●			●	
Surface Features	Sample number YL	15	16	17	18	19	20

■ Abundant – 75%
◪ Common 25-75%
● Present 1-25%
☐ Absent – 1%

Figure 3.4.8.5.2.4. Summary of quartz grain surface textures, Clay Shaft, Old Jant Mine.

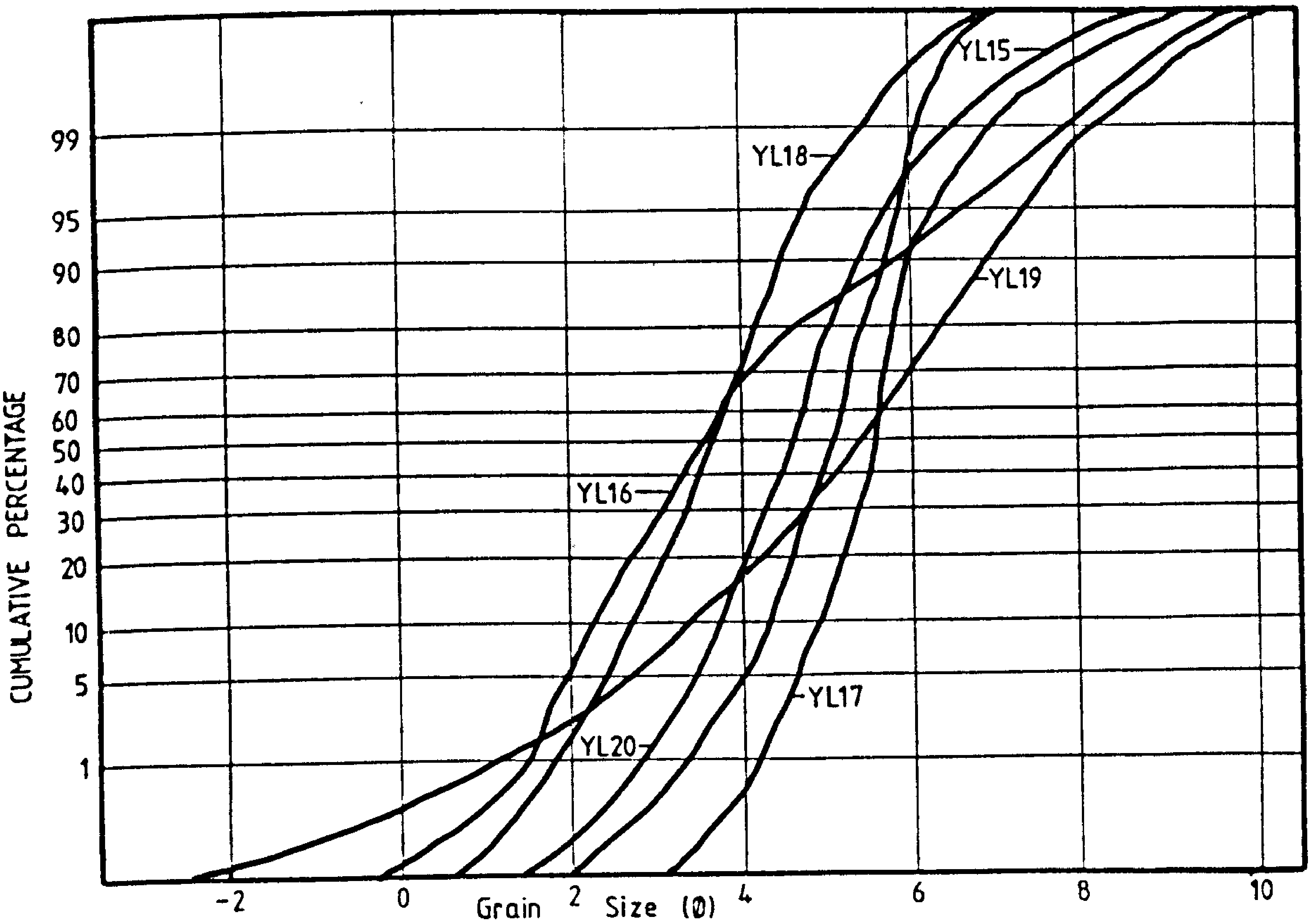


Figure 3.4.8.5.2.5. Sediment Size Analysis. Clay Shaft, Old Jant Mine.

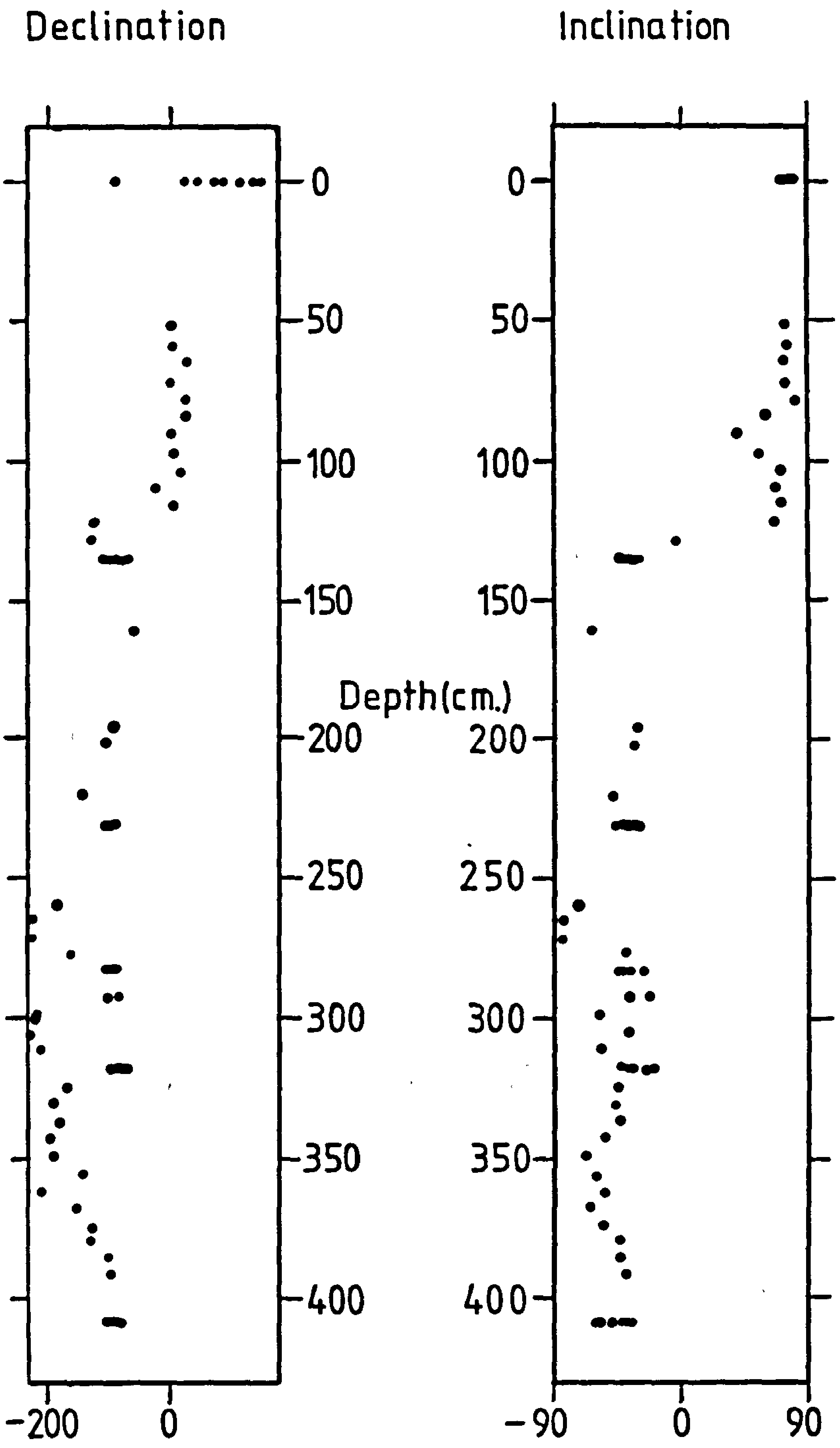


Figure 3.4.8.5.2.6. Palaeomagnetic profile, Clay Shaft. Demagnetised at 150 O_e.

that the reversal occurs at a point representing a break in sedimentation.

3.4.8.5.3. Climbing Shaft

This shaft, over 11 metres deep, provides a section through a thick sequence of sands, silts and clays, some of which have a steep sedimentary dip to the north indicating that the sediment was derived from the south (fig. 3.4.8.5.3.1.).

The lowest layers show small compaction faults which displace the bedding. These are faults with throws of up to 3 cm.. The sediments higher up the succession do not show this faulting.

The layers immediately below the vein calcite (fig. 3.4.8.5.3.1.) containing large blocks of limestone and calcite are probably mining waste dumped before the shaft was constructed. The bottom of the succession is not exposed. Although only 30 metres away from the Clay Shaft not even a tentative correlation can be made between the sediments in these two sections.

The composition of the sediments is given in figure 3.4.8.5.3.2..

The results of S.E.M. studies show that the quartz grains are of fluvial origin (plate 3.4.8.5.3.1.) with approximately 5 percent of authigenic quartz (fig. 3.4.8.5.3.3.). The authigenic quartz grains were derived from the limestones or dolomites, showing no signs of

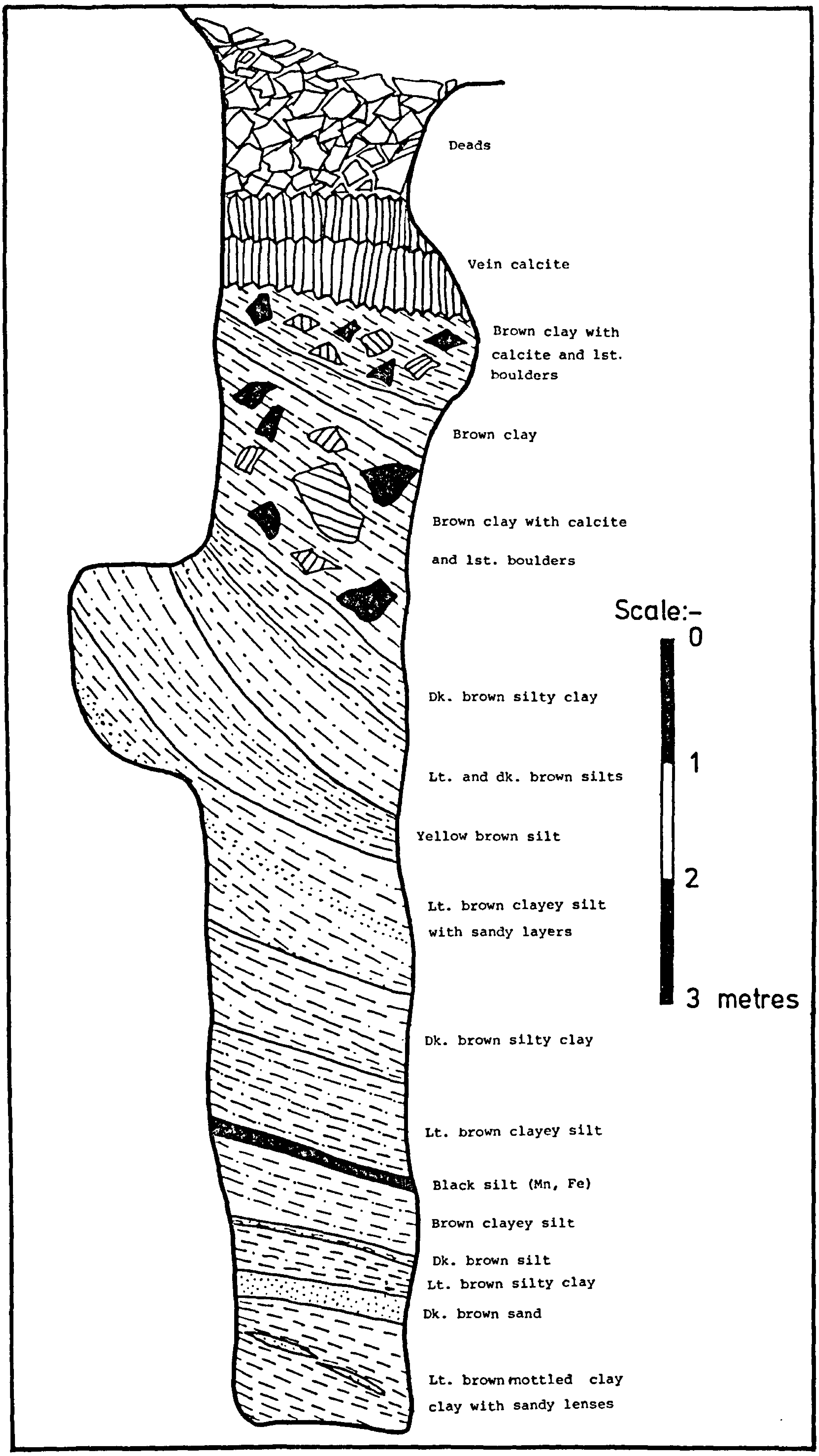


Figure 3.4.8.5.3.1. The sedimentry sequence exposed in Climbing Shaft, Old Jant Mine.

Sample Numbers YL 7–14

		%
1	Limestone (decalcified)	0 — 4
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena (with cerussite coating)	0 — 1·5
	Fluorite	7 — 21
	Baryte	0 — 5
	Calcite	0 — 2·5
2	Quartz	15 — 37
	Sandstone	0 — 2
	Feldspar	
	Mica	0 — 3
	Shale	
	Quartzite	
	Balance (mainly clay)	45 — 91

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	30 — 55
Kaolinite	12 — 28
Chlorite	4 — 6·5
Mixed layer smectites	4 — 7

Figure 3.4.8.5.3.2. Summary of sediment composition, Climbing Shaft, Old Jant Mine.

Surface Features	Sample number YL	7	8	9	10	11	12	13	14
Chemical	Euhedral silica			●	◪				
	Amorphous silica		●	●			●	●	●
	Solution crevasses								
	Solution pits		●	●	●		●		
	Oriented etch pits	●		●				●	●
Loessic	Dulled surface	●			●			●	
	Smooth surface	●							
	Rounded	◪						◪	●
	Dish-shaped pits							●	
Fluvial	Subangular	●	●	■	◪	●	●	◪	●
	Subrounded	◪	◪	●	◪	■	■	◪	■
	Mechanical V-pits	◪	◪	●	■	■	■	■	■
	Curved scratches	●	●		●	●	◪	◪	●
	Straight scratches		●				●	●	●
Glacial	Chattermarks			●					
	Angular		●	●	◪			●	
	Fracture plates								
	Adhering particles								
	Imbricate grinding			●					
	Parallel striations			●					
	Conchoidals >10μ		●	◪		●		●	
	Conchoidals <10μ	●		●				●	●
	Breakage blocks >10μ			●					
	Breakage blocks <10μ			●					●
General	Euhedral quartz			●	■	◪	●		
	Scaling	●	◪	●	●	●	●	●	◪
	High relief	●	●	■	◪		●		●
	Medium relief	●	◪	●	◪	●	●	■	◪
	Low relief	■	◪	●	◪	■	■	●	◪
	Meandering ridges		●		●	●		●	
	Arcuate steps	●					●		
	Straight steps	●						●	●
	Edge abrasion	●	●	●		●	●	●	◪
	Grain breakage	●			●		●		●

■ Abundant – 75% ◪ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 3.4.8.5.3.3. Summary of quartz grain surface textures, Climbing Shaft, Old Jant Mine.

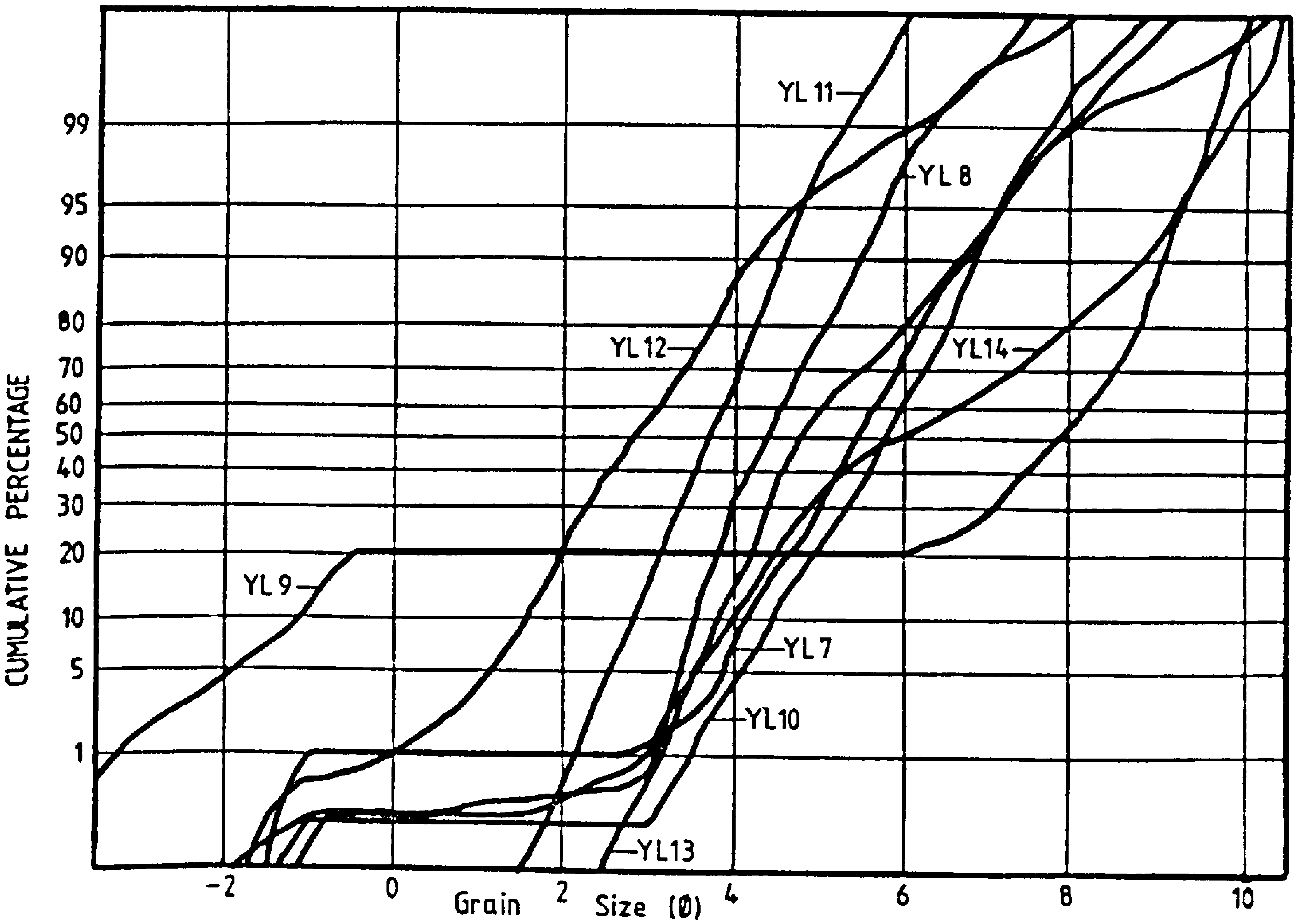


Figure 3.4.8.5.3.4. Sediment Size Analysis. Climbing Shaft.

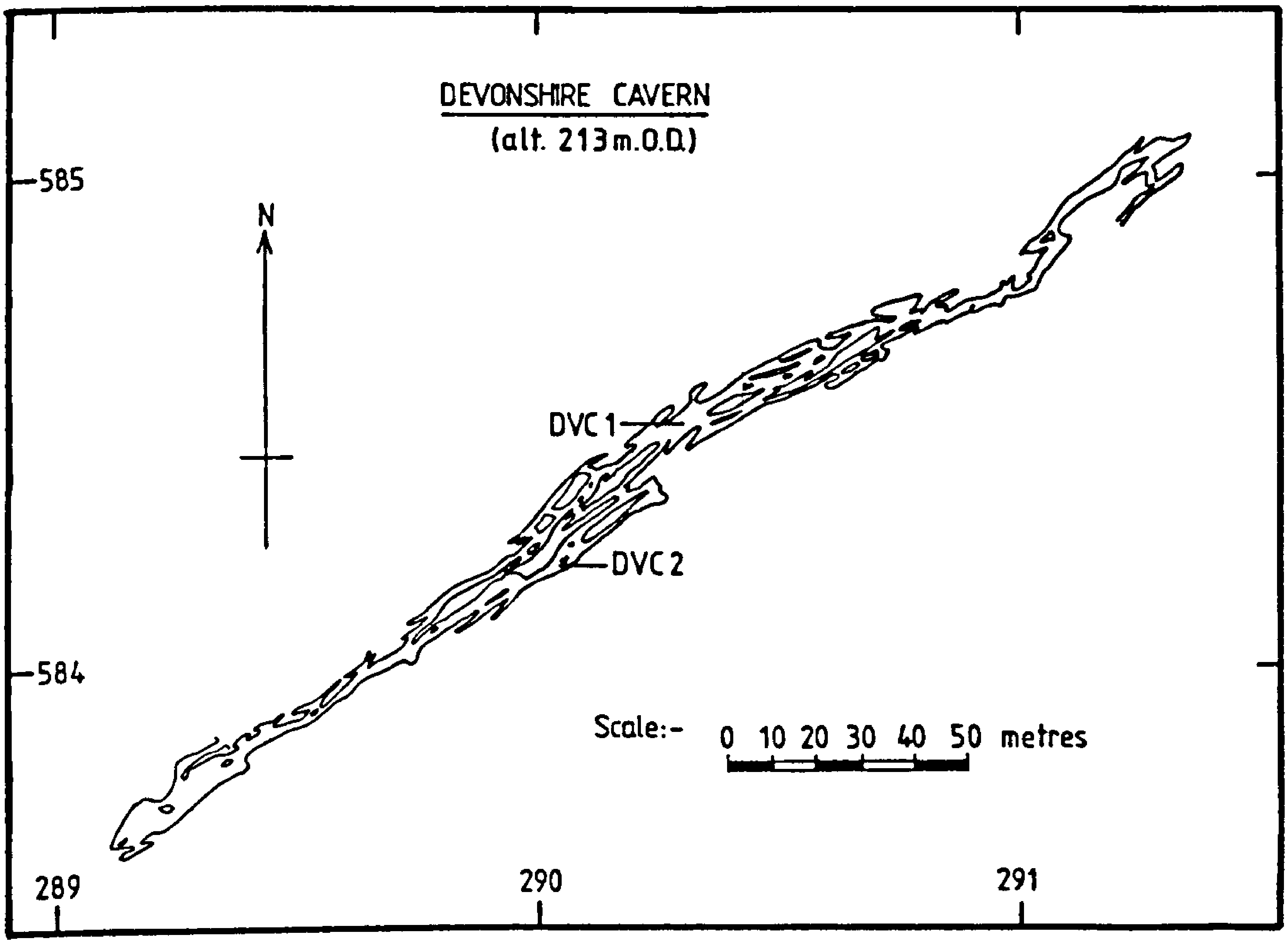
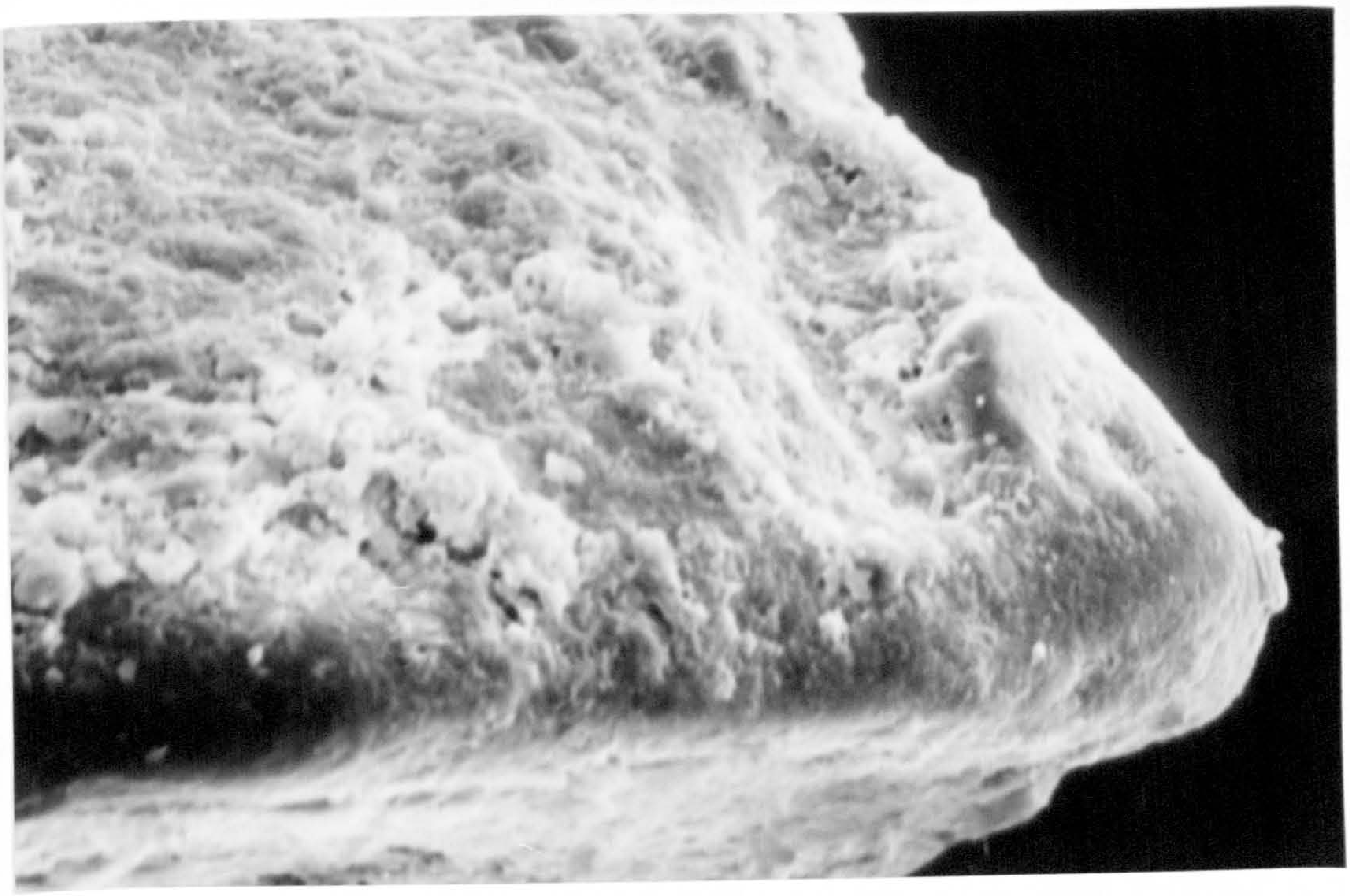
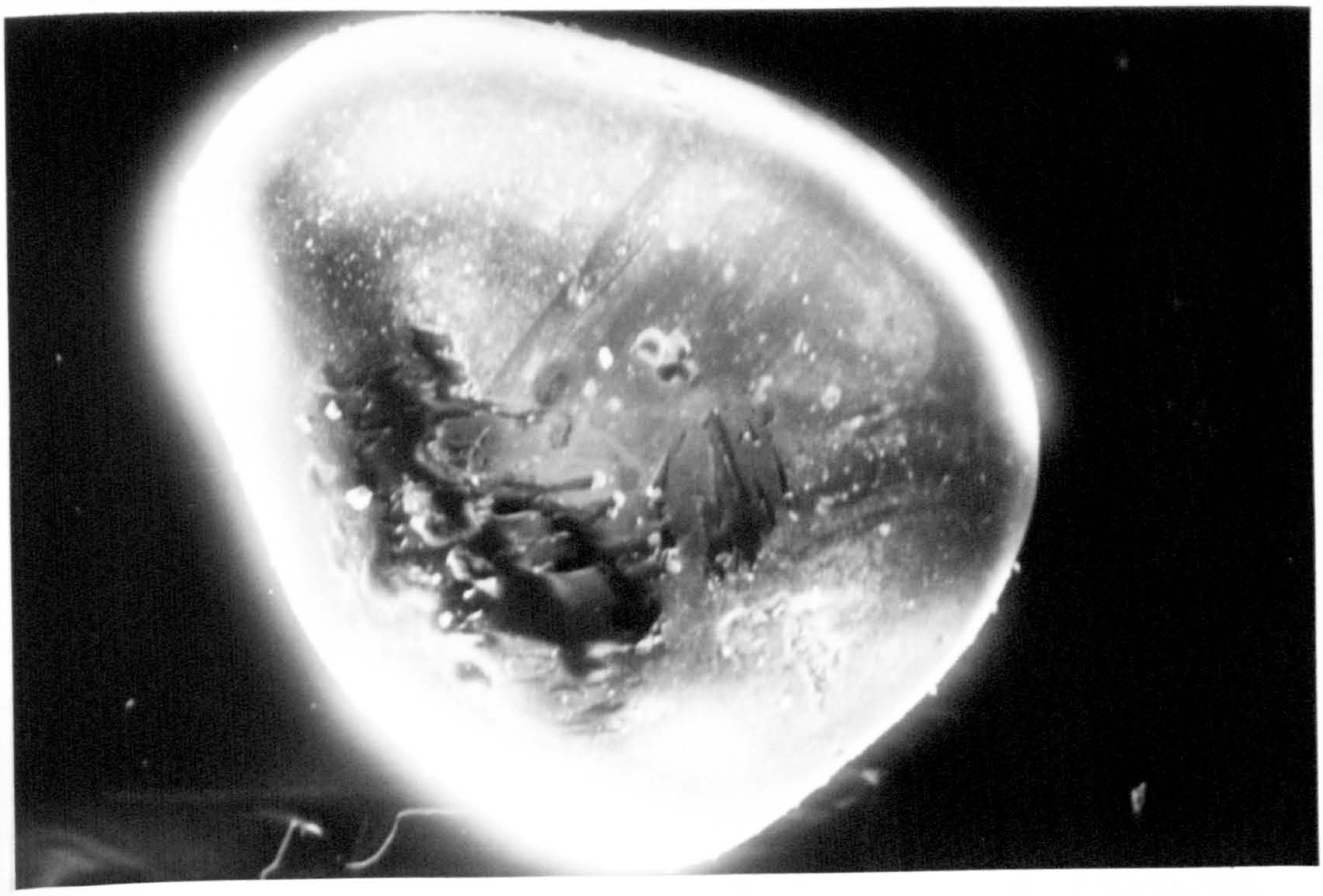


Figure 3.4.9.1. Plan of Devonshire Cavern, Matlock Bath, showing sample locations after Larson (1954).



3.4.8.5.3.1. S.E.M. photomicrograph of a fluvio - glacial quartz grain, Climbing Shaft.



3.4.10.1. S.E.M. photomicrograph of a rounded fluorite grain, Royal Mine.

abrasion. Size analysis shows that the sediments are well sorted, platykurtic silty sands. Towards the top of the section the sediments are slightly fine skewed (fig. 3.4.8.5.3.4.). The platykurtic nature of the sediments indicates that they were derived from two sources which the sediment composition study shows to have been autochthonous primary mineralization and allochthonous quartz sand, silt and clay.

Palaeomagnetic studies on these sediments are of limited value. The compaction faulting present in some of the horizons, their coarse - grained nature and the steep sedimentary dip contribute to poor stability and wide scatter of the natural remanent magnetization of these sediments, though they consistantly show reversed remanent magnetization.

3.4.9. Devonshire Cavern

Situated at SK 290,584, Devonshire Cavern was a show cave after mining ceased but is now disused. An account of the accessible workings has been given by Larson (1954) (fig. 3.4.9.1.).

Coalpithole Rake and associated fluorite replacement flats have been worked in Devonshire Cavern. Mineralization is confined to the Matlock Lower Limestone above the Matlock Lower Lava (Worley, 1978).

Only limited post mineralization cavernization has occurred in this area. Two small sediment - filled pockets have been located, each in dolomitised limestone which has resisted fluoritzation.

Sample Numbers DVC 1-2

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	47 — 53
	Galena	
	Fluorite	34 — 48
	Baryte	
	Calcite	
2	Quartz	
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	3 — 15

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	31 — 43
Kaolinite	37 — 46
Chlorite	5 — 12
Mixed layer smectites	6 — 14

Figure 3.4.9.2. Summary of sediment composition, Devonshire Cavern.

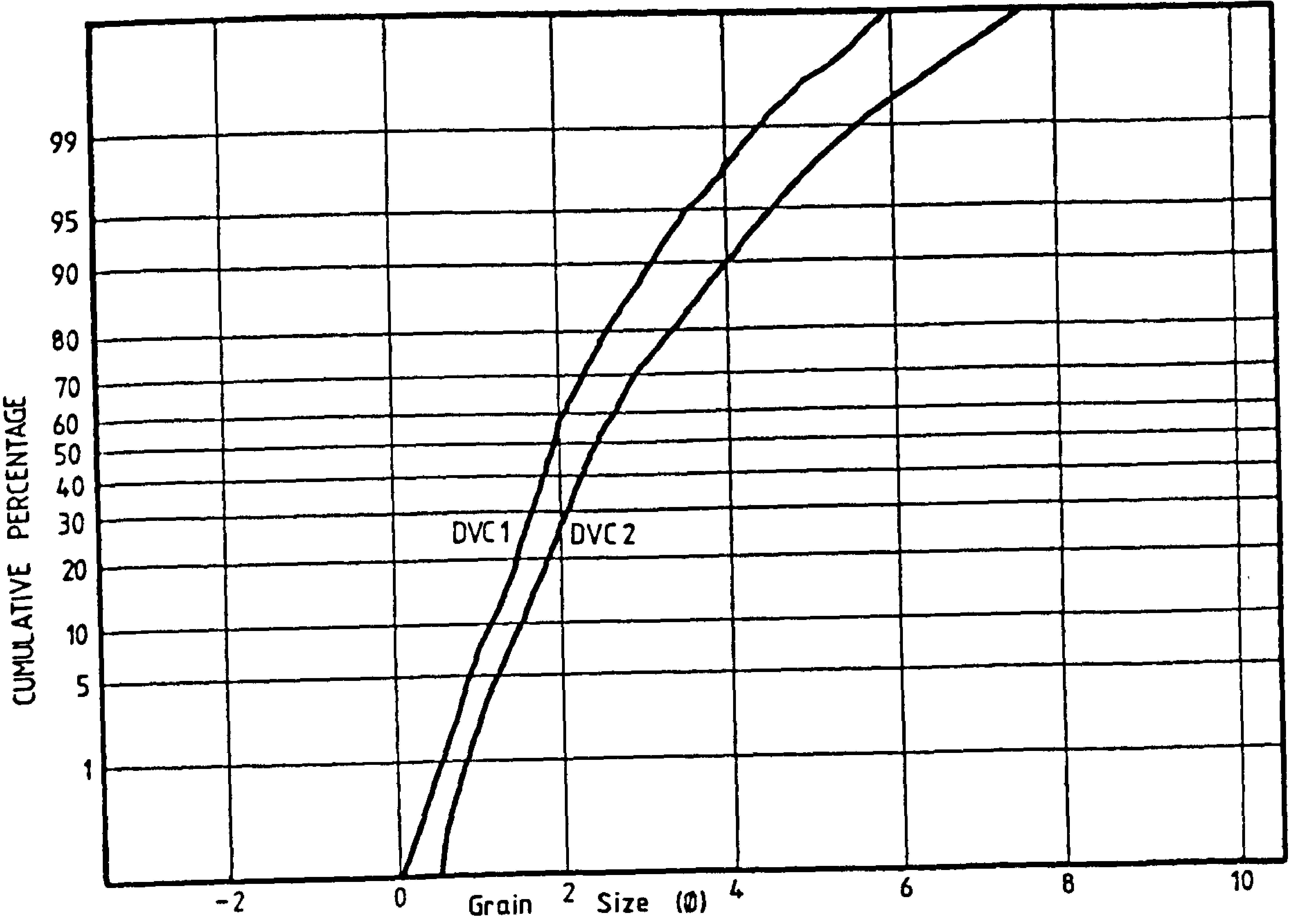


Figure 3.4.9.3. Sediment Size Analysis. Devonshire Cavern.

The composition of the sediments is given in figure 3.4.9.2..

Size analysis shows that the sediments are moderately well sorted, mesokurtic sands (fig. 3.4.9.3.) indicating a single source. The results of S.E.M. study (fig. 3.4.9.4.) shows that the quartz has been derived from the authigenic quartz present in some of the dolomitised limestone and to have undergone little abrasion. The fluorite is also euhedral and shows no rounding indicating limited movement from its original location.

Size analysis, the results of the S.E.M. study and their composition shows that all the sediment in these cavities has an autochthonous source probably very close to the location of the deposits as there is no evidence of abrasion of the grains. The clay fraction has been derived from the prominent clay wayboard exposed in parts of the mine workings.

3.4.10. Royal, Speedwell, Hopping and Tear Breeches Mine Complex

Only one entrance to this complex system of mine workings at SK 292,579 remains open and in use as a show cave (Royal Cave), the other entrances being sealed in 1979 and 1980. The workings were surveyed by Flindall and Hayes (1973) (fig. 3.4.10.1.) who also presented an account of the mines' history.

These interconnected mines form a complex of pipe veins associated with a number of small veins. Butcher

Surface Features		Sample number DVC 1	2
Chemical	Euhedral silica		
	Amorphous silica		
	Solution crevasses		
	Solution pits	●	●
	Oriented etch pits		
Loessic	Dulled surface		
	Smooth surface		
	Rounded		
	Dish-shaped pits		
Fluvial	Subangular		
	Subrounded		
	Mechanical V-pits	●	●
	Curved scratches	●	●
	Straight scratches		
Glacial	Chattermarks		
	Angular		
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10µ	●	●
	Conchoidals <10µ		
	Breakage blocks>10µ		
	Breakage blocks<10µ		
General	Euhedral quartz		
	Scaling		
	High relief		
	Medium relief		
	Low relief		
	Meandering ridges		
	Arcuate steps		
	Straight steps		
	Edge abrasion		
	Grain breakage	◣	◣

■ Abundant – 75% ◣ Common 25–75% ● Present 1–25% ☐ Absent – 1%

Figure 3.4.9.4. Summary of quartz grain surface textures, Devonshire Cavern.

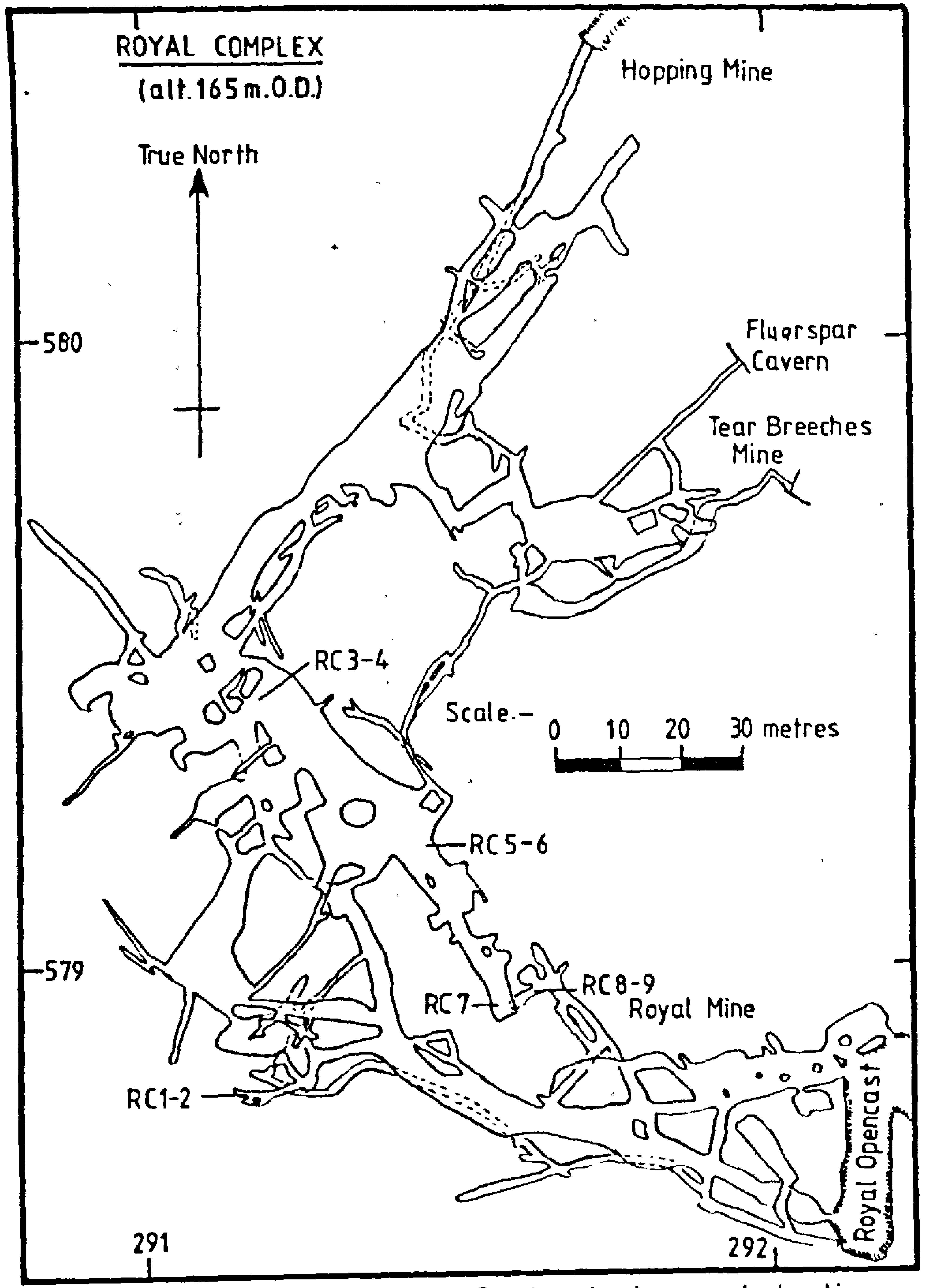


Figure 3.4.10.1. Plan of the Royal Mine Complex showing sample locations. After Flindall and Hayes (1973).

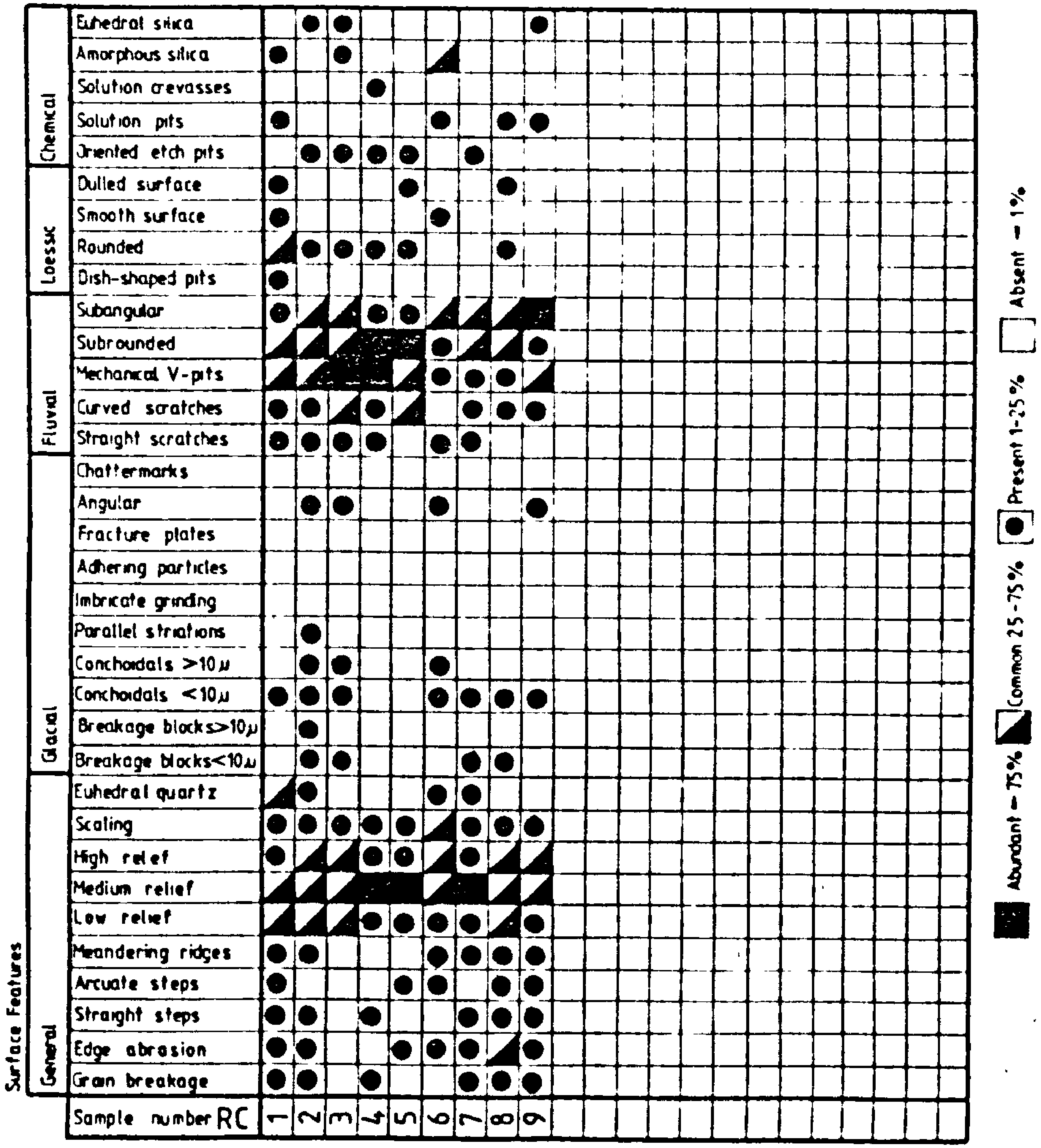
(1976) showed that these deposits are situated on the upthrow side of the Speedwell Fault. They are hosted in partly dolomitised Matlock Lower Limestones above the Matlock Lower Lava and below a prominent wayboard. Mineralization consists of pipe vein and replacement fluorite and calcite with some galena.

Post - mineralization solutional modification of the pipe veins has been extensive forming large caverns with boulder strewn floors. Many of these cavities and those remaining within the pipe veins appear to have been filled with sediment before mining occurred. Much of this has now been totally removed and seems to have been the primary objective of the miners here.

Two distinctive sedimentary deposits occur within the mine. Firstly a coarse sand and gravel with little or no finer fraction the composition of which is given in figure 3.4.10.2.. The results of S.E.M. studies show that the clasts are generally well rounded, including the fluorite (plate 3.4.10.1.) and calcite clasts, are of fluvial origin (fig. 3.4.10.3.).

Sediment size analysis shows that these coarse grained sediments are well sorted to moderately well sorted, slightly coarse - skewed to slightly fine - skewed, mesokurtic to platykurtic sandy gravels (fig. 3.4.10.4.).

The variable character of these sediments is an indication of variable flow conditions during deposition. The well rounded nature of the autochthonous material indicates that turbulent conditions existed to produce the degree of rounding present.



Chemical	Euhedral silica		●	●						●
	Amorphous silica	●		●			◢			
	Solution crevasses				●					
	Solution pits	●					●		●	●
	Oriented etch pits		●	●	●	●		●		
Loessic	Dulled surface	●				●			●	
	Smooth surface	●					●			
	Rounded	◢	●	●	●	●			●	
	Dish-shaped pits	●								
Fluvial	Subangular	●	◢	◢	●	●	◢	◢	◢	■
	Subrounded	◢	◢	◢	■	■	●	◢	◢	●
	Mechanical V-pits	◢	◢	■	■	◢	●	●	●	◢
	Curved scratches	●	●	◢	●	◢		●	●	●
	Straight scratches	●	●	●	●		●	●		
Glacial	Chattermarks									
	Angular		●	●			●			●
	Fracture plates									
	Adhering particles									
	Imbricate grinding									
	Parallel striations		●							
	Conchoidals >10μ		●	●			●			
	Conchoidals <10μ	●	●	●			●	●	●	●
	Breakage blocks>10μ		●							
	Breakage blocks<10μ		●	●				●	●	
General	Euhedral quartz	◢	●				●	●		
	Scaling	●	●	●	●	●	◢	●	●	●
	High relief	●	◢	◢	●	●	◢	●	◢	◢
	Medium relief	◢	◢	◢	■	■	◢	■	◢	◢
	Low relief	◢	◢	◢	●	●	●	●	◢	●
	Meandering ridges	●	●				●	●	●	●
	Arcuate steps	●				●	●		●	●
	Straight steps	●	●		●			●	●	●
	Edge abrasion	●	●			●	●	●	◢	●
	Grain breakage	●	●		●			●	●	●
Surface Features	Sample number RC	1	2	3	4	5	6	7	8	9

■ Abundant – 75% ◢ Common 25-75% ● Present 1-25% □ Absent – 1%

Figure 3.4.10.3. Summary of quartz grain surface textures, Royal Complex.

Sample Numbers RC 1-3		
		%
1	Limestone	
	Dolomite	
	Volcanics	1 — 5
	Chert	1 — 4
	Silicified fossils	0 — 2
	Authigenic quartz	
	Galena	
	Fluorite	25 — 61
	Baryte	
	Calcite	14 — 21
2	Quartz	21 — 36
	Sandstone	0 — 2·5
	Feldspar	
	Mica	
	Shale	0 — 1·5
	Quartzite	1 — 3
	Balance (mainly clay)	

1 Autochthonous 2 Allochthonous

Figure 3.4.10.2. Summary of sediment composition, Royal Complex.

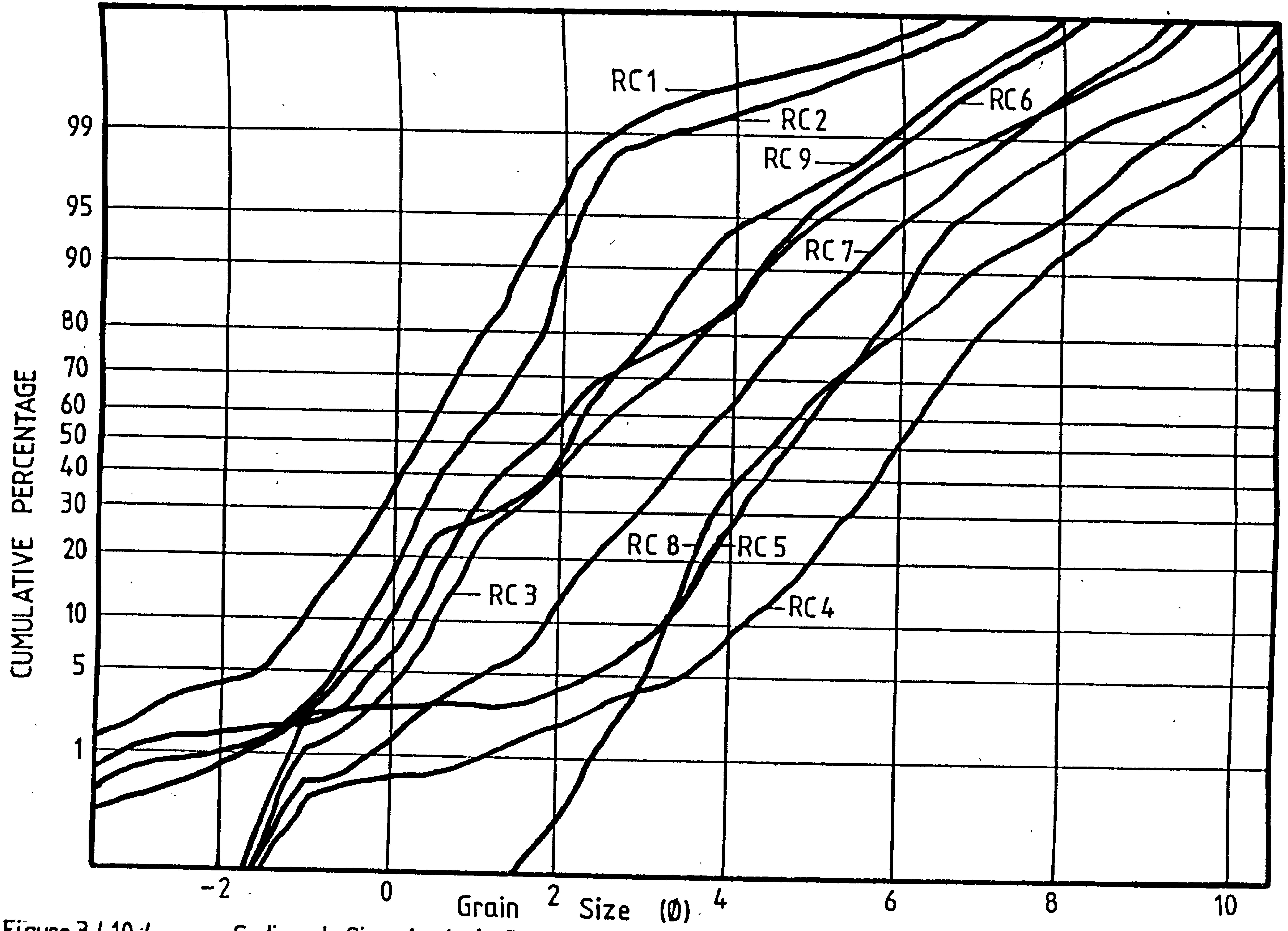


Figure 3.4.10.4. Sediment Size Analysis, Royal Mine.

Secondly a silty - mud deposit that occurs in numerous small cavities throughout the pipe vein system. The composition of these deposits is given in figure 3.4.10.5..

Size analysis of these sediments show them to be moderately well sorted, nearly symmetrical, mesokurtic silts (fig. 3.4.10.4.). Most of this sediment is autochthonous with only a minor contribution from outside the system. Some of the clay may have been derived from the earlier coarse - grained deposits.

3.4.11. Temple Mine

Temple Mine is a small mine at SK 292,581 situated below the Royal Mine complex. It has recently (1982) been opened to the public in conjunction with the Mining Museum by the Peak District Mines Historical Society. It consists of a number of small pipe veins and associated non - mineralized caverns (fig. 3.4.11.1.).

The pipe veins are developed in the Matlock Lower Limestone immediately above the Matlock Lower Lava which has been penetrated by a level in part of the mine. Mineralization occurs as a series of interconnecting pipe veins with calcite and fluorite linings. Galena is almost absent.

Post - mineralization cavernization has occurred, particularly in the southern part of the mine, and is not generally associated with the pipe veins, producing large caverns with boulder strewn floors. These are filled to the roof by well bedded clayey silts. Numerous primary

Sample Numbers RC 3-9

		%
1	Limestone	0 — 2
	Dolomite	
	Volcanics	
	Chert	0 — 3
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	10 — 21
	Baryte	
	Calcite	1 — 6
2	Quartz	32 — 56
	Sandstone	0 — 1
	Feldspar	
	Mica	0 — 2·5
	Shale	
	Quartzite	0 — 1·5
	Balance (mainly clay)	31 — 55

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	36 — 54
Kaolinite	23 — 41
Chlorite	15 — 29
Mixed layer smectites	3 — 5

Figure 3.4.10.5. Summary of sediment composition, Royal Complex.

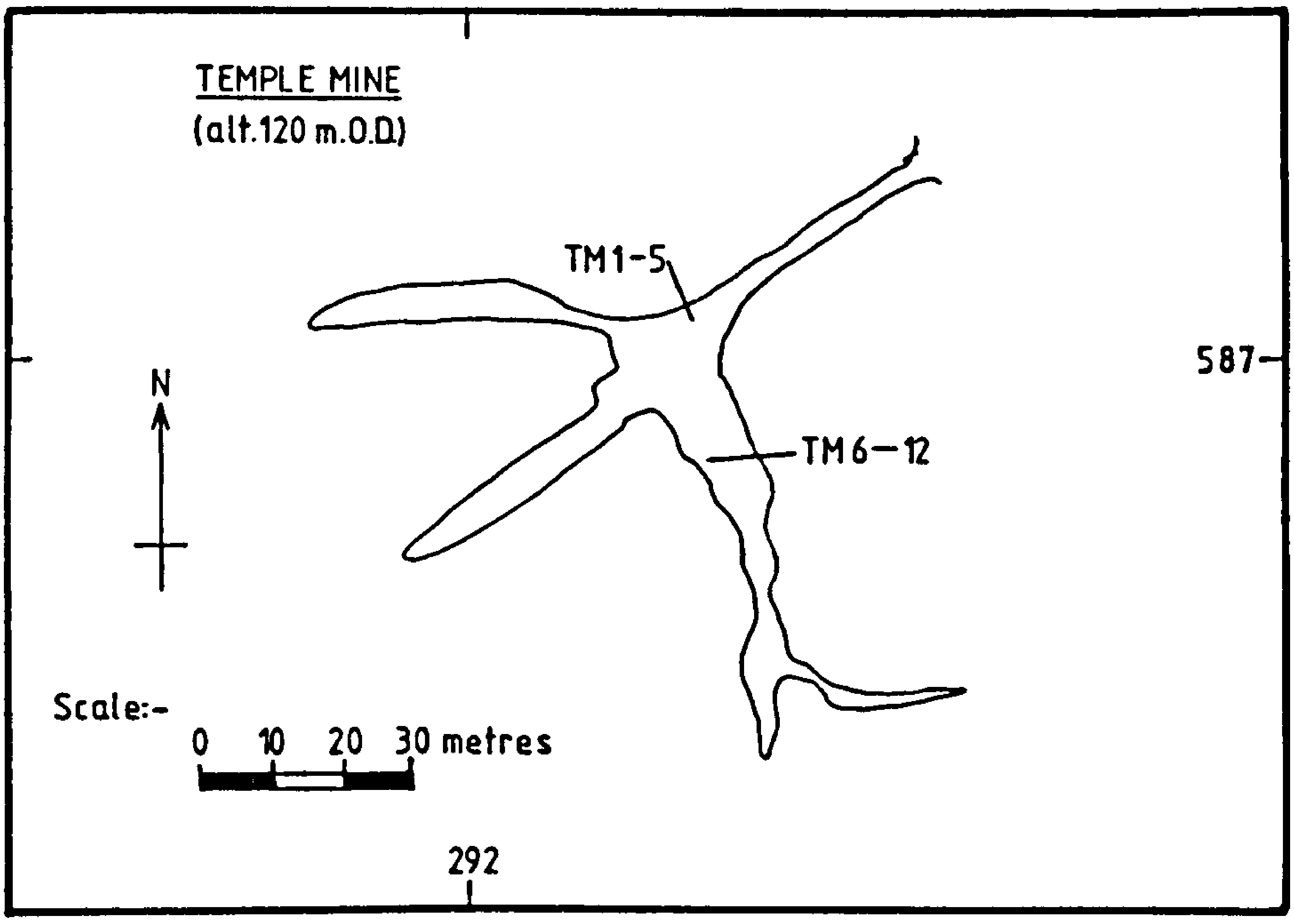


Figure 3.4.11.1. Plan of Temple Mine showing sample locations. After Flindal and Hayes (1973).

bedding structures are displayed including long wave ripples, cross and ripple drift bedding (plates 3.4.11.1. and 3.4.11.2) indicating that deposition was under moderately deep, sluggishly moving water.

The composition of these sediments is given in figure 3.4.11.2..

Size analysis shows the sediments to be well sorted, slightly fine - skewed, mesokurtic fine sands (fig. 3.4.11.3.), most of the sediment being allochthonous. The results of S.E.M. studies of quartz grain surface textures show that the sediments are of fluvial origin with some features indicative of a fluvio - glacial source (fig. 3.4.11.4.).

The composition and the mesokurtic nature of these sediments indicates that they were probably derived from a single source, the derivation being by fluvial and fluvio - glacial procersses.

Some of the cavities remaining in the pipe veins are filled with a crudely bedded, coarse - grained sediment composed of fluorite (60 to 83%), calcite (10 to 37%) and limestone (3 to 7%) of very local origin. Size analysis shows these sediments to be poorly sorted, coarse - skewed leptokurtic coarse sands. All the clasts are angular and many euhedral fluorite crystals are present indicating limited movement from their source, perhaps barely more than solutional stoping of the pipe vein cavity walls.

3.4.12. Cumberland Cavern and Wapping Mine

The entrance to Cumberland Cavern, a former show

Sample Numbers TM 1—12

		%
1	Limestone	
	Dolomite	
	Volcanics	5 — 12
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	36 — 71
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	17 — 59

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	31 — 49
Kaolinite	29 — 46
Chlorite	16 — 31
Mixed layer smectites	4 — 6

Figure 3.4.11.2. Summary of sediment composition, Temple Mine.

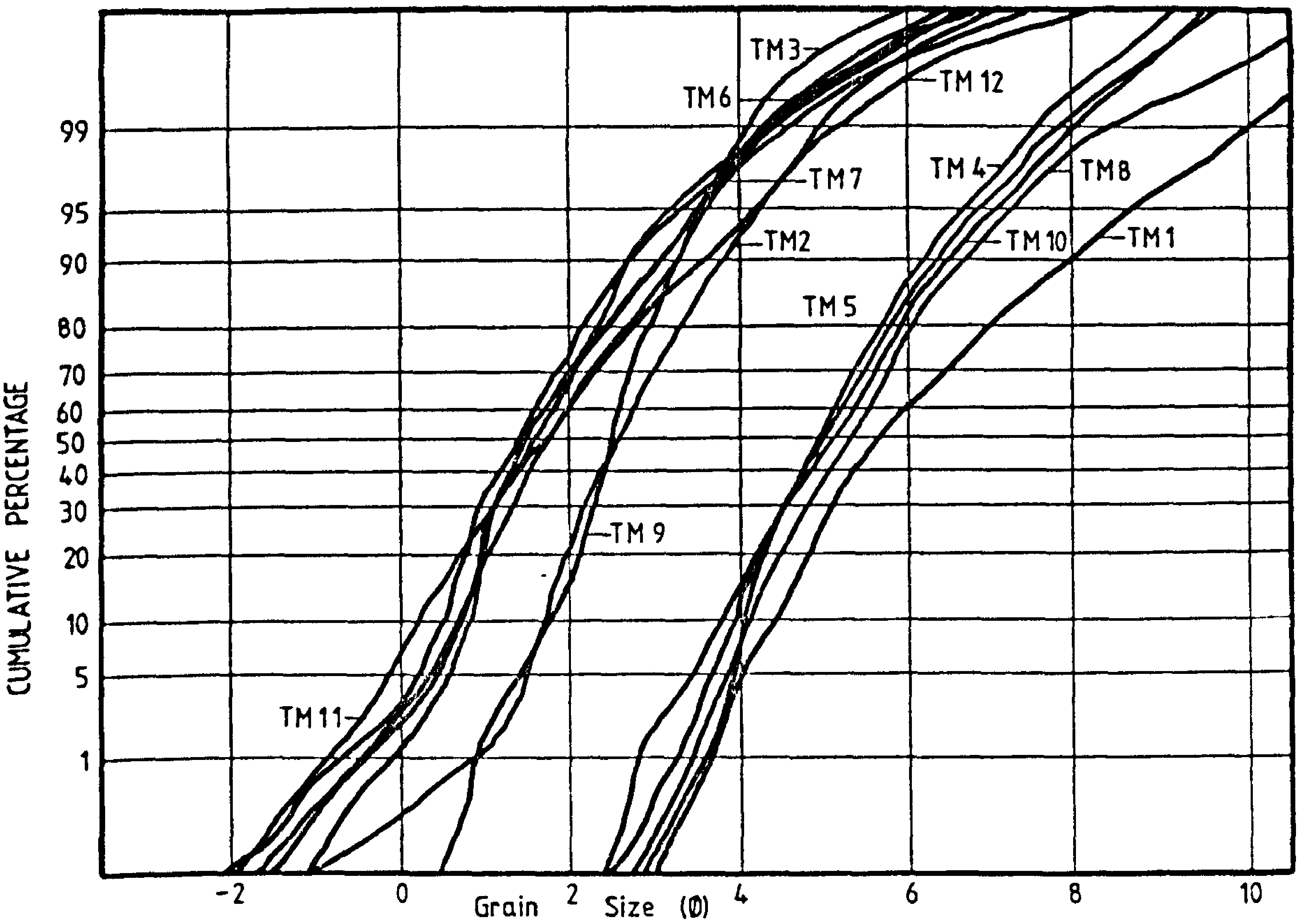
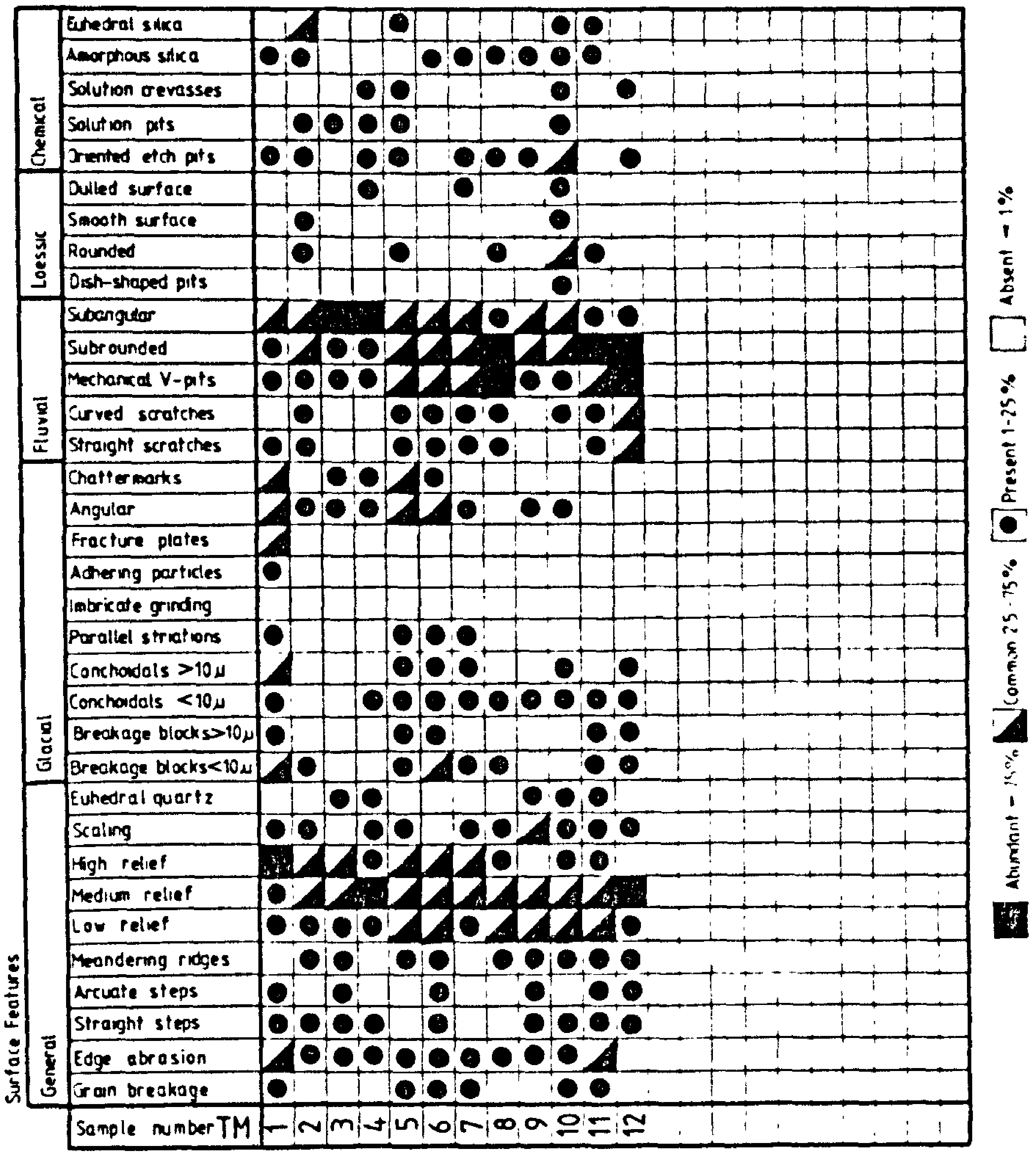


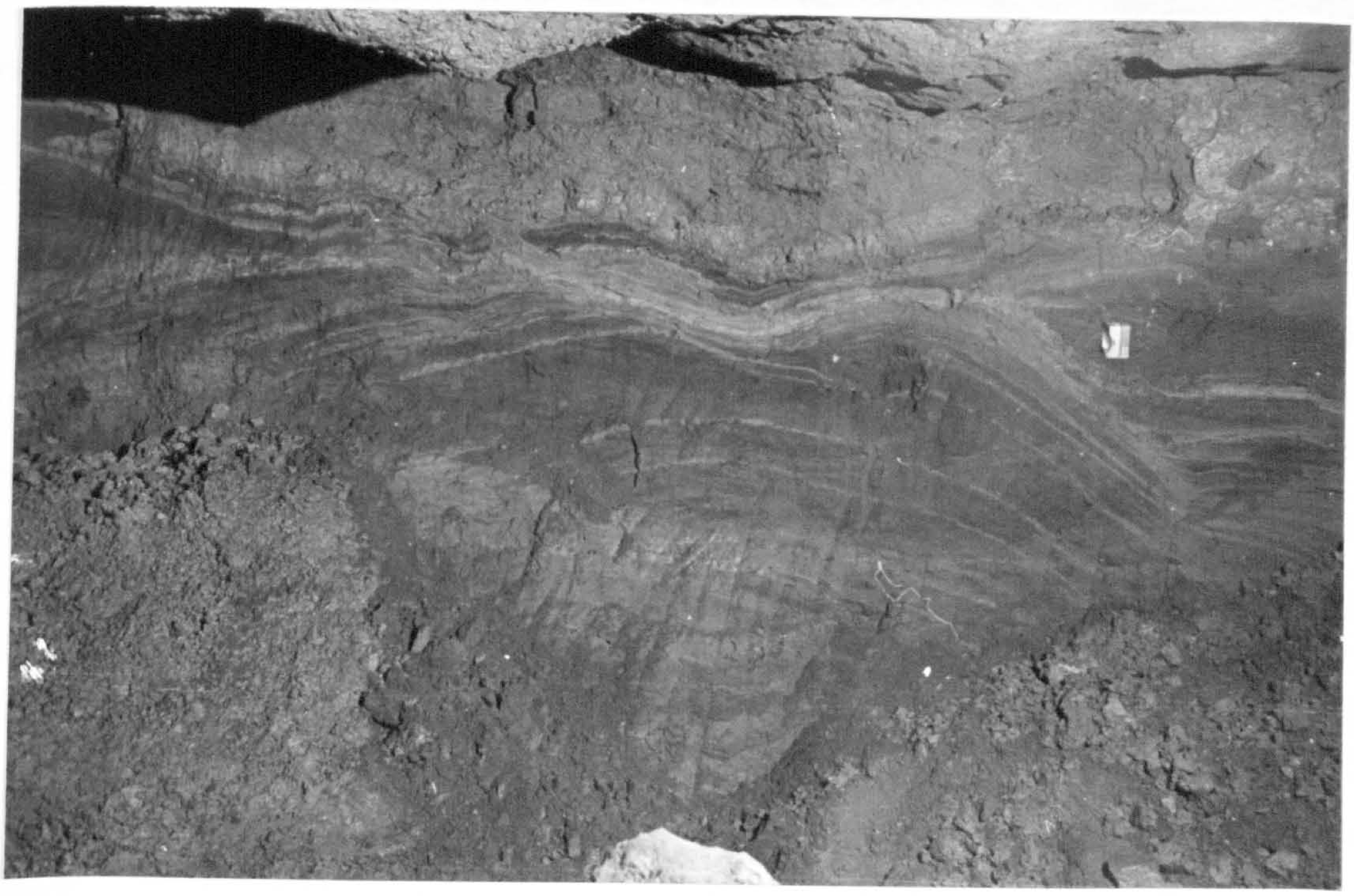
Figure 3.4.11.3. Sediment Size Analysis. Temple Mine.



		Sample number TM	1	2	3	4	5	6	7	8	9	10	11	12
	Chemical	Euhedral silica		◢			●					●	●	
		Amorphous silica	●	●				●	●	●	●	●	●	
		Solution crevasses				●	●					●		●
		Solution pits		●	●	●	●					●		
		Oriented etch pits	●	●		●	●		●	●	●	◢		●
	Loessic	Dulled surface				●			●			●		
		Smooth surface		●								●		
		Rounded		●			●			●		◢	●	
		Dish-shaped pits										●		
	Fluvial	Subangular	◢	◢	■	■	◢	◢	◢	●	◢	◢	●	●
		Subrounded	●	◢	●	●	◢	◢	◢	■	◢	◢	■	■
		Mechanical V-pits	●	●	●	●	◢	◢	◢	■	●	●	◢	■
		Curved scratches		●			●	●	●	●		●	●	◢
		Straight scratches	●	●			●	●	●	●			●	◢
	Glacial	Chattermarks	◢		●	●	◢	●						
		Angular	◢	●	●	●	◢	◢	●		●	●		
		Fracture plates	◢											
		Adhering particles	●											
		Imbricate grinding												
		Parallel striations	●				●	●	●					
		Conchoidals >10µ	◢				●	●	●			●		●
		Conchoidals <10µ	●			●	●	●	●	●	●	●	●	●
		Breakage blocks>10µ	●				●	●					●	●
		Breakage blocks<10µ	◢	●			●	◢	●	●			●	●
Surface Features	General	Euhedral quartz			●	●					●	●	●	
		Scaling	●	●		●	●		●	●	◢	●	●	●
		High relief	■	◢	◢	●	◢	◢	◢	●		●	●	
		Medium relief	●	◢	◢	■	◢	◢	◢	◢	◢	◢	◢	■
		Low relief	●	●	●	●	◢	◢	●	◢	◢	◢	◢	●
		Meandering ridges		●	●		●	●		●	●	●	●	●
		Arcuate steps	●		●			●			●		●	●
		Straight steps	●	●	●	●		●			●	●	●	●
		Edge abrasion	◢	●	●	●	●	●	●	●	●	●	◢	
		Grain breakage	●				●	●	●			●	●	

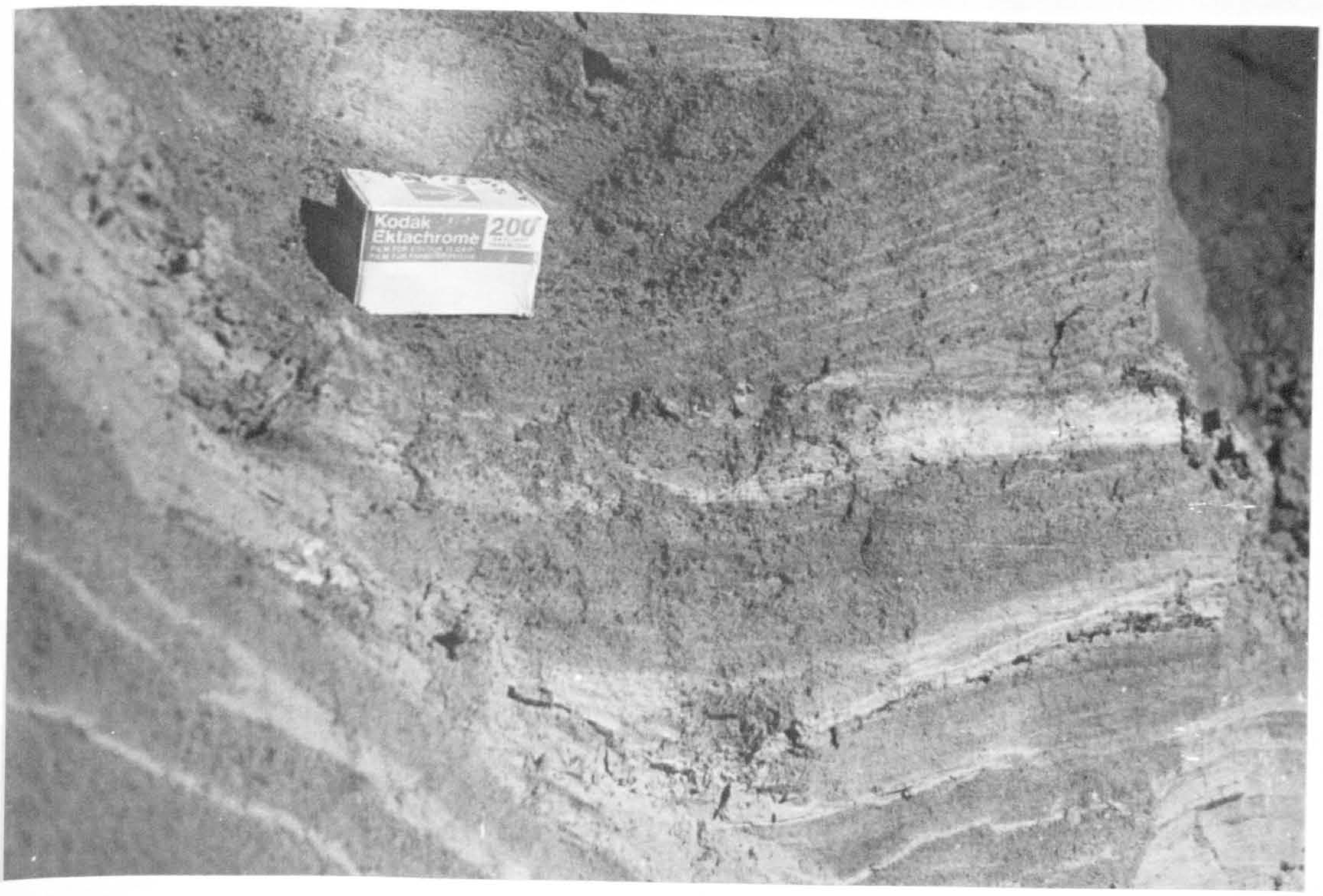
■ Abundant – 75%
◢ Common 25 - 75%
● Present 1-25%
☐ Absent – 1%

Figure 3.4.11.4. Summary of quartz grain surface textures, Temple Mine.



1/2 metre

3.4.11.1. Bedded sands and Silts, Temple Mine.



5 cm.

3.4.11.2. Detail of section in previous plate showing cross bedding.

cave, at SK 292,577 has recently been re-opened. That to Wapping Mine at SK 294,587 has been walled up and sealed. The two sets of workings are connected underground.

These two complex systems of cave and mine passages have been described and surveyed by Flindall and Hayes (1972) (fig. 3.4.12.1.). Wapping Mine was worked into the 1950's for fluorspar.

Developed in dolomitised Matlock Lower Lava these two connected mines are distinctly different. Cumberland Cavern is a series of bedding controlled phreatic caverns first entered by miners who worked a few small scrin and pipe veins close to the present entrance. The rest of the cave system is devoid of mineralization. Wapping Mine consists of a series of replacement flats developed between a series of closely spaced scrins associated with Moletrap Rake (Butcher, 1976) in which some of the mine workings are situated.

Mineralization consists of calcite - fluorite wall rock replacements with calcite - filled pipe veins close to Moletrap Rake. Moletrap Rake and associated scrins are composed of banded fluorite, calcite and galena mineralization with a complex paragenetic sequence.

Cumberland Cavern is almost devoid of any sedimentary deposits. In a few isolated areas a thin coating of silt occurs on the floor and loose boulders, the composition of which is given in figure 3.4.12.2.. Size analysis shows that the sediments are poorly sorted, mesokurtic silty clays (fig. 3.4.12.3.).

The results of S.E.M. studies show that the quartz grains are of loessic origin (fig. 3.4.12.4., plate

Figure 3.4.12.1. Plan of Wapping Mine and Cumberland showing sample locations. After Flindall and Hayes (1972)

Sample Numbers CuC 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	64
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	36

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	54
Kaolinite	26
Chlorite	5
Mixed layer smectites	15

Figure 3.4.12.2. Summary of sediment composition, Cumberland Cavern.

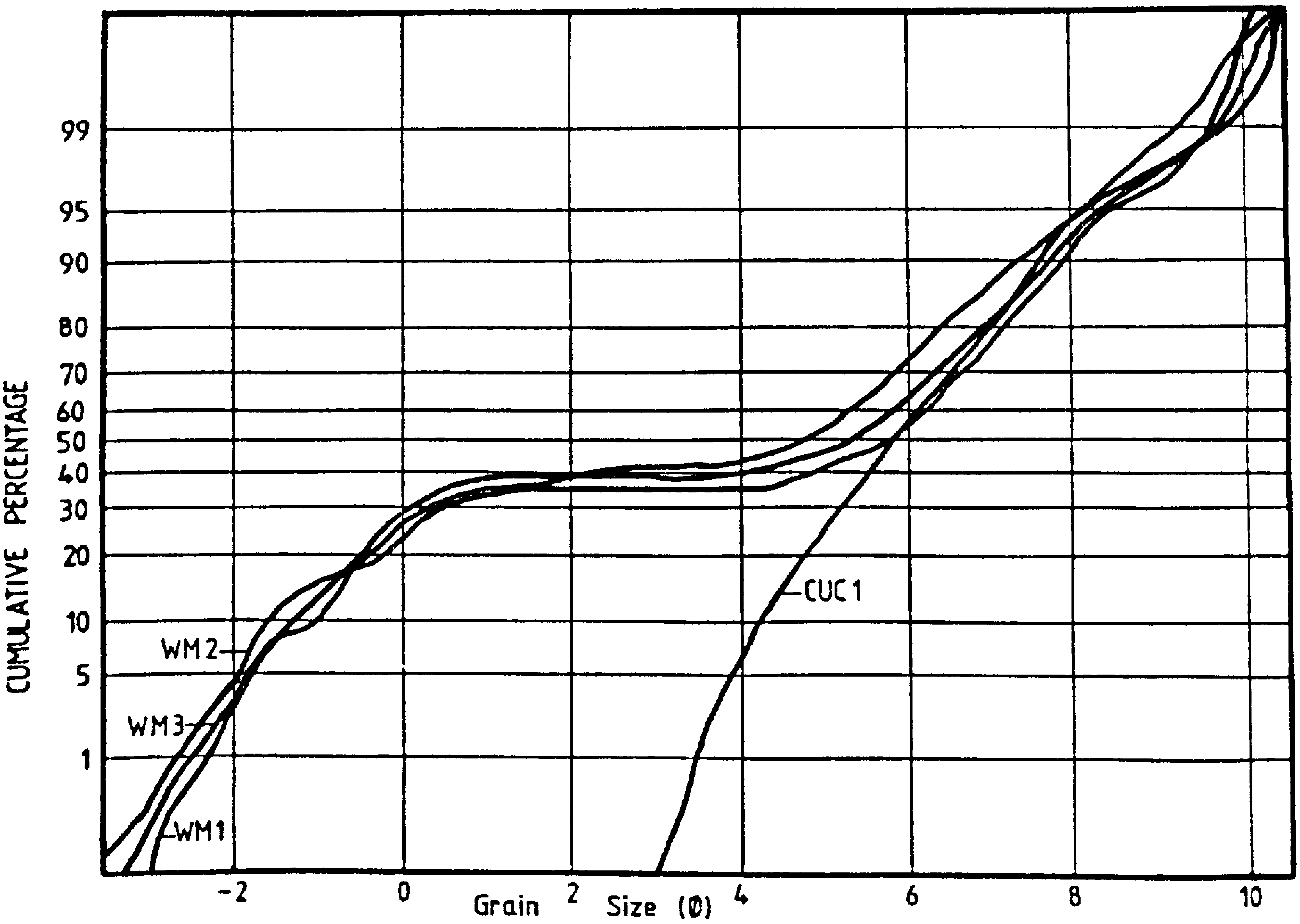
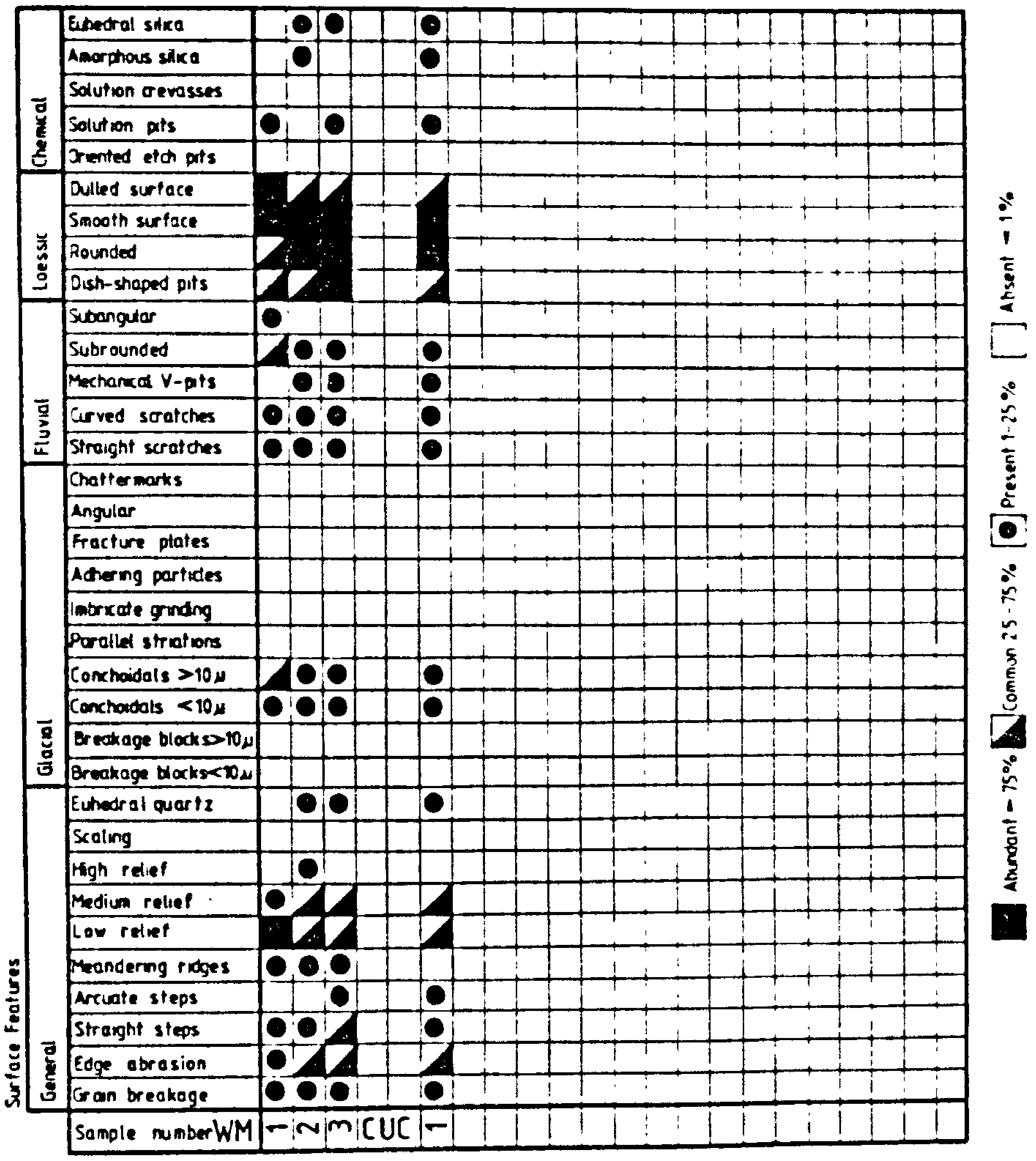


Figure 3.4.12.3. Sediment Size Analysis. Cumberland Cavern and Wapping Mine.



Surface Features — Chemical	Euhedral silica		●	●			●
	Amorphous silica		●				●
	Solution crevasses						
	Solution pits	●		●			●
	Oriented etch pits						
Loessic	Dulled surface	■	◢	◢			◢
	Smooth surface	■	■	■			■
	Rounded	◢	■	■			■
	Dish-shaped pits	◢	◢	■			◢
Fluvial	Subangular	●					
	Subrounded	◢	●	●			●
	Mechanical V-pits		●	●			●
	Curved scratches	●	●	●			●
	Straight scratches	●	●	●			●
Glacial	Chattermarks						
	Angular						
	Fracture plates						
	Adhering particles						
	Imbricate grinding						
	Parallel striations						
	Conchoidals >10μ	◢	●	●			●
	Conchoidals <10μ	●	●	●			●
	Breakage blocks>10μ						
	Breakage blocks<10μ						
General	Euhedral quartz		●	●			●
	Scaling						
	High relief		●				
	Medium relief	●	◢	◢			◢
	Low relief	■	◢	◢			◢
	Meandering ridges	●	●	●			
	Arcuate steps			●			●
	Straight steps	●	●	◢			●
	Edge abrasion	●	◢	◢			◢
	Grain breakage	●	●	●			●
	Sample number WM	1	2	3	CUC		1

■ Abundant = 75%
◢ Common 25-75%
● Present 1-25%
☐ Absent = 1%

Figure 3.4.12.4. Summary of quartz grain surface textures, Cumberland Cavern and Wapping Mine.

3.4.12.1.). This sediment has been derived via post - cavernization percolation water from loessic deposits which probably once covered the slopes of the Derwent Gorge.

Above the entrance to Wapping Mine is a cavity filled with coarse, angular calcite and fluorite. This is an accumulation of ore - washing waste. Within the mine only three small, isolated cavities were found, each containing a sedimentary fill, in the walls of Moletrap Rake. These are filled with poorly sorted gravel in a silty clay matrix, the composition of which is given in figure 3.4.12.5.. Size analysis shows the sediments to be very poorly sorted, coarse - skewed, platykurtic, muddy gravels (fig. 3.4.12.3.). The results of S.E.M. studies show that the quartz is of loessic origin (fig. 3.4.12.4.).

Hand specimen examination and size analysis show the sediment to have two sources, the autochthonous vein material having a very local source and the allochthonous silty clay being derived from surface loess deposits.

3.4.13. Ball Eye Mine and Quarry

At Ball Eye on the north side of the Via Gellia a complex system of pipe veins, replacement flats and fissure veins has been worked as Ball Eye Mine (SK 285,574) and is also exposed in Ball Eye Quarry (SK 284,575). Ball Eye Quarry works dolomitised Matlock Lower Limestone on top of the Matlock Lower Lava faulted against Cawdor Limestones by the Bonsall Fault just to the north.

Sample Numbers BEQ 1-2

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	47 — 76
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	24 — 53

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	29 — 48
Kaolinite	32 — 41
Chlorite	12 — 38
Mixed layer smectites	8 — 12

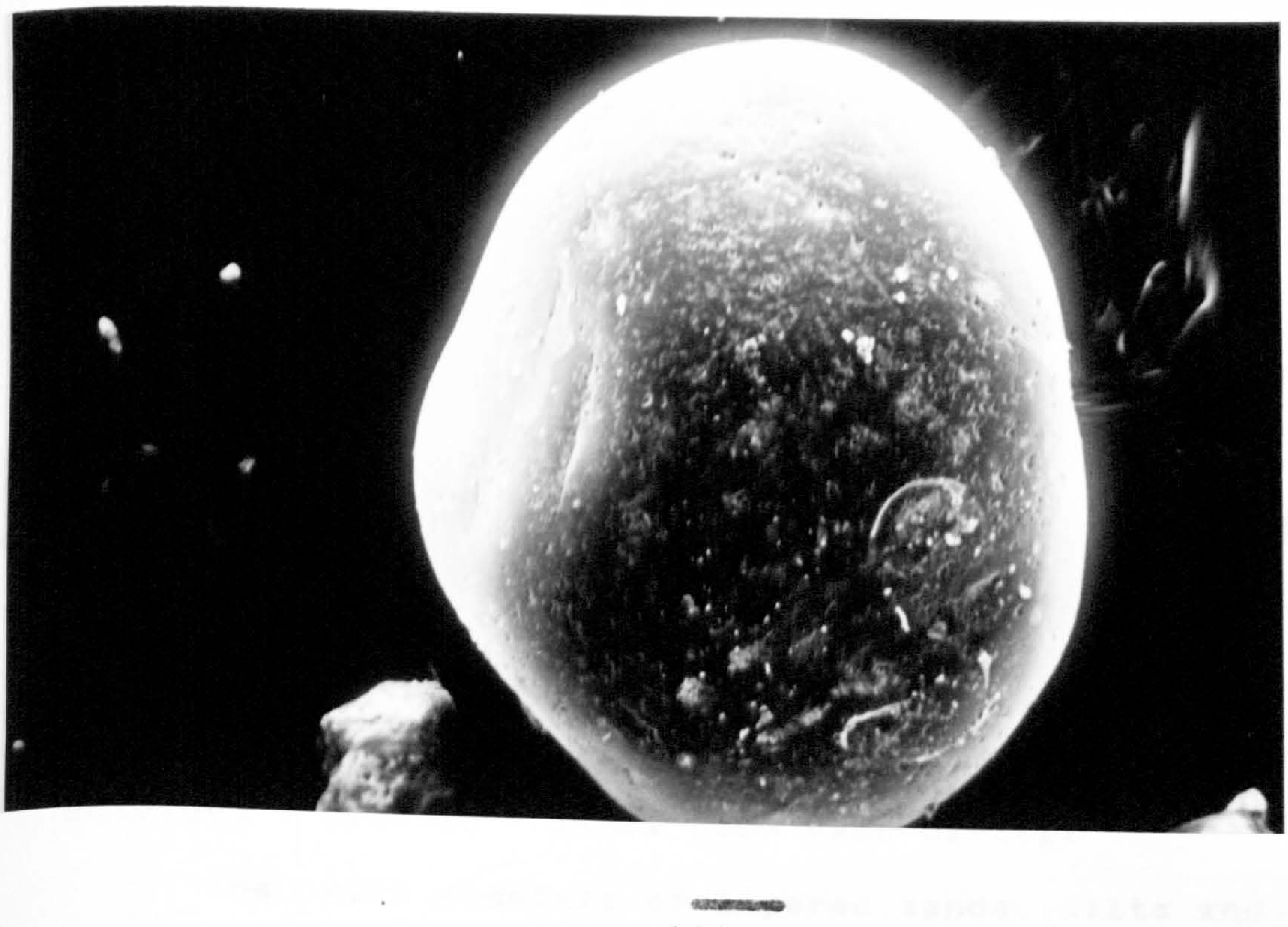
Figure 3.4.13.1. Summary of sediment composition,
Ball Eye Quarry.

Sample Numbers WW 1-3

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	26 — 35
	Baryte	
	Calcite	15 — 27
2	Quartz	31 — 48
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	14 — 20

1 Autochthonous 2 Allochthonous

Figure 3.4.12.5. Summary of sediment composition,
Wapping Mine.



3.4.12.1. S.E.M. photomicrograph of a loessic quartz grain, Cumberland Cavern.

Solution collapse has let down small quantities of Namurian Shale (Butcher, 1976).

Mineralization consists of pipe and fissure veins and replacement flat deposits of galena, baryte and fluorite with some calcite. Substantial post - mineralization cavernization has occurred.

Solutionally enlarged joints in the quarry are filled with a stiff yellow clayey silt, the composition of which is given in figure 3.4.13.1..

The results of S.E.M. study of quartz grain surface textures shows that this sediment is of loessic origin (fig. 3.4.13.2.), having been washed into the fissures from surface deposits.

It is apparent from the workings of Ball Eye Mine (fig. 3.4.13.3.) that much of the former sediment fill has been worked out by the lead miners. Only one section remains undisturbed. This consists of a solutionally enlarged , calcite - lined pipe vein cavity.

The fill consists of layered sands, silts and clays including solution collapse breccias of roof material, channel fills and mud flake breccias. Solutional collapse occurred during initial sedimentation and later after a period of erosion and channel filling (fig. 3.4.13.4.). Current bedding is evident in parts of the section.

The composition of the sediments is given in figure 3.4.13.5..

Sediment size analysis shows the sediments to be generally moderately well sorted, slightly fine - skewed, platykurtic to mesokurtic silty sands (fig. 3.4.13.6.). The platykurtic nature of some horizons

Surface Features		
Chemical	Euhedral silica	●
	Amorphous silica	●
	Solution crevasses	
	Solution pits	●
	Oriented etch pits	
Loessic	Dulled surface	◢
	Smooth surface	■
	Rounded	◢
	Dish-shaped pits	●
Fluvial	Subangular	●
	Subrounded	◢
	Mechanical V-pits	
	Curved scratches	●
	Straight scratches	
Glacial	Chattermarks	
	Angular	
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10µ	●
	Conchoidals <10µ	
	Breakage blocks>10µ	
	Breakage blocks<10µ	
General	Euhedral quartz	●
	Scaling	●
	High relief	
	Medium relief	●
	Low relief	■
	Meandering ridges	
	Arcuate steps	
	Straight steps	
	Edge abrasion	●
	Grain breakage	
	Sample number BEQ	2

■ Abundant – 75% ◢ Common 25-75% ● Present 1-25% □ Absent – 1%

Figure 3.4.13.2. Summary of quartz grain surface textures, Ball Eye Quarry.

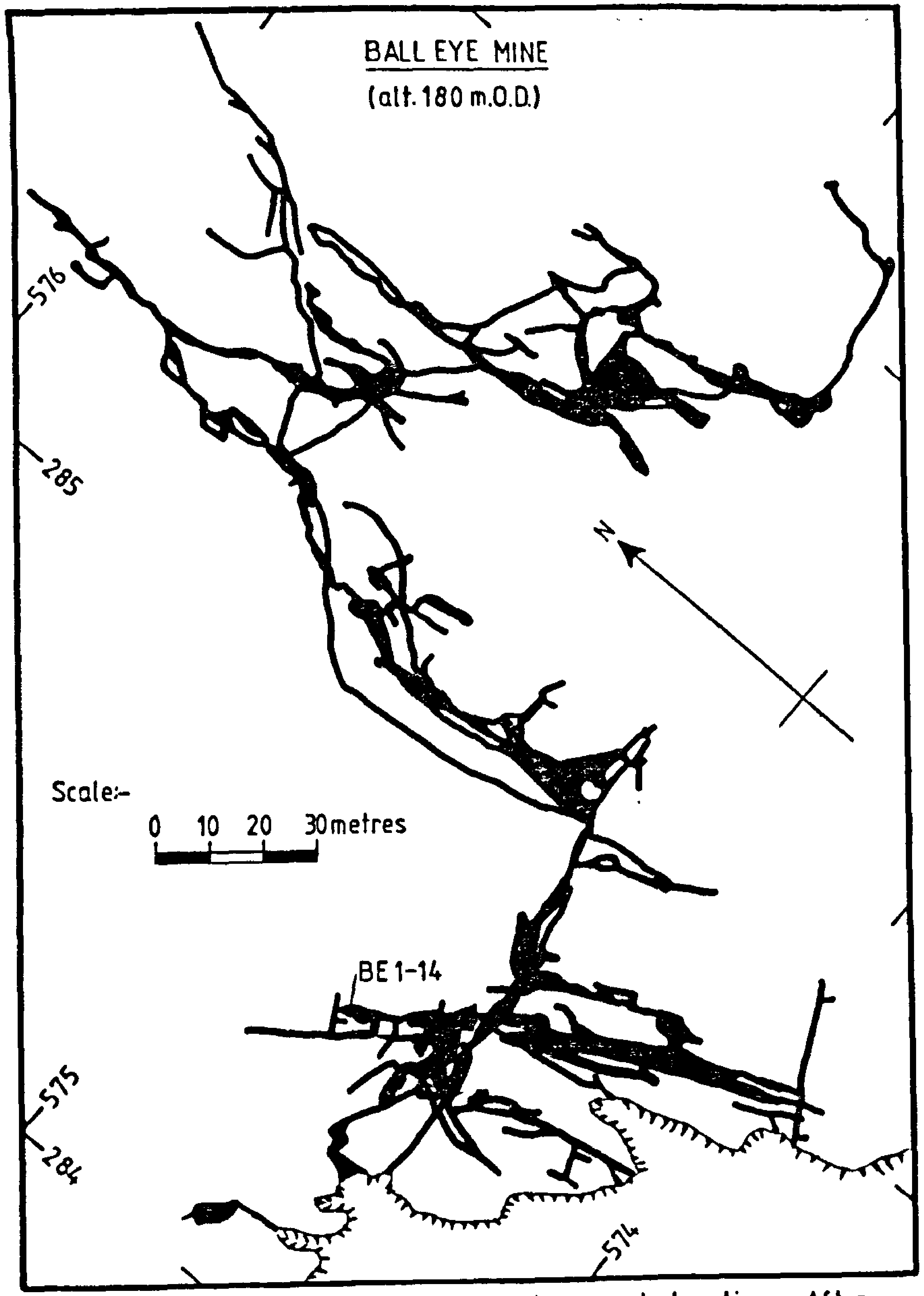


Figure 3.4.13.3. Plan of Ball Eye Mine showing sample locations. After Hurt (1970).

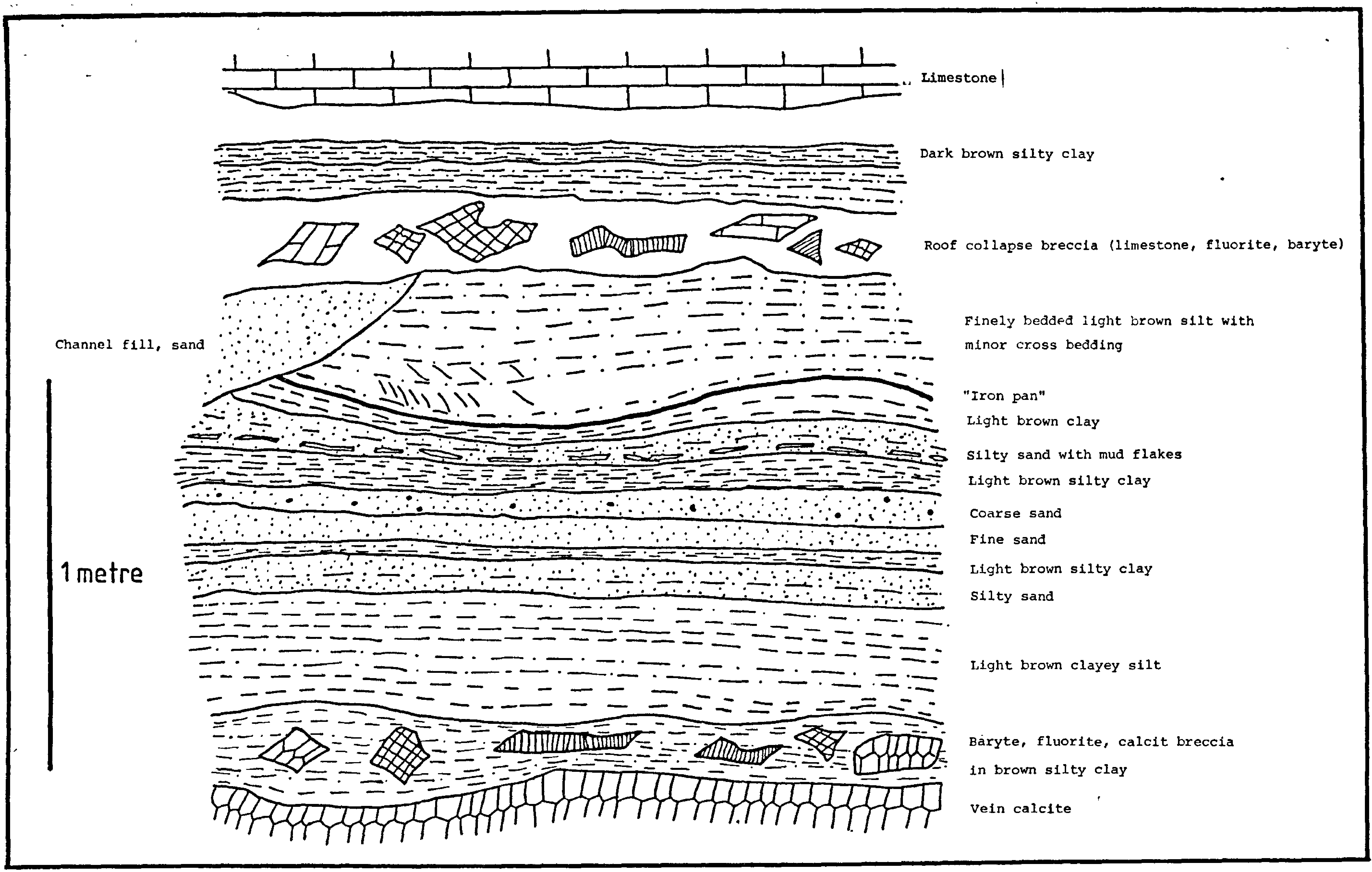


Figure 3.4.13.4. The sedimentry sequence exposed in Ball Eye Mine.

Sample Numbers BE 1–14

		%
1	Limestone	0 — 14
	Dolomite	
	Volcanics	
	Chert	0 — 2·5
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0 — 12
	Baryte	0 — 8
	Calcite	0 — 6
2	Quartz	21 — 52
	Sandstone	
	Feldspar	
	Mica	0·5 — 3
	Shale	1 — 4·5
	Quartzite	0 — 2·5
	Balance (mainly clay)	33 — 61

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	31 — 48
Kaolinite	31 — 49
Chlorite	5 — 8
Mixed layer smectites	6 — 12

Figure 3.4.13.5. Summary of sediment composition, Ball Eye Mine.

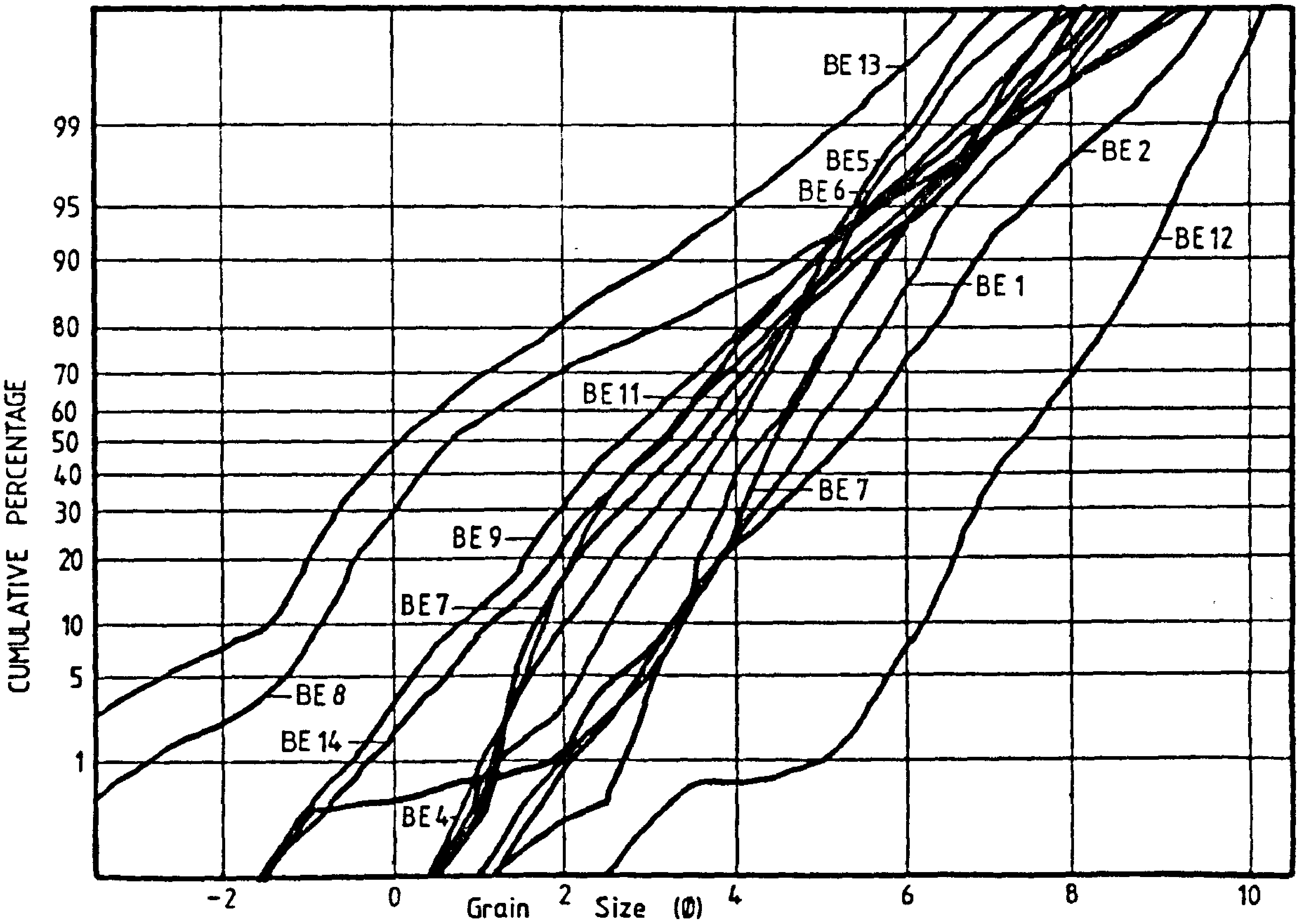


Figure 3.4.13.6. Sediment Size Analysis. Ball Eye Mine.

reflects the presence of autochthonous material in those horizons. The results of S.E.M. studies show the quartz grains to have surface textures associated with a fluvio-glacial environment.

The composition of the sediments shows that much of the allochthonous material has been derived from the Namurian sediment and the results of S.E.M. study show that they were derived by fluvio - glacial processes.

3.4.14. Houghton Pipe

Situated about 100 metres west of Ball Eye Mine, Houghton Pipe is part of the same complex system of mine workings within dolomitized Matlock Lower Limestone just above the Matlock Lower Lava. The pipe trends north-west and consists of a series of pipe vein cavities mineralized with fluorite, baryte, calcite and galena. Like Ball Eye Mine post - mineralization cavernisation has been extensive and many of the cavities produced were once filled with sediment. Only two isolated pockets and one large section remain untouched by mining activity.

Like the deposit in Ball Eye Mine the deposits are developed in solutionally enlarged calcite - lined pipe vein cavities (fig. 3.4.14.1.). Solutional collapse has occurred during sedimentation with large blocks of vein calcite and limestone detached from the roof within the sequence. (fig. 3.4.14.2.) The sediments vary from gritty sands to clays and show forset bedding and channel fills.

The composition of the sediments is given in figure 3.4.14.3..

Surface Features	Sample number BE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Chemical	Euhedral silica	●	●	●	●			●			●	●			
	Amorphous silica		●		◢				●						●
	Solution crevasses			●			●		●	●			●		
	Solution pits		●		●	●			●		●			●	●
	Oriented etch pits			●		●						●	●		
Loessic	Dulled surface							●							
	Smooth surface		◢	●		●		●	◢	◢		●		●	●
	Rounded				●			●	●			●			
	Dish-shaped pits						●						●		
Fluvial	Subangular	◢	●	◢	●	■	◢	◢	◢	■	■	◢	◢	●	◢
	Subrounded	◢	■	◢	■	◢	◢	■	■	◢	●	◢	◢	●	◢
	Mechanical V-pits	◢	●	●	●	◢	●	◢	◢	■	◢	●	●	●	◢
	Curved scratches	●	●	◢	●	◢	◢	●	●	●	●	◢	●	◢	◢
	Straight scratches	◢	●	●	◢	●	◢	●	●	◢	●	●	●	●	●
Glacial	Chattermarks	●		●	◢		●				◢	●	●	◢	
	Angular	●		●	●	●	◢			●	◢	◢	◢	■	◢
	Fracture plates								●						
	Adhering particles							●	●						
	Imbricate grinding			●		●									
	Parallel striations		●		●	◢		●	◢	◢	●	●	●	●	◢
	Conchoidals >10µ	◢	●	◢	◢	◢	●	◢	◢	●	●	◢	●	●	●
	Conchoidals <10µ	●	●	●	●	●	◢	●	●	●	●	●	◢	◢	●
	Breakage blocks>10µ		●			●				●	◢	●			
	Breakage blocks<10µ		●		●	●	●				●				
General	Euhedral quartz			●				●			●	●			
	Scaling					●			●	●					
	High relief	◢	●	◢	◢	■	●	◢	◢	●	●	●	◢	●	◢
	Medium relief	◢	■	◢	●	●	■	◢	◢	■	■	●	◢	◢	◢
	Low relief	◢	●	●	●	●	●	◢	◢	●	●	■	◢	◢	●
	Meandering ridges	●	●	◢				●					◢		
	Arcuate steps	●	●	●	●	●	◢	◢	◢	●	●	◢	●	●	●
	Straight steps	●	●	●	◢	◢	●	◢	●	●	◢	●	●	●	●
	Edge abrasion	●	●	◢	●	●	◢	◢	◢	●	●	●	●	◢	◢
	Grain breakage		●		●	●		●					●	●	

■ Abundant — 75%
◢ Common 25-75%
● Present 1-25%
☐ Absent — 1%

Figure 3.4.13.7. Summary of quartz grain surface textures, Ball Eye Mine.

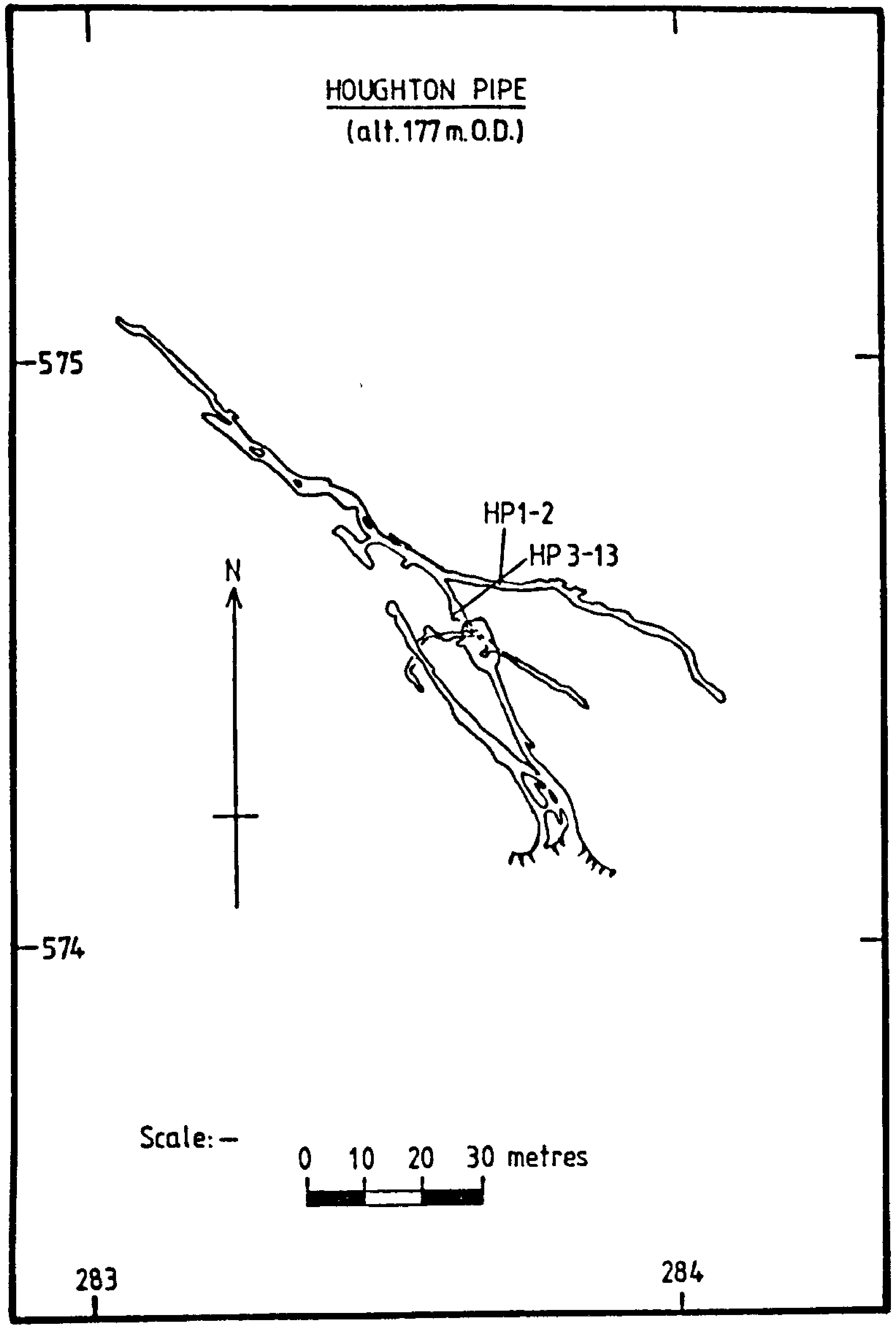


Figure 3.4.14.1. Plan of Houghton Pipe showing sample locations. After Hurt (1970).

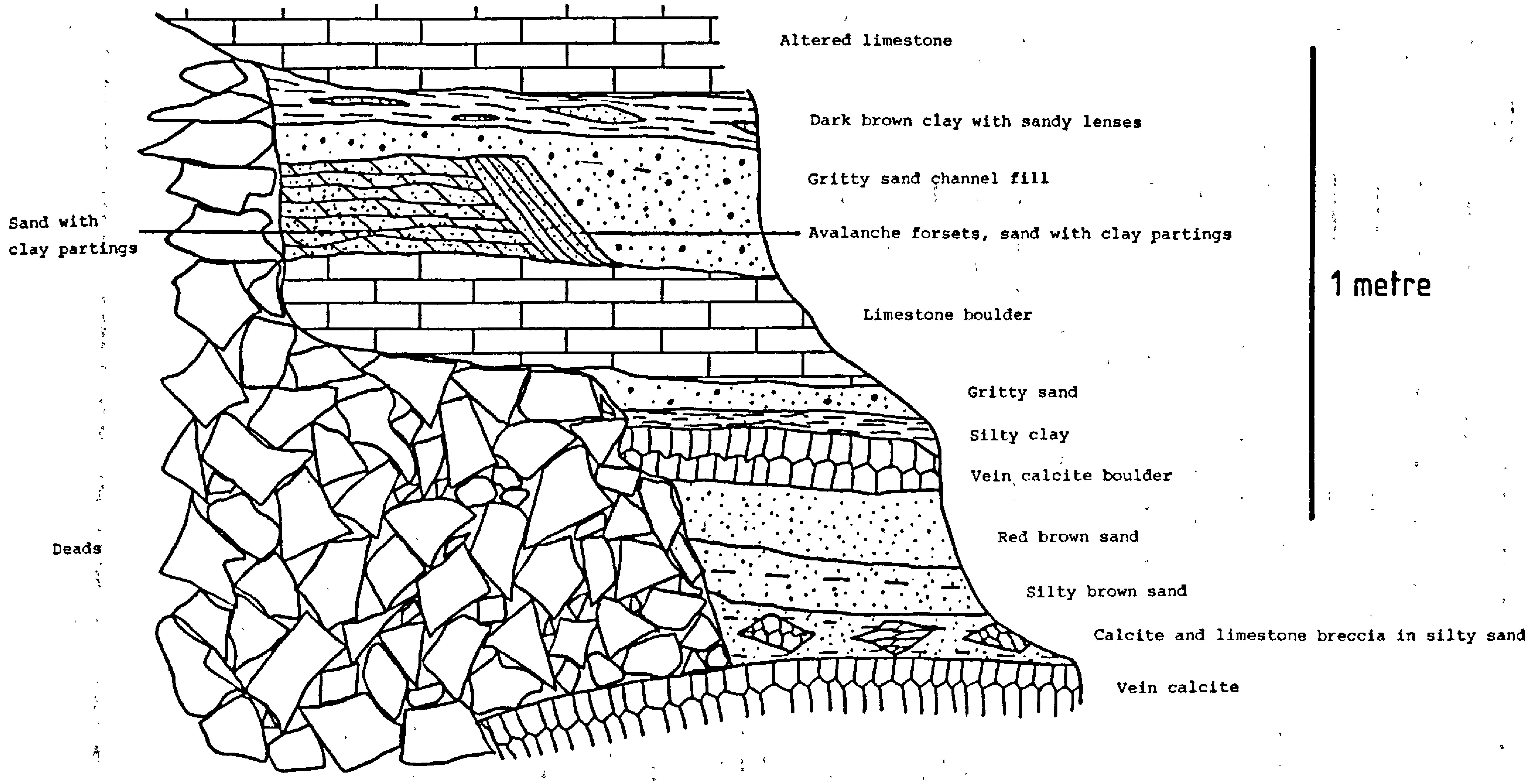


Figure 3.4.14.2. The sedimentry sequence exposed in the workings of Houghton Pipe.

Sample Numbers HP 1–3

		%
1	Limestone	2·5 — 7
	Dolomite	
	Volcanics	0 — 1·5
	Chert	0 — 4
	Silicified fossils	
	Authigenic quartz	
	Galena	0 — 0·5
	Fluorite	3 — 11
	Baryte	0 — 2
	Calcite	0·5 — 6
2	Quartz	0 — 41
	Sandstone	0 — 4·5
	Feldspar	
	Mica	
	Shale	0 — 2
	Quartzite	1 — 3·5
	Balance (mainly clay)	38 — 82

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	36 — 42
Kaolinite	43 — 63
Chlorite	11 — 25
Mixed layer smectites	8 — 12

Figure 3.4.14.3. Summary of sediment composition, Houghton Pipe.

Sediment size analysis shows the sediments to be poorly sorted, moderately coarse - skewed, platykurtic gravelly sands (fig. 3.4.14.4.). Their platykurtic nature is the result of a substantial quantity of autochthanous material being present in the sediments.

The results of S.E.M. study of quartz grain surface textures shows the quartz grains to have a fluvial origin (fig. 3.4.14.5.).

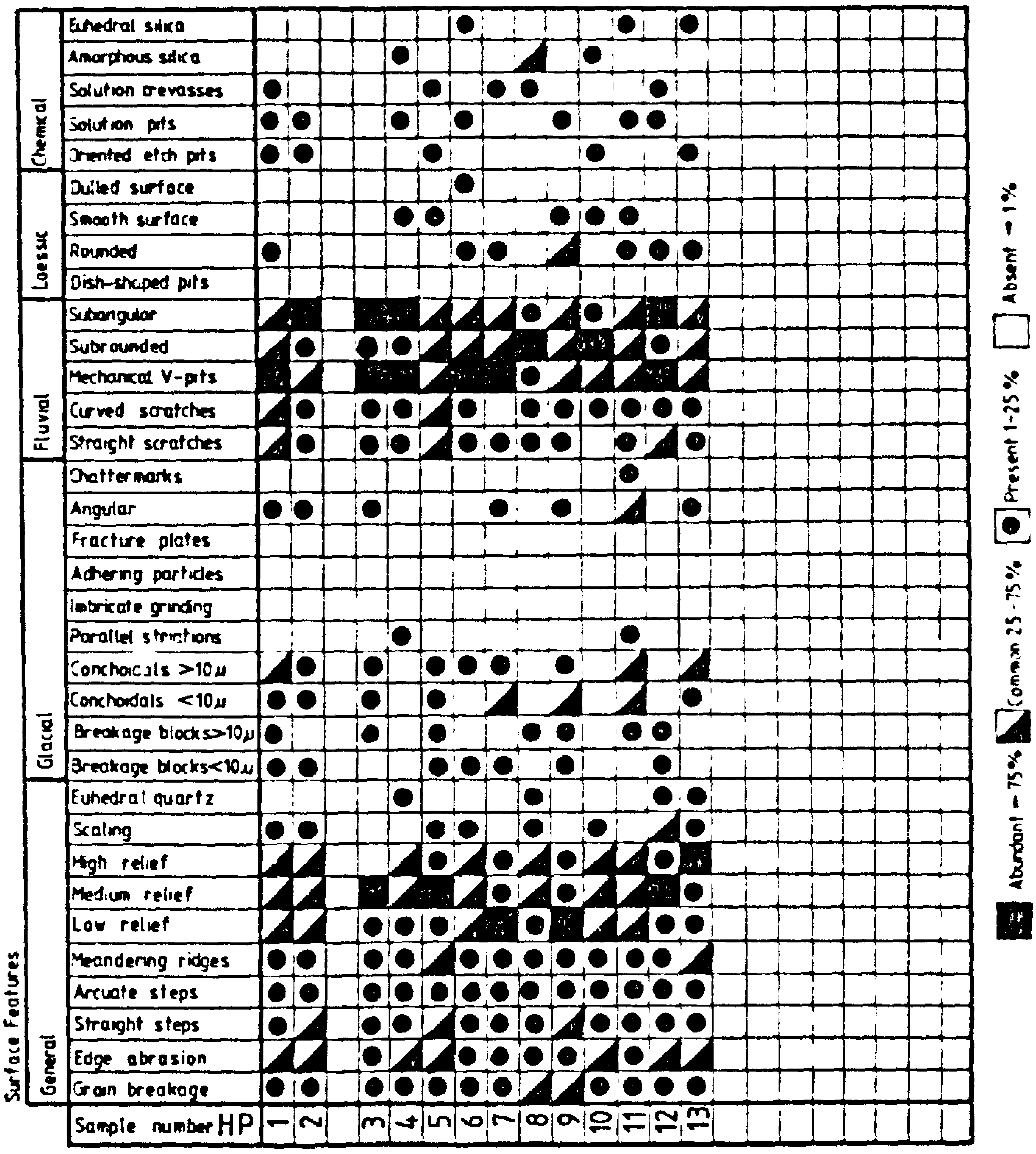
Their composition shows that most of the allochthonous fraction of these sediments has been derived from the Namurian sediments which once overlaid the limestones in this area while the results of the S.E.M. study show that they were derived by fluvial processes.

3.4.15. Bonsall Moor

Numerous pits have been or are being worked on Bonsall Moor for fluorite. Many of these reveal clay - filled fissures and some show larger sediment - filled cavities. One pit, at SK 261 586, has been studied. (fig. 3.4.15.1.)

The host - rocks are partially dolomitized Carboniferous Limestone containing numerous interbedded wayboards. The limestones are massive, well - jointed and contain both crinoidal and coral beds. The wayboards have been altered to green, red and grey mottled clays ranging up to 30 cm. in thickness. X.R.D. analysis shows them to be composed mainly of mixed layer smectite and kaolinite with some chlorite.

Two rake veins have been worked in the pit, each up



Chemical	Euhedral silica							●					●		●
	Amorphous silica					●				◪		●			
	Solution crevasses	●					●		●	●				●	
	Solution pits	●	●			●		●			●		●	●	
	Oriented etch pits	●	●				●					●			●
Loessic	Dulled surface							●							
	Smooth surface					●	●				●	●	●		
	Rounded	●						●	●		◪		●	●	●
	Dish-shaped pits														
Fluvial	Subangular	◪	■		■	■	◪	◪	◪	●	◪	●	◪	■	◪
	Subrounded	◪	●		●	●	◪	◪	◪	■	◪	■	◪	●	◪
	Mechanical V-pits	■	◪		■	■	◪	■	■	●	◪	◪	◪	■	◪
	Curved scratches	◪	●		●	●	◪	●		●	●	●	●	●	●
	Straight scratches	◪	●		●	●	◪	●	●	●	●		●	◪	●
Glacial	Chattermarks												●		
	Angular	●	●		●				●		●		◪		●
	Fracture plates														
	Adhering particles														
	Imbricate grinding														
	Parallel striations					●							●		
	Conchoidals >10μ	◪	●		●		●	●	●		●		◪		◪
	Conchoidals <10μ	●	●		●		●		◪		◪		◪		●
	Breakage blocks>10μ	●			●		●			●	●		●	●	
	Breakage blocks<10μ	●	●				●	●	●		●			●	
General	Euhedral quartz					●				●				●	●
	Scaling	●	●				●	●		●		●		◪	●
	High relief	◪	◪			◪	●	◪	●	◪	●	◪	◪	●	■
	Medium relief	◪	◪		■	◪	■	◪	●	◪	●	◪	◪	■	●
	Low relief	◪	◪		●	●	●	◪	■	●	■	◪	◪	●	●
	Meandering ridges	●	●		●	●	◪	●	●	●	●	●	●	●	◪
	Arcuate steps	●	●		●	●	●	●	●	●	●	●	●	●	●
	Straight steps	●	◪		●	●	◪	●	●	●	◪	●	●	●	●
	Edge abrasion	◪	◪		●	◪	◪	●	●	●	●	◪	●	◪	◪
	Grain breakage	●	●		●	●	●	●	●	◪	◪	●	●	●	●
	Sample number HP	1	2		3	4	5	6	7	8	9	10	11	12	13

Figure 3.4.14.5. Summary of quartz grain surface textures, Houghton Pipe.

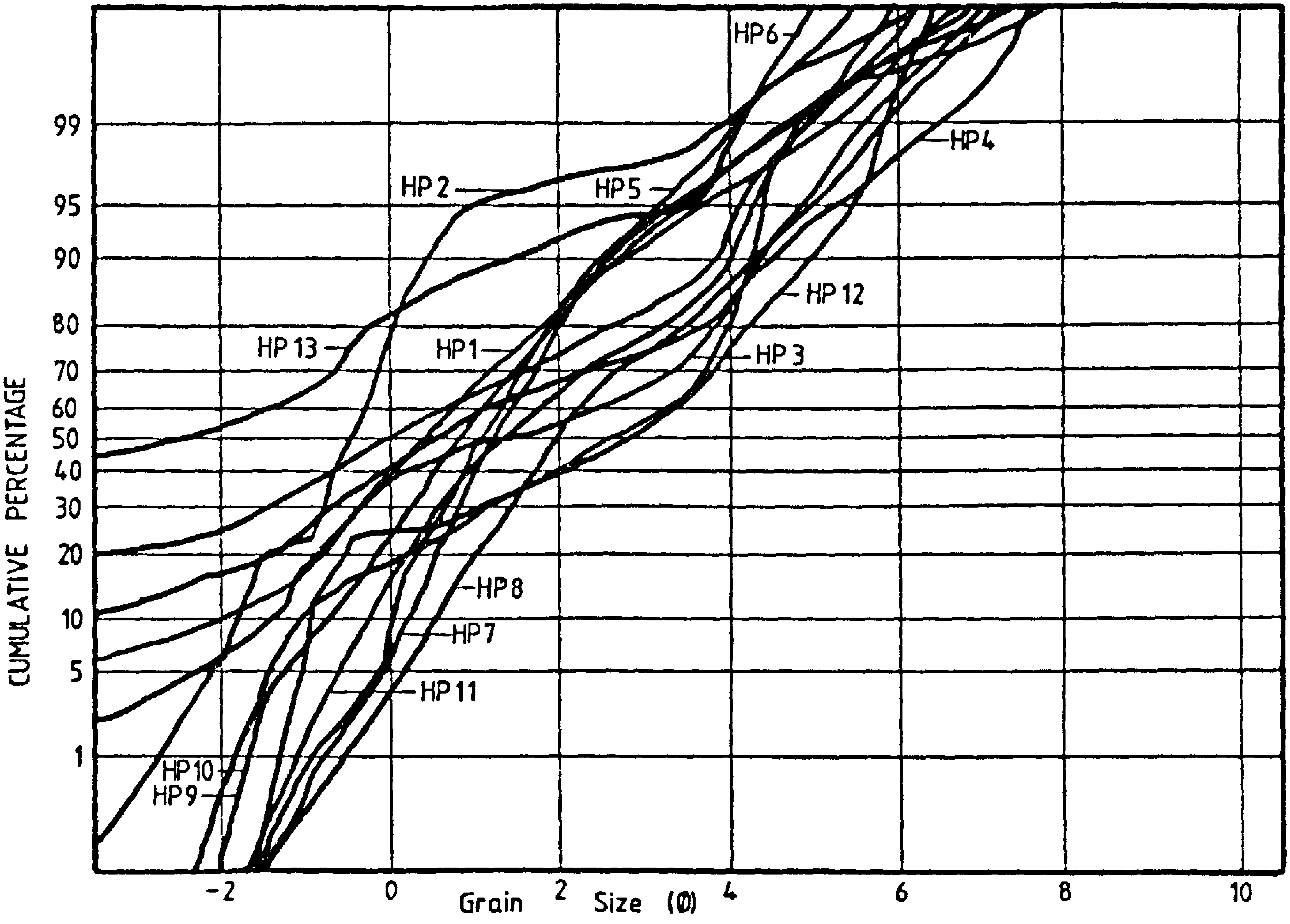


Figure 3.4.14.4. Sediment Size Analysis. Houghton Pipe.

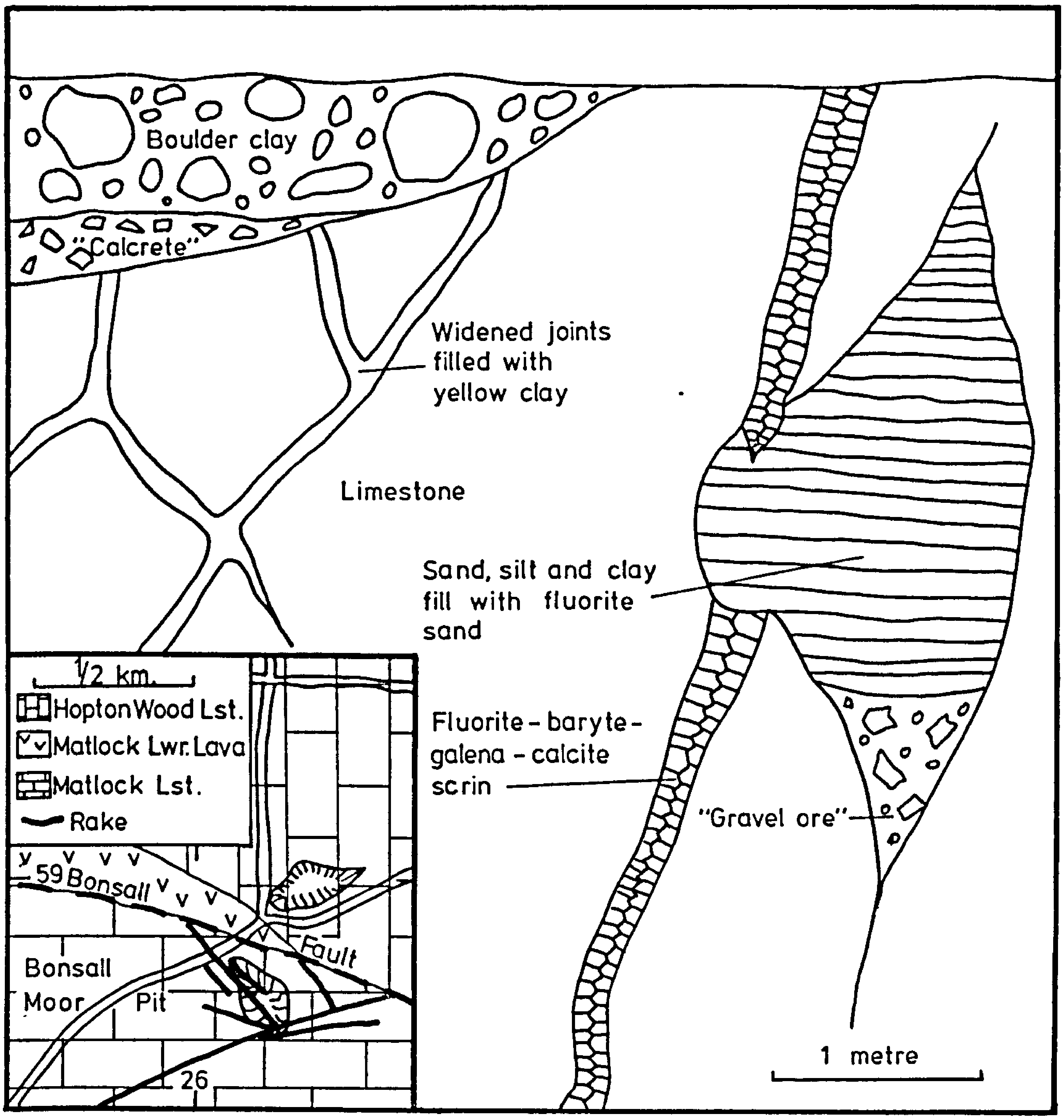


Figure 3.4.15.1. Schematic section of the residual ore deposits at Bonsall Moor. Boulder clay and "calcrete" overlying widened clay filled joints and a cavity, intersecting a mineral vein, containg residual ore overlain by layered sands, silts and clays.

to 3 metres wide. Both veins consist mainly of fluorite with minor galena and traces of sphalerite. Some later calcite is present in vugs. Numerous scrins up to 3 cm. wide and many mineralized joints are also present.

The area has undergone deep weathering, possibly under warmer conditions than prevailing today, prior to glaciation. This has produced a soil layer containing a calcified layer resembling "calcrete" (fig. 3.4.15.2.), overlain in some places by a quartz sand, perhaps derived from the Namurian sandstones. In turn this is overlain by up to 6 metres of boulder clay. This clay matrix, probably nearly all locally derived, contains boulders up to 0.75 metres across, of sandstone, Carboniferous Limestone and basalt with a few minor exotic erratics (some from the Lake District). It also contains numerous shale fragments, and small blocks of shale.

The deep weathering of the limestone has widened many of the joints to a considerable depth (over 10m below ground level) in some parts of the pit (plate 3.4.15.1.). These joints are now filled with 5 - 8 cm. width of stiff yellow clay. Any insoluble residue, such as fluorite, has accumulated in small pockets.

In places the process of limestone dissolution has occurred more selectively, producing fewer but larger cavities, up to 2 metres high and 1.5 metres wide, often oriented along scrins. All the cavities formed under fairly static conditions with little evidence of flowing vadose waters. All are completely filled with sandy sediments which are sometimes finely layered, perhaps representing settling out of suspension from ponded

Sample Numbers NS 1–5, A-P, X-Z ,CC		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	3 — 70
	Baryte	
	Calcite	
2	Quartz	23 — 95
	Sandstone	
	Feldspar	0 — 10
	Mica	2 10
	Shale	
	Quartzite	
	Balance (mainly clay)	14 — 37

1 Autochthonous 2 Allochthonous

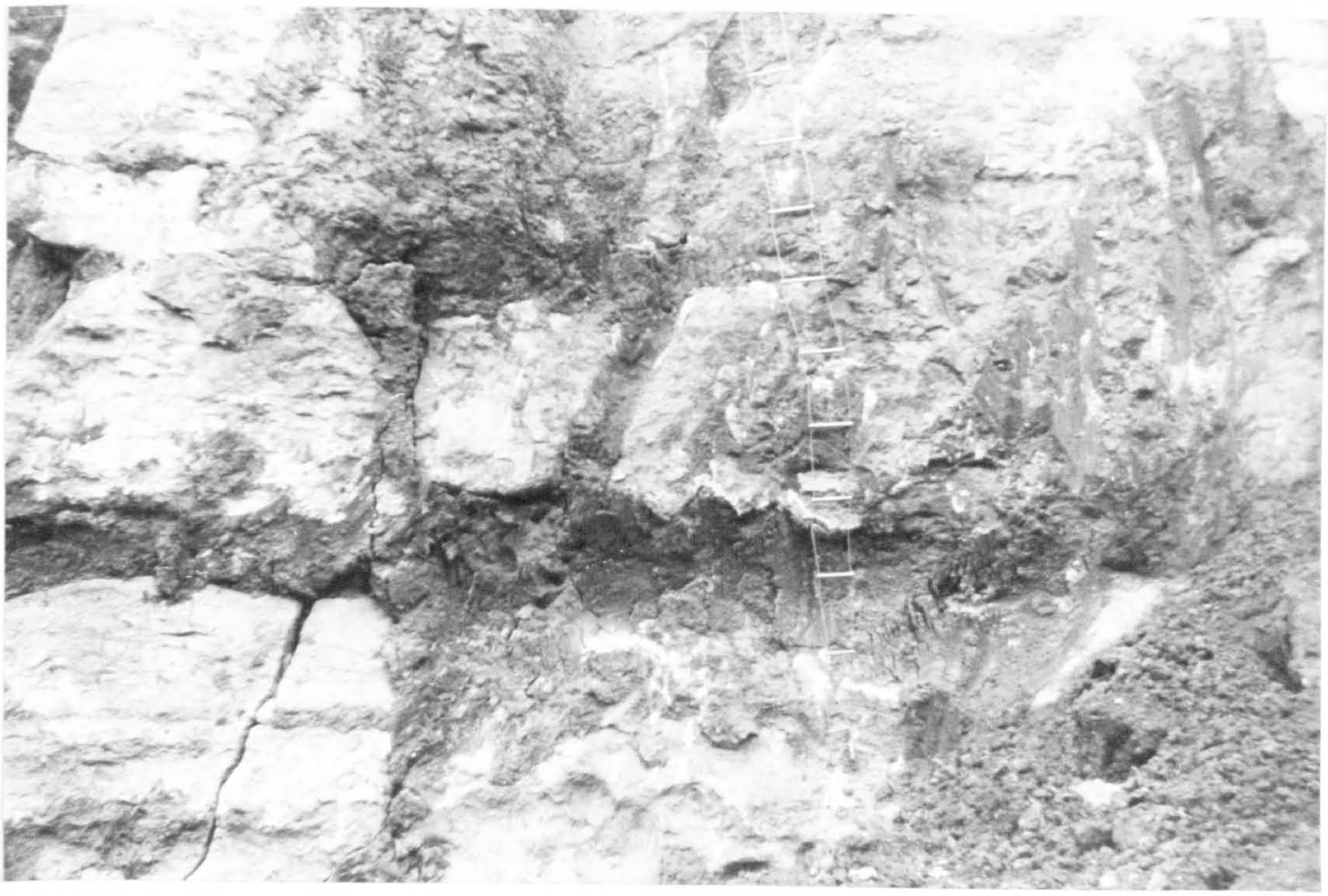
Clay Mineralogy	
	%
Illite	36 — 51
Kaolinite	23 — 42
Chlorite	1 — 7
Mixed layer smectites	11 — 17

Figure 3.4.15.2. Summary of sediment composition, Bonsall Moor.

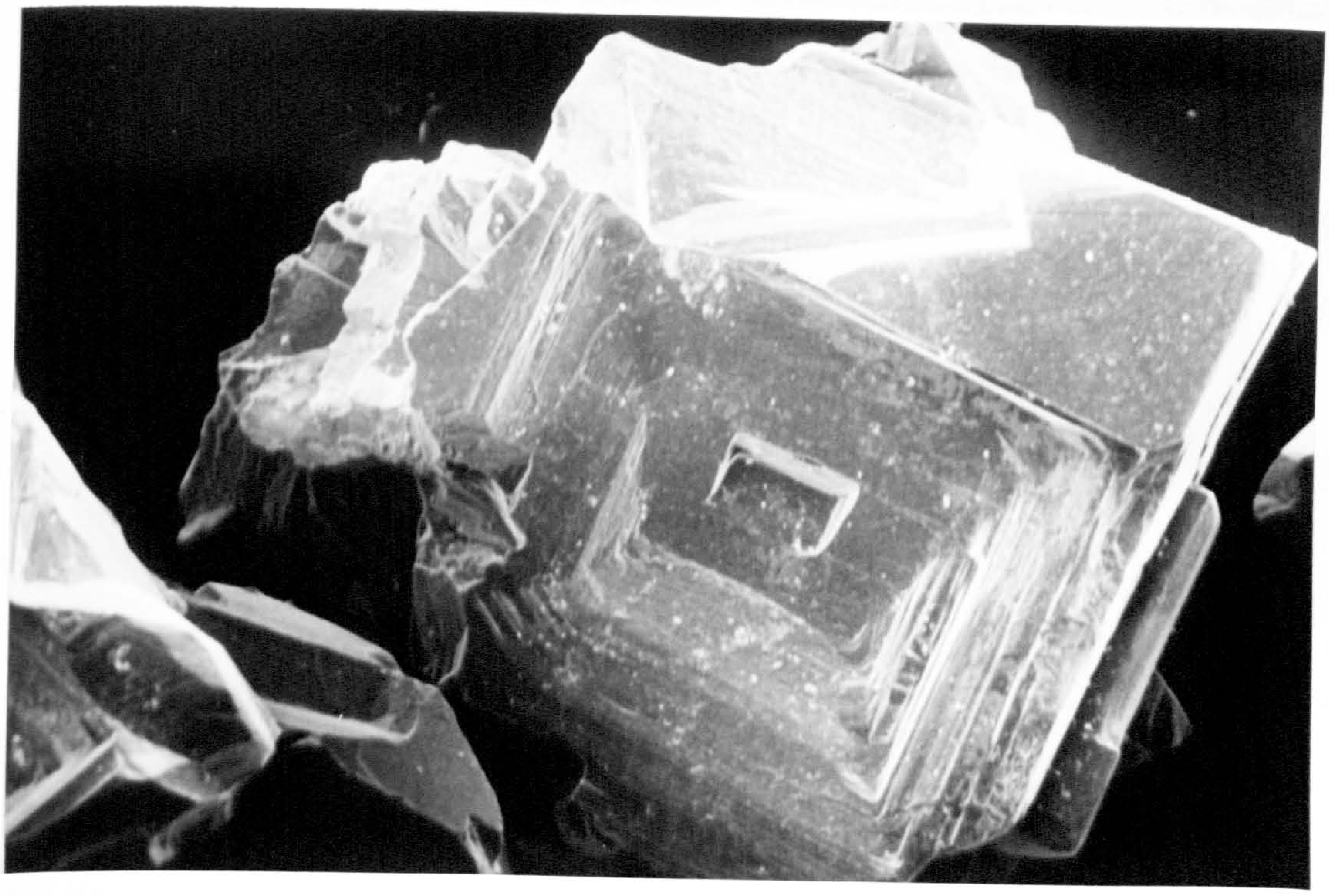
Surface Features	Sample number	B	X	Z	CC	A	N1	N2	N3
Chemical	Euhedral silica	●		●			●	●	
	Amorphous silica		●		●		●	●	●
	Solution crevasses			●	●				
	Solution pits	●	●		●			●	●
	Oriented etch pits		●	●	◢	●	●	●	
Loessic	Dulled surface				●	●			
	Smooth surface				●	●		●	
	Rounded		●			●		●	
	Dish-shaped pits								
Fluvial	Subangular	●	◢	■	●	◢	◢	◢	■
	Subrounded	●	◢	●	●	◢	●	◢	●
	Mechanical V-pits	◢	●	●		■	◢	◢	◢
	Curved scratches	●	●	●	●	●		●	●
	Straight scratches	●	◢	●	◢	●		●	●
Glacial	Chattermarks	●	■	◢	■	●	◢		●
	Angular	■	◢	●	■	◢	◢	◢	●
	Fracture plates	●		●			●		●
	Adhering particles		●	◢		●			●
	Imbricate grinding				◢		●	●	
	Parallel striations	◢			●				
	Conchoidals >10μ	◢	●		●	●	●	●	
	Conchoidals <10μ	◢	●	●	◢		●	●	●
	Breakage blocks>10μ	●			●				
	Breakage blocks<10μ	●			◢			●	
General	Euhedral quartz		●						●
	Scaling			●	●		●	●	●
	High relief	■	◢	◢	■	◢	◢	◢	◢
	Medium relief	●	◢	◢	●	◢	◢	◢	◢
	Low relief	●	◢	●	●	◢	●	◢	●
	Meandering ridges	●		●		●	●		●
	Arcuate steps	●			●	●		●	
	Straight steps		●	●	●		●		●
	Edge abrasion	◢	●	●	●	●	●		●
	Grain breakage		●	●			●	●	●

■ Abundant – 75% ◢ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 3.4.15.3. Summary of quartz grain surface textures, Bonsall Moor Pit.



3.4.15.1. Clay filled solutionally enlarged joints, south face, Bonsall Moor Pit.



3.4.15.2. S.E.M. photomicrograph of an unabraded fluorite crystal, Bonsall Moor Pit.

waters. As well as the accumulations of remnant and residual blocks of mineral vein present in the bottoms of these cavities, the sand also contains derived fluorite, forming up to 70% of the sediment. The fluorite grains, up to 5 mm. in length, still retain their crystal faces (plate 3.4.15.2.) and therefore cannot have been carried far.

The composition of the sands is given in figure 3.4.15.2.. The results of S.E.M. study of the surfaces of quartz grains often shows textures associated with some glacial transportation (fig. 3.4.15.3.). The source rock is probably mainly the Namurian sandstone escarpments, though the nearest is several kilometres away. The deposits may have been formed from glacial outwash material. The fine banding shown in some of the deposits indicates intermittent current velocities suggestive of proglacial ponding of a varved character.

The ore-mineral fraction, which varies from 3 to 70 percent of the cavity fill can be divided into two types.

Firstly, remnant and residual ore which consists of relatively insoluble mineral vein material accumulating in the bottoms of the cavities. It comprises lumps of fluorite vein material, often still showing euhedral growth faces, with, occasionally, some baryte and/or calcite. In one cavity galena is also present where it had a thick (approximately 1 mm.) coating of cerussite.

Secondly is the fluorite sand. It consists of coarse- to fine - grained euhedral fluorite grains showing no signs of abrasion indicating a local derivation. It occurs interbedded and intermixed with the quartz sand fills.

3.5. Conclusions

In Tertiary times regional uplift of the area started and following the removal of the Permo - Triassic sediments from the summit of Masson Hill percolating groundwaters used the pre - existing pipe and fissure vein cavities as an underground plumbing system, perhaps penetrating several 100 metres below the Namurian cover as at Millclose Mine. This process produced a network of phreatic drainage systems controlled by the impervious horizons in the limestones (lavas and wayboards) and the system of mineral veins. Because Masson Hill is anticlinal these cave systems radiate from the crest which was the first exposed limestone in the area. This phase of phreatic cavernization by slow - moving groundwater detached insoluble vein material from the pipe vein walls and concentrated this with the insoluble fraction of the limestone host rocks as layers of residual ore in a silty clay matrix in the bottom of many of the cavities.

With the beginning of the incision of the River Derwent in early Pleistocene times, a hydraulic gradient was established which accelerated the above process perhaps with allogenic streams entering the cave systems from outliers of Namurian and Permo - Triassic sediments. At this stage some of the high level phreatic caves would have been abandoned and may have been partly filled with fluvial and/or fluvio - glacial sediments derived from the Namurian and Triassic cover rocks. Some were later modified by vadose stream invasion, probably from glacial meltwater sources.

During glacial phases all groundwater movement ceased as did cavernization but under periglacial conditions surface drainage occurred during the summer melt periods producing the dry valley systems such as Northern Dale. Under these conditions underground drainage could occur through any open swallets, carrying with it considerable quantities of sediment some of which has been deposited in the cave systems, particularly towards the top of Masson Hill.

In these phases of high run off caused by glacier and snowfield melt, rapid, but intermittent, deepening of the Derwent Gorge occurred. Once temperate conditions returned underground drainage in Masson Hill, other than limited percolation drainage, would cease leaving the sediments in the caves abandoned.

Successive glacial phases, each with a deeper base level as the Derwent was incised deeper, would contribute further to these deposits.

At a later period, probably during the Devensian, loessic silts were deposited as a blanket over much of the area. Some of this sediment was carried underground, via joints, by the mechanism of translatory flow (Bull, 1981b) and accumulated in some cavities. Subsequently surface loess deposits have been eroded from the sides of the Matlock Gorge.

The composition of the sediments shows that they were derived from both autochthonous and allochthonous sources.

The autochthonous fraction of the sediments consists of locally derived fluorite, baryte, calcite and galena with occasional limestone, chert, and lava clasts and residual clay from the limestones and lavas. Euhedral quartz is also present, especially in the Masson Mine Complex, where it is derived from authigenic quartz present in some of the dolomitised limestone.

In most cases the vein material has simply fallen from the roof and walls of the cavities and accumulated on the floor or within the the sediments. It is also present as sand sized clasts throughout many of the sediments where it varies from euhedral crystals showing no abrasion indicating limited transport from its source to well rounded grains indicating a sustained period in the fluvial environment.

The allochthonous fraction consists of quartz sand silt and clay with occasional shale, gritstone and muscovite clasts derived from the overlying Namurian strata. Some quartzite is also present, especially in the south of the area, which have been derived from the former cover of Triassic pebble beds (Sherwood Formation). Quartzite pebbles can be picked up in the fields on the top of Masson Hill (Smith et al, 1967) but none have been found greater than coarse sand size in the underground sediments. Much of this material has a fluvio - glacial origin being derived via glacial erosion and deposited underground by meltwater streams during glacial retreat or reworked from surface fluvio - glacial deposits. The coarse layers being deposited during summer thaws, with a degree of winnowing of the finer sediment, and the fine layers at the end of each summer season accounting for the "varved" nature of some of the sediments.

Size analysis shows that the sediments are highly variable in character. Part of this variability may be explained by the mixture of allochthonous and autochthonous sediments and by the varied sources and processes of transportation.

S.E.M. studies have shown that the sediments have been derived by a number of processes including fluvial, fluvio - glacial and aeolian.

Some of the deposits are of fluvial origin being deposited by allogenic streams draining remnants of Namurian and Permo - Triassic strata before they were totally stripped from the flanks of Masson Hill. The lack of muscovite in these deposits, compared with those deposited by allogenic streams in the Eyam and Castleton areas, is due to the smaller quantity present in the Namurian sediments of this area which were derived from a land mass to the south (Smith et al, 1967; Jones, 1980).

The loessic material found in many of the isolated vein cavities and widened joints far underground, and numerous fissures close to the surface, has been derived from sheets of loess which were deposited over the area during the Devensian glaciation (Pigott, 1962) when ice did not cover this area. The was probably been carried underground by the mechanism of translatory flow as postulated by Bull (1981b).

None of the Derwent terraces are identifiable in the Matlock Gorge but altitudes for them can be projected through the gorge from information in Waters and Johnson

(1958) who have mapped the terraces both upstream and down stream of the gorge. The altitudes of the three readily recognised terraces above the present day river level (91 metres O.D.) are given in figure 3.5.1..

Higher benches exist in the Derwent catchment area but are too inconsistent and scattered for correlation. Boulder clay has been found on the Hathersage Terrace at Bakewell and in Bradford Dale (Waters and Johnson, 1958) and is present on the northern side of the Via Gellia southwest of Black Tor at about 210 metres O.D. (Smith et al, 1967). As boulder clay has not been found on or below any of the more recent terraces the Derwent appears to have cut down to about 122 metres O.D. in the Matlock area by the end of the Wolstonian Glaciation, which was the last glaciation to have affected the Peak District.

The incision of the gorge to 122 metres O.D. by the end of the Wolstonian Glaciation agrees with the deduction of Ford and Burek (1976) that the incision was either late Wolstonian or Devensian in age, though incision to 122 metres O.D. had occurred by the close of the Wolstonian Glaciation.

No natural cavities occur below this altitude in the Matlock Gorge which indicates that cavernization was also complete by the close of the Wolstonian. It is also likely that many of the sediments, except those derived from the loess, are of Wolstonian orpre - Wolstonian age.

The consistent reversed natural remnanent magnetization of some of the sediments in the Masson - Youds complex indicates an age in excess of 690,000 years B.P. since only limited period reversals have occured

Terrace	Altitude (m. O.D.)
Hathersage	122
Hope	104
Great Rowsley	93
Present River	91

Figure 3.5.1. Altitudes of the higher Derwent terraces in the Matlock Gorge projected from data of Walters and Johonson (1959).

since that time (Rampino, 1981). If these sediments are of fluvio - glacial origin then these deposits represent a glaciation which is not recorded elsewhere in Britain though evidence of glacial phases prior to those recorded in Britain are known in continental Europe where there is evidence going back at least 1 million years B.P. and from deep sea cores which record cold phases going back 2.5 million years B.P. (Shackleton et al, 1984).

4. WIRKSWORTH AREA

4.1. Introduction

The Wirksworth area extends from the Via Gellia in the north to Yokecliffe Rake in the south and from Black Rocks in the east to Ryder Point in the west (fig. 4.1.1.). The area contains many disused lead mines, some of which have been worked more recently for fluorspar and calcite. The mineralization consists of fissure veins of various sizes, with only a small number of pipe veins and flats in contrast to the Matlock area. The area is an important limestone quarrying area and abounds in working and disused limestone quarries.

A few of the quarries and mines have intersected cavities, both in the veins and the limestone, containing sediment.

4.2. Geological Setting

The area is situated in the south east extremity of the limestone massif of Derbyshire. The limestones are typically varied limestones of the Hopton Wood, Matlock and Cawdor Groups (Frost and Smart, 1979).

The Hopton Wood Limestones, up to 90 metres thick in this area, crop out over the western part of the area. They are pale grey to off-white, fine - grained to porcellanous, partly oolitic and massively bedded limestones of Asbian (D_1) age (Frost and Smart, 1979).

The Matlock Limestones, up to 43 metres thick, crop out northwest of Wirksworth. The limestones are dark grey

57
56
55
54
26
27
28
VIA GELLIA
MIDDLETON
WIRKSWORTH
GULF
FAULT
N
1/2 km.
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪

and well - bedded containing many bedded and irregular chert nodules and are of Brigantian (D_2) age. At the base of the Matlock Limestone is the Matlock Lower Lava, which is only 3 metres thick in this area (Frost and Smart, 1979).

The Cawdor Group consists of fossiliferous, thinly bedded, cherty limestone up to 20 metres thick with local reef development doubling this thickness, such as in Coal Hills Quarry and Dene Quarry. This is overlain by the 6 metre thick Cawdor Shale. This group is unconformable on both the Matlock and Hopton Wood Limestones and is of P_2 age (Frost and Smart, 1979).

Unconformably overlying the limestones are the Namurian sediments with shales at the base and increasing thicknesses of sandstone further up the succession (Frost and Smart, 1979).

Interbedded with the limestones are a number of volcanic horizons including lavas and tuffs (wayboards) and an agglomerate filled vent (Frost and Smart, 1979).

The Hopton Wood and Matlock Limestones are patchily dolomitised, especially at their higher elevations. This dolomitisation has been ascribed to the action of percolating Triassic magnesium - rich brines (Frost and Smart, 1979). The dolomite is porous and has an irregular base.

Pebbly Triassic sediments (Sherwood Sandstones) crop out to the southwest of the area and, if extrapolated, their base would only have been a short distance above the dolomitised areas (Frost and Smart, 1979). Pebbles derived from the Triassic sediments can be found on the limestone around Dream Mine (SK 273,532).

The major structural feature of the area is the Gulf, an area of Namurian shale down faulted by two faults (the Gulf and Rantor Faults) into limestones, the fault having throws of more than 60 metres. The limestone over the whole area has been very gently folded but is generally nearly horizontally bedded with a slight easterly dip below the Namurian cover.

The area has been intensively mineralized resulting in a large number of near vertical veins (rakes and scrins), with an east - west or northwest - southeast trend containing banded fluorite, baryte, calcite and galena with minor pyrite and sphalerite. The area of the Gulf has been intensely mineralized below the shale cover. Most of the larger mineral veins are normal and/or shear faults with limited throw though the Gulf Fault, Rantor Vein and Yokecliffe Rake have much larger throws. The smaller veins (scrins) are mineralized widened joints.

Once the Namurian and, at least, part of the Triassic cover had been removed from the area underground drainage could occur, controlled by the location of pre-existing mineral vein cavities and impermeable lava and wayboard horizons and the overlying strata, draining north from a catchment in the south of the area.

4.3. Types of Deposit

Once the limestone was exposed and the Derwent valley and the Via Gellia had been initiated in early Pleistocene times producing a hydraulic gradient the intense mineralization and jointing of this area lead to the rapid development of underground drainage. Once integrated underground drainage occurred, solutional enlargement of pre - existing vein cavities and the development of joint - controlled phreatic drainage tubes also occurred.

As the Derwent valley and the Via Gellia deepened, lower outlets to the underground drainage network became available the cave systems extended further down dip towards Wirksworth and the Via Gellia. These cave systems were in limestones to some extent controlled by the impervious Lower Matlock Lava and the clay wayboard horizons.

These processes led to an intricate system of interconnecting, enlarged fissure vein cavities and non-vein oriented passages, probably with a number of input and resurgence points. Most of these cavities, including many small and apparently isolated vein cavities, have been almost totally filled with mainly surface - derived sediment.

As the sediment was not washed through the system some form of trap preventing free flow of the groundwater is required. This trap may have been a section of restricted passage or, perhaps, passage restricted by roof falls as proposed by Ford and Worley (1977b). Sluggish water movement through the phreatic system would enable the deposition of any suspended sediment load as would ponding during flooding in vadose parts of the system. Ice damming during glacial and periglacial conditions could also cause ponding.

As a result of many centuries of lead, and more recently, fluorspar and limestone mining and limestone quarrying this intricate system of sediment filled passage has been extensively disrupted. In places the fill has been totally extracted leaving no trace of its former presence. Much of the rest has been processed for galena and is therefore well mixed. This leaves isolated pockets and some larger deposits with their relationships to each other difficult or impossible to evaluate.

Many small vein cavities, unrelated to the larger sediment - filled voids, are filled with fine - grained silt and clay, sometimes showing fine lamination. The complete filling of these isolated pockets is best explained by diffuse sedimentation via cracks and fissures from the surface and controlled by the translatory-flow mechanism as postulated by Bull (1981b).

4.4. Sites Studied

4.4.1. Middleton Mine

The entrance to this active high purity limestone mine is at SK 277,577. Underground mining started in 1959 when the overburden thickness reached about 50 metres in the quarry (Anon., 1961; Clemmow, 1967). For a short time mining was carried out on two levels but a large collapse (7 acres) brought an end to this mining method. A large area of limestone has been extracted by pillar and stall mining fig. 4.4.1.1.) which is continuing at a rate of about 10,000 tonnes per week. The limestone workings have intersected a number of older lead mine workings and both open and sediment - filled caverns.

A large cavity, at least 30 metres high and 15 metres wide, has been intersected on two levels by the limestone workings (fig. 4.4.1.1:, MM 7 - 12). The cavity is adjacent to the lead mine workings of Samuel Mine and may cut off the vein worked in that mine.

Much of the sediment which filled this cavern has slumped into the limestone stalls taking with it a certain amount of wall rock. The cavity walls show large scale scalloping typical of caves formed under phreatic conditions.

The sediment is poorly bedded and its composition is detailed in figure 4.4.1.2.. Size analysis shows that the sediments are poorly sorted, strongly coarse - skewed, very platykurtic silty pebble gravels (fig. 4.4.1.3.). The platykurtic nature of these deposits reflects the nature of the source conglomerates from which most of the sediment was derived.

S.E.M. study of the quartz grain surface textures shows that the quartz is of fluvial origin (fig. 4.4.1.4., MM 10, 12, plate 4.4.1.1.).

Another cavity formed under phreatic conditions is developed on a small scrin parallel to the Gang Vein (figs. 4.4.1.1., MM 1 - 5, 21 - 23 and 4.4.1.5.)

The limestone wall rocks of this cavity are highly altered and on superficial examination resemble laminated silts. The limestone is extensively partially de-calcified and is variably a soft to hard, grey, powdery rock. Fossils occur in this rock unaltered and undisturbed. The

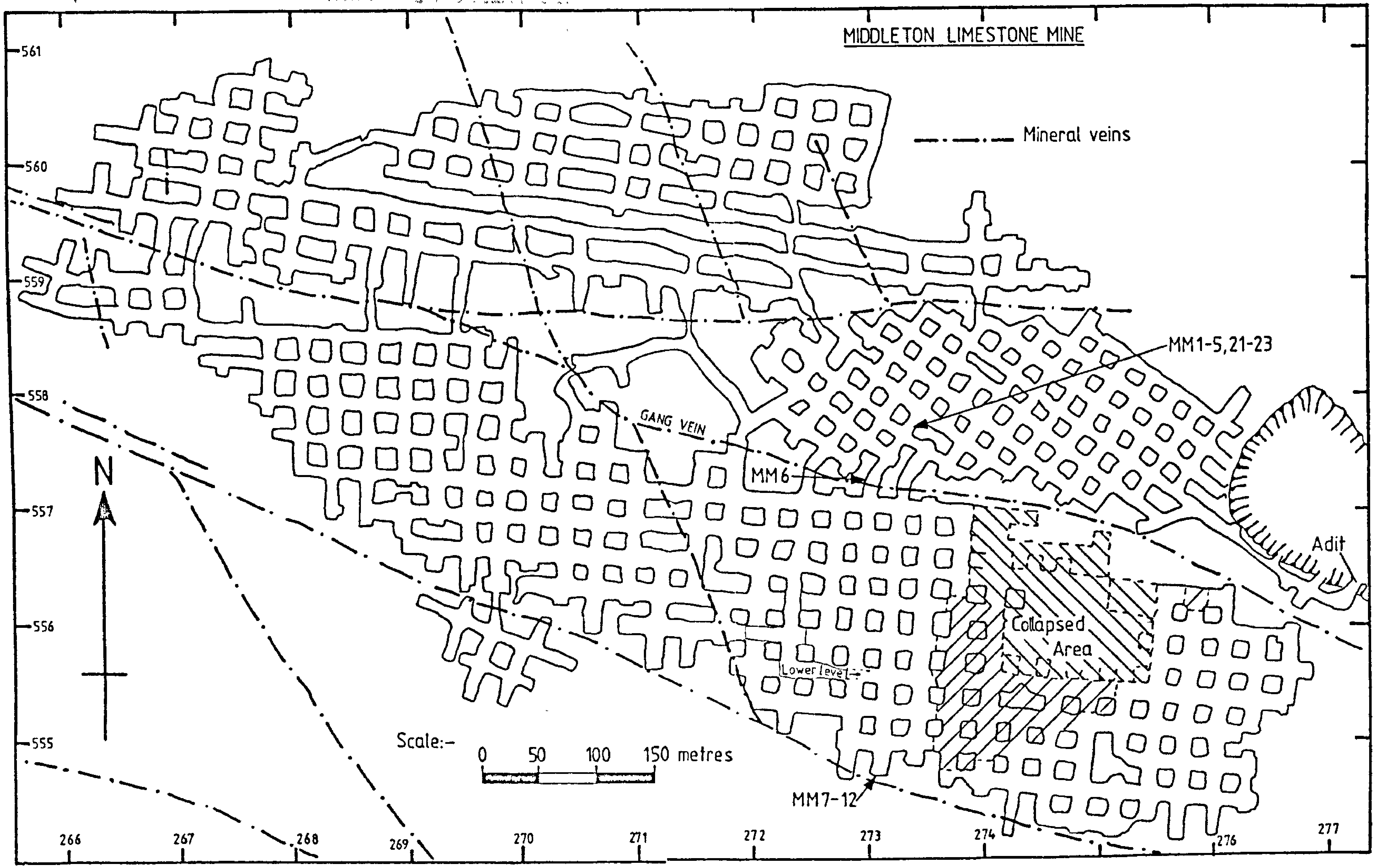


Figure 4.4.1.1. Plan of Middleton Limestone Mine showing some mineral veins and sample locations.

Sample Numbers MM 7— 12		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	10 - 21
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Sherwood Sandstone pebbles	61 — 85
	Balance (mainly clay)	5 —28
1 Autochthonous 2 Allochthonous		

Figure 4.4.1.2. Summary of sediment composition, Middleton Mine.

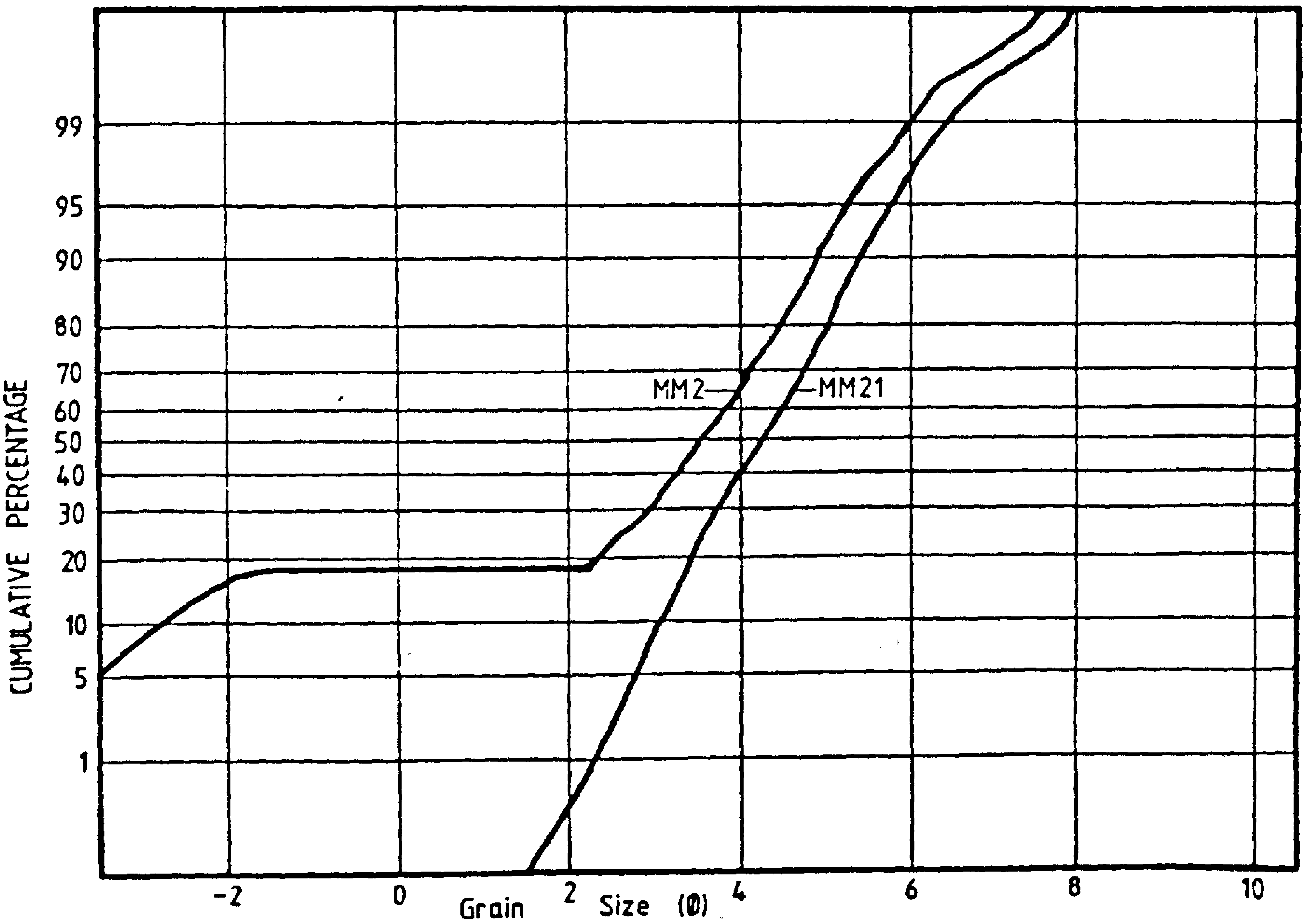


Figure 4.4.1.3. Sediment Size Analysis. Middleton Mine.

Surface Features	Chemical	Euhedral silica					
		Amorphous silica	●	●		●	●
		Solution crevasses		●			
		Solution pits	●	●		●	
		Oriented etch pits	●	●		●	●
	Loessic	Dulled surface				◪	◪
		Smooth surface				◪	◪
		Rounded	●			■	■
		Dish-shaped pits				◪	●
	Fluvial	Subangular	◪	●			
		Subrounded	◪	■		●	●
		Mechanical V-pits	◪	■			●
		Curved scratches	●	●		●	●
		Straight scratches	●	●		●	●
	Glacial	Chattermarks					●
		Angular					
		Fracture plates					
		Adhering particles					
		Imbricate grinding					
		Parallel striations					
		Conchoidals >10μ	●			●	
		Conchoidals <10μ	●				
		Breakage blocks>10μ					
		Breakage blocks<10μ					
	General	Euhedral quartz	●	●		●	●
		Scaling	●	●			
		High relief	◪	●			
		Medium relief	◪	■		●	●
		Low relief	◪	●		■	■
		Meandering ridges	●	●			
		Arcuate steps		●			
		Straight steps					
		Edge abrasion	●	◪		●	●
		Grain breakage	●	●		●	●
		Sample number MM	2	21		10	12

■ Abundant – 75% ◪ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 4.4.1.4. Summary of quartz grain surface textures, Middleton Mine.

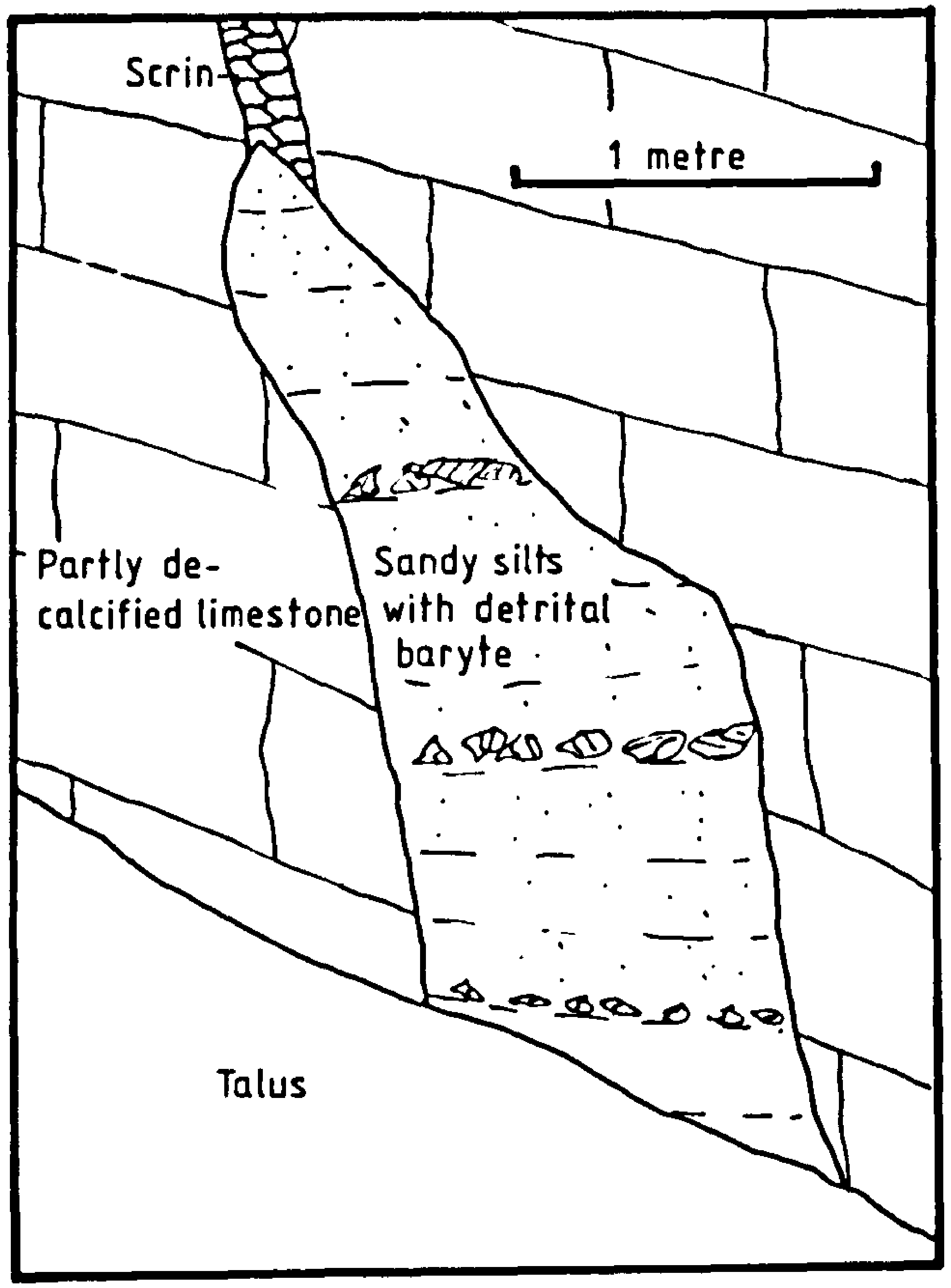
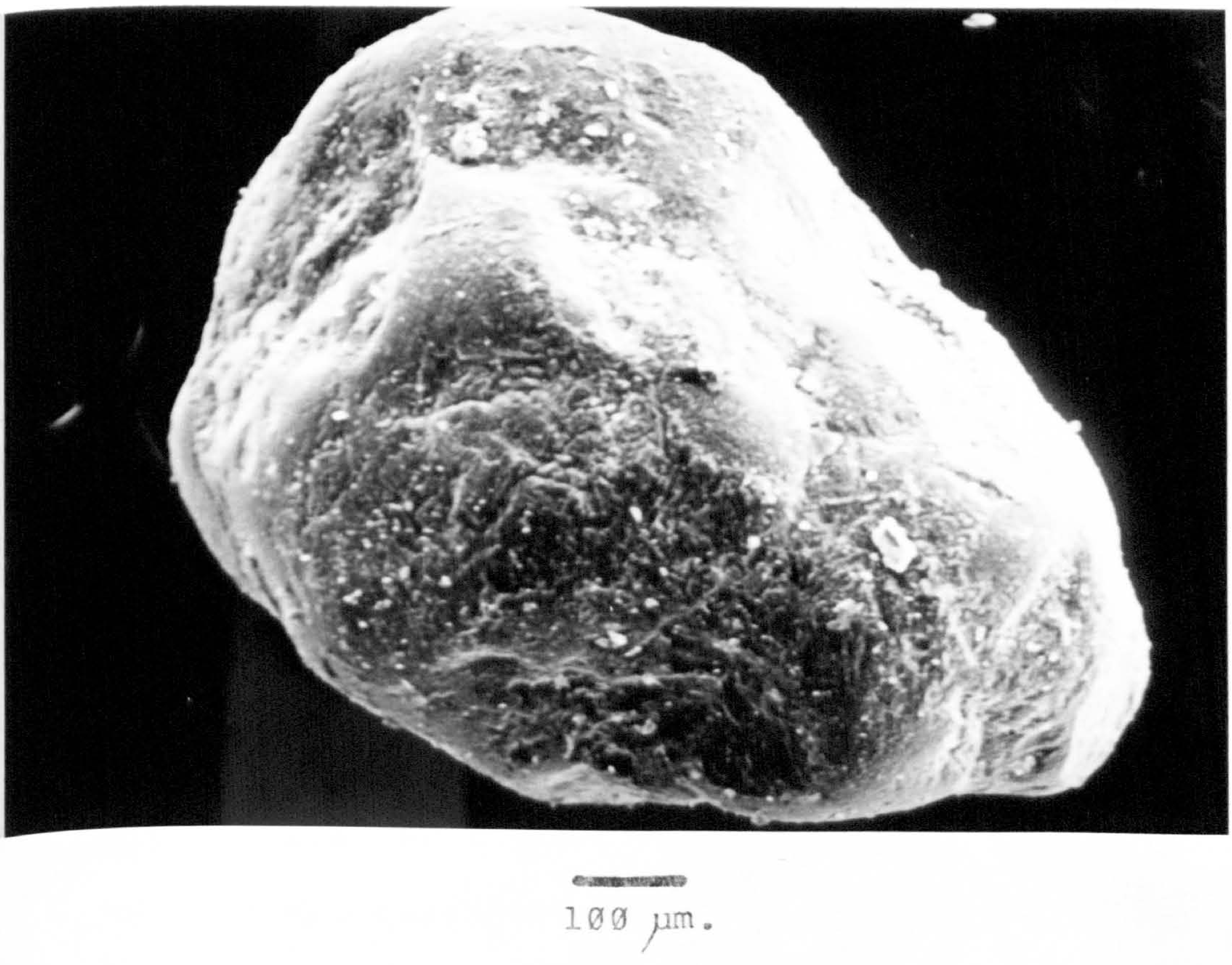


Figure 4.4.1.5. Cavity near Gang Vein, Middleton Mine.



4.4.1.1. S.E.M. photomicrograph of a fluvial quartz grain, Middleton Mine.

sediments are well laminated orange - brown silts containing detrital baryte in some horizons. Some baryte is also present which appears to have grown in situ within the sediments since they were deposited.

The composition of the sediments and the results of X.R.D. analysis are given in figure 4.4.1.6..

Size analysis shows the sediments to be moderately well sorted, nearly symmetrical, mesokurtic silts (fig. 4.4.1.7.). S.E.M. studies show that the quartz grains are of loessic origin (fig. 4.4.1.4., MM 2, 21), and that the deposit has accumulated from loess - derived sediment washed underground from a former cover of loessic sediment.

4.4.2. Middle Peak Quarry

Middle Peak Quarry is a large working limestone quarry at SK 546,281. Limestones of the Matlock and Hopton Wood Groups are extracted for use as roadstone. In the main part of the quarry a number of phreatic tubes filled with sediment have been intersected.

The sediment is poorly bedded and its composition is given in figure 4.4.2.1.. The shale clasts are angular and up to 8 cm. in diameter.

Size analysis shows that these sediments are poorly sorted, strongly coarse - skewed, very platykurtic sandy - pebble gravels (fig. 4.4.2.2.). Apart from their shale content these sediments are similar to those in Middleton Mine, which are only 0.5 km. away, and are also developed in a phreatic cavity but at a slightly lower elevation.

Sample Numbers	MM 1 – 5, 21 – 23	
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0 – 2
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	0 – 3
	Calcite	
2	Quartz	68 – 82
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	16 – 29

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	36 – 43
Kaolinite	28 – 37
Chlorite	15 – 20
Mixed layer smectites	5 – 16

Figure 4.4.1.6. Summary of sediment composition, Middleton Mine.

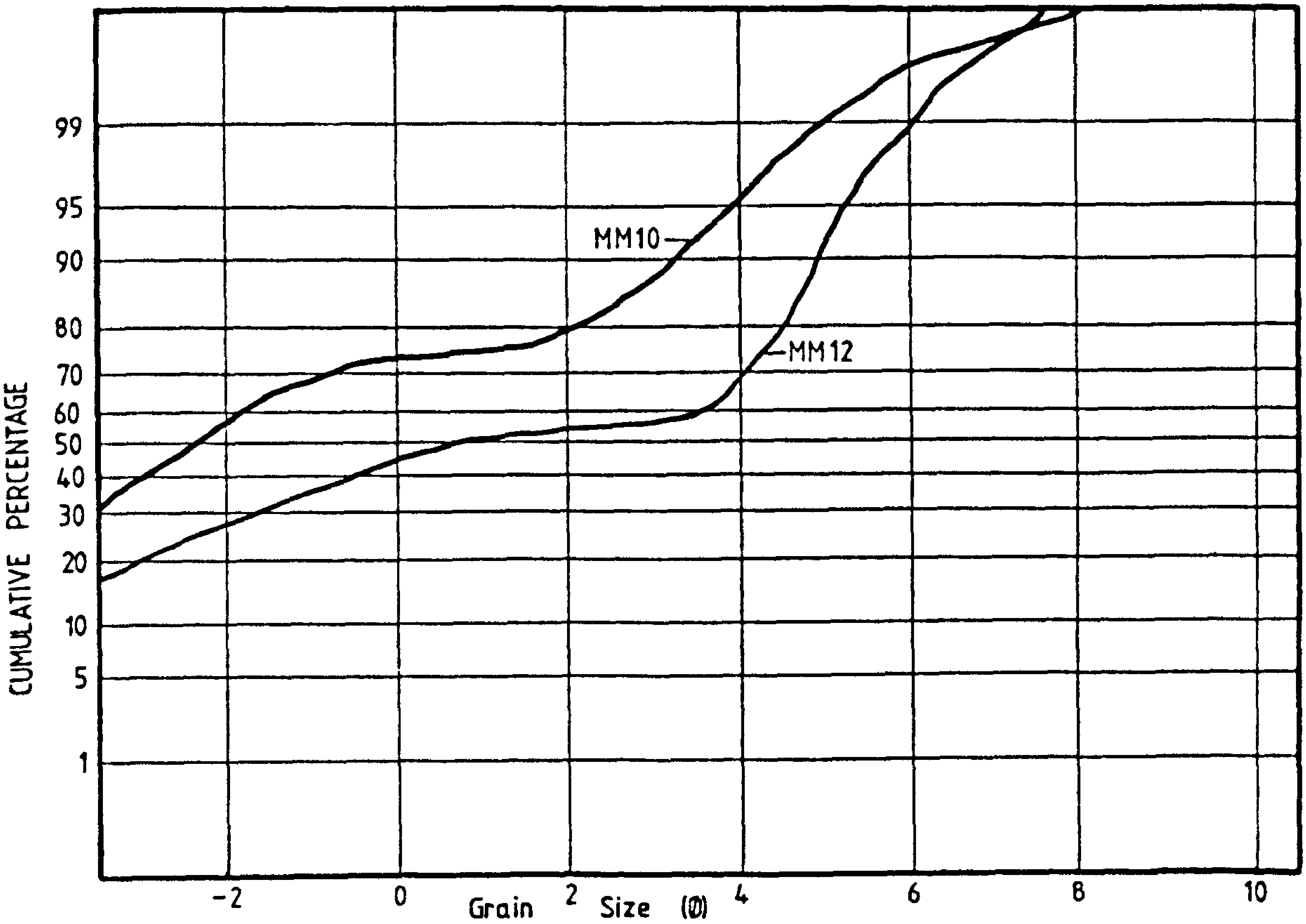


Figure 4.4.1.7. Sediment Size Analysis. Middleton Mine.

Sample Numbers MPQ 1-6		
		%
1	Limestone	0·5 – 13·5
	Dolomite	
	Volcanics	0 – 4·5
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	0 – 3·5
	Calcite	
2	Quartz	16 – 22
	Sandstone	0 – 5
	Feldspar	
	Mica	
	Shale	3 – 21
	Quartzite	
	Sherwood Sandstone pebbles	48 – 61
	Balance (mainly clay)	8 – 19
1 Autochthonous 2 Allochthonous		

Figure 4.4.2.1. Summary of sediment composition, Middle Peak Quarry.

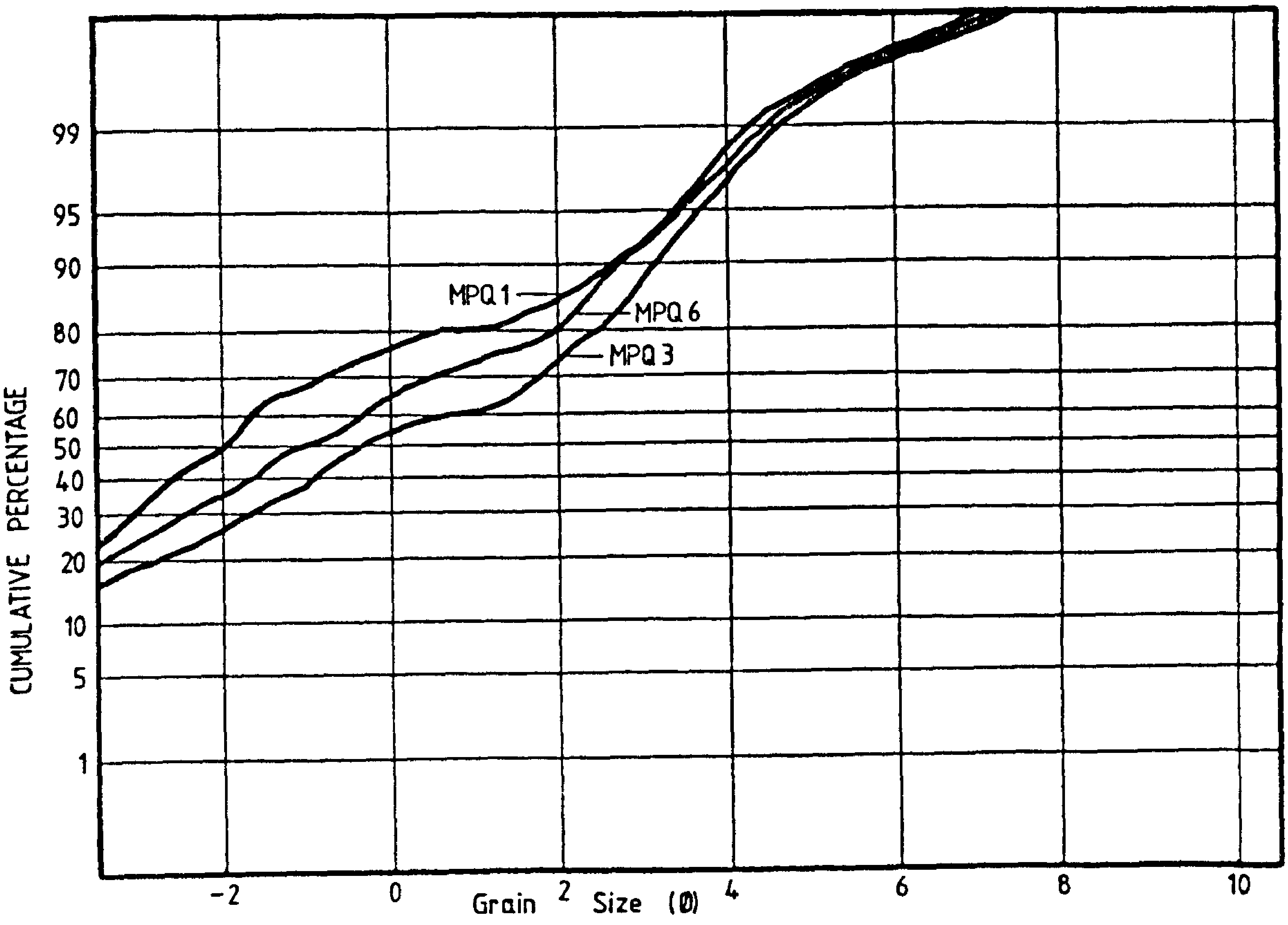


Figure 4.4.2.2. Sediment Size Analysis. Middle Peak Quarry.

The shale content of the Middle Peak Quarry sediments indicates that they were deposited closer to the input swallets to the system which probably drained to a resurgence in the Wirksworth area or to one in a former, higher level, Via Gellia. Scalloping on the walls of these phreatic tubes indicate a current direction from the south to the north.

4.4.3. Ratchwood Mine

Ratchwood Founder Shaft, at SK 2818,5521, was uncovered and re-explored during 1981 and 1982 (Warriner and Birkett, 1982). The shaft gives access to a number of workings on several fissure veins which extend under Middle Peak Quarry (fig. 4.4.3.1.). The shaft is sunk through 20 metres of down faulted Namurian shale into the Cawdor Limestones. The workings extend south - east through the Gulf Fault into the Matlock Lower Limestone and Hopton Wood Limestone.

A pipe vein close to the entrance shows a phase of pre-mineralization sediment deposition (fig. 4.4.3.2.) consisting of laminated quartz sand, now lithified to sandstone, composed entirely of quartz with a silica cement. No features have been found to establish whether the quartz is solutionally extracted authigenic quartz or whether it has been derived from the Namurian strata.

The Gulf Fault is intersected by the mine workings and here consists of a number of large fault gouges, up to 3 metres wide, filled with limestone, shale and fluorite/baryte blocks in a clay matrix. Adjacent to one

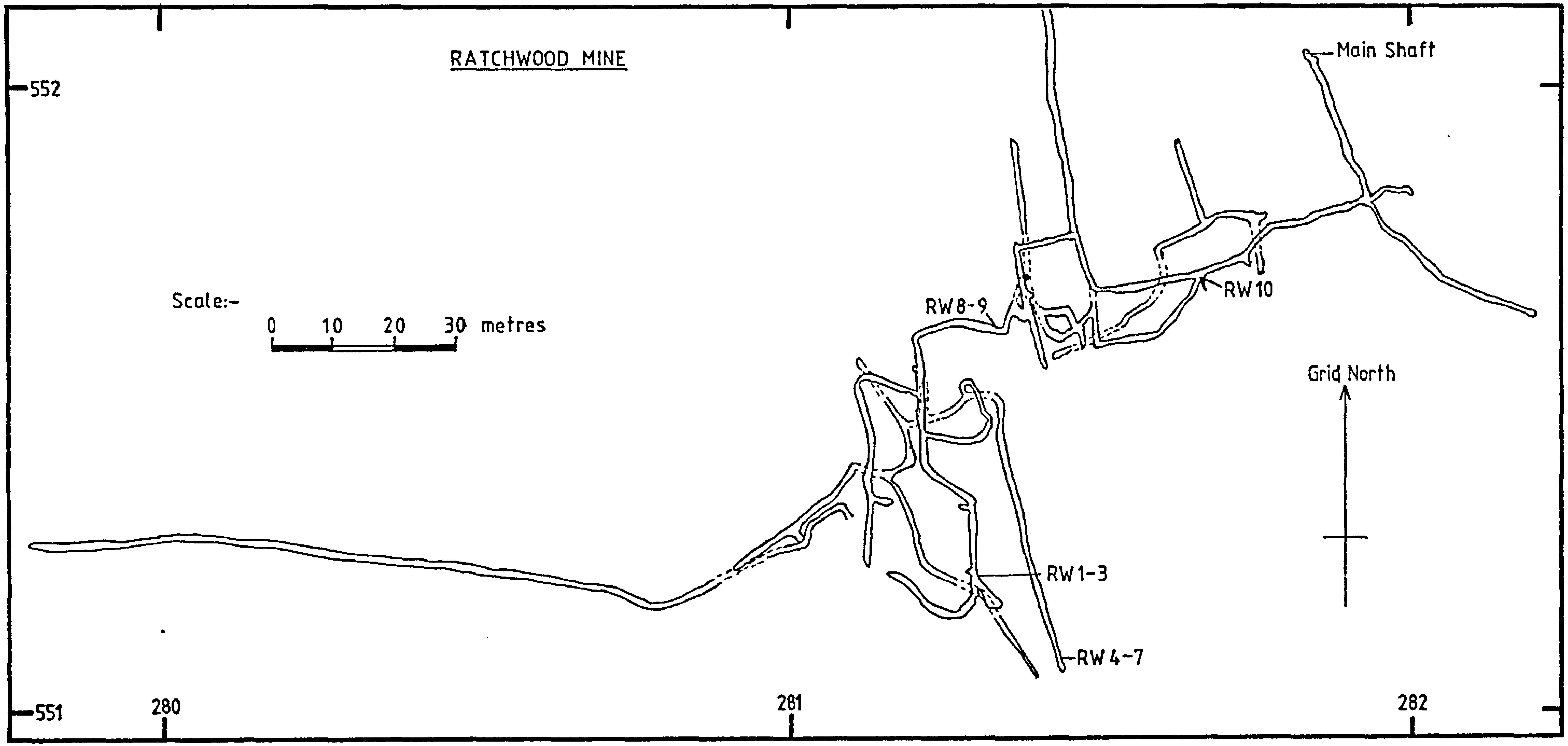


Figure 4.4.3.1: Plan of Ratchwood Mine showing sample locations. After Warriner and Birkett (1982).

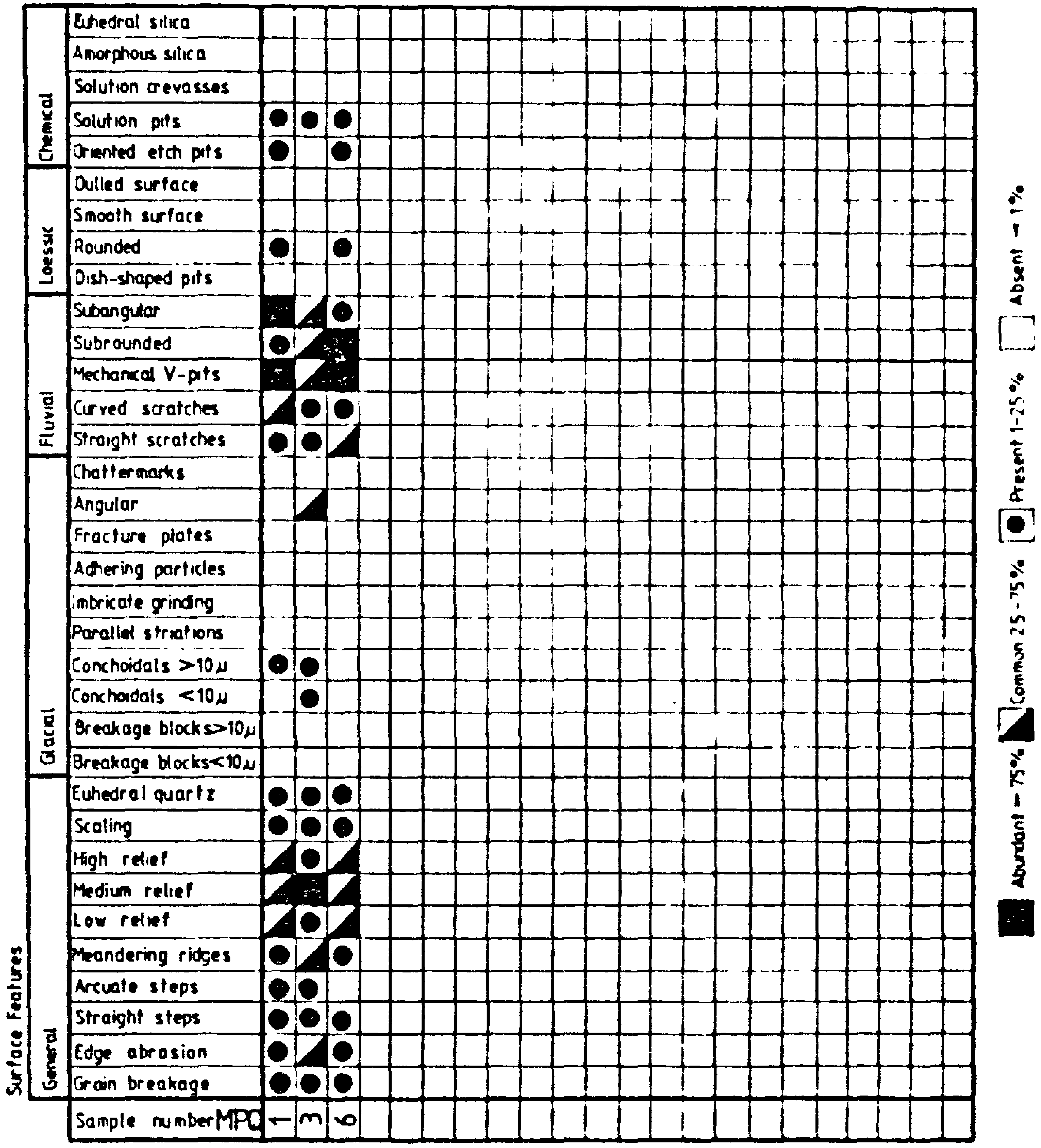


Figure 4.4.2.3. Summary of quartz grain surface textures, Middle Peak Quarry.

Surface Features				
	Sample number MPQ	1	3	6
Chemical	Euhedral silica			
	Amorphous silica			
	Solution crevasses			
	Solution pits	●	●	●
	Oriented etch pits	●		●
Loessic	Dulled surface			
	Smooth surface			
	Rounded	●		●
	Dish-shaped pits			
Fluvial	Subangular	■	◢	●
	Subrounded	●	◢	■
	Mechanical V-pits	■	◢	■
	Curved scratches	◢	●	●
	Straight scratches	●	●	◢
Glacial	Chattermarks			
	Angular		◢	
	Fracture plates			
	Adhering particles			
	Imbricate grinding			
	Parallel striations			
	Conchoidals >10μ	●	●	
	Conchoidals <10μ		●	
	Breakage blocks>10μ			
	Breakage blocks<10μ			
General	Euhedral quartz	●	●	●
	Scaling	●	●	●
	High relief	◢	●	◢
	Medium relief	◢	■	◢
	Low relief	◢	●	◢
	Meandering ridges	●	◢	●
	Arcuate steps	●	●	
	Straight steps	●	●	●
	Edge abrasion	●	◢	●
	Grain breakage	●	●	●

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

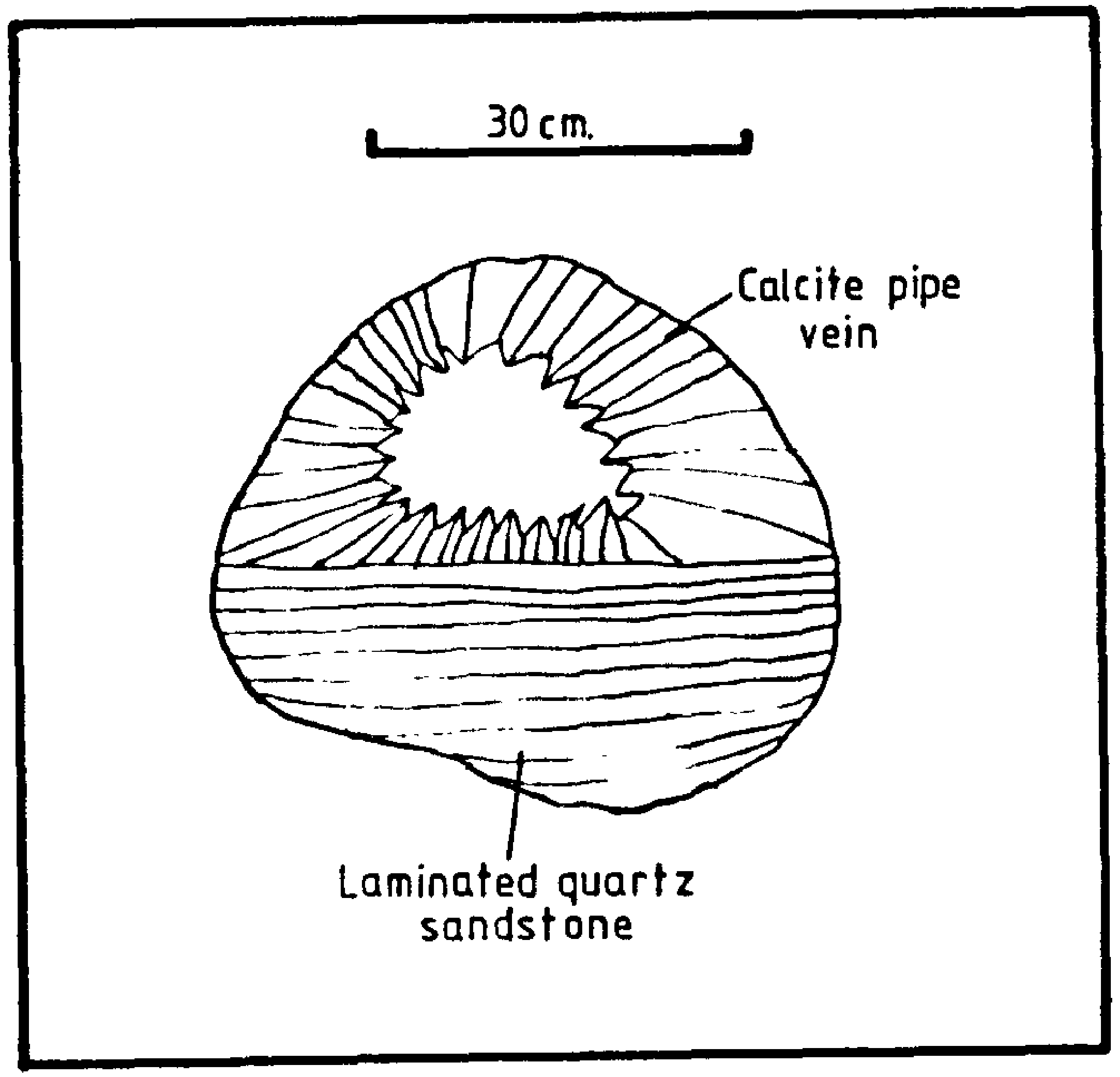


Figure 4.4.3.2. Pipe vein, Ratchwood Mine.

of these faults is a small cavity in Matlock Limestone filled with derived silicified limestone fossils.

A phreatic cavity above a sump in the mine workings on the 200 ft. level (fig. 4.4.3.1., RW 1 - 3) is filled with clayey silts. The composition of these sediments is given in figure 4.4.3.3.. S.E.M. study of quartz grain surface textures show that the quartz is probably of fluvial origin (fig. 4.4.3.4.). Size analysis of these sediments shows that they are moderately well sorted, nearly symmetrical, mesokurtic clayey silts (fig. 4.4.3.5.).

A pipe vein cavity on the 270 ft. level (fig. 4.4.3.1., RW 4 - 7) has early calcite followed by later baryte mineralization. The remainder of the cavity has been filled with residual angular baryte in a clayey matrix overlain by silty clays (4.4.3.6.).

The composition of the barytic horizon is given in figure 4.4.3.7. and that of the overlying sediments in figure 4.4.3.8.. S.E.M. studies show that the quartz is of fluvial origin (fig 4.4.3.9.).

Size analysis of the residual sediments shows them to be poorly sorted, slightly coarse - skewed, mesokurtic silts (fig. 4.4.3.10.). The baryte has been derived from the walls and roof of the cavity by solutional collapse. The matrix of this layer and the sediments in the remainder of the cavity and those in the cavity on the 200 ft. level is of allochthonous origin, possibly being derived from the Namurian strata of the Gulf.

Sample Numbers RW 1 – 3		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	43 – 62
	Sandstone	
	Feldspar	
	Mica	0 – 0·5
	Shale	
	Quartzite	
	Balance (mainly clay)	38 – 57
1 Autochthonous 2 Allochthonous		

Figure 4.4.3.3. Summary of sediment composition, 200 ft. Level, Ratchwood Mine.

Surface Features	Chemical	Euhedral silica			●
		Amorphous silica	●	●	
		Solution crevasses			
		Solution pits		●	
		Oriented etch pits	●	●	●
	Loessic	Dulled surface			
		Smooth surface			
		Rounded		◢	●
		Dish-shaped pits			
	Fluvial	Subangular	■	◢	●
		Subrounded	●	◢	■
		Mechanical V-pits	◢	◢	◢
		Curved scratches	●	◢	●
		Straight scratches	●	●	●
	Glacial	Chattermarks			
		Angular	●	●	
		Fracture plates			
		Adhering particles			
		Imbricate grinding			
		Parallel striations			
		Conchoidals >10µ	●	●	●
		Conchoidals <10µ		●	●
		Breakage blocks>10µ			
		Breakage blocks<10µ			
	General	Euhedral quartz	●		●
		Scaling	●	●	◢
		High relief	●	◢	◢
		Medium relief	■	◢	◢
		Low relief	●	◢	◢
		Meandering ridges	●	●	●
		Arcuate steps	●	●	●
		Straight steps	●	●	●
		Edge abrasion	◢	●	●
		Grain breakage	●		●
		Sample number RW	1	2	3

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 4.4.3.4. Summary of quartz grain surface textures, Ratchwood Mine, 200 ft. Level.

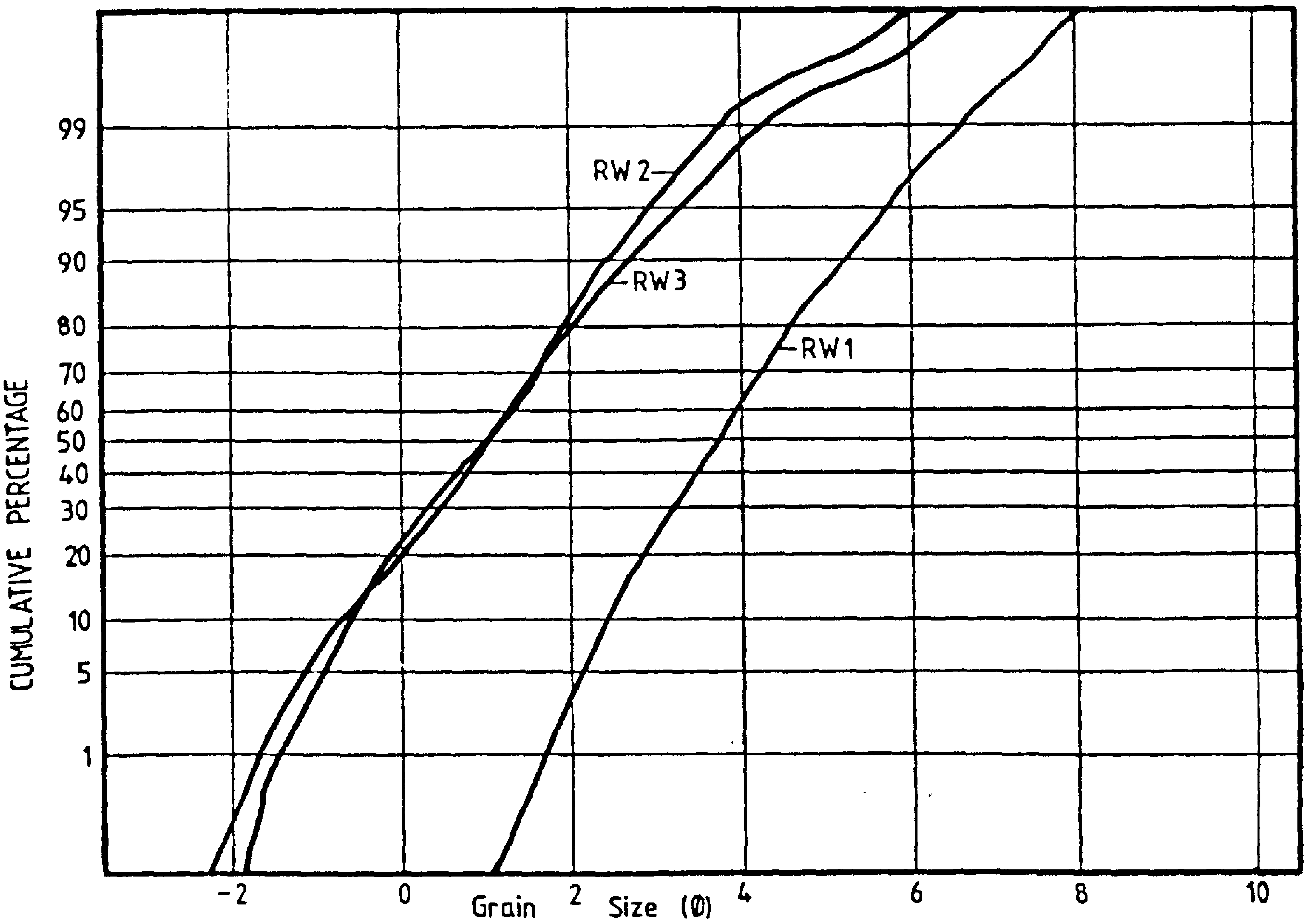


Figure 4.4.3.5. Sediment Size Analysis. Ratchwood Mine.

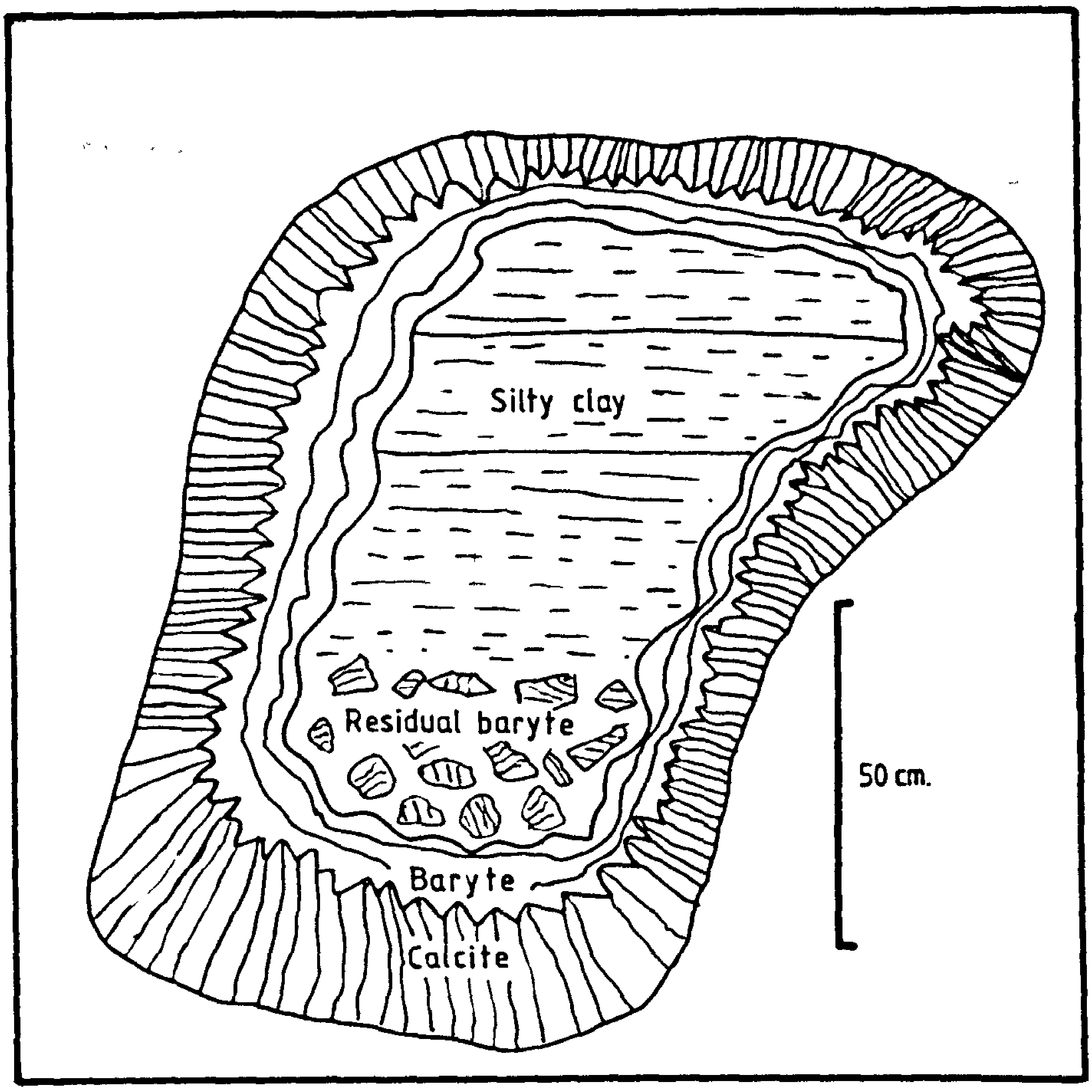


Figure 4.4.3.6. Pipe vein, Ratchwood Mine.

Sample Numbers RW 4		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte (angular)	82
	Calcite	3
2	Quartz	4
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	11

1 Autochthonous 2 Allochthonous

Figure 4.4.3.7. Summary of sediment composition, 270 ft. Level, Ratchwood Mine.

Sample Numbers RW 5 - 7		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	36 - 42
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	58 - 64

1 Autochthonous 2 Allochthonous

Figure 4.4.3.8. Summary of sediment composition, 270 ft. Level, Ratchwood Mine.

	Chemical	Euhedral silica			●	
		Amorphous silica	●	●	●	●
		Solution crevasses		●		
		Solution pits	●	●	◩	●
		Oriented etch pits	●		●	●
	Loessic	Dulled surface		●		
		Smooth surface	●		●	●
		Rounded		●	●	●
		Dish-shaped pits		●		
	Fluvial	Subangular	■	◩	◩	◩
		Subrounded	●	◩	◩	◩
		Mechanical V-pits	■	◩	◩	◩
		Curved scratches	●	●	◩	●
		Straight scratches	◩	◩	●	●
	Glacial	Chattermarks				
		Angular	●	●	●	●
		Fracture plates				
		Adhering particles				
		Imbricate grinding				
		Parallel striations				
		Conchoidals >10µ	●	●	●	●
		Conchoidals <10µ	●		●	
		Breakage blocks>10µ				
		Breakage blocks<10µ				
Surface Features	General	Euhedral quartz		●		
		Scaling	●	◩	●	●
		High relief	●	◩	●	◩
		Medium relief	■	◩	●	◩
		Low relief	●	◩	■	●
		Meandering ridges	●	●		
		Arcuate steps		●	●	●
		Straight steps		●		
		Edge abrasion	●	●	●	●
		Grain breakage	●		●	●
		Sample number RW	4	5	6	7

■ Abundant - 75% ◩ Common 25-75% ● Present 1-25% ☐ Absent - 1%

Figure 4.4.3.9. Summary of quartz grain surface textures, Ratchwood Mine, 270 ft. Level.

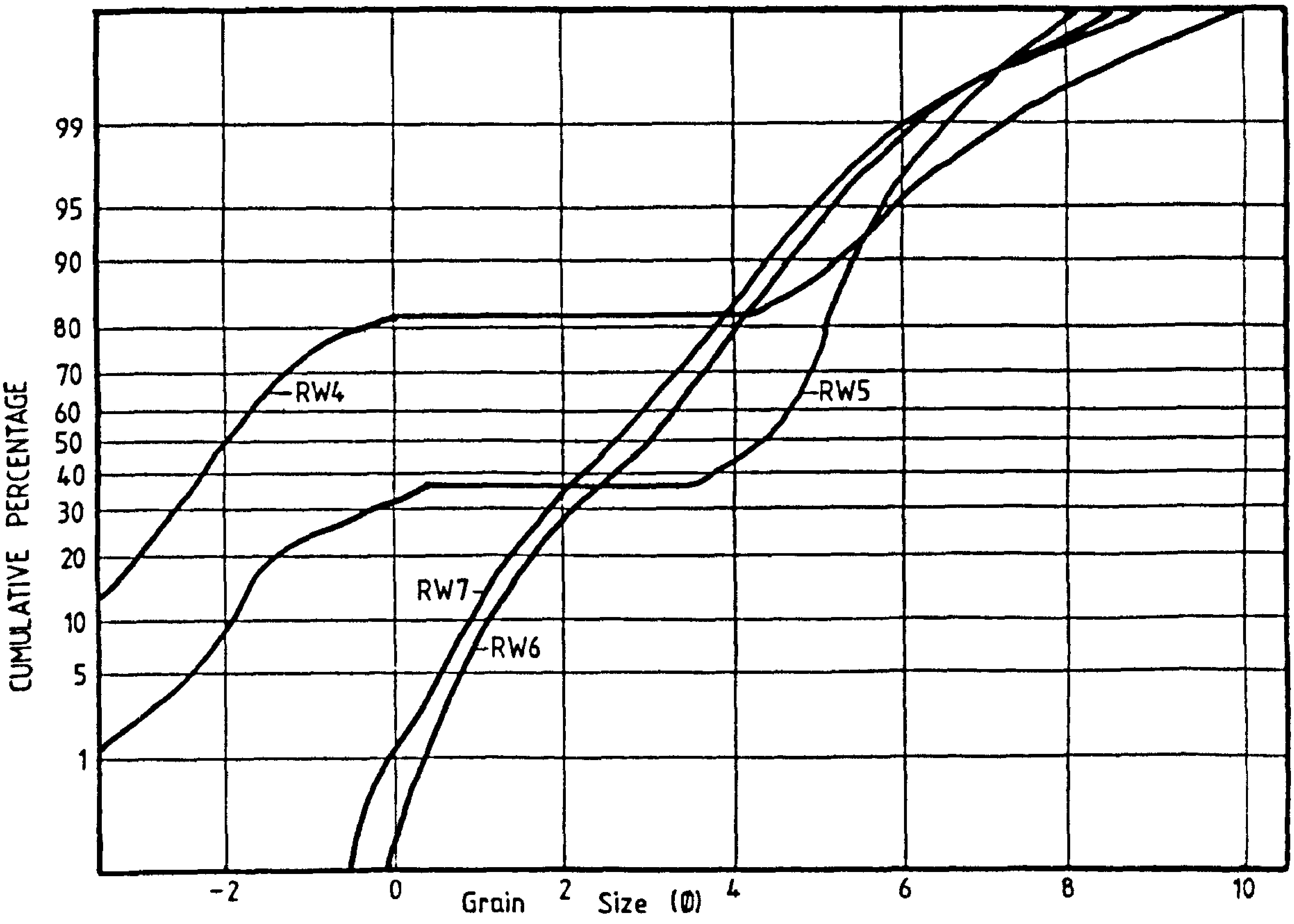


Figure 4.4.3.10. Sediment Size Analysis. Ratchwood Mine.

4.4.4. Shaw's Quarry

Situated at SK 285,552, Shaw's Quarry was worked for lime used by Stanton and Stavely ironworks during the 1930's and again for road fill hardcore during the construction of the M1 through Derbyshire and Nottinghamshire but is now disused. The quarry worked limestones of the Cawdor Group which here consist of biohermal reef masses and intra - reef channel fills. A number of mineralized joints and small scrins carrying fluorite, baryte and galena cut the limestone.

On the upper level of the quarry a small phreatic cavity developed within a pipe vein is filled with orange - brown silty clay (fig. 4.4.4.1.). The sediment composition is given in figure 4.4.4.2.. A layer at the bottom of the cavity, 17 cm. thick, contains up to 50% of residual ore minerals comprising galena (83 to 92%), fluorite (5 to 9%) and baryte (3 to 8%). The galena occurs as detached lumps, often showing octahedral crystal faces which are deeply corroded but not coated in cerussite.

The results of X.R.D. analysis of the clay fraction are presented in figure 4.4.4.2.. S.E.M. study of quartz grain surface textures shows that they are of loessic origin (fig. 4.4.4.3.).

Size analysis shows that the sediment is moderately well sorted, near symmetrical, mesokurtic silty clay (fig. 4.4.4.4.). Apart from the residual "ore" mineral content of the lowest horizon it has an allochthonous origin, perhaps the mechanism of translatory flow introducing the sediment from surface loess deposits, only 4 metres above,

Sample Numbers SQ 1 — 3		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	29 — 42
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	58 — 71
1 Autochthonous 2 Allochthonous		
Clay Mineralogy		
		%
	Illite	33 — 46
	Kaolinite	31 — 40
	Chlorite	9 — 16
	Mixed layer smectites	14 — 19

Figure 4.4.4.2. Summary of sediment composition, Shaw's Quarry.

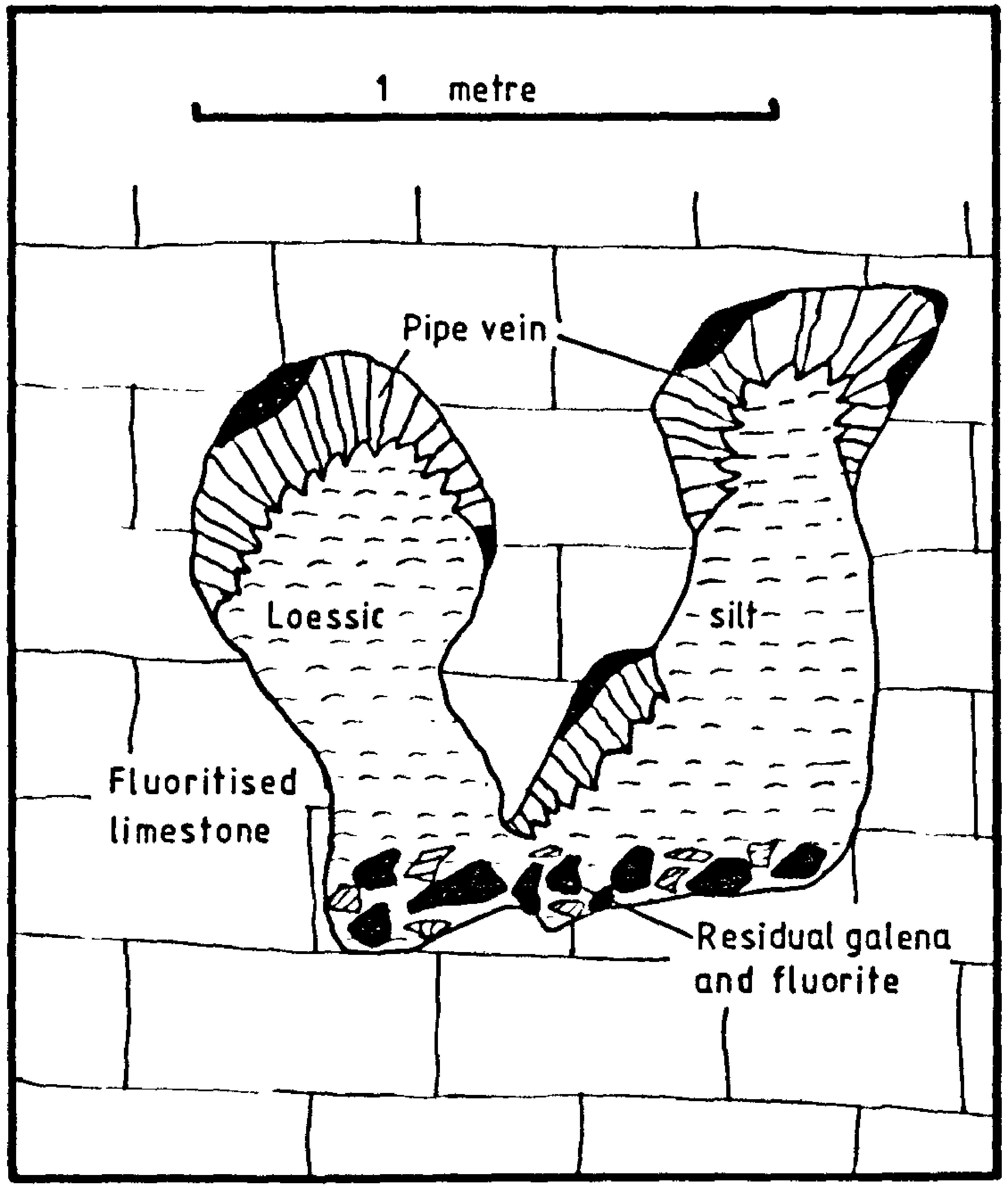
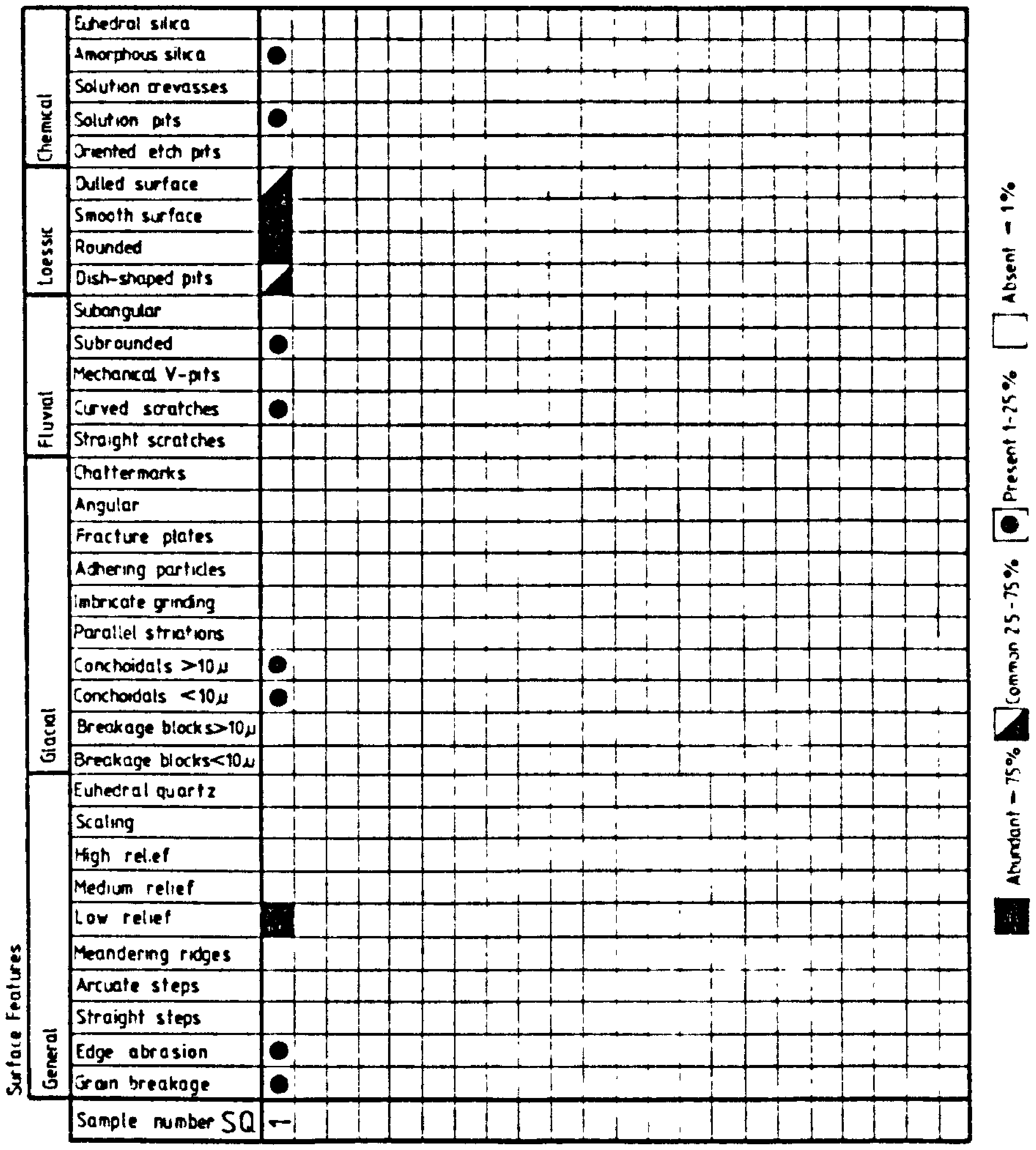


Figure 4.4.4.1. Pipe vein, Shaw's Quarry.



Chemical	Euhedral silica	
	Amorphous silica	●
	Solution crevasses	
	Solution pits	●
	Oriented etch pits	
Loessic	Dulled surface	◪
	Smooth surface	■
	Rounded	■
	Dish-shaped pits	◪
Fluvial	Subangular	
	Subrounded	●
	Mechanical V-pits	
	Curved scratches	●
	Straight scratches	
Glacial	Chattermarks	
	Angular	
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10µ	●
	Conchoidals <10µ	●
	Breakage blocks>10µ	
	Breakage blocks<10µ	
Surface Features General	Euhedral quartz	
	Scaling	
	High relief	
	Medium relief	
	Low relief	■
	Meandering ridges	
	Arcuate steps	
	Straight steps	
	Edge abrasion	●
	Grain breakage	●
	Sample number SQ	←

■ Abundant – 75% ◪ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 4.4.4.3. Summary of quartz grain surface textures, Shaw's Quarry.

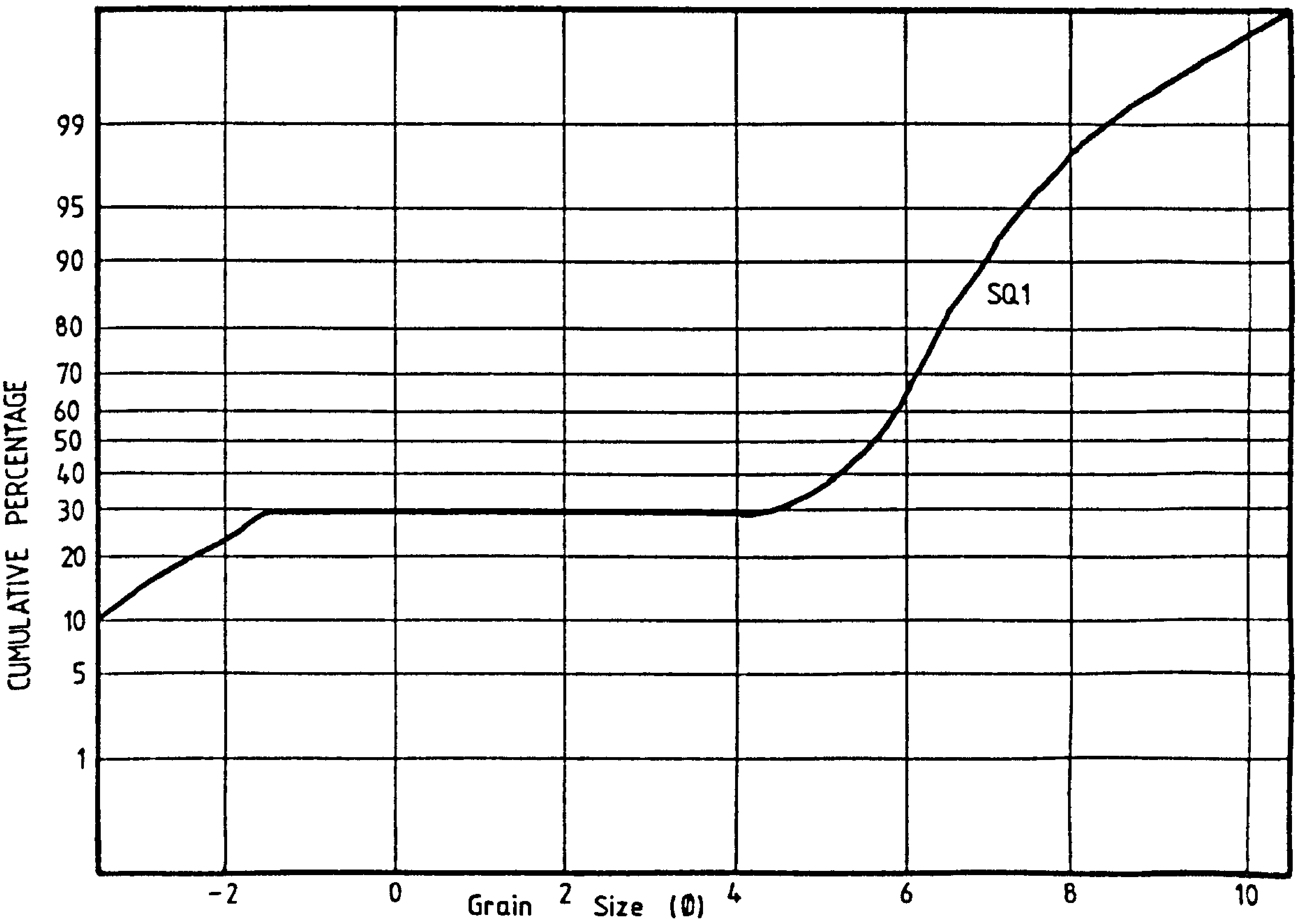


Figure 4.4.4.4. Sediment Size Analysis. Shaw's Quarry.

through the scrin on which the pipe vein is developed.

4.4.5. Coal Hills Quarry

Again worked for fill during the construction of the M1 this quarry, at SK 552,288, worked similar limestones to those in Shaw's Quarry. A rift developed on a major joint filled with sediment has been intersected in part of the quarry. The composition of the sedimentary fill, which is much disturbed by blasting and subsequent weathering, is given in figure 4.4.5.1.. S.E.M. studies show that the quartz grains are probably of loessic origin (fig. 4.4.5.2.).

Size analysis shows that the sediments are moderately well sorted, near symmetrical, mesokurtic silty clays (fig. 4.4.5.3.). The mineralogy and nature of these sediments are very similar to those of the deposit in Shaw's Quarry. The roof of this cavity is less than 1 metre below the surface and it is likely that the sediment accumulated via a direct opening to the surface.

4.4.6. Steeple House Quarry

Situated at SK 554,287 this quarry, now disused, worked limestones towards the top of the Cawdor Group as building and ornamental stone. The limestones are well bedded, biosparites with numerous chert nodules and layers. A number of scrins and mineralized joints have been intersected by the quarry workings, some of which were previously worked for lead. Two solutionally -

Sample Numbers	CHQ 1 – 2	
		%
1	Limestone	30 — 41
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	36 — 57
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	18 — 34

1 Autochthonous 2 Allochthonous

Figure 4.4.5.1. Summary of sediment composition, Coal Hills Quarry.

Surface Features		
Chemical	Euhedral silica	
	Amorphous silica	●
	Solution crevasses	
	Solution pits	●
	Oriented etch pits	
Loessic	Dulled surface	◩
	Smooth surface	■
	Rounded	■
	Dish-shaped pits	◩
Fluvial	Subangular	
	Subrounded	●
	Mechanical V-pits	
	Curved scratches	●
	Straight scratches	●
Glacial	Chattermarks	
	Angular	
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10μ	●
	Conchoidals <10μ	●
	Breakage blocks>10μ	
	Breakage blocks<10μ	
General	Euhedral quartz	
	Scaling	
	High relief	
	Medium relief	●
	Low relief	■
	Meandering ridges	
	Arcuate steps	
	Straight steps	
	Edge abrasion	●
	Grain breakage	●
	Sample number CHQ	1

■ Abundant – 75% ◩ Common 25-75% ● Present 1-25% □ Absent – 1%

Figure 4.4.5.2. Summary of quartz grain surface textures, Coal Hills Quarry.

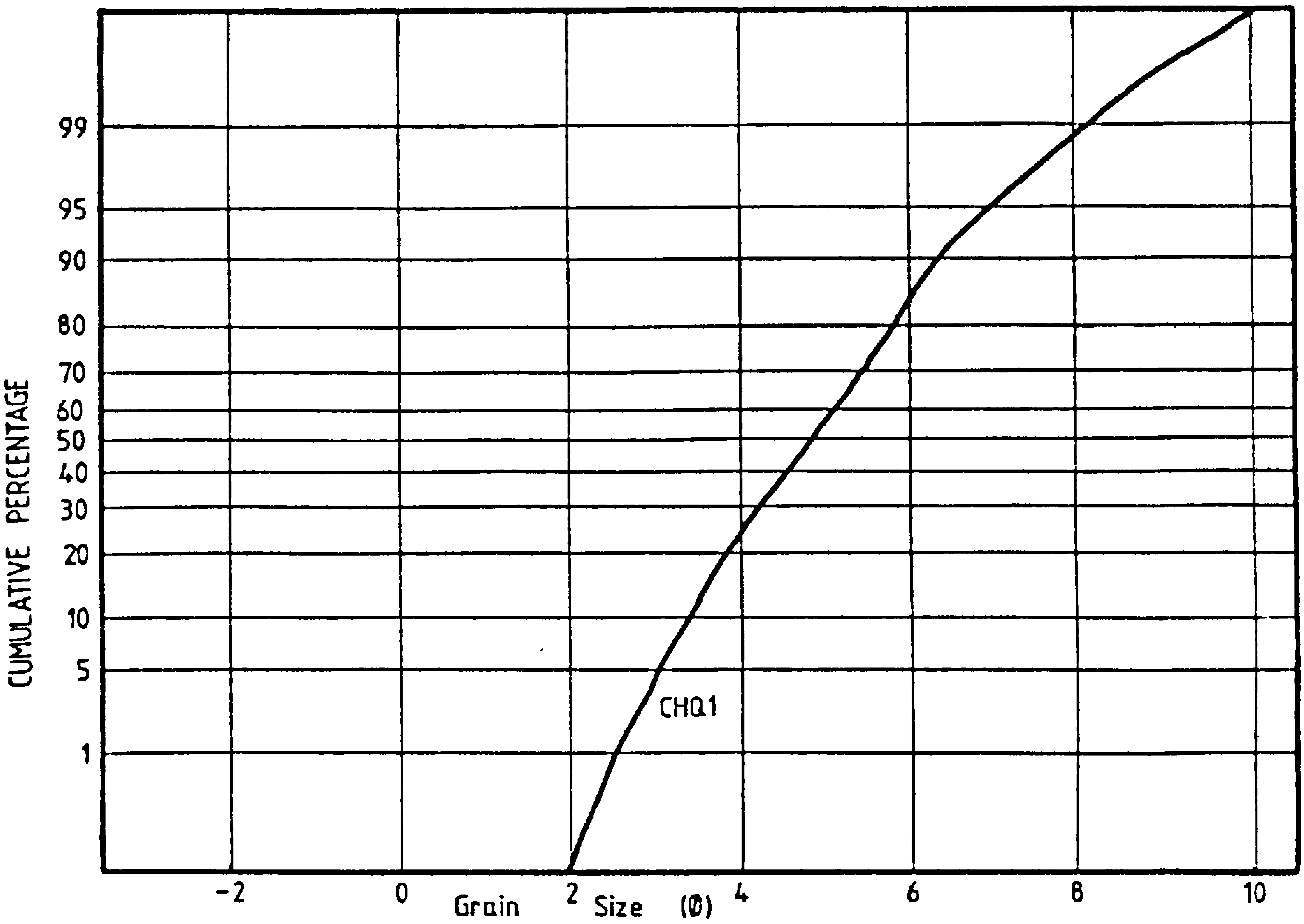


Figure 4.4.5.3. Sediment Size Analysis. Coal Hills Quarry.

Sample Numbers SHQ 1 – 2		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	23 – 27
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	28 – 37
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	40 – 49
1 Autochthonous 2 Allochthonous		

Figure 4.4.6.1. Summary of sediment composition, Steeple House Quarry.

widened joints are filled with insoluble chert debris in a silty - clay matrix.

The composition of the sedimentry fill is given in figure 4.4.6.1.. S.E.M. studies of quartz grain surface textures show that they are loess derived (fig. 4.4.6.2.). The chert is directly derived from the walls of the fissures by solutional removal of the limestone, a process which was still continuing during the introduction of the silty - clay.

Size analysis shows that the sediments are moderately sorted, coarse - skewed, very platykurtic silty - chert gravels (fig. 4.4.6.3.). Their platykurtic nature reflects their bimodal origin, chert from the limestone and loess from the surface. The fissures extend the full height of the quarry face (8 metres) to the surface.

4.4.7. Snake Mine

Situated at SK 262,555, Snake Mine has been described by Tune et al (1968). The mine worked a small vein and associated scrins for lead ore into the 1930's. At a number of localities in the upper levels (fig. 4.4.7.1.) post - mineralization solutional enlargement of the scrin has occurred producing cavities up to 0.45 metre wide in the vein and wall rocks.

The vein, up to 0.1 metre wide, is composed of calcite, baryte and galena with minor fluorite. The wall rock limestones, in the upper levels of the mine, are well bedded, medium - grained limestones of the lower part of the Hopton Wood Group and contain a number of thin clay

Chemical	Euhedral silica	
	Amorphous silica	●
	Solution crevasses	
	Solution pits	◪
	Oriented etch pits	
Loessic	Dulled surface	◪
	Smooth surface	◪
	Rounded	■
	Dish-shaped pits	◪
Fluvial	Subangular	
	Subrounded	●
	Mechanical V-pits	
	Curved scratches	
	Straight scratches	
Glacial	Chattermarks	
	Angular	
	Fracture plates	●
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10μ	●
	Conchoidals <10μ	●
	Breakage blocks>10μ	
	Breakage blocks<10μ	
Surface Features General	Euhedral quartz	●
	Scaling	
	High relief	●
	Medium relief	●
	Low relief	◪
	Meandering ridges	
	Arcuate steps	
	Straight steps	●
	Edge abrasion	●
	Grain breakage	●
	Sample number SHQ	1

■ Abundant – 75%
◪ Common 25 - 75%
● Present 1-25%
□ Absent – 1%

Figure 4.4.6.2. Summary of quartz grain surface textures, Steeple House Quarry.

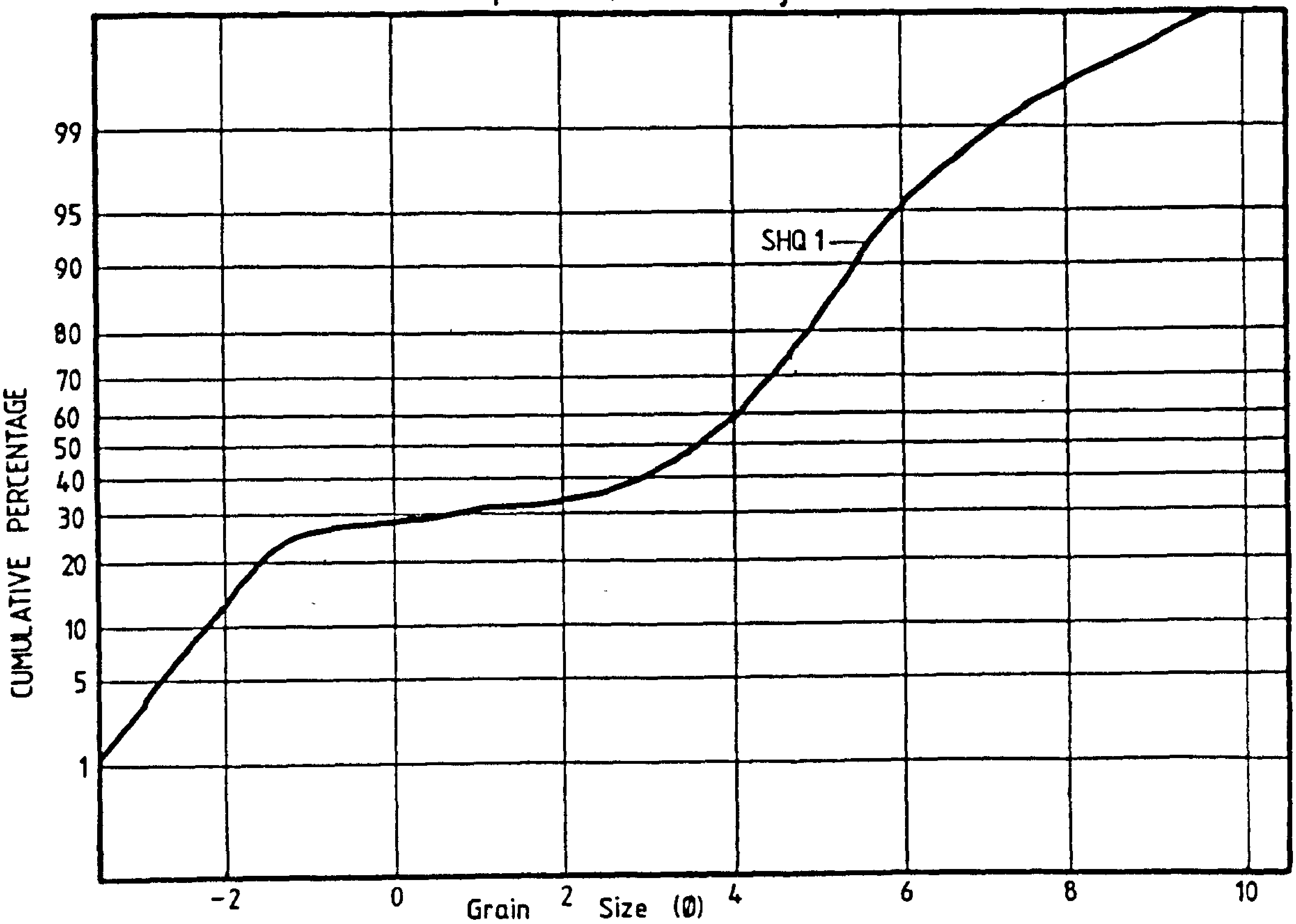


Figure 4.4.6.3. Sediment Size Analysis. Steeple House Quarry.

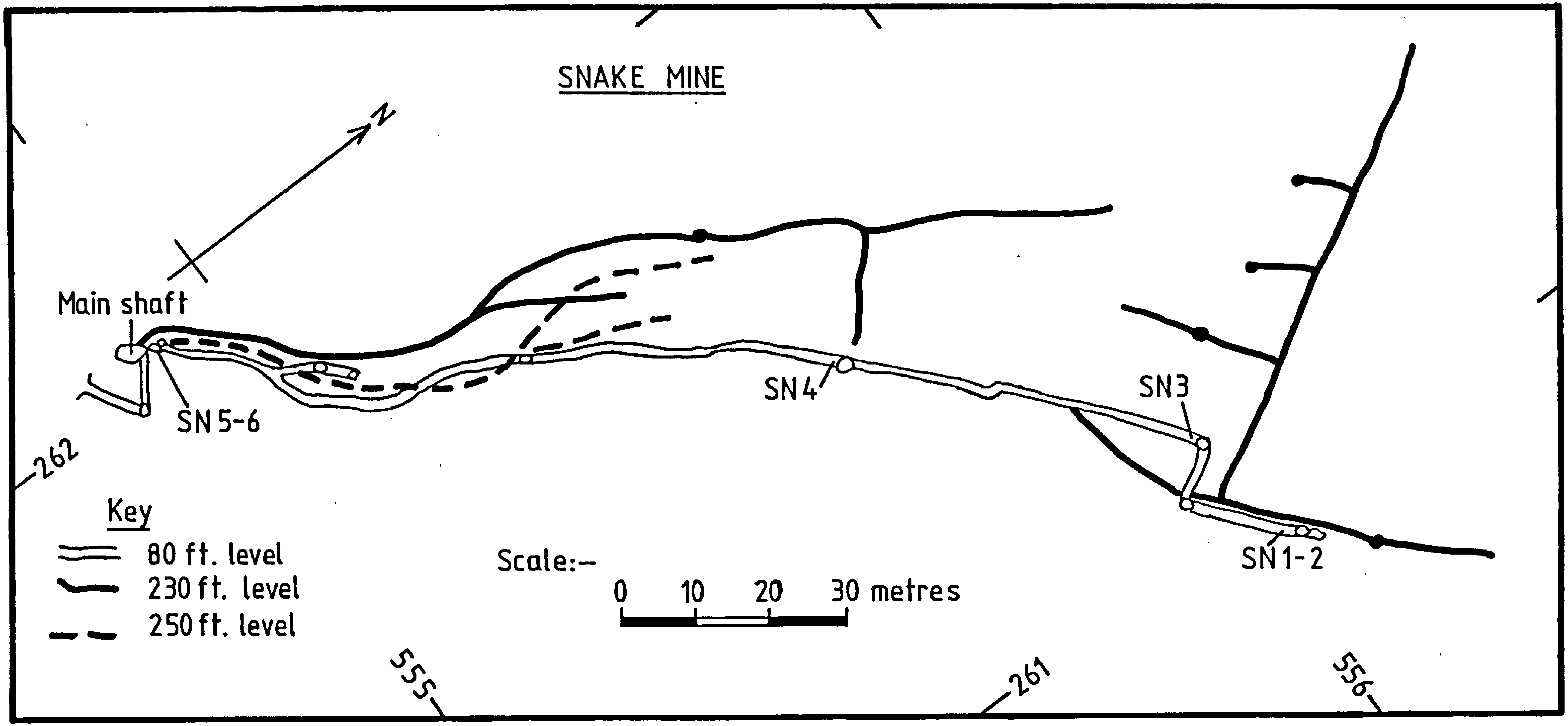


Figure 4.4.7.1. Plan of Snake Mine, Hopton Wood, showing sample locations. After Tune et al (1968).

wayboards. These overlie limestones of the Griffe Grange Beds which are exposed in the deeper workings of the mine.

The solutional cavities are filled with a silty, angular gravel, the composition of which is given in figure 4.4.7.2.. Size analysis shows that the sediments are moderately well sorted, strongly coarse - skewed, very platykurtic silty, angular chert gravels (fig. 4.4.7.3.).

S.E.M. study of the quartz grain surface textures shows that the quartz grains are of loessic origin (fig. 4.4.7.4., plates 4.4.7.1. and 4.4.7.2.). The chert and some of the clay was derived from the limestone,the remainder of the clay may be of wayboard origin.

4.4.8. Gell's and Spar Mine

These interconnected mines were worked, initially for lead and later for calcite at Spar Mine into the 1920's. The shaft into Spar Mine is at SK 538,270. The mine worked a calcite - rich rak vein, up to 5 metres wide, the workings of which intersect the older lead stopes of Gell's Mine.

A small solution cavity in Spar Mine is filled with silty clay, the composition of which is given in figure 4.4.8.1.. Size analysis shows that the sediment is moderately well sorted, slightly fine skewed, mesokurtic silty clays (fig. 4.4.8.2.). S.E.M. study of the quartz grain surface textures shows that the quartz is probably of loessic origin (fig. 4.4.8.3.), the limestone and calcite being derived from the wall rocks and vein respectively.

Sample Numbers SN 1 — 5		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	18 — 71
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	12 — 23
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	21 — 68
1 Autochthonous 2 Allochthonous		

Figure 4.4.7.2. Summary of sediment composition, Snake Mine.

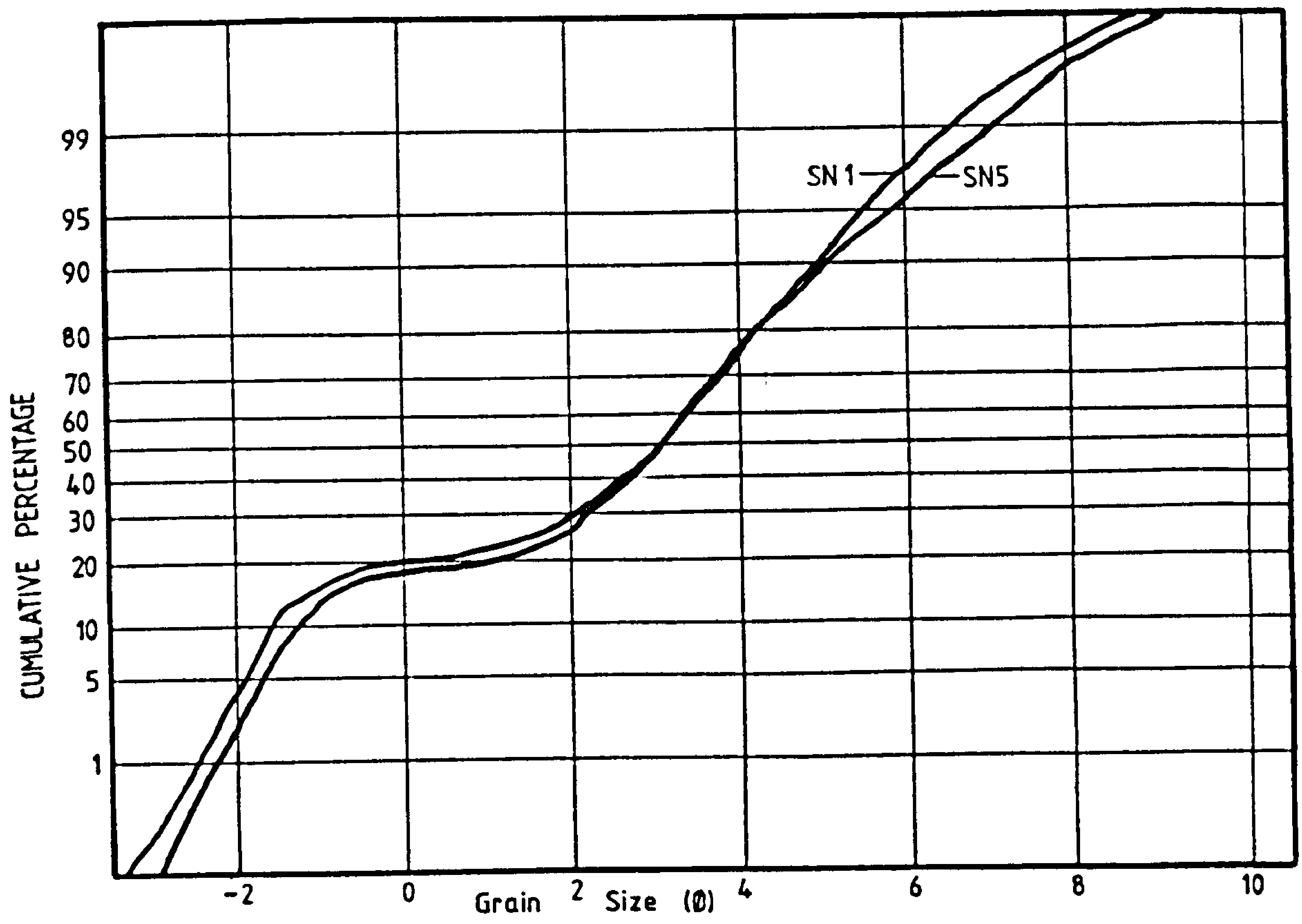


Figure 4.4.7.3. Sediment Size Analysis. Snake Mine.

Surface Features		1	5
Chemical	Euhedral silica		●
	Amorphous silica	●	
	Solution crevasses		
	Solution pits	●	●
	Oriented etch pits		
Loessic	Dulled surface	◩	■
	Smooth surface	■	◩
	Rounded	■	■
	Dish-shaped pits	◩	■
Fluvial	Subangular		
	Subrounded	●	●
	Mechanical V-pits		●
	Curved scratches	●	
	Straight scratches	●	
Glacial	Chattermarks		
	Angular		
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10µ	●	●
	Conchoidals <10µ	●	●
	Breakage blocks>10µ		
	Breakage blocks<10µ		
General	Euhedral quartz		
	Scaling		
	High relief		
	Medium relief	●	◩
	Low relief	■	◩
	Meandering ridges		
	Arcuate steps		
	Straight steps		
	Edge abrasion	●	●
	Grain breakage	◩	●
	Sample number SN	1	5

■ Abundant – 75% ◩ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 4.4.7.4. Summary of quartz grain surface textures, Snake Mine.

Sample Numbers SPAR 1		
		%
1	Limestone	12
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	4
2	Quartz	39
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	45

1 Autochthonous 2 Allochthonous

Figure 4.4.8.1. Summary of sediment composition, Spar Mine.

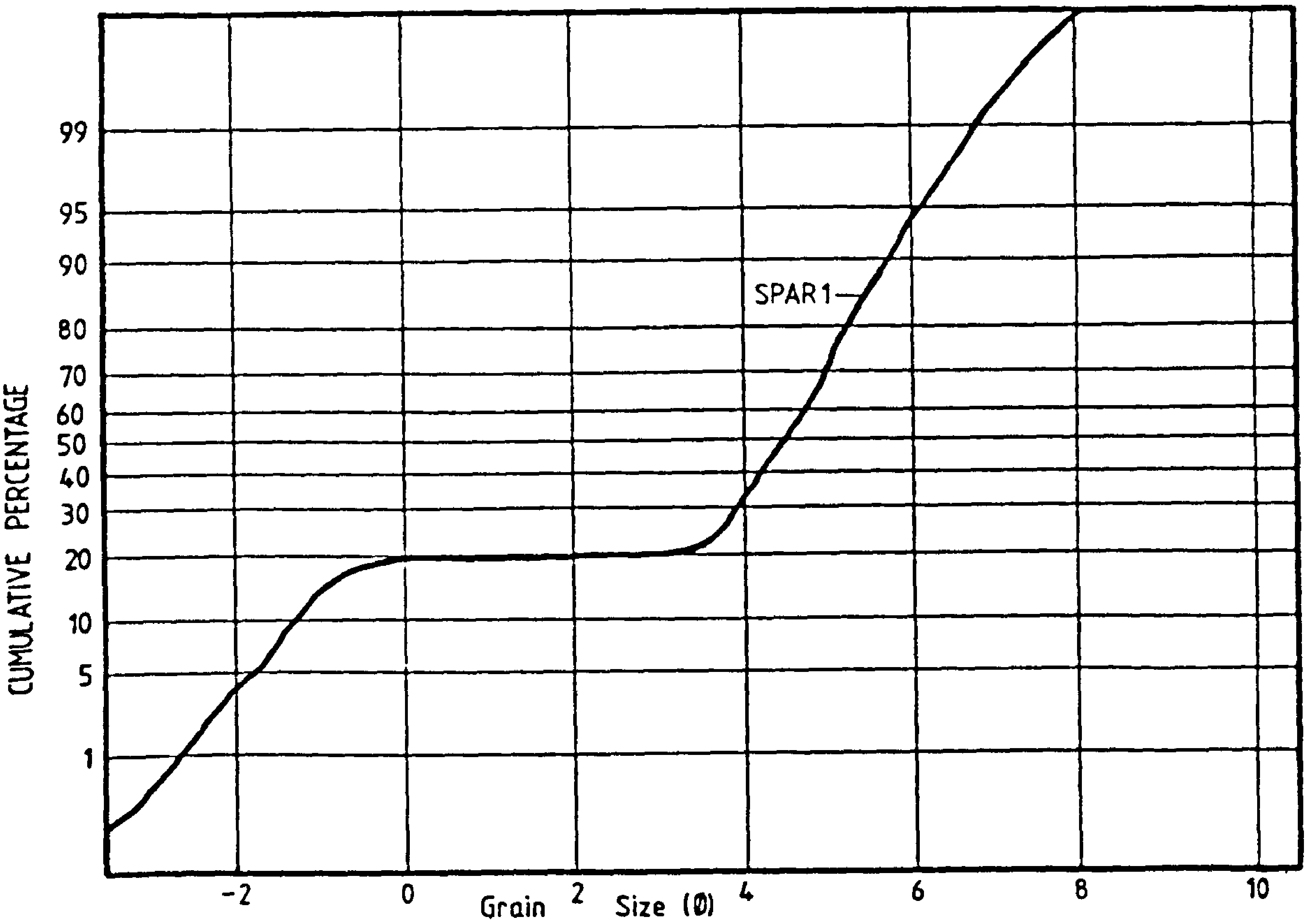
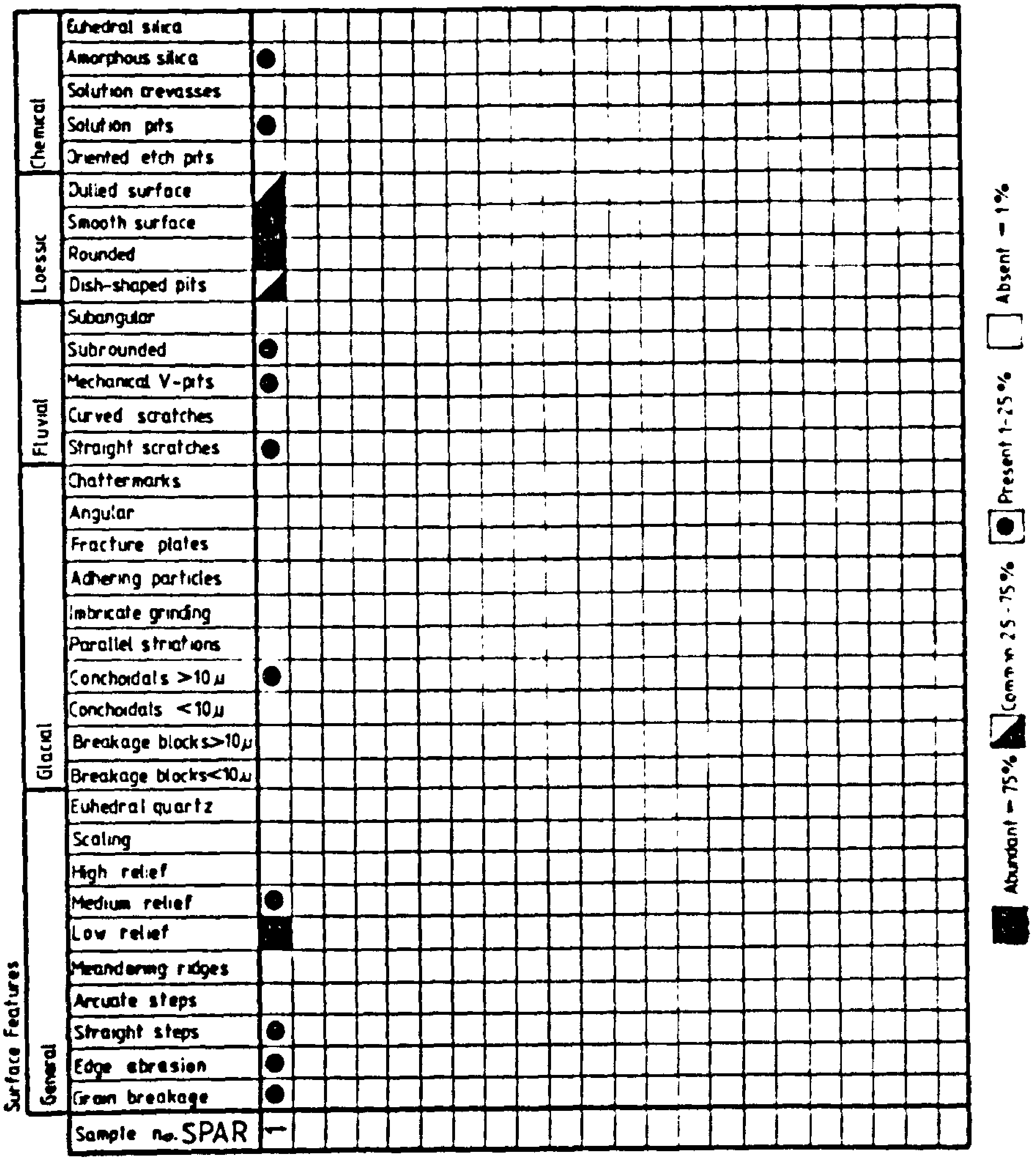
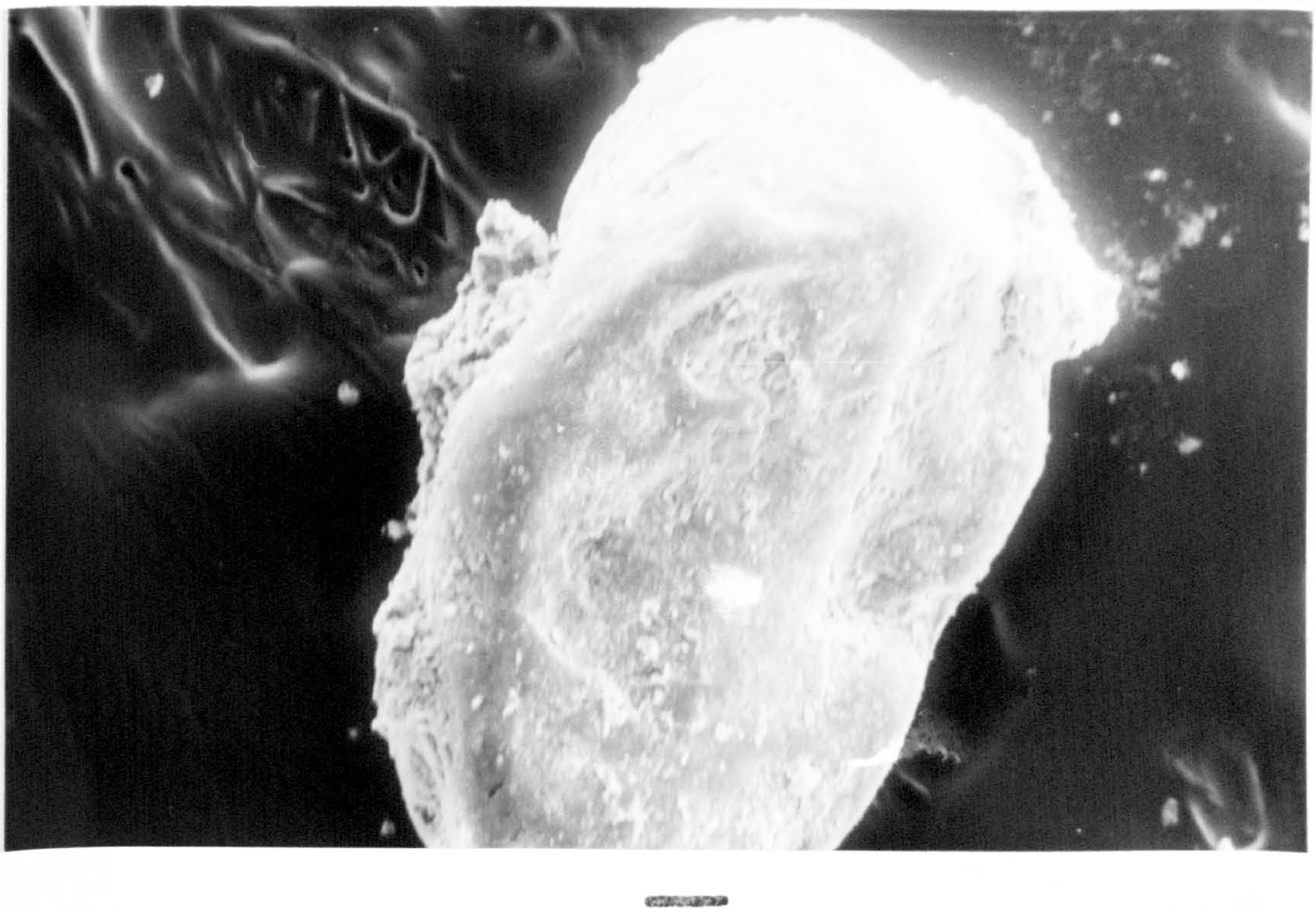


Figure 4.4.8.2. Sediment Size Analysis. Spar Mine.

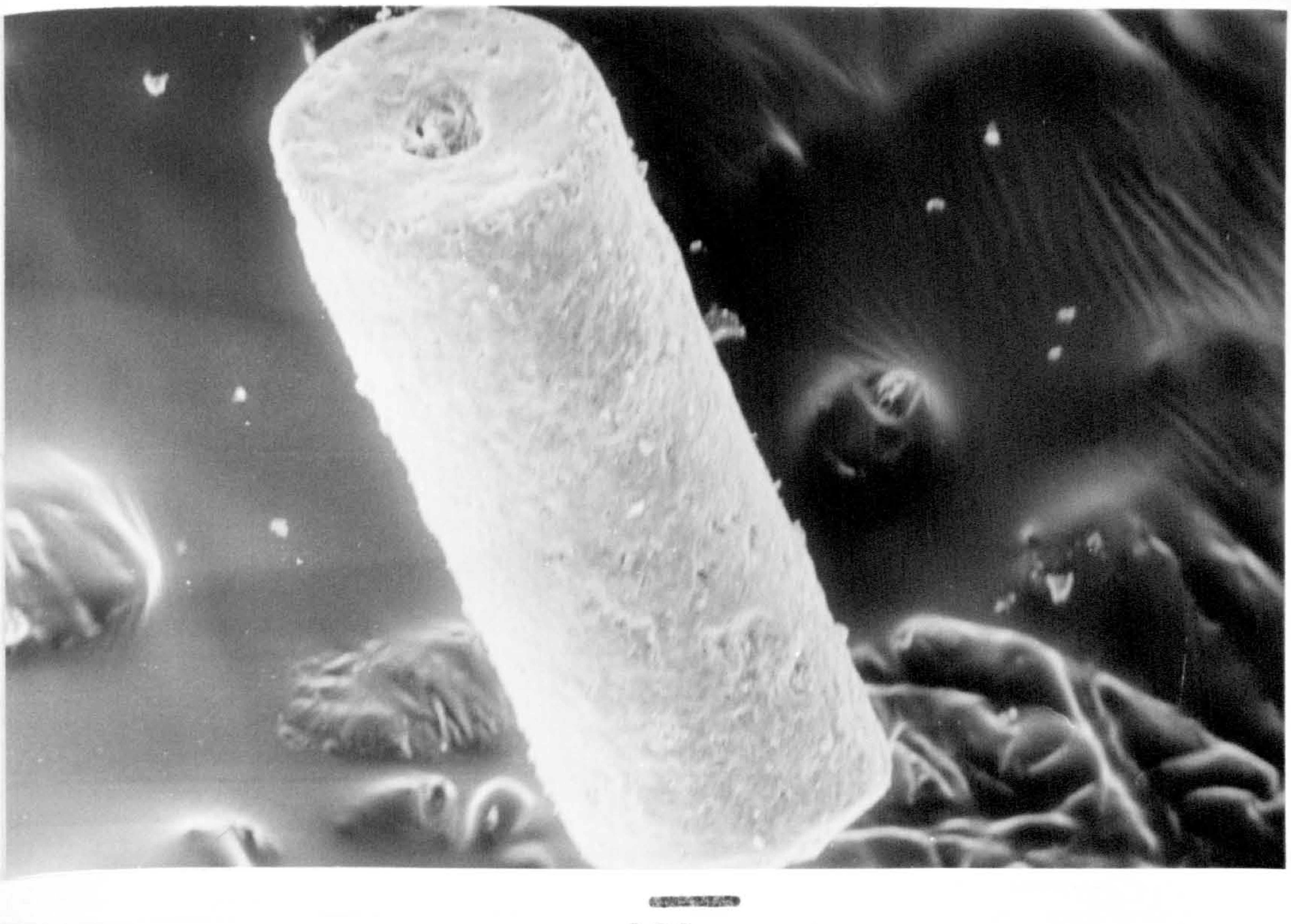


Chemical	Euhedral silica	
	Amorphous silica	●
	Solution crevasses	
	Solution pits	●
	Oriented etch pits	
Loessic	Dulled surface	◩
	Smooth surface	■
	Rounded	■
	Dish-shaped pits	◩
Fluvial	Subangular	
	Subrounded	●
	Mechanical V-pits	●
	Curved scratches	
	Straight scratches	●
Glacial	Chattermarks	
	Angular	
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10µ	●
	Conchoidals <10µ	
	Breakage blocks>10µ	
	Breakage blocks<10µ	
Surface Features General	Euhedral quartz	
	Scaling	
	High relief	
	Medium relief	●
	Low relief	■
	Meandering ridges	
	Arcuate steps	
	Straight steps	●
	Edge abrasion	●
	Grain breakage	●
	Sample no. SPAR	1

Figure 4.4.8.3. Summary of quartz grain surface textures, Spar Mine



4.4.7.1. S.E.M. photomicrograph of a loessic quartz grain, Snake Mine.



4.4.7.2. S.E.M. photomicrograph of a silicified crinoid stem section, Snake Mine.

Small vein cavities in Gell's Mine are filled with a stiff yellow clay which S.E.M. study shows to be of loessic origin.

4.4.9. Groaning Tor Adit

Also known as Hallicar Wood Level, the portal of this trial level is at SK 283,572. The trial has been described by Smith and Ford (1971) and by Flindall et al (1977) and its geology by Walters and Ineson (1980b). The adit intersects increasingly older beds of the Matlock Limestone and penetrates the top of the Matlock Lower Lava where the level has now collapsed. The Matlock Upper Lava is not present in this area but may be represented by a clay wayboard horizon, several of which are cut by the level.

The limestones close to the entrance are dolomitised to varying extents forming a porous dolomite. Further into the adit the limestones are massively bedded pale - grey micrites. Mineralization consists of a few small scrins carrying calcite with minor baryte and galena.

Within the dolomitised limestone a number of small solutional cavities occur. These are filled with gravelly clay, th composition of which is given in figure 4.4.9.2.. Size analysis shows that the sediments are moderately well sorted, fine - skewed, very platykurtic gravelly - clays (fig. 4.4.9.3.). the coarse fraction is derived from the limestone/dolomite, wayboards and scrins. S.E.M. studies show that most of the quartz is of loessic origin (fig. 4.4.9.4.).

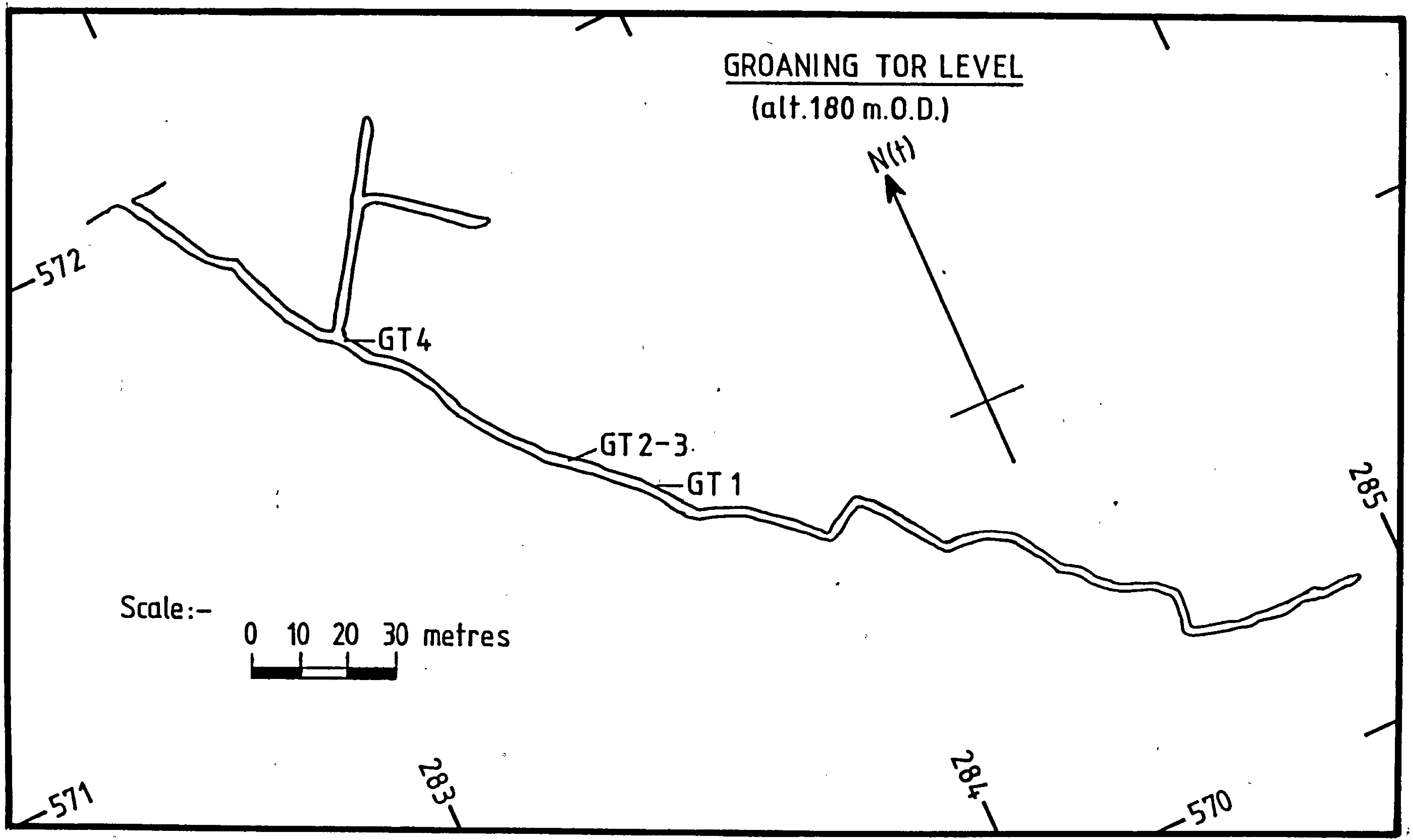


Figure 4.4.9.1. Plan of Groaning Tor (Hallicar Wood) Level showing sample locations. After Flindall et al (1977).

Sample Numbers GT 1 – 5

		%
1	Limestone	3 – 12
	Dolomite	
	Volcanics	0 – 3
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	0 – 2·5
2	Quartz	40 – 58
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	35 – 51

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	31 – 38
Kaolinite	42 – 51
Chlorite	13 – 29
Mixed layer smectites	8 – 14

Figure 4.4.9.2. Summary of sediment composition, Groaning Tor Level.

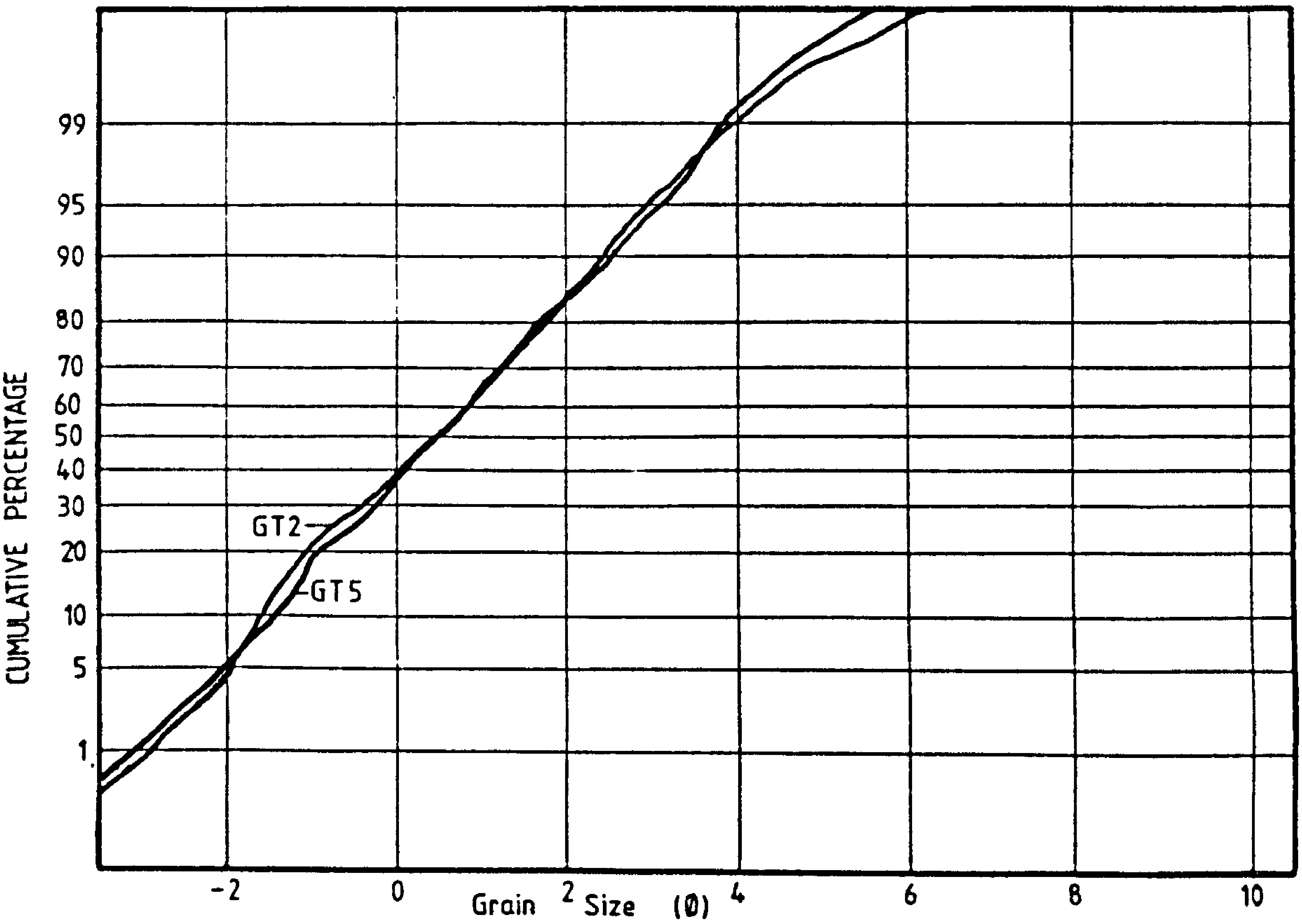
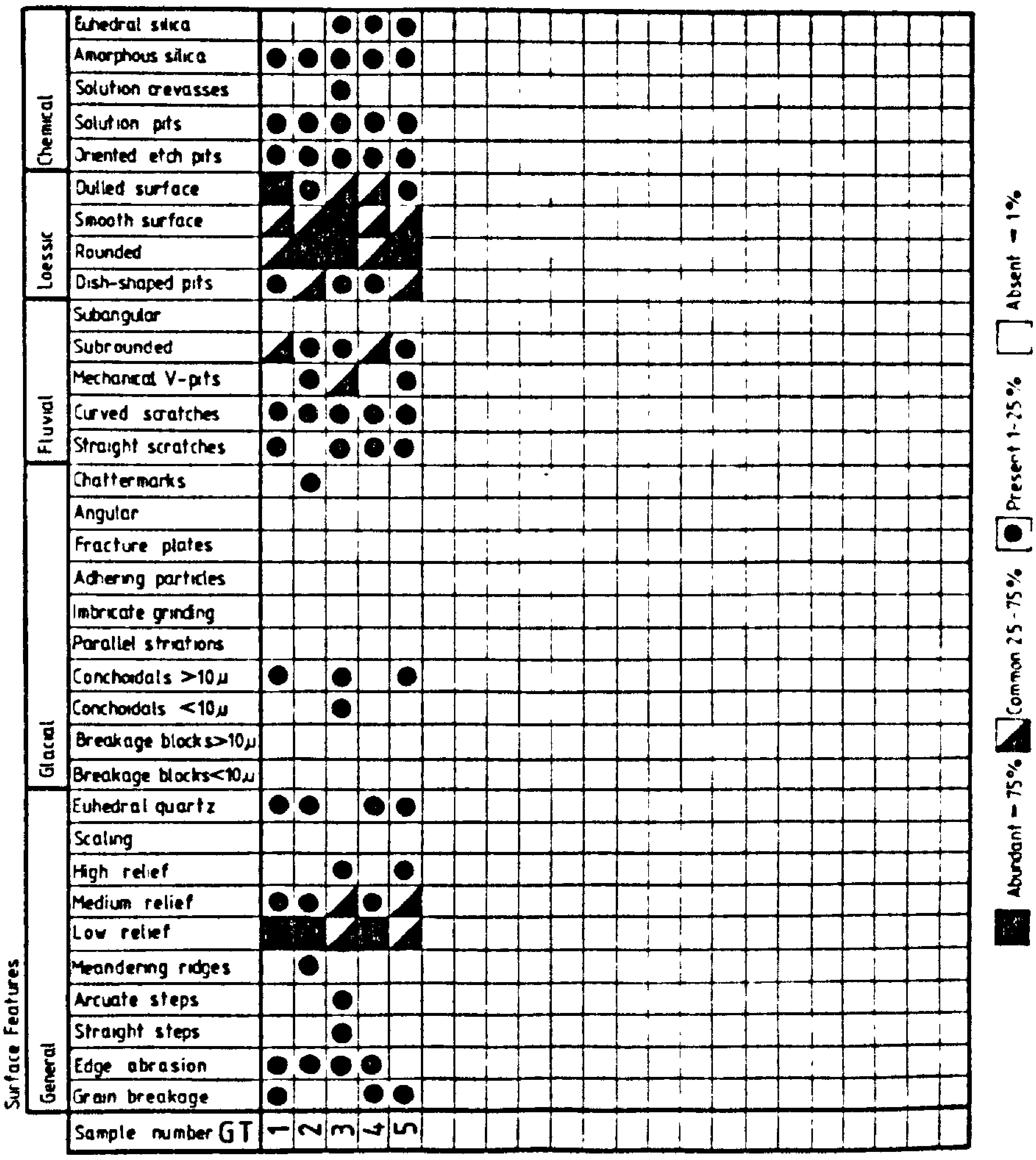


Figure 4.4.9.3. Sediment Size Analysis. Groaning Tor Level.



Chemical	Euhedral silica			●	●	●
	Amorphous silica	●	●	●	●	●
	Solution crevasses			●		
	Solution pits	●	●	●	●	●
	Oriented etch pits	●	●	●	●	●
Loessic	Dulled surface	■	●	◢	◢	●
	Smooth surface	◢	◢	■	◢	◢
	Rounded	◢	■	■	◢	■
	Dish-shaped pits	●	◢	●	●	◢
Fluvial	Subangular					
	Subrounded	◢	●	●	◢	●
	Mechanical V-pits		●	◢		●
	Curved scratches	●	●	●	●	●
	Straight scratches	●		●	●	●
Glacial	Chattermarks		●			
	Angular					
	Fracture plates					
	Adhering particles					
	Imbricate grinding					
	Parallel striations					
	Conchoidals >10μ	●		●		●
	Conchoidals <10μ			●		
	Breakage blocks>10μ					
	Breakage blocks<10μ					
General	Euhedral quartz	●	●		●	●
	Scaling					
	High relief			●		●
	Medium relief	●	●	◢	●	◢
	Low relief	■	■	◢	■	◢
	Meandering ridges		●			
	Arcuate steps			●		
	Straight steps			●		
	Edge abrasion	●	●	●	●	
	Grain breakage	●			●	●
	Sample number GT	1	2	3	4	5

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 4.4.9.4. Summary of quartz grain surface textures, Groaning Tor Adit.

4.4.10. Dream Mine

Situated at SK 275,530, Dream Mine was the site of the discovery of an almost complete rhinoceros skeleton by miners digging through a sediment filled cave (Buckland, 1823; Dawkins, 1874). All that remains today is a scree slope into a small chamber which contains no deposits left undisturbed by past mining or archaeological activity.

4.4.11. Golconda Mine

The main shaft to this extensive lead mine is at SK 246,554. Permission to descend the mine was not forthcoming from the owners but an extensive selection of samples (fig. 4.4.11.1.) was collected in the 1960's by Dr. C.H.James of Leicester University and these were studied.

The mine worked complex galena - baryte mineralization associated with the base of dolomitisation (Ford and King, 1965). The host rocks are thickly bedded bioclastic limestones in the lower part of the Hoptonwood Group (Asbian(D_1)). The limestones are irregularly dolomitised to a porous dolomite, the base of which is not coincident with the bedding. Mineralization is more intense in an area of limestone protruding up into the dolomite and is associated with extensive post - mineralization cavernization at the same horizon (Ford and King, 1965 and 1966).

Many of the caverns were totally or partially

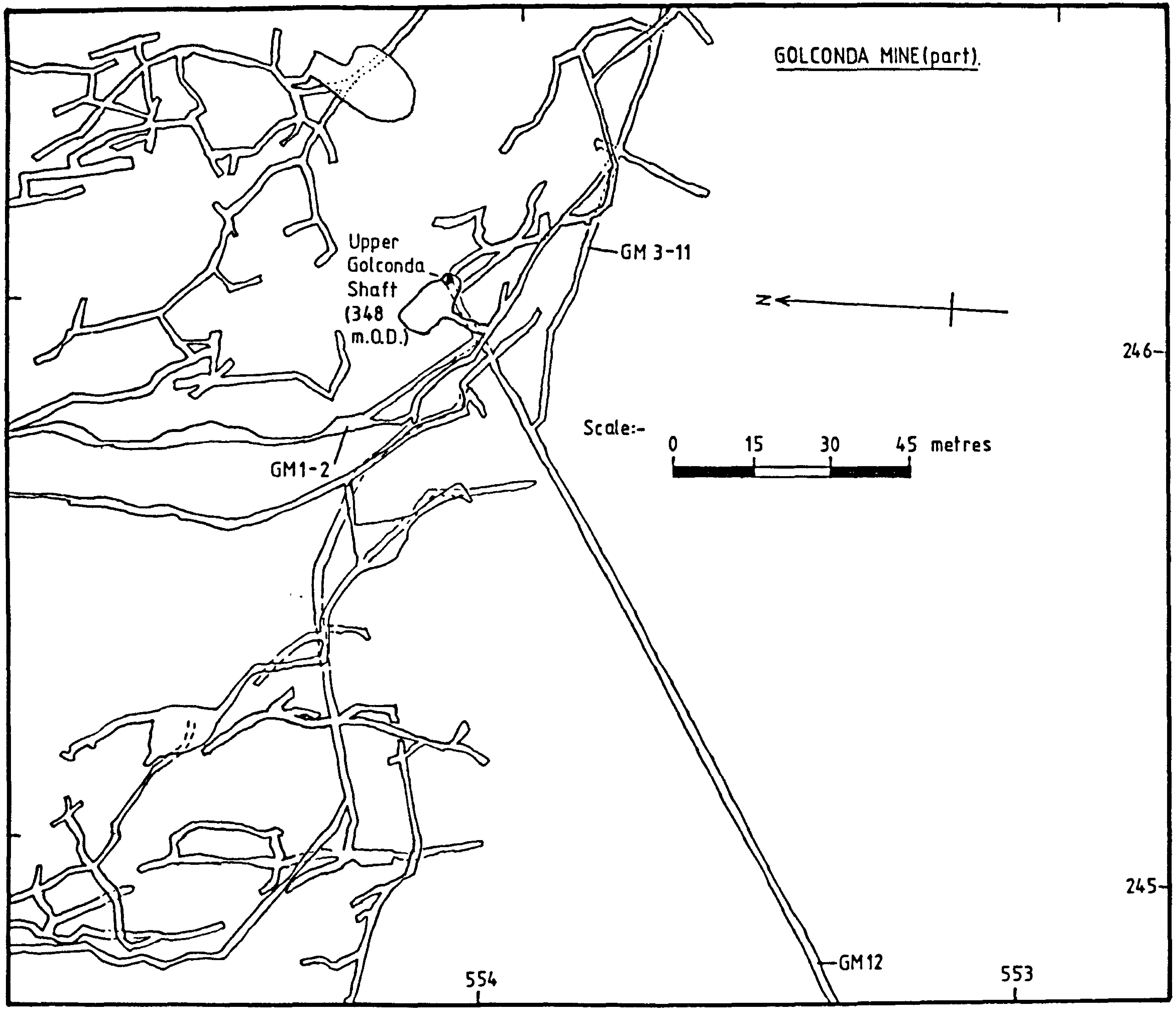


Figure 4.4.11.1. Plan of part of Golconda Mine showing sample locations.

filled with a sandy sediment when they were discovered. These deposits often contained locally derived mineralization which the miners extracted. The samples were obtained from smaller sedimentary deposits of similar nature. The overall composition of the sediments is given in figure 4.4.11.2..

Size analysis shows that the sediments are moderately sorted, slightly coarse - skewed, mesokurtic silty - sands (fig. 4.4.11.3.).

Ford and King (1965) noted that the basal layers of many of the sediment accumulations consisted of a placer deposit of angular baryte and galena gravel. No samples of this horizon are available for study.

The composition of the sands indicate that part of the sediment is dolomite sand locally derived by solutional disaggregation of the dolomite. The remainder of the sand is similar in composition to that found in the Brassington Formation sediments. They may have been deposited at the same time as the surface accumulation of these beds but it is more probable that they are the result of fluvial re - working of Brassington Formation deposits.

4.5. Conclusions

During the Tertiary era regional uplift started, followed by the recession of the Sherwood Sandstone scarp to the south exposing the underlying limestone and shale. In Mio - Pliocene times the area was probably a flat plain, with the Triassic scarp to the south of the

Sample Numbers GM1−12		
		%
1	Limestone	0 − 13
	Dolomite	3 − 27
	Volcanics	
	Chert	
	Silicified fossils	0 − 1·5
	Authigenic quartz	0 − 0·5
	Galena	0 − 3·5
	Fluorite	
	Baryte	0 − 16
	Calcite	0 − 3
2	Quartz	67 − 83
	Sandstone	0 − 1·5
	Feldspar	0 − 3
	Mica	0 − 0·5
	Shale	
	Quartzite	1 − 7
	Balance (mainly clay)	5 − 17
1 Autochthonous 2 Allochthonous		

Figure 4.4.11.2. Summary of sediment composition, Golconda Mine.

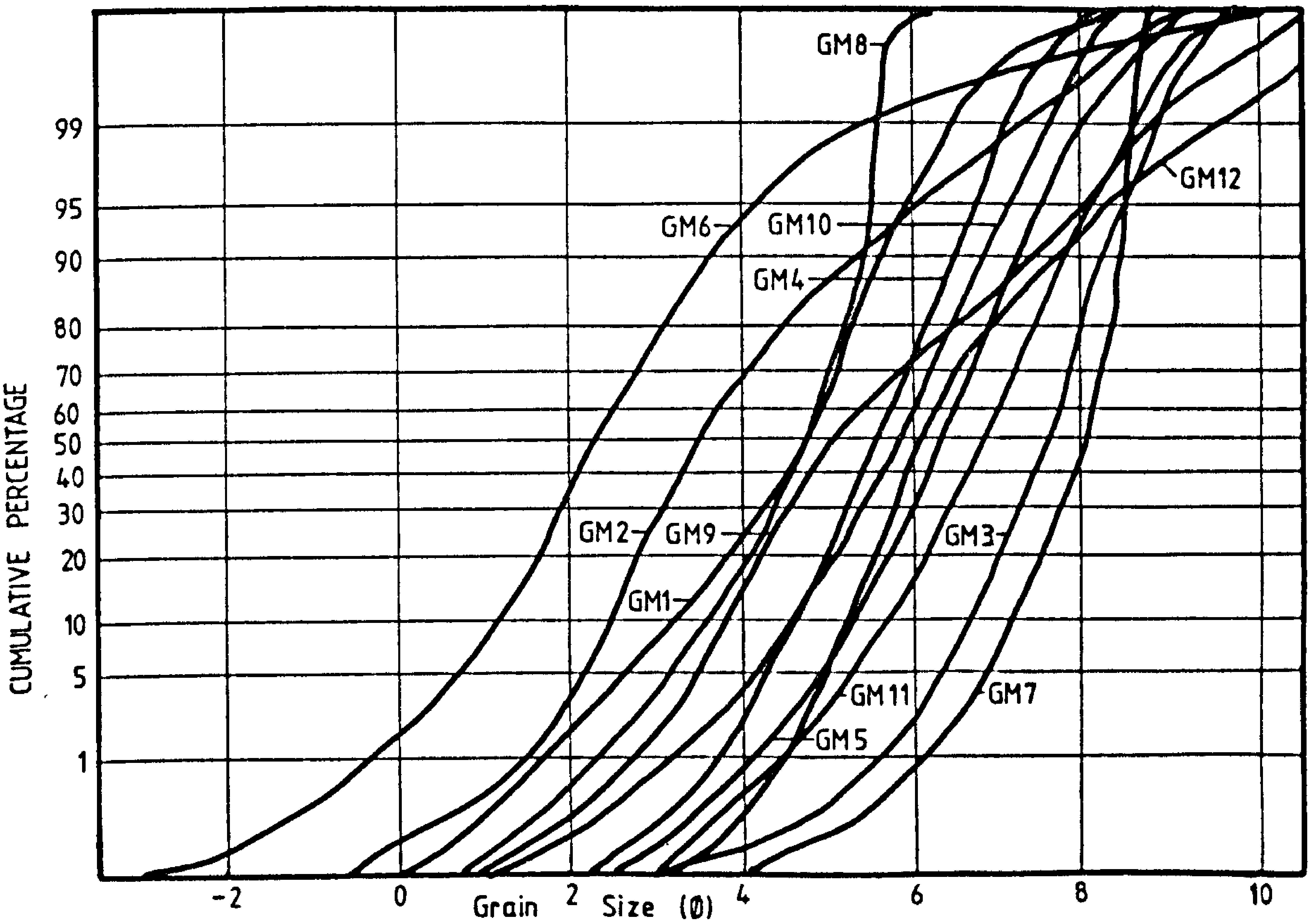


Figure 4.4.11.3. Sediment Size Analysis. Golconda Mine.

presently exposed limestone area, covered in Brassington Formation sediments (Walsh et al, 1980).

Once the limestone and dolomite areas were at least partly exposed, integrated underground drainage could occur. In the Wirksworth area the limestone is slightly domal (the Bole Hill Anticline) (Oakman, 1980) dipping south and east towards the shale cover and north towards Cromford and the Via Gellia. Underground drainage would have been extensively controlled by the dip of the limestone, the location of impermeable lava and wayboard horizons and the extensive system of mineral veins in the area. Phases of denudation may be related to high terrace remnant levels of the Derwent valley (Straw and Lewis, 1962) though these terraces have not been recognised in this area.

The composition of the sediments shows that they were derived from both autochthonous and allochthonous sources.

The autochthonous fraction of the sediments consists of locally derived fluorite, baryte and galena clasts with occasional limestone and chert clasts. Occasionally authigenic quartz grains derived from the limestone are also present.

The allochthonous fraction consists of quartz sand, silt and clay with larger shale and quartzite clasts derived from the Namurian shales and Triassic sediments to the south of the area.

Size analysis shows that the sediments are highly variable in nature, reflecting the diversity of the sources of the sediments and the processes of derivation.

S.E.M. studies show that the sediments have been derived by several processes including fluvial, fluvio - glacial and aeolian.

At Golconda Mine post mineralization solution led to the formation of an extensive network of underground cavities into some of which the Brassington Formation sagged. These cavities were partially filled by re - worked Brassington Formation sediments and autochthonous dolomite sand and baryte - galena gravel.

In Middle Peak Quarry derived Triassic pebbles and Namurian shale clasts contribute to the sediment fills of a number of phreatic tubes. Similar deposits occur, at a lower altitude, to the north - east in Middleton Mine and Ford (pers. comm., 1982) stated that another similar deposit occurs at the site of the crusher in Dene Quarry (SK 563,288), again at a lower altitude.

These may represent parts of a early underground drainage system draining the Triassic and Namurian sediments to the south - west of Wirksworth at an altitude of about 250 m. O.D.. This drainage network crossed the core of the Bole Hill Anticline, probably via a system of mineral vein controlled cavities, and resurged either in the Dene Hollow area (SK 290,563) at abot 175 m. O.D. or in a former, high level Via Gellia at a similar altitude to eventually drain to the Derwent. The fill of this drainage system is of fluvial origin and may pre - date glaciation in this area or may have been deposited during an inter - glacial phase. These sediments are similar to some of the horizons of the Brassington Formation and may be of similar age.

The isolated fluvial deposits of Ratchwood Mine may have been deposited from short lived streams draining isolated outliers of Namurian strata, perhaps sinking underground via the Gulf Fault.

Recently the area has received minor allogenic drainage and most of the ground water is of percolation origin. Many of the cavities studied in this area are apparently isolated and filled with fine - grained silty clay, sometimes with a proportion of the insoluble residue from the scrins on which many of these cavities are situated. Most of the cavities of this type are within 50 metres of the surface and have probably filled by the mechanism of translatory flow deriving the sediment from surface sheets of loessic material which were probably deposited during the Devensian.

5. STONEY MIDDLETON AREA

5.1. Introduction

This area extends from Eyam Edge in the north to Longstone Edge in the south, and from Foolow in the west to Calver in the east (see fig. 5.1.1.). The area contains a number of cave systems, both active and abandoned, and many disused lead mines. Some mines are still worked for fluorspar, including Sallet Hole Mine SK 219,741, Hanging Flats Mine SK 207,760 and Ladywash Mine SK 219,776), the latter on care and maintenance (1982).

The limestones in Stoney Middleton Dale are extensively quarried for roadstone and the dale has several working and disused limestone quarries.

5.2. Geological Setting

The area is situated in the north - east extremity of the Peak District Carboniferous Limestone Massif. The limestones are well bedded units of the Monsal Dale Group which are of Brigantian (D_2) age (Stevenson and Gaunt, 1971) and are overlain by Eyam Limestones. The Eyam Limestones are up to 50 metres thick and consist of dark, thin bedded, cherty limestones of (P_2) age (Stevenson and Gaunt, 1971; Aitkinhead and Chistholm, 1982). They rest unconformably on the underlying Monsal Dale Group Limestones. This unconformity is sometimes represented by a non-sequence (Shirley and Horsfield, 1945). The top 100 metres of these limestones is exposed (Beck, 1977) in the

Figure 5.1.1. Geological sketch map of the Stoney Middleton area.

□	Namurian sandstones and shales	
⁘	Eyam Limestone	Carboniferous Limestone
□	Monsall Dale Beds	
—	Mineral veins	

Key to localities

1 Ivy Green Cave
2 Carlswark Cavern
3 Merlin Mine
4 Nickergrove Mine
5 Streaks Pot
6 Hole-in-the-Wall
7 Lay-By Pot
8 Sallet Hole Mine
9 Ladywash Mine


9
1/2 km.
N
Eyam
4
6
7
5
3
2
1
to Stoney Middleton
8
Deep Rake

area and is unconformably overlain by Namurian sandstones and shales which form Eyam Edge and the country to the north and east. Interbedded with the limestones are a number of tuff and lava horizons of which the Litton Tuff (0-13m thick), the Upper Millers Dale Lava (0-30m thick) and the Cresbrookdale Lava are the most prominent.

The limestone is almost horizontally bedded with slight dips to the north and east. The exception to this is the Longstone Edge area where the limestones are folded into a monocline with an east - west trend and the steep limb facing south (Ford, 1968).

Mineralization in the area is variable, with major rakes beneath Eyam Edge (Hucklow Edge Vein) and Longstone Edge (Watersaw Rake, High Rake, Longstone Edge Vein and Deep Rake), the area between contains numerous scrins. The rakes have an east - west trend while the scrins generally have a northeast - southwest trend. The mineralization consists of banded fluorite, baryte, calcite and galena with minor pyrite and sphalerite (Worley, 1978).

Between Stoney Middleton Dale and the northern limit of the limestone outcrop at the base of Eyam Edge cave systems are well developed. Allogenic streams from Eyam Edge flow onto the limestone where most of them sink. Underground drainage is then via a series of underground networks to resurge in Stoney Middleton Dale (Beck, 1980). This drainage network was intersected by Moorwood Sough, commenced in 1750 (Rieuwerts, 1966), and this now takes most of the drainage from this area under normal flow conditions. In flood conditions the sough is unable to cope with the quantity of water and the overflow resurges from several points in the lower part of Stoney Middleton Dale and from Carlswark Cavern SK 221,758 (Beck, 1980).

The lower part of this drainage system shows the development of caves at a number of horizons, only the lowest now occupied by a stream, which reflect changes in base level controlled by events in the latter part of the Pleistocene (Beck, 1977). The area was glaciated during the Wolstonian and probably earlier glaciations and the dry valley network, including Stoney Middleton Dale, has largely been incised since then (Beck, 1977).

5.3. Types of Deposit

The majority of sites sampled are in the cave systems under the northern side of Stoney Middleton Dale, many of which intersect some of the scrins present in the area. Beck (1975, 1977 and 1980) has recognised four horizons of cave development, related to former water table levels and lithological controls of the limestones and has outlined their speleogenesis.

As each passage was abandoned and the streams developed lower drainage networks, the abandoned passages were silted by flood waters re-invading them when the new channels could not cope with the discharge. A sequence of phases of roof breakdown, silting, speleothem development and re-erosion have been postulated by Beck (1975).

By these processes many of the abandoned cave passages in this area were filled with surface derived sediment, sometimes with locally derived limestone and mineral vein pebbles.

As a result of centuries of lead and, more recently fluorspar, mining and exploration, many of these deposits have been partially excavated, but since they usually contain little or no galena parts of the deposits remain relatively undisturbed. In fact many of the cave systems in this area have been discovered or extended by mining activity.

5.4. Sites Studied

5.4.1. Ivy Green Cave

Ivy Green Cave is a heavily silted phreatic tube situated at SK 2224,7580 (fig. 5.4.1.1.). It forms part of Beck's (1975 and 1980) Second Remnant Complex. The cave is developed in limestones of the Upper Monsal Dale Beds.

Some of the sedimentary fill of this cave was removed during attempts to extend the cave which may connect to part of Carlswark Cavern (Noble, 1975).

The sediment fill of the tube is finely laminated yellow/brown silty - clay. The composition of the sediment is given in figure 5.4.1.2..

Size analysis shows that the sediments are well sorted, slightly coarse - skewed, leptokurtic clayey silts (fig. 5.4.1.3.). The results of S.E.M. analysis of quartz grain surface textures show that they are of fluvial origin (fig. 5.4.1.4.).

The composition of these sediments show that they were derived from the Namurian strata to the north. The presence of small shale clasts indicates that the sediment

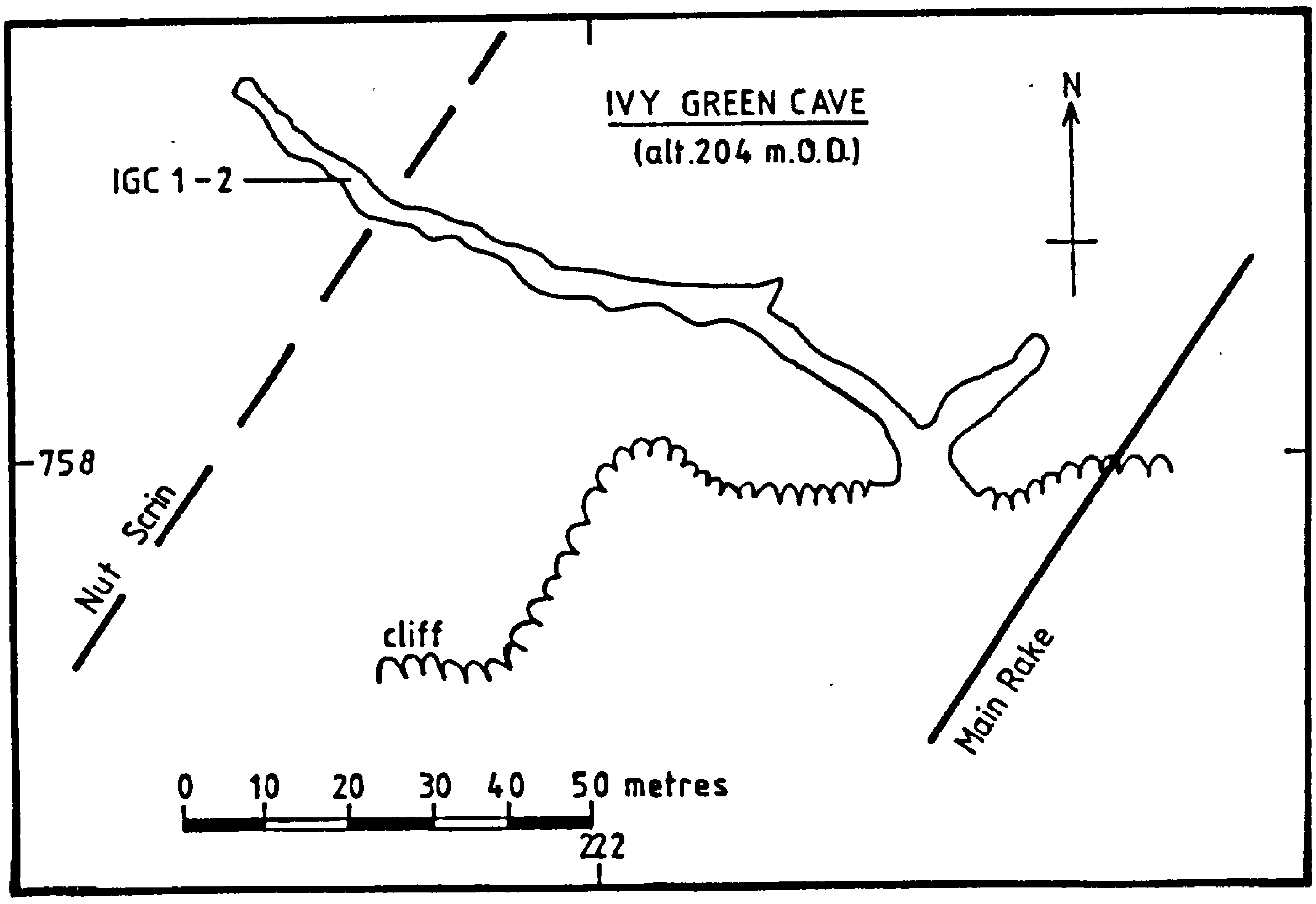


Figure 5.4.1.1. Plan of Ivy Green Cave showing sample locations. After Beck (1975).

Sample Numbers IGC 1−2		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	0 − 1·5
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	0 − 0·5
	Calcite	
2	Quartz	38 − 43
	Sandstone	21 − 28
	Feldspar	1 − 1·5
	Mica	4 − 6·5
	Shale	7 − 13
	Quartzite	
	Balance (mainly clay)	13 − 24
1 Autochthonous 2 Allochthonous		

Figure 5.4.1.2. Summary of sediment composition,
Ivy Green Cave.

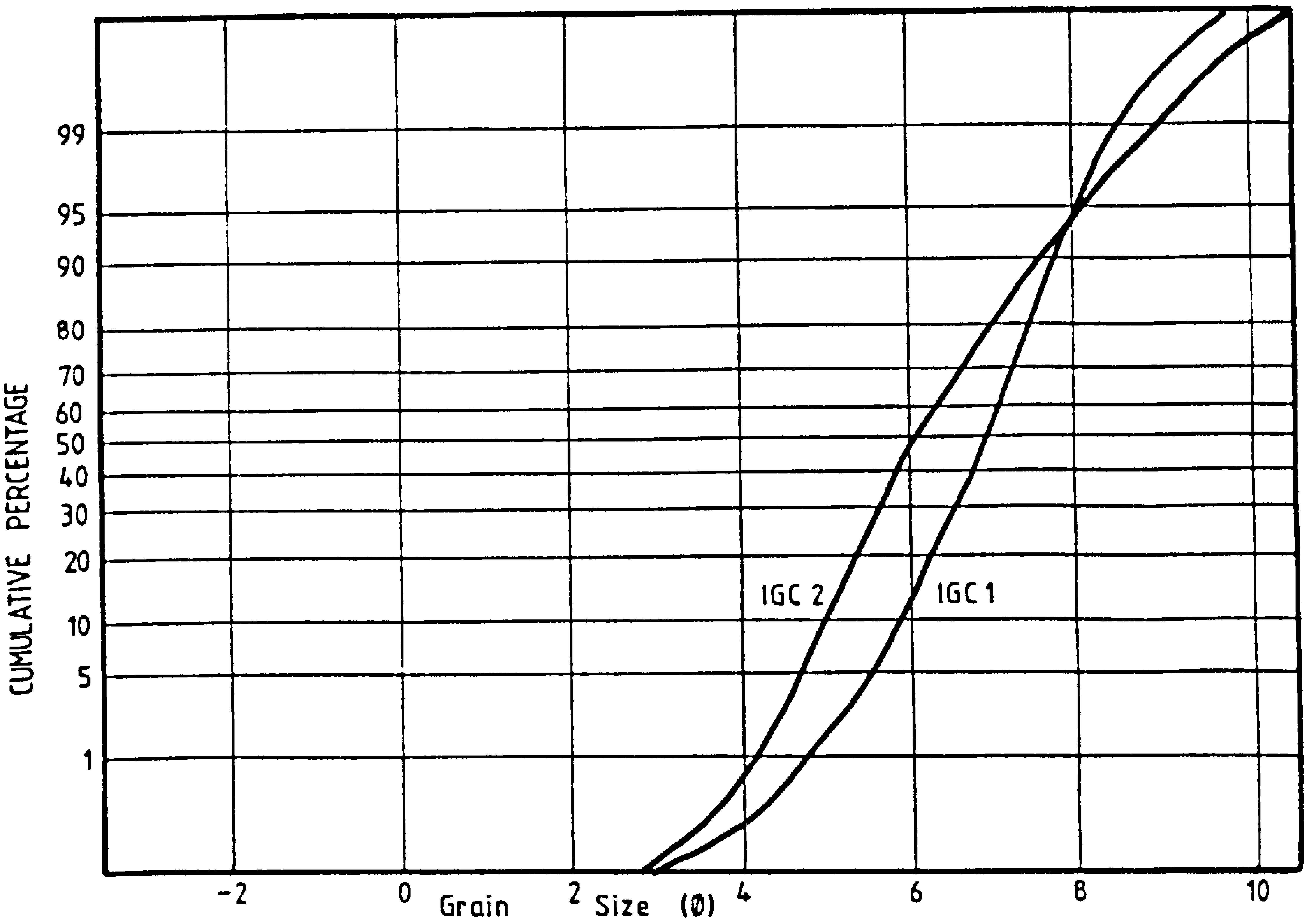


Figure 5.4.1.3. Sediment Size Analysis. Ivy Green Cave.

Surface Features	Chemical	Euhedral silica		
		Amorphous silica	●	●
		Solution crevasses	●	●
		Solution pits		●
		Oriented etch pits	●	●
	Loessic	Dulled surface		●
		Smooth surface	●	
		Rounded	◪	●
		Dish-shaped pits		
	Fluvial	Subangular	◪	●
		Subrounded	◪	■
		Mechanical V-pits	■	■
		Curved scratches	◪	◪
		Straight scratches	●	◪
	Glacial	Chattermarks		
		Angular	●	●
		Fracture plates	●	●
		Adhering particles		
		Imbricate grinding		
		Parallel striations		
		Conchoidals >10µ	●	◪
		Conchoidals <10µ	●	●
		Breakage blocks>10µ		
		Breakage blocks<10µ		
	General	Euhedral quartz		
		Scaling	●	●
		High relief	◪	●
		Medium relief	◪	◪
		Low relief	◪	◪
		Meandering ridges	●	●
		Arcuate steps	●	
		Straight steps	●	●
		Edge abrasion	◪	●
		Grain breakage	●	
		Sample number IGC	1	2

■ Abundant – 75%
◪ Common 25-75%
● Present 1-25%
☐ Absent – 1%

Figure 5.4.14. Summary of quartz grain surface textures, Ivy Green Cave.

was not in the fluvial environment for long and therefore that the source was fairly close to the cave. The fine - grained nature of these sediments indicates that they were deposited by floodwaters in an area of limited or non-existent flow.

5.4.2. Carlswark Cavern

The most used entrance to this extensive cave system is at SK 221,758. Carlswark Cavern is an extensive complex of strike - oriented phreatic tubes with smaller connecting dip tubes (fig. 5.4.2.1.). The cave system covers all four of Beck's (1975 and 1980) development levels, the majority of the system belonging to the Carlswark Complex level. This level is the most recently abandoned and parts of it still carry flood flows.

The speleogenesis of the cave system has been described by King (1962) and Beck (1975) and a modern survey has been produced by Chistopher and Beck (1977).

The Carlswark Complex level is developed in Upper Monsal Dale Limestones immediately below the lower shell bed. This shell bed is up to 3 metres thick, composed of silicified productid shells in a fine - grained matrix (Stevenson and Gaunt, 1971).

All the sites sampled in Carlswark Cavern are sediment - filled phreatic tubes belonging to Beck's Carlswark Complex Level (Beck 1975 and 1980).

At all three sample sites the cave passages were filled to the roof with sediment and all had a thin (~1cm thick) stalagmite layer in the sediments (fig. 5.4.2.2.).

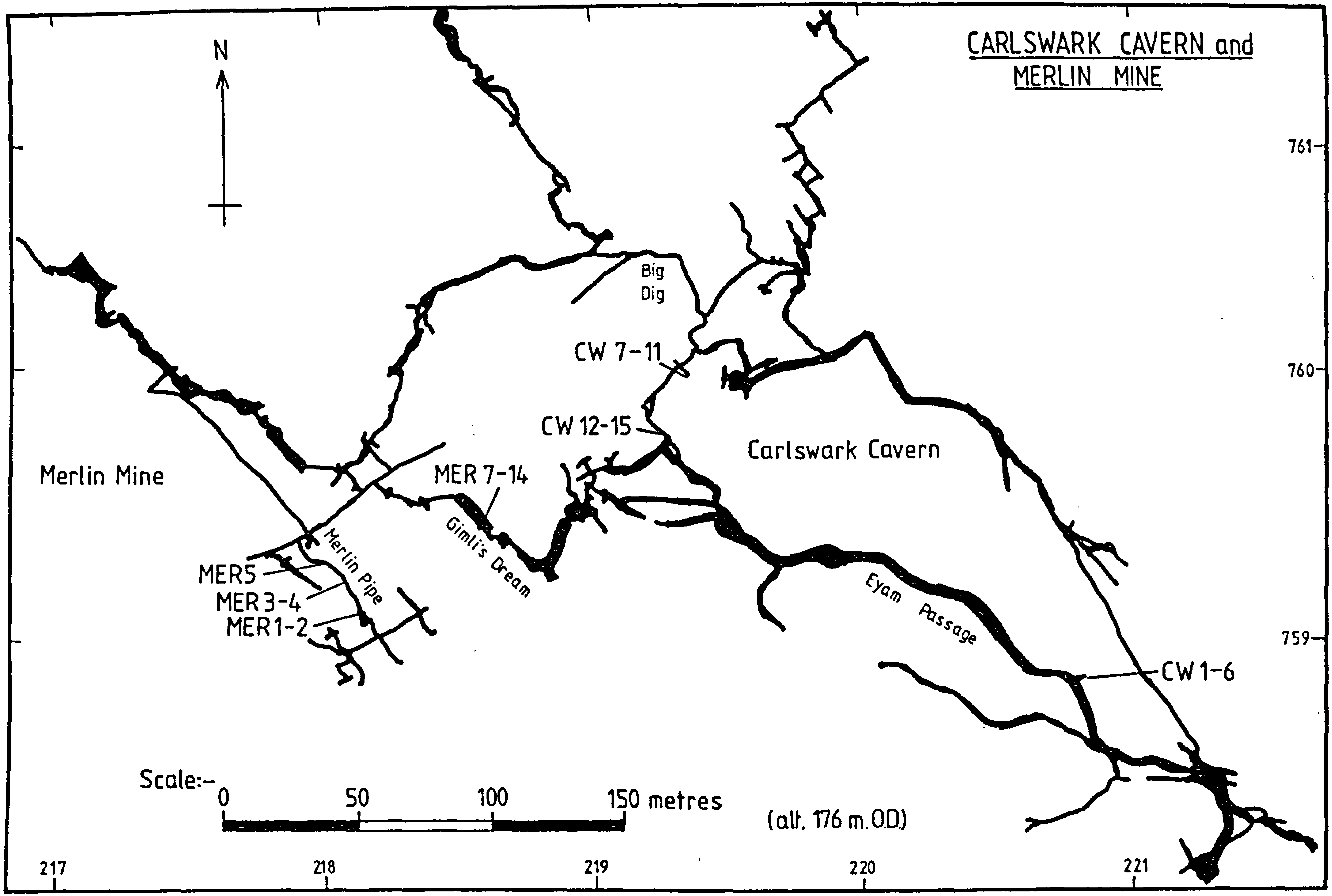


Figure 5.4.2.1. Plan of Carlswark Cavern and Merlin Mine showing sample locations. After Christopher and Beck (1977) and Beck (1979).

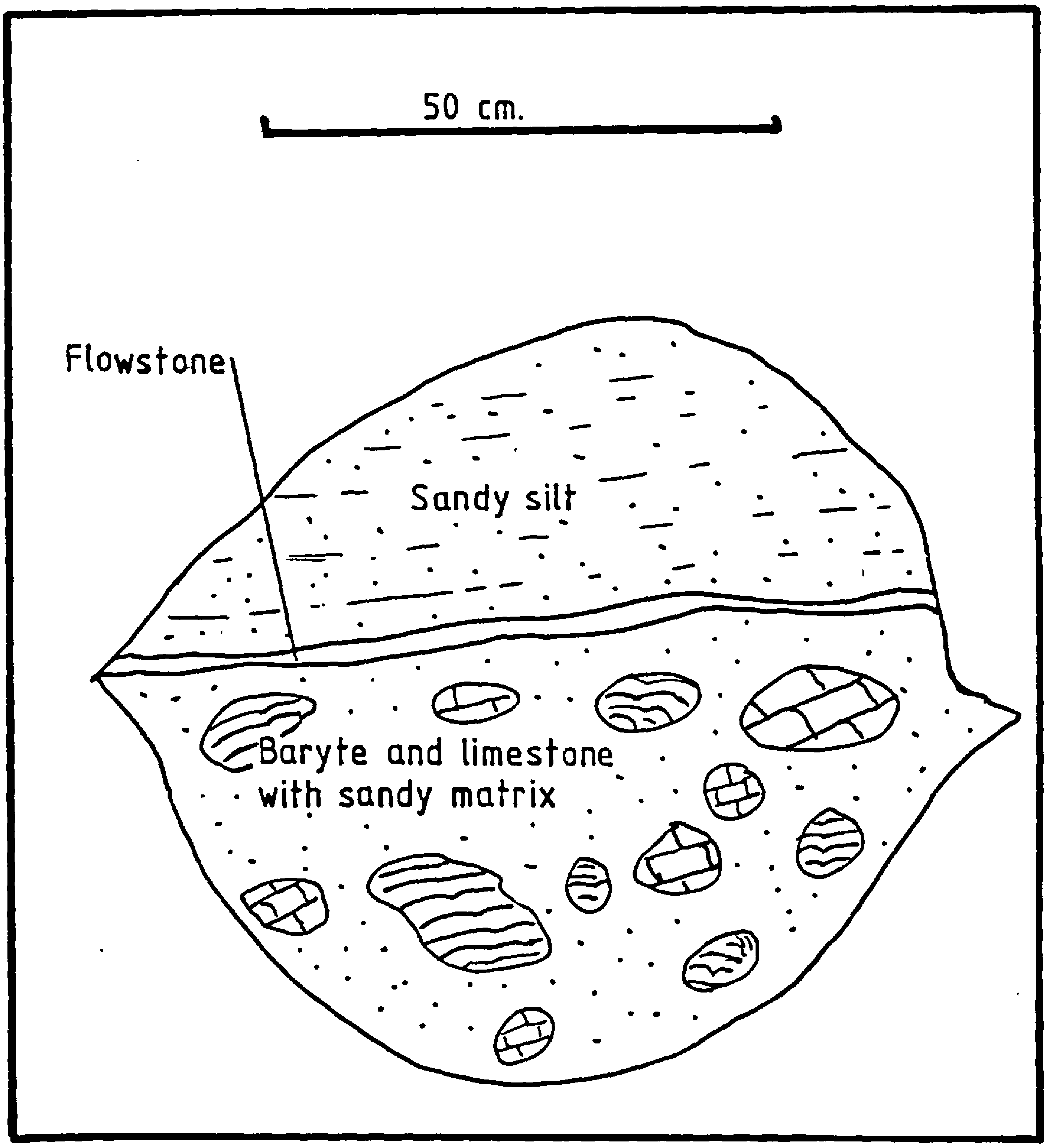


Figure 5.4.2.2. Sediments, Carlswark Cavern.

The sediments below the stalagmite layers are pebbly sands. The pebbles are well rounded baryte and limestone. Their overall composition is given in figure 5.4.2.3.. The results of S.E.M. analysis of quartz grain surface textures show that they are fluvially derived (fig. 5.4.2.4.), some still showing characteristics (Wilson, 1978) of their Namurian sandstone source (plate 5.4.2.1.).

The results of size analysis show that the sediments are moderately sorted, slightly coarse - skewed, platykurtic silty - pebbly - sands (fig. 5.4.2.5.).

The sediments above the stalagmite layers are sandy silts and do not contain baryte or limestone pebbles. The composition of these sediments is given in figure 5.4.2.6.. The results of S.E.M. analysis of quartz grain surface textures show that they are again fluvially derived (fig. 5.4.2.7.).

The results of sediment size analysis show that the sediments are well sorted, mesokurtic sandy - silts (fig. 5.4.2.8.).

The composition and character of these sediments indicate that they have been derived from Namurian sediments, from the north and northwest.

As the sediments below the stalgmite layer contain pebbles of limestone and baryte and are coarse grained, they were probably deposited by fast flowing floodwater. The overlying fine - grained sediments have a more uniform grain size and were deposited by more static floodwater as the Lower Complex Level (the presently active level) of Beck (1975 and 1980) became better established.

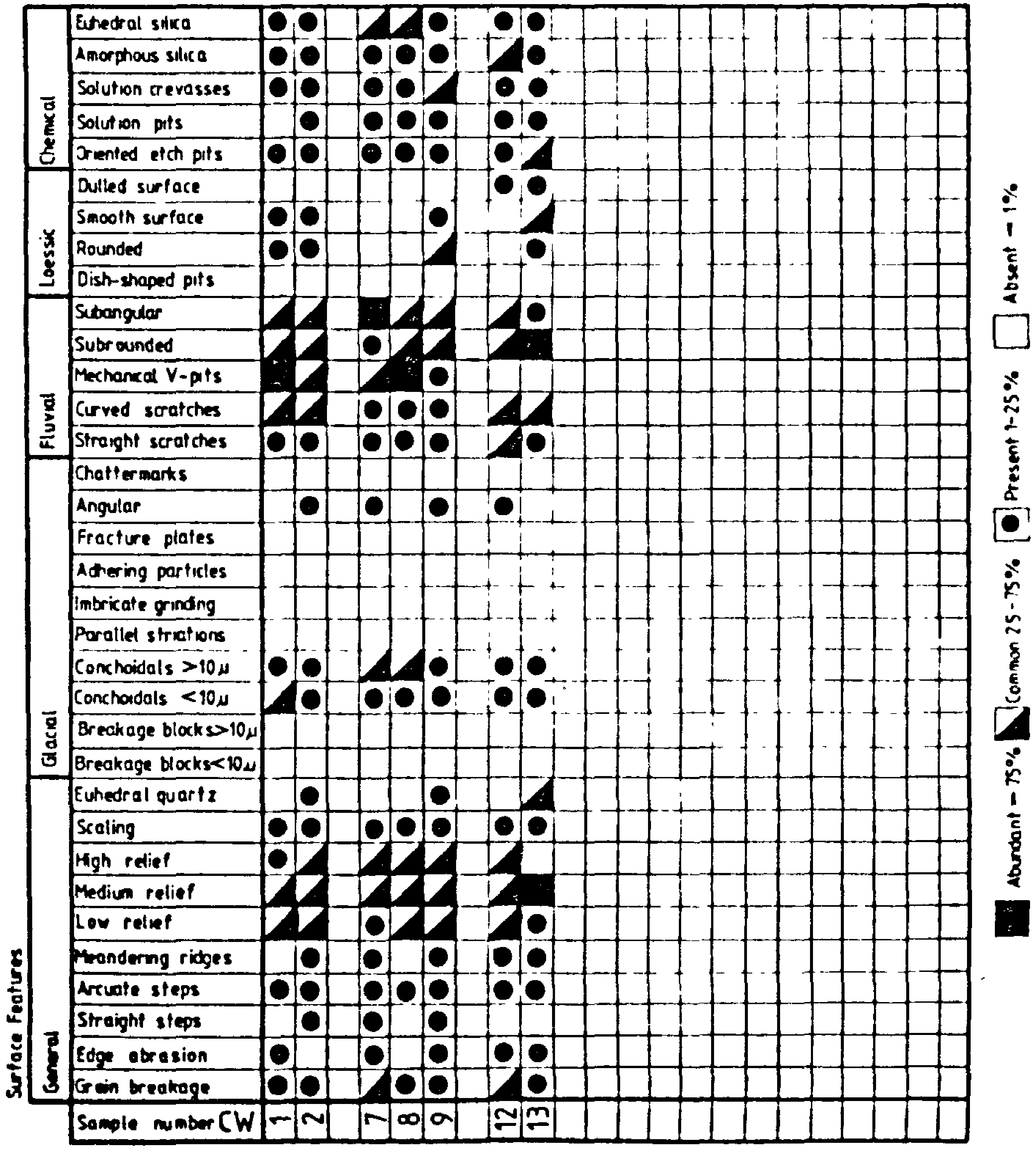
There may be close correlation of these sediments

Sample Numbers CW 1–2, 7–9, 12–13		
		%
1	Limestone	12 – 15
	Dolomite	
	Volcanics	
	Chert	0 – 1·5
	Silicified fossils	3·5 – 7·5
	Authigenic quartz	0 – 2
	Galena	0 – 0·5
	Fluorite	
	Baryte	7 – 23
	Calcite	3 – 6
2	Quartz	36 – 49
	Sandstone	12 – 25
	Feldspar	35 – 9
	Mica	4 – 6·5
	Shale	2·5 – 8
	Quartzite	
	Balance (mainly clay)	17 – 32

1 Autochthonous 2 Allochthonous

Clay Mineralogy	
	%
Illite	46 – 53
Kaolinite	29 – 32
Chlorite	4 – 7
Mixed layer smectites	6 – 10

Figure 5.4.2.3. Summary of sediment composition, Carlswark Cavern.



Surface Features										
Chemical	Euhedral silica	●	●		◢	◢	●		●	●
	Amorphous silica	●	●		●	●	●		◢	●
	Solution crevasses	●	●		●	●	◢		●	●
	Solution pits		●		●	●	●		●	●
	Oriented etch pits	●	●		●	●	●		●	◢
Loessic	Dulled surface								●	●
	Smooth surface	●	●				●			◢
	Rounded	●	●				◢			●
	Dish-shaped pits									
Fluvial	Subangular	◢	◢		■	◢	◢		◢	●
	Subrounded	◢	◢		●	◢	◢		◢	■
	Mechanical V-pits	■	◢		◢	■	●			
	Curved scratches	◢	◢		●	●	●		◢	◢
	Straight scratches	●	●		●	●	●		◢	●
Glacial	Chattermarks									
	Angular		●		●		●		●	
	Fracture plates									
	Adhering particles									
	Imbricate grinding									
	Parallel striations									
	Conchoidals >10μ	●	●		◢	◢	●		●	●
	Conchoidals <10μ	◢	●		●	●	●		●	●
	Breakage blocks>10μ									
	Breakage blocks<10μ									
General	Euhedral quartz		●				●			◢
	Scaling	●	●		●	●	●		●	●
	High relief	●	◢		◢	◢	◢		◢	
	Medium relief	◢	◢		◢	◢	◢		◢	■
	Low relief	◢	◢		●	◢	◢		◢	●
	Meandering ridges		●		●		●		●	●
	Arcuate steps	●	●		●	●	●		●	●
	Straight steps		●		●		●			
	Edge abrasion	●			●		●		●	●
	Grain breakage	●	●		◢	●	●		◢	●
	Sample number CW	1	2		7	8	9		12	13

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 5.4.2.4. Summary of quartz grain surface textures, Carlswark Cavern.

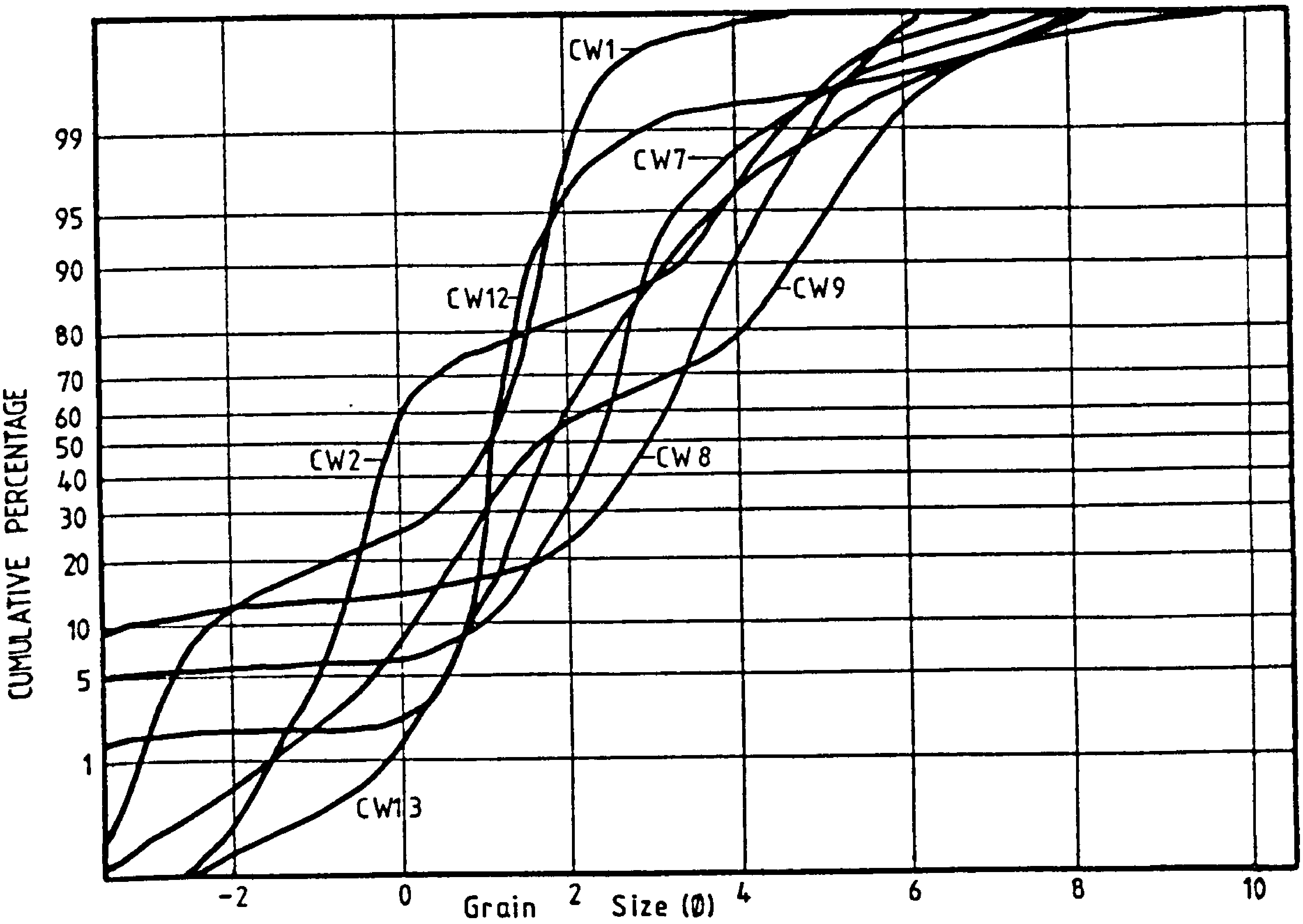


Figure 5.4.2.5. Sediment Size Analysis. Carlswark Cavern.

Sample Numbers CW 3-6, 10-11, 14-15

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	1 — 2·5
	Authigenic quartz	1·5 — 2·5
	Galena	
	Fluorite	
	Baryte	0 - 2
	Calcite	
2	Quartz	53 — 63
	Sandstone	9 — 14
	Feldspar	3 — 5
	Mica	6 — 10
	Shale	1 — 3·5
	Quartzite	
	Balance (mainly clay)	4 — 11

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	44 — 50
Kaolinite	31 — 35
Chlorite	4 — 9
Mixed layer smectites	5 — 9

Figure 5.4.2.6. Summary of sediment composition,

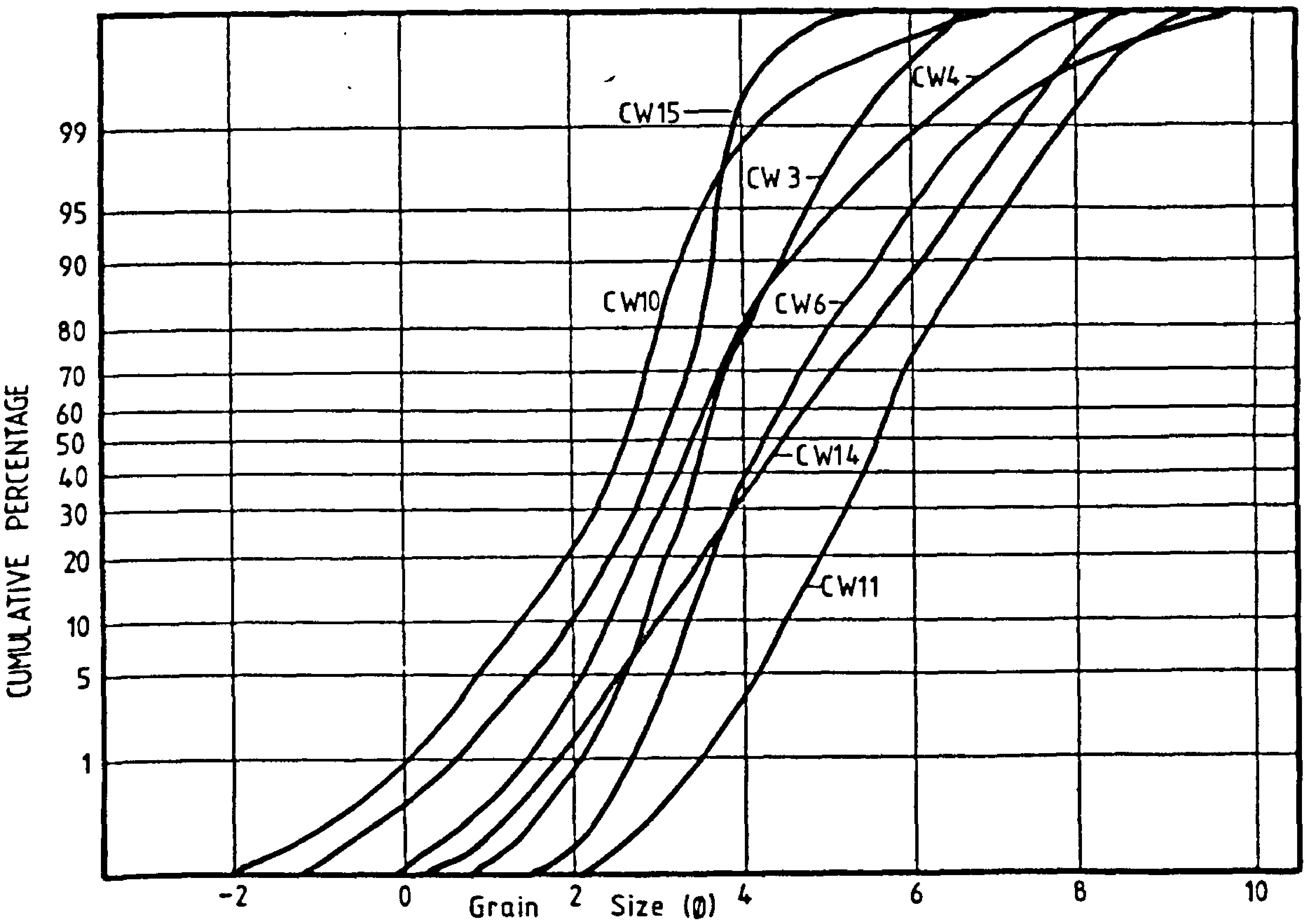
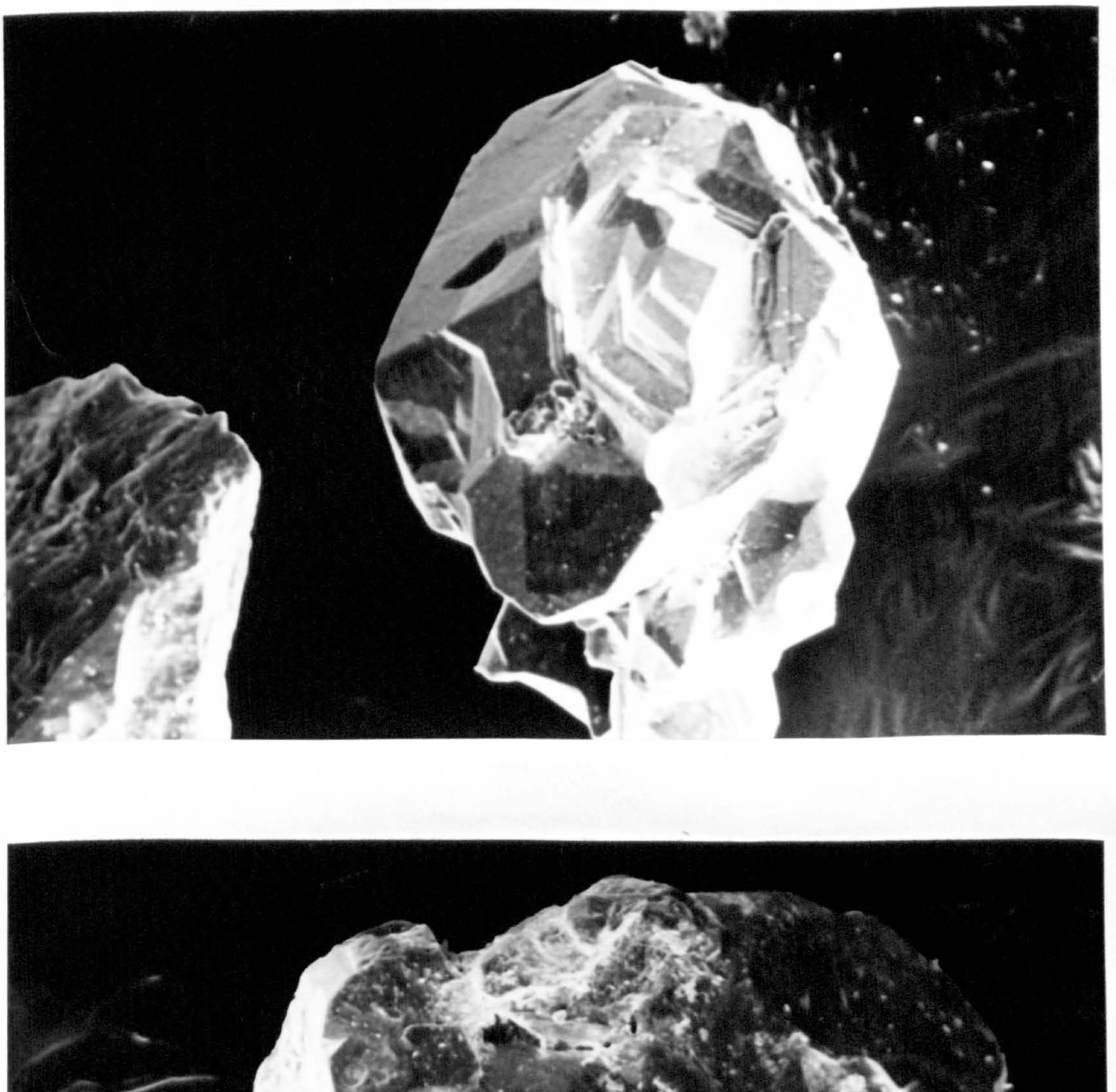


Figure 5.4.2.8. Sediment Size Analysis. Carlswark Cavern.

Chemical	Euhedral silica	●	●		●			●	●
	Amorphous silica		●		●	●		●	
	Solution crevasses	●			●			●	
	Solution pits	●	●		●			●	●
	Oriented etch pits	●			●	●		●	
Loessic	Dulled surface		●						
	Smooth surface		●			●			●
	Rounded	●	●		●	●		●	●
	Dish-shaped pits								
Fluvial	Subangular	◢	●		◢	◢		◢	◢
	Subrounded	◢	■		◢	◢		◢	◢
	Mechanical V-pits	◢	■		◢	◢		◢	◢
	Curved scratches	●	●			●		●	●
	Straight scratches	●			●	●		●	
Glacial	Chattermarks								
	Angular	●				●		●	
	Fracture plates								
	Adhering particles								
	Imbricate grinding								
	Parallel striations								
	Conchoidals >10μ	●	●		●	●		●	◢
	Conchoidals <10μ	◢	◢		●	●		●	●
	Breakage blocks>10μ								
	Breakage blocks<10μ								
Surface Features General	Euhedral quartz		●		●	●		●	
	Scaling	●	●		◢	●		●	●
	High relief	●			◢	●		◢	◢
	Medium relief	◢	●		◢	◢		◢	◢
	Low relief	◢	■		◢	◢		◢	◢
	Meandering ridges	●	●		●	●		●	
	Arcuate steps	●	●		●	●		●	●
	Straight steps		●		●				
	Edge abrasion	●			●	●			
	Grain breakage	●	●		●	◢			
	Sample number CW	3	6		10	11		14	15

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 5.4.2.7. Summary of quartz grain surface textures, Carlswark Cavern.



5.4.2.1. S.E.M. photomicrographs of quartz grains derived fron nearby Namurian sandstone, Carlswark Cavern.

and stalagmite layers with those described by Beck (1977) in the Gimli's Dream part of the Carlswark System accessible from Merlin Mine (see next section).

In the Big Dig (see fig. 5.4.2.1.) a well laminated sandy sediment which filled the cave passage to the roof was thought to be of fluvio - glacial origin (Beck, 1977). Excavation of the sediment, up to 2.5 metres thick, during attempts to extend the cave revealed early eighteenth century miners timbers on the floor of the passage indicating that silting by flood water had occurred since that date (Beck, 1977).

5.4.3. Merlin Mine

Merlin Mine, at SK 218,759, is developed along a number of scrins, the working of which broke into a series of natural passages (Rieuwerts, 1960). These form the western end of the Carlswark System (fig. 5.4.2.1.). The only passable link between the two cave systems is blocked because it was found to be unstable.

Two sites were sampled in Merlin Mine. The first was a number of small solutional pockets on the line of Merlin Pipe and the second was the sediment in the large phreatic tube of Gimli's Dream, some 20 metres lower.

Merlin Pipe is a discontinuous pipe vein, probably developed along a scrin, trending northwest - southeast. It has been followed by lead miners for a distance of nearly 100 metres. Mineralization consists of cavity linings of baryte and calcite, with occasional nonpersistant galena adjacent to the limestone wall rocks.

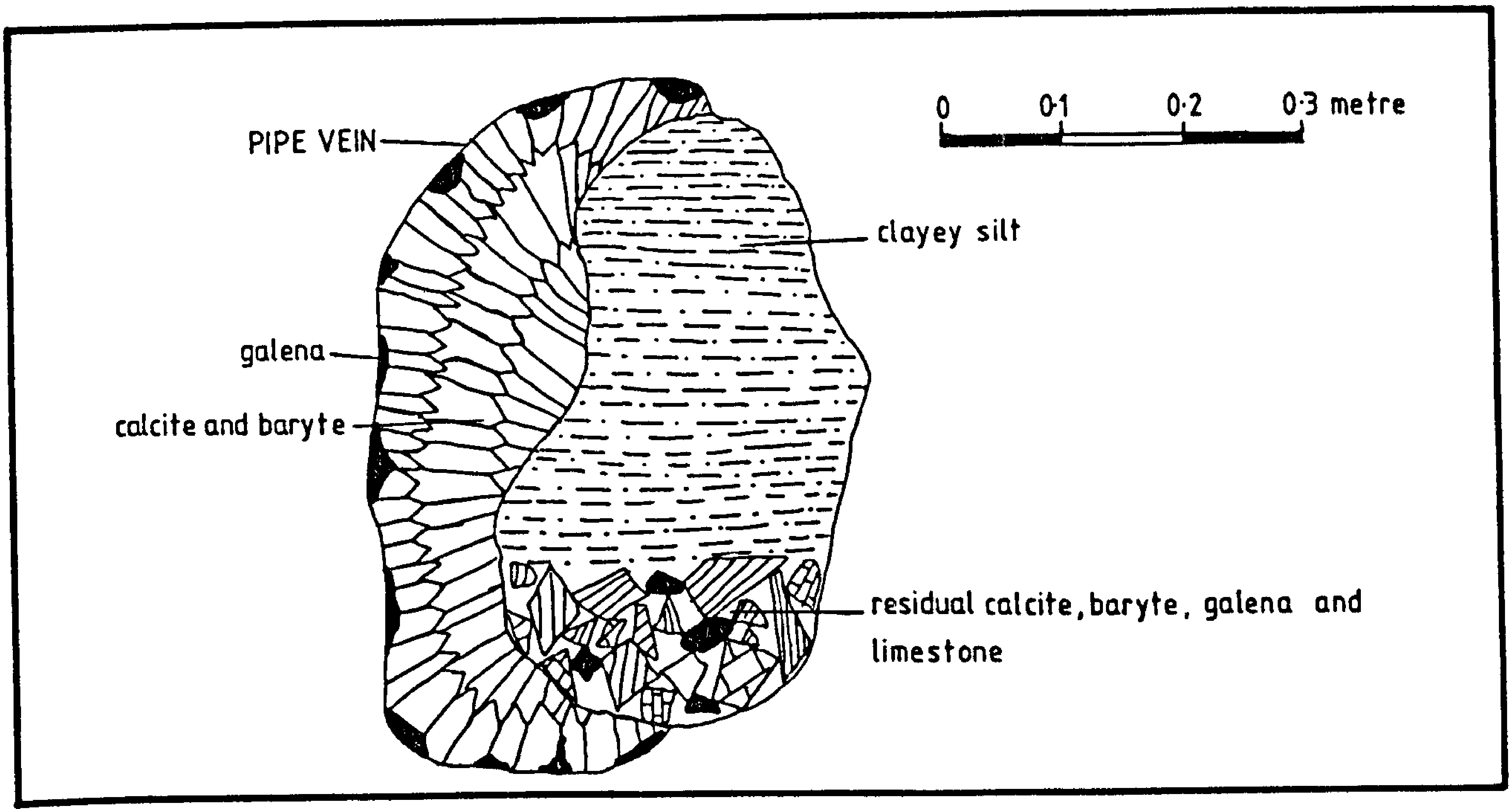


Figure 5.4.3.1. Merlin Pipe, Merlin Mine.

Sample Numbers MER 1 – 5		
		%
1	Limestone	7 – 12
	Dolomite	
	Volcanics	
	Chert	0·5 – 3
	Silicified fossils	0 – 2·5
	Authigenic quartz	1 – 2
	Galena	0 – 1·5
	Fluorite	
	Baryte	2 – 4·5
	Calcite	3 – 5·5
2	Quartz	33 – 57
	Sandstone	
	Feldspar	
	Mica	3 – 6
	Shale	
	Quartzite	
	Balance (mainly clay)	31 – 46
1 Autochthonous 2 Allochthonous		
Clay Mineralogy MER 1 & 4		
		%
	Illite	39 – 52
	Kaolinite	28 – 35
	Chlorite	14 – 21
	Mixed layer smectites	5 – 9

Figure 5.4.3.2. Summary of sediment composition,

Surface Features — Chemical	Euhedral silica	●	●
	Amorphous silica	●	●
	Solution crevasses	●	●
	Solution pits	●	●
	Oriented etch pits		●
Loessic	Dulled surface	◢	●
	Smooth surface	◢	●
	Rounded	◢	●
	Dish-shaped pits	●	
Fluvial	Subangular	●	◢
	Subrounded	◢	◢
	Mechanical V-pits	◢	■
	Curved scratches	●	◢
	Straight scratches	●	●
Glacial	Chattermarks		
	Angular		●
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10μ		
	Conchoidals <10μ	●	
	Breakage blocks>10μ		
	Breakage blocks<10μ	●	
General	Euhedral quartz	●	●
	Scaling	●	◢
	High relief	●	●
	Medium relief	●	◢
	Low relief	■	◢
	Meandering ridges	●	
	Arcuate steps	●	●
	Straight steps	●	●
	Edge abrasion	●	●
	Grain breakage	●	
	Sample number MER	1	5

■ Abundant – 75%
◢ Common 25 - 75%
● Present 1-25%
□ Absent – 1%

Figure 5.4.3.3. Summary of quartz grain surface textures, Merlin Pipe, Merlin Mine.

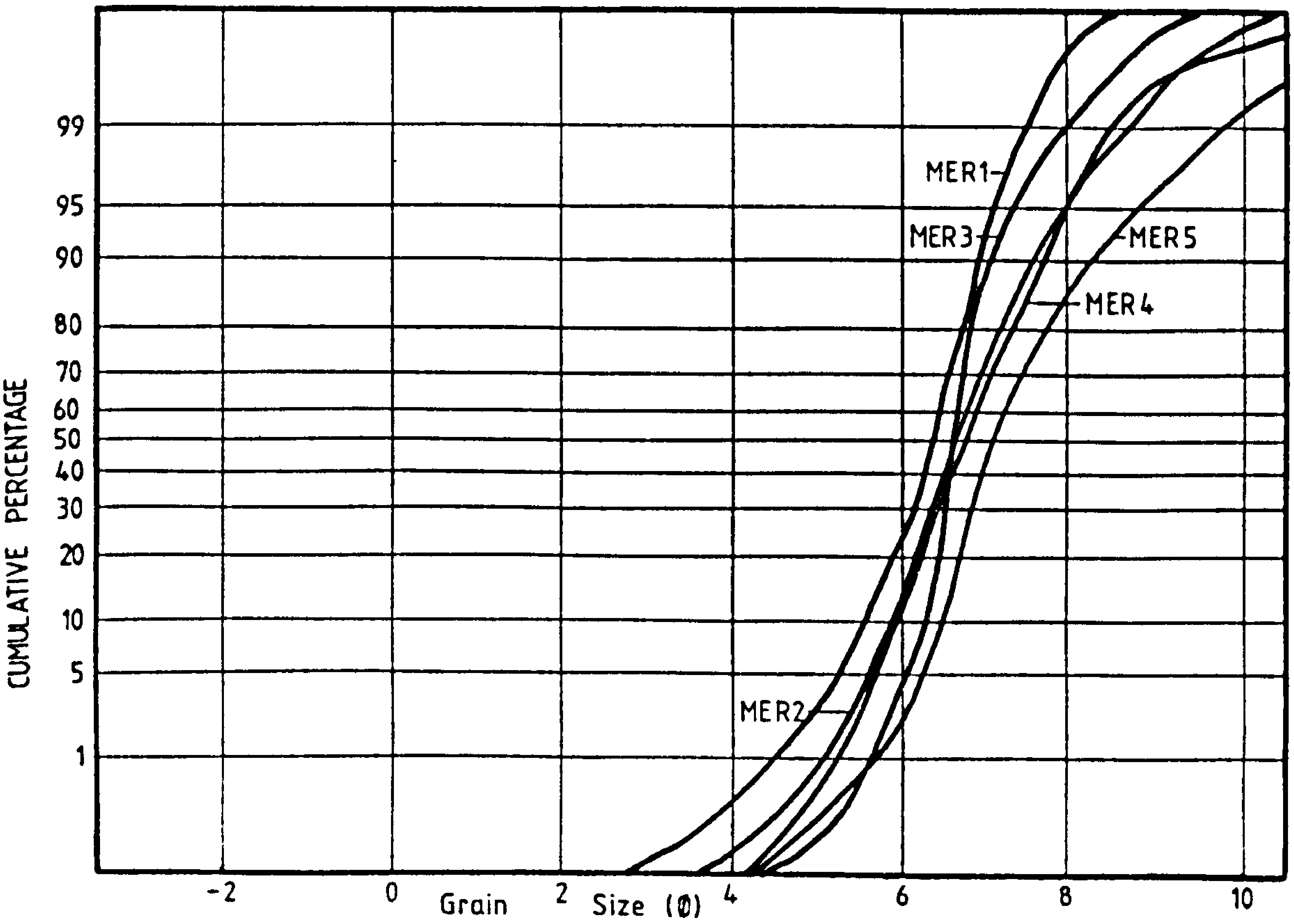


Figure 5.4.3.4. Sediment Size Analysis. Merlin Pipe, Merlin Mine.

of pebbles, gravel, sand and silt.

The overall composition of the sediment is given in figure 5.4.3.5.. Size analysis shows that the sediments are moderately sorted, coarse - skewed, mesokurtic pebbly sands and silts (fig. 5.4.3.6.). The results of S.E.M. analysis of quartz grain surface textures show that the sediments are of fluvial origin (fig. 5.4.3.7.).

These fining upwards sequences probably represent flood deposits laid down soon after the abandonment of this part of the cave as an active drainage route. The deposit is overlain by a stalagmite layer, with a maximum thickness of 35 cm., which was subsequently cut through by a later, vadose, invasion (Beck, 1977b). This re-invasion by a stream, though long enough to erode through the stalagmite layer and to excavate a trench through the sediments to the floor of the phreatic passage, did not survive long enough to cut a trench into the limestone. This stream may have existed at intervals of high water flow as the Lower Complex drainage network evolved.

The sediments in Gimli's Dream are derived from the Namurian strata, as shown by their shale and sandstone content, by fluvial processes and receive a local contribution from the limestone and its mineral veins.

5.4.4. Nickergrove Mine

Situated on the west side of The Delf at SK 2155,7595 this mine, which was worked for lead in the eighteenth and nineteenth centuries, intersects a number of natural cavities (fig. 5.4.4.1.).

Sample Numbers MER 7 - 9		
		%
1	Limestone	0 — 5
	Dolomite	
	Volcanics	
	Chert	0 — 2·5
	Silicified fossils	0 — 1
	Authigenic quartz	0 — 0·5
	Galena	
	Fluorite	0 — 0·5
	Baryte	0 — 2
	Calcite	0 — 1
2	Quartz	40 — 57
	Sandstone	16 — 29
	Feldspar	1 — 3
	Mica	5 — 8
	Shale	1 — 3·5
	Quartzite	
	Balance (mainly clay)	15 — 25
1 Autochthonous	2 Allochthonous	

Clay Mineralogy

	%
Illite	47 — 53
Kaolinite	28 — 34
Chlorite	13 — 15
Mixed layer smectites	6 — 8

Figure 5.4.3.5. Summary of sediment composition, Gimli's Dream, Merlin Mine.

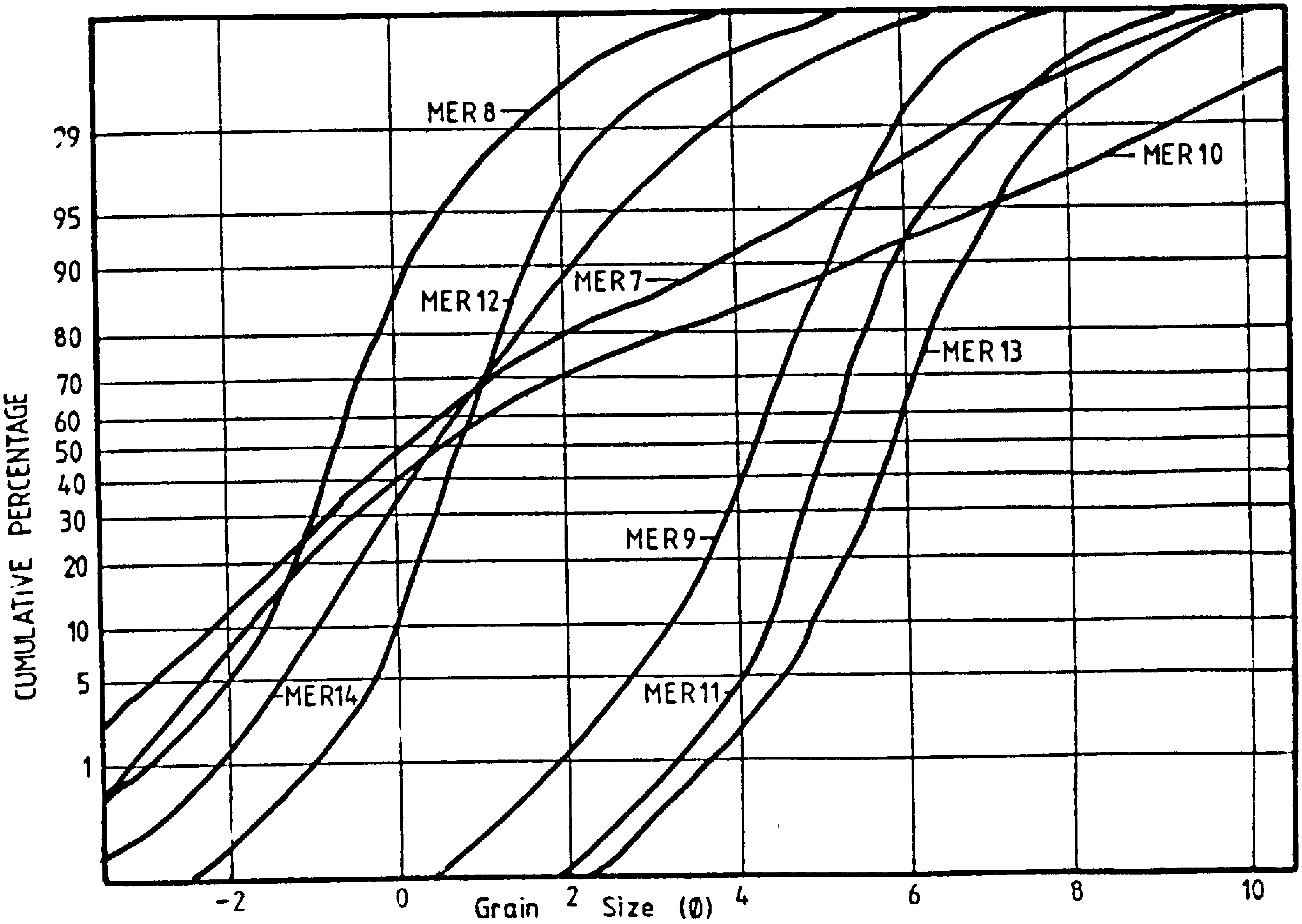


Figure 5.4.3.6. Sediment Size Analysis. Gimlis Dream, Merlin Mine.

Surface Features						
Chemical	Euhedral silica		●		●	●
	Amorphous silica	●		●	●	●
	Solution crevasses	●	●	●		
	Solution pits		●	●	●	●
	Oriented etch pits	●	●		●	
Loessic	Dulled surface	●		●	●	
	Smooth surface		●	●	●	●
	Rounded	◢	●	●	◢	●
	Dish-shaped pits	●			●	
Fluvial	Subangular	◢	●	●	◢	◢
	Subrounded	◢	■	■	◢	◢
	Mechanical V-pits	◢	◢	■	●	◢
	Curved scratches	●	●	●	◢	●
	Straight scratches	●	●	●	●	●
Glacial	Chattermarks					
	Angular	●				●
	Fracture plates					
	Adhering particles					
	Imbricate grinding					
	Parallel striations					
	Conchoidals >10µ	●	●	●	●	●
	Conchoidals <10µ		●		●	●
	Breakage blocks>10µ			●		
	Breakage blocks<10µ	●		●	●	
General	Euhedral quartz		●	●	●	
	Scaling	●	◢	●	◢	●
	High relief	◢	●		●	◢
	Medium relief	◢	◢	●	◢	◢
	Low relief	◢	◢	■	◢	◢
	Meandering ridges	●		●		
	Arcuate steps			●		
	Straight steps		●	●		
	Edge abrasion	●			●	●
	Grain breakage	●	●	●		
	Sample number MER	7	9	10	13	14

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 5.4.3.7. Summary of quartz grain surface textures, Gimli's Dream, Merlin Mine.

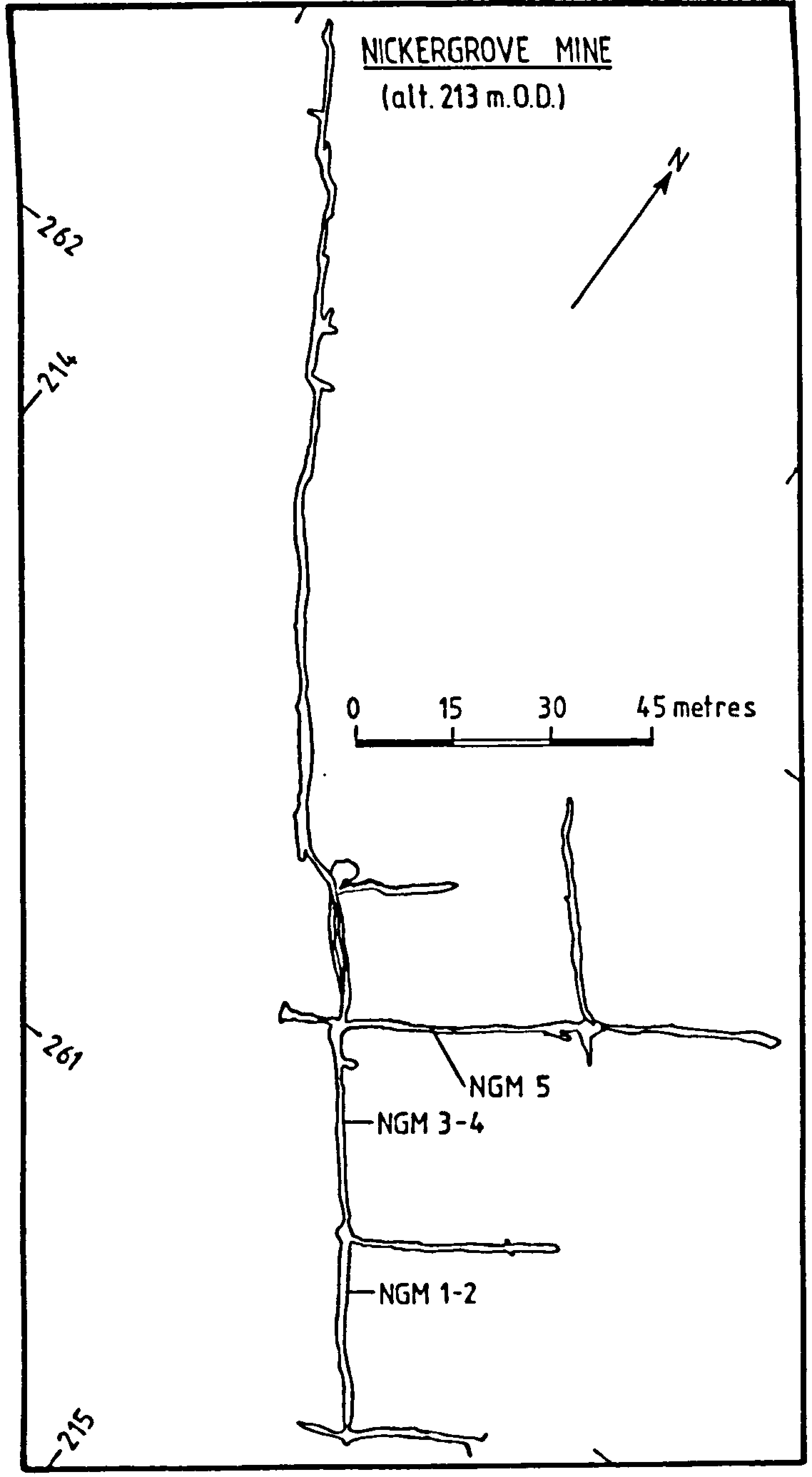


Figure 5.4.4.1. Plan of Nickergrove Mine showing sample locations. After Beck and Worley (1977).

The mine is driven along a number of scrins and pipe veins developed in Upper Monsal Dale Beds. Some of these scrins, barely more than mineralized joints, have been solutionally enlarged, especially the scrin along which many of the mine levels have been driven. The enlargement of these cavities had the effect of concentrating the primary baryte, fluorite and galena mineralization in secondary sedimentary deposits (fig. 5.4.4.2.). These deposits were sought by the lead miners as a valuable source of easily worked ore.

The composition of these sediments is given in figure 5.4.4.3.. Size analysis shows that the sediments are poorly sorted, coarse - skewed, platykurtic gravelly - sands (fig. 5.4.4.4.). The results of S.E.M. study of quartz grain surface textures shows that they are of fluvial origin (fig. 5.4.4.5.).

Beck and Worley's (1977) conclusion that these sediments were partly derived from the Namurian strata to the north by is supported by this study. The remainder of the sediment, which is the coarser fraction, is of autochthonous origin, being derived mainly by solutional activity from the walls of the fissures along which the cavities were formed. These cavities represent cave development related to either of Beck's Remnant Levels.

5.4.5. Streaks Pot

Discovered in 1979 (Beck, 1980b), Streaks Pot is situated on the north side of Stoney Middleton Dale at SK 213,759. The cave consists of a number of active and

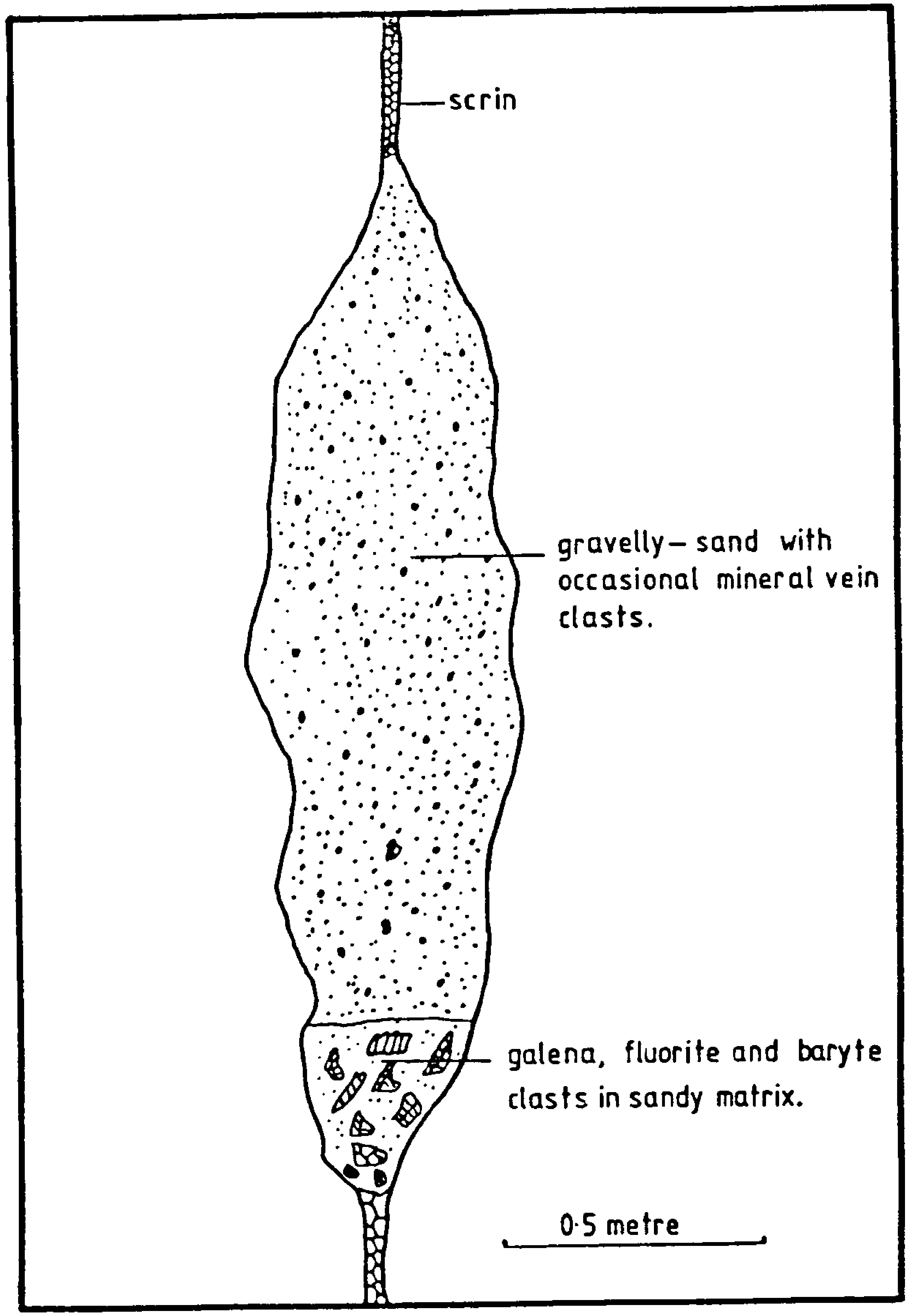


Figure 5.4.4.2. Cavity developed on a scrin, Nickergrove Mine.

Sample Numbers NGM 1,5		
		%
1	Limestone	2 — 5
	Dolomite	
	Volcanics	
	Chert	3 — 7·5
	Silicified fossils	8 — 12
	Authigenic quartz	0 — 1·5
	Galena	0 — 5
	Fluorite	2 — 12
	Baryte	6 — 21
	Calcite	0 — 1·5
2	Quartz	28 — 33
	Sandstone	7 — 15
	Feldspar	1 — 2
	Mica	3 — 7
	Shale	0 — 3·5
	Quartzite	
	Balance (mainly clay)	12 — 26
1 Autochthonous 2 Allochthonous		
Clay Mineralogy		
		%
	Illite	47 — 56
	Kaolinite	26 — 31
	Chlorite	2 — 5·5
	Mixed layer smectites	11 — 17

Figure 5.4.4.3. Summary of sediment composition, Nickergrove Mine.

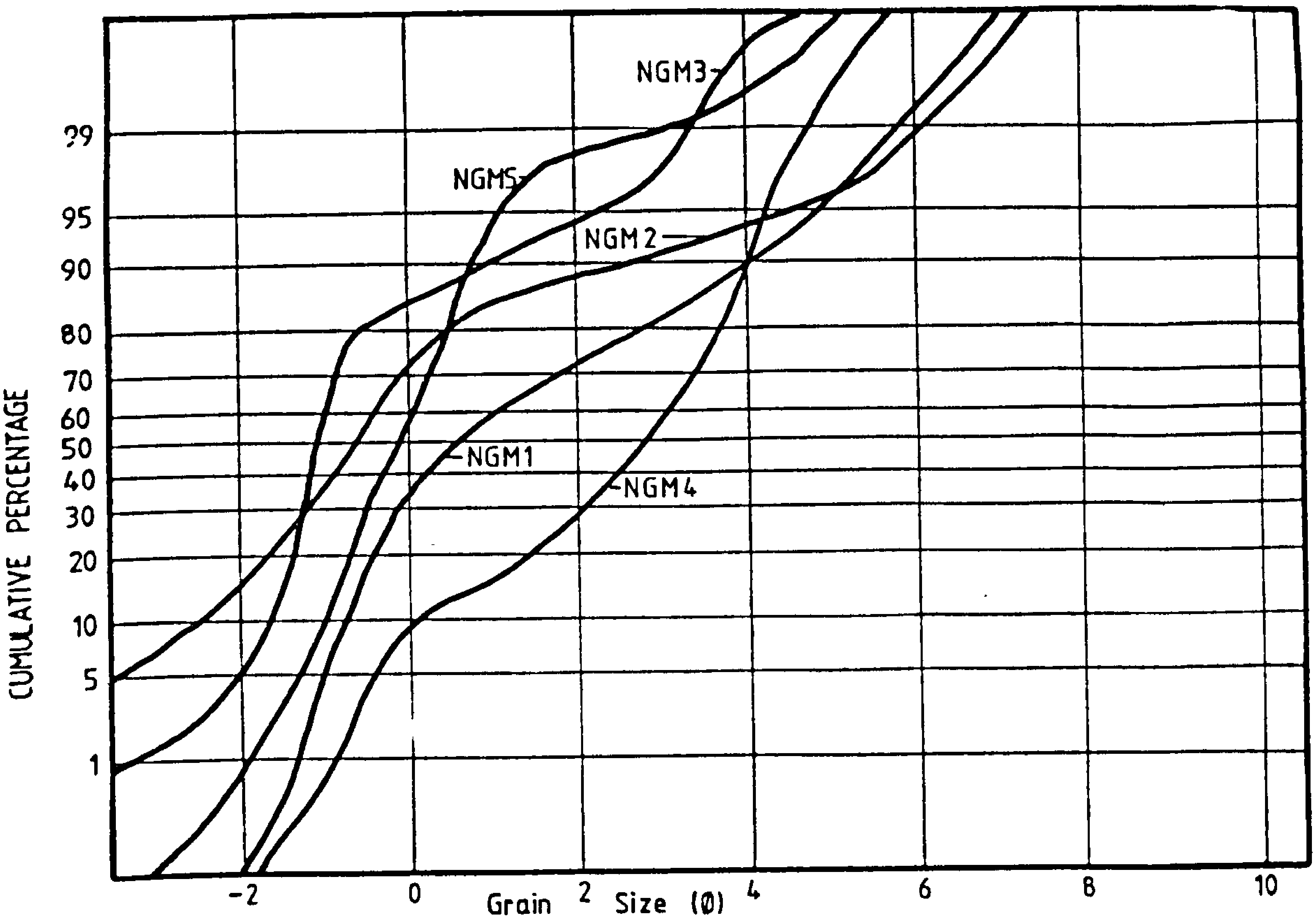


Figure 5.4.4.4. Sediment Size Analysis. Nickergrove Mine.

Surface Features	Chemical	Euhedral silica			●
		Amorphous silica	●	●	◢
		Solution crevasses	●	●	
		Solution pits	●	●	●
		Oriented etch pits	●	●	●
	Loessic	Dulled surface	●		
		Smooth surface	●		
		Rounded	●		
		Dish-shaped pits	●		
	Fluvial	Subangular	◢	◢	◢
		Subrounded	◢	◢	◢
		Mechanical V-pits	◢	●	●
		Curved scratches	●	◢	●
		Straight scratches	●	●	●
	Glacial	Chattermarks			
		Angular	●	●	●
		Fracture plates			
		Adhering particles			
		Imbricate grinding			
		Parallel striations			
		Conchoidals >10µ	●	●	●
		Conchoidals <10µ	●	●	●
		Breakage blocks>10µ	●		
		Breakage blocks<10µ			
	General	Euhedral quartz	●	●	
		Scaling	●	◢	●
		High relief	◢	◢	◢
		Medium relief	◢	◢	◢
		Low relief	◢	◢	◢
		Meandering ridges	●	●	●
		Arcuate steps	●	●	●
		Straight steps	●		
		Edge abrasion	●		
		Grain breakage	●	●	●
		Sample number NGM	1	3	4

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 5.4.4.5. Summary of quartz grain surface textures, Nickergrove Mine.

abandoned passages (fig. 5.4.5.1.) developed below the Lower Shell Bed in Upper Monsal Dale Beds.

The active part of the cave system contains quantities of silt which are believed to be tailings from a fluorspar dressing plant (Cavendish Mill) which were dumped into an abandoned mine shaft (Victory Shaft) when the plant was first operational. Waste water from the mill is still disposed of down this shaft (Christopher, 1979). Mineralogical examination of this material confirms that it is probably tailings. It consists of fine grained, angular fluorite, baryte, calcite and limestone.

Sediment samples taken from the floor of the inactive part of the cave system, which may still carry some flow under high flood conditions, are not tailings. The composition of this material is given in figure 5.4.5.2..

Size analysis shows that these sediments are poorly sorted, coarse skewed, platykurtic silty - sands (fig. 5.4.5.3.).

The inactive part of Streaks Pot is part of Beck's (1975 and 1980) Carlswark Complex level though its sediments are different from those found further east at this level in their composition and degree of sorting. This can be partly explained by the fact that most of the allogenic streams joined the underground drainage network east of Streaks Pot and did not contribute sediment to this area. This is certainly true of the present drainage of the area (Christopher, 1979).

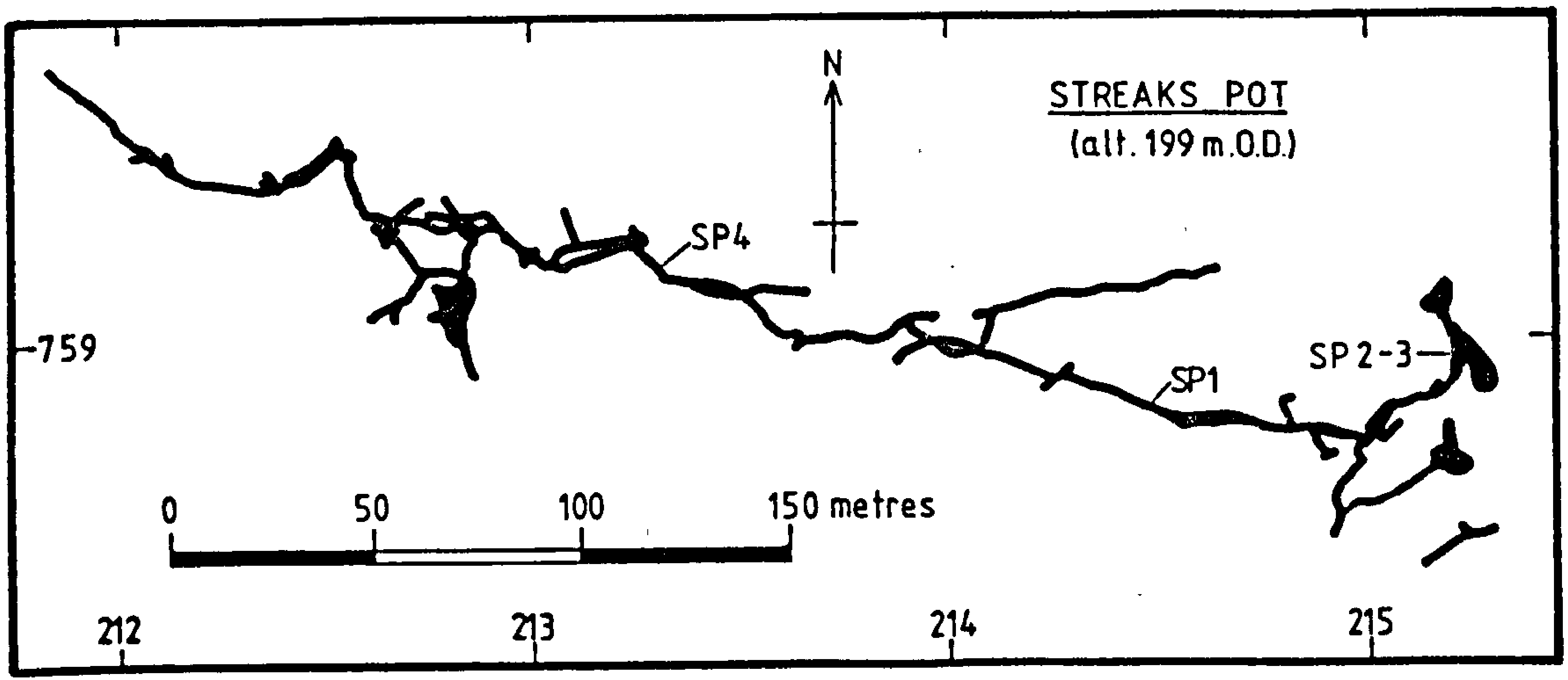


Figure 5.4.5.1. Plan of Streaks Pot showing sample locations. After Beck (1980 b).

Sample Numbers SP 1, 3		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0 — 1·5
	Baryte	0 — 0·5
	Calcite	
2	Quartz	68 — 79
	Sandstone	0 — 3
	Feldspar	
	Mica	0 — 1·5
	Shale	0 — 1
	Quartzite	
	Balance (mainly clay)	19 — 27

1 Autochthonous 2 Allochthonous

Figure 5.4.5.2. Summary of sediment composition, Streaks Pot.

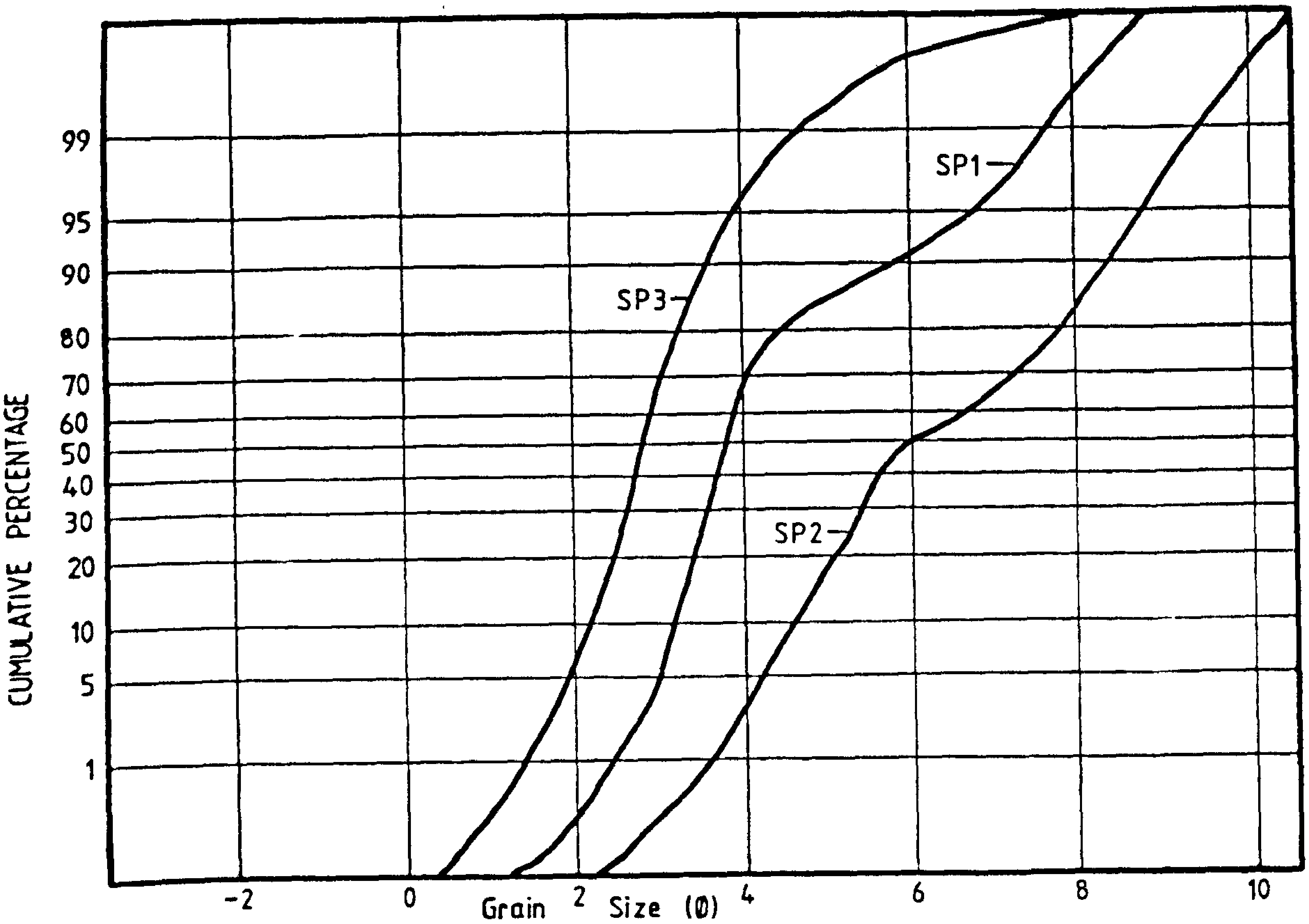


Figure 5.4.5.3. Sediment Size Analysis. Streaks Pot.

Sample Numbers HW 1–7		
		%
1	Limestone	1 — 2·5
	Dolomite	
	Volcanics	
	Chert	3 — 6·5
	Silicified fossils	0 — 2
	Authigenic quartz	
	Galena	0 — 0·5
	Fluorite	0 — 1
	Baryte	0 — 1·5
	Calcite	0 — 0·5
2	Quartz	49 — 62
	Sandstone	4 — 12
	Feldspar	3 — 9
	Mica	5 — 10
	Shale	1 — 4
	Quartzite	
	Balance (mainly clay)	13 — 33
1 Autochthonous 2 Allochthonous		
Clay Mineralogy		
		%
	Illite	56 — 59
	Kaolinite	34 — 41
	Chlorite	3 — 6
	Mixed layer smectites	1 — 7

Figure 5.4.6.1. Summary of sediment composition, Hole-in-the-Wall.

5.4.6. Hole in the Wall

This is a phreatic cave passage, 1 to 2 metres in diameter, intersected by the working face of a disused limestone quarry, at SK 209,761. The tube is filled with gravelly sediments through which access is being excavated (1982) by cavers searching for further passages.

The cave is developed in limestone of the Upper Monsal Dale Beds and may be part of Beck's (1975 and 1980) Second Remnant Complex level.

The fill consists of several fining upwards units, the overall composition of which is given in figure 5.4.6.1.. Size analysis of these sediments shows that they are moderately sorted, very coarse - skewed, platykurtic gravelly - sands (fig. 5.4.6.2.). The results of the S.E.M. study of quartz grain surface textures show that these sediments are of fluvial origin (fig. 5.4.6.3.).

The composition of these sediments shows that they were derived from the Namurian escarpment to the north by fluvial processes.

5.4.7. Lay - By Pot

Situated just to the north of the road through Stoney Middleton Dale at SK 2035,7599, Lay - By Pot has been described by Gill (1976). A mined entrance shaft gives access to a network of low, phreatic cavities just below the Lower Shell Bed in the Upper Monsal Dale Beds (Beck, 1977) (Fig. 5.4.7.1.). Here the Shell Bed is not as pronounced as it is further east and has not had such a

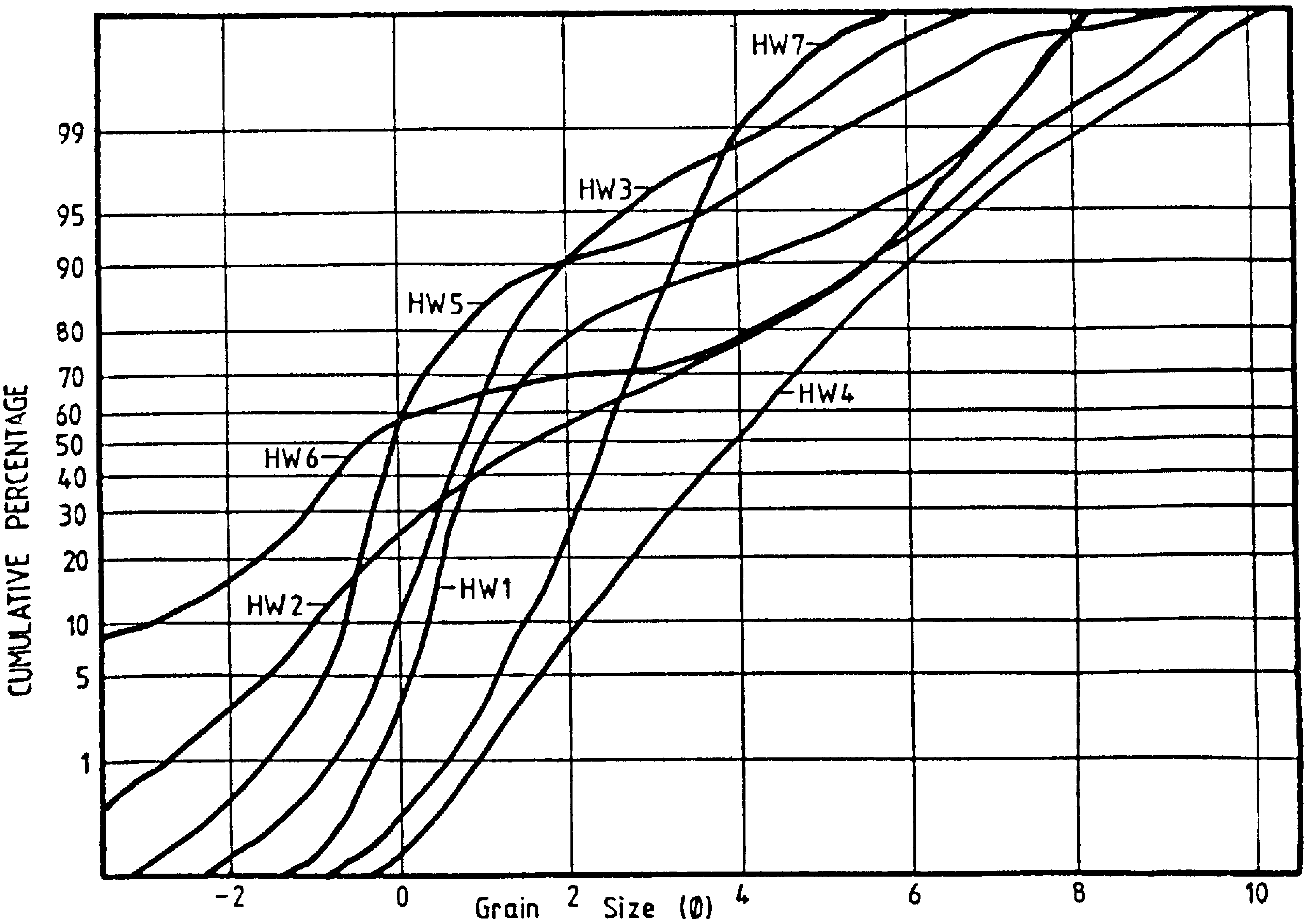
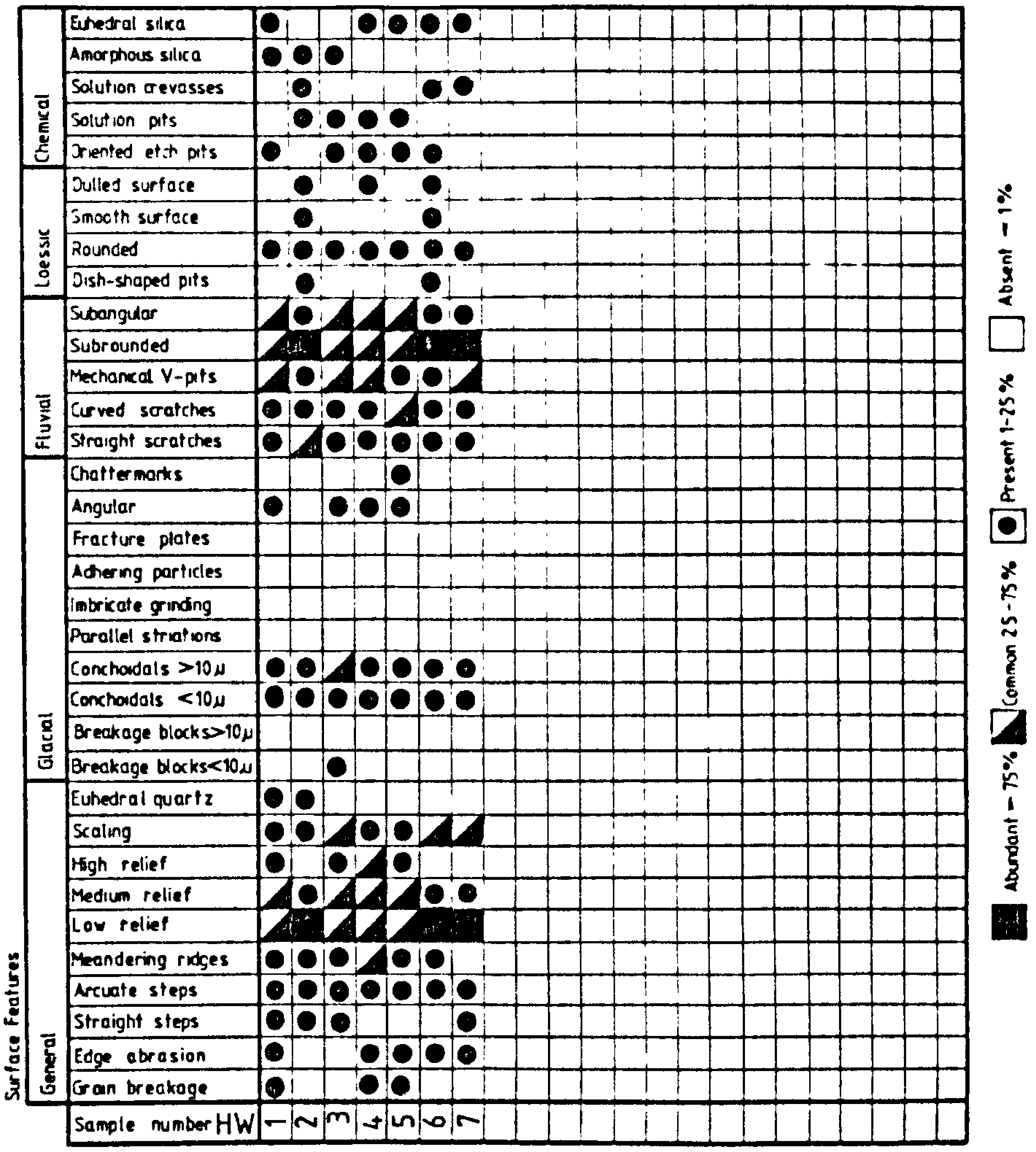


Figure 5.4.6.2. Sediment Size Analysis. Hole-in-the-Wall.



Chemical	Euhedral silica	●			●	●	●	●
	Amorphous silica	●	●	●				
	Solution crevasses		●				●	●
	Solution pits		●	●	●	●		
	Oriented etch pits	●		●	●	●	●	
Loessic	Dulled surface		●		●		●	
	Smooth surface		●				●	
	Rounded	●	●	●	●	●	●	●
	Dish-shaped pits		●				●	
Fluvial	Subangular	◢	●	◢	◢	◢	●	●
	Subrounded	◢	■	◢	◢	◢	■	■
	Mechanical V-pits	◢	●	◢	◢	●	●	◢
	Curved scratches	●	●	●	●	◢	●	●
	Straight scratches	●	◢	●	●	●	●	●
Glacial	Chattermarks					●		
	Angular	●		●	●	●		
	Fracture plates							
	Adhering particles							
	Imbricate grinding							
	Parallel striations							
	Conchoidals >10µ	●	●	◢	●	●	●	●
	Conchoidals <10µ	●	●	●	●	●	●	●
	Breakage blocks>10µ							
	Breakage blocks<10µ			●				
General	Euhedral quartz	●	●					
	Scaling	●	●	◢	●	●	◢	◢
	High relief	●		●	◢	●		
	Medium relief	◢	●	◢	◢	◢	●	●
	Low relief	◢	■	◢	◢	◢	■	■
	Meandering ridges	●	●	●	◢	●	●	
	Arcuate steps	●	●	●	●	●	●	●
	Straight steps	●	●	●				●
	Edge abrasion	●			●	●	●	●
	Grain breakage	●			●	●		
Surface Features	Sample number HW	1	2	3	4	5	6	7

■ Abundant – 75%
◢ Common 25-75%
● Present 1-25%
☐ Absent – 1%

Figure 5.4.6.3. Summary of quartz grain surface textures, Hole-in-the-Wall.

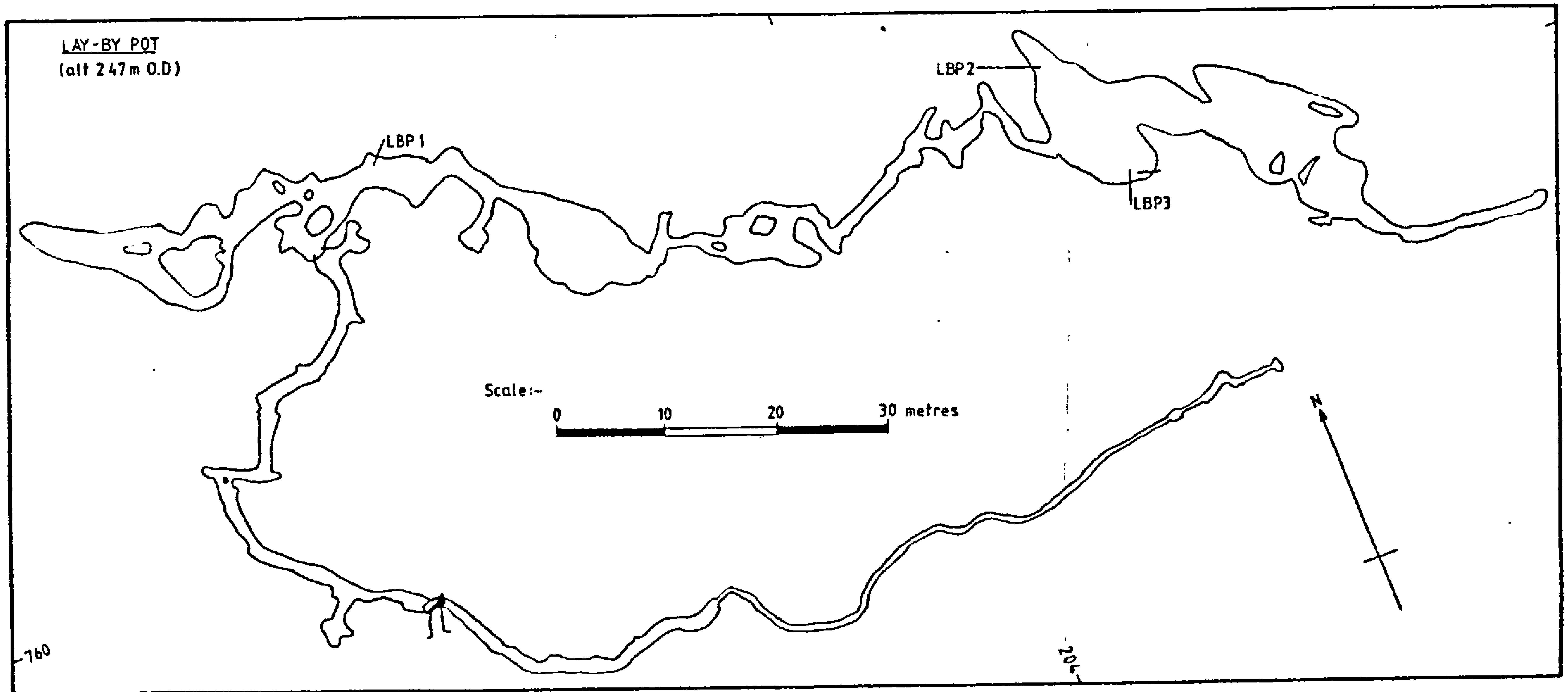


Figure 5.471 Plan of Lay-By Pot showing sample locations. After Gill (1976).

controlling influence on the development of the cave (Beck. 1977).

The floor and boulders in the cave are covered by a layer of silty - sand. The composition of this sediment is given in figure 5.4.7.2.. Size analysis shows of these sediments shows that they are moderately sorted, fine - skewed, mesokurtic silty - sands (fig. 5.4.7.3.). The results of S.E.M. study of quartz grain surface textures show that these sediments are of fluvial origin (fig. 5.4.7.4.).

These sediments are very similar to those in Streaks Pot and have probably been derived from the same source.

5.4.8. Sallet Hole Mine

Sallet Hole Mine works fluorite bearing veins beneath Longstone Edge. Access is by means of a drift, driven from Coombs Dale at SK 219,741, and a decline driven beside the vein. Ore is extracted from Deep and High rakes by sub - level caving methods. The veins, often over 4 metres wide, are composed of banded fluorite with minor galena, baryte and calcite. The host rocks are limestones of the Upper Monsal Dale Beds and the Litton Tuff. The limestone is often fluoritized close to the veins.

Small post - mineralization solution cavities are common close to the vein walls but, due to the nature of the mining method, examination is rarely practical.

A pipe vein cavity in the south wall of Deep Rake was examined (fig. 5.4.8.1.). The mineralization of the

Sample Numbers LBP 1–3		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	0 — 1
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	67 — 83
	Sandstone	0 — 1
	Feldspar	0 — 0·5
	Mica	1 — 4·5
	Shale	0 — 1·5
	Quartzite	
	Balance (mainly clay)	12 — 28
1 Autochthonous 2 Allochthonous		

Figure 5.4.7.2. Summary of sediment composition, Lay — By Pot.

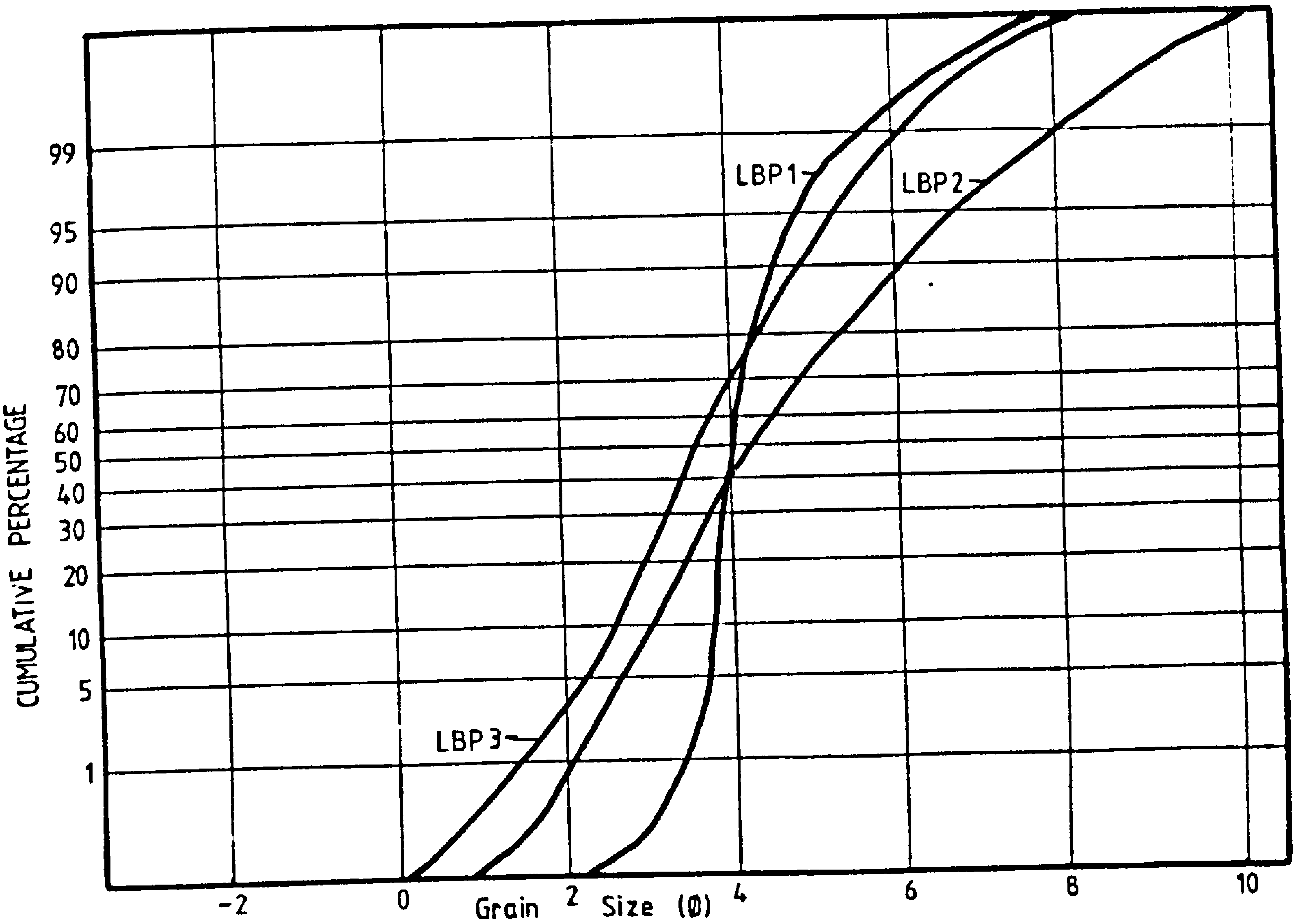


Figure 5.4.7.3. Sediment Size Analysis. Lay — By Pot.

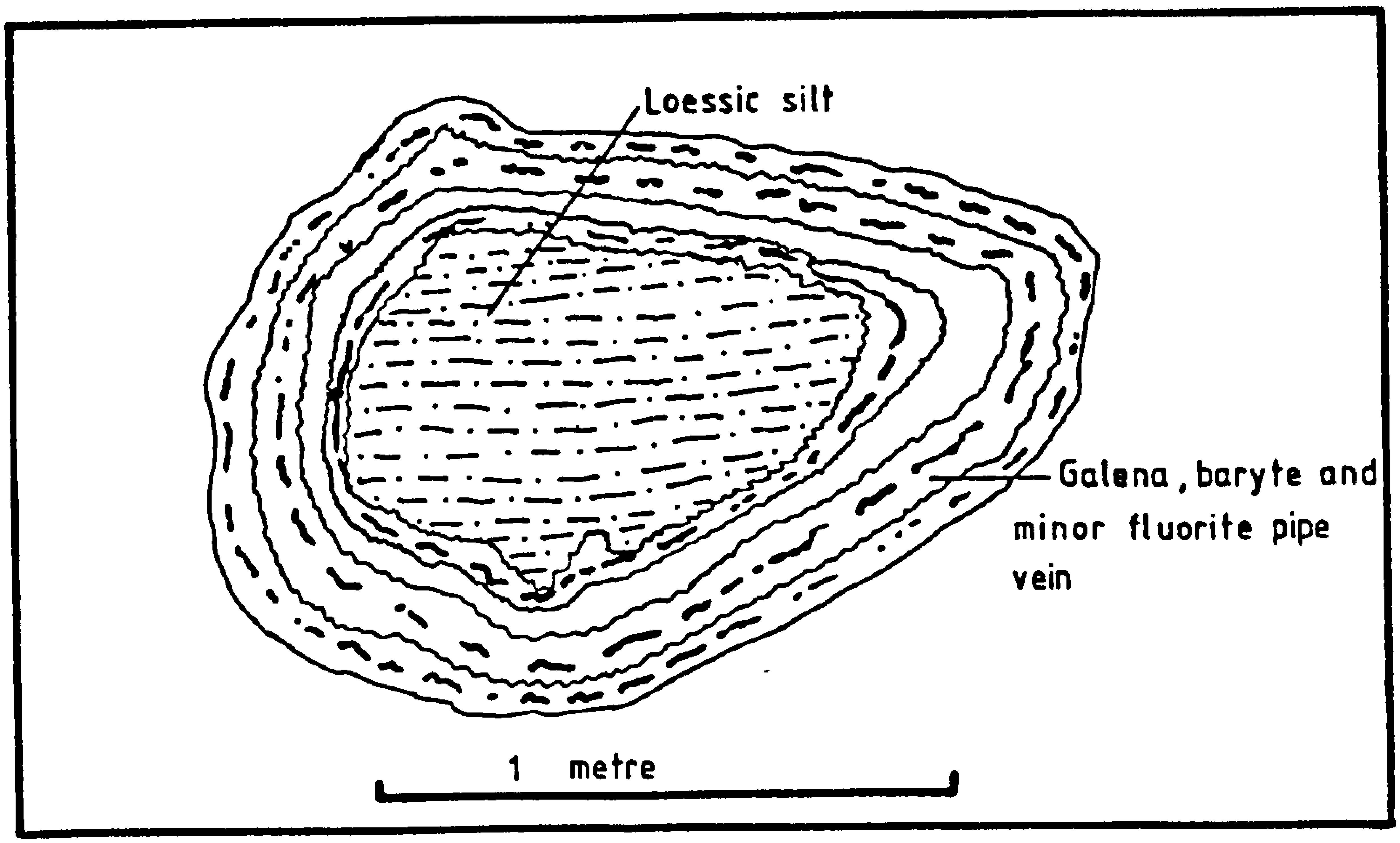
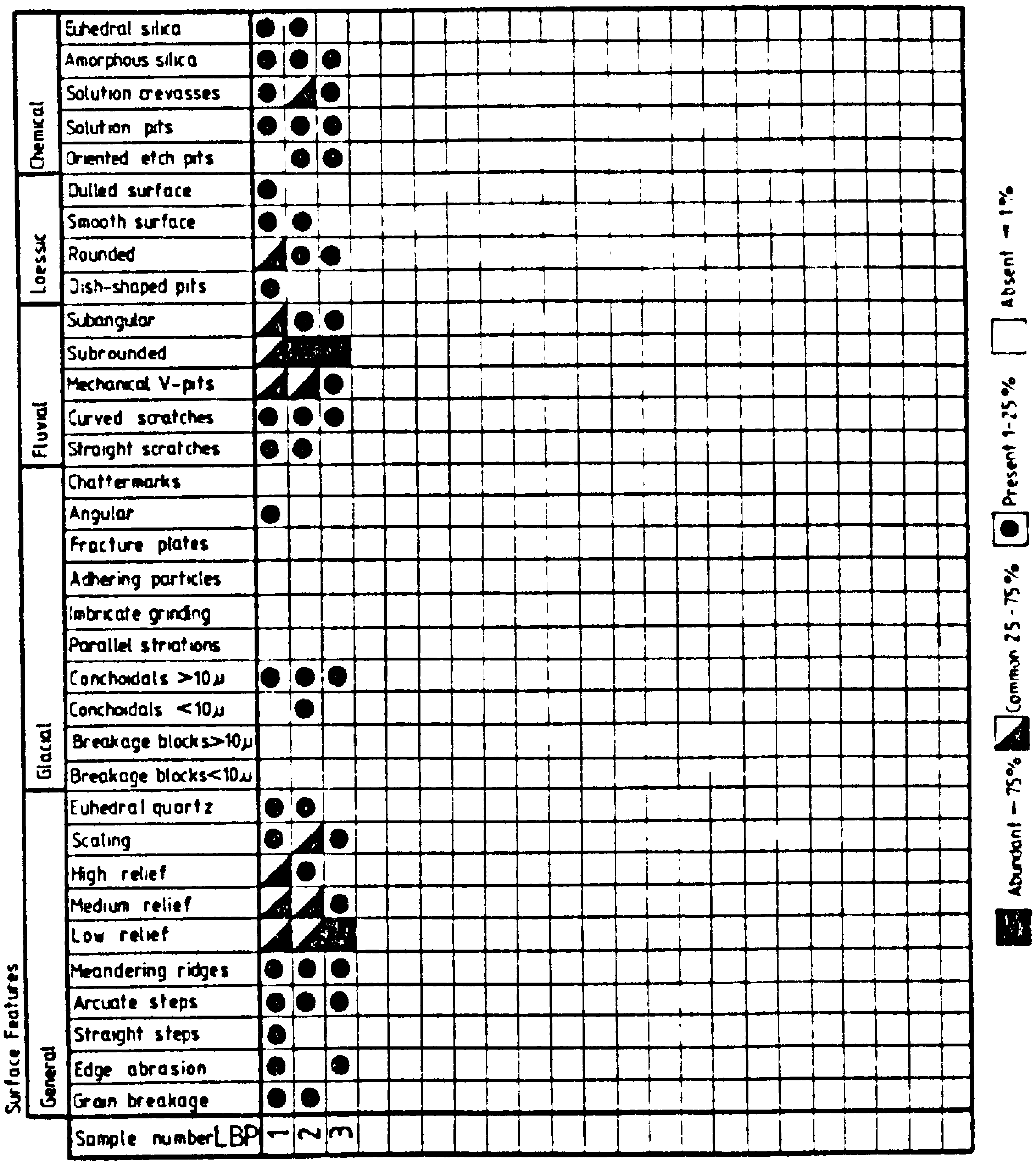


Figure 5.4.8.1. Pipe vein cavity filled with loessic silt, Sallet Hole Mine.



Surface Features		Sample number LBP	1	2	3
	Chemical	Euhedral silica	●	●	
		Amorphous silica	●	●	●
		Solution crevasses	●	◢	●
		Solution pits	●	●	●
		Oriented etch pits		●	●
	Loessic	Dulled surface	●		
		Smooth surface	●	●	
		Rounded	◢	●	●
		Dish-shaped pits	●		
	Fluvial	Subangular	◢	●	●
		Subrounded	◢	■	■
		Mechanical V-pits	◢	◢	●
		Curved scratches	●	●	●
		Straight scratches	●	●	
	Glacial	Chattermarks			
		Angular	●		
		Fracture plates			
		Adhering particles			
		Imbricate grinding			
		Parallel striations			
		Conchoidals >10µ	●	●	●
		Conchoidals <10µ		●	
		Breakage blocks>10µ			
		Breakage blocks<10µ			
	General	Euhedral quartz	●	●	
		Scaling	●	◢	●
		High relief	◢	●	
		Medium relief	◢	◢	●
		Low relief	◢	◢	■
		Meandering ridges	●	●	●
		Arcuate steps	●	●	●
		Straight steps	●		
		Edge abrasion	●		●
		Grain breakage	●	●	

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 5.4.7.4. Summary of quartz grain surface textures, Lay-By Pot.

pipe vein consists of a complex sequence of layered baryte and galena with some fluorite, in contrast to that of the rakes. The remainder of the cavity was filled with silty sand.

The composition of this sediment, which showed no evidence of bedding, is given in figure 5.4.8.2.. Size analysis shows that the sediment is moderately well sorted, fine - skewed, mesokurtic silty - sand (fig. 5.4.8.3). The results of S.E.M. study of quartz grain surface textures suggests that these sediments are of loessic origin (fig. 5.4.8.4.).

Despite the occurrence of these sediments over 100 metres below the present surface it is likely that they were derived from former loess deposits by the mechanism of translatory flow postulated by Bull (1981b). The fractured, open structure of Deep Rake and the limestone wall rocks would have permitted easy operation of this process.

5.4.9. Ladywash Mine

The main shaft to this extensive, modern fluorspar mine is at SK 219,776. The mine has been on a care and maintenence basis since March 1979.

The mine worked a number of large veins beneath the shale and sandstone cover of Eyam Edge. These veins are hosted by limestones and volcanics of the Eyam and Monsal Dale Groups. Due to the condition of the mine access was not possible during the course of this study.

Worley (1978) noted secondary, sedimentary

Sample Numbers SH 1, 2		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	0 — 1
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	64 — 78
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	22 —35
1 Autochthonous 2 Allochthonous		

Figure 5.4.8.2. Summary of sediment composition, Sallet Hole Mine.

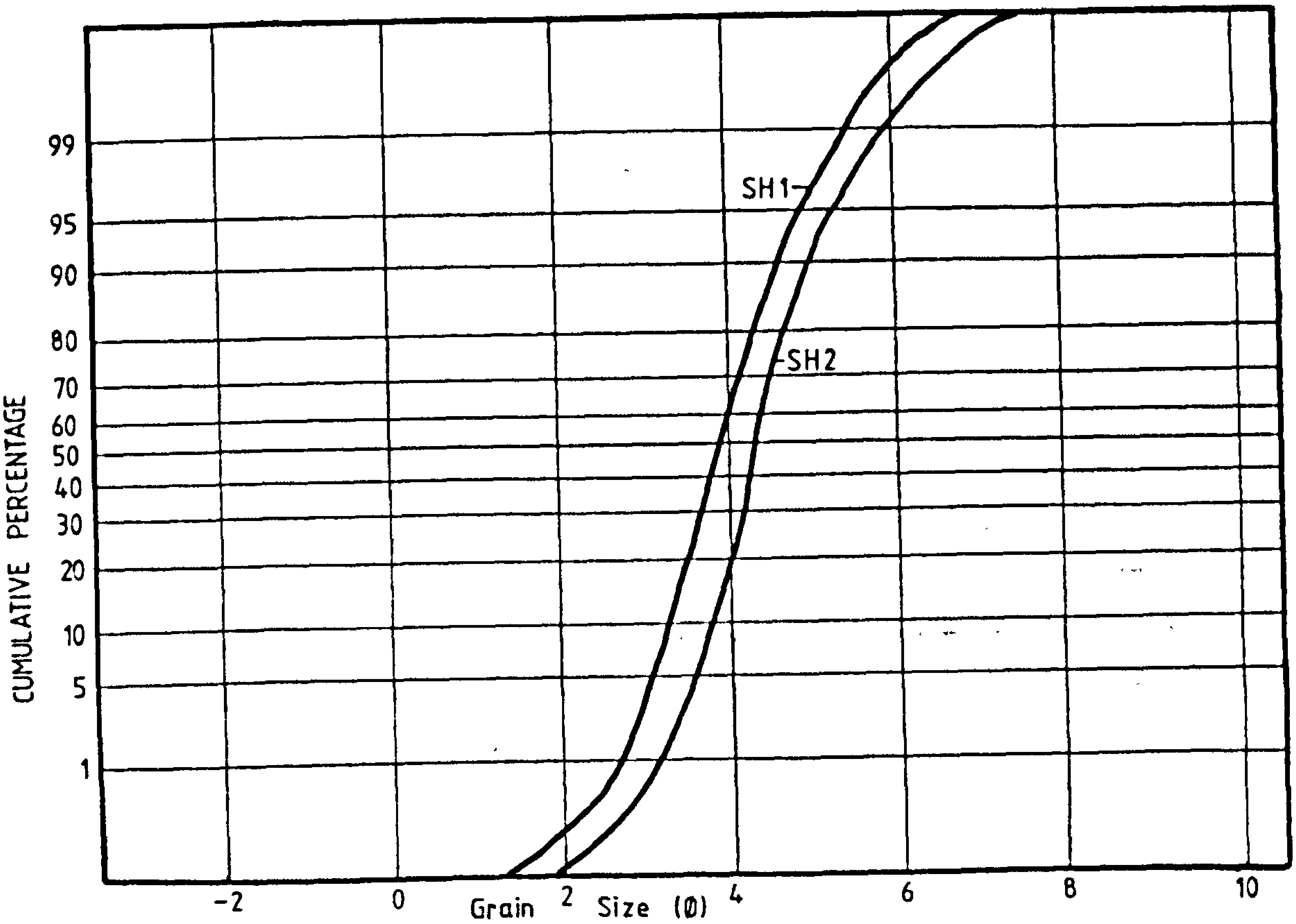


Figure 5.4.8.3. Sediment Size Analysis. Sallet Hole Mine.

Surface Features

Chemical	Euhedral silica	●	●
	Amorphous silica	●	
	Solution crevasses	●	◢
	Solution pits	●	●
	Oriented etch pits	●	
Loessic	Dulled surface	●	◢
	Smooth surface.	◢	◢
	Rounded	■	■
	Dish-shaped pits	●	●
Fluvial	Subangular		
	Subrounded	●	●
	Mechanical V-pits	●	
	Curved scratches		●
	Straight scratches	●	
Glacial	Chattermarks		
	Angular		
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10µ		
	Conchoidals <10µ		
	Breakage blocks>10µ		
	Breakage blocks<10µ		
General	Euhedral quartz		●
	Scaling	●	●
	High relief		
	Medium relief	●	●
	Low relief	■	■
	Meandering ridges	●	
	Arcuate steps	●	
	Straight steps		
	Edge abrasion	●	
	Grain breakage		●
	Sample number SH	1	2

■ Abundant – 75%
◢ Common 25-75%
● Present 1-25%
☐ Absent – 1%

Figure 5.4.8.4. Summary of quartz grain surface textures, Sallet Hole Mine.

accumulations of galena in Ashton's Pipe. Here the mineralization consists of fluorite lined pipe vein cavities containing large irregular galena inclusions. The action of water passing through the pipe, in times of flood, has washed large amounts of galena from the fluorite and redeposited it as rounded, cerussite coated, fragments on the pipe floor (Worley, 1978).

Worley (1978) also notes the occurrence of a series of large, post - mineralization, solution caverns that have been filled with brown clays and silts containing fluorite. These are associated with Phillips Pipe (also known as Paul Pipe) in the Glebe section of the mine.

5.5. Conclusions

Following partial removal of the shale cover underground drainage started in this area. Caves of the First Remnant Complex level were formed at this time (Beck, 1975 and 1980). Successive lowering of the water table by base level changes led to the formation of caves of the Second Remnant Complex, Carlswark Complex and Lower Complex levels (Beck, 1980). These cave levels cannot be easily related to terrace remnants in the valley but the mouth of the dale may be an indistinct nick point at the head of Hope Terrace. Till overlying the limestone on the south side of the dale may represent terrace remnants at the level of the Hathersage Terrace or an earlier terrace. This indicates that the dale, and therefore the cave systems, developed between the formation of these two terraces (Ford et al, 1983).

are in cave passages related to Beck's Second Remnant Complex and Carlswark Complex level (Beck, 1975 and 1980). The sediments in caves at the former level are generally coarse - grained and contain large clasts derived from the Namurian strata of the Eyam Edge area. The size of the clasts, some of them of shale, indicate that the source was closer to the caves than it is today. The sediments of the Carlswark Complex level tend to be more fine - grained but still contain sandstone and shale clasts indicating derivation from the Namurian strata but at a greater distance.

Deposition of the sediments could only occur in the final stages of abandonment when it would not be removed by subsequent flooding. All the deposits studied indicate that deposition was fairly rapid and was followed by periods during which normal conditions prevailed and no deposition occurred. The stalagmite layers in some of the sediment deposits indicate that there was no sedimentation for a considerable time.

The fluvial character of the sediments, with no loessic or fluvio - glacial material, indicate that deposition occurred during interglacial or interstadial periods. The lack of fluvio - glacial sediments may be due to ice or debris preventing underground drainage with surface drainage removing the sediment from the area.

6. BRADWELL - CASTLETON AREA

6.1. Introduction

The Bradwell - Castleton area lies at the northern extremity of the Peak District limestone area. It extends from Bradwell Dale in the east to Sparrowpit in the west and from Mam Tor in the north to Little Hucklow in the south (fig. 6.1.1.). The area has two large, active limestone quarries, Earle's Quarry (SK 160,820) and Eldon Hill Quarry (SK 113,815).

The limestone area is devoid of surface drainage. All streams that rise on the shale and sandstone edges sink as soon as they reach the limestone. The underground drainage in the Bradwell area resurges from Bagshaw Resurgance Cave (SK 174,811) in Bradwell while that from the swallets at the base of Rushup Edge, to the west of Castleton, resurges from Russet Well (SK 148,827) in Peak Cavern Gorge. A stream also rises from Peak Cavern (SK 149,825) which is derived partly from percolation water in the southern part of the area and partly from flood overflow from the Russet Well system (Christopher, 1981).

A large number of active and abandoned cave systems occur in the area, some of which are used as show caves (Blue John Caverns, SK 132,832, Treak Cliff Cavern, SK 136,832, Speedwell Cavern, SK 139,828, Peak Cavern, SK 149,825, and Bagshaw Cavern, SK 172,809).

Several large rake veins, together with a number of scrins and pipes, cross the area and were extensively worked for lead ores in the past. In some areas open pit

Figure 6.1.1. Geological sketch map of the Castleton area.

▭	Namurian sandstones and shales	
▦	Monsall Dale Beds	Carboniferous Limestone
▭	Bee Low Limestones	
R R	Reef limestones	
V V	Volcanics	
━	Mineral Veins	

Key to localities

1 Bagshaw Cavern
2 Hazlebadge Mine
3 Moorfurlong Mine
4 Earle's Quarry
5 Blue John Caverns
6 Odin Cave
7 Odin Bank Shaft
8 Treak Cliff Cavern
9 Suicide Cave
10 Old Tor Mine
11 Winnats Head Cave
12 Longcliffe Mine
13 Longcliffe Back Shaft
14 Windy Knoll Cave
15 Peak Cavern
16 Speedwell Cavern
17 Jackpot
18 Giants Hole
19 Maskill Mine
20 Portway Pit


1/2 km.
N
CASTLETON
BRADWELL
DIRTLOW RAKE
83
82
81
11
12
13
14
15
16
17
①
②
③
④
⑤
⑥
⑦
⑧
⑨
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⑮
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⑰
⑱
⑲
⑳
R
V

operations are currently extracting fluorite, calcite and baryte from these deposits.

6.2. Geological Setting

The limestones of this area vary from lagoonal, through back reef and reef to fore reef limestones. The back reef limestones are typically well - bedded, pale grey calcarenites which dip gently eastwards (Stevenson and Gaunt, 1971). Towards the northern limit of the limestone outcrop these back reef limestones are replaced by more massive reef limestones with irregular bedding planes. These reefs formed the northern edge of the shallow lagoon and are flanked on the north by fore reef deposits. These reef limestones, consisting of shell and algal debris in a sparry matrix, have steep sedimentary dips to the north and northeast of between 20 and 35 degrees (Stevenson and Gaunt, 1971).

The lagoonal limestones belong to the Bee Low (Aspian (D1)) and Monsal Dale (Brigantian (D2)) Beds. The former outcrop to the north of Dirtlow Rake and the latter to the south.

The reef limestones are of Asbian (P_1 and B_2) age and form a belt about a kilometre wide, between the lagoonal limestones and the overlying Namurian strata.

Interbedded with the limestones are a number of volcanic rocks. These include the basaltic Cave Dale Lava and the Speedwell Vent. The latter variously regarded as a vent or as a mass of lava which was broken up on flowing over the reefs from the parent Cave Dale flow. Also present is a thick succession of pyroclastic deposits below Earle's Quarry (Parkinson, 1947; Stevenson and Gaunt, 1971; Ford, 1977). Interbedded with the lagoonal limestones are a number of wayboard horizons varying from a few centimetres to a metre or so thick.

The limestone is unconformably overlain by the Edale Shale, the basal unit of the Namurian Strata (Jackson, 1925). This unconformity is sometimes marked by a massive boulder bed, consisting of boulders in a shale matrix, resting on eroded D_1 reef limestones (Simpson and Broadhurst, 1969).

The Edale Shale is dark, often pyritic, containing ironstone bands and nodules (Stevenson and Gaunt, 1971). The Edale Shale is overlain by the Mam Tor Beds which consist of an alternating sequence of muddy sandstones, siltstones and shales. These are turbidite deposits laid down in front of an advancing delta (Allen, 1960). The face of Rushup Edge is mainly underlain by these beds. The sandstone units are characterised by quartz sand with muscovite feldspars, often altered to kaolinite, and carbonaceous material (Stevenson and Gaunt, 1971).

Considerable areas of the limestone plateau are covered by superficial deposits of Pleistocene age. These are variably loess, silty - drift and more unusually till (Burek, 1978).

The limestones are cut by three major rakes, Odin Rake in the north, Dirtlow Rake and Moss Rake in the south. Dirtlow Rake splits in the west into a series of smaller rakes including Oxlow Rake and Old Wham Vein.

Numerous minor veins also occur and trend approximately east - west. The veins are dominantly fluorite carrying in the east, progressively giving way to baryte and then to calcite to the west (Dunham, 1952).

Some pipe veins have been worked for lead and fluorite, notably Smalldale Pipe, Moorfurlong Pipe and Hazlebadge Pipe (Worley, 1978).

Castleton is well known for the Blue John deposits that occur in Treak Cliff. Its occurrence is restricted to Treak Cliff. This may be explained by the fact that a gap between reef knolls existed at the site of the Winnats Pass and was filled with Edale Shale. This restricted the movement of the solutions which led to the Blue John mineralisation (Ford, 1969a).

In Treak Cliff Cavern the Blue John mineralization occurs as a complex pipe vein system in boulder bed and pre-mineralisation karstic cavities in the underlying limestone (Ford, 1969a).

6.3 Types of Deposit

Many of the sites studied are in cave systems, both active and abandoned, which drain Rushup Edge and Bradwell Edge.

These cave systems are part of a fully integrated drainage network draining to Russet Well, Peak Cavern and Bagshaw Resurgance Cave (Beck, 1980). The limited amount of speleothem dating that has been undertaken shows that many of these caves have a long history (Ford et al, 1983). Beck (1980) showed that different levels in the Peak - Speedwell system may be related to terraces in the Hope Valley and to episodes of damming of the resurgence at Peak Cavern by talus.

The development of the swallet caves has been controlled by the varied limestones and structure of the reef facies (Beck, 1980).

The early underground drainage of the area would have utilised the existing networks of cavities in the mineral vein systems (Beck, 1980). As the networks evolved the mineral vein system became less important, but many of the present cave systems are partially developed along mineral veins or in the more fractured wall rocks associated with the mineral veins (Beck, 1980).

When cave development occurred in association with mineral veins these caves often contain reworked mineral vein material in sedimentary deposits.

6.4. Sites Studied

6.4.1. Bagshaw Cavern

Situated at SK 172,809 Bagshaw Cavern was found by the lead miners of Mule Spinner Mine in the eighteenth century (Ford et al, 1977). It contains both active and abandoned passages, and comprises the only currently accessible part of the underground drainage network of the Bradwell area (Baker, 1903).

The cave consists of a series of phreatic passages, with occasional later vadose trenches cut into the floor, developed from a prominent bedding plane (Ford et al, 1975) (fig. 6.4.1.). Part of the cave is used as a show cave and much of the rest used for "Adventure Caving Trips" led by the owners.

When the cave was discovered by the lead miners it was at least half full of alluvial sediments. A channel has subsequently been cut through these to ease access. The sediments fill a vadose trench and its phreatic predecessor.

The composition of these sediments is given in figure 6.4.1.2.. Size analysis shows that the sediments are moderately sorted, coarse - skewed, very platykurtic, pebbly - sands (fig. 6.4.1.3.). The results of S.E.M. study of quartz grain surface textures show that these deposits are of fluvial origin (fig. 6.4.1.4.).

Samples of silty - sand were taken from the Hippodrome area of the cave, which still takes some flow under high water conditions. The composition of these sediments is given in figure 6.4.1.5.. Size analysis shows that these sediments are poorly sorted, slightly fine - skewed, mesokurtic, silty - sands (fig. 6.4.1.6.). The results of S.E.M. study of quartz grain surface textures show that the sediments are of fluvial origin (fig. 6.4.1.4.).

The mineralogy of these sediments indicates that they were derived from the Namurian strata, probably from Bradwell Edge to the east and southeast of the cave. Both deposits have been deposited by floodwaters at different stages in the cave's development as lower

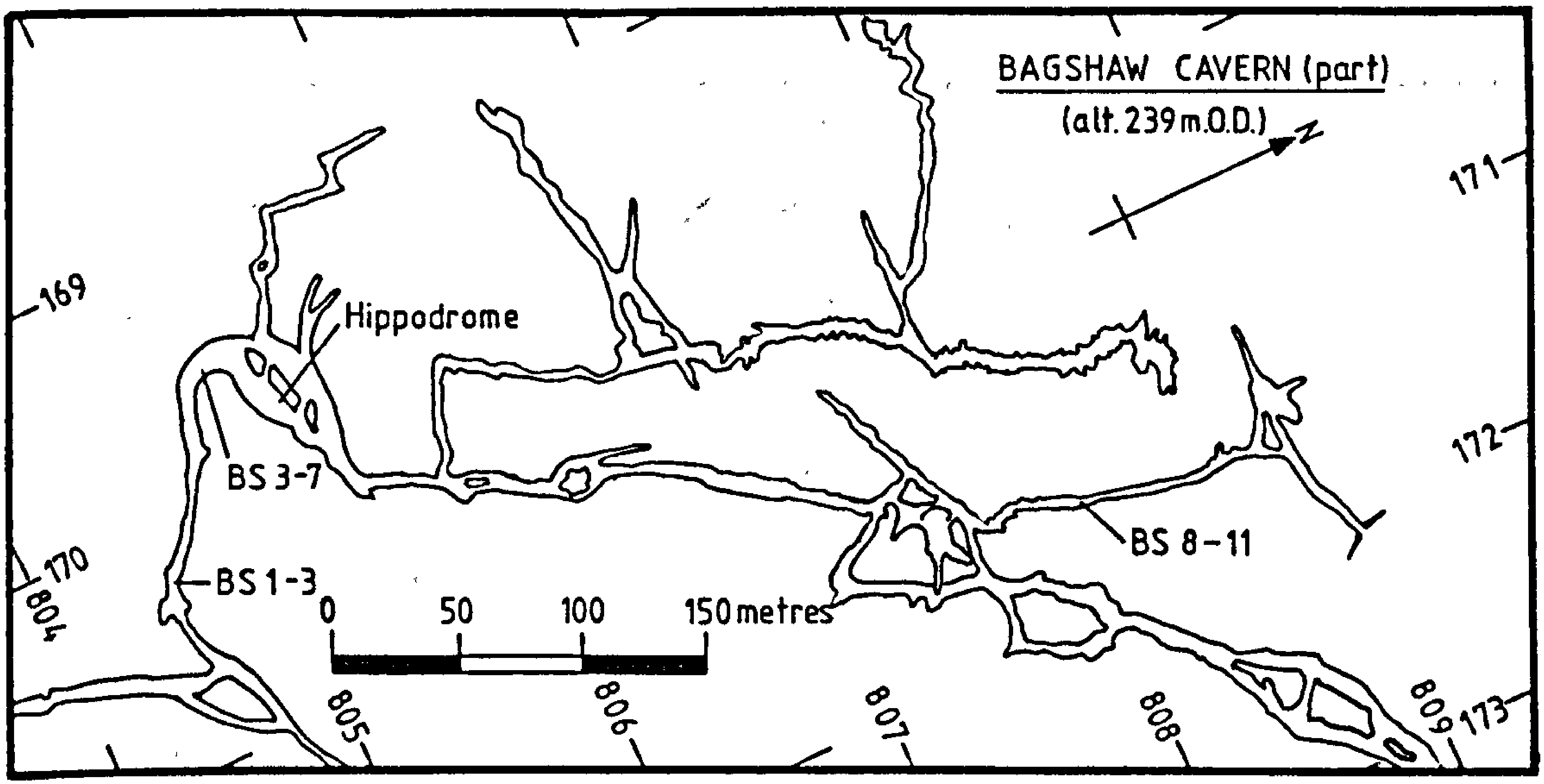


Figure 6.4.1.1. Plan of Bagshaw Cavern showing sample locations. After Ford et al (1975).

Sample Numbers BS 8 − 11		
		%
1	Limestone	3 − 17
	Dolomite	
	Volcanics	0 − 2
	Chert	3 − 7
	Silicified fossils	0 − 1·5
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	36 − 61
	Sandstone	28 − 32
	Feldspar	4 − 9
	Mica	7 − 14
	Shale	1 − 4
	Quartzite	
	Balance (mainly clay)	6 − 13

1 Autochthonous 2 Allochthonous

Figure 6.4.1.2. Summary of sediment composition, Show Cave Passage, Bagshaw Cavern.

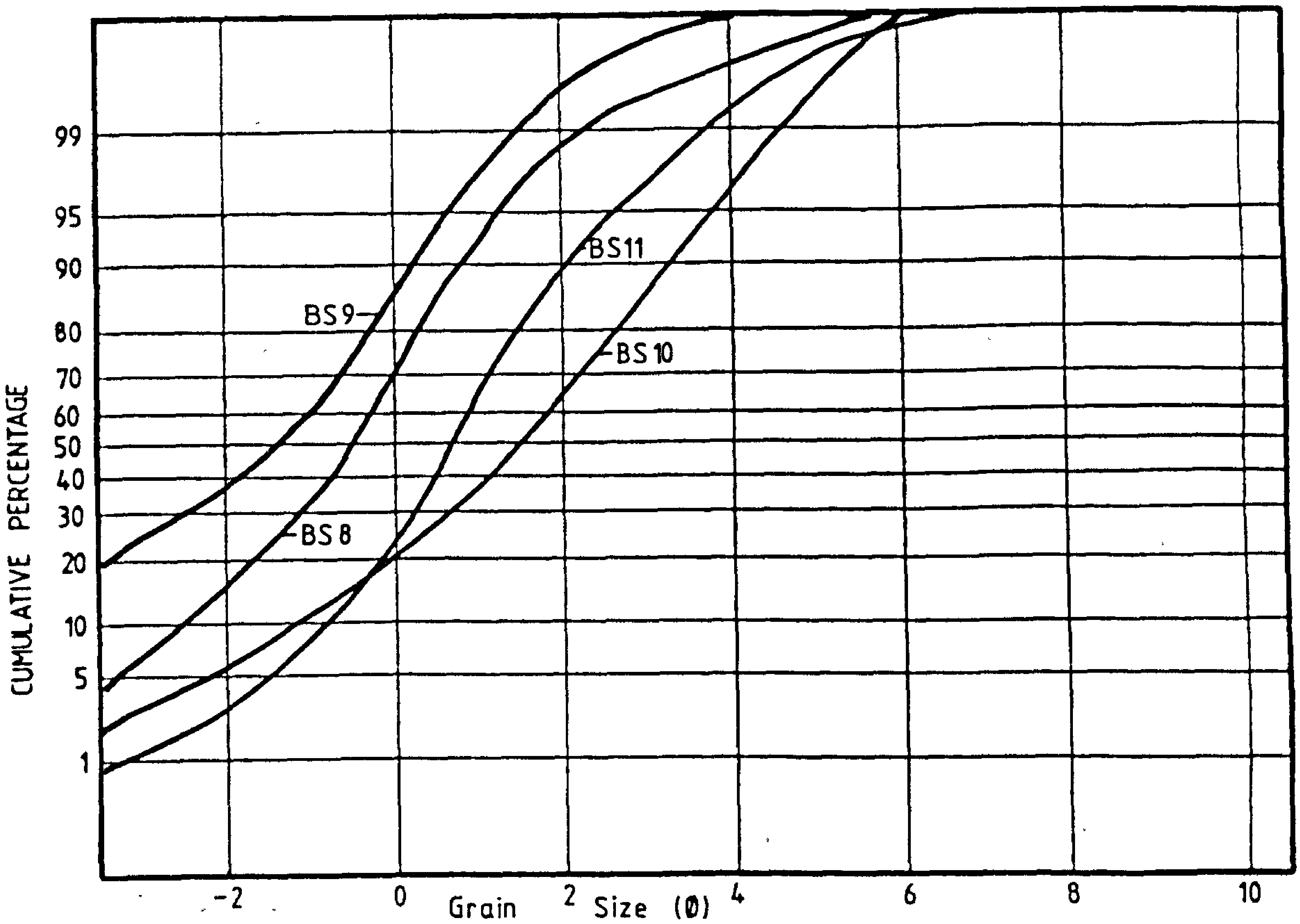


Figure 6.4.1.3. Sediment Size Analysis. Bagshaw Cavern.

Surface Features	Chemical	Euhedral silica		●		●	●	●		●
		Amorphous silica	●	●	●	●	●	●	●	●	●
		Solution crevasses						●	●		
		Solution pits	●	●	●	●	●	●		●	●
		Oriented etch pits	●		●		●	●		●	●
	Loessic	Dulled surface		●	●			●	●		●
		Smooth surface									
		Rounded	●	●	●		●	●		●	●
		Dish-shaped pits			●						
	Fluvial	Subangular	◪	◪	●	◪	◪	●	◪	◪	●
		Subrounded	◪	◪	■	◪	◪	■	◪	◪	■
		Mechanical V-pits	◪	◪	◪	◪	◪	◪	●	◪	◪
		Curved scratches	●	●	●	●	●	●	●	●	●
		Straight scratches	●		●	●		●	●		
	Glacial	Chattermarks									
		Angular					●				
		Fracture plates									
		Adhering particles									
		Imbricate grinding									
		Parallel striations									
		Conchoidals >10μ	●	●			●				
		Conchoidals <10μ		●			●				●
		Breakage blocks>10μ									
		Breakage blocks<10μ									
	General	Euhedral quartz	●	●			●		●	●	●
		Scaling	●	◪	●	●	●	●	●	●	●
		High relief	●		●	●	◪		●	●	
		Medium relief	◪	●	◪	◪	◪	●	◪	◪	●
		Low relief	◪	■	◪	◪	◪	■	◪	◪	■
		Meandering ridges	●	●		●	●	●	●	●	
		Arcuate steps	●			●	●				●
		Straight steps	●	●		●	●	●		●	●
		Edge abrasion	●	●	●	●	●	●		●	●
		Grain breakage		●			●	●		●	●
		Sample number BS	8	9	10	11	1	2	3	6	7

■ Abundant – 75% ◪ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 6.4.1.4. Summary of quartz grain surface textures, Bagshaw Cavern.

drainage routes evolved. This process still continues in the Hippodrome area.

6.4.2. Hazlebadge Pipe Caverns

Situated at SK 171,801, just to the east of Bradwell Dale, Hazlebadge Pipe Caverns consist of a complex series of pipe veins and flats (Crabtree, 1964). The mines have been extensively worked for fluorspar and include Revell's Pipe, Hazlebadge Pipe and Cow Hole Pipe. The pipes are developed in coarse crinoidal Eyam Limestones very close to the Namurian Shales (Worley, 1978). The mineralization consists of cavities lined with fluorite and lesser quantities of baryte, calcite and galena.

Post - mineralization phreatic cavernization in Hazlebadge Pipe (fig. 6.4.2.1.) has occurred leading to the accumulation of residual lumps of fluorite, baryte, calcite and galena in the base of the cavities (fig. 6.4.2.2.). This is overlain by a sequence of coarse sands.

A fissure broken into during 1973 yielded a number of bones representing a Devensian cold fauna indicating that parts of the caverns were open to the surface at that time (Ford et al, 1977).

The composition of the sands is given in figure 6.4.2.3.. Size analysis shows that these sands are moderately well sorted, leptokurtic coarse sands (fig. 6.4.2.4.). The results of S.E.M. study of quartz grain surface textures shows that the deposits are of fluvial

Sample Numbers BS 1 − 7		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0 — 1·5
	Silicified fossils	0 — 0 5
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	0 — 2·5
	Calcite	
2	Quartz	68 — 79
	Sandstone	3 — 12
	Feldspar	3 — 4·5
	Mica	5 — 16
	Shale	0 — 3·5
	Quartzite	
	Balance (mainly clay)	14 — 28
1 Autochthonous 2 Allochthonous		

Figure 6.4.1.5. Summary of sediment composition, Hippodrome, Bagshaw Cavern.

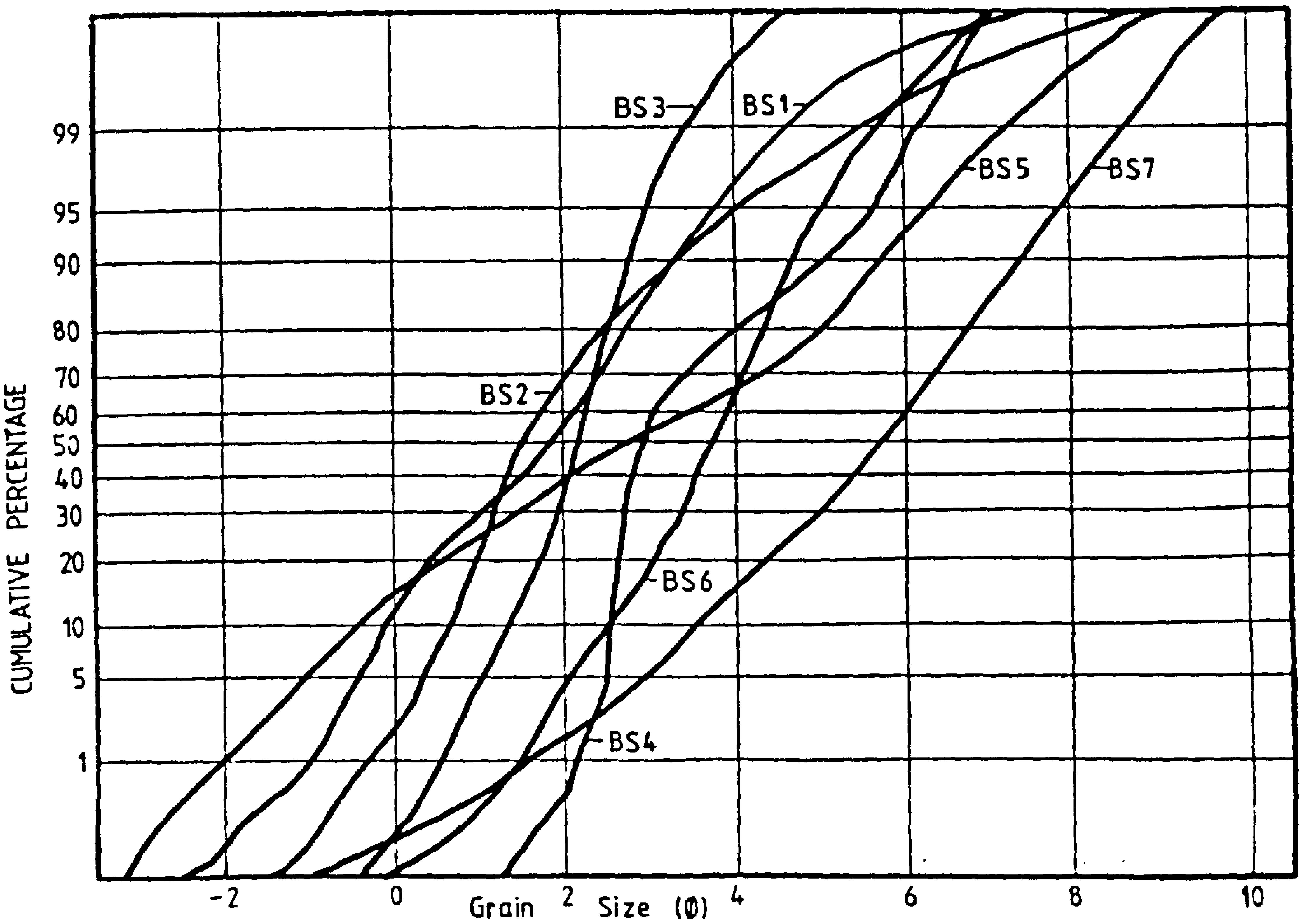


Figure 6.4.1.6. Sediment Size Analysis. Hippodrome, Bagshaw Cavern.

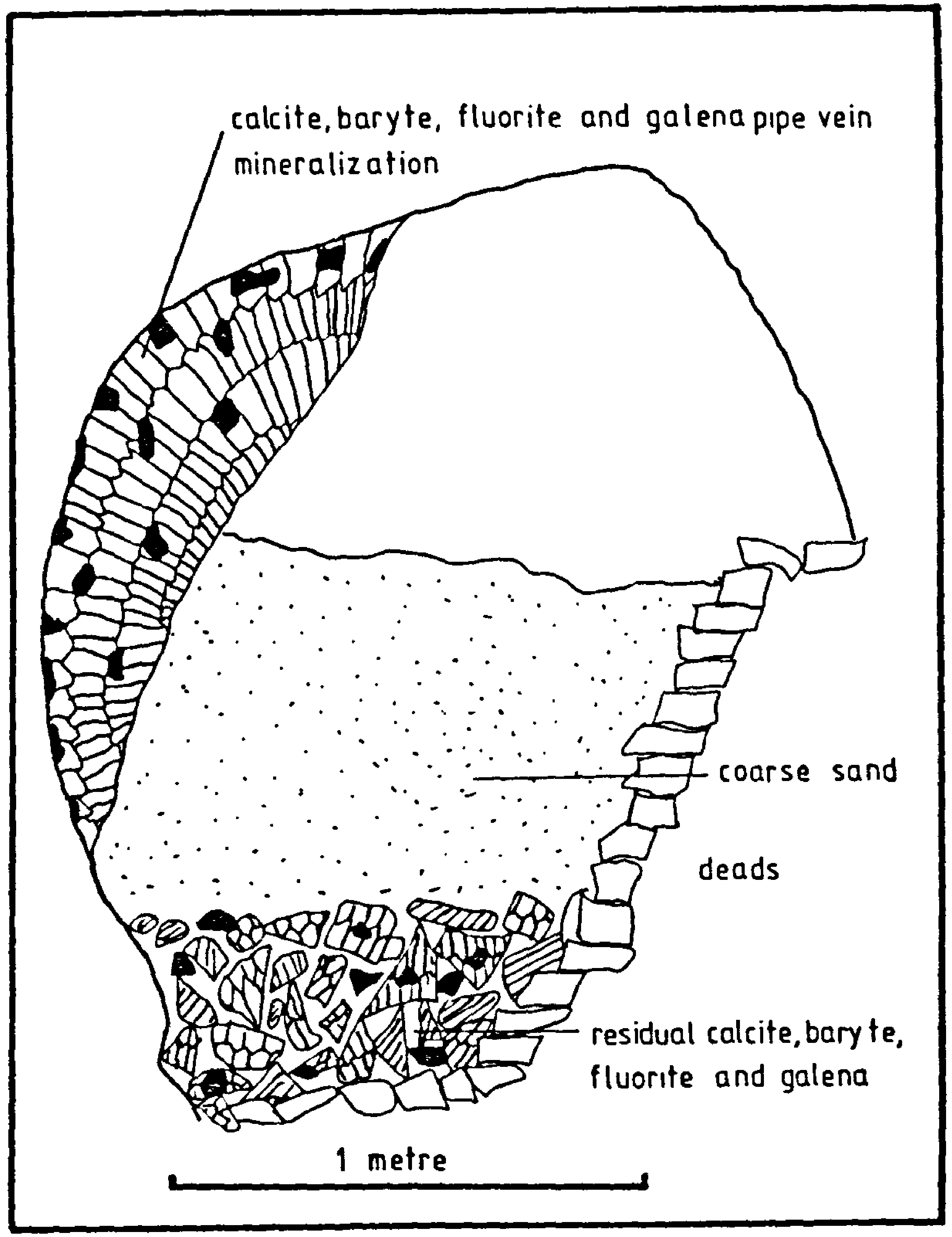


Figure 6.4.2.2. Residual deposit associated with Hazlebadge Pipe.

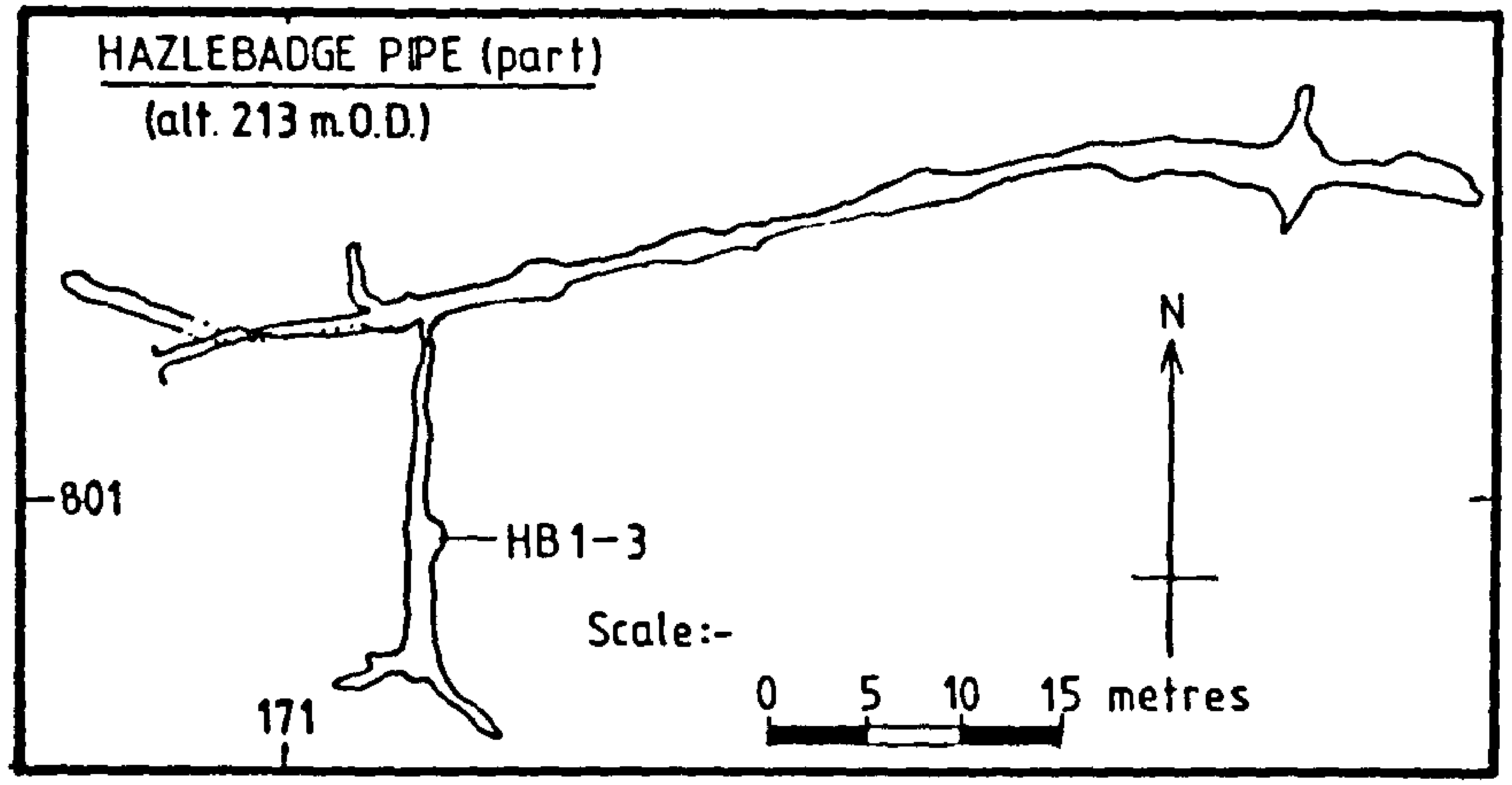


Figure 6.4.2.1. Plan of part of Hazlebadge Pipe showing sample locations After Crabtree (1964).

Sample Numbers HB 1-2		
		%
1	Limestone	0 — 1·5
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	0 — 0·5
	Fluorite	0·5 — 14
	Baryte	1 — 2·5
	Calcite	0 — 2
2	Quartz	68 — 81
	Sandstone	8 — 12
	Feldspar	2 — 3
	Mica	4 — 9
	Shale	3 — 8
	Quartzite	
	Balance (mainly clay)	4 — 8
1 Autochthonous 2 Allochthonous		

Figure 6.4.2.3. Summary of sediment composition, Hazlebadge Pipe.

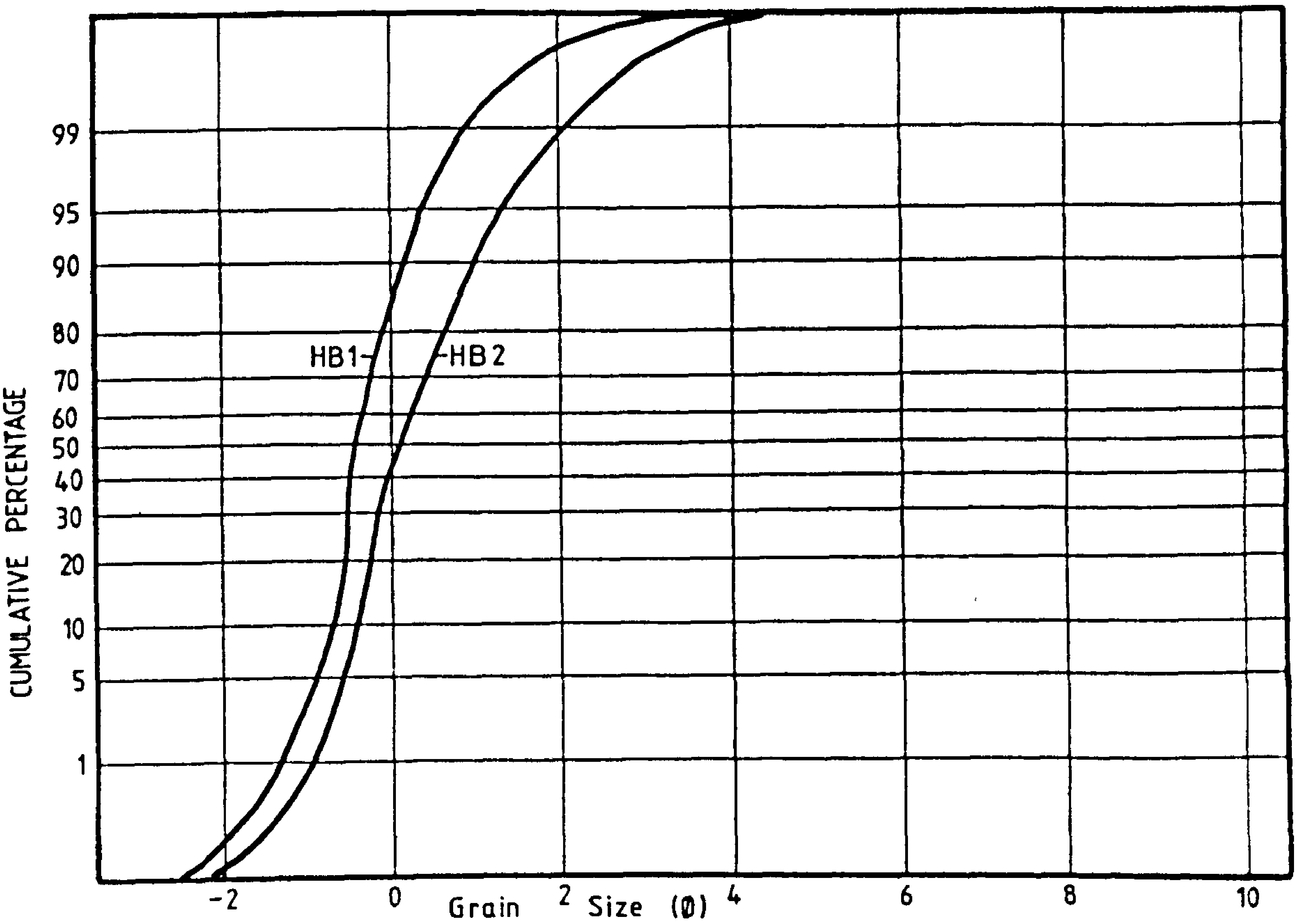


Figure 6.4.2.4. Sediment Size Analysis. Hazlebadge Cavern.

origin (fig. 6.4.2.5.).

The composition and coarse - grained nature of these sediments show that they are derived from nearby Namurian strata of Bradwell Edge. The sediment has been introduced into the cave system by fluvial processes and is unlikely to be of fluvio - glacial origin as suggested by Worley (1978).

6.4.3. Moorfurlong Mine

This mine is entered via a shaft at SK 168,812 which leads to a northwest - southeast trending pipe vein and associated caverns (Worley and Beck, 1976).

The pipe vein lies in Upper Monsal Dale Beds which consist of varying dark, bituminous to pale, crinoidal limestones (Worley and Beck, 1976). The mineralization consists of fluorite, baryte, calcite and galena cavity filling with fluoritization of the wall rocks (Worley and Beck, 1976).

Post - mineralization cavernization consists of a series of bedding plane controlled cavities cross - cutting the pipe vein mineralizaton (fig. 6.4.3.1.). These appear to have been totally filled with a coarse - grained, gravelly sediment which has been excavated by the miners. Underground ore-washing and mining operations have extensively disrupted this sediment although isolated undisturbed pockets survive.

The composition of this sediment is given in figure 6.4.3.2.. Size analysis shows that the gravel is poorly sorted, slightly fine - skewed, mesokurtic, sandy

Figure 6.4.3.1. Plan of Moorfurlong Mine showing sample locations. After Worley and Beck (1976)

Surface Features			
Chemical	Euhedral silica		
	Amorphous silica	●	●
	Solution crevasses	●	
	Solution pits	●	◢
	Oriented etch pits	●	●
Loessic	Dulled surface	●	●
	Smooth surface	●	
	Rounded	●	●
	Dish-shaped pits		
Fluvial	Subangular	◢	◢
	Subrounded	◢	◢
	Mechanical V-pits	◢	◢
	Curved scratches	●	◢
	Straight scratches	●	●
Glacial	Chattermarks		
	Angular	●	
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10μ	●	
	Conchoidals <10μ	●	●
	Breakage blocks>10μ		
	Breakage blocks<10μ		
General	Euhedral quartz		●
	Scaling	◢	●
	High relief	●	●
	Medium relief	◢	◢
	Low relief	◢	◢
	Meandering ridges	●	
	Arcuate steps	●	●
	Straight steps	●	●
	Edge abrasion	●	●
	Grain breakage	●	
	Sample number HB	1	2

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 6.4.2.5. Summary of quartz grain surface textures, Hazlebadge Pipe.

Sample Numbers MFM 1-3		
		%
1	Limestone	1 – 3·5
	Dolomite	
	Volcanics	0 — 0·5
	Chert	0·5 — 2
	Silicified fossils	0·5 — 1·5
	Authigenic quartz	2 — 3
	Galena	3 — 7
	Fluorite	37 — 54
	Baryte	15 — 28
	Calcite	13 — 29
2	Quartz	14 — 26
	Sandstone	4 — 5
	Feldspar	0 — 0·5
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	9 — 18

1 Autochthonous 2 Allochthonous

Figure 6.4.3.2. Summary of sediment composition, Moorfurlong Mine.

gravel (fig. 6.4.3.3.). The results of S.E.M. study of quartz grain surface textures shows that they are probably of fluvio - glacial origin (fig. 6.4.3.4., and plate 6.4.3.1.). A large proportion of this sediment has been derived from the pipe vein mineralization.

The northwest (upper) end of the mine (fig. 6.4.3.1.) is blocked by a large accumulation of sediment. Ford et al (1975) considered that this is the fill in a pothole that was once open to the surface.

The sediment consists of rounded blocks and pebbles, often showing glacial striations, in a sandy - silt matrix. The overall composition is given in figure 6.4.3.5.. Size analysis shows that these sediments are poorly sorted, very coarse - skewed, very platykurtic, pebbly silts (fig. 6.4.3.6.). The results of S.E.M. study of the quartz grain surface textures show that the matrix of the sediments is probably of glacial origin (fig. 6.4.3.4.).

This study supports the view of Ford et al (1975) that this deposit is partially derived from till. The deposit shows no evidence of bedding or of any degree of size sorting and may be an in situ till deposit. It could also have slumped from a surface deposit into an open pothole as a mud flow or by soli-fluction processes.

6.4.4. Earle's Quarry

Earle's Quarry is a large quarry working limestone for cement manufacture, centred on SK 160,820. Bee Low

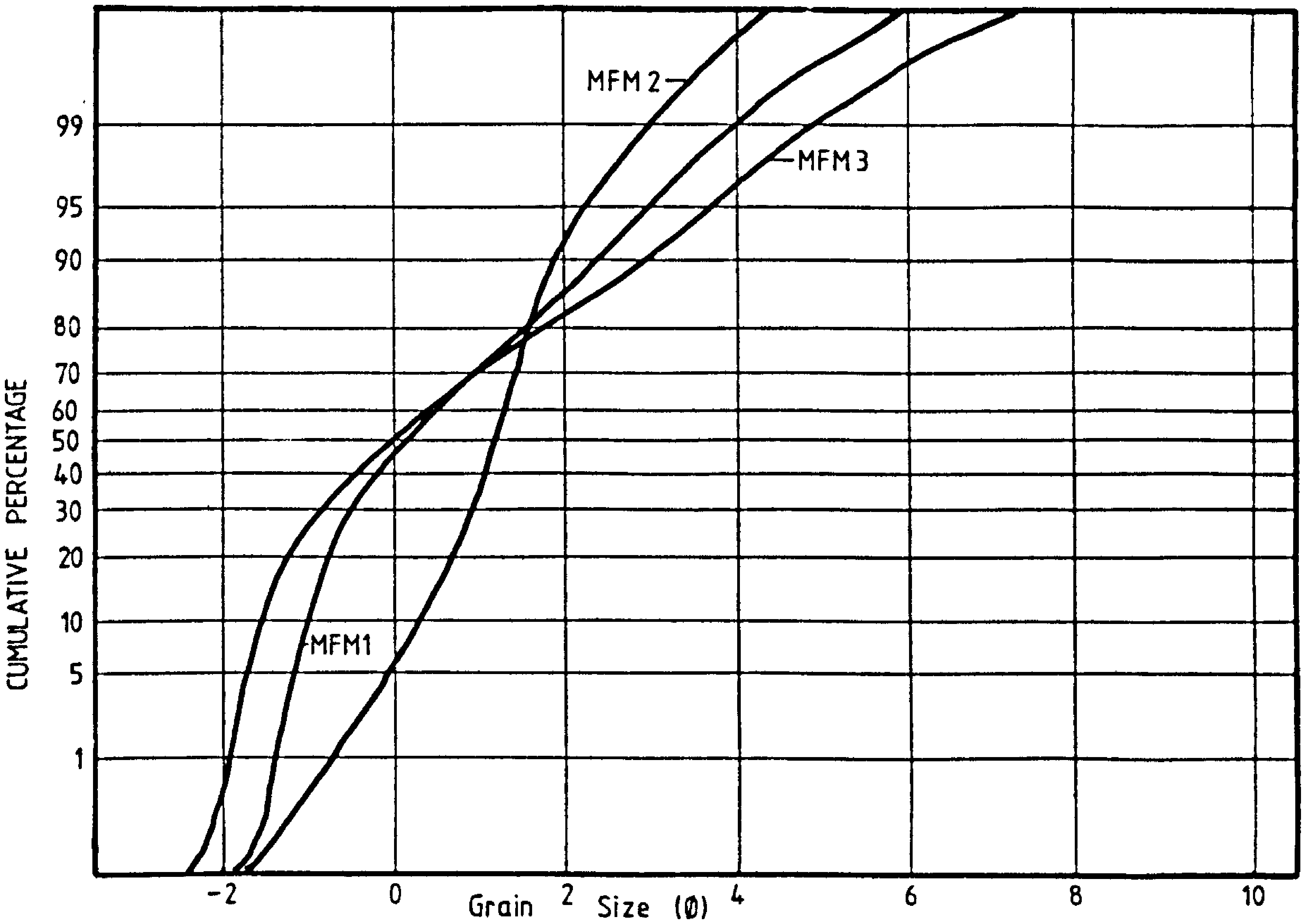
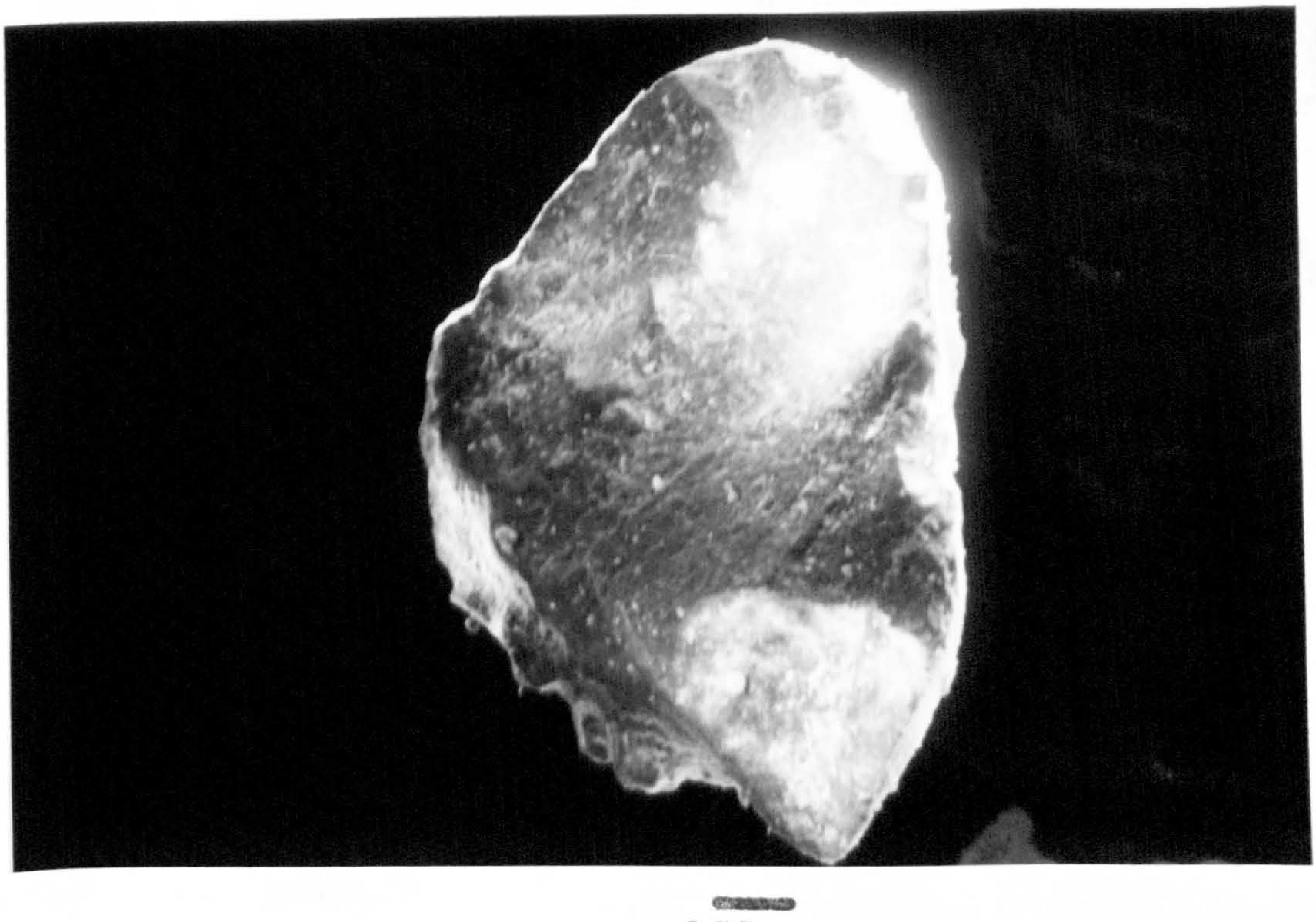


Figure 6.4.3.3. Sediment Size Analysis. Moorfurlong Mine.

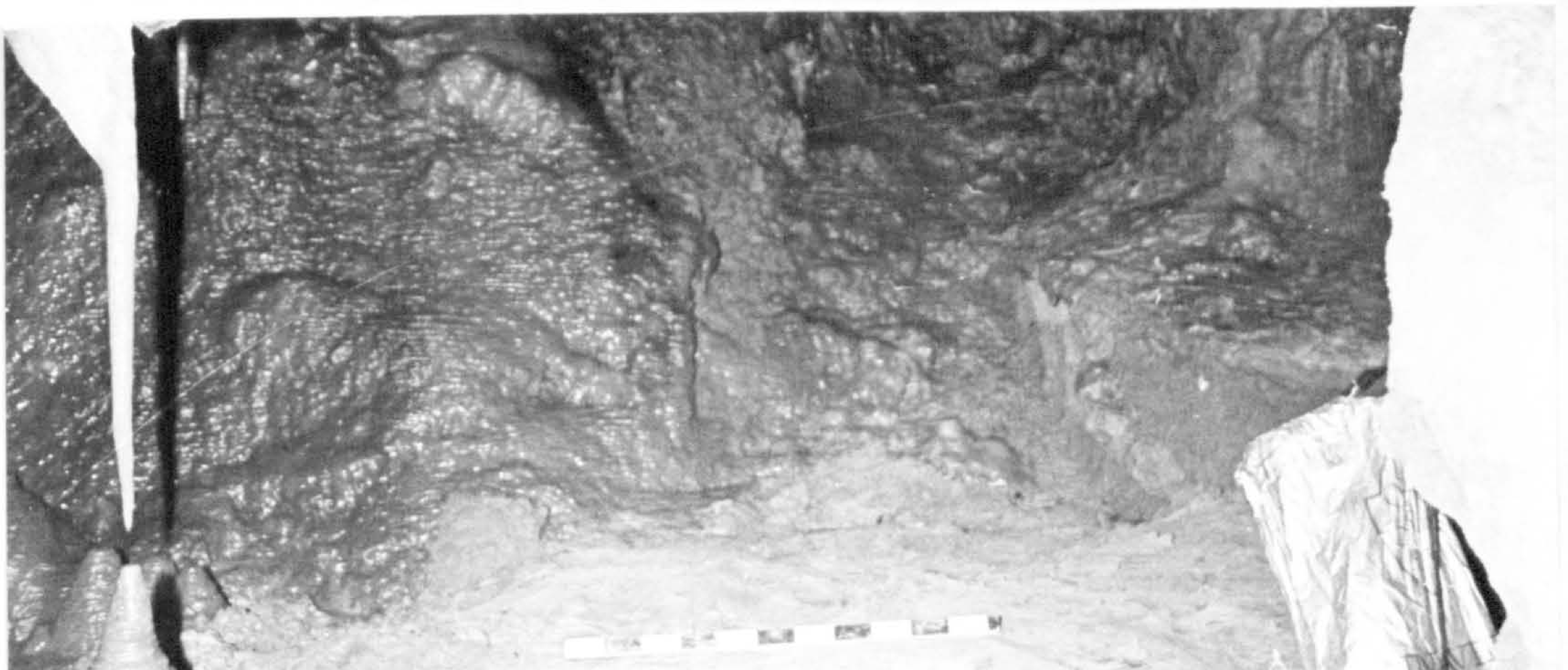
Chemical	Euhedral silica	●				●		
	Amorphous silica	●	●		●	●	●	●
	Solution crevasses	●			●		●	
	Solution pits	●	●		●		●	●
	Oriented etch pits	●			●	●	●	
Loessic	Dulled surface	●					●	●
	Smooth surface							
	Rounded							
	Dish-shaped pits							
Fluvial	Subangular	◢	■		◢	◢	◢	●
	Subrounded	●	●					
	Mechanical V-pits	●	◢					
	Curved scratches					●		
	Straight scratches							
Glacial	Chattermarks	◢	◢		◢	◢	◢	■
	Angular	◢	●		◢	◢	◢	■
	Fracture plates	●	●		●	◢	◢	●
	Adhering particles	●	◢		●	●	●	●
	Imbricate grinding	●	●		●	●	◢	●
	Parallel striations	●	◢		●	◢	◢	◢
	Conchoidals >10μ	●	◢		●	◢	●	●
	Conchoidals <10μ	●	◢		●	●	●	◢
	Breakage blocks>10μ	●	●		●	●	●	●
	Breakage blocks<10μ	●	●		●	●	●	●
Surface Features General	Euhedral quartz	●	●		●			
	Scaling	●	◢		●		●	●
	High relief	◢	■		◢	◢	●	◢
	Medium relief	◢	◢		◢	◢	■	◢
	Low relief	◢	●		◢	◢	●	◢
	Meandering ridges	●	●		●	●	●	●
	Arcuate steps	●			●		●	
	Straight steps	●	●		●	●	●	
	Edge abrasion	●	◢		●	◢	◢	●
	Grain breakage	●	◢		◢	●	●	●
	Sample number MFM	1	3		4	6	8	9

■ Abundant — 75%
◢ Common 25-75%
● Present 1-25%
□ Absent — 1%

Figure 6.4.3.4. Summary of quartz grain surface textures, Moorfurlong Mine.



6.4.3.1. S.E.M. photomicrograph of a typical fluvio - glacial quartz grain, Moorfurlong Mine.



Scale divisions 5 cm.

6.4.8.1. Loessic silts below stalagmite horizon, Dream Cave, Treak Cliff Cavern.

and Monsal Dale Limestones are exposed in the quarry (Eden et al, 1964) and these overlie a degraded agglomerate cone (Stevenson and Gaunt, 1971).

The southern face of the quarry intersects the northwestern end of the Smalldale Pipe at SK 155,816. This is the continuation of the pipe vein in which Moorfurlong Mine is developed. The mineralization in the pipe consists of fluorite with baryte, calcite and galena as open cavity fillings and fluorite replacement of the wall rocks.

Pre - mineralization cavernization occurred below the cover of Edale Shale. In places the collapse of the cavities brought down blocks of shale from above (fig. 6.4.4.1.). It is probable that this collapse occurred at the onset of mineralization at this locality. This implies that at least the initial mineralizing fluids were aggressive, leading to to the dissolution of the limestone prior to mineralization. Mineralization occurred as a number of distinct phases, with intervals of quiescence represented by thin clay beds between the layers of mineralization. In places small clasts of shale have been incorporated in the mineral deposit having been altered from their usual dark grey colour to a pale brown. The margins of the larger shale blocks in the collapse breccias are similarly altered. Similar deposits have not been recognised elsewhere in the Peak District.

Following the removal of the shale cover during the Pleistocene, percolating groundwater initiated another phase of cavernization, partly in the limestone and

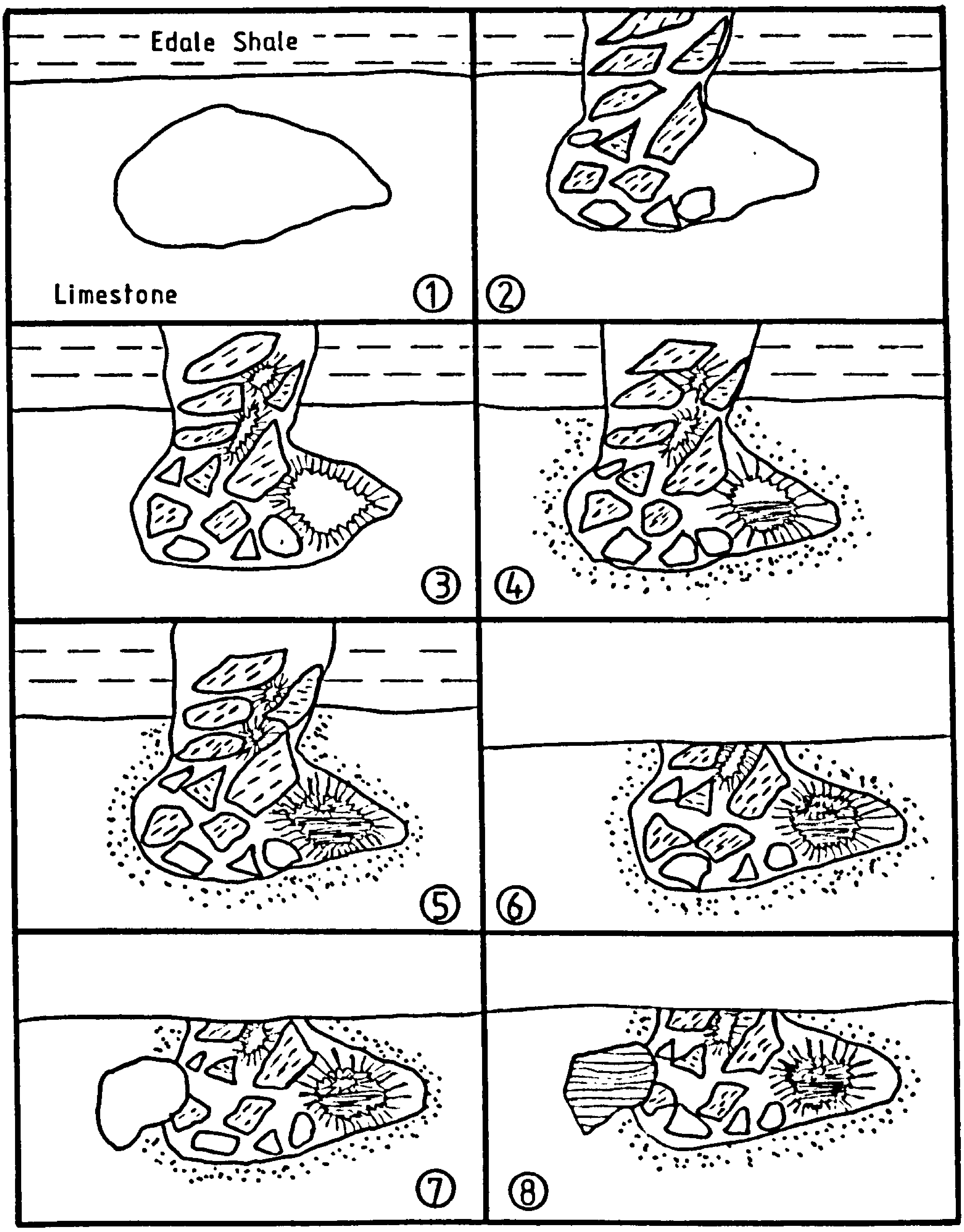


Figure 6.4.4.1. Mineralization of Smalldale Pipe in Earle's Quarry.
1. Formation of cavity below cover of Edale Shale by hydrothermal solutions. 2. Roof collapse and formation of collapse breccia. 3. Early calcite - fluorite mineralization. 4. Fluorite - baryte - galena mineralization and fluoritization of limestone wall rocks. 5. Late calcite in remaining cavities. 6. removal of shale cover. 7. Renewed cavernization by groundwater following removal of shale cover. 8. Infilling of new cavities with surface-derived sediment.

partly in the pipe vein. These cavities contain basal accumulations of residual pipe vein mineralization and were subsequently filled with sediment (fig. 6.4.4.2.).

The overall composition of these sediments is given in figure 6.4.4.3.. Size analysis shows that these sediments are moderately sorted, fine - skewed, mesokurtic silty - sands (fig. 6.4.4.4.). The results of S.E.M. study of quartz grain surface textures shows that they are of fluvial origin with the incorporation of a small proportion of loessic silts (fig. 6.4.4.5.).

The composition of these sediments indicates that the source of most of the sediment is the Namurian strata. Most of it has been derived by fluvio - glacial processes. Some loessic sediment has been mixed with this prior to deposition.

A number of small scrins are also intersected by the quarry faces. These are mineralized with fluorite, baryte and galena. A scrin at SK 158,815 has been solutionally enlarged to a fissure 0.5 metre wide (fig. 6.4.4.6.). The bottom of the cavity contains an accumulation of the insoluble residue from the scrin consisting of fluorite, baryte, galena and chert gravel. This is overlain by a sandy - silt, the composition of which is given in figure 6.4.4.7.. Size analysis shows that the sediments are well sorted, slightly coarse - skewed, mesokurtic sandy - silts (fig. 6.4.4.8.).

At SK 154,817 the quarry face cuts through a filled channel with nearly vertical walls, 4 to 6 metres apart and has been cut down to a depth of nearly 8 metres

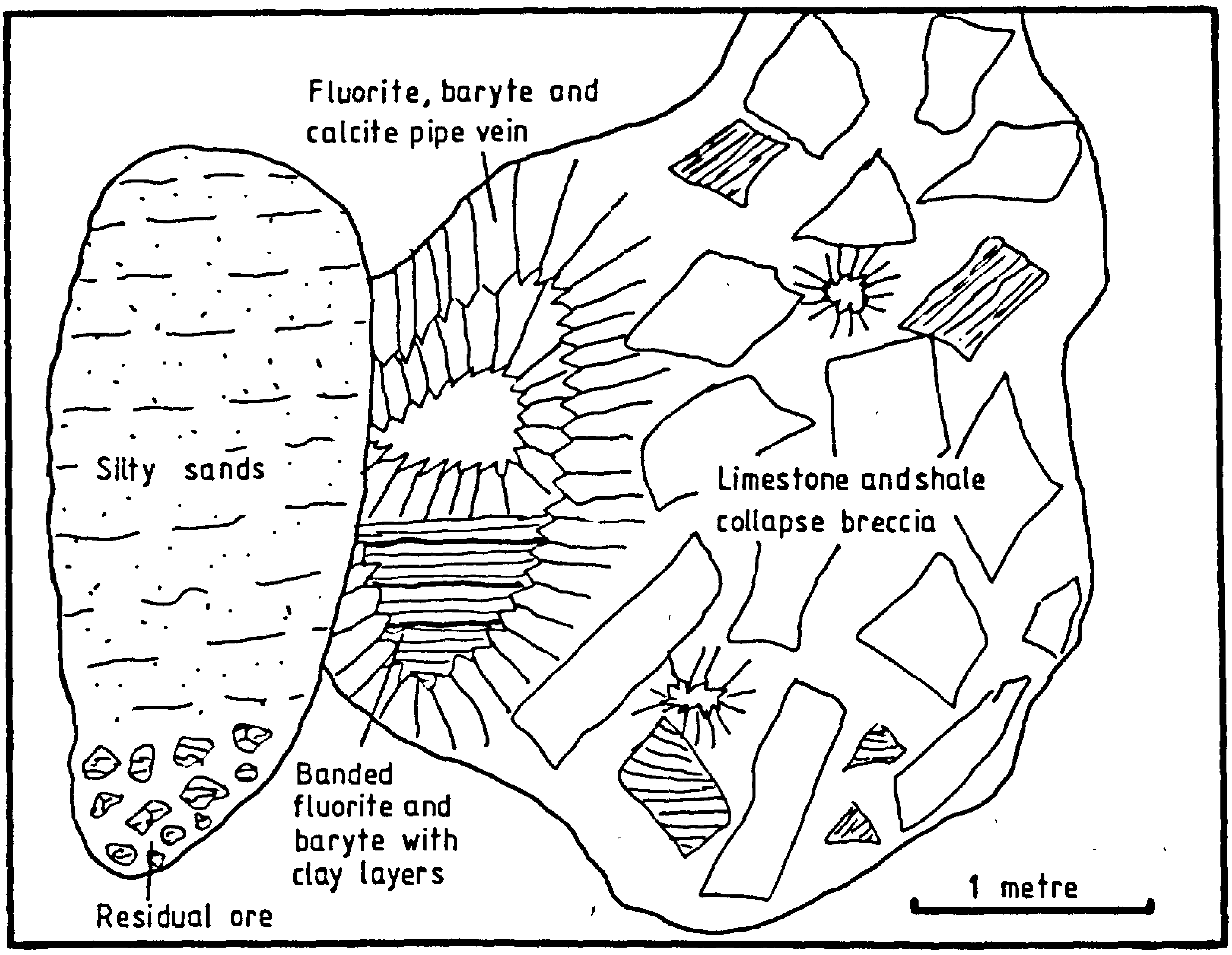


Figure 6.4.4.2. Smalldale Pipe, Earle's Quarry.

Sample Numbers HQ 1 – 3		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0 — 1·5
	Silicified fossils	0·5 – 1·5
	Authigenic quartz	
	Galena	0 — 0·5
	Fluorite	3 — 7
	Baryte	1 — 3
	Calcite	0 — 2·5
2	Quartz	75 — 86
	Sandstone	
	Feldspar	1 — 2
	Mica	0 — 0·5
	Shale	3 — 14
	Quartzite	
	Balance (mainly clay)	4 — 9
1 Autochthonous 2 Allochthonous		

Figure 6.4.4.3. Summary of sediment composition, Smalldale Pipe, Earle's Quarry.

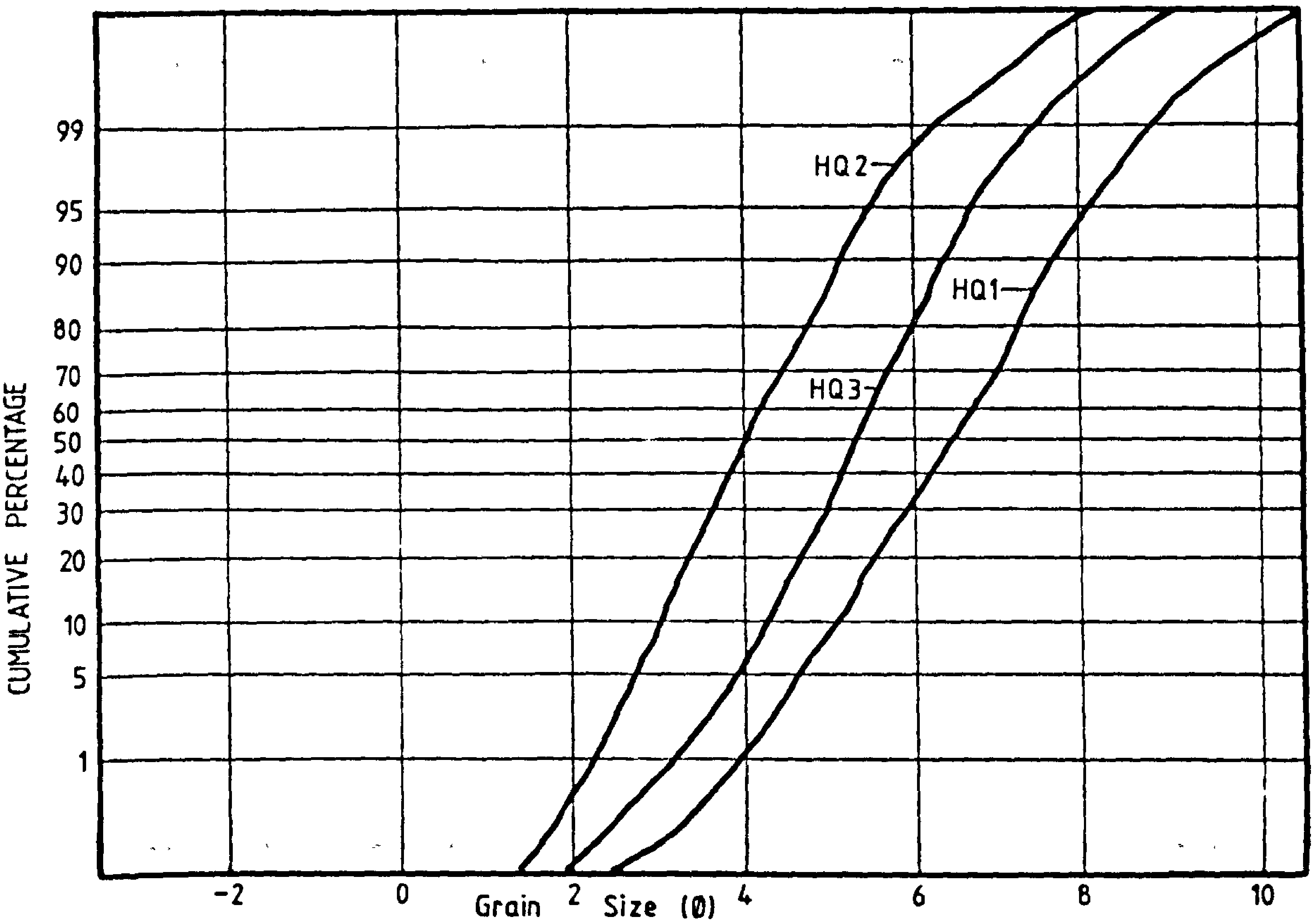


Figure 6.4.4.4. Sediment Size Analysis.Earle's Quarry.

Surface Features	Chemical			
	Euhedral silica	●	●	
	Amorphous silica	●	●	●
	Solution crevasses	●	●	●
	Solution pits	●	●	●
	Oriented etch pits	●	●	
	Loessic			
	Dulled surface	●	◢	◢
	Smooth surface	●	●	◢
	Rounded	●	●	◢
	Dish-shaped pits	●	●	●
	Fluvial			
	Subangular	◢	◢	●
	Subrounded	●	●	◢
	Mechanical V-pits	◢	●	●
	Curved scratches	●	●	●
	Straight scratches	●	●	
	Glacial			
	Chattermarks	◢	●	●
	Angular	◢	◢	●
	Fracture plates			
	Adhering particles			
	Imbricate grinding			
	Parallel striations	◢	●	●
	Conchoidals >10μ	●	◢	●
	Conchoidals <10μ	●	●	●
	Breakage blocks>10μ	●	◢	●
	Breakage blocks<10μ	●	●	●
	General			
	Euhedral quartz	●		
	Scaling	●	◢	●
	High relief	◢	◢	◢
	Medium relief	◢	◢	◢
	Low relief	◢	◢	◢
	Meandering ridges	●	●	●
	Arcuate steps	●	●	
	Straight steps	●	●	●
	Edge abrasion	●	◢	◢
	Grain breakage	◢	●	●
	Sample number HQ	1	2	3

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 6.4.4.5. Summary of quartz grain surface textures, Smalldale Pipe, Earle's Quarry.

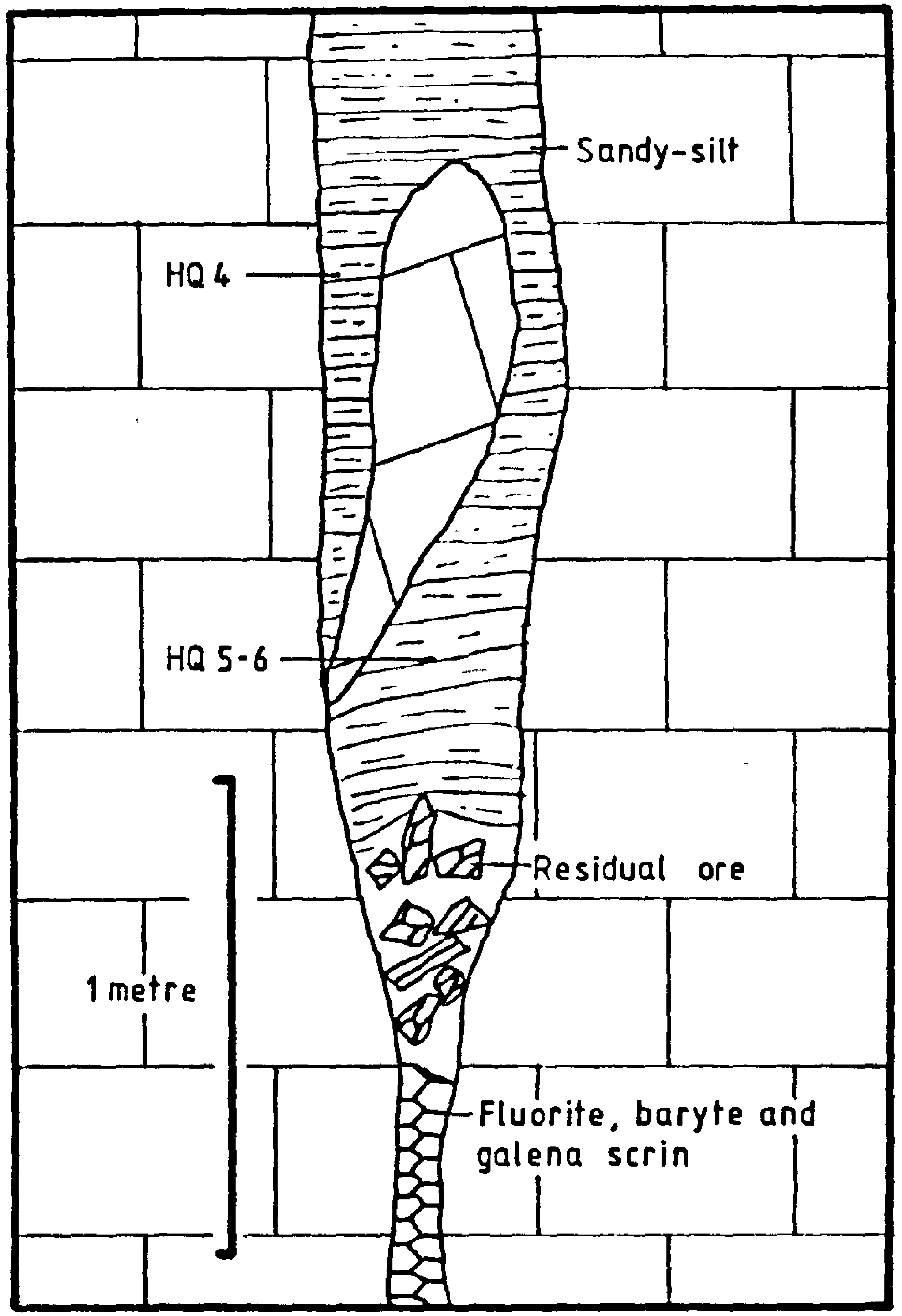


Figure 6.4.4.6. Solutionally enlarged scrin, Earle's Quarry.

Sample Numbers HQ 4-6		
		%
1	Limestone	10 — 26
	Dolomite	
	Volcanics	
	Chert	3 — 7·5
	Silicified fossils	1 — 2
	Authigenic quartz	0 — 1·5
	Galena	3 — 9
	Fluorite	2 — 5
	Baryte	1 — 3
	Calcite	0 — 1·5
2	Quartz	54 — 71
	Sandstone	
	Feldspar	
	Mica	0 — 0·5
	Shale	
	Quartzite	
	Balance (mainly clay)	12 — 24
1 Autochthonous 2 Allochthonous		

Figure 6.4.4.7. Summary of sediment composition, Earle's Quarry.

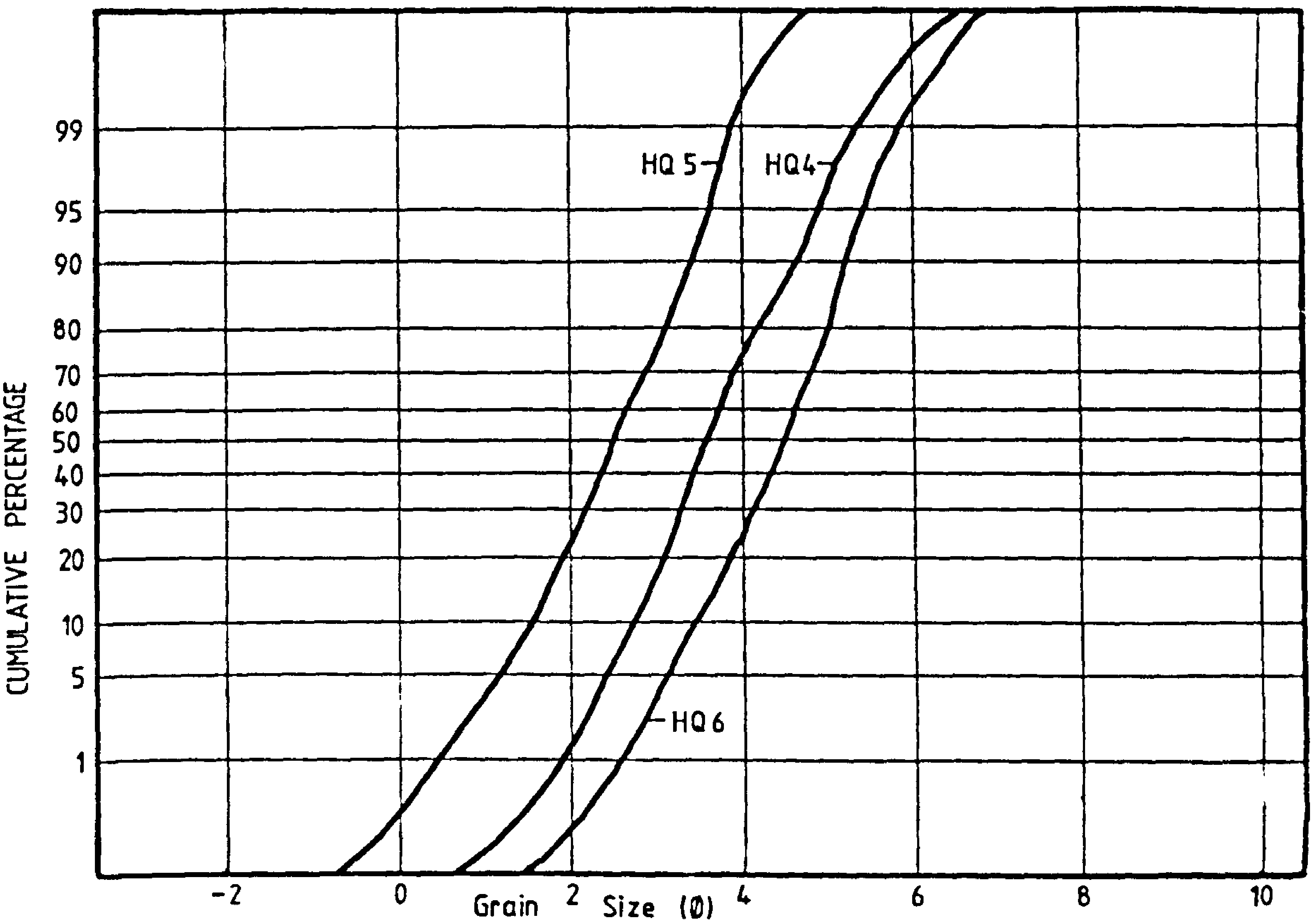


Figure 6.4.4.8. Sediment Size Analysis, Earle's Quarry.

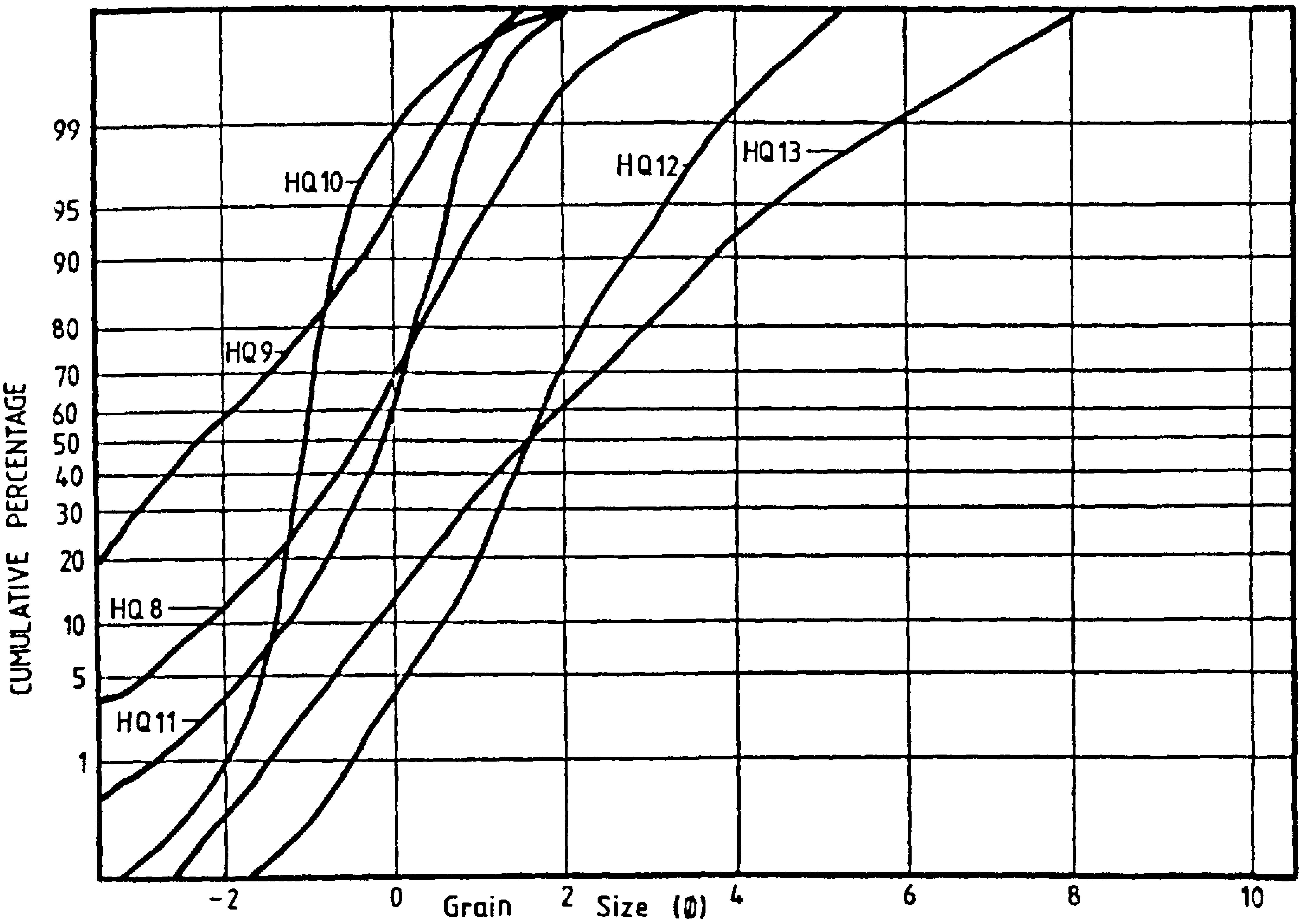


Figure 6.4.4.10. Sediment Size Analysis. Earle's Quarry.

(fig. 6.4.4.9.).

The channel is filled by a bouldery sediment which shows no bedding. The boulders are well - rounded and consist of limestone, chert, shale and sandstone. Some of the blocks carry glacial striations. Smaller blocks of fluorite and baryte are also present.

The matrix of these boulders is a poorly sorted, platykurtic gravelly - sand (fig. 6.4.4.10.) the composition of which is given in figure 6.4.4.11.. The results of S.E.M. study of quartz grain surface textures shows that the sediments are of fluvio - glacial origin (fig. 6.4.4.12.).

Overlying the channel fill is an irregular layer of derived chert nodules overlain by a sandy - silt deposit. The results of S.E.M. study of quartz grain surface textures shows that this sediment is of loessic origin (fig. 6.4.4.12.).

The channel can be traced in the opposite face of the quarry at SK 156,816 but quarrying has obscured the exposure.

From the available evidence it appears that this channel is a sub - glacial or a marginal meltwater channel that is filled with fluvio - glacial sediments. The size of some of the boulders indicates that high flow velocities occurred, typical of such channels. The presence of shale and sandstone clasts shows that some of the sediment has been derived from the Namurian strata. No erratics have been found. There is no evidence present to indicate flow direction but a northwest to southeast flow towards Smalldale is likely.

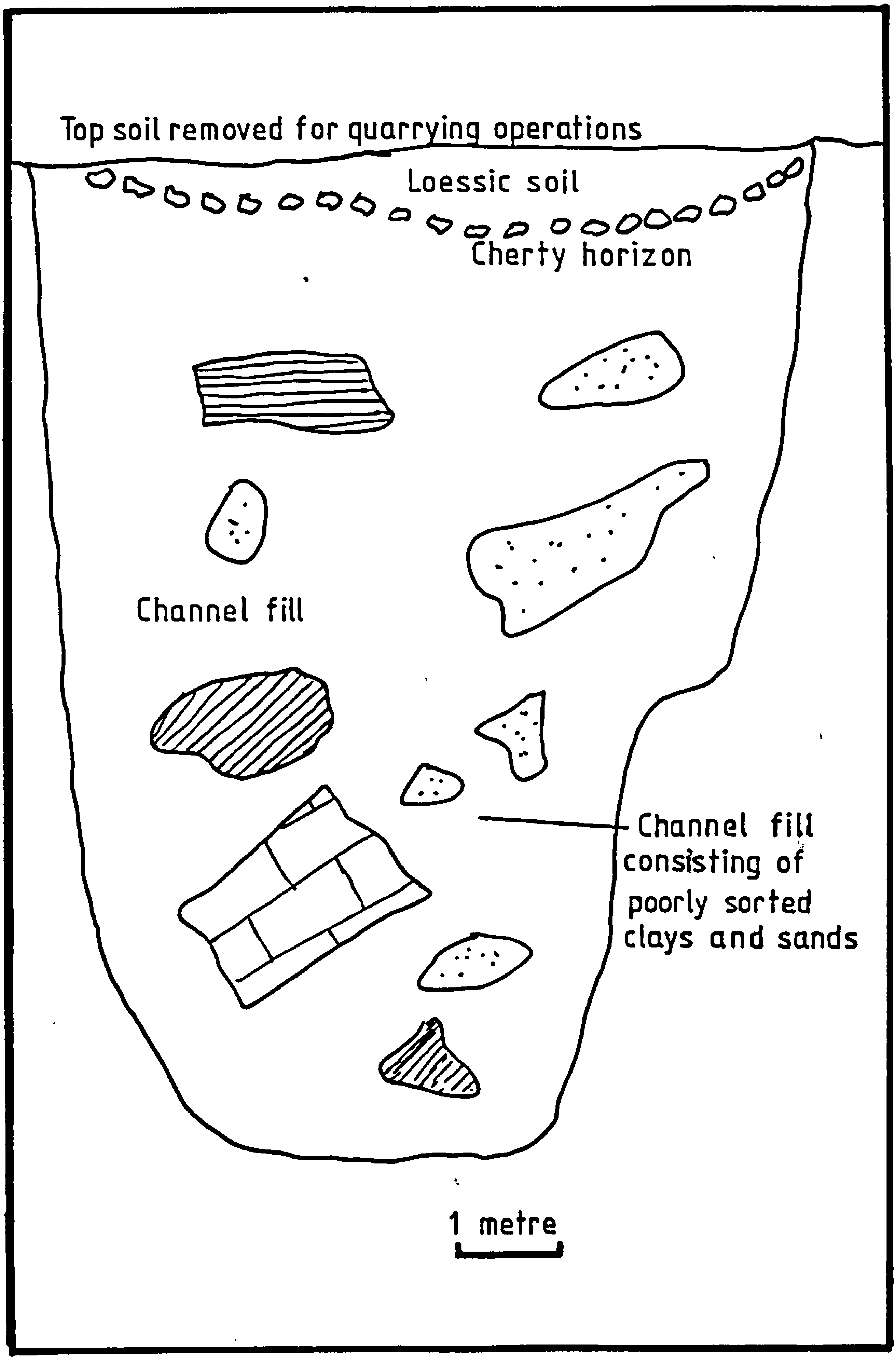
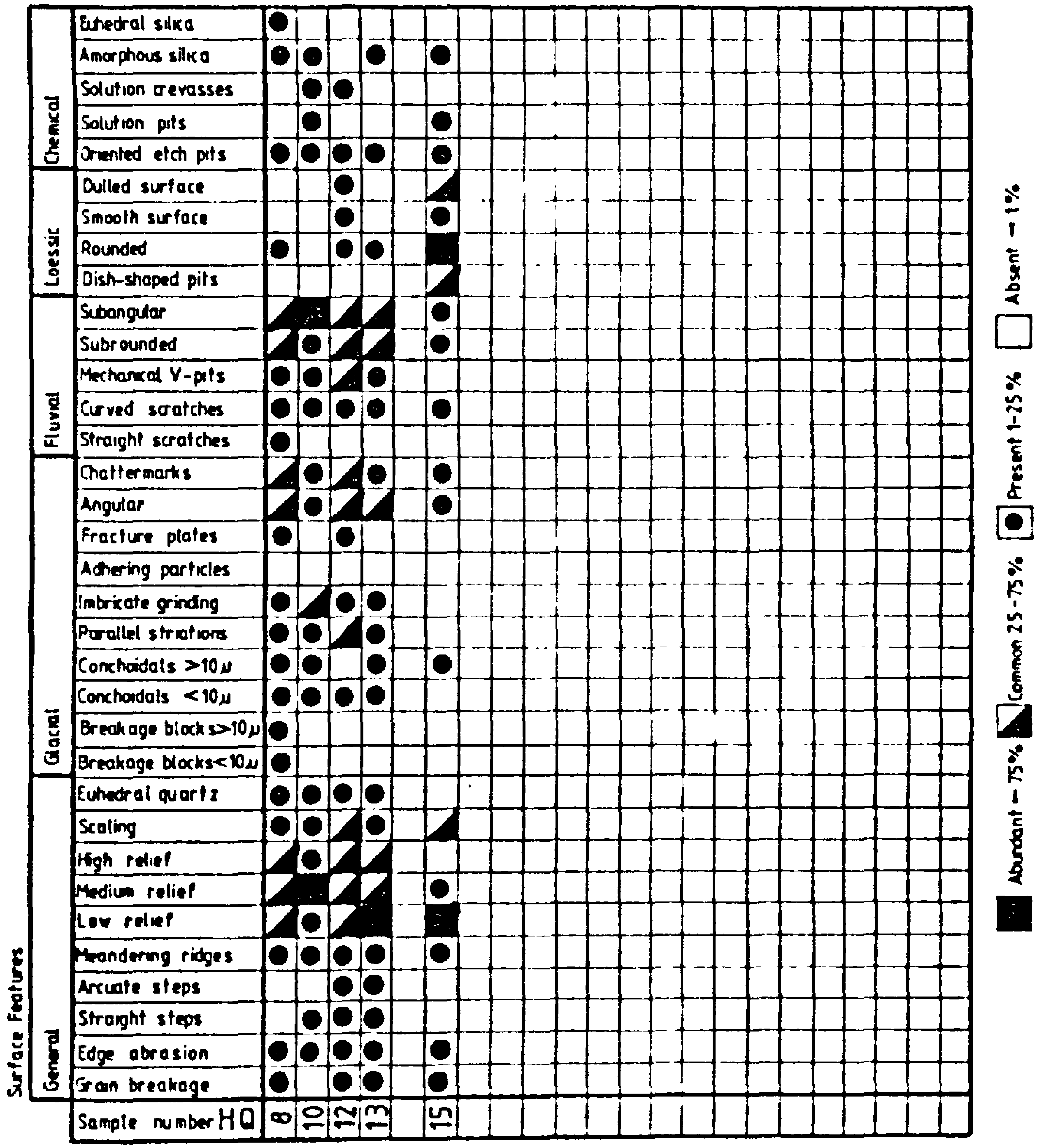


Figure 6.4.4.9. Schematic section of glacial meltwater channel, Earle's Quarry.

Sample Numbers HQ 8 – 13		
		%
1	Limestone	4 — 12
	Dolomite	
	Volcanics	0 — 2·5
	Chert	1 — 3·5
	Silicified fossils	0 — 1
	Authigenic quartz	1 — 6
	Galena	0 — 0·5
	Fluorite	2 — 4·5
	Baryte	0·5 — 3
	Calcite	0 — 1·5
2	Quartz	68 — 73
	Sandstone	13 — 17
	Feldspar	1 — 4
	Mica	2 — 5
	Shale	7 — 13
	Quartzite	
	Balance (mainly clay)	12 — 19

1 Autochthonous 2 Allochthonous

Figure 6.4.4.11. Summary of sediment composition, Channel Fill, Earle's Quarry.



Surface Features		Sample number HQ	8	10	12	13		15
	Chemical	Euhedral silica	●					
		Amorphous silica	●	●		●		●
		Solution crevasses		●	●			
		Solution pits		●				●
		Oriented etch pits	●	●	●	●		●
	Loessic	Dulled surface			●			◢
		Smooth surface			●			●
		Rounded	●		●	●		■
		Dish-shaped pits						◢
	Fluvial	Subangular	◢	■	◢	◢		●
		Subrounded	◢	●	◢	◢		●
		Mechanical V-pits	●	●	◢	●		
		Curved scratches	●	●	●	●		●
		Straight scratches	●					
	Glacial	Chattermarks	◢	●	◢	●		●
		Angular	◢	●	◢	◢		●
		Fracture plates	●		●			
		Adhering particles						
		Imbricate grinding	●	◢	●	●		
		Parallel striations	●	●	◢	●		
		Conchoidals >10μ	●	●		●		●
		Conchoidals <10μ	●	●	●	●		
		Breakage blocks>10μ	●					
		Breakage blocks<10μ	●					
	General	Euhedral quartz	●	●	●	●		
		Scaling	●	●	◢	●		◢
		High relief	◢	●	◢	◢		
		Medium relief	◢	■	◢	◢		●
		Low relief	◢	●	◢	■		■
		Meandering ridges	●	●	●	●		●
		Arcuate steps			●	●		
		Straight steps		●	●	●		
		Edge abrasion	●	●	●	●		●
		Grain breakage	●		●	●		●

■ Abundant – 75% ◢ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 6.4.4.12. Summary of quartz grain surface textures, Channel, Earles Quarry.

The overlying loessic sediment was deposited over a weathering and erosion horizon, represented by the chert nodule layer, during the Devensian.

6.4.5. Blue John Caverns

The entrance to this show cave is situated at SK 132,832. The cave has been described by Whitehouse (1970) who also presented a survey. An early account of the geology, mineralization and cave formation of Blue John Cavern has been given by Barnes and Holroyd (1896). Permission from the owners for systematic study was not forthcoming but one sample was obtained from the show cave part of the system (fig. 6.4.5.1.).

The cave is developed in reef and fore reef limestones at the northern extremity of the exposed limestone.

The composition of the sediment is given in figure 6.4.5.2.. Size analysis shows that the sediment is moderately sorted, coarse - skewed, platykurtic silty - sand (fig. 6.4.5.3.). The results of S.E.M. study of quartz grain surface textures show that the quartz is of loessic origin (fig. 6.4.5.4.). The Blue John fluorite present in the sample is angular and may be the result of contamination from mining activity.

6.4.6. Odin Cave

Odin Cave is a small cave on the south side of Odin Gorge at SK 135,834. The cave is of phreatic origin and

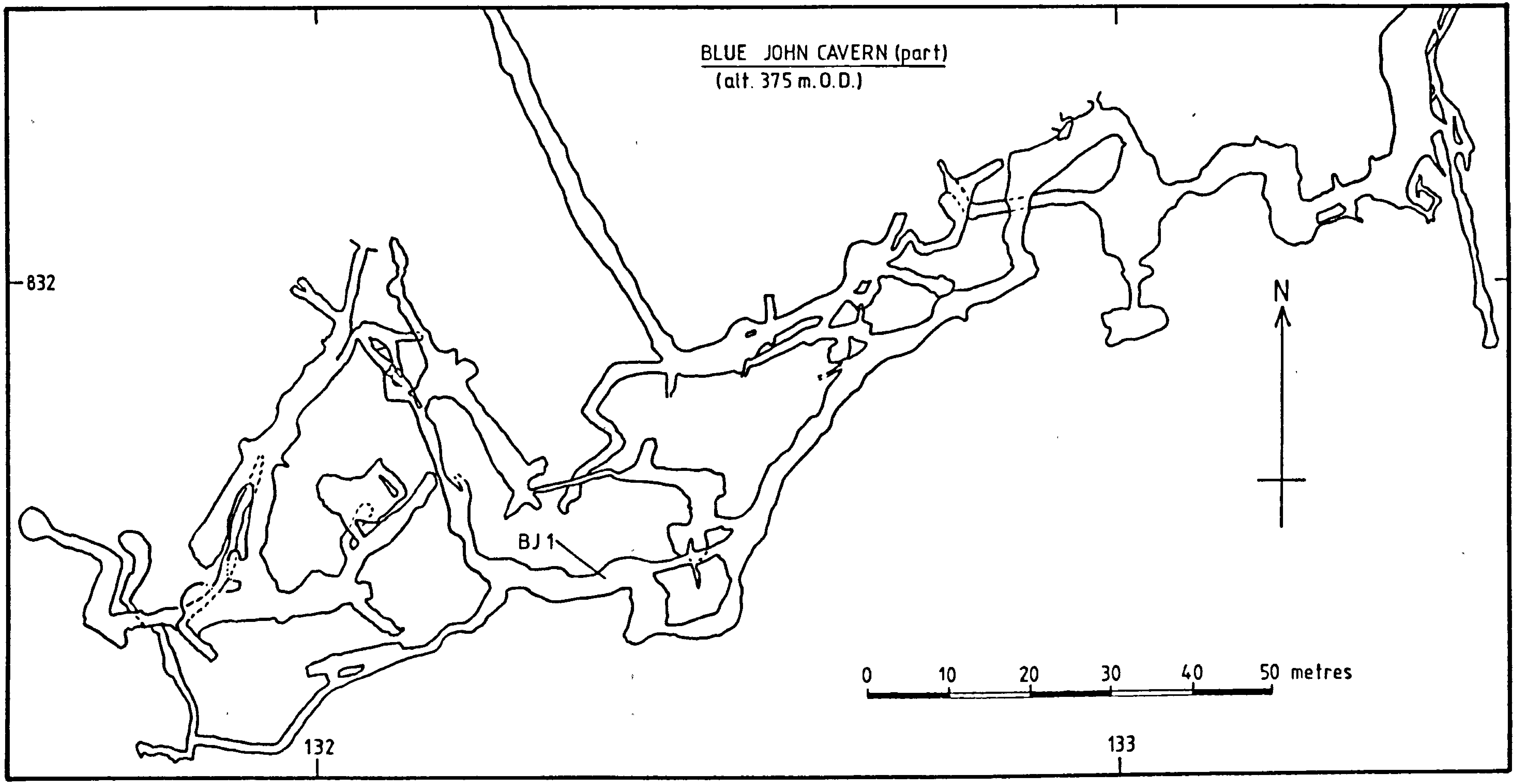


Figure 6.4.5.1. Plan of part of Blue John Cavern showing sample location. After Whitehouse (1970).

Sample Numbers BJ 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	2
	Authigenic quartz	1·5
	Galena	
	Fluorite (Blue John)	13
	Baryte	
	Calcite	
2	Quartz	74
	Sandstone	
	Feldspar	0·5
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	9
1 Autochthonous 2 Allochthonous		

Figure 6.4.5.2. Summary of sediment composition, Blue John Cavern

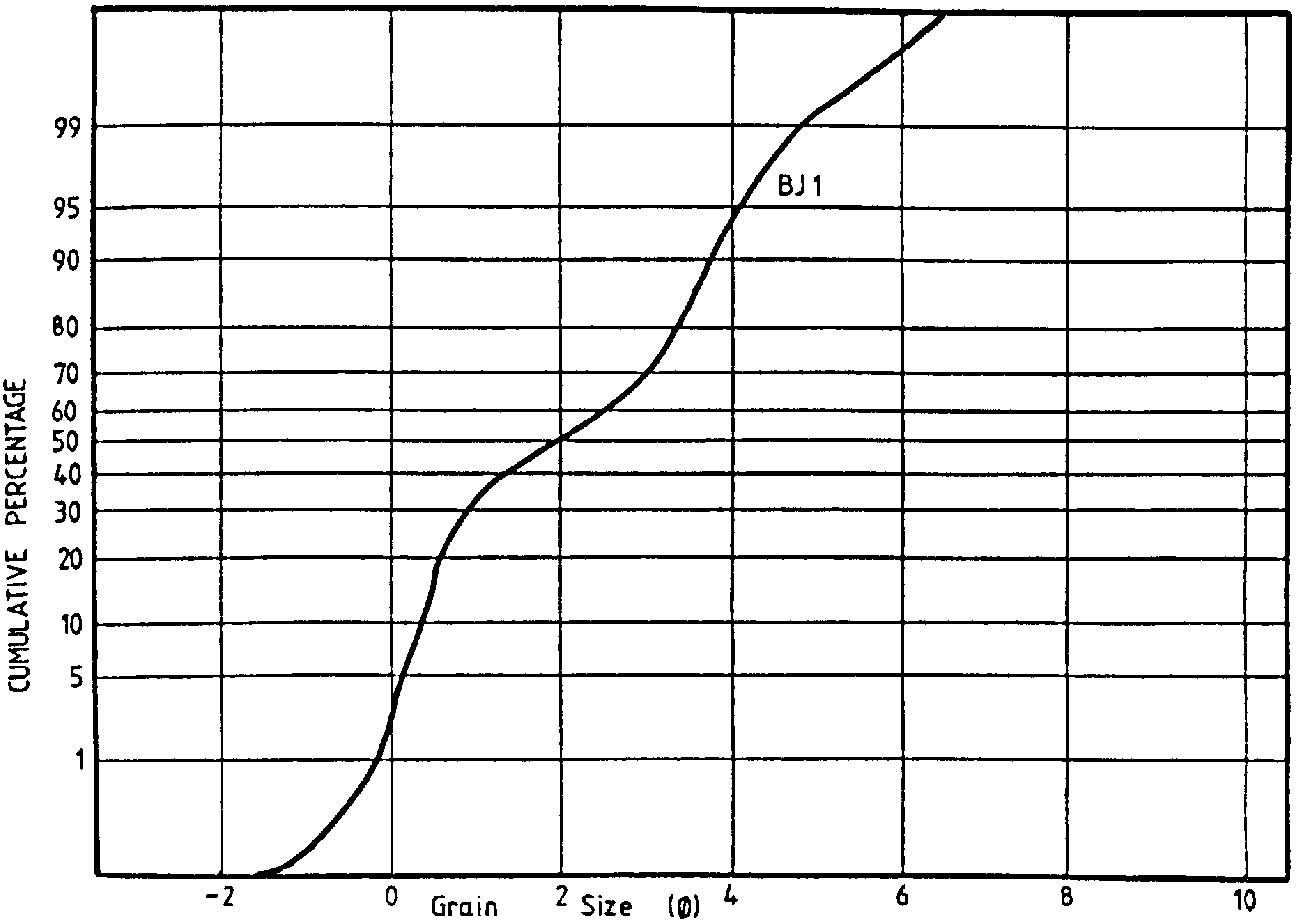


Figure 6.4.5.3. Sediment Size Analysis. Blue John Cavern.

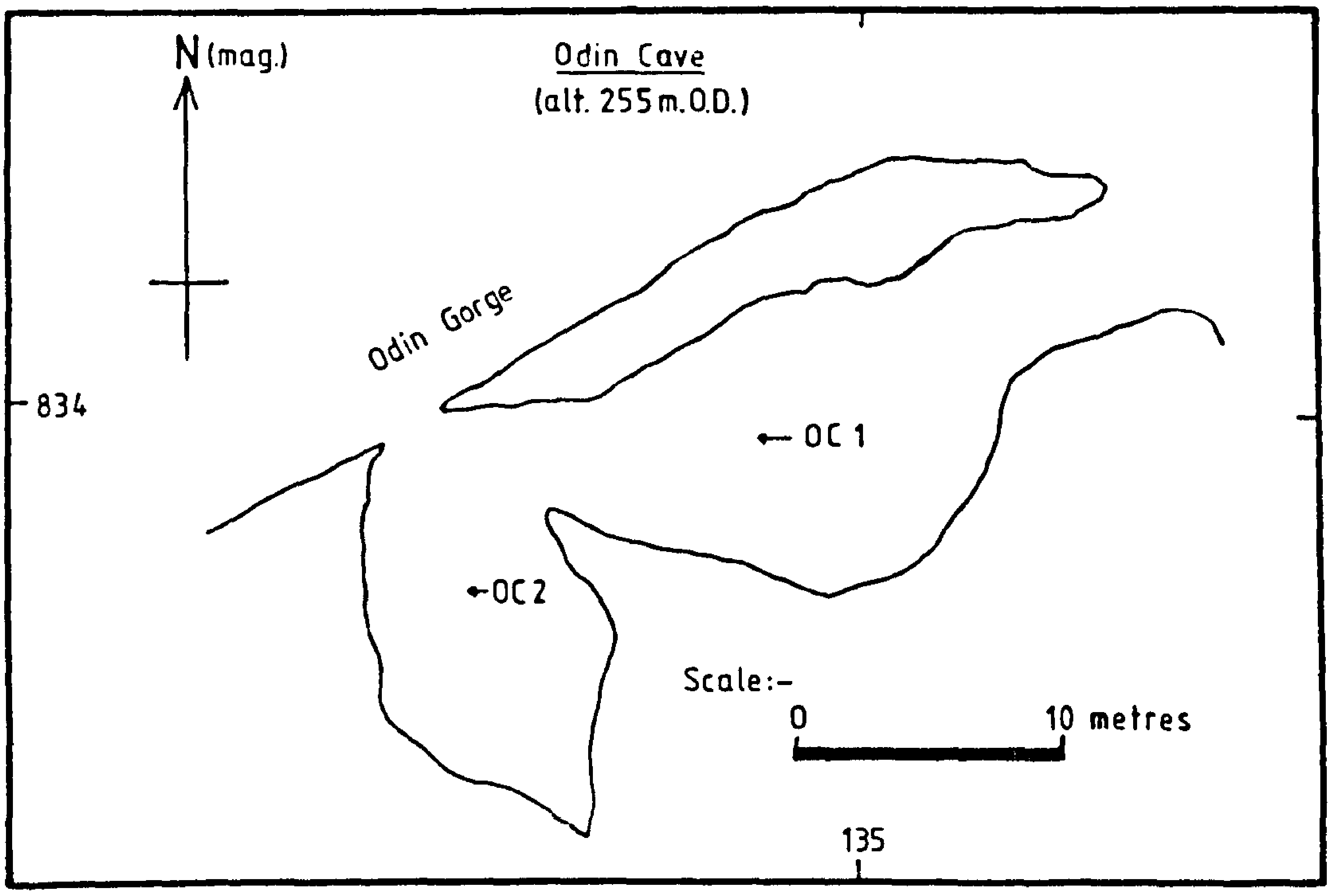
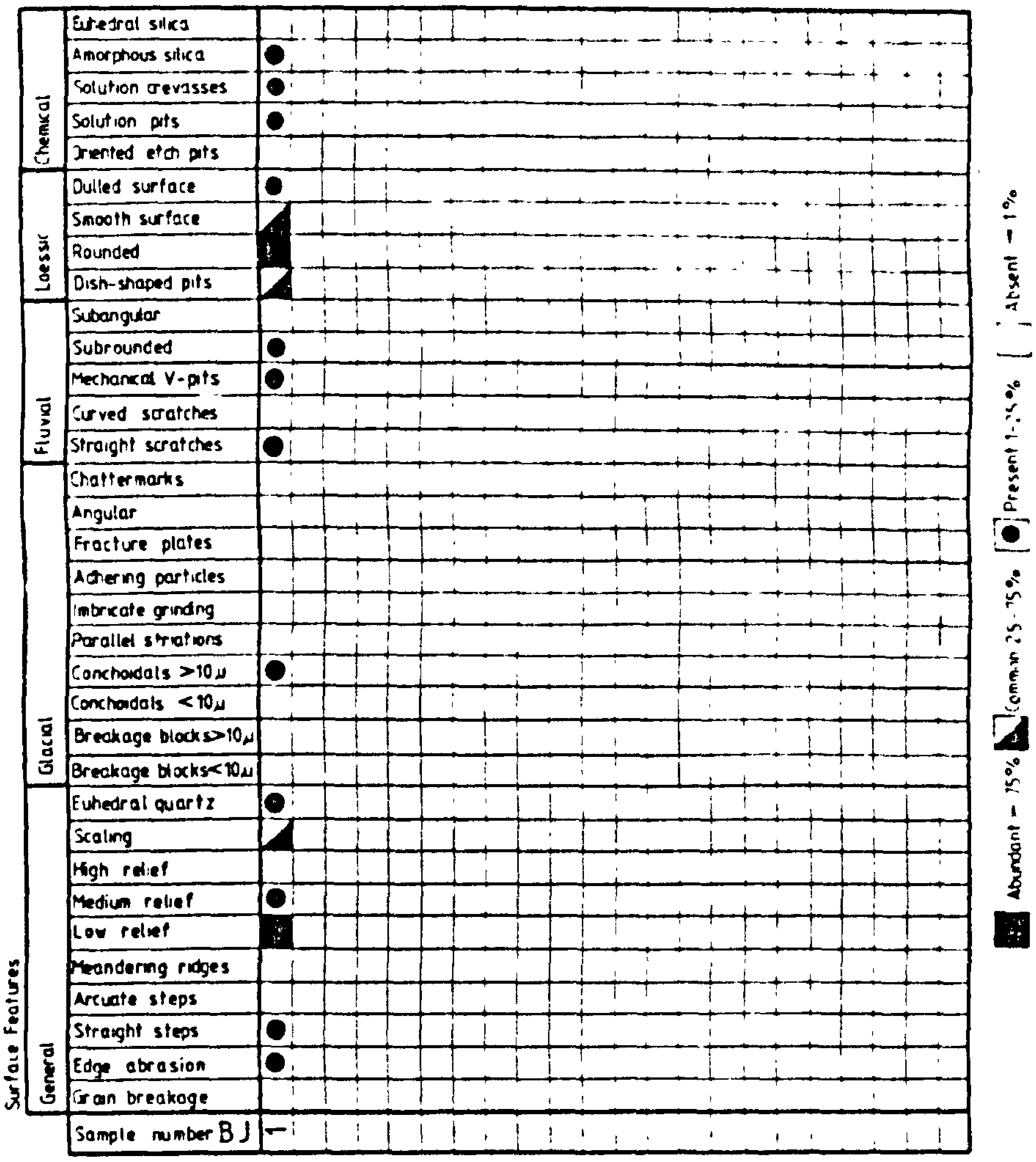


Figure 6.4.6.1. Plan of Odin Cave, showing sample locations. After Elliot (1977)



Chemical	Euhedral silica	
	Amorphous silica	●
	Solution crevasses	●
	Solution pits	●
	Oriented etch pits	
Loessic	Dulled surface	●
	Smooth surface	◢
	Rounded	■
	Dish-shaped pits	◢
Fluvial	Subangular	
	Subrounded	●
	Mechanical V-pits	●
	Curved scratches	
	Straight scratches	●
Glacial	Chattermarks	
	Angular	
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10µ	●
	Conchoidals <10µ	
	Breakage blocks>10µ	
	Breakage blocks<10µ	
Surface Features General	Euhedral quartz	●
	Scaling	◢
	High relief	
	Medium relief	●
	Low relief	■
	Meandering ridges	
	Arcuate steps	
	Straight steps	●
	Edge abrasion	●
	Grain breakage	
	Sample number BJ	1

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ¦ Absent – 1%

Figure 6.4.5.4. Summary of quartz grain surface textures, Blue John Cavern.

is formed along the parting between the base of the Boulder Bed and the underlying limestone. The floor of the cave (fig. 6.4.6.1.) is covered by a 10 to 15 cm. thick layer of unbedded sediment containing Blue John (Rieuwerts and Ford, 1976).

The composition of this fill is given in figure 6.4.6.2.. Size analysis shows that the sediment is a moderately sorted, coarse - skewed, platykurtic gravelly - silt (fig. 6.4.6.3.). The Blue John content of the sediment is coarse - grained and angular and has probably been derived from the Blue John deposits a short distance up the hill. The results of S.E.M. study of quartz grain surface textures shows that the fine - grained fraction of the sediment is of loessic origin (fig. 6.4.6.4.).

The similarity between the sediments here with those of the Blue John Cavern indicates that this cave may once have been the resurgence for the small stream that flows through part of the Blue John Cavern.

6.4.7. Odin Bank Shaft

This shaft is a small shaft sunk on a scrin about 75 metres south of Odin Gorge at SK 1332,8342. A short section of workings on the scrin is accessible (fig. 6.4.7.1.). The scrin consists of banded fluorite and baryte 8 to 14 cm. wide hosted in crinoidal, bioclastic fore - reef limestones.

A small phreatic solution cavity on the south side of the scrin contains a crinoidal gravel with fluorite

Sample Numbers OC 1 − 2		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	1 − 2·5
	Authigenic quartz	1 − 1·5
	Galena	
	Fluorite (Blue John)	17 — 25
	Baryte	0 — 1
	Calcite	
2	Quartz	63 — 71
	Sandstone	
	Feldspar	
	Mica	2 — 3
	Shale	
	Quartzite	
	Balance (mainly clay)	12 — 17
1 Autochthonous 2 Allochthonous		

Figure 6.4.6.2. Summary of sediment composition, Odin Cave.

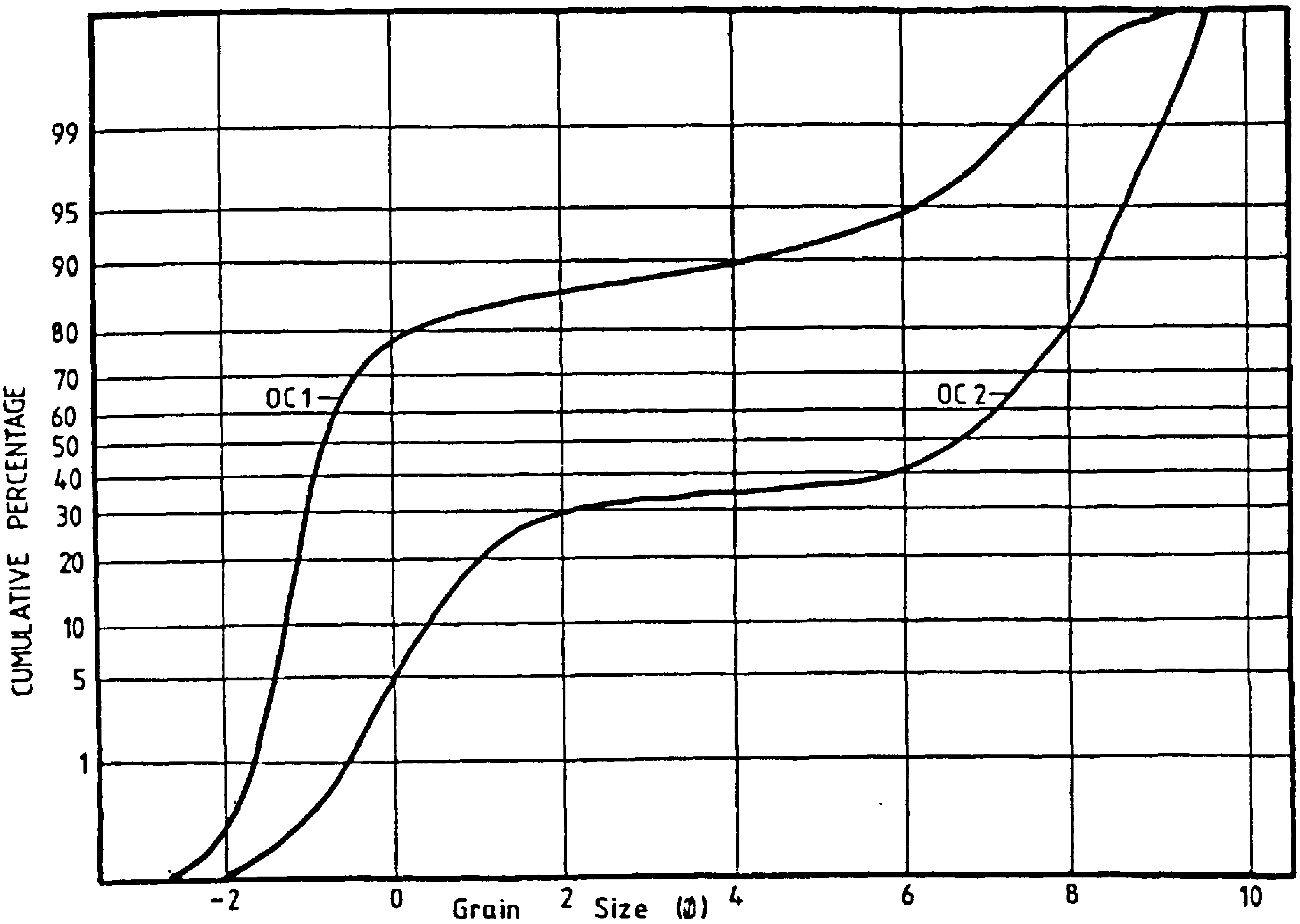


Figure 6.4.6.3. Sediment Size Analysis. Odin Cave.

Surface Features	Chemical	Euhedral silica		
		Amorprous silica	●	
		Solution crevasses		●
		Solution pits	●	●
		Oriented etch pits	●	
	Loessic	Dulled surface	◢	●
		Smooth surface	◢	◢
		Rounded	◢	■
		Dish-shaped pits	◢	●
	Fluvial	Subangular	●	
		Subrounded	◢	●
		Mechanical V-pits	●	
		Curved scratches		
		Straight scratches	●	
	Glacial	Chattermarks		
		Angular		
		Fracture plates		
		Adhering particles		
		Imbricate grinding		
		Parallel striations		
		Conchoidals >10μ		●
		Conchoidals <10μ		
		Breakage blocks>10μ		
		Breakage blocks<10μ		
	General	Euhedral quartz	●	●
		Scaling	◢	●
		High relief		
		Medium relief	◢	●
		Low relief	◢	■
		Meandering ridges	●	
		Arcuate steps		●
		Straight steps	●	●
		Edge abrasion	●	●
		Grain breakage		
	Sample number OC		1	2

■ Abundant — 75% ◢ Common 25–75% ● Present 1–25% ☐ Absent — 1%

Figure 6.4.6.4. Summary of quartz grain surface textures, Odin Cave.

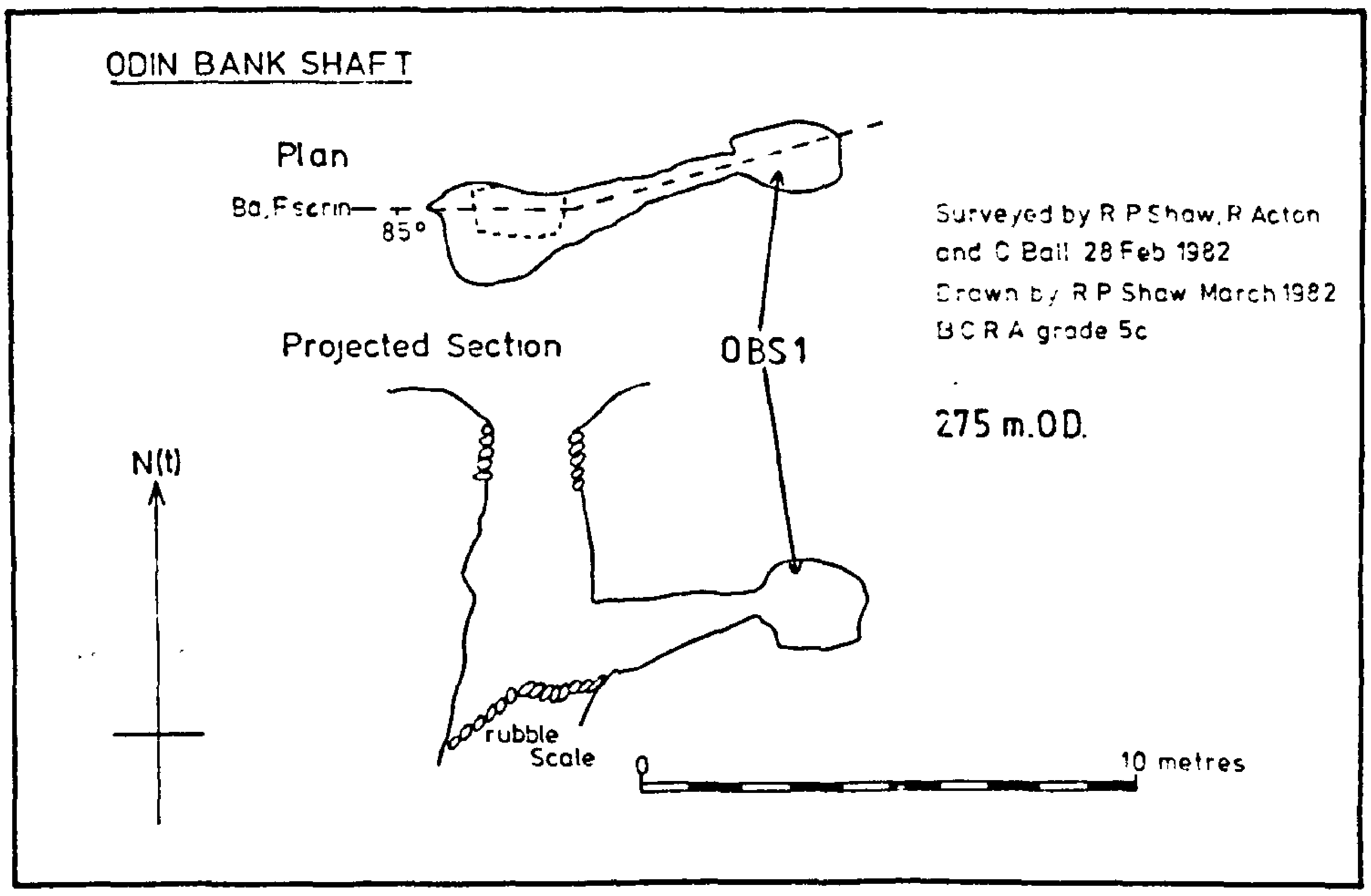


Figure 6.4.7.1. Plan and section of Odin Bank Shaft showing sample location.

and baryte clasts in a fine grained matrix. The composition of this sediment is given in figure 6.4.7.2.. Size analysis shows that the cavity fill is moderately sorted, very coarse - skewed, very platykurtic silty - gravel (fig. 6.4.7.3.). The very platykurtic nature of this sediment reflects the distinct contrast between the coarse and fine fractions of the sediment.

The results of S.E.M. study of quartz grain surface textures shows that the fine grained quartz is of loessic origin (fig. 6.4.7.4.).

The coarse - grained crinoidal debris and the baryte and fluorite clasts accumulated as the result of solutional removal of the surrounding limestone adjacent to the scrin. The loessic sediment was probably derived from surface loess deposits by the mechanism of translatory flow as postulated by Bull (1981b). The present surface is approximately 3.5 metres above the cavity and the open nature of the scrin would allow this process to operate.

6.4.8. Treak Cliff Cavern

First discovered in the mid eighteenth century Treak Cliff Cavern is situated at SK 136,832. A complex pipe vein trending northeast - southwest has been worked in the cavern (Worley, 1978) (fig. 6.4.8.1.). The pipe has been described by Ford (1955 and 1969). It is partly developed in cavities in the Boulder Bed beneath the shale cover and partly in karstic solution cavities in

Sample Number OBS 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Crinoid debris	48
	Galena	0·5
	Fluorite	11
	Baryte	4·5
	Calcite	
2	Quartz	29
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	7
1 Autochthonous 2 Allochthonous		

Figure 6.4.7.2. Summary of sediment composition, Odin Bank Shaft.

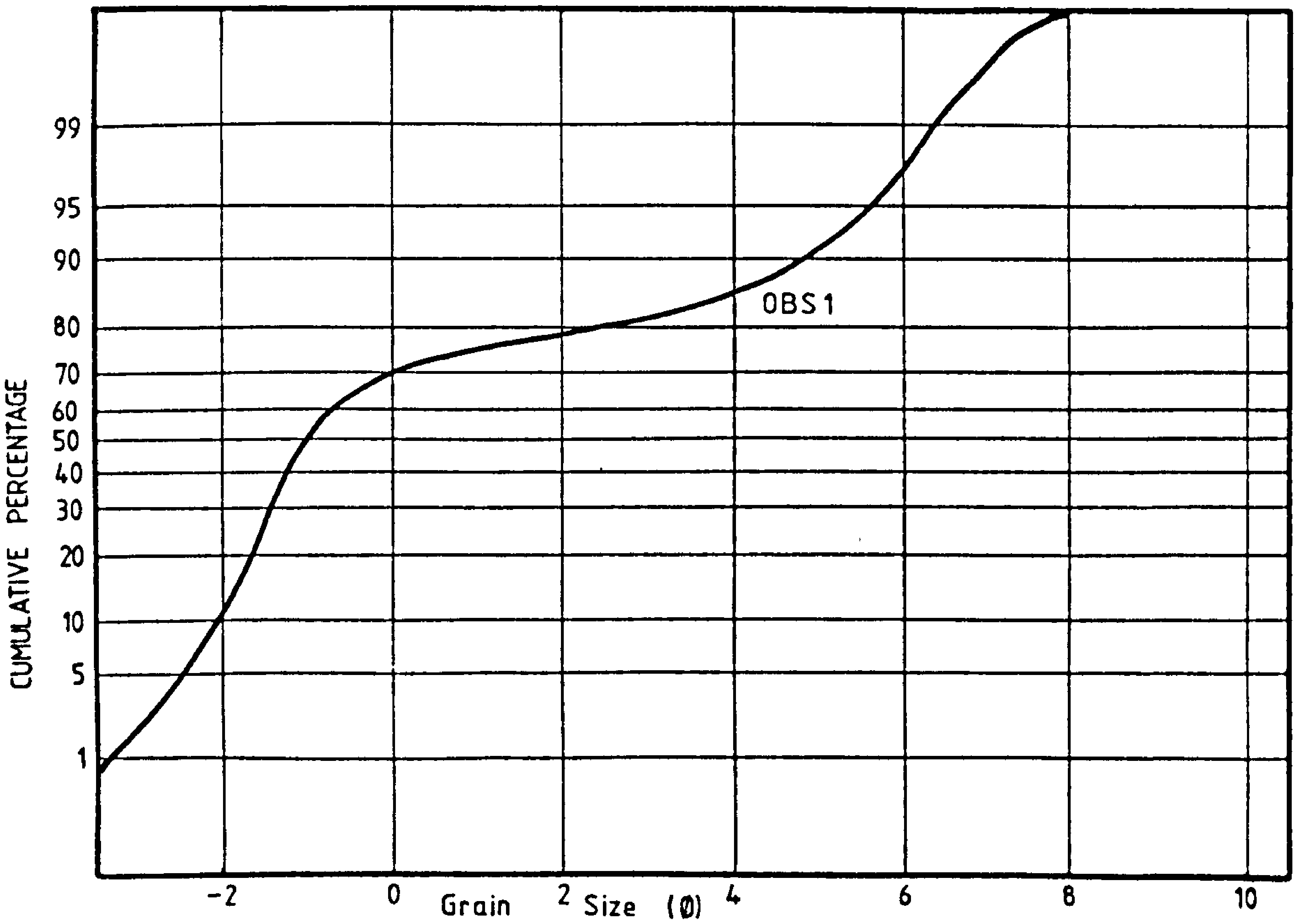


Figure 6.4.7.3. Sediment Size Analysis. Odin Bank Shaft.

Surface Features

Chemical	Euhedral silica																						
	Amorphous silica	●																					
	Solution crevasses	●																					
	Solution pits	●																					
	Oriented etch pits	●																					
Loessic	Dulled surface	◪																					
	Smooth surface	●																					
	Rounded	◪																					
	Dish-shaped pits	◪																					
Fluvial	Subangular	●																					
	Subrounded	◪																					
	Mechanical V-pits																						
	Curved scratches																						
	Straight scratches																						
Glacial	Chattermarks																						
	Angular																						
	Fracture plates																						
	Adhering particles																						
	Imbricate grinding																						
	Parallel striations																						
	Conchoidals >10µ																						
	Conchoidals <10µ																						
	Breakage blocks>10µ																						
	Breakage blocks<10µ																						
General	Euhedral quartz	●																					
	Scaling	◪																					
	High relief																						
	Medium relief	●																					
	Low relief	■																					
	Meandering ridges																						
	Arcuate steps																						
	Straight steps	●																					
	Edge abrasion	●																					
	Grain breakage																						
	Sample number OBS	1																					

■ Abundant – 75% ◪ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 6.4.7.4. Summary of quartz grain surface textures, Odin Bank Shaft.

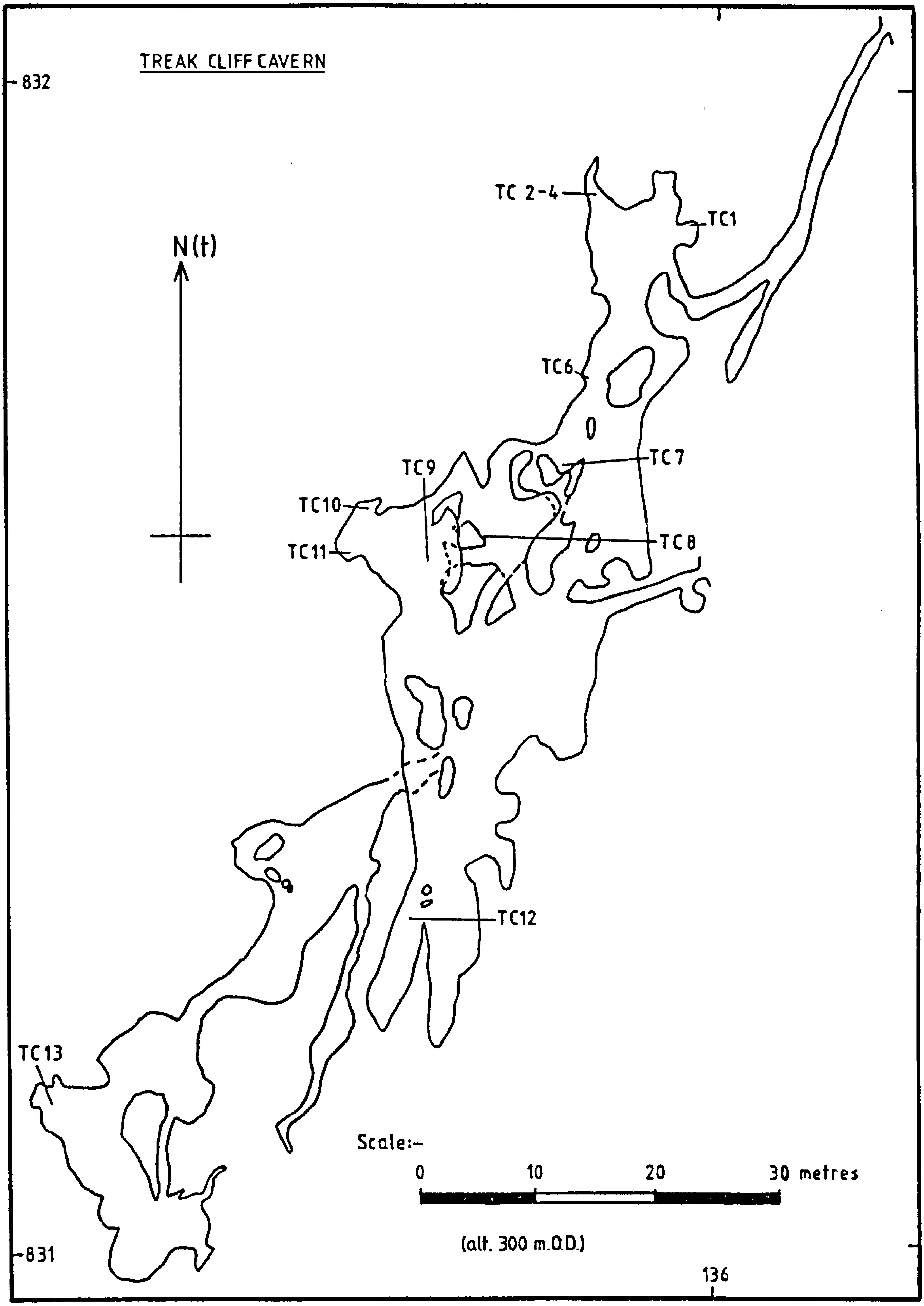


Figure 6.4.8.1. Plan of Treak Cliff Cavern showing sample locations. After Ford (1954).

the Asbian reef limestones below (Worley, 1978). These cavities are presumably of mid - Carboniferous (pre - Edale Shale) age as they contain in situ Edale Shale.

The mineralization consists almost entirely of the Blue John variety of fluorite which was deposited as void fillings. Minor calcite and baryte are also present. Worley (1978) notes that replacement of the limestone by fluorite is also present, especially at the bases of some cavities. Some cavities also contain basal layers of calcite and fluorite crystals with an acicular quartz matrix which Ford (1969) regarded as a sedimentary infill.

In 1926 spar miners broke into a series of well decorated caverns (the New Series) (Ford, 1954) developed in reef limestones. These caverns do not contain any Blue John deposits but their rich stalactitic decoration led to the opening of Treak Cliff Cavern as a show cave in 1935 (Ford, 1954). This part of the cave consists of a sinuous vadose passage which has been modified by breakdown.

U/Th dating carried out on flowstone from a collapsed block gave ages of between 120,000 and 135,000 years B.P. (Ford et al, 1983).

Cavities in the pipe vein are filled or partially filled with a gravelly, clayey - silt, the composition of which is given in figure 6.4.8.2.. As shown in this figure a large fraction of this sediment consists of locally derived and re - worked Blue John and acicular quartz. Size analysis shows that these sediments are poorly sorted, coarse - skewed, platykurtic gravelly -

Sample Numbers TC 1-11

		%
1	Limestone	1 — 16
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	0 — 4
	Authigenic quartz	7 — 28
	Galena	
	Fluorite (Blue John)	3 — 54
	Baryte	0 — 2·5
	Calcite	0 1·5
2	Quartz	24 — 70
	Sandstone	
	Feldspar	
	Mica	0 — 1
	Shale	
	Quartzite	
	Balance (mainly clay)	16 — 33

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	68 — 71
Kaolinite	23 — 27
Chlorite	3 — 5
Mixed layer smectites	8 — 14

Figure 6.4.8.2. Summary of sediment composition, Treak Cliff Cavern.

clayey - silts (fig. 6.4.8.3.). This again reflects the contrast between the allochthonous and the autochthonous fractions. The results of S.E.M. study of quartz grain surface textures shows that the allochthonous grains are of loessic origin with a small quantity of fluviall;y derived sediment (fig. 6.4.8.4., TC 1-11).

In the New Series there are accumulations of silt preserved below recent stalagmite layers (plate 6.4.8.1.). The composition of the sediments is given in figure 6.4.8.5. which shows a considerably reduced autochthonous fraction. Size analysis of the sediments shows them to be moderately sorted, leptokurtic silts (fig. 6.4.8.6.). The results of S.E.M. study of quartz grain surface textures shows that these sediments are of loessic origin with a small fraction of fluvial sediment (Fig. 6.4.8.4., TC 12-13).

Treak Cliff Cavern probably represents part of a swallet drainage network, partially developed in Blue John pipe vein mineralization. The speleothem dates indicate that the cave was abandoned, or approaching abandonment, by 130,000 years B.P.. As these dates fall into the last interglacial and most of the loess deposits of the Peak District are Devensian (17,000 to 90,000 years B.P.) (Piggot, 1962) it is probable that these sediments were derived during a short term re - activation of the cave system by surface drainage during Mid or late Devensian times.

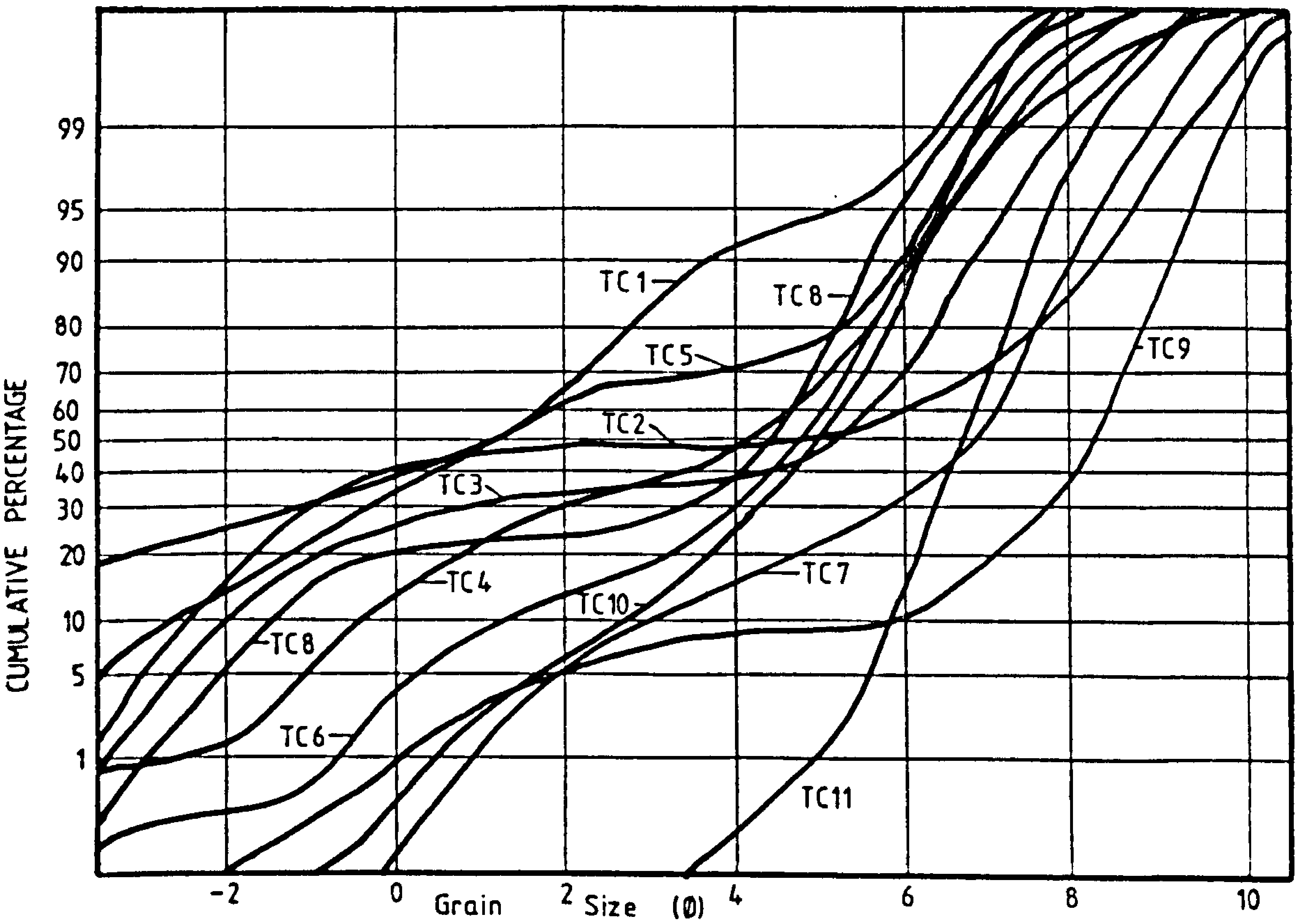
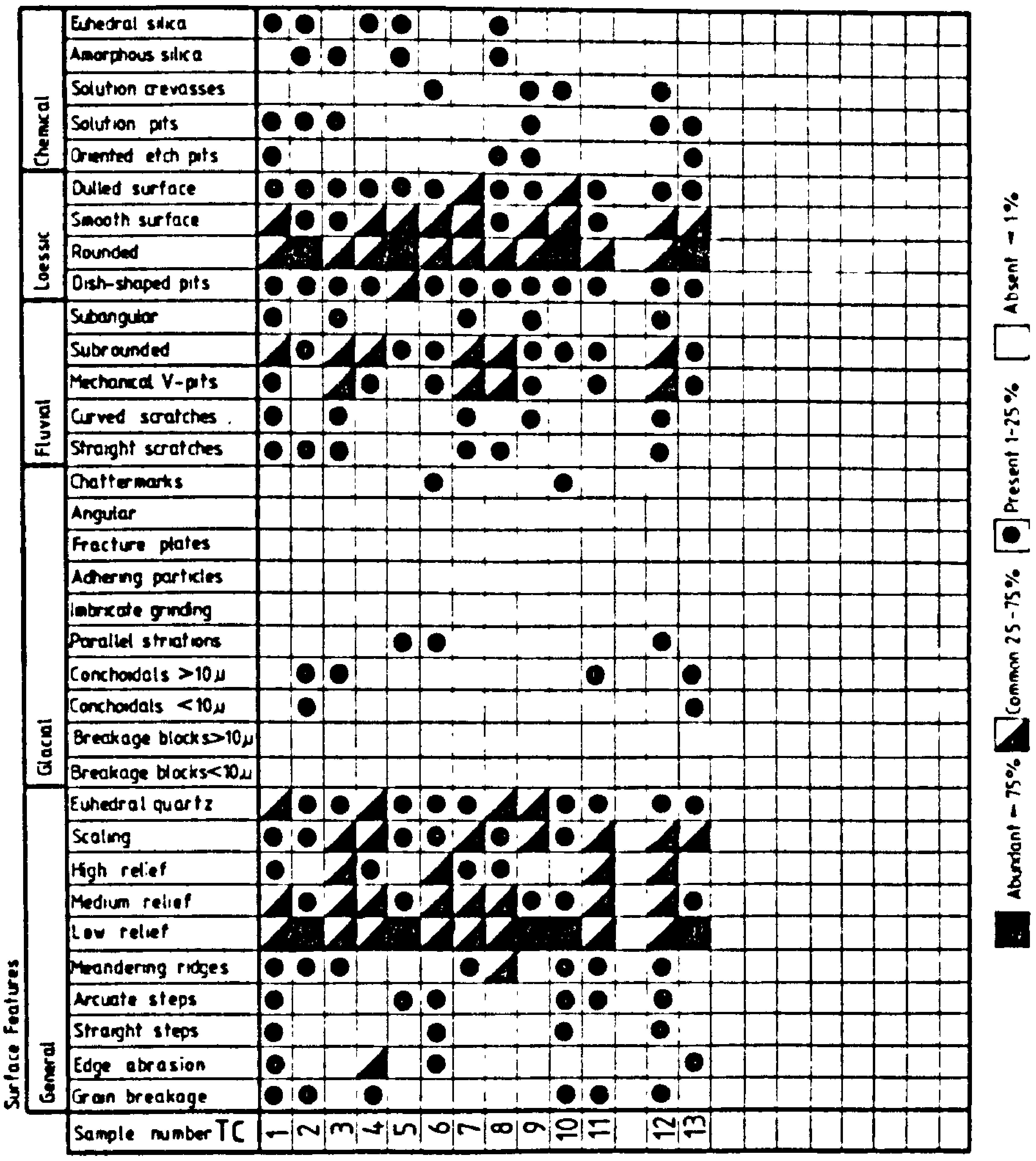


Figure 6.4.8.3. Sediment Size Analysis. Treak Cliff Cavern.



Surface Features	Chemical	Euhedral silica	●	●		●	●			●						
		Amorphous silica		●	●		●			●						
		Solution crevasses						●			●	●			●	
		Solution pits	●	●	●						●				●	●
		Oriented etch pits	●							●	●					●
	Loessic	Dulled surface	●	●	●	●	●	●	◢	●	●	◢	●		●	●
		Smooth surface	◢	●	●	◢	◢	◢	◢	●	◢	◢	●		◢	◢
		Rounded	◢	■	◢	◢	■	◢	◢	◢	◢	■	◢		◢	■
		Dish-shaped pits	●	●	●	●	◢	●	●	●	●	●	●		●	●
	Fluvial	Subangular	●		●				●		●				●	
		Subrounded	◢	●	◢	◢	●	●	◢	◢	●	●	●		◢	●
		Mechanical V-pits	●		◢	●		●	◢	◢	●		●		◢	●
		Curved scratches	●		●				●		●				●	
		Straight scratches	●	●	●				●	●					●	
	Glacial	Chattermarks						●				●				
		Angular														
		Fracture plates														
		Adhering particles														
		Imbricate grinding														
		Parallel striations					●	●							●	
		Conchoidals >10µ		●	●								●			●
		Conchoidals <10µ		●												●
		Breakage blocks>10µ														
		Breakage blocks<10µ														
	General	Euhedral quartz	◢	●	●	◢	●	●	●	◢	◢	●	●		●	●
		Scaling	●	●	◢	◢	●	●	◢	●	◢	●	◢		◢	◢
		High relief	●		◢	●		◢	●	●			◢		◢	
		Medium relief	◢	●	◢	◢	●	◢	◢	◢	●	●	◢		◢	●
		Low relief	◢	■	◢	◢	■	◢	◢	◢	■	■	◢		◢	■
		Meandering ridges	●	●	●				●	◢		●	●		●	
		Arcuate steps	●				●	●				●	●		●	
		Straight steps	●					●				●			●	
		Edge abrasion	●			◢		●								●
		Grain breakage	●	●		●						●	●		●	
		Sample number TC	1	2	3	4	5	6	7	8	9	10	11		12	13

■ Abundant – 75%
◢ Common 25-75%
● Present 1-25%
□ Absent – 1%

Figure 6.4.8.4. Summary of quartz grain surface textures, Treak Cliff Cavern.

Sample Numbers TC 12–13		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	21 — 40
	Galena	
	Fluorite (Blue John)	3 — 7
	Baryte	
	Calcite	
2	Quartz	42 — 63
	Sandstone	
	Feldspar	
	Mica	0 — 2
	Shale	
	Quartzite	
	Balance (mainly clay)	11 — 27
1 Autochthonous 2 Allochthonous		

Figure 6.4.8.5. Summary of sediment composition, New Series, Treak Cliff Cavern.

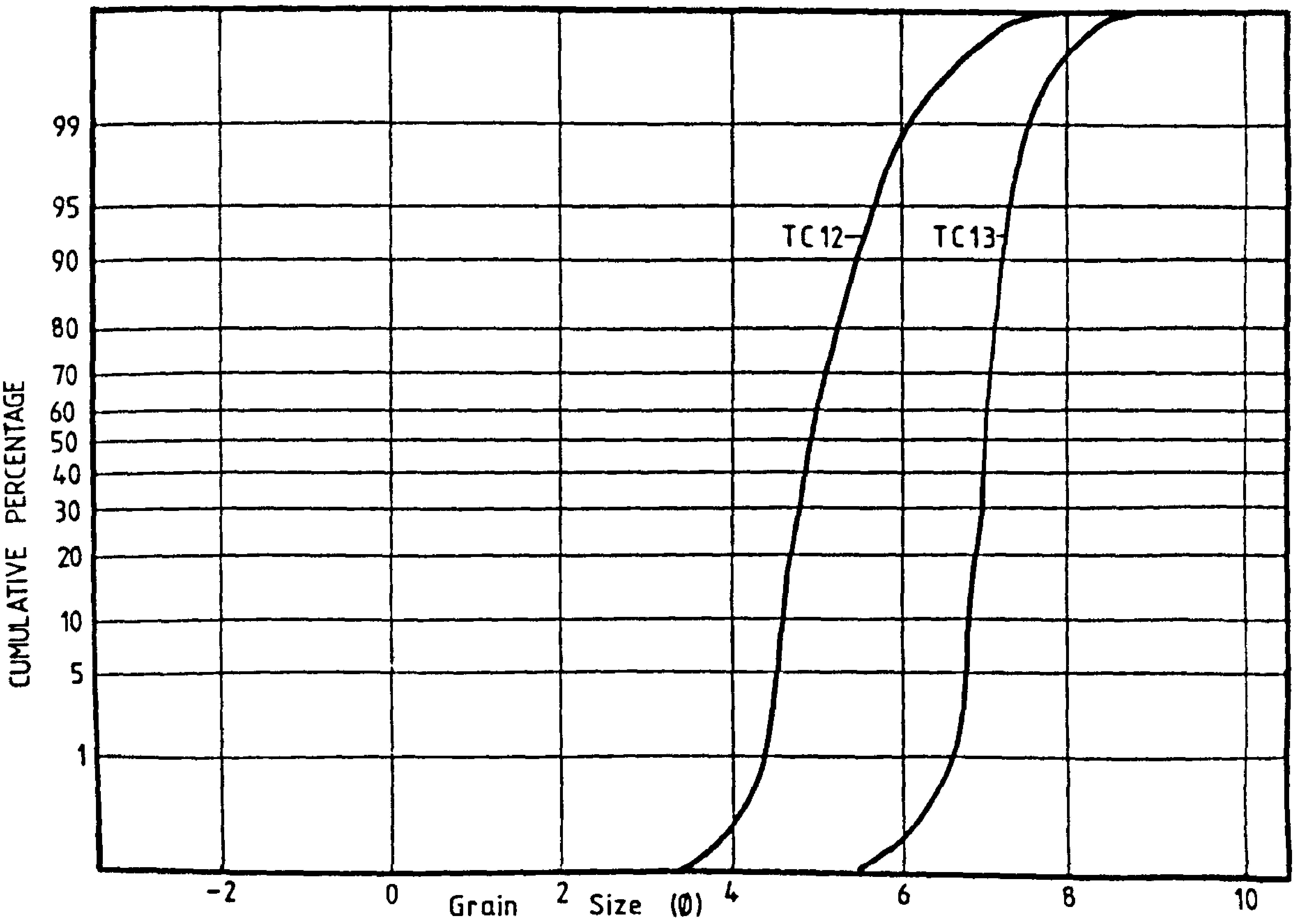


Figure 6.4.8.6. Sediment Size Analysis, Treak Cliff Cavern.

6.4.9. Suicide Cave

Situated at the bottom of the Winnats Pass at SK 137,827, Suicide Cave may represent the former resurgance of the former stream through Treak Cliff Cavern (Ford, 1954). The cave is developed in fore reef limestones close to the overlying shales.

The floor of one part of the cave (fig. 6.4.9.1.) is covered with a silty sediment, the composition of which is given in figure 6.4.9.2.. Size analysis shows that the sediment is a moderately sorted, leptokurtic silt (fig. 6.4.9.3.). The results of S.E.M. study of quartz grain surface textures shows that the quartz is reworked loess (fig. 6.4.9.4.).

The close similarity of the deposits of Treak Cliff Cavern and Suicide Cave supports Ford's (1954) theory that the two caves are part of the same drainage system. The Blue John fluorite content of Suicide Cave may be derived from exposures within the cave or from other, unknown, deposits and not necessarily from those of Treak Cliff Cavern.

6.4.10. Old Tor Mine

Situated high on the north side of the Winnats Pass at SK 134,828, Old Tor Mine was worked for Blue John which occurs as an irregular pipe vein. The vein consists of alternating bands of fluorite and baryte deposited as void fillings (Worley, 1978). The host rocks are reef limestones.

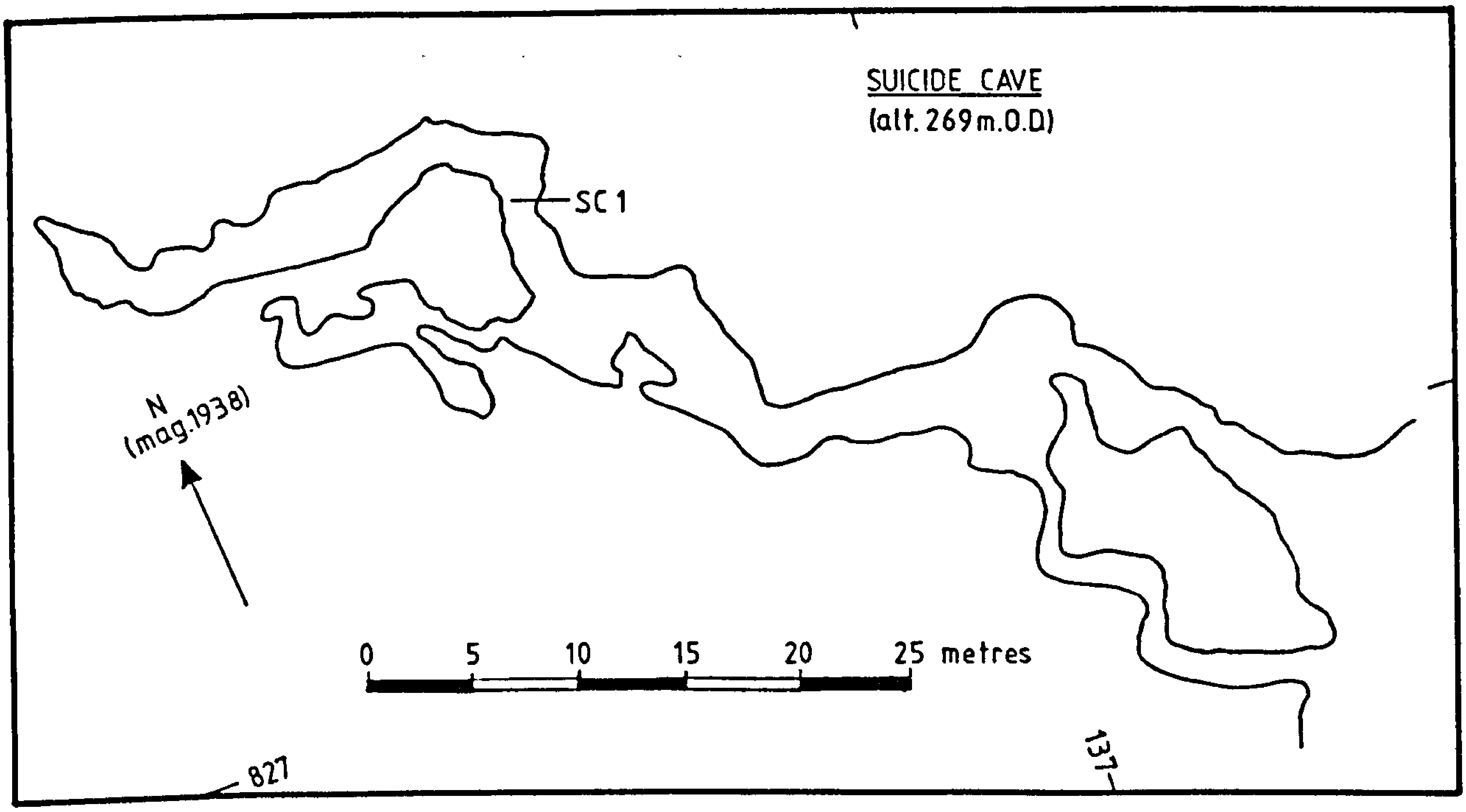


Figure 6.4.9.1. Plan of Suicide Cave showing sample location (after survey by A.L.Butcher).

Sample Number SC 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	5
	Galena	
	Fluorite (Blue John)	3·5
	Baryte	
	Calcite	1·5
2	Quartz	75
	Sandstone	
	Feldspar	
	Mica	2
	Shale	
	Quartzite	
	Balance (mainly clay)	13
1 Autochthonous 2 Allochthonous		

Figure 6.4.9.2. Summary of sediment composition, Suicide Cave.

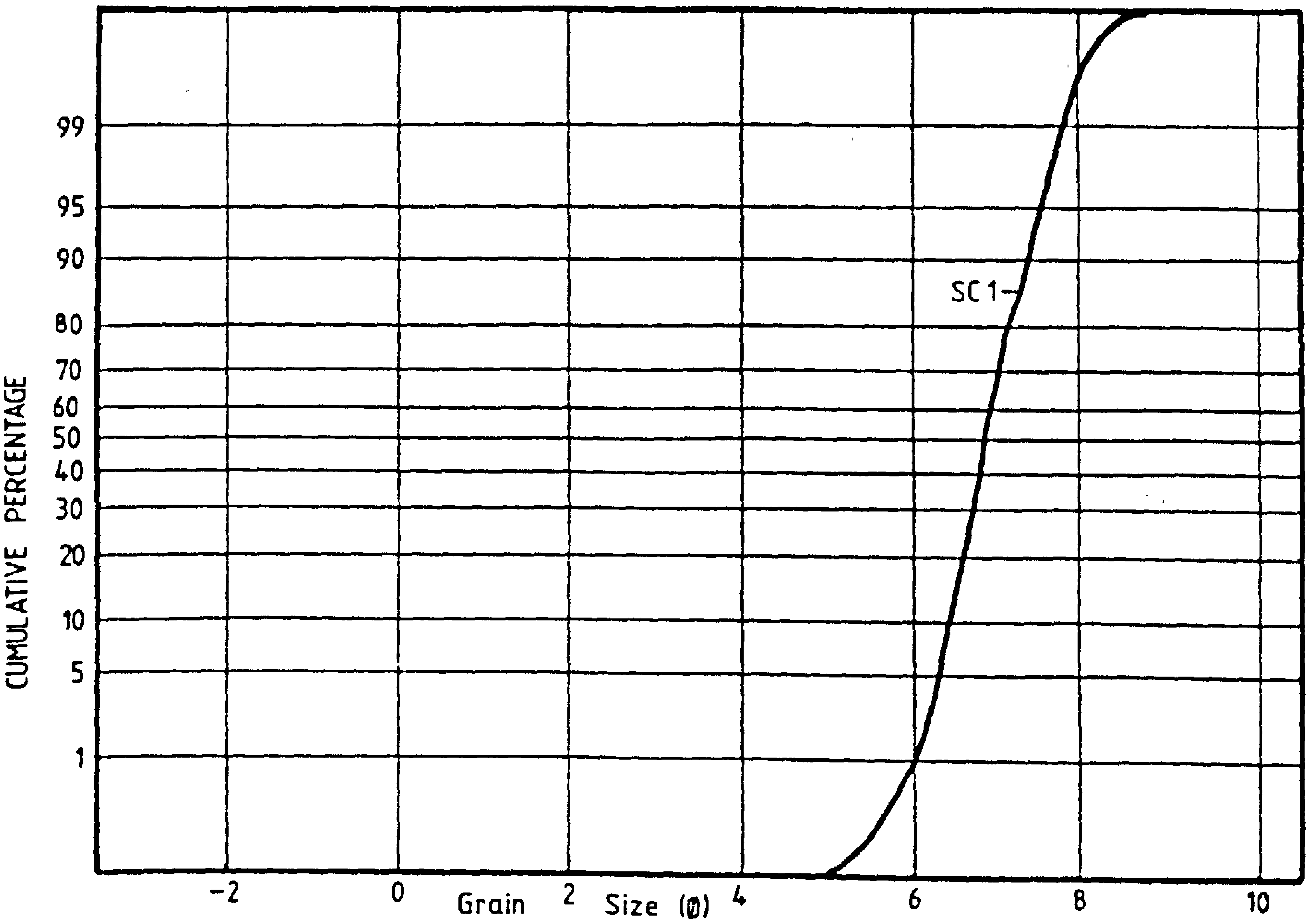
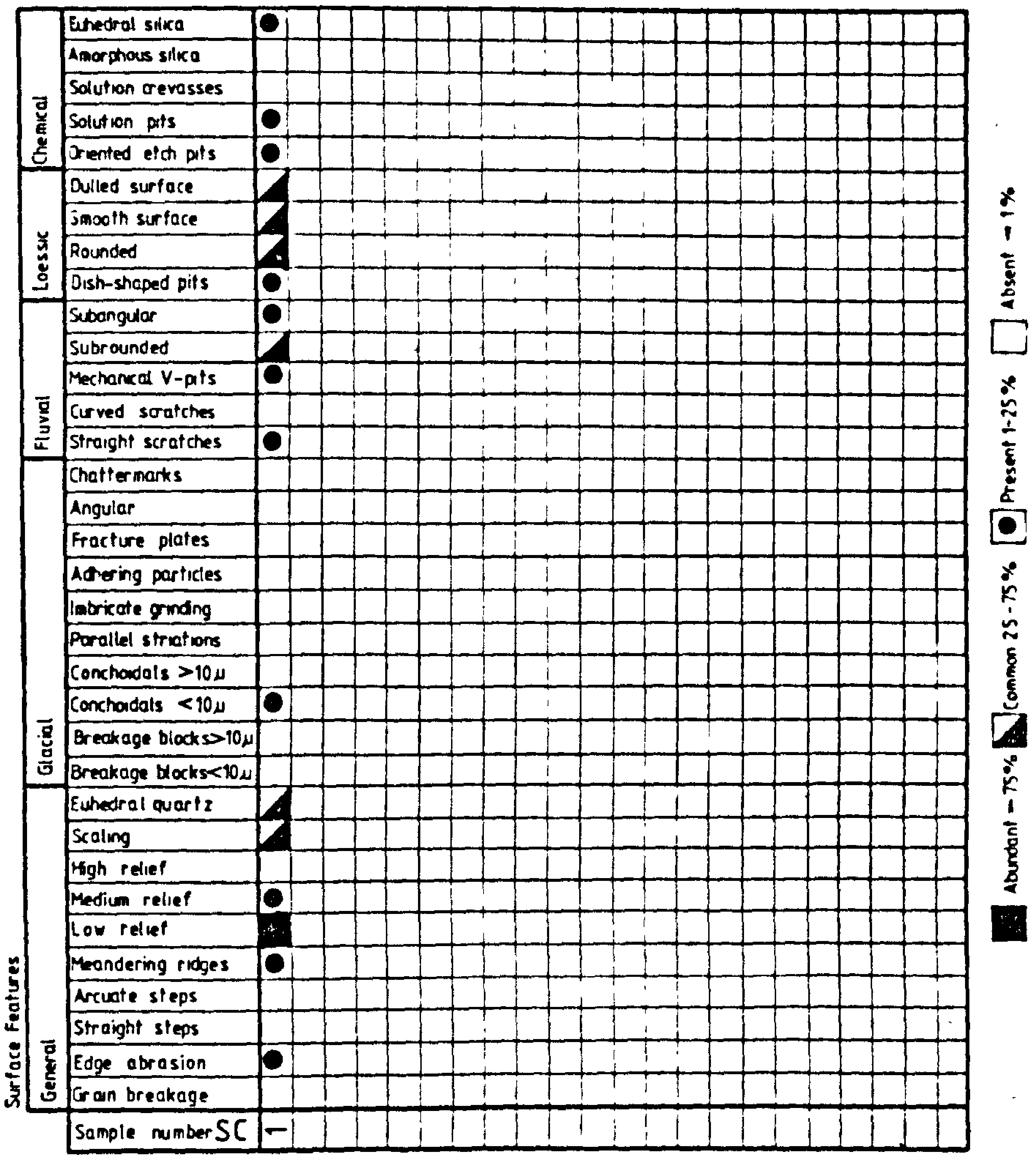


Figure 6.4.9.3. Sediment Size Analysis. Suicide Cave.



Chemical	Euhedral silica	●
	Amorphous silica	
	Solution crevasses	
	Solution pits	●
	Oriented etch pits	●
Loessic	Dulled surface	◩
	Smooth surface	◩
	Rounded	◩
	Dish-shaped pits	●
Fluvial	Subangular	●
	Subrounded	◩
	Mechanical V-pits	●
	Curved scratches	
	Straight scratches	●
Glacial	Chattermarks	
	Angular	
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10μ	
	Conchoidals <10μ	●
	Breakage blocks>10μ	
	Breakage blocks<10μ	
Surface Features General	Euhedral quartz	◩
	Scaling	◩
	High relief	
	Medium relief	●
	Low relief	■
	Meandering ridges	●
	Arcuate steps	
	Straight steps	
	Edge abrasion	●
	Grain breakage	
	Sample number SC	1

■ Abundant - 75% ◩ Common 25 - 75% ● Present 1-25% □ Absent - 1%

Figure 6.4.9.4. Summary of quartz grain surface textures, Suicide Cave.

Small phreatic cavities and pipe vein cavities are partially filled with sediment (fig. 6.4.10.1.), the composition of which is given in figure 6.4.10.2.. Size analysis shows that the sediment is a moderately sorted, slightly fine - skewed, mesokurtic silt (fig. 6.4.10.3.). The results of S.E.M. study of quartz grain surface textures shows features characteristic of a loessic origin (fig. 6.4.10.4.).

It is likely that these sediments were derived from former surface loess deposits by the mechanism of translatory flow proposed by Bull (1981b) via small phreatic and vein cavities.

6.4.11. Winnats Head Cave

Situated close to the head of the Winnats Pass at SK 131,828, Winnats Head Cave represents a former swallet cave. The cave was extended between 1976 and 1978 (Gill, 1978; Phipps, 1981). Recent (1982) collapse has made access to the lower part of the cave dangerous.

The cave is developed in lagoonal Bee Low limestones and intersects a wayboard horizon which may represent the Cave Dale Lava at this locality. A large part of the cave consists of breakdown debris composed of limestone boulders up to 10 metres across.

In all parts of the cave below the Main Chamber the boulders and ledges are covered by a silt deposit. In places this layer is overlain by a stalagmite layer. Dating of speleothems from Fox Chamber gives ages of between 9,000 and 54,000 years B.P. while ages for

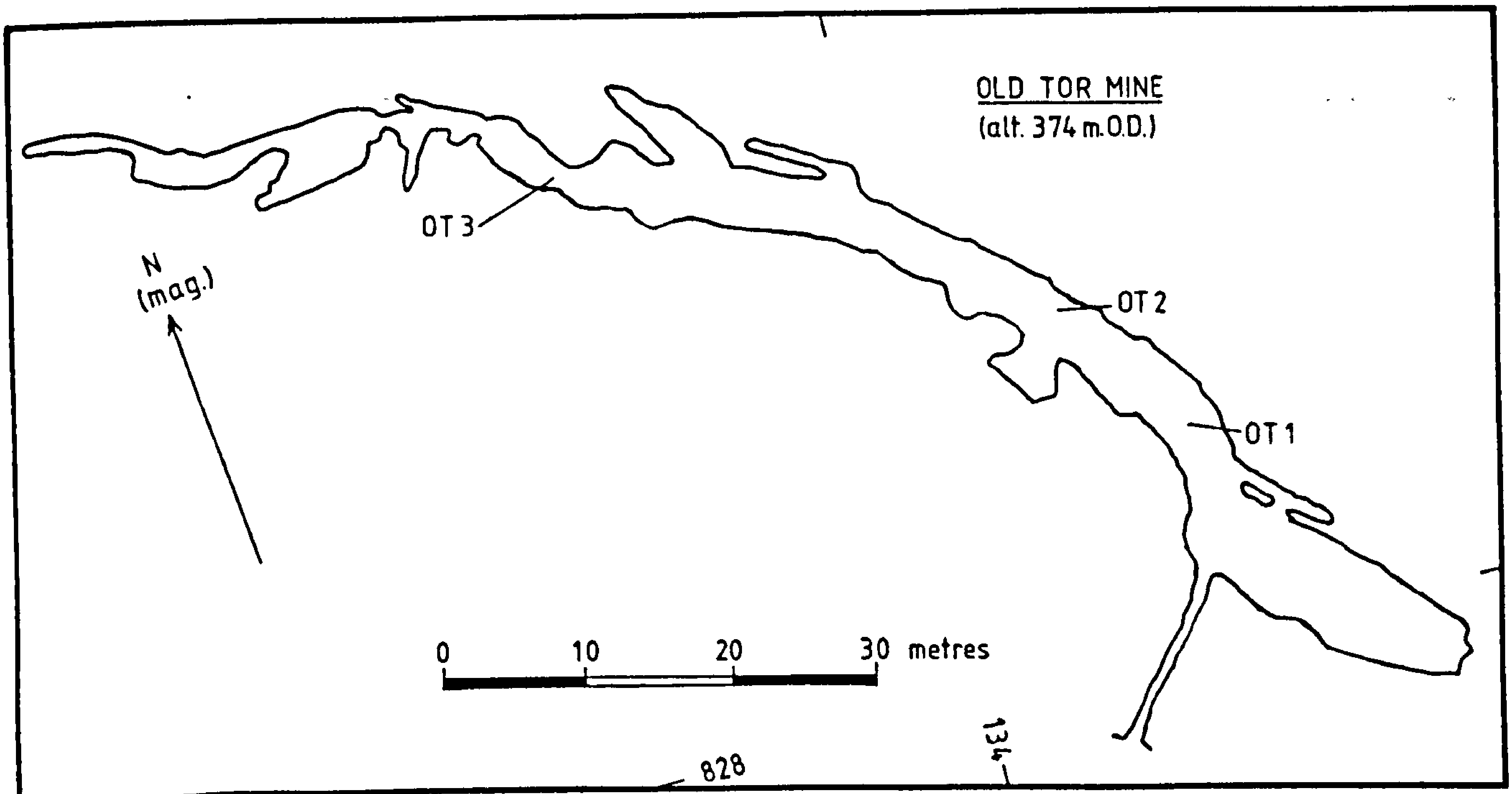


Figure 6.4.10.1. Plan of Old Tor Mine showing sample locations (after Elliot,1977).

Sample Numbers OT 1 – 2		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	0 — 1·5
	Galena	
	Fluorite	9 — 21
	Baryte	3 — 14
	Calcite	
2	Quartz	63 — 74
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	16 — 26
1 Autochthonous 2 Allochthonous		

Figure 6.4.10.2. Summary of sediment composition, Old Tor Mine.

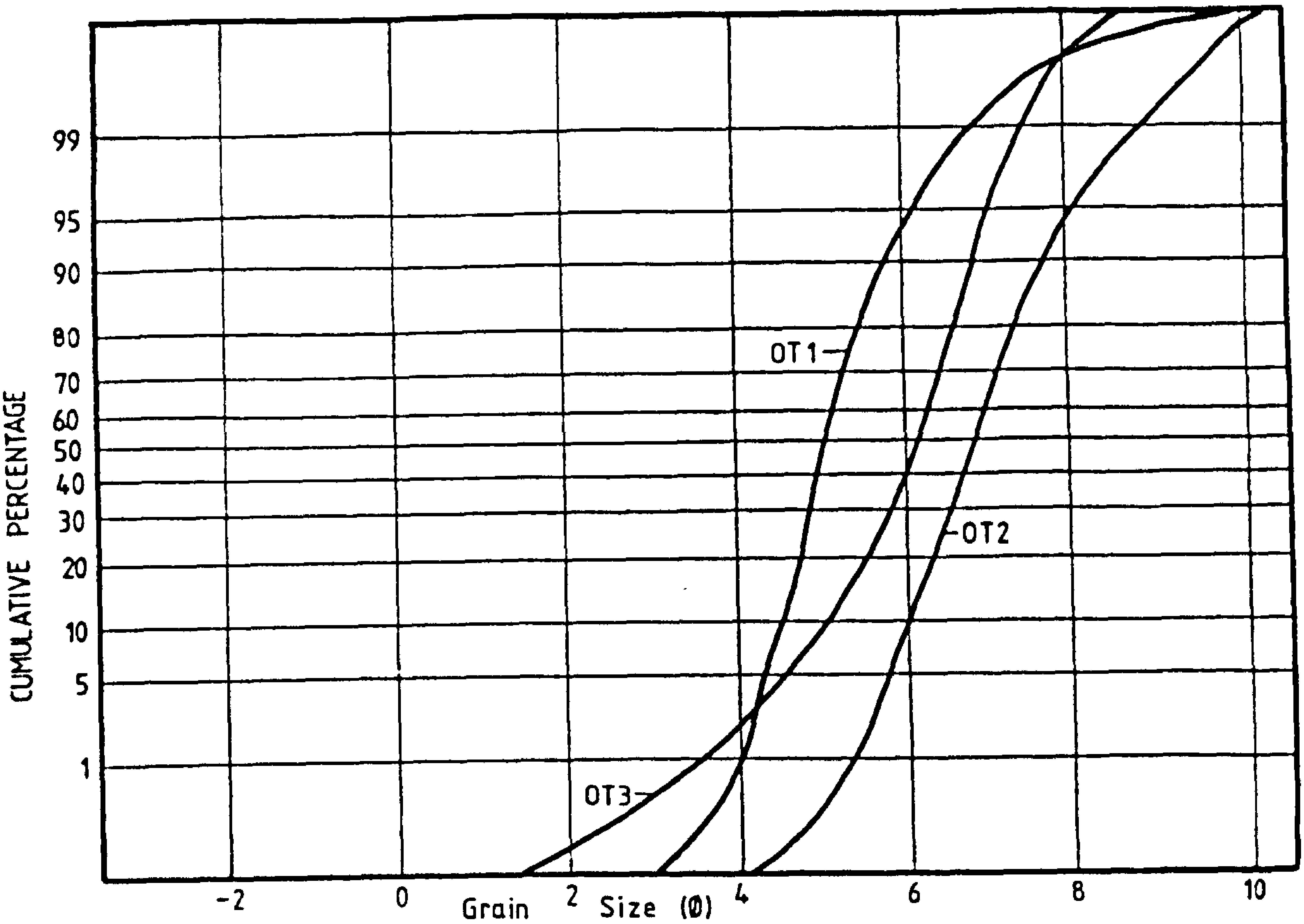
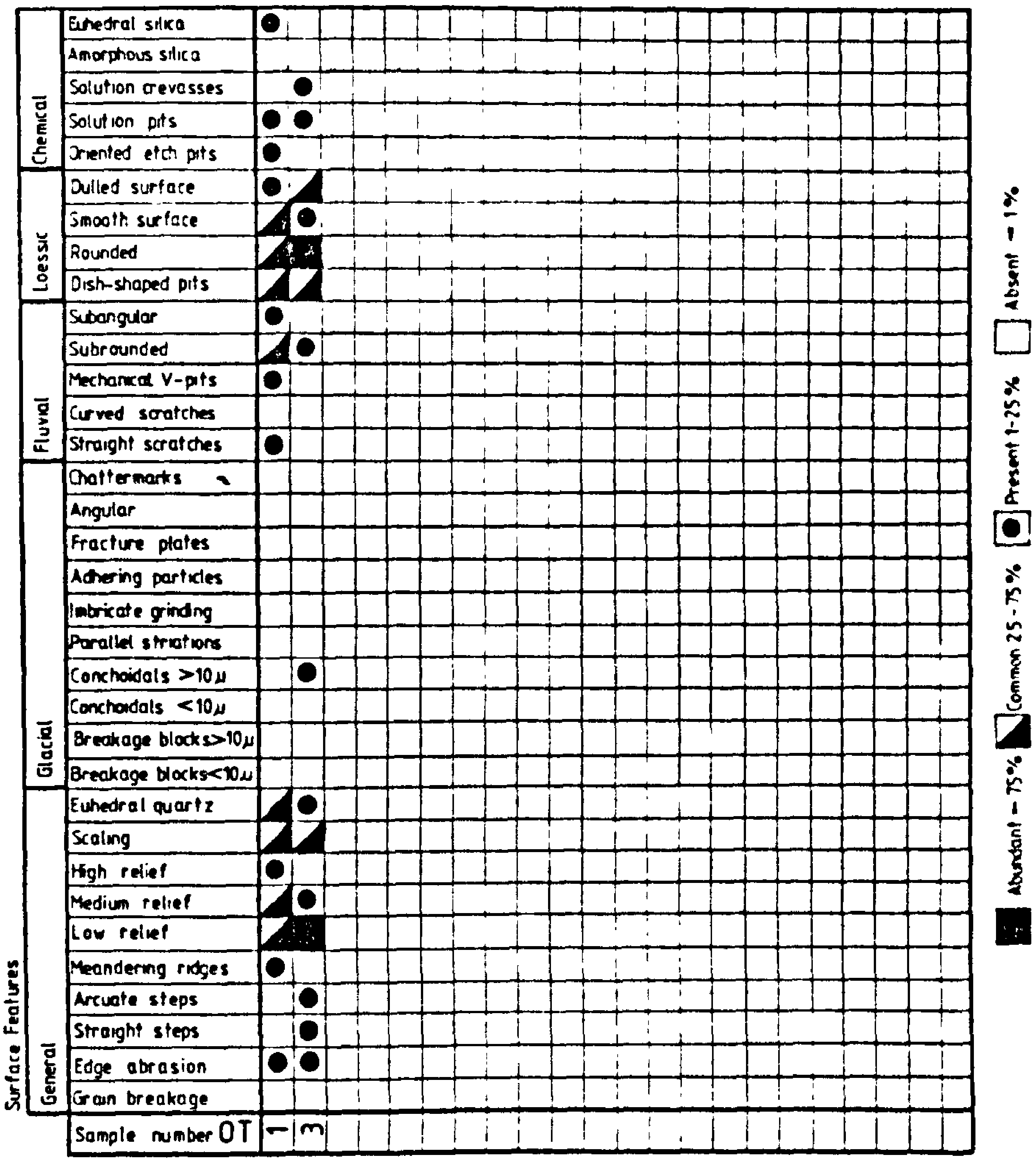


Figure 6.4.10.3. Sediment Size Analysis. Old Tor Mine.



			1	3
Surface Features	Chemical	Euhedral silica	●	
		Amorphous silica		
		Solution crevasses		●
		Solution pits	●	●
		Oriented etch pits	●	
	Loessic	Dulled surface	●	◢
		Smooth surface	◢	●
		Rounded	◢	■
		Dish-shaped pits	◢	◢
	Fluvial	Subangular	●	
		Subrounded	◢	●
		Mechanical V-pits	●	
		Curved scratches		
		Straight scratches	●	
	Glacial	Chattermarks		
		Angular		
		Fracture plates		
		Adhering particles		
		Imbricate grinding		
		Parallel striations		
		Conchoidals >10µ		●
		Conchoidals <10µ		
		Breakage blocks>10µ		
		Breakage blocks<10µ		
	General	Euhedral quartz	◢	●
		Scaling	◢	◢
		High relief	●	
		Medium relief	◢	●
		Low relief	◢	■
		Meandering ridges	●	
		Arcuate steps		●
		Straight steps		●
		Edge abrasion	●	●
		Grain breakage		
		Sample number OT	1	3

■ Abundant – 75%
◢ Common 25-75%
● Present 1-25%
☐ Absent – 1%

Figure 6.4.10.4. Summary of quartz grain surface textures, Old Tor Mine.

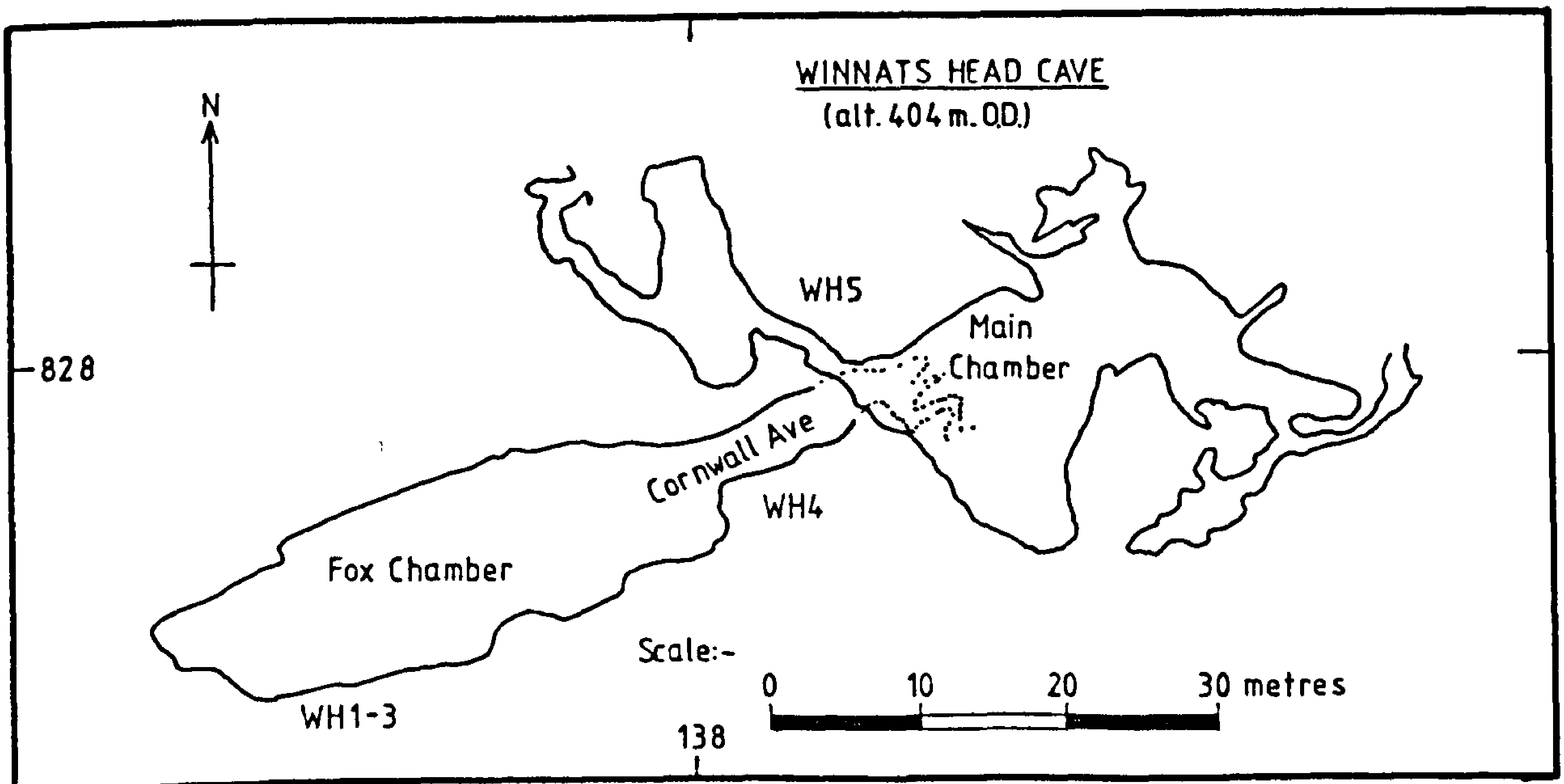


Figure 6.4.11.1. Plan of Winnats Head Cave showing sample locations. After a survey by John Beck.

Sample Numbers WH 1–5

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	1 – 4
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	76 – 83
	Sandstone	
	Feldspar	
	Mica	1 – 35
	Shale	
	Quartzite	
	Balance (mainly clay)	15 – 21

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	53 – 64
Kaolinite	27 – 31
Chlorite	5 – 16
Mixed layer smectites	9 – 13

Figure 6.4.11.2. Summary of sediment composition, Winnats Head Cave.

speleothems in higher parts of the cave are between 170,000 and 200,000 years B.P. (Ford et al, 1983).

The composition of the silt is given in figure 6.4.11.2.. Size analysis shows that the sediment is moderately sorted, slightly fine - skewed, mesokurtic silt (fig. 6.4.11.3.). The results of S.E.M. study of quartz grain surface textures show that the silt is re - worked loess (fig. 6.4.11.4.).

At the head of Cornwall Avenue (fig. 6.4.11.1.) the cave intersects a mineral vein and a number of small pipe veins (Shaw, 1979). The mineralization consists of banded fluorite, baryte, calcite and galena hosted by extensively jointed limestone. Breakdown of these deposits, a process still (1982) continuing, has led to the formation of a talus slope down Cornwall Avenue. This is composed of limestone and mineral vein blocks, the finer grained clasts having been removed by the small stream that flows down Cornwall Avenue to Fox Chamber.

The silt deposit is derived loess and was washed into the cave system when the cave was flooded to, at least, the level of the Main Chamber. This was probably due to a temporary blockage of the outlet from the cave. It appears that the cave drained rapidly and has since carried only a limited quantity of percolation drainage.

6.4.12. Longcliff Mine

Situated at SK 141,825 on Longcliff this mine worked part of Longcliff Vein where Shack Hole Scrin branches

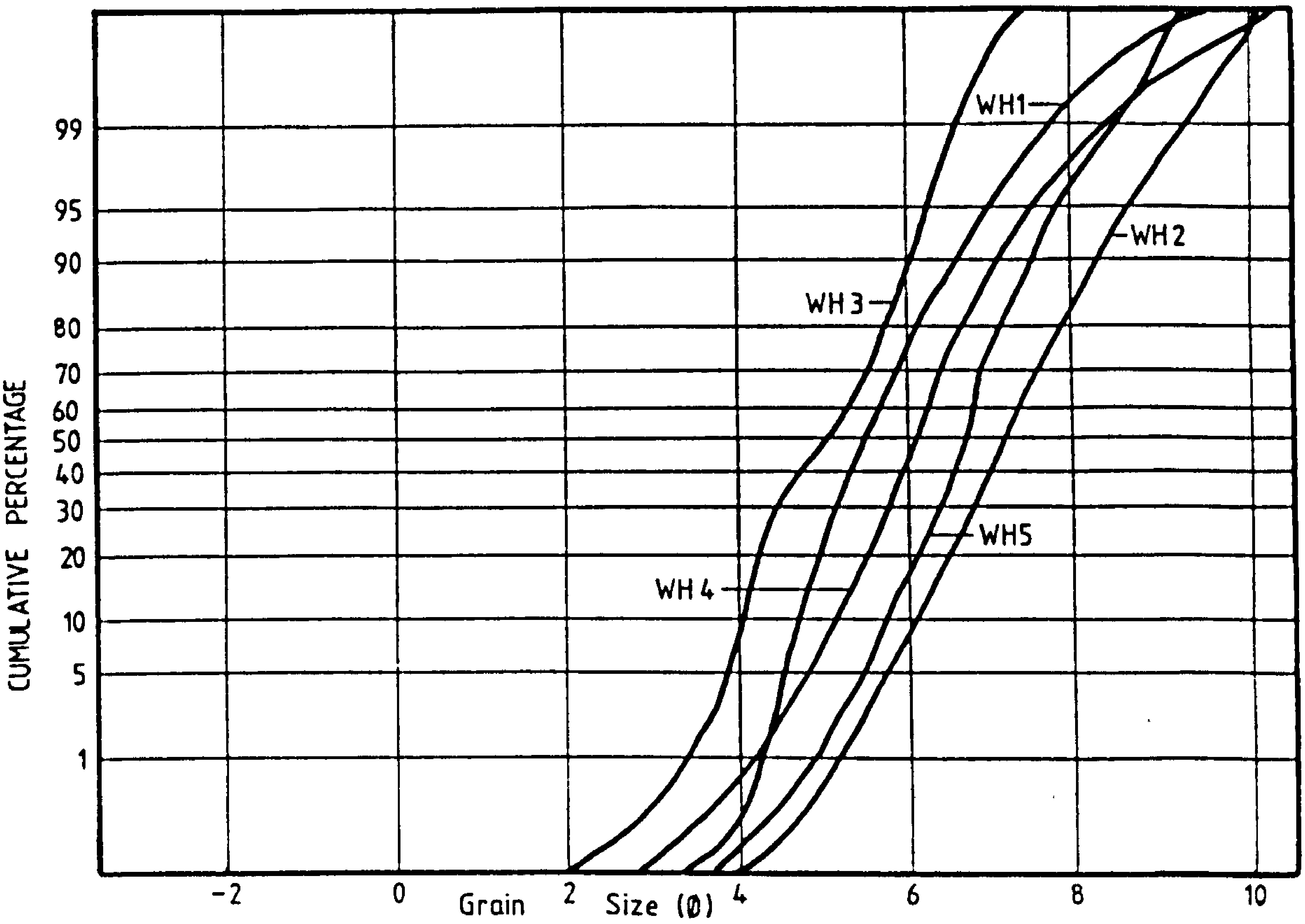
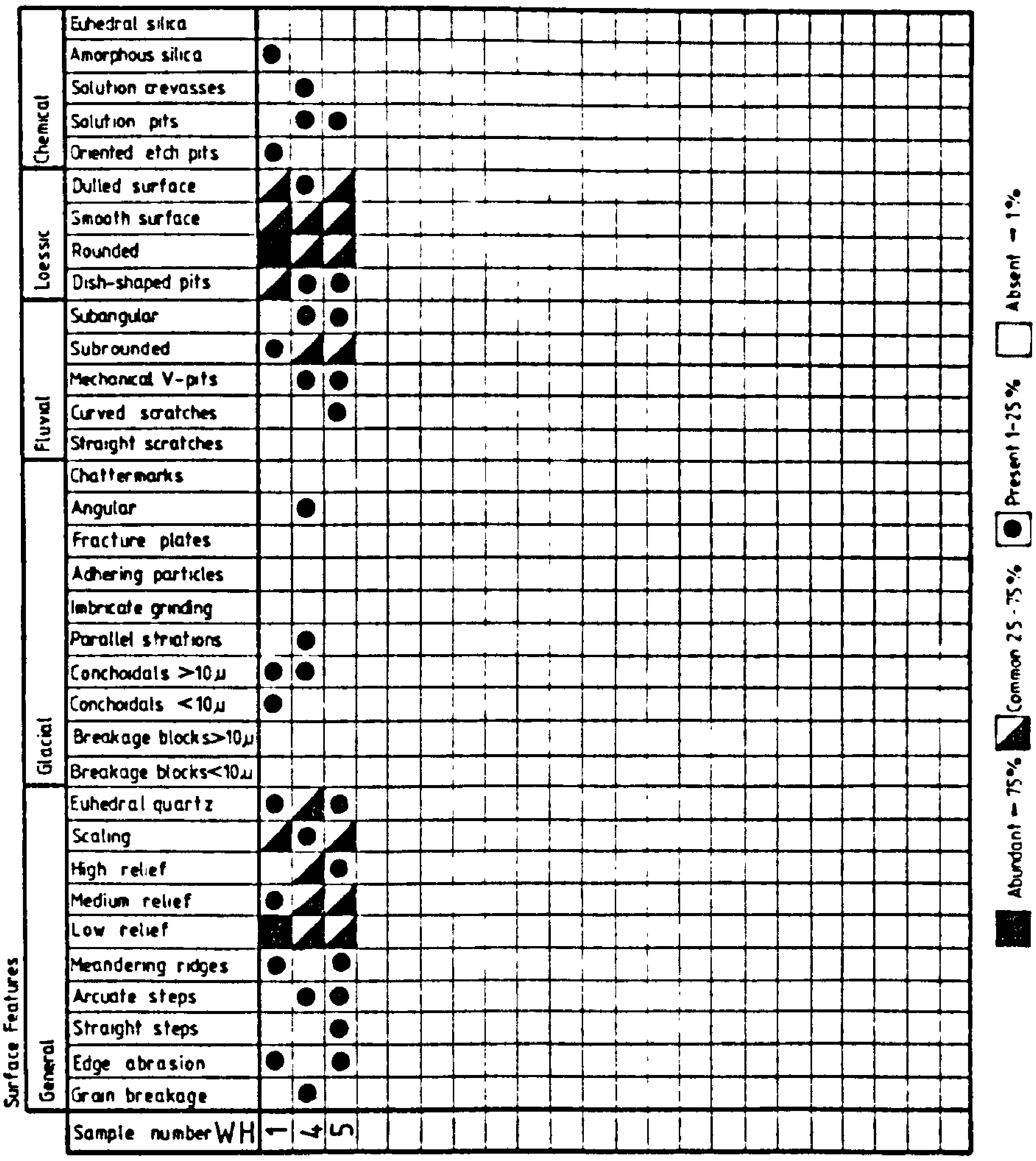


Figure 6.4.11.3. Sediment Size Analysis. Winnats Head Cave.



Surface Features	Chemical	Euhedral silica			
		Amorphous silica	●		
		Solution crevasses		●	
		Solution pits		●	●
		Oriented etch pits	●		
	Loessic	Dulled surface	◢	●	◢
		Smooth surface	◢	◢	◢
		Rounded	■	◢	◢
		Dish-shaped pits	◢	●	●
	Fluvial	Subangular		●	●
		Subrounded	●	◢	◢
		Mechanical V-pits		●	●
		Curved scratches			●
		Straight scratches			
	Glacial	Chattermarks			
		Angular		●	
		Fracture plates			
		Adhering particles			
		Imbricate grinding			
		Parallel striations		●	
		Conchoidals >10μ	●	●	
		Conchoidals <10μ	●		
		Breakage blocks>10μ			
		Breakage blocks<10μ			
	General	Euhedral quartz	●	◢	●
		Scaling	◢	●	◢
		High relief		◢	●
		Medium relief	●	◢	◢
		Low relief	■	◢	◢
		Meandering ridges	●		●
		Arcuate steps		●	●
		Straight steps			●
		Edge abrasion	●		●
		Grain breakage		●	
		Sample number WH	1	4	5

■ Abundant – 75%
◢ Common 25-75%
● Present 1-25%
☐ Absent – 1%

Figure 6.4.11.4. Summary of quartz grain surface textures, Winnats Heat Cave.

off (Ford, 1962). Only part of the mine shown on Ford's (1962) plan was accessible in 1983, the lower part of the shaft being blocked by collapsed shaft lining (fig. 6.4.12.1.). Another shaft, 5 metres to the southeast is also accessible for a short distance.

A 1.1 metre diameter phreatic solution cavity in the south wall of the vein contains the remains of a sedimentary fill, the composition of which is given in figure 6.4.12.2.. Size analysis shows that the sediment is a poorly sorted, very coarse - skewed, very platykurtic gravelly - silt (fig. 6.4.12.3.).

The coarse - grained fraction consists of allochthonous fluorite, baryte, calcite and galena and the fine grained fraction consists of quartz silt which is probably re - worked loess.

6.4.13. Longcliff Back Shaft

This is a small shaft, at SK 1387,8234, leading to restricted workings on a scrin branching from Faucet Rake (fig. 6.4.13.1.). The mineralization of the scrin consists of banded fluorite, baryte and galena hosted in Bee Low Limestones.

A small cavity a short distance below the surface is filled with sediment, the composition of which is given in figure 6.4.13.2.. Size analysis shows that the sediment is a poorly sorted, coarse - skewed, platykurtic gravelly - silt (fig. 6.4.13.3.). The results of S.E.M. study of quartz grain surface textures shows that the silt is re - worked loess (fig.

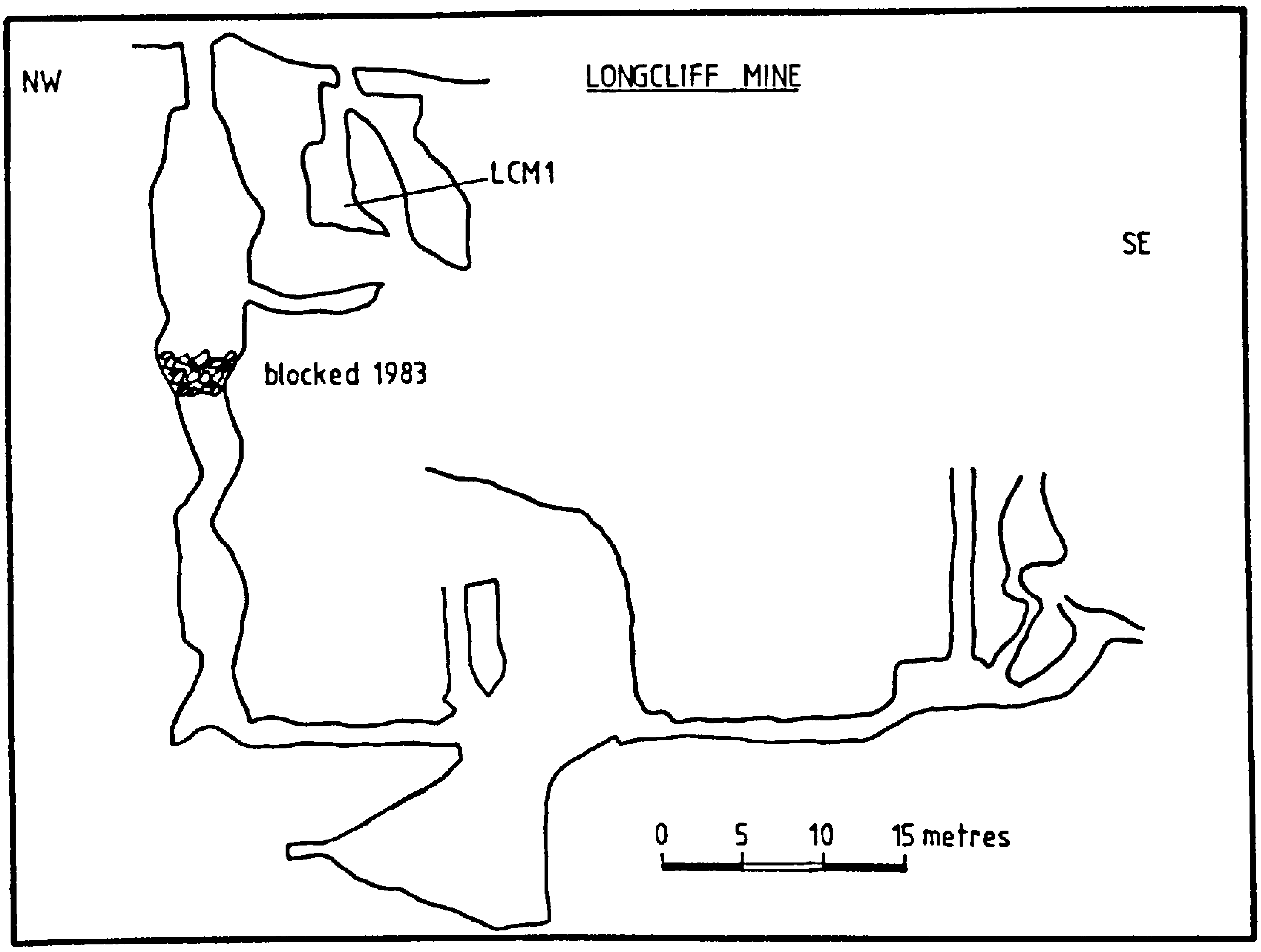


Figure 6.4.12.1. Section of Longcliffe Mine showing sample location. After Ford (1962).

Sample Number LM 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	8
	Silicified fossils	
	Authigenic quartz	15
	Galena	3·5
	Fluorite	2
	Baryte	2·5
	Calcite	1·5
2	Quartz	62
	Sandstone	
	Feldspar	0·5
	Mica	1·5
	Shale	
	Quartzite	
	Balance (mainly clay)	17
1 Autochthonous 2 Allochthonous		

Figure 6.4.12.2. Summary of sediment composition, Longcliffe Mine.

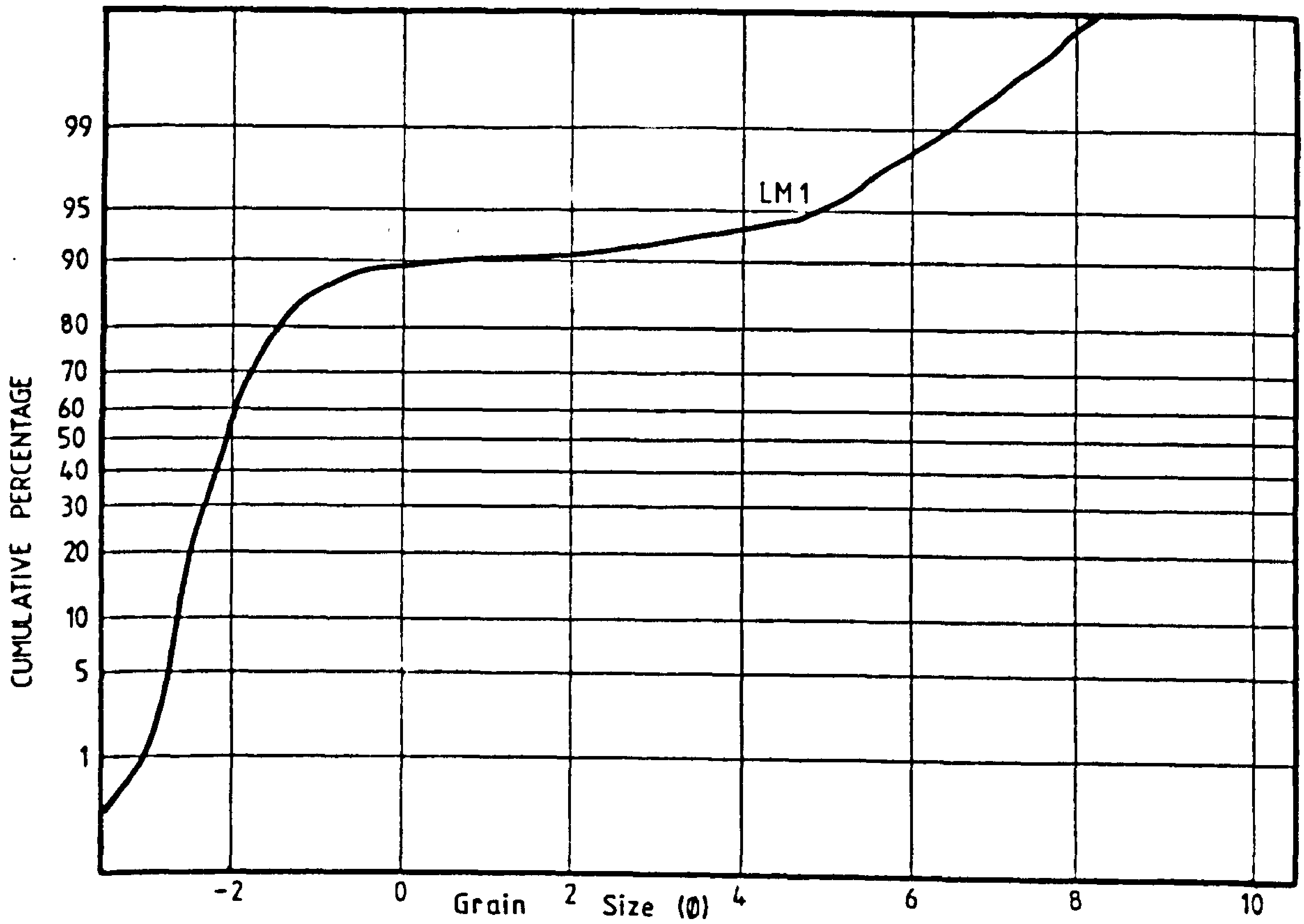


Figure 6.4.12.3. Sediment Size Analysis. Longcliffe Mine.

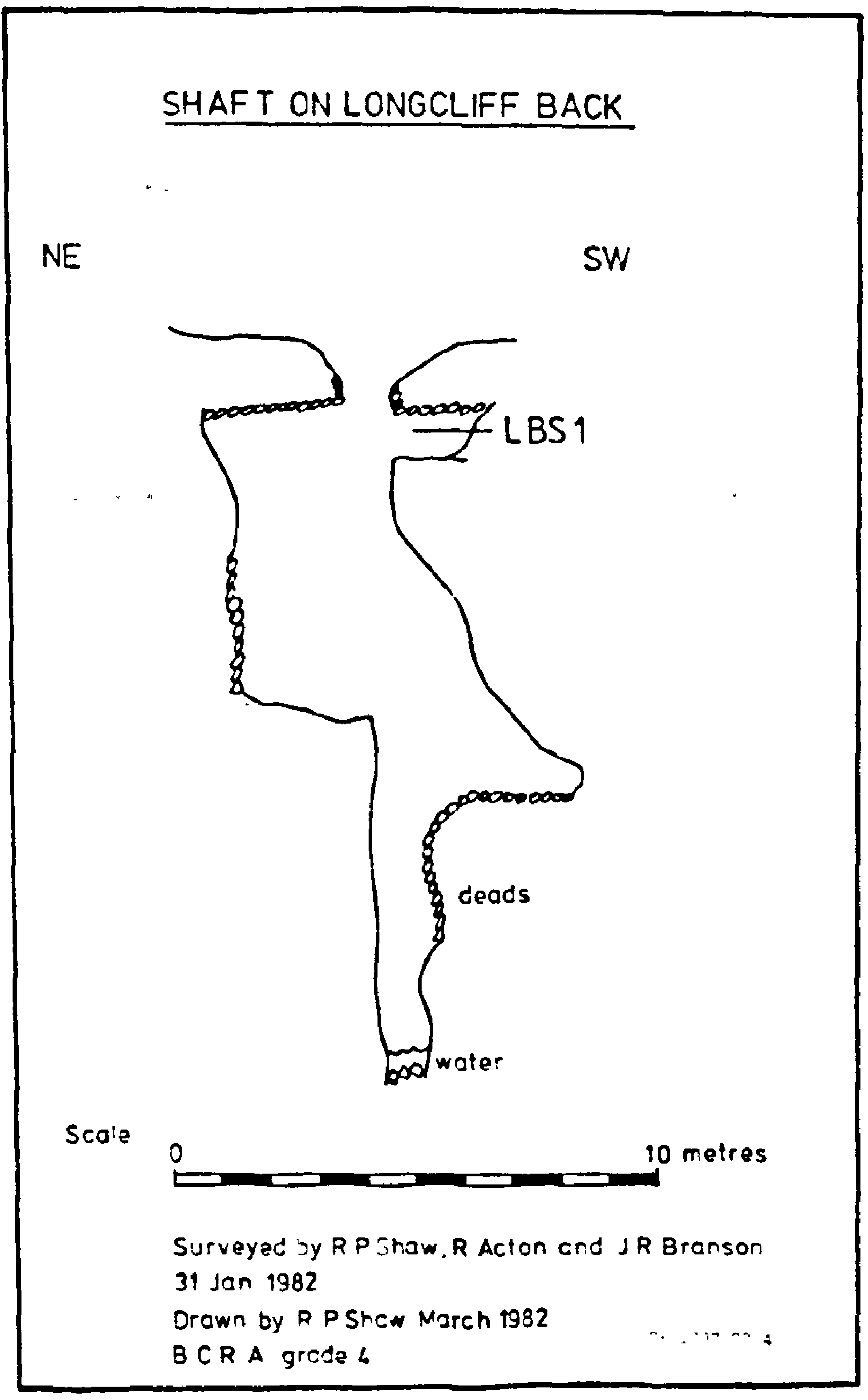


Figure 6.4.13.1. Section of Longcliffe Back Shaft showing sample location.

Sample Number LBS 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	2
	Silicified fossils	1·5
	Authigenic quartz	0·5
	Galena	1·5
	Fluorite	6
	Baryte	3·5
	Calcite	1
2	Quartz	70
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	13
1 Autochthonous 2 Allochthonous		

Figure 6.4.13.2. Summary of sediment composition, Longcliff Back Shaft.

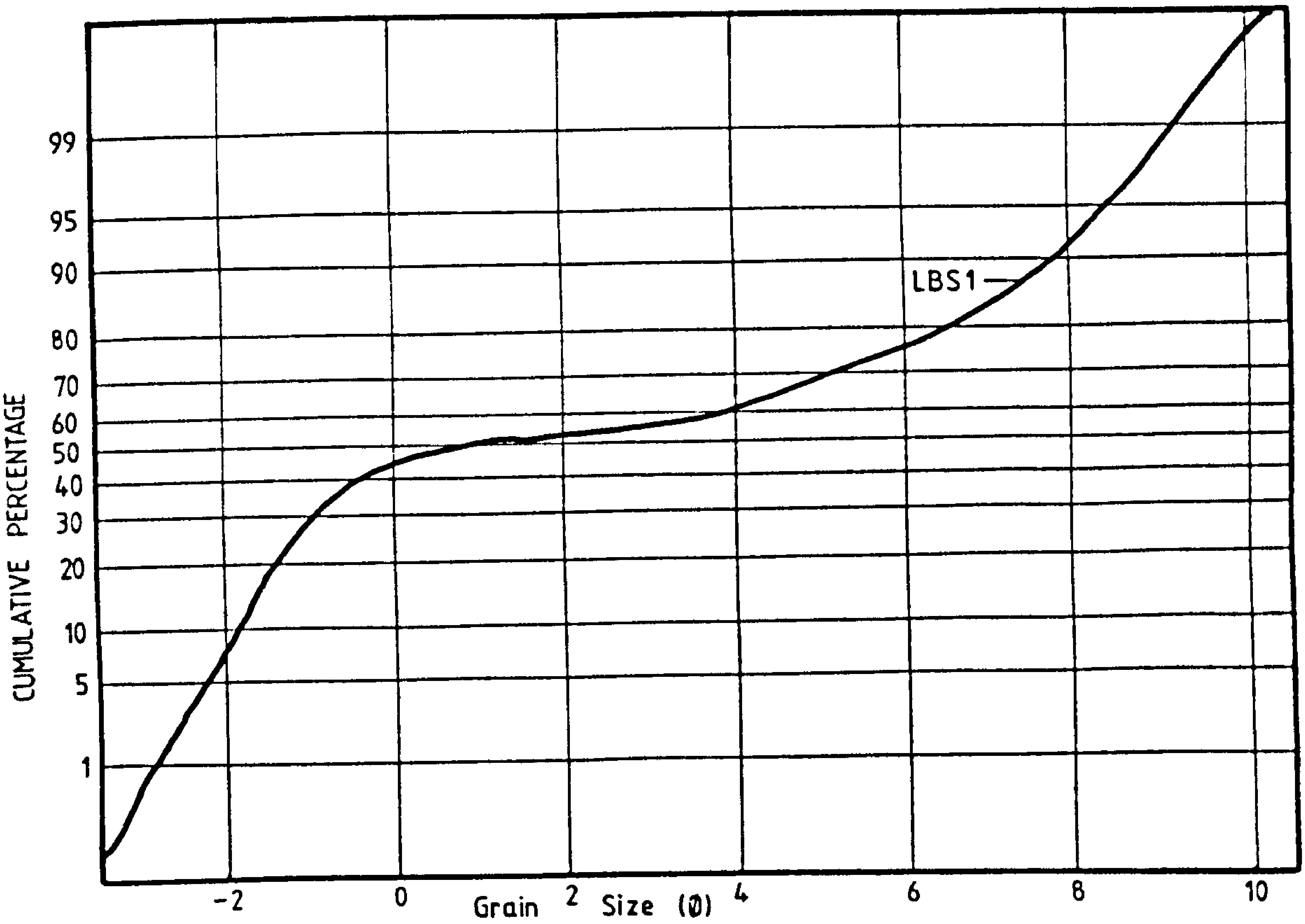


Figure 6.4.13.3. Sediment Size Analysis. Longcliffe Back Shaft.

6.4.13.4.).

The coarse - grained fraction consists of autochthonous chert and mineral vein clasts and the fine - grained fraction consists of allochthonous quartz silt of loessic origin. The cavity was probably filled by direct infilling from the surface.

6.4.14. Windy Knoll Cave

Situated at SK 126,830, a fissure outside the entrance to the cave was an important site for Pleistocene mammal bones (Pennington, 1874 and 1875; Dawkins, 1875). The cave is roofed by the Boulder Bed and is developed in the reef limestones below. It was once a swallet cave carrying water underground from a former Rushup Edge (Ford, 1977b).

The cave contains remnants of a sedimentary fill (fig. 6.4.14.1.) but these have been greatly disturbed. The composition of the sediments is given in figure 6.4.14.2.. Size analysis shows that the sediments are moderately well sorted, coarse - skewed, mesokurtic silty - sand (fig. 6.4.14.3.). The results of S.E.M. study of quartz grain surface textures shows that the sediment has been fluvially derived (fig. 6.4.14.4.).

The composition of the sediments indicates that they were derived from the Namurian strata of Rushup Edge . This derivation was by fluvial processes. Since the cave ceased being an active swallet substantial frost shattering has altered the morphology of the cave and this has contributed to the disruption of the sediments.

Surface Features		
Chemical	Euhedral silica	
	Amorphous silica	●
	Solution crevasses	
	Solution pits	●
	Oriented etch pits	●
Loessic	Dulled surface	●
	Smooth surface	◩
	Rounded	■
	Dish-shaped pits	◩
Fluvial	Subangular	●
	Subrounded	●
	Mechanical V-pits	
	Curved scratches	
	Straight scratches	
Glacial	Chattermarks	
	Angular	
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10µ	
	Conchoidals <10µ	
	Breakage blocks>10µ	
	Breakage blocks<10µ	
General	Euhedral quartz	●
	Scaling	●
	High relief	
	Medium relief	●
	Low relief	■
	Meandering ridges	
	Arcuate steps	
	Straight steps	
	Edge abrasion	●
	Grain breakage	
	Sample number LBS	1

■ Abundant − 75%
◩ Common 25-75%
● Present 1-25%
☐ Absent − 1%

Figure6.4.13.4. Summary of quartz grain surface textures, Longcliffe Back Shaft.

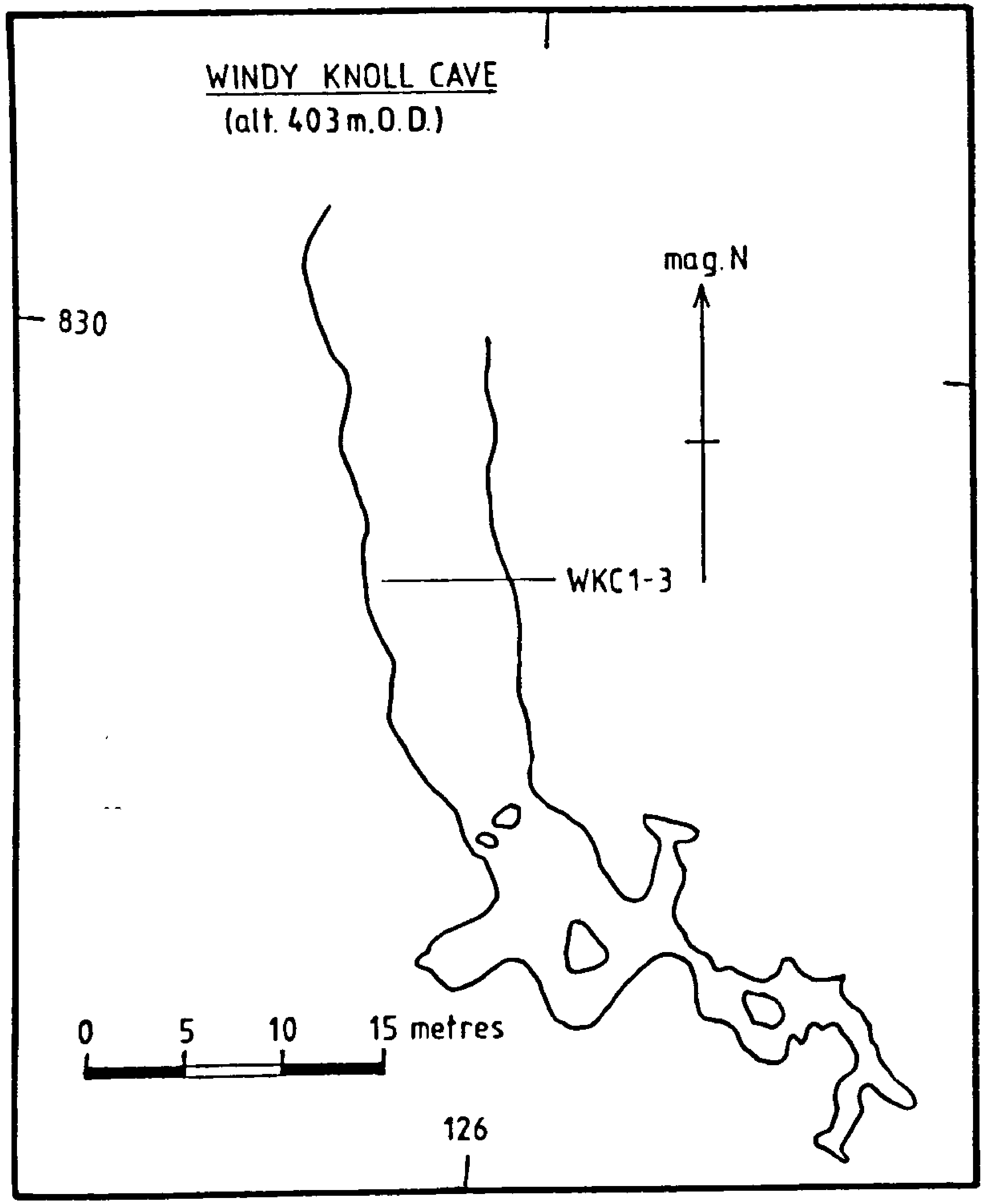


Figure 6.4.14.1. Plan of Windy Knoll Cave showing sample locations. After Elliot (1976).

The relationship between these sediments and those of the bone - bearing deposit outside the cave is unknown.

6.4.15. Peak Cavern

Peak Cavern is an extensive cave system collecting percolation drainage from a large area in the south and southwest of the area. It also takes flood overflow from the Speedwell system (Christopher, 1981). The first half kilometre of the cave is used as a show cave. Numerous descriptions of the cave system have been published including those of Simpson (1948), Gilbert (1949) and Salmon (1952 and 1962). The entrance to the cave is at the head of the Peak Cavern Gorge at SK 148,825.

Peak Cavern has acted as a resurgence for drainage in this area for a considerable period of time. The relative chronology of the development of the cave system has been outlined by Beck (1980) but little positive dating can be applied. Speleothem dating of flowstone in Victoria Passage and the Stream Passage gives ages from 1,000 to 75,000 years B.P. (Ford et al, 1983).

A number of sites have been studied in the cave system (fig. 6.4.15.1.):-

6.4.15.1. Victoria Passage

Two sites were sampled in Victoria Passage (fig. 6.4.15.1., PC 1-3, 4-6). At both sites the sediments are

Sample Numbers WKC 1-3		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0 — 0·5
	Baryte	
	Calcite	
2	Quartz	59 — 73
	Sandstone	11 — 14
	Feldspar	3 — 5
	Mica	4 — 9
	Shale	1 — 4
	Quartzite	
	Balance (mainly clay)	13 — 17
1 Autochthonous 2 Allochthonous		

Figure 6.4.14.2. Summary of sediment composition, Windy Knoll Cave.

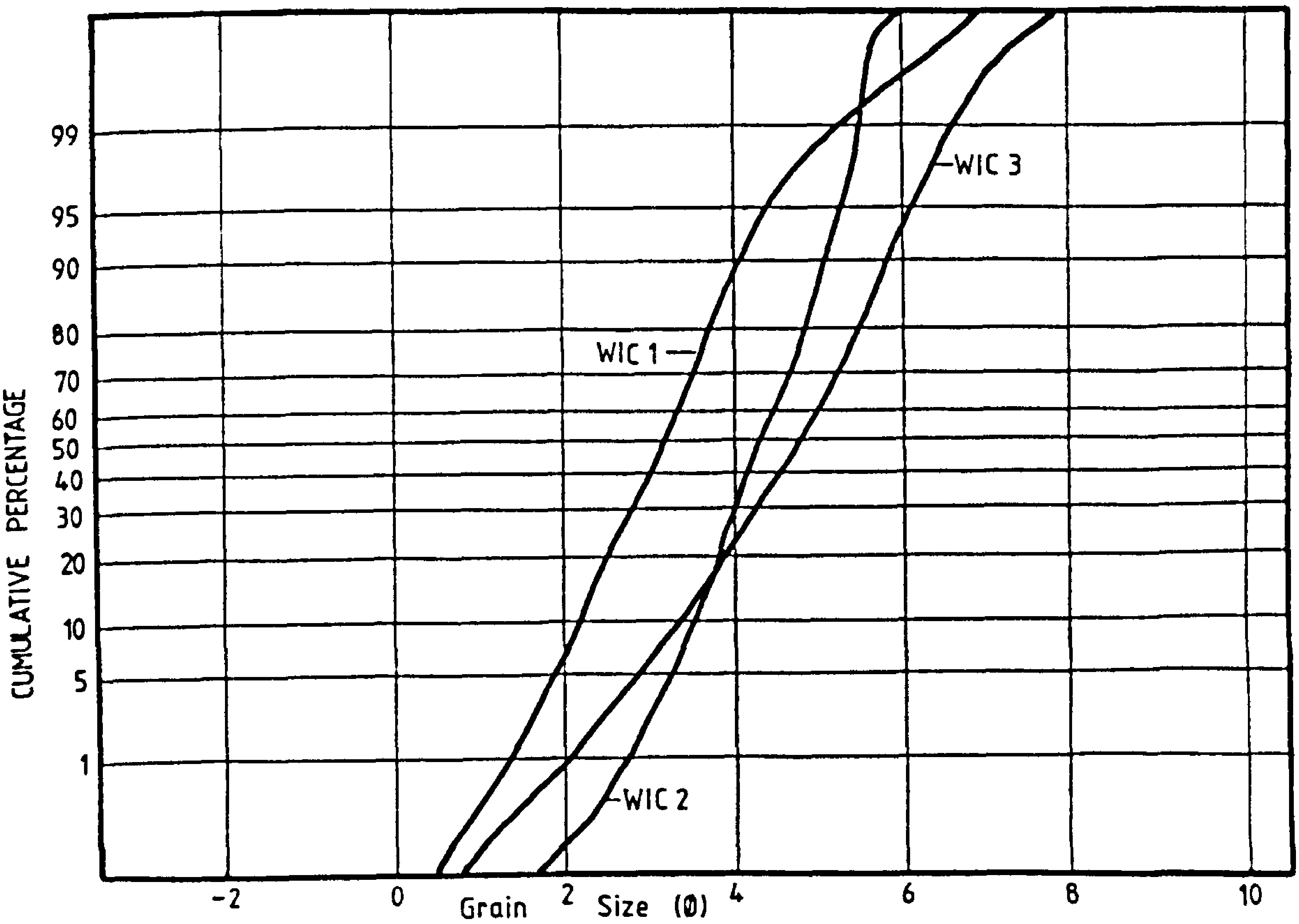


Figure 6.4.14.3. Sediment Size Analysis. Windy Knoll Cave.

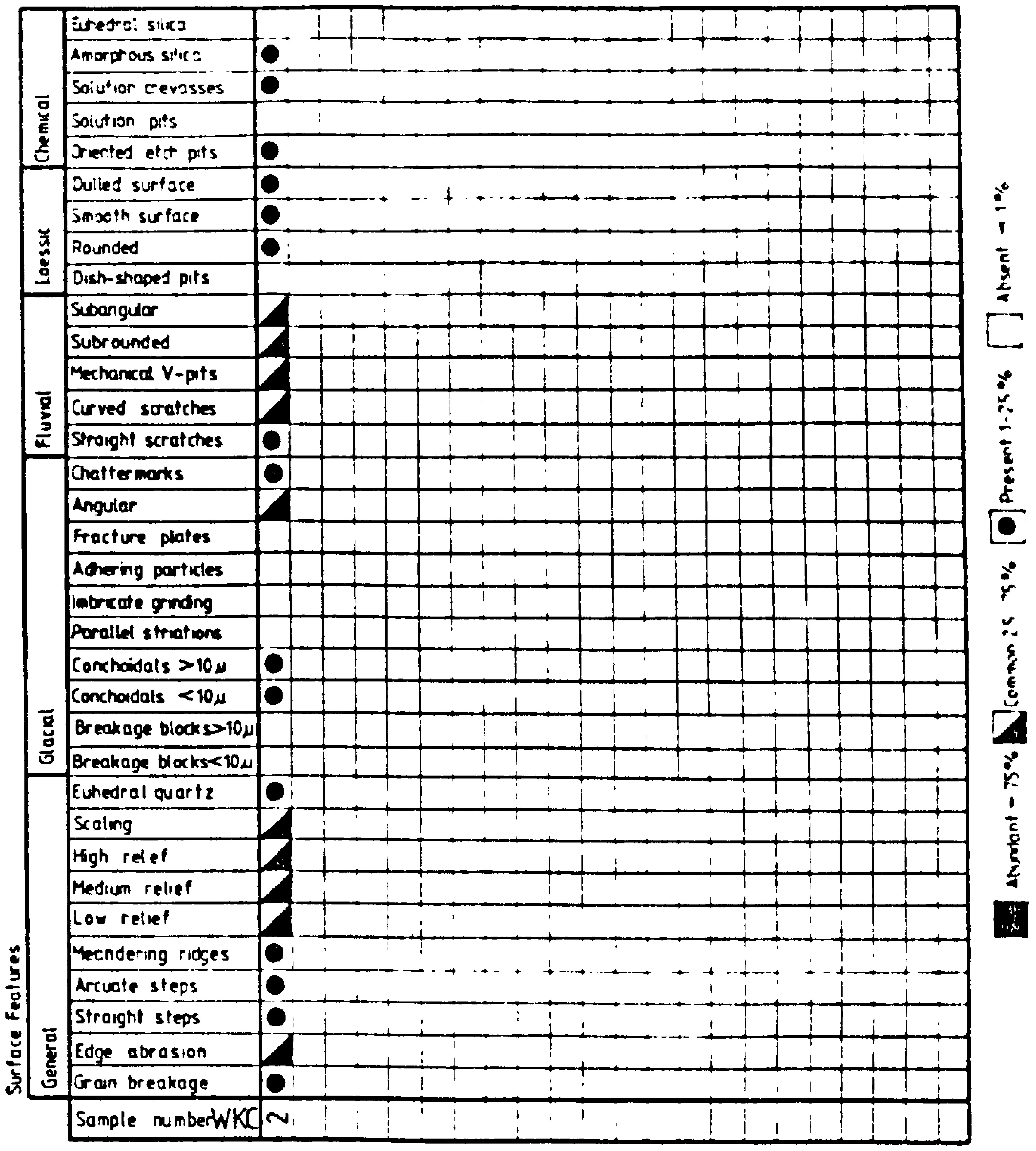


Figure 6.4.14.4. Summary of quartz grain surface textures, Windy Knoll Cave.

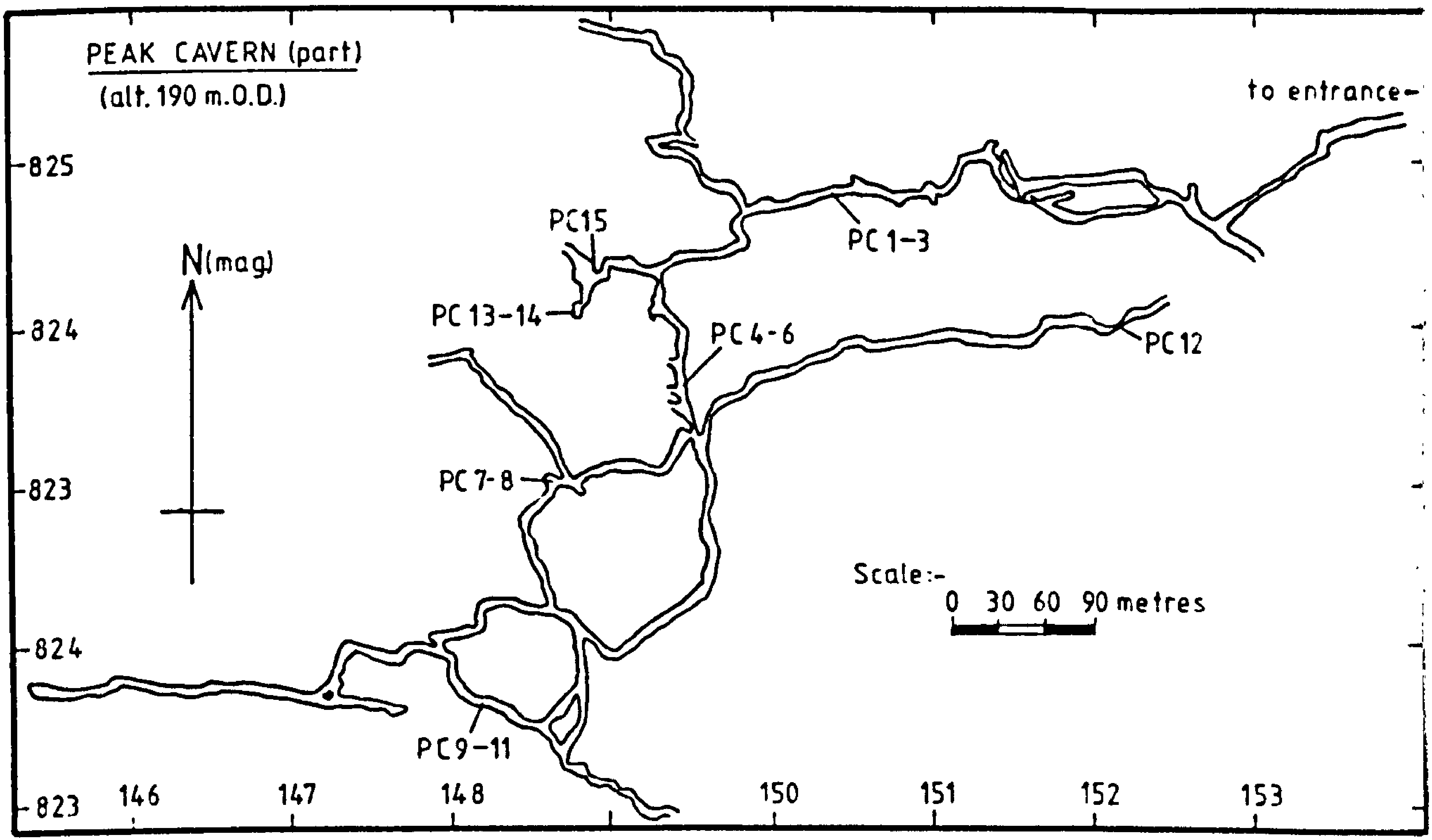


Figure 6.4.15.1. Plan of part of Peak Cavern showing sample locations. After Salmon (1962).

well - bedded silts and they have been partly re - eroded.

The composition of the sediment is given in figure 6.4.15.1.1.. Size analysis shows that the sediments are moderately sorted, fine - skewed, mesokurtic clayey silts (fig. 6.4.15.1.2.). The results of S.E.M. study of quartz grain surface textures shows features characteristic of a fluvial environment (fig. 6.4.15.1.3.).

6.4.15.2. Galena Chamber

Galena Chamber is developed in a mineral vein containing calcite, fluorite and galena mineralization. The floor of the chamber is covered by a gravelly - silt, the composition of which is given in figure 6.4.15.2.1.. Size analysis shows that the sediment is a poorly sorted, very coarse - skewed, platykurtic gravelly - silt (fig. 6.4.15.2.2.). The coarse fraction is composed of angular galena, fluorite and calcite clasts derived from the mineral vein. The results of S.E.M. study of quartz grain surface textures shows that the silt is of fluvial origin (fig. 6.4.15.2.3.).

6.4.15.3. Far Stream Passage

The lower section of this passage contains numerous remnants of a formerly extensive accumulation of sediments, up to two metres thick. The present, intermittent, stream has removed a large quantity of

Sample Numbers PC 1-6

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	63 — 81
	Sandstone	2 — 4
	Feldspar	1 — 3
	Mica	3 — 9
	Shale	0 — 1·5
	Quartzite	
	Balance (mainly clay)	17 — 28

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	53 — 61
Kaolinite	46 — 54
Chlorite	3 — 7
Mixed layer smectites	4 — 8

Figure 6.4.15.1.1. Summary of sediment composition, Victoria Passage, Peak Cavern.

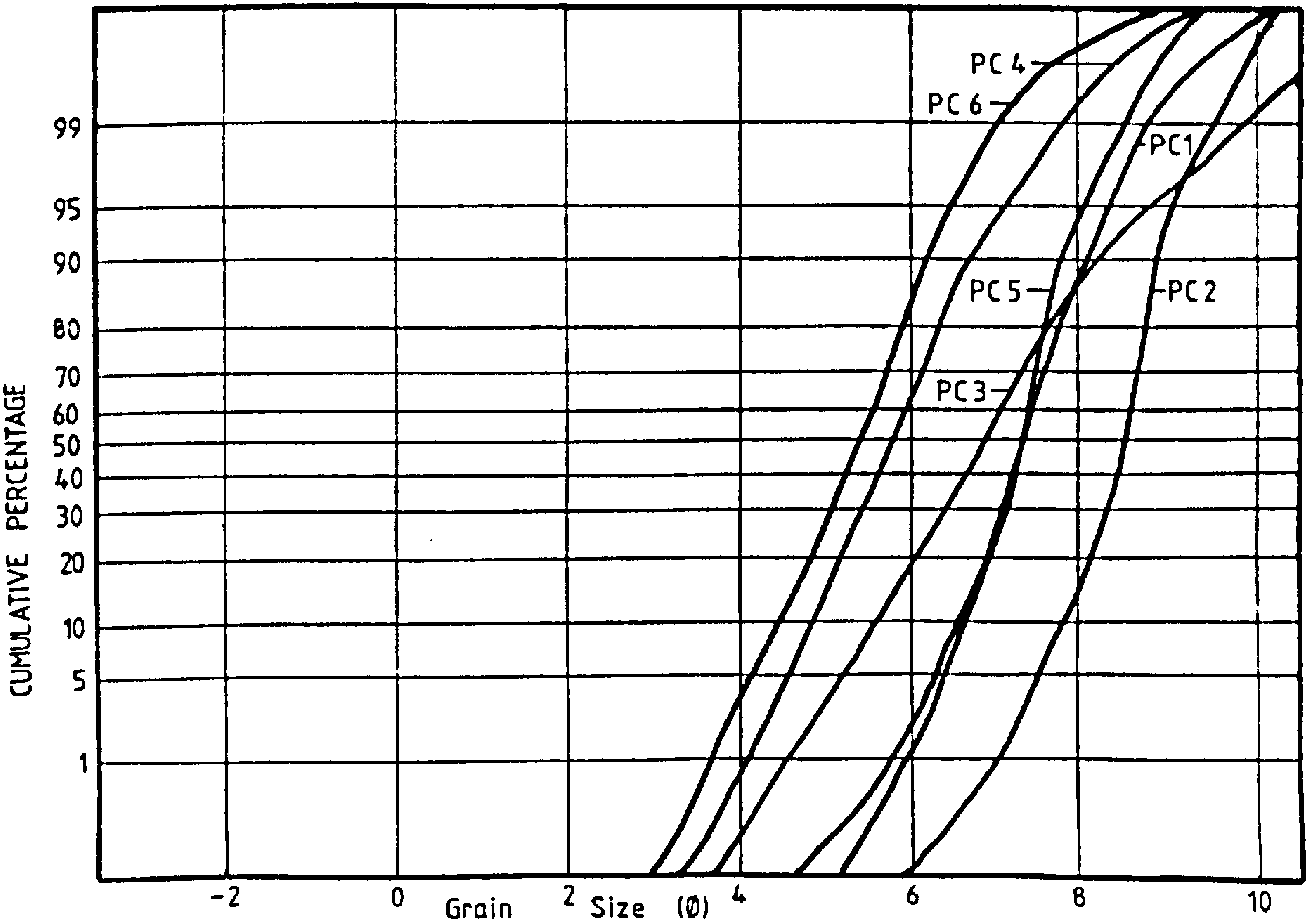


Figure 6.4.15.1.2. Sediment Size Analysis. Victoria Passage, Peak Cavern.

Surface Features				
Chemical	Euhedral silica			●
	Amorphous silica		●	●
	Solution crevasses	●	●	
	Solution pits		●	●
	Oriented etch pits	●	●	
Loessic	Dulled surface		●	
	Smooth surface	●	●	●
	Rounded	●	●	
	Dish-shaped pits	●		
Fluvial	Subangular	◪	◪	◪
	Subrounded	◪	◪	◪
	Mechanical V-pits	■	◪	■
	Curved scratches	●	●	◪
	Straight scratches	●	●	●
Glacial	Chattermarks			
	Angular		●	●
	Fracture plates			
	Adhering particles			
	Imbricate grinding			
	Parallel striations	●		
	Conchoidals >10µ			●
	Conchoidals <10µ		●	●
	Breakage blocks>10µ			
	Breakage blocks<10µ			
General	Euhedral quartz	●	●	●
	Scaling	◪	●	●
	High relief	●	●	●
	Medium relief	●	◪	◪
	Low relief	■	◪	◪
	Meandering ridges	●	●	●
	Arcuate steps	●		●
	Straight steps		●	
	Edge abrasion	●		●
	Grain breakage	●	◪	●
	Sample number PC	1	3	6

■ Abundant − 75% ◪ Common 25-75% ● Present 1-25% ☐ Absent − 1%

Figure 6.4.15.1.3. Summary of quartz grain surface textures, Victoria Passage, Peak Cavern.

Sample Numbers PC 7-8		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	7 — 12
	Fluorite	1 — 4
	Baryte	
	Calcite	6 — 15
2	Quartz	47 — 65
	Sandstone	
	Feldspar	1 — 3
	Mica	0 — 3
	Shale	
	Quartzite	
	Balance (mainly clay)	27 — 41
1 Autochthonous 2 Allochthonous		

Figure 6.4.15.2.1 Summary of sediment composition, Galena Chamber, Peak Cavern.

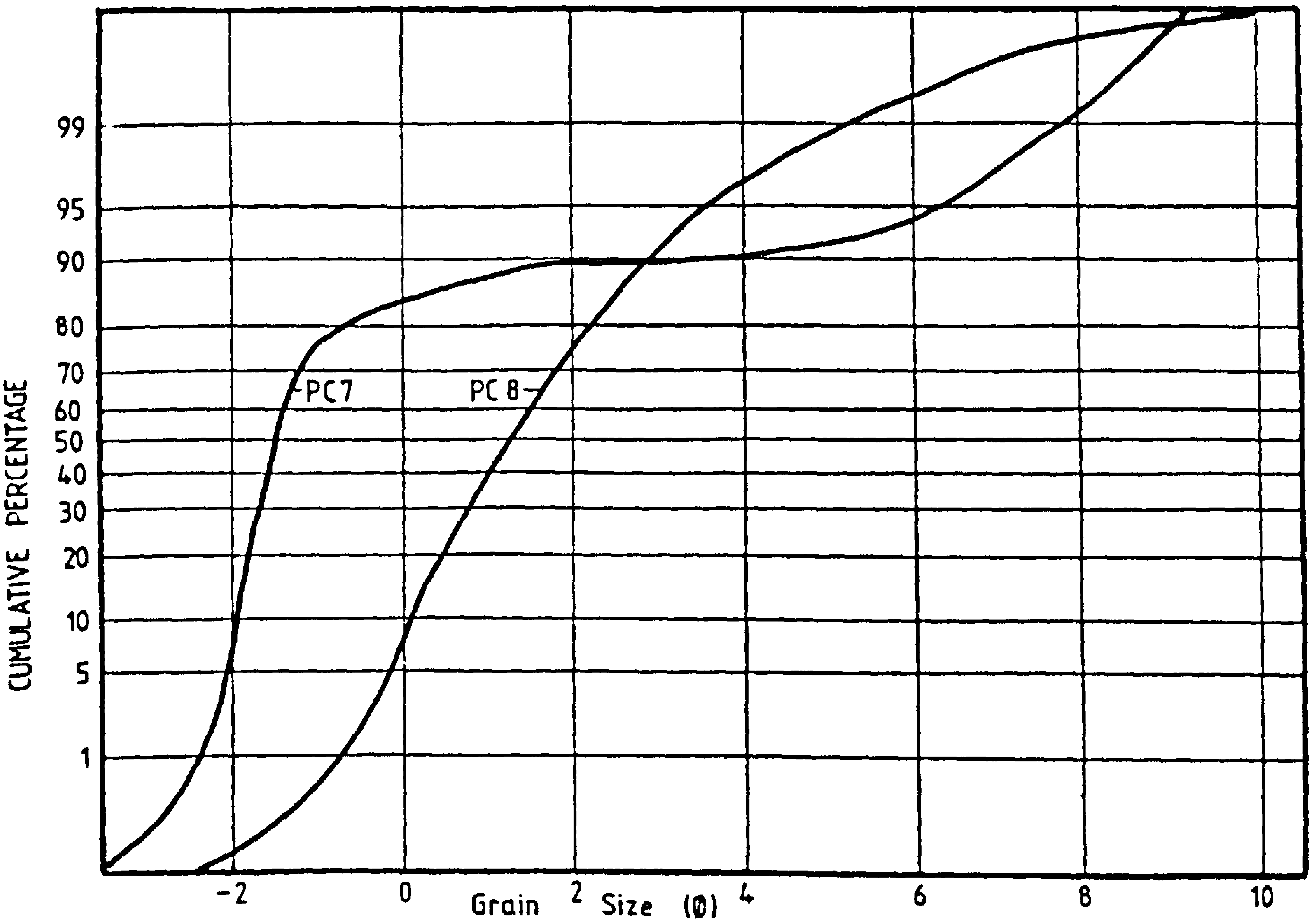


Figure 6.4.15.2.2. Sediment Size Analysis, Galena Chamber, Peak Cavern.

Surface Features	Chemical	Euhedral silica		
		Amorphous silica	●	●
		Solution crevasses		●
		Solution pits	●	
		Oriented etch pits	●	●
	Loessic	Dulled surface		●
		Smooth surface	●	●
		Rounded	●	●
		Dish-shaped pits		●
	Fluvial	Subangular	◢	●
		Subrounded	◢	■
		Mechanical V-pits	◢	◢
		Curved scratches	●	●
		Straight scratches	●	
	Glacial	Chattermarks		
		Angular	●	
		Fracture plates		
		Adhering particles		
		Imbricate grinding		
		Parallel striations		
		Conchoidals >10µ	●	●
		Conchoidals <10µ		●
		Breakage blocks>10µ		
		Breakage blocks<10µ		
	General	Euhedral quartz	●	●
		Scaling	◢	●
		High relief	◢	
		Medium relief	◢	●
		Low relief	◢	■
		Meandering ridges	●	●
		Arcuate steps	●	
		Straight steps	●	
		Edge abrasion		●
		Grain breakage		●
		Sample number PC	7	8

■ Abundant – 75%
◢ Common 25-75%
● Present 1-25%
☐ Absent – 1%

Figure 6.4.15.2.3. Summary of quartz grain surface textures, Galena Chamber, Peak Cavern.

these deposits. The deposit is very well laminated and sometimes shows iron staining indicating some remobilization of iron hydroxides within the deposit.

The composition of the sediment is given in figure 6.4.15.3.1.. Size analysis shows that the sediments are moderately well sorted, leptokurtic silts (fig. 6.4.15.3.2.). The results of S.E.M. study of quartz grain surface textures shows that the silts are of fluvial origin (fig. 6.4.15.3.3.).

Their composition shows that these sediments have been derived from the Namurian strata. Their fine - grained nature suggests that they have been deposited in slow moving water, perhaps behind a boulder dam in the streamway, after the coarser fraction has been deposited. As these deposits are traced upstream there is a distinct coarsening of the sediments and thickening of the units.

Palaeomagnetic studies were carried out over a thickness of 1.2 metres of these silts, the results of which are given in figure 6.4.15.3.4.. Comparison of these results with standardised magnetic profiles for British lake sediment cores (Turner and Thompson, 1981 and 1982) shows close correlation over the period from 5,000 to 1,000 yrs. B.P. during which period these sediments must have been deposited.

One speleothem date for a stalagmite overlying these sediments gives an age of 1,000 to 1,200 yrs. B.P. (Ford et al, 1983) which supports this evidence.

No evidence can be found in the cave as to the cause of the sediment deposition in this passage or of the

Sample Numbers PC 9-11

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	58 — 66
	Sandstone	1 — 4
	Feldspar	3 — 7
	Mica	3 — 16
	Shale	0 — 2
	Quartzite	
	Balance (mainly clay)	19 — 23

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	59 — 74
Kaolinite	21 — 43
Chlorite	7 — 16
Mixed layer smectites	4 — 9

Figure 6.4.15.3.1. Summary of sediment composition, Far Stream Passage, Peak Cavern.

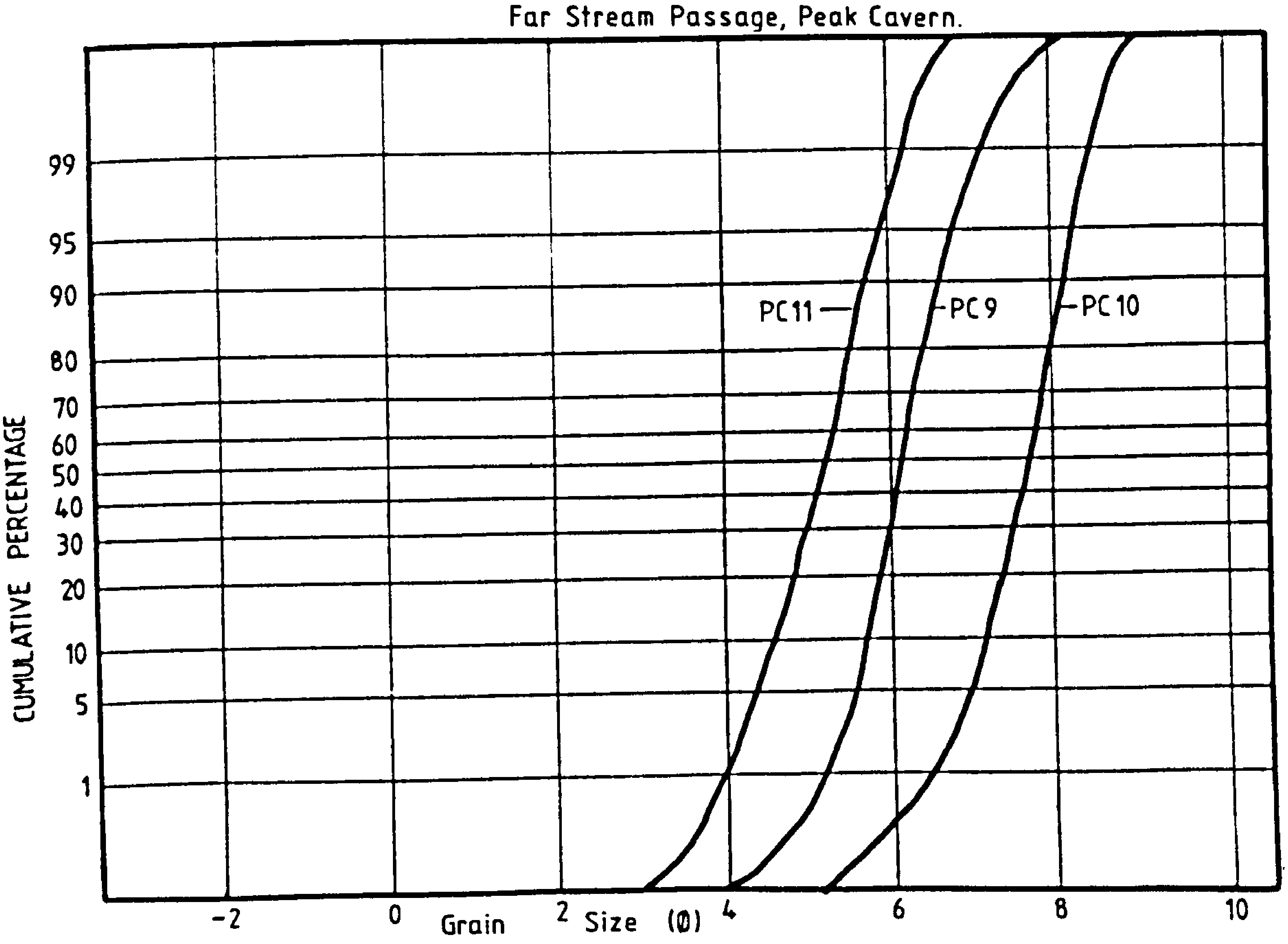


Figure 6.4.15.3.2. Sediment Size Analysis, Far Stream Passage, Peak Cavern.

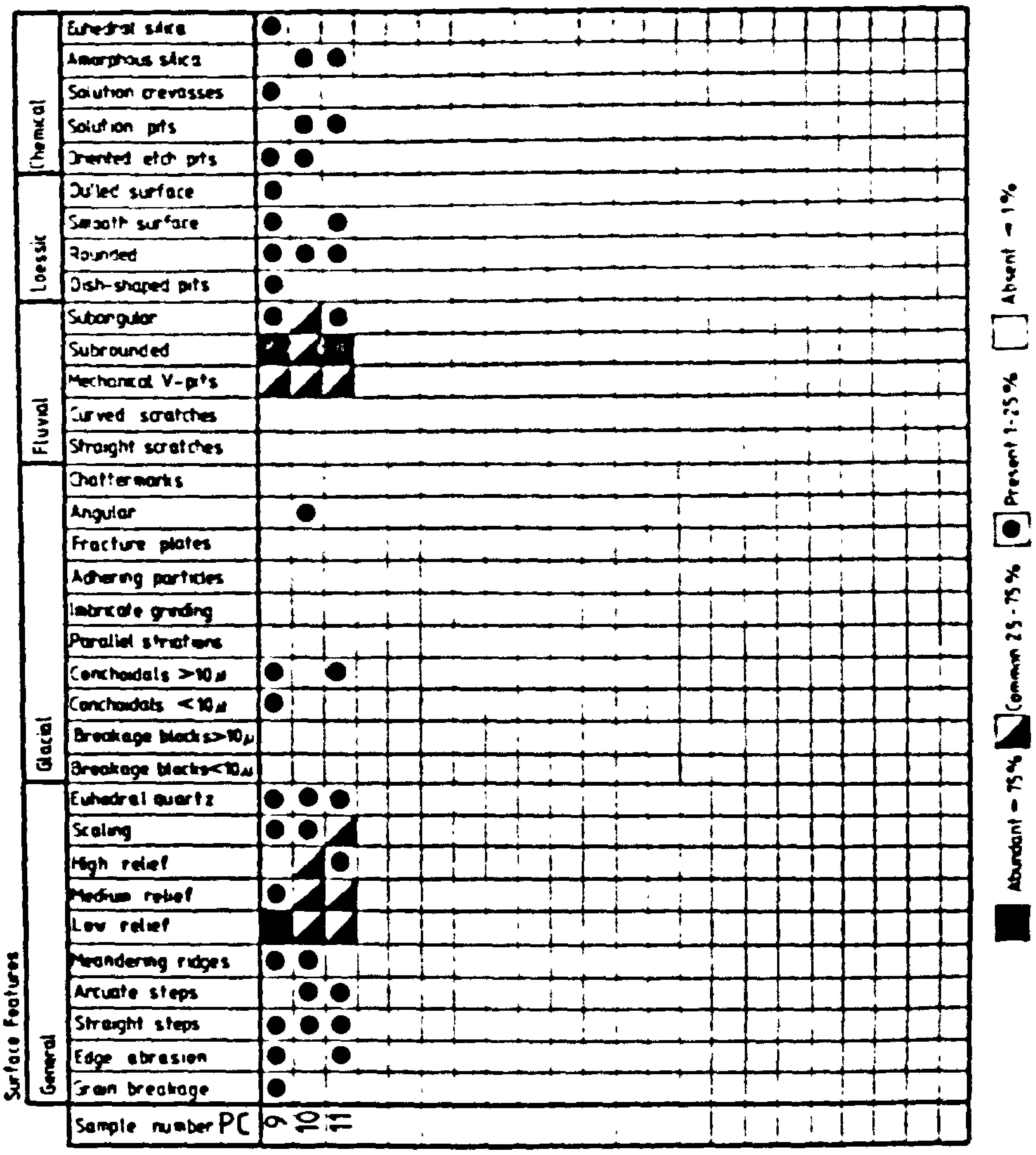


Figure 6.4.15.3.3 Summary of quartz grain surface textures, Far Stream Passage, Peak Cavern.

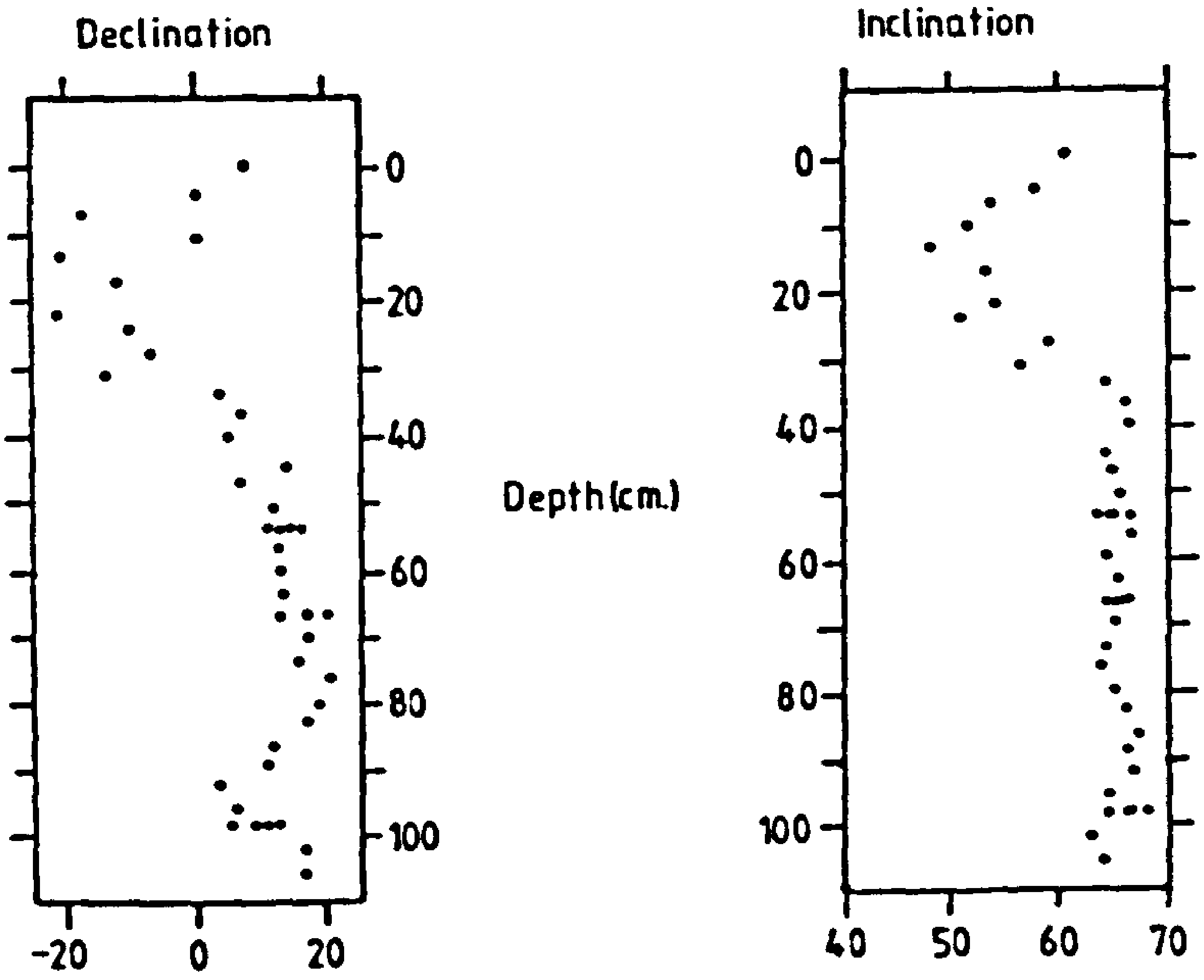


Figure 6.4.15.3.4. Palaeomagnetic profile, Far Stream Passage, Peak Cavern. Demagnetised at 100 O_e.

reason for its subsequent removal which has occured in the last 1,000 years. It cannot be due to the activities of man within the cave as this part of the system was not discovered until 1949 (Salmon, 1962).

6.4.15.4. Main Stream Sump

In times of flood the main stream backs up until the passage is flooded to a depth of nearly 15 metres. This leads to the deposition of fine - grained sediments on all surfaces from the slow flowing stream. Deposition also occurs on vertical and steeply inclined surfaces (plate 6.4.15.4.1.) by parallel accretion (Bull, 1981b). On retreat of the floodwater silt deposited on the stream bed is soon removed by the fast flowing water but that on other surfaces remains. In some cases dripping water removes some of the silt leaving silt pillars up to 10 cm. high (plate 6.4.15.4.2.).

The composition of the silt is given in figure 6.4.15.4.1.. Size analysis shows that the sediment is a moderately sorted, fine - skewed, leptokurtic silt (fig. 6.4.15.4.2.).

6.4.15.5. The Treasury and Speedwell Water Passage

When the Speedwell system floods and overflows into Peak Cavern water enters Peak Cavern via a number of passages including the Treasury and Speedwell Pot. The Treasury and Speedwell Water Passage carry the flood

Sample Numbers PC12		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0·5
	Baryte	
	Calcite	
2	Quartz	72
	Sandstone	3
	Feldspar	0·5
	Mica	2
	Shale	4
	Quartzite	
	Balance (mainly clay)	18

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	62
Kaolinite	29
Chlorite	3
Mixed layer smectites	6

Figure 6.4.15.4.1. Summary of sediment composition, Main Stream Sump, Peak Cavern.

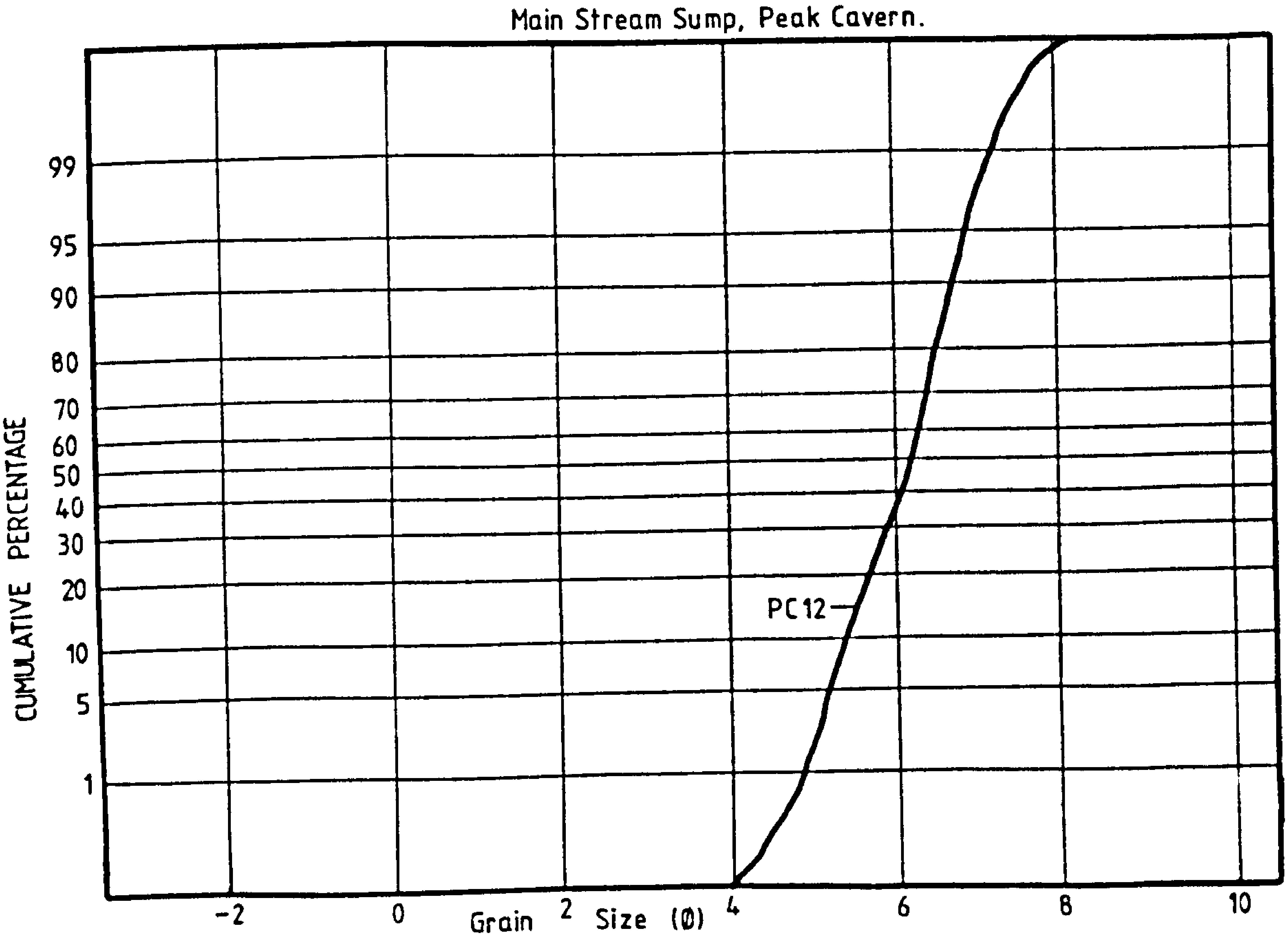
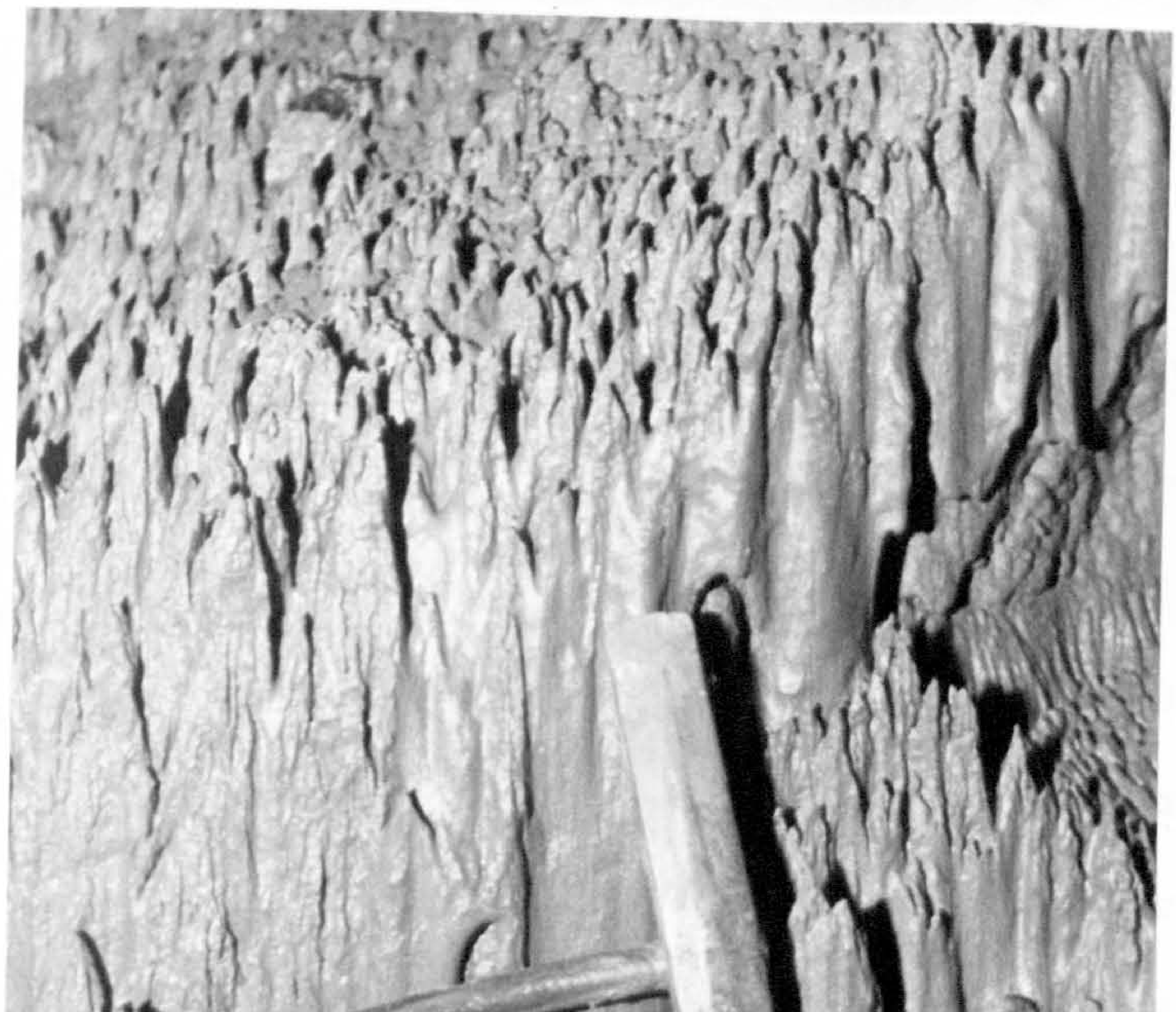


Figure 6.4.15.4.2. Sediment Size Analysis. Main Stream Sump, Peak Cavern.

20 cm.

6.4.15.4.1. Drip pits and dendritic surge marks, Main Stream Passage, Peak Cavern.



20 cm.

6.4.15.4.2. Silt pillars, Main Stream Passage, Peak Cavern.

water to the main stream at the end of the Peak Cavern show cave. In times of flood this section of the cave is under a considerable depth of water and this leads to the deposition of sediment from the flood water. In the Treasury and Speedwell Water Passage this takes the form of banks of sand often with ripple marks (plate 6.4.15.5.1.) indicating flow velocities less than 2 metres per second. These banks may contain deposits up to 1.5 metres thick, which may be removed or redistributed by subsequent flooding.

The composition of the sediment is given in figure 6.4.15.5.1.. Size analysis shows that the sediments are moderately well sorted, mesokurtic sands (fig. 6.4.15.5.2.). The results of S.E.M. study of quartz grain surface textures show that the sediment has been derived by fluvial processes (fig. 6.4.15.5.3.).

At the downstream end of Treasury Sump is a large gravel bank. Under flood conditions water at this point has to rise 8 metres before flowing into The Treasury. The rapidity of the overflowing stream has winnowed out the fine - grained fraction of the sediment and carried it away leaving the gravel which the water velocity is too low to remove. The composition of the gravel is given in figure 6.4.15.5.4. which shows it to consist mainly of autochthonous limestone and mineral vein clasts and allochthonous Namurian sandstone clasts.

6.4.16. Speedwell Cavern

Speedwell Cavern was discovered by lead miners in

Sample Numbers PC 13, 16 − 17		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	3 − 5
	Calcite	
2	Quartz	67 − 81
	Sandstone	6 − 8
	Feldspar	1 − 4
	Mica	4 − 8
	Shale	2 − 6
	Quartzite	
	Balance (mainly clay)	2 − 5
1 Autochthonous 2 Allochthonous		

Figure 6.4.15.5.1. Summary of sediment composition, The Treasury and Speedwell Pot, Peak Cavern.

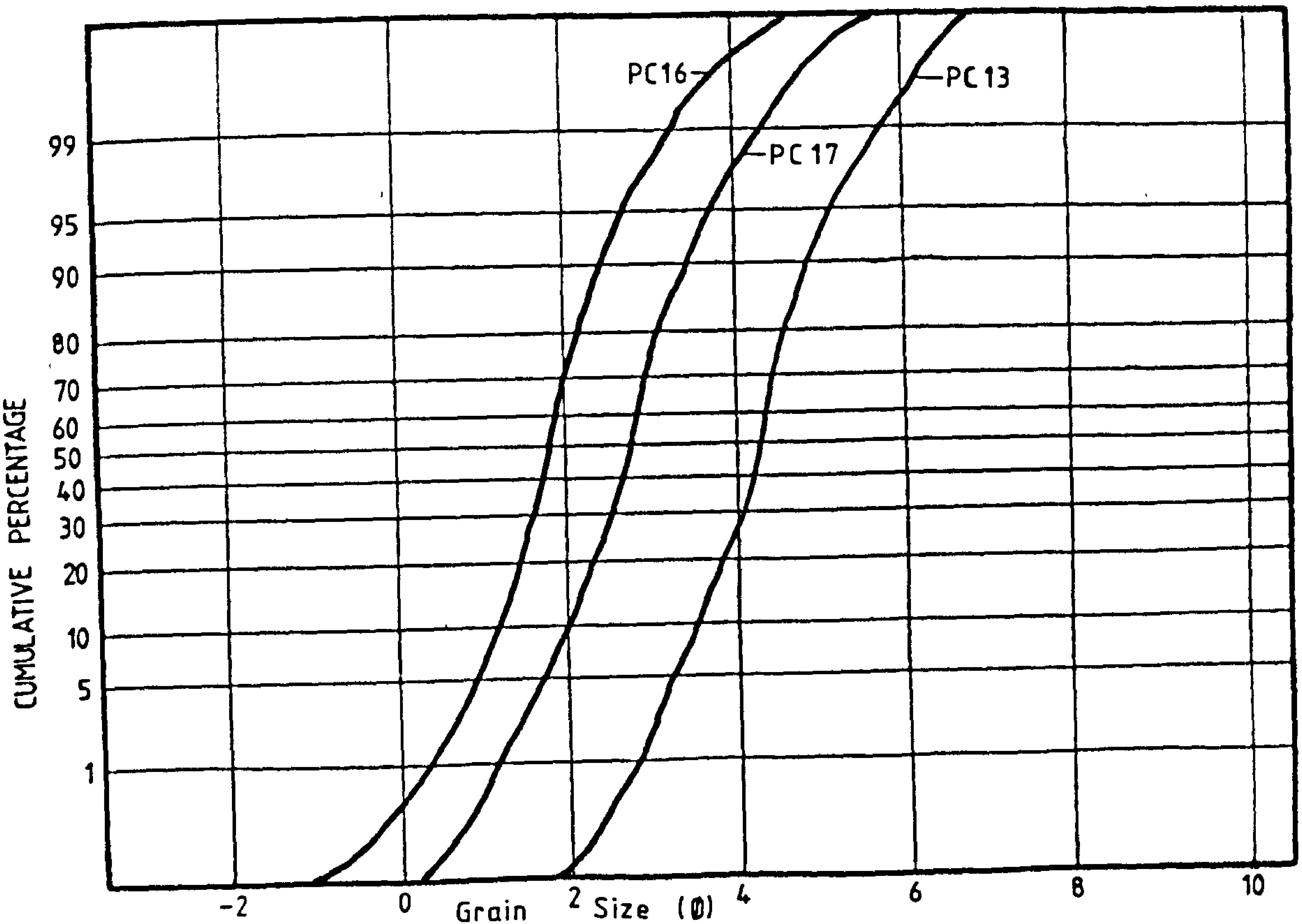


Figure 6.4.15.5.2. Sediment Size Analysis. The Treasury and Speedwell Pot, Peak Cavern.

Surface Features		13	17
Chemical	Euhedral silica		
	Amorphous silica	●	
	Solution crevasses	●	
	Solution pits	●	●
	Oriented etch pits		●
Loessic	Dulled surface		
	Smooth surface		●
	Rounded	●	●
	Dish-shaped pits		
Fluvial	Subangular	◩	◩
	Subrounded	◩	◩
	Mechanical V-pits	◩	■
	Curved scratches	◩	■
	Straight scratches	●	◩
Glacial	Chattermarks		
	Angular	●	●
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10µ		
	Conchoidals <10µ	●	
	Breakage blocks>10µ		
	Breakage blocks<10µ		
General	Euhedral quartz	●	●
	Scaling	●	●
	High relief	●	◩
	Medium relief	◩	◩
	Low relief	◩	◩
	Meandering ridges		
	Arcuate steps		●
	Straight steps		
	Edge abrasion	●	●
	Grain breakage		●
	Sample number PC	13	17

■ Abundant – 75% ◩ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure6.4.15.5.3.Summary of quartz grain surface textures, The Treasury and Speedwell Pot, Peak Cavern.

Sample Numbers PC 14–15		
		%
1	Limestone	17 — 21
	Dolomite	
	Volcanics	
	Chert	3 — 5
	Silicified fossils	2 — 3
	Authigenic quartz	
	Galena	0 — 1·5
	Fluorite	8 — 19
	Baryte	11 — 14
	Calcite	10 — 14
2	Quartz	
	Sandstone	31 — 52
	Feldspar	
	Mica	
	Shale	1 — 4
	Quartzite	
	Balance (mainly clay)	

1 Autochthonous 2 Allochthonous

Figure 6.4.15.5.4.Summary of sediment composition, Treasury Sump, Peak Cavern.

6.4.15.6.1. Ripple marks, Speedwell Passage, Peak Cavern.

the 1760's (Pilkington, 1789). A level was then driven from the Winnats Pass to intersect the cave system to enable the veins discovered to be exploited. Boat haulage was to be used for ore and waste removal (Simpson, 1953; Ford, 1956; Rieuwerts and Ford, 1983).

The canal, driven from the foot of a shaft at SK 139,828, is used as a show cave as far as the Bottomless Pit (fig. 6.4.16.1.).

The cave system is developed in lagoonal limestones of the Bee Low Beds. Most of the system is developed in one prominent bedding plane, originally as a phreatic network but now with varying amounts of vadose modification. The cave is the "main drain" from streams flowing underground at the foot of Rushup Edge and resurging from Russet Well.

Sediment samples collected from flood deposits in Whirlpool Passage and Main Passage (WWP & MR, fig. 6.4.16.1.) show that the sediment is a well sorted, leptokurtic sand (fig. 6.4,16.2.).

In the Main Passage these sediment deposits are only found upstream from the Boulder Piles which have a damming effect on the stream leading to the deposition of part of the streams sediment load. There are no sediment deposits in the active stream downstream from the Boulder Piles.

The composition of the sand is given in figure 6.4.16.3.. The results of S.E.M. study of quartz grain surface textures confirm the fluvial nature of these deposits (fig. 6.4.16.4.).

Ledges in the passage from the Bathing Pool to the

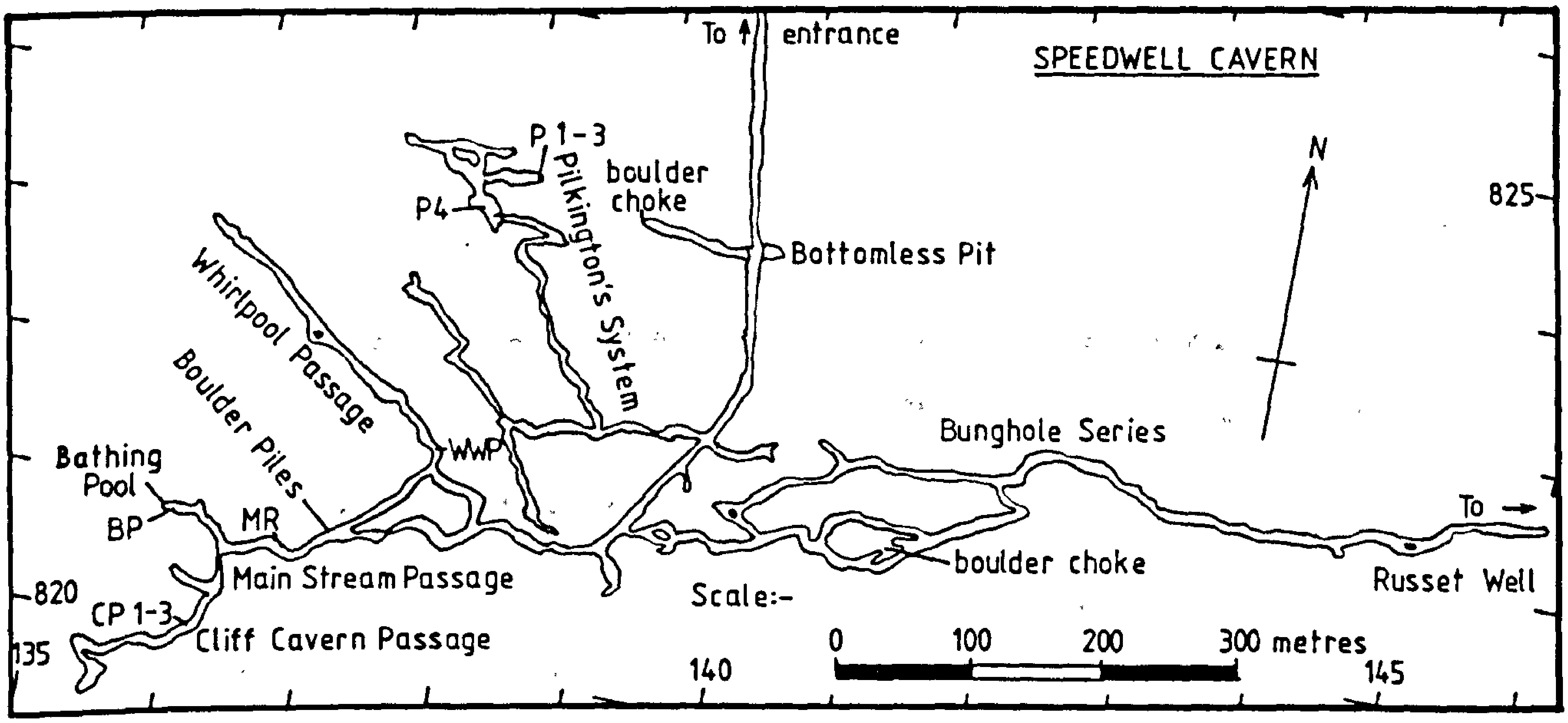


Figure 6.4.16.1. Plan of Speedwell Cavern showing sample locations. After Shaw (1983c).

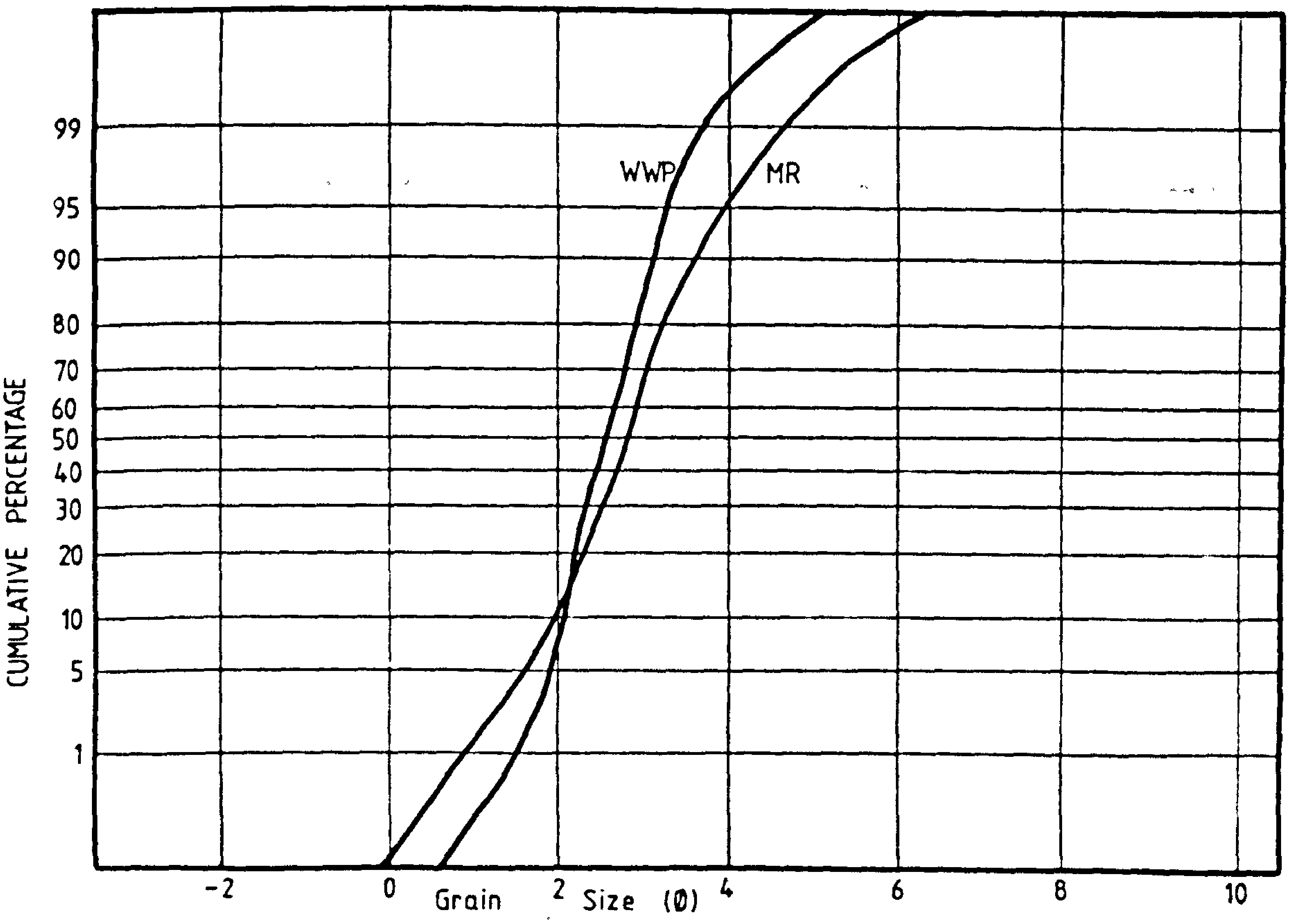


Figure 6.4.16.2. Sediment Size Analysis. Speedwell Cavern.

Sample Numbers MR, WWP		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0 — 2
	Baryte	0 — 1
	Calcite	0 — 1·5
2	Quartz	77 — 83
	Sandstone	3 — 6
	Feldspar	1 — 4
	Mica	5 — 9
	Shale	7 — 8
	Quartzite	
	Balance (mainly clay)	1 — 3

1 Autochthonous 2 Allochthonous

Figure 6.4.16.3. Summary of sediment composition, Whirlpool and Main Passages, Speedwell Cavern.

Surface Features		MR	WP	BP	CP	CP2	P1	P2	P3
Chemical	Euhedral silica	●	◢		●	●	●		
	Amorphous silica		●	●		●	●	●	●
	Solution crevasses	●	●	●	●		●	●	
	Solution pits		●	●	●	●		●	●
	Oriented etch pits	●			●		●		●
Loessic	Dulled surface		●		◢	●		●	●
	Smooth surface		●	●	●	◢	●	●	●
	Rounded	●	●	◢	◢	◢	●	●	●
	Dish-shaped pits	●		●	●	◢			●
Fluvial	Subangular	◢	◢	◢	●	●	◢	◢	●
	Subrounded	◢	◢	◢	◢	◢	◢	◢	■
	Mechanical V-pits	■	◢	◢	●	◢	◢	◢	◢
	Curved scratches	◢	●	●	◢	◢	●		◢
	Straight scratches	■	◢	●	●	●	●	●	●
Glacial	Chattermarks						●	●	
	Angular	◢	●	●			●	◢	
	Fracture plates							●	
	Adhering particles								
	Imbricate grinding								
	Parallel striations								
	Conchoidals >10μ	●	●		●	●	●	◢	●
	Conchoidals <10μ	●		●	●			●	
	Breakage blocks>10μ								
	Breakage blocks<10μ								
General	Euhedral quartz	●		●	●		●	●	●
	Scaling	●	●	◢	◢	◢	◢	●	◢
	High relief	◢	●	●	●		◢	◢	●
	Medium relief	◢	◢	◢	◢	●	◢	◢	◢
	Low relief	◢	◢	◢	◢	■	◢	◢	◢
	Meandering ridges	●	●	●	●		●	●	●
	Arcuate steps	●			●		●		
	Straight steps	●	●	●	●	●	●	●	●
	Edge abrasion	●	●	●	●		●		●
	Grain breakage	●		●	●	●	●	●	
	Sample number	MR	WP	BP	CP	CP2	P1	P2	P3

■ Abundant – 75% ◢ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 6.4.16.4. Summary of quartz grain surface textures, Speedwell Cavern.

Main Stream Passage have a coating of silt, up to 5 cm. thick. Around the Bathing Pool these silts exhibit well developed dendritic surge marks (plate 6.4.16.1.) which Bull (1976a) attributes to frequent rising and falling levels of silt - laden water. These features are now fossil and they may be related to when the Bathing Pool operated as a rising before the development of the Main and Whirlpool risings.

The composition of the sediment is given in figure 6.4.16.5.. Size analysis shows that the sediment is a moderately well sorted, slightly fine - skewed, leptokurtic silt (fig. 6.4.16.6.). The results of S.E.M. study of quartz grain surface textures shows that the silt is of fluvial origin (fig. 6.4.16.4., BP).

A phreatic tube, 0.8 metre high, leading from Cliff Cavern Passage (fig. 6.4.16.1., CP 1-3) is filled to the roof by fine - grained, laminated sediment (plate 6.4.16.2.). The composition of which is given in figure 6.4.16.7.. Size analysis shows that the sediment is a moderately sorted, fine - skewed, mesokurtic clayey - silt (fig. 6.4.16.8.). The results of S.E.M. study of quartz grain surface textures shows that the silt is of loessic and fluvial origin (fig. 6.4.16.4., CP 1,3).

Discoveries between 1981 and 1982 (Shaw, 1983b) led to the lost part of the cave system described by Pilkington (1789). A large natural chamber at the top of the Pilkington system (fig. 6.4.16.1., P 1-3) is associated with Faucet Rake, which here consists of three parallel veins with fluorite, baryte, calcite and galena mineralization (Shaw, 1983b). The eastern end of

Sample Number BP		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	72
	Sandstone	5
	Feldspar	3·5
	Mica	5·5
	Shale	2
	Quartzite	
	Balance (mainly clay)	13
1 Autochthonous 2 Allochthonous		

Figure 6.4.16.5. Summary of sediment composition, Bathing Pool Passage, Speedwell Cavern.

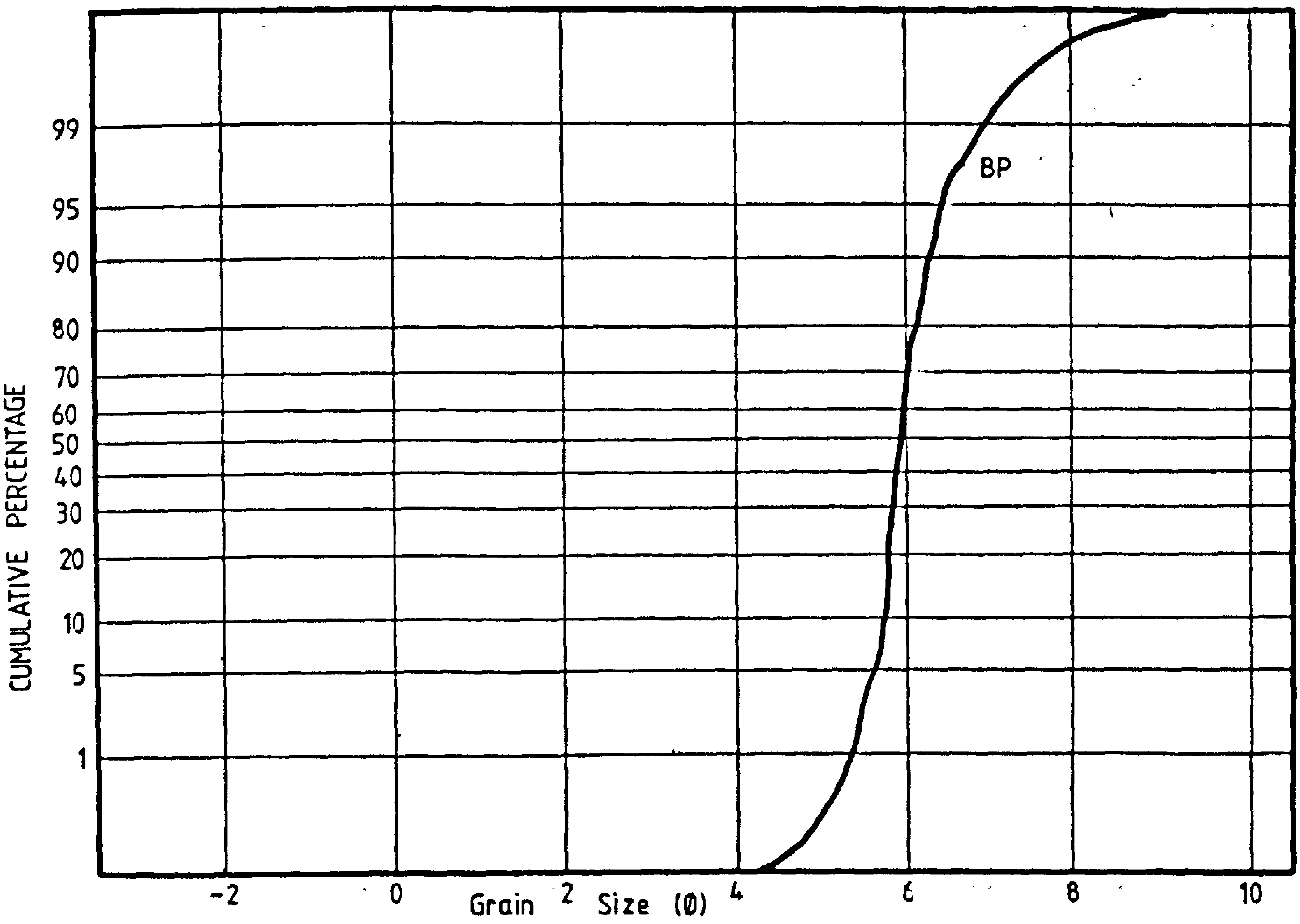


Figure 6.4.16.6. Sediment Size Analysis. Bathing Pool, Speedwell Cavern.

Sample Numbers CP 1–3

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	79 — 84
	Sandstone	0 — 0·5
	Feldspar	3 — 5
	Mica	5 — 8
	Shale	0 — 2
	Quartzite	
	Balance (mainly clay)	14 — 18

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	46 — 51
Kaolinite	37 — 49
Chlorite	8 — 11
Mixed layer smectites	5 — 7

Figure 6.4.16.7. Summary of sediment composition, Cliff Cavern Passage, Speedwell Cavern.

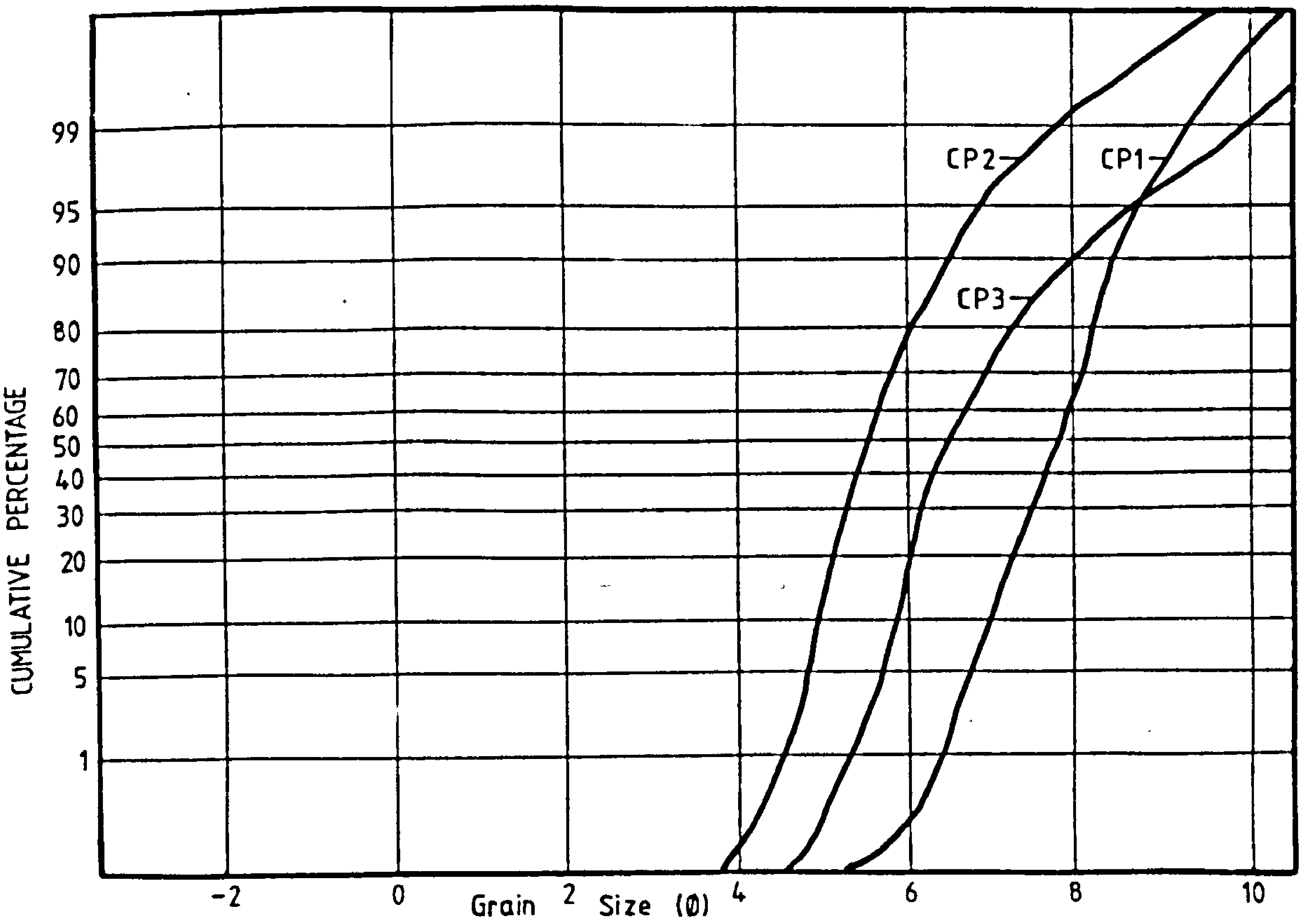


Figure 6.4.16.8. Sediment Size Analysis. Cliff Cavern Passage Speedwell Cavern.

the chamber is filled with a silty - gravel.

The composition of the sediment is given in figure 6.4.16.9.. Size analysis shows that the sediment is a poorly sorted, fine - skewed, platykurtic silty - pebbly - gravel (fig. 6.4.16.10.). The results of S.E.M. study of quartz grain surface textures shows that, at least the fine fraction, is probably of fluvio - glacial origin (fig. 6.4.16.4., P1 and 3). The unbedded character of the deposit, very similar to one in Giant's Hole (described below in section 6.4.18.) may be the result of slumping or solifluction flow of a surface deposit into a pothole to this point approximately 50 metres below ground level. The composition of the deposit indicates that it has been derived from the local Namurian strata.

Lower down the system in Mud Hall (fig. 6.4.16.1., P4) a fine - grained sediment covers all surfaces. The composition is given in figure 6.4.16.11.. Size analysis shows that the sediment is a moderately sorted, fine - skewed mesokurtic silt (fig. 6.4.16.12.). The results of S.E.M. study of quartz grain surface textures shows that the silt is of fluvial origin (fig. 6.4.16.4., P1).

Throughout the active streamways of the cave system a number of mineral veins are exposed. Downstream from these exposures pebbles of baryte, calcite and galena occur as gravel in stream floor potholes. At three localities, in the main stream passage, Bung Hole series and the Bottomless Pit boulder chokes occur associated with mineral veins. The resulting deposit is a limestone, baryte, calcite and galena breccia also, in

Sample Numbers P 2-4

		%
1	Limestone	13 — 19
	Dolomite	
	Volcanics	
	Chert	1 — 5
	Silicified fossils	
	Authigenic quartz	
	Galena	1 — 4
	Fluorite	3 — 7
	Baryte	4 — 9
	Calcite	1 — 3
2	Quartz	36 — 49
	Sandstone	16 — 25
	Feldspar	2 — 3
	Mica	3 — 7
	Shale	5 — 12
	Quartzite	
	Balance (mainly clay)	6 — 17

1 Autochthonous 2 Allochthonous

Figure 6.4.16.9. Summary of sediment composition, Watricle Cavern, Speedwell Cavern.

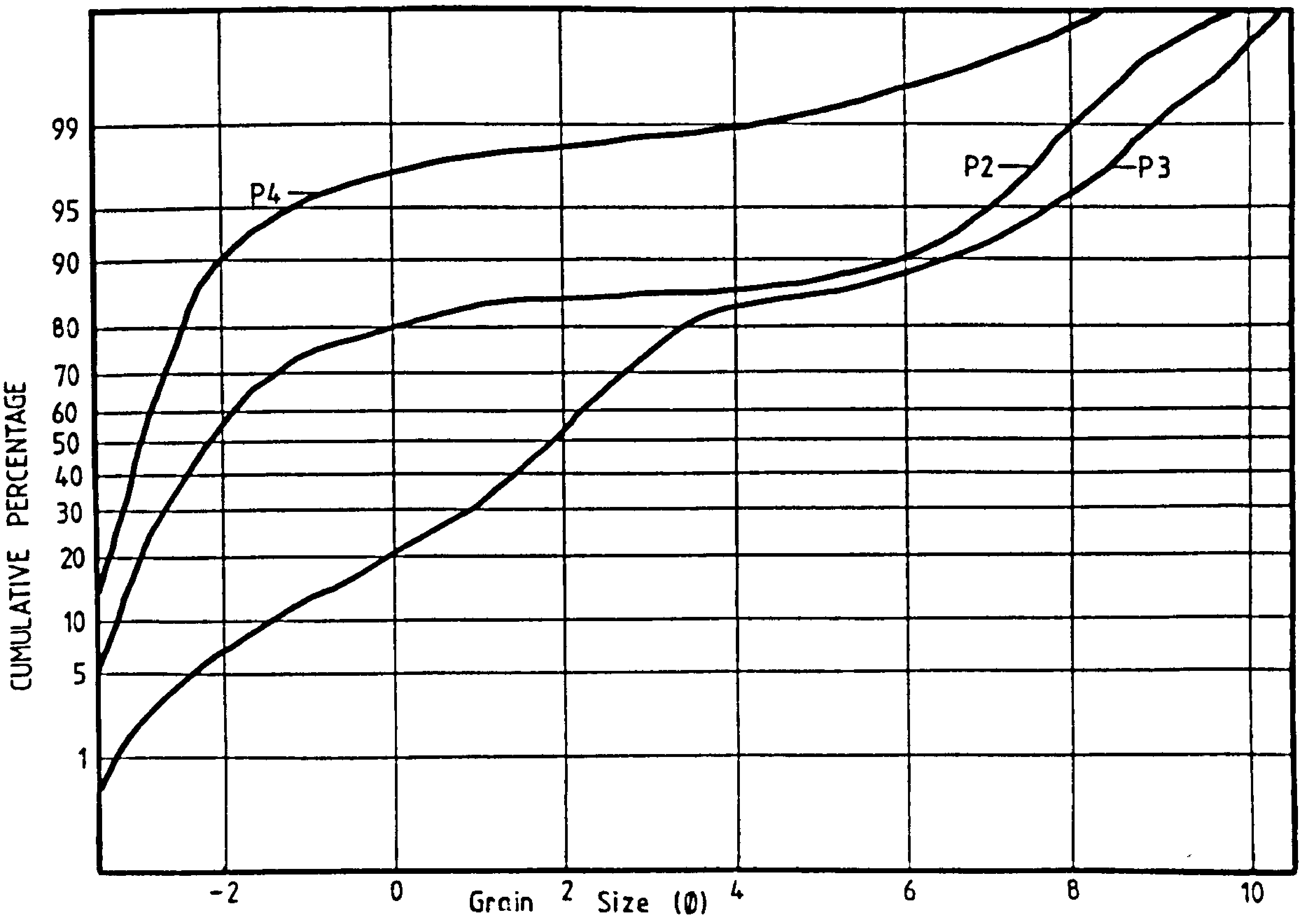


Figure 6.4.16.10. Sediment Size Analysis. Watricle Cavern, Speedwell Cavern.

Sample Number P1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	76
	Sandstone	2
	Feldspar	3
	Mica	7
	Shale	1
	Quartzite	
	Balance (mainly clay)	11
1 Autochthonous 2 Allochthonous		

Figure 6.4.16.11. Summary of sediment composition, Mud Hall, Speedwell Cavern.

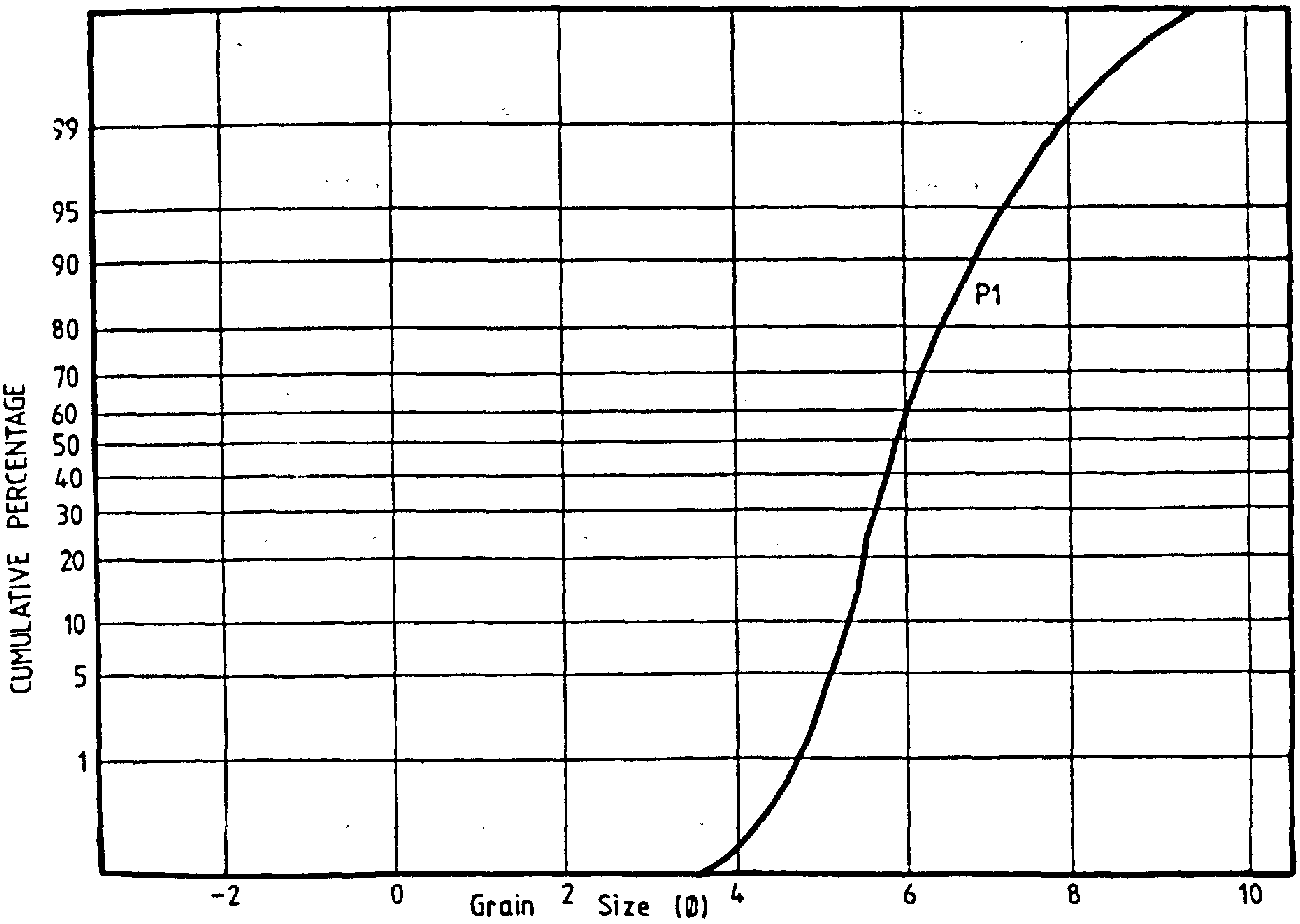


Figure 6.4.16.12. Sediment Size Analysis. Mud Hall, Speedwell Cavern.

the case of the Bung Hole series deposit, containing stalagmite blocks. Both these types of accumulation were worked or investigated by the lead miners.

6.4.17. Jackpot

This "swallet" cave, also known as P8, is situated at SK 108,818. The stream in the cave has been dye - tested to Speedwell Cavern and then to Russet Well (Christopher, 1981). The cave system has been described by Westlake and Cobbett (1972) and its evolution discussed by Smith and Waltham (1973). For its size the cave is a very complex system (fig. 6.4.17.1.) of active and abandoned cave passages taking water from a number of streams draining Rushup Edge.

The cave is developed in reef limestones of Asbian age which are cut by a number of small scrins.

A number of sediment accumulations occur throughout the cave, all of which are similar. Their overall composition is given in figure 6.4.17.2. which shows that they were derived from Namurian sediments. Size analysis shows that the sediments are moderately sorted, slightly coarse - skewed, mesokurtic sands (fig. 6.4.17.3.). The results of S.E.M. study of quartz grain surface textures shows that the sediments are of fluvial origin (fig. 6.4.17.4. and plate 6.4.17.1.). The angular character of some of the grains is typical of those in the Namurian source rocks which have undergone weathering (Wilson, 1978).

In the Old Man's Rift some of the sand deposits have

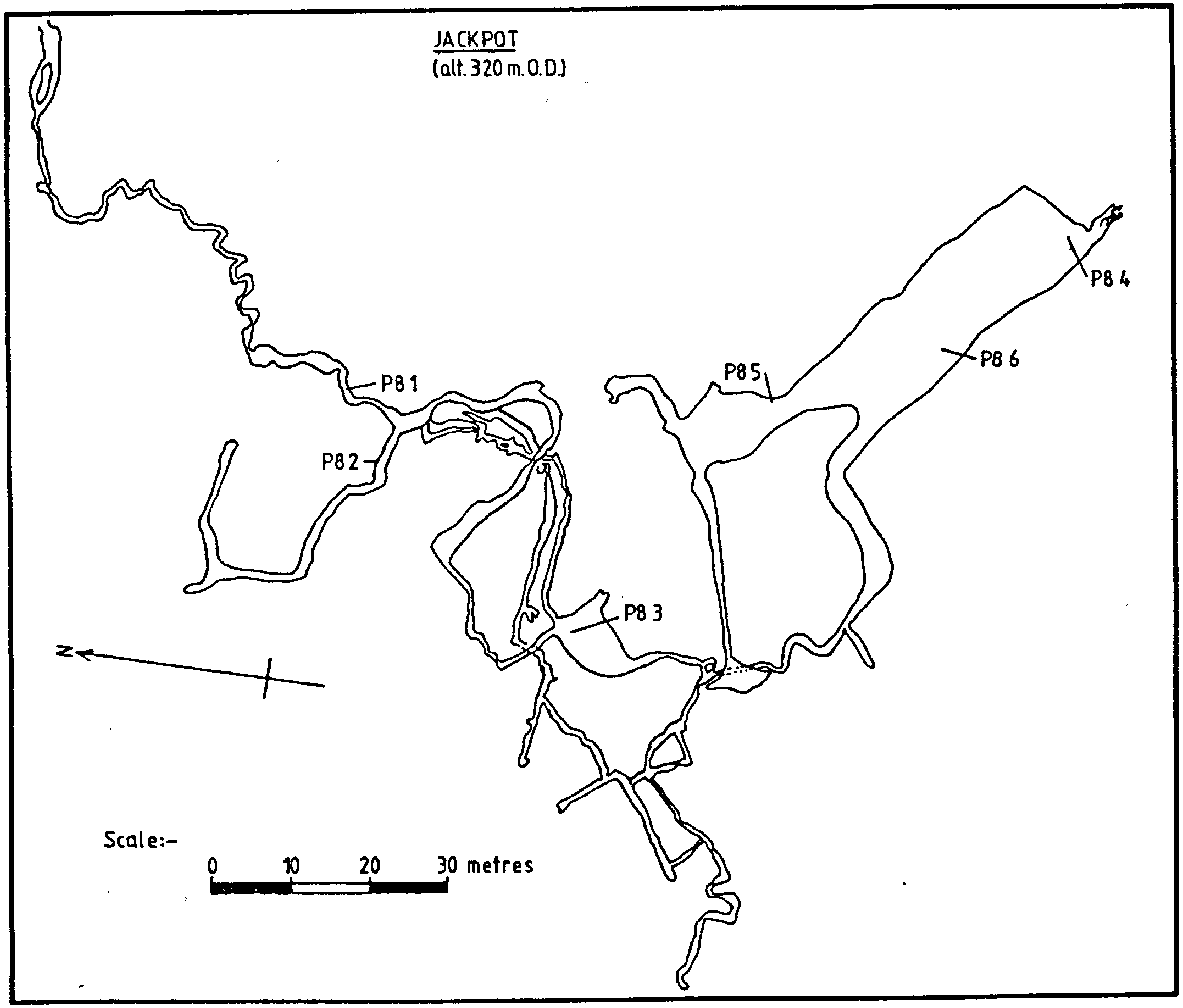


Figure 6.4.17.1. Plan of Jackpot showing sample locations. After Smith and Waltham (1973)

Sample Numbers P8 1–6

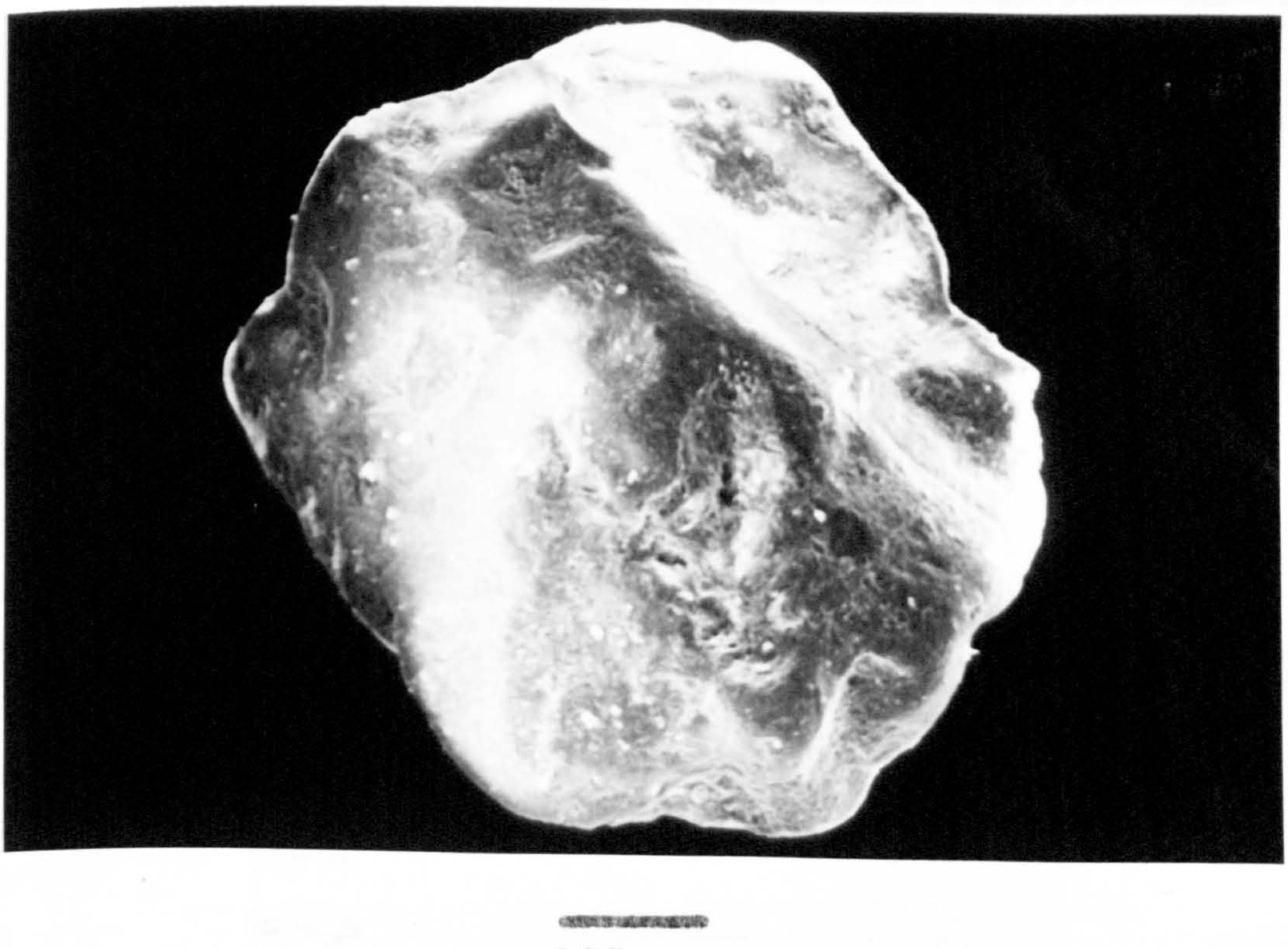
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0 – 1·5
	Baryte	0 – 0·5
	Calcite	
2	Quartz	74 – 79
	Sandstone	3 – 7
	Feldspar	1 – 3
	Mica	6 – 9
	Shale	5 – 12
	Quartzite	
	Balance (mainly clay)	4 – 7

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	65 – 71
Kaolinite	27 – 29
Chlorite	4 – 9
Mixed layer smectites	22 – 4

Figure 6.4.17.2. Summary of sediment composition, Jackpot.



6.4.17.1. S.E.M. photomicrograph of a fluvially reworked Namurian sandstone quartz grain, Jackpot (P8). Note rounding of grain outline.

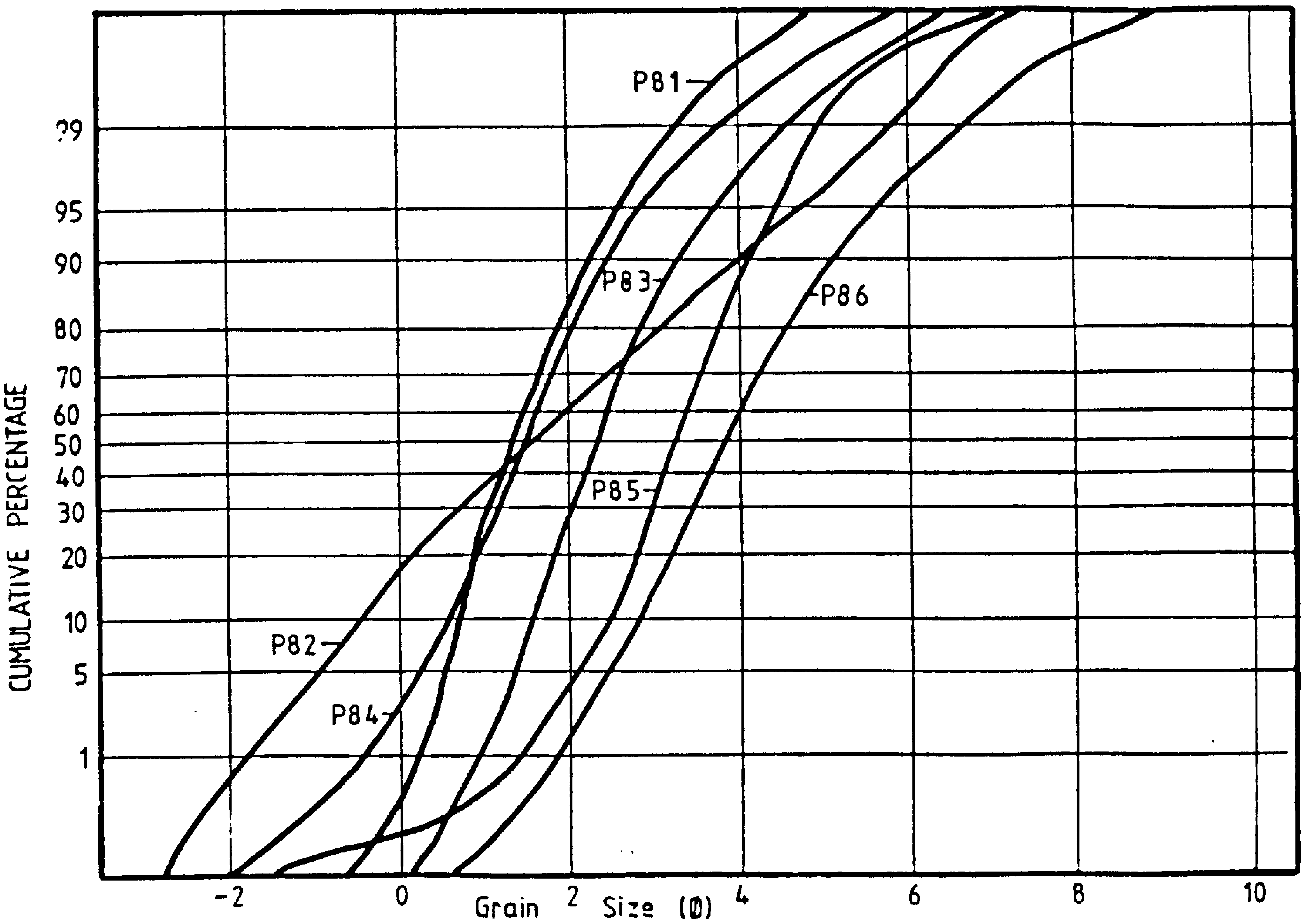


Figure 6.4.17.3. Sediment Size Analysis. Jackpot.

Chemical	Euhedral silica	◪	◪	◪
	Amorphous silica	●	●	●
	Solution crevasses	●	●	
	Solution pits	●	●	
	Oriented etch pits	●	●	●
Loessic	Dulled surface		●	●
	Smooth surface	●		
	Rounded	●		
	Dish-shaped pits	●		●
Fluvial	Subangular	◪	◪	◪
	Subrounded	◪	◪	◪
	Mechanical V-pits	◪	■	■
	Curved scratches	●	◪	◪
	Straight scratches	●	●	●
Glacial	Chattermarks			
	Angular	●	●	◪
	Fracture plates			
	Adhering particles			
	Imbricate grinding			
	Parallel striations			
	Conchoidals >10µ	●	●	●
	Conchoidals <10µ	●	●	
	Breakage blocks>10µ			
	Breakage blocks<10µ			
General	Euhedral quartz	●		
	Scaling	●	◪	●
	High relief	◪	◪	◪
	Medium relief	◪	◪	◪
	Low relief	◪	◪	◪
	Meandering ridges	●	●	
	Arcuate steps	●		
	Straight steps	●	●	●
	Edge abrasion	●		●
	Grain breakage	●	●	
Surface Features	Sample number P8	1	4	6

■ Abundant – 75% ◪ Common 25 - 75% ● Present 1-25% □ Absent – 1%

Figure 6.4.17.4. Summary of quartz grain surface textures, Jackpot.

been partially cemented by calcite forming a porous sandstone.

6.4.18. Giants Hole

Giants Hole is another large swallet cave system at the foot of Rushup Edge situated at SK 119,826 draining to Russet Well via Speedwell Cavern (Christopher, 1981). The system has been described by numerous authors including Atkinson (1948), Salmon (1955 and 1959) and Westlake (1967). Salmon (1965) commented on the geological control on the development of the cave and on some aspects of the sedimentary fill.

The cave system (fig. 6.4.18.1.) contains both active and abandoned passages and is developed in Bee Low lagoonal limestones containing chert bands and stylolite seams. The outer part of the cave is developed in reef complex limestones with varied bedding. A number of small baryte scrins are present in parts of the system.

Two distinctive sedimentary fills occur in the cave. In the first 350 metres of the cave a number of remnants of a pebbly fill occur (fig. 6.4.18.1., GH 5-9 and plate 6.4.18.1.).

The overall composition of this fill is given in figure 6.4.18.2.. Size analysis shows that the sediment is very poorly sorted, very coarse - skewed, platykurtic silty - pebbly - gravel (fig. 6.4.18.3.). The results of S.E.M. study of quartz grain surface textures shows that the quartz grains have not undergone any modification

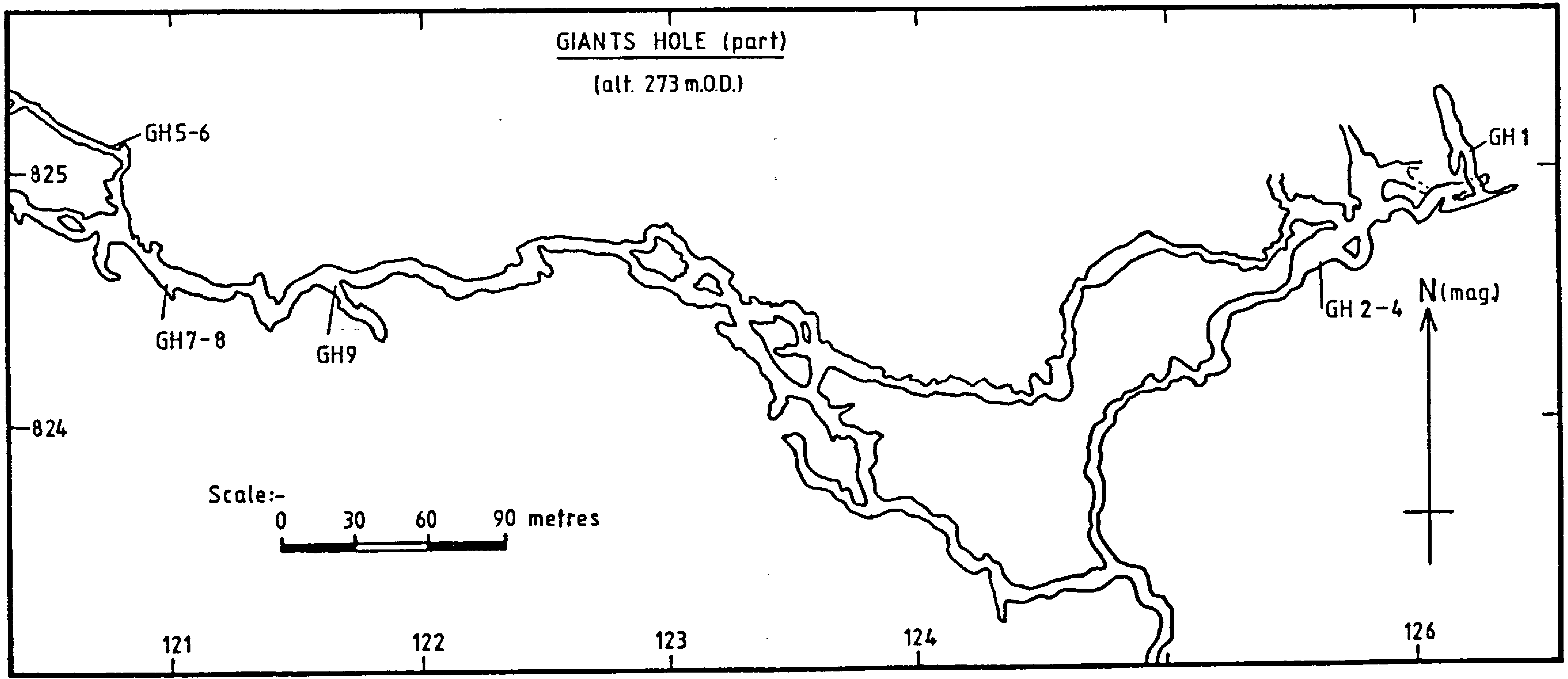
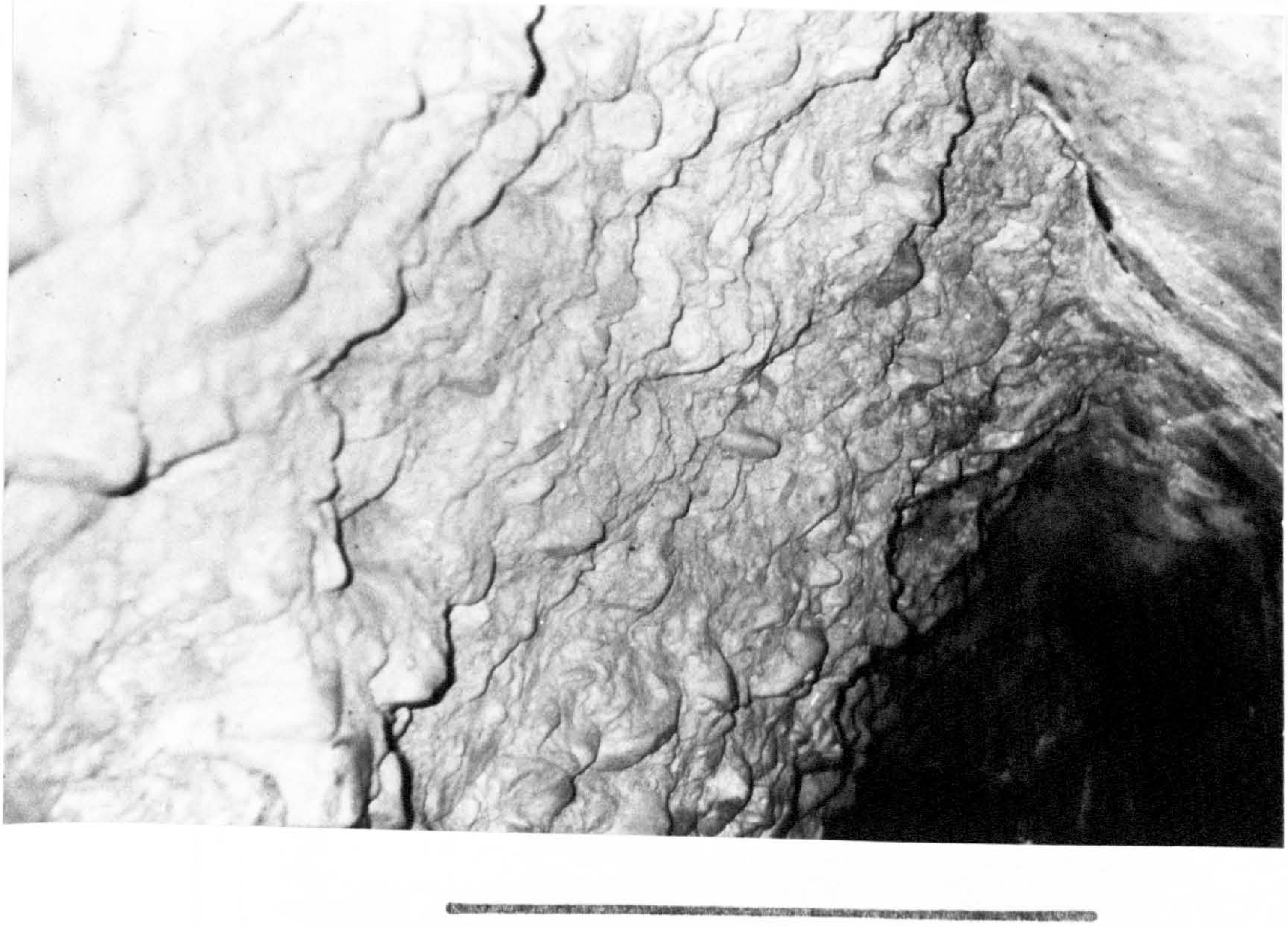
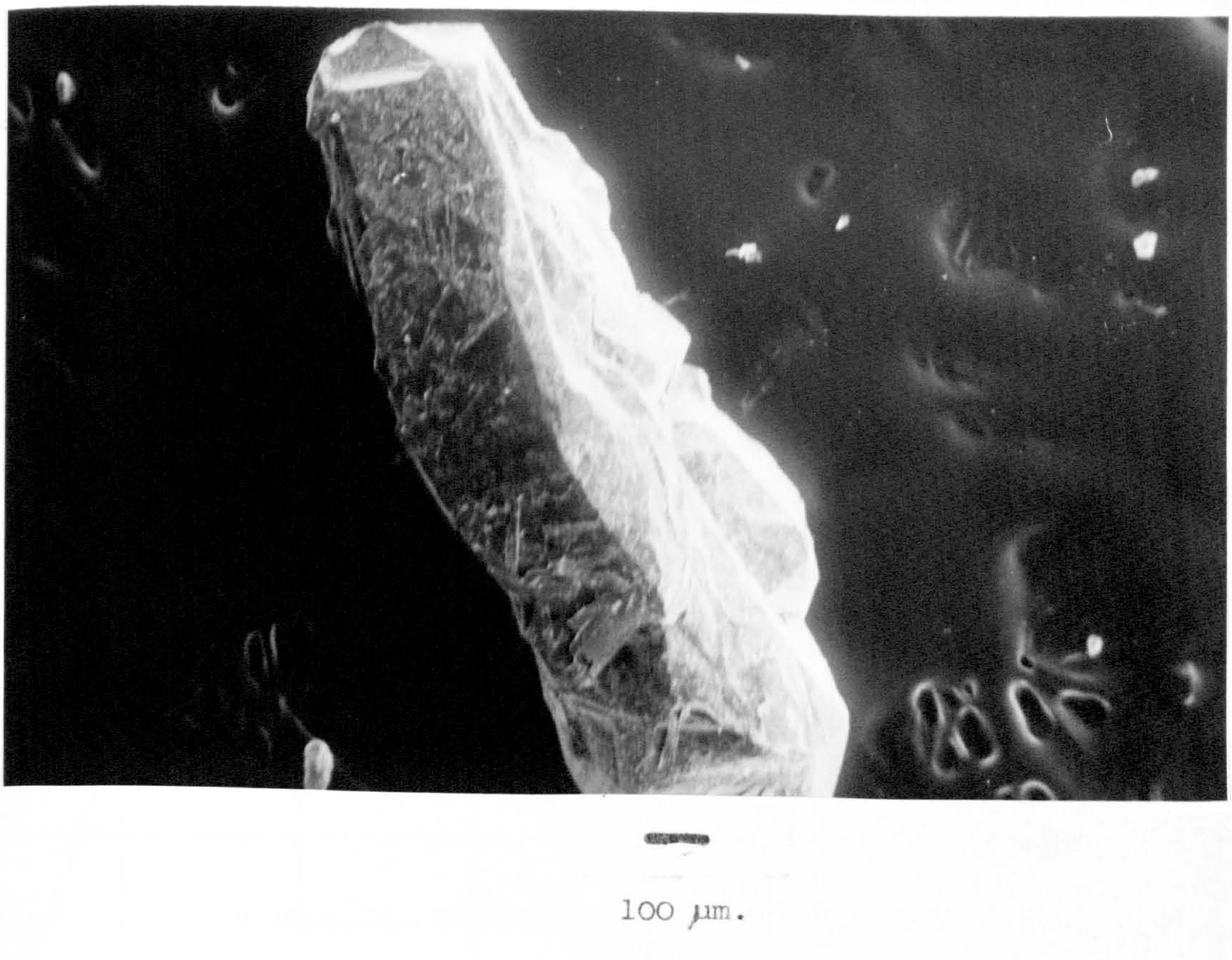


Figure 6.4.18.1. Plan of Giants Hole (part) showing sample locations. After Salmon (1959).



6.4.18.1. Solifluction deposits, Giants Hole.



6.4.18.2. Unabraded quartz grain derived from Namurian sediments, Giants Hole.

Sample Numbers GH 5 − 9		
		%
1	Limestone	10 — 17
	Dolomite	
	Volcanics	
	Chert	3 — 8
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	38 — 57
	Sandstone	14 — 29
	Feldspar	2 — 5
	Mica	6 — 11
	Shale	13 — 20
	Quartzite	
	Balance (mainly clay)	16 — 27
1 Autochthonous 2 Allochthonous		

Figure 6.4.18.2.Summary of sediment composition, Giants Hole.

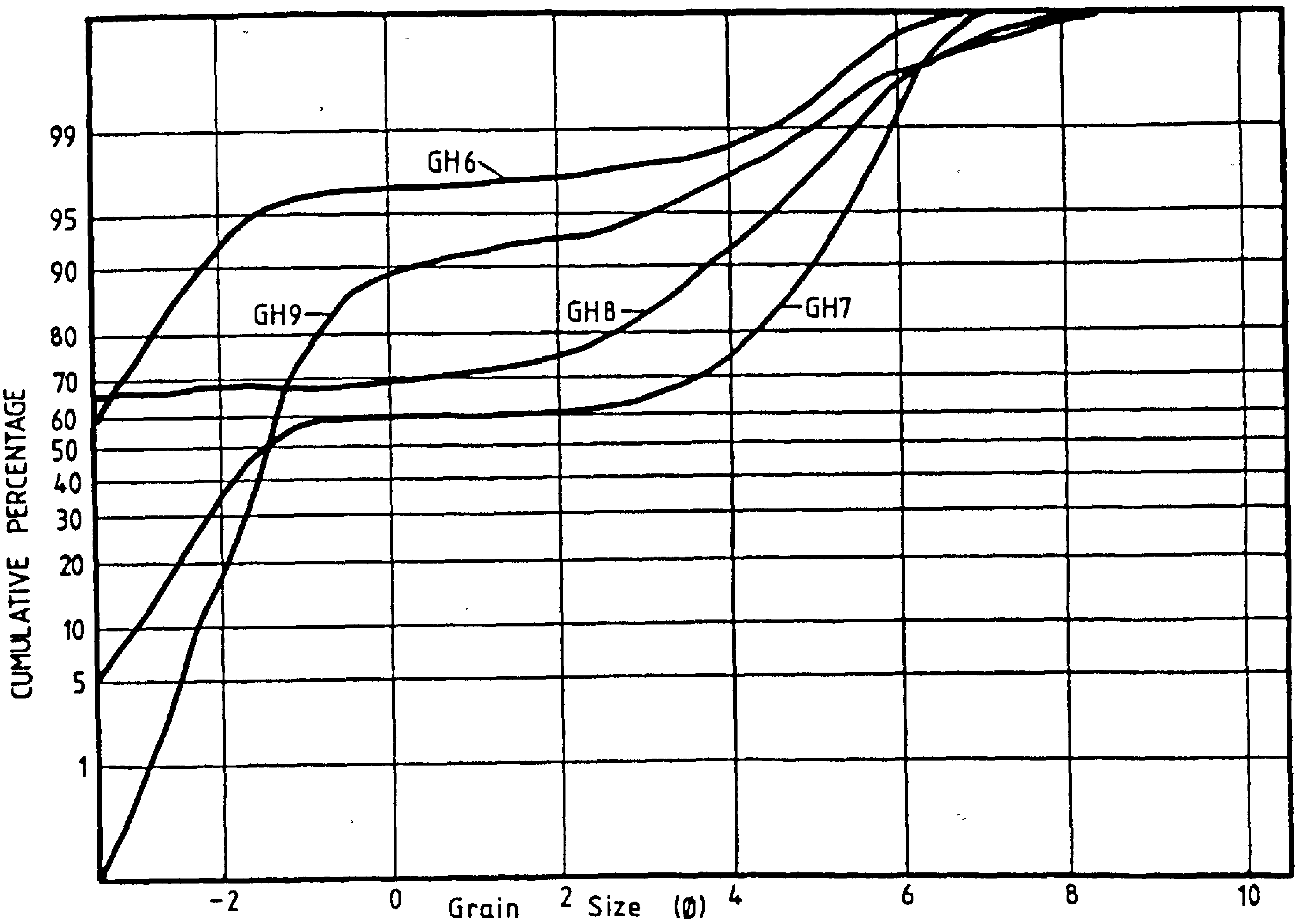


Figure 6.4.18.3. Sediment Size Analysis. Giants Hole.

when compared to examples from weathered Namurian sandstone (Wilson, 1978) (fig. 6.4.18.4., GH 6, 8-9, and plate 6.4.18.2.).

The deposits, which have been extensively re-eroded by the present stream, display no bedding and probably slumped into the cave as a mud flow by solifluction processes. This deposit is very similar to the deposit in Watricle Cavern in Speedwell Cavern.

In the Maginn's Rift area of the cave (fig. 6.4.18.1., GH 1-4) speleothem dating gives ages between 47,000 and 55,000 years B.P. (Ford et al, 1983). Sediment underlying the flowstone in this part of the cave has the composition given in figure 6.4.18.5..

The results of S.E.M. study of quartz grain surface textures shows that the sediment is re-worked loess (fig. 6.4.18.4., GH 1,3). Size analysis shows that the sediment is moderately well sorted, slightly fine - skewed, mesokurtic clayey - silt (fig. 6.4.18.6.).

These deposits are probably derived from early Devensian surface loess deposits and some were coated with flowstone during the mid - Devensian Interstadial (45,000 to 75,000 years B.P.).

6.4.19. Maskill Mine

The shaft into Maskill Mine is at SK 123,823. The shaft is sunk in Oxlow Rake which here consists of a solutionally enlarged vein and enters a natural cave developed on the rake (Salmon and Baldock, 1951).

At the bottom of the shaft a gravelly sediment

Sample Numbers GH1-4		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	71 — 84
	Sandstone	
	Feldspar	1 — 3
	Mica	1 — 2
	Shale	
	Quartzite	
	Balance (mainly clay)	14 — 26

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	67 — 73
Kaolinite	24 — 31
Chlorite	2 — 7
Mixed layer smectites	1 — 3

Figure 6.4.18.5. Summary of sediment composition, Maginn's Rift, Giants Hole.

Surface Features								
Chemical	Euhedral silica	◢	■	◢		●	●	●
	Amorphous silica	●	●	●		●		
	Solution crevasses					●		
	Solution pits	●	●	●		●	◢	◢
	Oriented etch pits	◢	●	◢		●	●	●
Loessic	Dulled surface	●				◢	●	●
	Smooth surface	●	●			●	◢	●
	Rounded	●	●	●		◢	■	◢
	Dish-shaped pits					◢	■	■
Fluvial	Subangular	◢	◢	◢		●		
	Subrounded	◢	◢	◢		◢	●	●
	Mechanical V-pits	●	●	●		●		
	Curved scratches	●		●				
	Straight scratches	●	●				●	
Glacial	Chattermarks							
	Angular	◢	●	●				
	Fracture plates		●	◢				
	Adhering particles							
	Imbricate grinding							
	Parallel striations	●						
	Conchoidals >10µ	●	◢	●			●	●
	Conchoidals <10µ	●	●	●		●	●	
	Breakage blocks>10µ							
	Breakage blocks<10µ							
General	Euhedral quartz	●	●			●	●	●
	Scaling	◢	●	●		◢	●	◢
	High relief	●	◢	◢		●	●	
	Medium relief	●	◢	◢		◢	◢	●
	Low relief	■	◢	◢		◢	◢	■
	Meandering ridges	●	●	●			●	
	Arcuate steps	●	●			●		●
	Straight steps	●	●	●		●	●	●
	Edge abrasion	●				●	●	●
	Grain breakage	●	●			●		●
	Sample number GH	6	8	9		1	3	4

■ Abundant — 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent — 1%

Figure 6.4.18.4. Summary of quartz grain surface textures, Giants Hole.

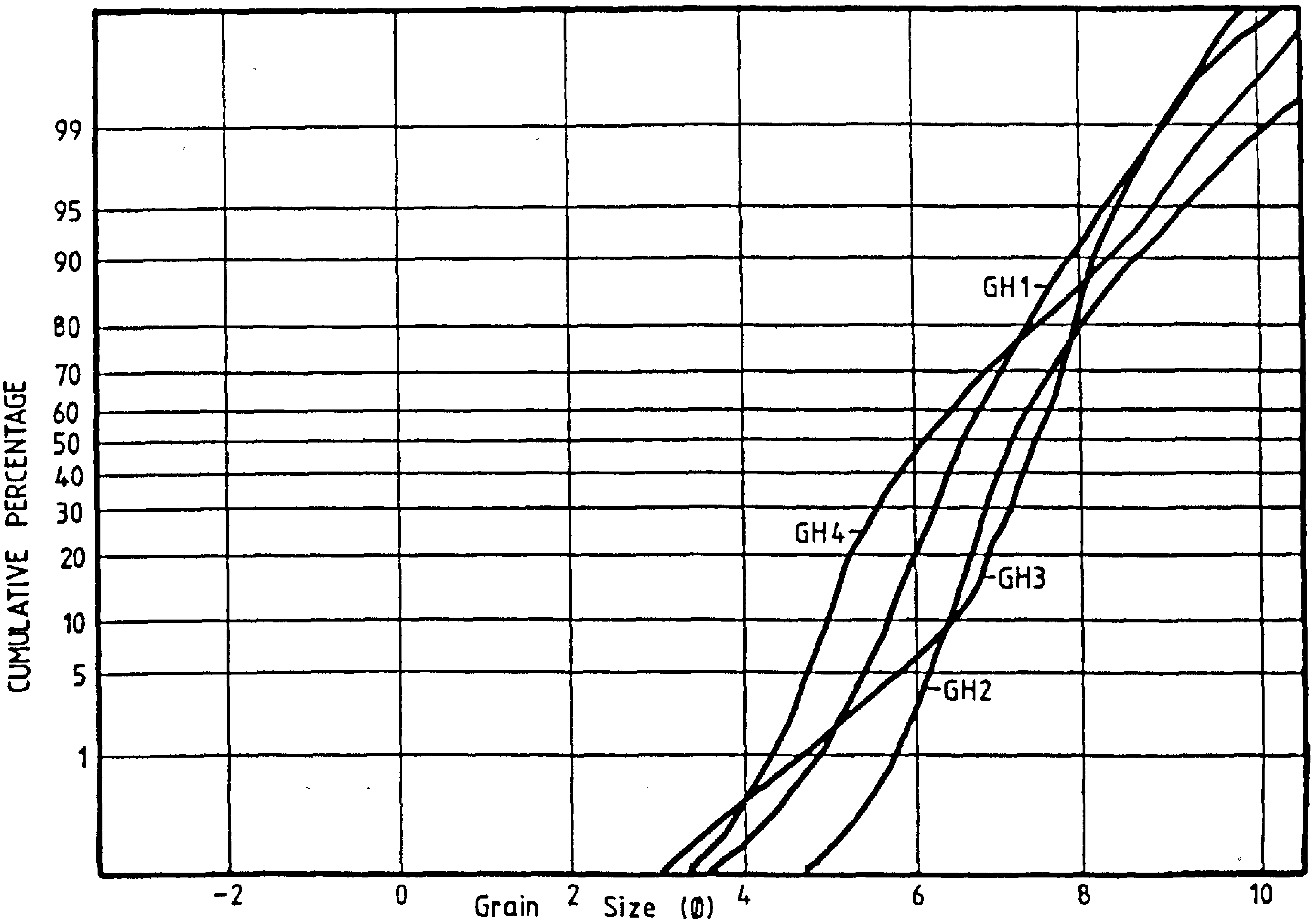


Figure 6.4.18.6. Sediment Size Analysis. Maginns Rift, Giants Hole.

Sample Numbers MK 1-2		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0 — 1
	Silicified fossils	
	Authigenic quartz	
	Galena	2 — 7
	Fluorite	1 — 3
	Baryte	4 — 16
	Calcite	3 — 4
2	Quartz	64 — 71
	Sandstone	
	Feldspar	
	Mica	0 — 1
	Shale	
	Quartzite	
	Balance (mainly clay)	11 — 23
1 Autochthonous 2 Allochthonous		

Figure 6.4.19.1. Summary of sediment composition, Maskill Mine.

occupies the rake, the overall composition of which is given in figure 6.4.19.1.. Size analysis shows that the sediment is a poorly sorted, coarse - skewed, platykurtic gravelly - silt (fig. 6.4.19.2.). The results of S.E.M. study of quartz grain surface textures shows that the fine fraction is re-worked loessic silt (fig. 6.4.19.3.).

The coarse fraction consists of angular calcite, baryte and galena clasts derived from Oxlow Rake.

6.4.20. Portway "Gravel" Pit

The pit is situated at SK 127,812 on the line of Old Wham Vein (fig. 6.4.20.1.) and has been described by Shaw (1983a). The occurrence of residual baryte in the form of concretionary and radiating masses in a brown clay at or close to this locality was noted by Dines (1945).

Unaltered limestone is not exposed in the pit itself but an old quarry about 100 metres to the north shows it to be a well - bedded slightly crinoidal limestone. Chert nodules are well developed. Contemporary volcanic rocks are present in the area but none have been found in the pit.

Within the pit itself the limestone has undergone intense silicification to produce a patchy "quartz rock" (Ford, 1967). Two varieties of the quartz rock are present: firstly, partially silicified limestone containing as much as 50% acicular quartz crystals up to 0.5mm long. Secondly, the "maggot" rock which was

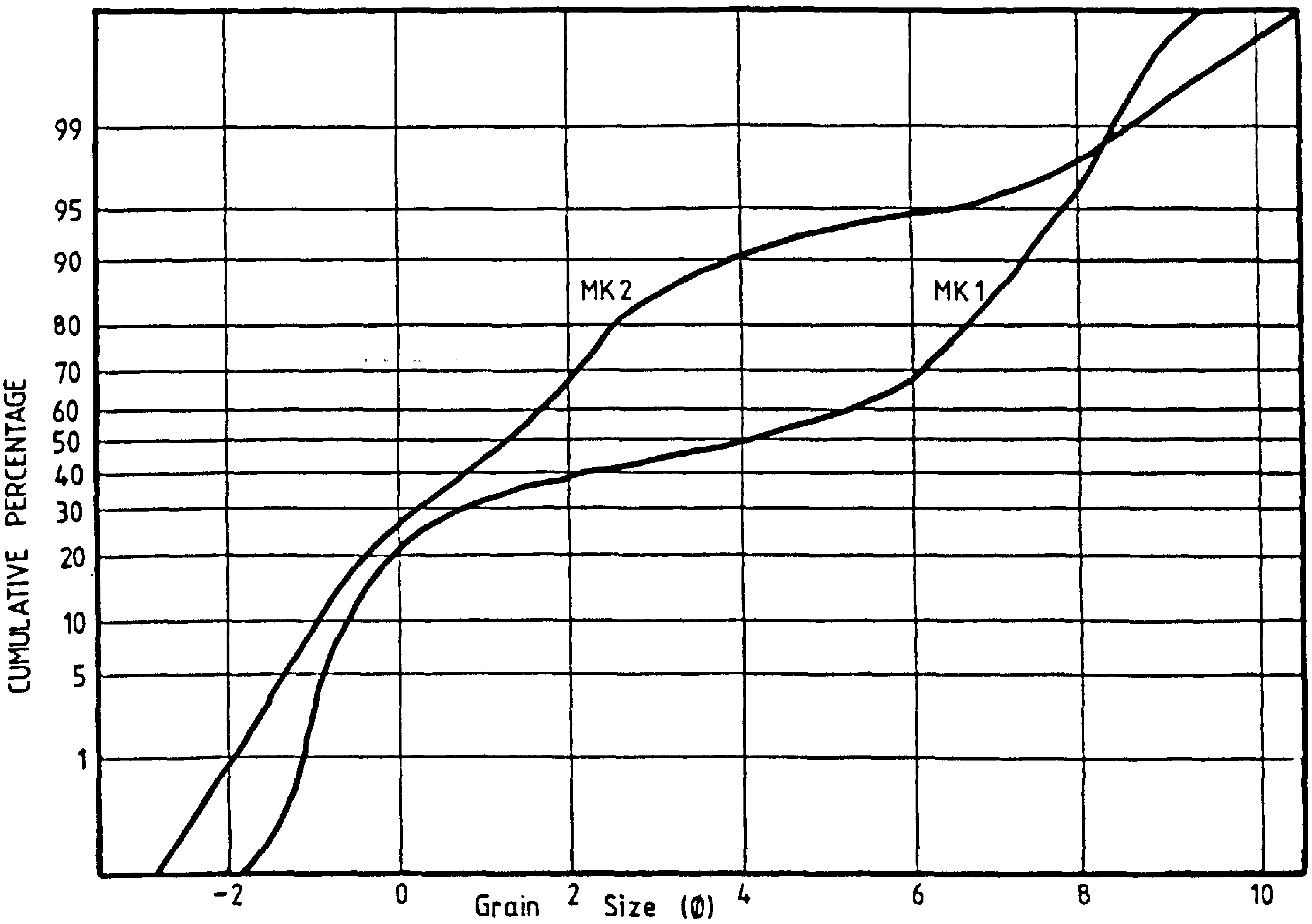
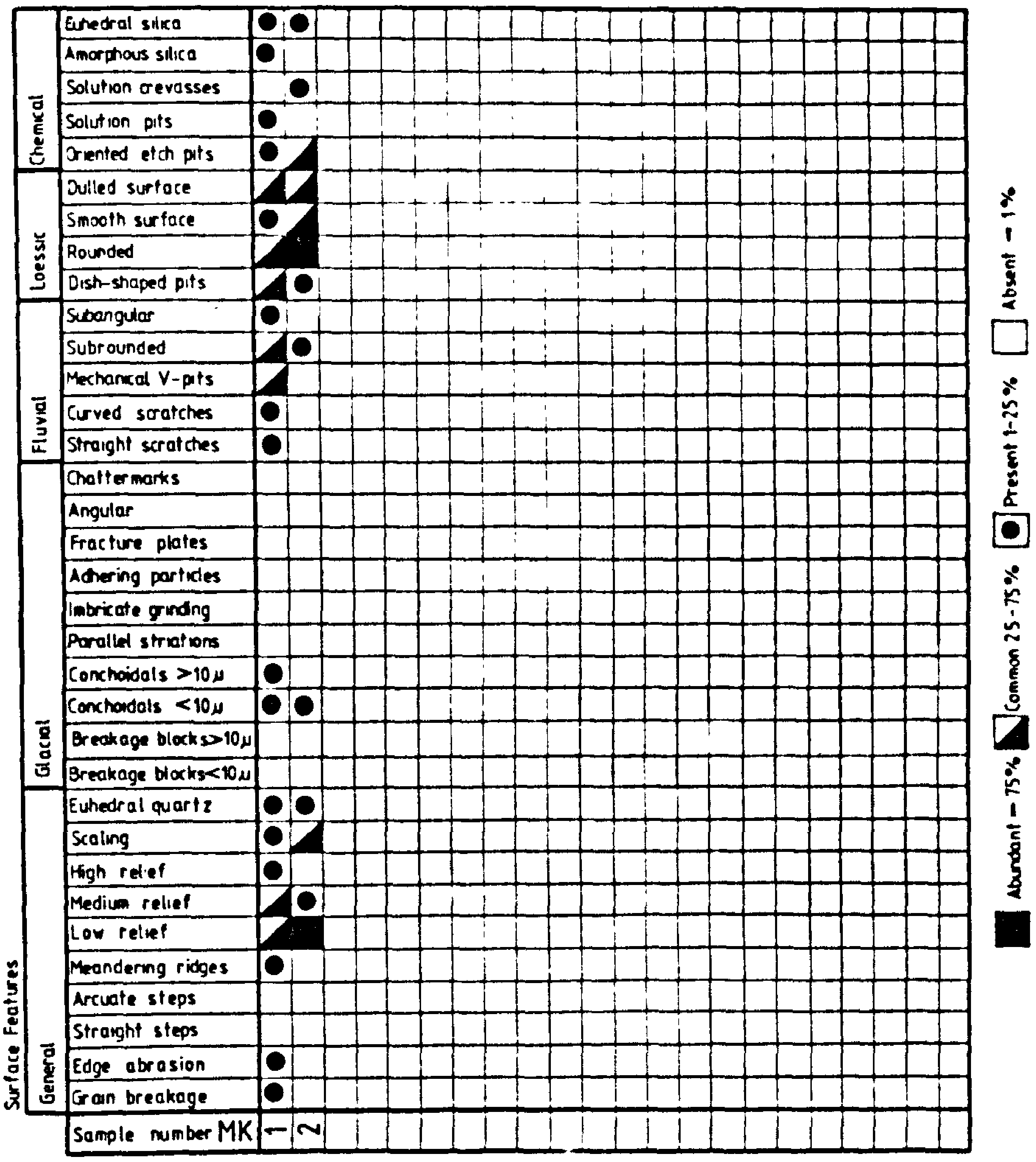


Figure 6.4.19.2. Sediment Size Analysis. Maskill Mine.



Surface Features	Chemical	Euhedral silica	●	●
		Amorphous silica	●	
		Solution crevasses		●
		Solution pits	●	
		Oriented etch pits	●	◪
	Loessic	Dulled surface	◪	◪
		Smooth surface	●	◪
		Rounded	◪	■
		Dish-shaped pits	◪	●
	Fluvial	Subangular	●	
		Subrounded	◪	●
		Mechanical V-pits	◪	
		Curved scratches	●	
		Straight scratches	●	
	Glacial	Chattermarks		
		Angular		
		Fracture plates		
		Adhering particles		
		Imbricate grinding		
		Parallel striations		
		Conchoidals >10μ	●	
		Conchoidals <10μ	●	●
		Breakage blocks>10μ		
		Breakage blocks<10μ		
	General	Euhedral quartz	●	●
		Scaling	●	◪
		High relief	●	
		Medium relief	◪	●
		Low relief	◪	■
		Meandering ridges	●	
		Arcuate steps		
		Straight steps		
		Edge abrasion	●	
		Grain breakage	●	
		Sample number MK	1	2

■ Abundant – 75%
◪ Common 25-75%
● Present 1-25%
□ Absent – 1%

Figure 6.4.19.3. Summary of quartz grain surface textures, Maskill Mine.

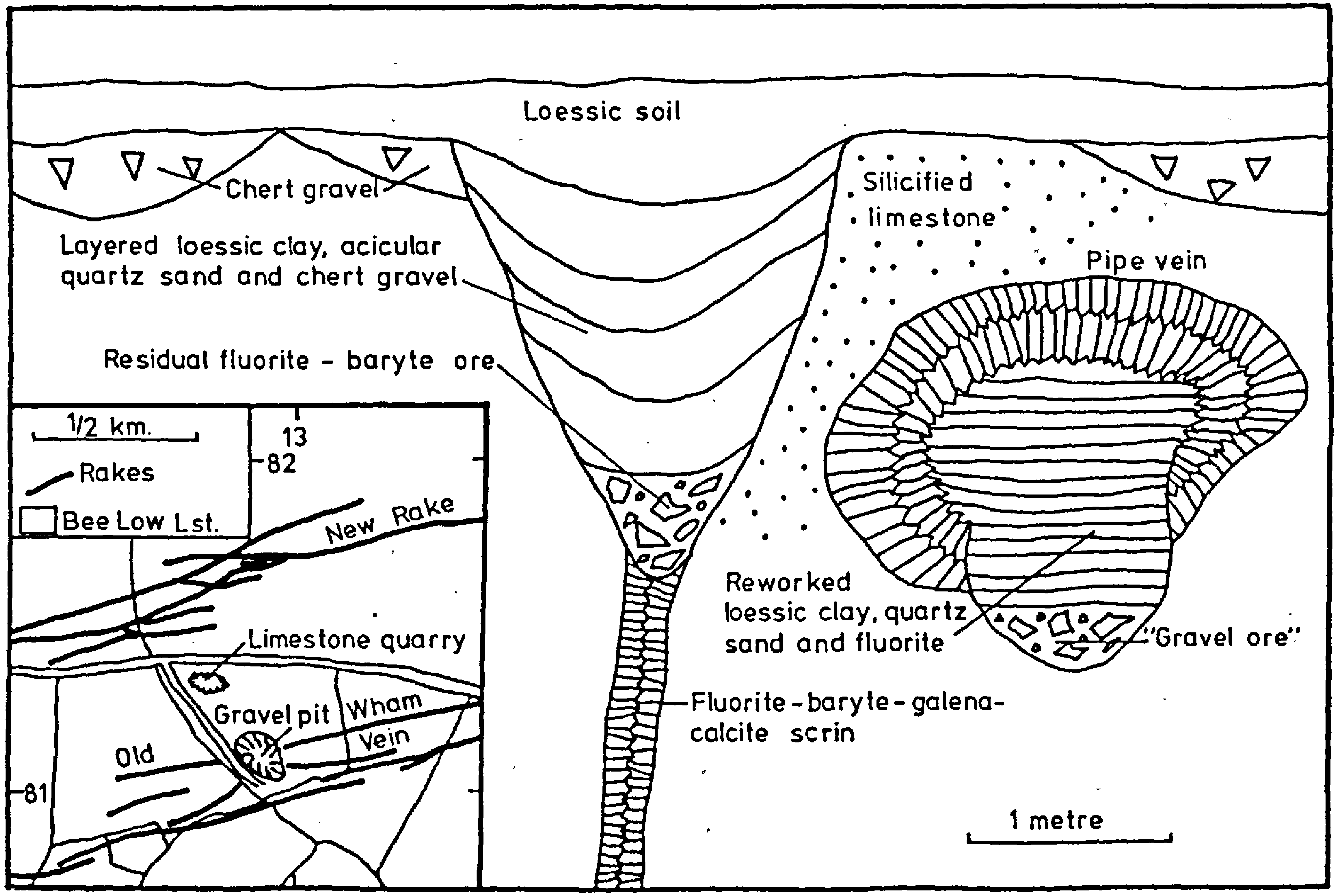


Figure 6.4.20.1. Schematic section of the residual ore deposits at Portway Mines. Loessic soil and pockets of chert gravel overlying partially silicified limestone containing a solution hollow developed on a mineral vein with a residual ore and layered sedimentary fill and a pipe vein with later solutional modification containing "gravel ore" and layered sedimentary fill.

originally a fossiliferous limestone composed mainly of compound corals. The matrix was selectively replaced by crystalline quartz but the corals were resistant and remained as calcite. Later decalcification has removed the corals leaving a porous quartz rock full of coral moulds or "maggot holes".

In parts of the pit both types of silicified limestone have been completely decalcified and disaggregated producing a white sand composed of acicular quartz needles which form from 10 to 100 percent of the sediments in the solutional cavities. Despite the abundance of acicular quartz grains at this locality they are almost absent in all of the other deposits studied in the area including the Peak Cavern and Speedwell Cavern cave systems which take the underground drainage from this area. At the margins of the silicified area unaltered limestone has silicified joints, in places decalcified to yield quartz crystal "sand" veneer. The quartz replacement of the limestone is generally thought to be associated with epigenetic mineral fluids having attacked basaltic rocks lower in the stratigraphic sequence thereby extracting silica. At this locality silicification was apparently complete before the deposition of any epigenetic minerals.

The pit is on the line of Old Wham Vein which can be traced across the fields east and west of the pit by the lines of old workings but it is not evident in the present pit walls where mineralization is present as a series of pipes, veins and mineralized joints. The pipe veins are solution cavities up to 3m in diameter, lined with baryte, fluorite, a little galena and late calcite, often as corroded scalenohedra. Remaining voids in the pipes are filled to varying extent with laminated clays and silts. The pit is worked for numerous baryte nodules present in both the epigenetic and residual fractions.

The overburden consists of a residual chert gravel, containing blocks and lenses of derived baryte and fluorite, overlain by up to 0.5m of light brown loessic subsoil.

Karstification at this locality consists of enlargement of pre-existing pipe vein cavities and of the formation of solution pipes from the surface (figs. 6.4.20.2., 6.4.20.3. and 6.4.20.4.). The solution pipes are filled with surface derived sediment, the composition of which is given by figure 6.4.20.5.. Size analysis shows that the sediments vary from well sorted, leptokurtic authigenic quartz sands to poorly sorted, coarse - skewed, platykurtic gravelly - silts (fig. 6.4.20.6.).

The results of S.E.M. study of quartz grain surface textures show that the quartz fraction is derived both from the acicular quartz needles (plate 6.4.20.1.) and from loess deposits (fig. 6.4.20.7. and plate 6.4.20.2.).

Collapse structures and mixing caused by slumping as the limestone is dissolved away are evident. Patches of laminated clay have been caught up in the collapses indicating that the process is still in operation.

In both pipe veins and solution collapse structures the "ore" fraction consists of residual lumps of

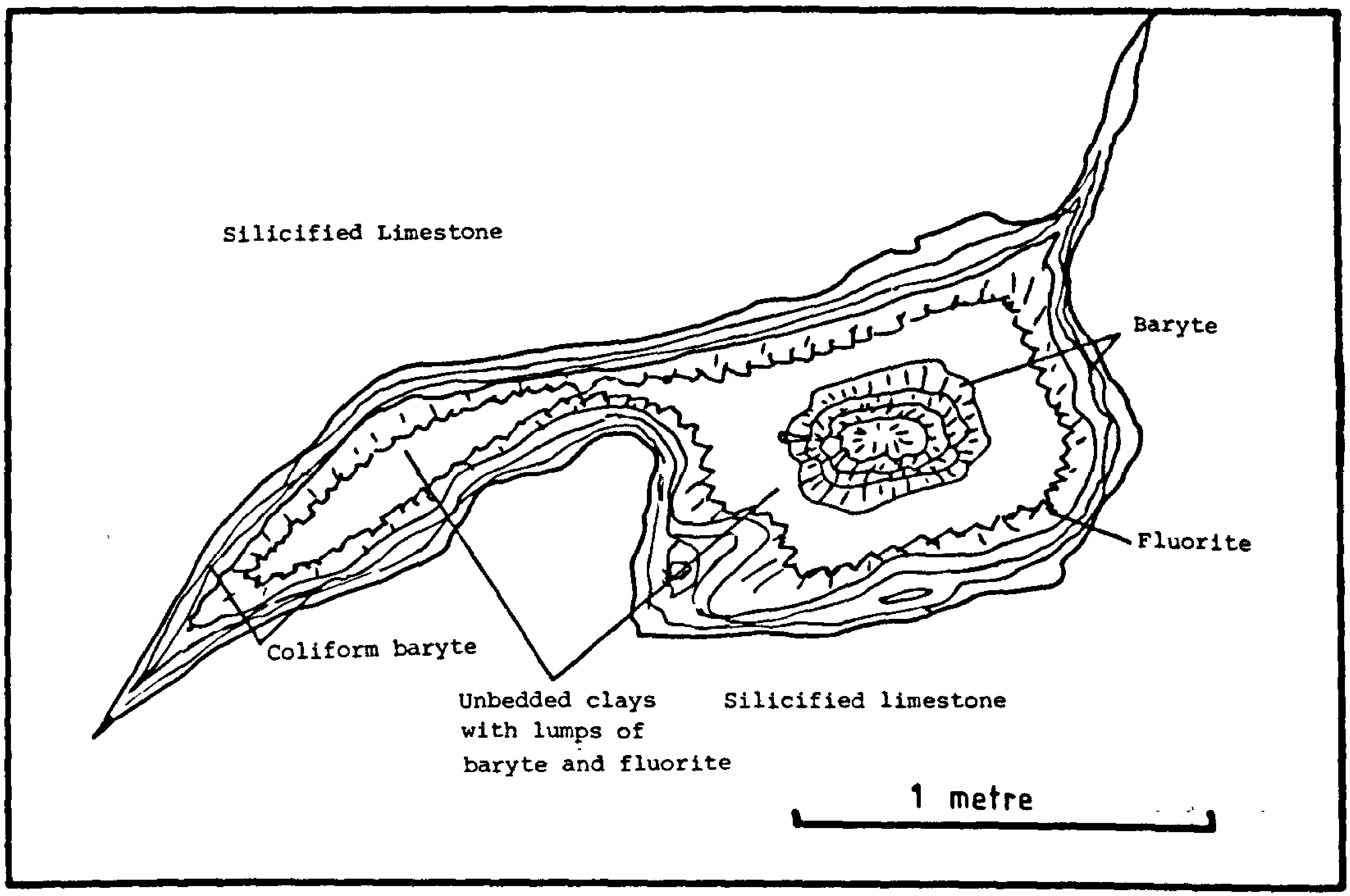


Figure 6.4.20.2. Pipe vein, Portway Pit.

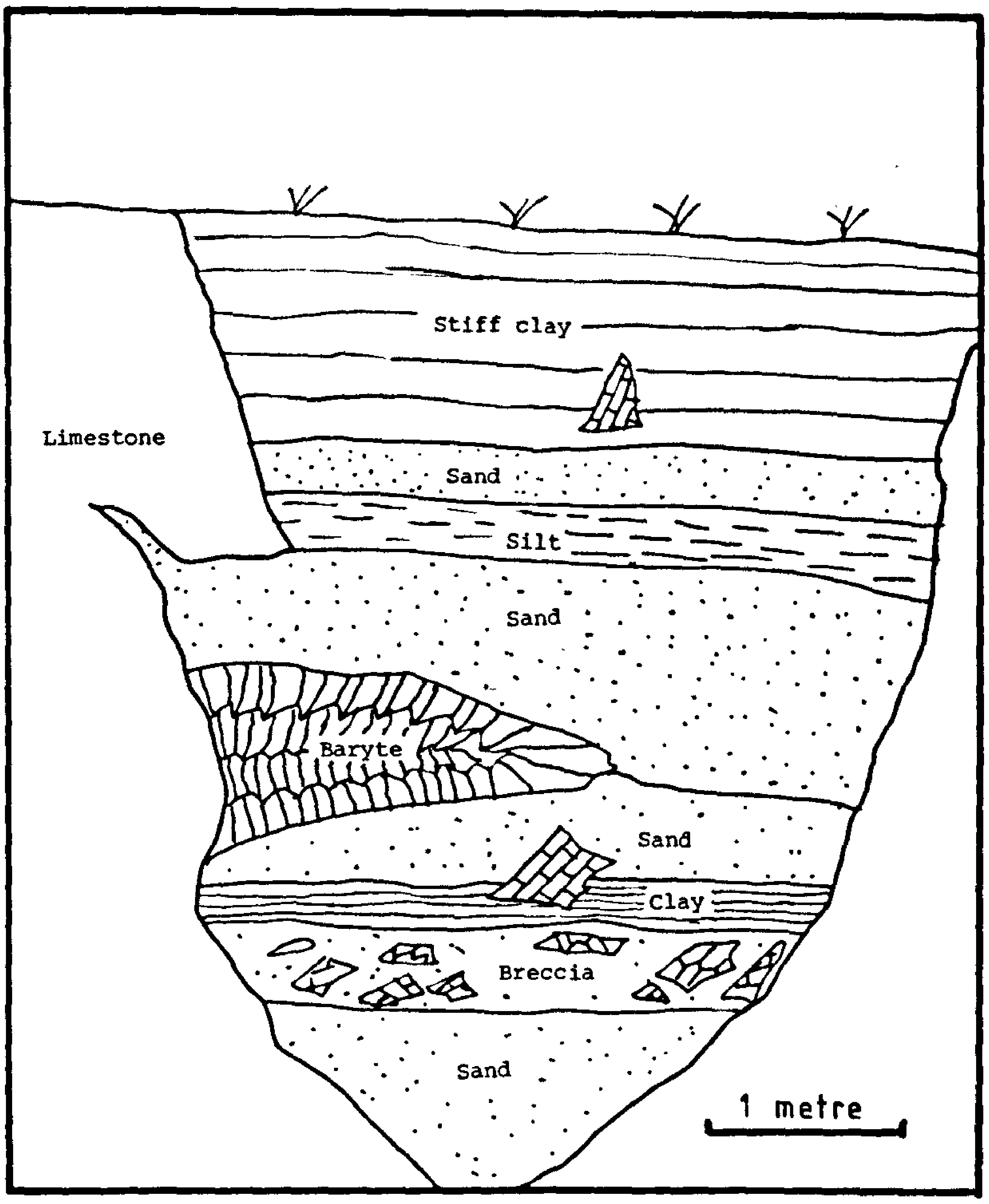


Figure 6.4.20.3. Sediment filled solution hollow, Portway Pit.

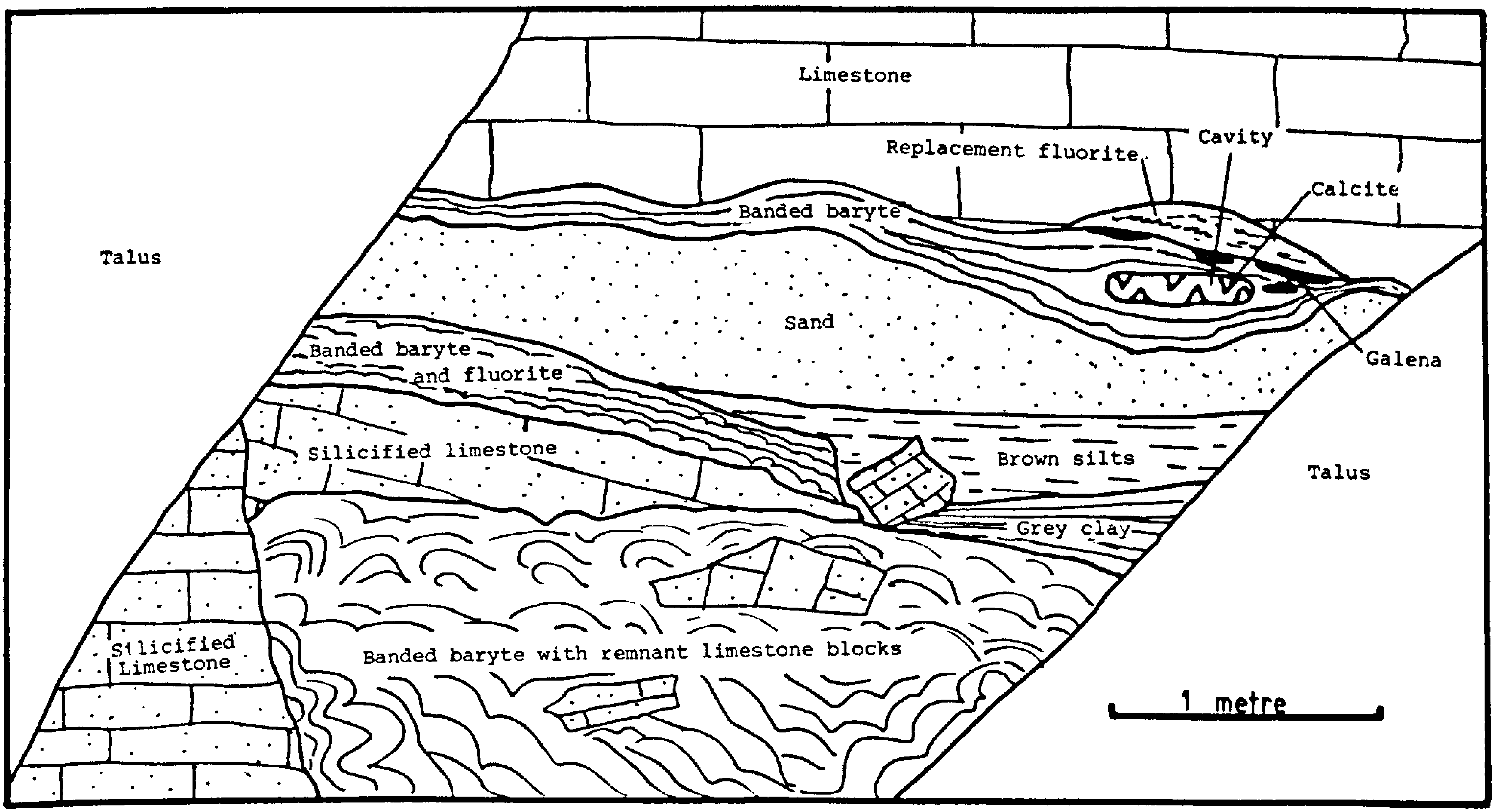


Figure 6.4.20.4. Pipe vein, Portway Pit.

Sample Numbers GP 1-2, DR 1-12		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0 — 50
	Silicified fossils	0 — 15
	Authigenic quartz	10 — 100
	Galena	0 — 2
	Fluorite	0 — 5
	Baryte	0 — 30
	Calcite	0 — 6
2	Quartz	0 — 67
	Sandstone	
	Feldspar	0 — 1
	Mica	0 — 3
	Shale	
	Quartzite	
	Balance (mainly clay)	0 — 36

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	67 — 81
Kaolinite	17 — 26
Chlorite	1 — 3
Mixed layer smectites	2 — 5

Figure 6.4.20.5. Summary of sediment composition, Portway Pit.

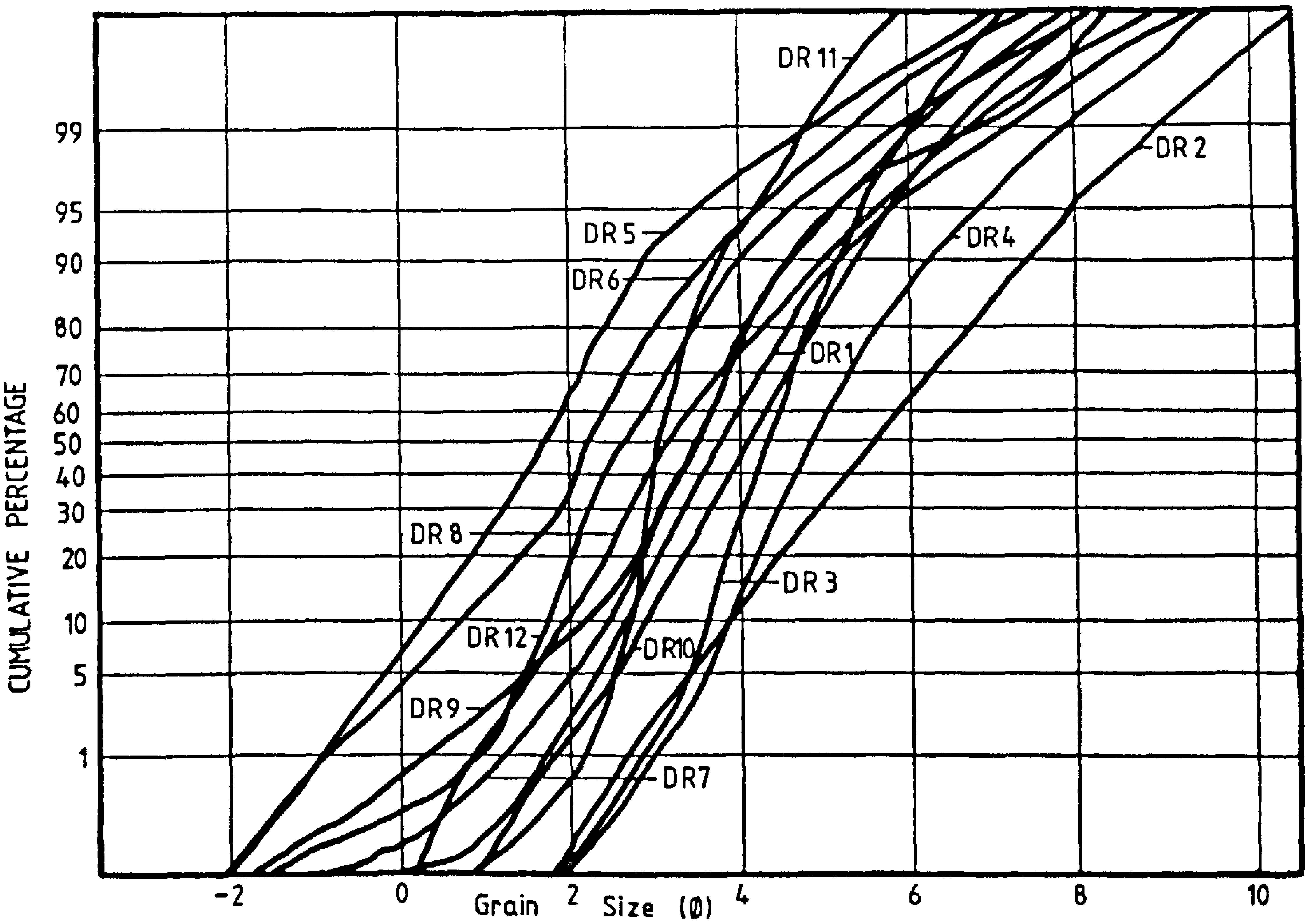
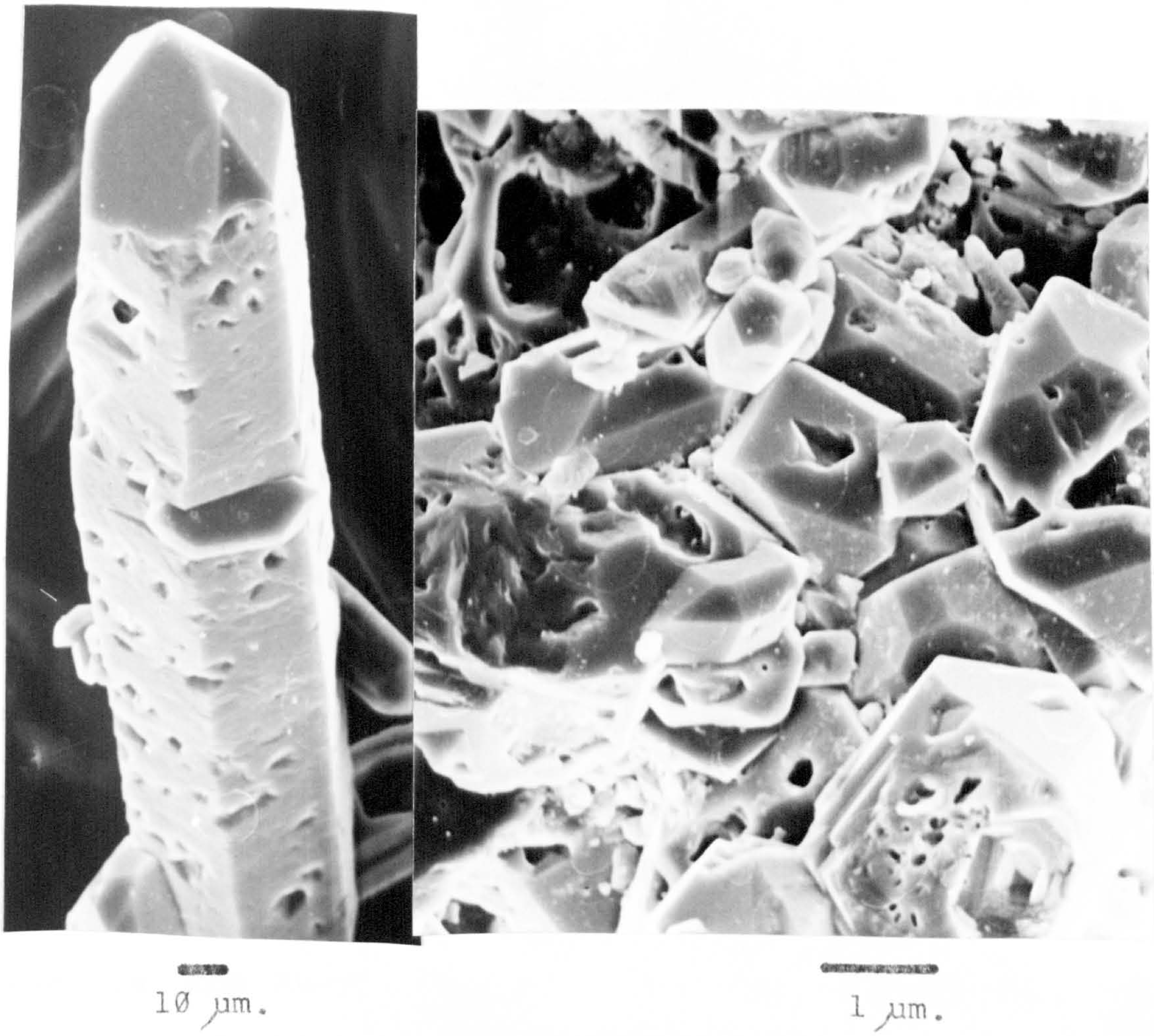


Figure 6.4.20.6. Sediment Size Analysis. Portway Pit.

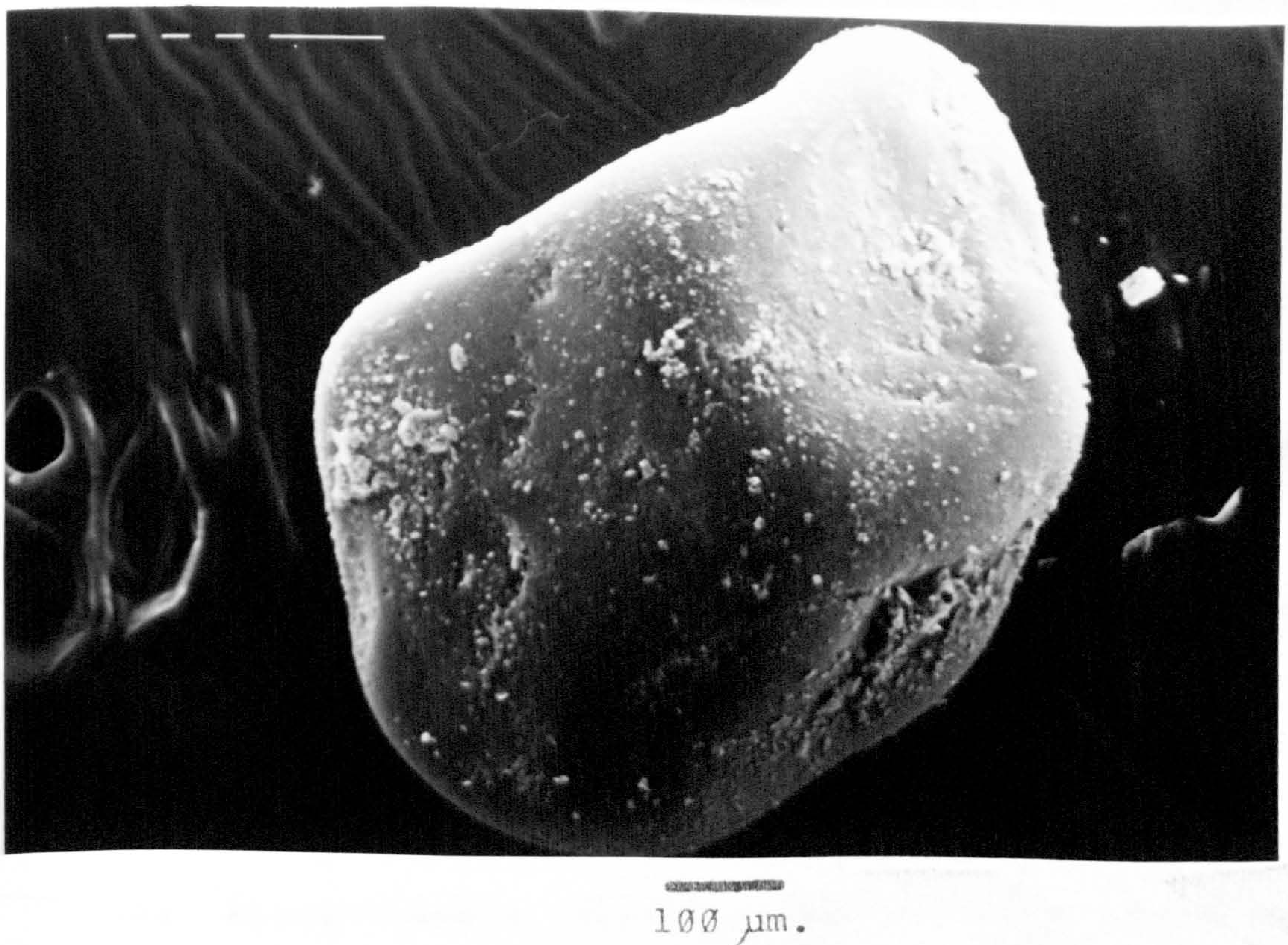
Chemical	Euhedral silica				●			
	Amorphous silica			●		●	●	
	Solution crevasses				●	●		
	Solution pits			●	●	●		
	Oriented etch pits	●	●	◪	●	◪	●	●
Loessic	Dulled surface	●	●	◪	◪	◪	◪	◪
	Smooth surface	■	■	◪	◪	◪	◪	◪
	Rounded	●	●	■	◪	◪	●	◪
	Dish-shaped pits		●	◪	◪	■	●	◪
Fluvial	Subangular	●	●	●	●	●	●	●
	Subrounded	●	●	●	●	●	●	●
	Mechanical V-pits			●		●		
	Curved scratches			●	●			●
	Straight scratches					●	●	
Glacial	Chattermarks							
	Angular	■	■	●	◪	◪	◪	◪
	Fracture plates							
	Adhering particles							
	Imbricate grinding							
	Parallel striations							
	Conchoidals >10µ			●	●		●	
	Conchoidals <10µ				●	●	●	
	Breakage blocks>10µ							
	Breakage blocks<10µ							
Surface Features General	Euhedral quartz	■	■	◪	◪	◪	●	◪
	Scaling			●	●	●		●
	High relief				●	●	●	
	Medium relief	●	●	●	◪	◪	◪	●
	Low relief	■	■	■	◪	◪	◪	■
	Meandering ridges			●	●	●	●	
	Arcuate steps				●			
	Straight steps				●	●		
	Edge abrasion				●	●	●	
	Grain breakage			●		●	●	●
	Sample number DR	1	3	4	7	8	10	12

■ Abundant – 75% ◪ Common 25-75% ● Present 1-25% □ Absent – 1%

Figure 6.4.20.7. Summary of quartz grain surface textures, Portway Pit.



6.4.20.1. S.E.M. photomicrographs of complex authigenic quartz grains, Portway Pit.



6.4.20.2. S.E.M. photomicrograph of a loessic quartz grain, Portway Pit.

epigenetic pipe vein mineralization which has undergone little or no transportation from the original site. Baryte is dominant with fluorite and some etched calcite crystals present. Secondary goethite, after marcasite, is also present both in the joints in the quartz rock and as small derived lumps in the fills.

6.5. Conclusions

This area has had a complex history of cave development and abandonment related to the retreat of Rushup Edge and Bradwell Edge (Ford, 1966; Beck, 1980) and to the development of Peak Cavern, Russet Well and Bradwell Resurgance Cave as outlets for the underground drainage of the area (Beck, 1980). As a result of the complexity of the evolution of the karst in this area the sediments found in many of the caves and mines are highly varied.

The composition of the sediments shows that they were derived from both autochthonous and allochthonous sources, the former being dominant in some vein cavities and the latter in the active and recently abandoned stream caves.

The autochthonous fraction of the sediments consists of fluorite (including the Blue John variety), baryte, galena, chert, limestone and authigenic quartz clasts and some of the clay fraction.

The allochthonous fraction consists of shale and sandstone clasts,quartz sand, silt and clay derived from the Namurian strata to the north and east of the area.

Considerable quantities of reworked loessic silt are also present.

Size analysis shows that the sediments are varied in character, especially those in isolated cavities where mixed allochthonous and autochthonous sediments occur. In the active cave systems size analysis often reveals a downstream reduction in grain size.

S.E.M. studies show that these sediments have been derived by fluvial, fluvio - glacial and aeolian processes.

The active cave systems contain sediments derived from the erosion of the Namurian strata of Rushup Edge and Bradwell Edge. These sediments are continually being re - eroded and re - deposited as they are carried through the cave systems from the swallets. Deposits in passages now abandoned by the streams may contain identical sediments which are now out of range of flooding and have become dormant. The grain size of these deposits usually reflects the distance travelled from their source area, with a gradual reduction down stream.

Parts of some of the caves, close to their present or former swallets, contain pebbly sediments which appear to be mud flow deposits, possibly of solifluction origin. These deposits are probably of late Devensian age.

Many of the now abandoned cave systems and parts of still active systems contain silty sediments which are largely composed of re - worked loessic silt. In some cases this appears to have been washed into the caves by streams which dropped part of their sediment load when stream flow was restricted causing damming. In other localities the loessic silt has accumulated in surface solution depressions. In many near surface cavities, often associated with mineral veins, loessic silt has accumulated. It has probably been carried underground down joint systems and vein cavities by the mechanism of translatory flow postulated by Bull (1981b).

Where speleothems overlying deposits of loessic silt have been dated (Ford et al, 1983) they indicate that silt deposition was complete by mid - Devensian times. This indicates that the loess was probably brought into the area during the Devensian I glacial (75,000 to 90,000 years B.P.).

The glacial and fluvio - glacial deposits of the Earle's Quarry area indicate that the limestones in this area had been stripped of their shale cover by the time of the Wolstonian Glaciation (145,000 to 170,000 years B.P.).

The glacial and fluvio - glacial deposits contain no exotic erratics which confirms that the ice sheet in this area was part of the near stagnant ice in the lee of Kinder Scout (Burek, 1978). The deposits are composed of fluvially re - worked glacial debris and represent deposits from sub - glacial or marginal drainage channels and were therefore probably deposited during the waning stages of the glaciation.

Many of these deposits contain locally re - worked epigenetic minerals, a process still continuing in Speedwell Cavern, though only in Treak Cliff Cavern and

Portway Pit are they worked for their contained minerals. These minerals are present as residual accumulations which formed as the more soluble limestones were dissolved or as small clasts within the sediments having been eroded from surface or underground exposures of mineral veins.

7. WYE VALLEY AND LATHKILLDALE AREA

7.1. Introduction

This area extends from Buxton in the west to Rowsley in the east as a broad band across the central Peak District (fig. 7.1.1.). In this area the limestone plateau is deeply incised by the valleys of the Wye and Lathkill. The area contains few known caves and most of those that are known were discovered as the result of mining activity.

In the Buxton area the limestones are extensively quarried for roadstone and for the chemical, lime and steel industries. Fluorspar is worked from the eastern end of Long Rake by open pit methods and calcite was mined from the western end of Long Rake until 1981.

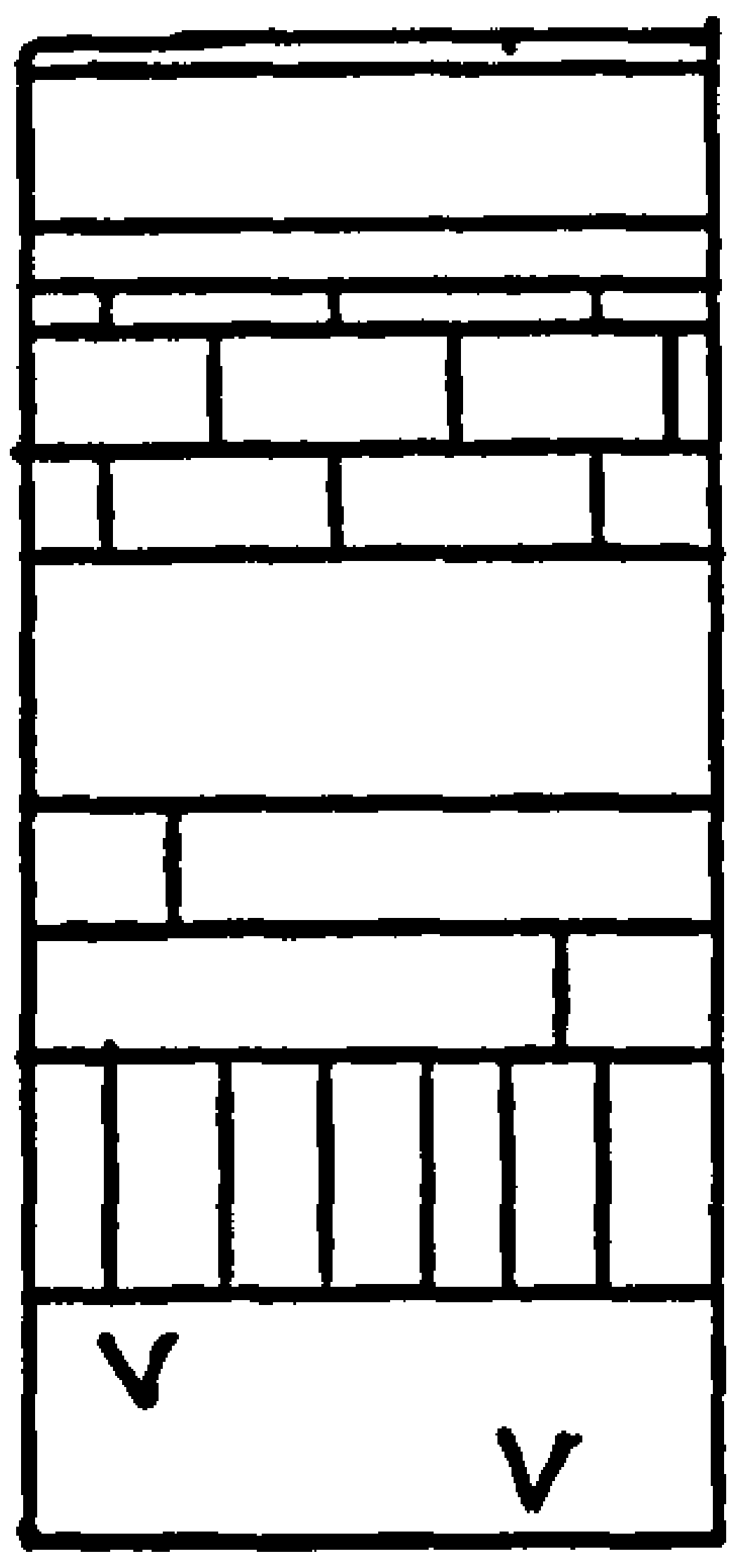
7.2. Geological Setting

The River Wye crosses the Carboniferous Limestone massif, rising on the Namurian shales to the west of Buxton, then crossing the limestone and returning to the shales near Bakewell.

The limestones exposed in the area are the Woodale Limestone of early Asbian (S_2) age, the Bee Low Limestone of Asbian (D_1) age, the Monsal Dale Beds of Brigantian (D_2) age and the Eyam Limestone of late Brigantian (P_2) age (Aitkenhead and Chisholm, 1982). In total about 500 metres of limestone is exposed in the area displaying highly varied lithology.

Interbedded with the limestones are a number of volcanic horizons, including the Millers Dale Upper and Lower lavas

Figure 7.1.1. Geological sketch map of the Wye Valley.



Namurian sandstones and shales

Eyam Limestones

Monsall Dale Beds

Bee Low Limestone

Woodale Limestones

Volcanics

Eyam Limestones, Monsall Dale Beds, Bee Low Limestone, Woodale Limestones: Carboniferous Limestone

Key to localities

1 Pooles Cavern
2 Knotlow Mine
3 Tunstead Quarry
4 Water Icicle Close Cavern
5 Arbor Low Mine
6 Long Rake Spar Mine
7 Mandale Mine
8 Shining Sough

BUXTON
①
③
River
Wye
BAKEWELL
②
Lathkill
River
⑦
⑧
④
⑤
⑥
N
2 km.

and the Litton Tuff.

The limestones have variable, though usually gentle, dips and are folded into a number of broad anticlinal and synclinal structures (Butcher and Ford, 1977).

Mineralization is patchy with a limited number of deposits having been worked in the past, usually from small fissure veins. The exception to this is the Long Rake which is a vein 12 km. long and frequently 6 metres wide. In the east Long Rake is worked for fluorspar and towards its western limit was worked for calcite until 1981.

The mineralization usually consists of banded galena and calcite, sometimes with sphalerite, baryte and fluorite. Baryte and fluorite become dominant towards the east of the area.

The rivers Wye and Lathkill are the only surface drainage channels in the area. The remainder of the drainage is underground from percolation. Only in the west of the area do streams flow from the overlying shales onto the limestone where they sink.

7.3. Types of Deposit

Apart From Poole's Cavern and Tunstead Quarry all the sites studied were natural, post - mineralization solution cavities discovered by mining activity. Most are associated with mineral veins. Many more are recorded as occurring but are no longer accessible, e.g. Chatsworth Cavern and Devil's Hole in Magpie Mine (Willies, et al, 1980) and the Hubbadale Mines (Worley, et al, 1978).

All the sites found in the mines contain clastic sediments in phreatically - formed cavities. Whether the draining of these cavities was a result of mining activity in the area or by natural water table lowering cannot be ascertained.

Poole's Cavern is a former resurgence cave and has been accessible since at least the time of the Roman occupation (Ford and Allsop, 1977).

The sites in Tunstead Quarry are small bedding- and joint - oriented fissures close to the present surface which have been enlarged by the solutional activity of percolating groundwater.

7.4. Sites Studied

7.4.1. Poole's Cavern

Poole's Cavern, situated at S.K. 050,726, is a show cave and an archaeologically important site. The cave has been described by various authors including Glennie (1953a) and McIntosh (1972).

The cave is developed in Bee Low Limestones of Asbian (D_1) age (Harrison, 1981) which have a dip of nearly 15° to the north (Glennie, 1953a). The limestones are well - bedded bioclastics with numerous joints.

The cave carries a small stream which is known to flow from the shales and into a swallet at SK 045,708 (Glennie, 1953b). Before the stream enters the swallet water has been extracted for water supply purposes since before 1920. Prior to this date severe flooding could occur in Poole's Cavern during periods of wet weather. Normally the stream sinks in

Poole's Cavern and re-emerges at Wye Head (SK 050,730) (Glennie, 1953b).

Accumulations of silty - clays, at least 2 metres thick, occur in the Roman Chamber (fig. 7.4.1.1.). The sedimentary sequence is shown in figure 7.4.1.2. and shows archaeologically barren sediments overlain by stalagmite deposits and associated Romano - British finds (Ford and Allsop, 1977). This is in turn overlain by a further sequence of barren silts. Both sequences are sedimentologically identical and their composition is given in figure 7.4.1.3. which shows that the sediment has largely been derived from the Namurian strata.

Size analysis shows that the sediments are well bedded, moderately well sorted, coarse - skewed, mesokurtic silty - sands (fig. 7.4.1.4.). The results of S.E.M. study of quartz grain surface textures shows that they have been derived from the Namurian strata to the southwest of the cave by fluvial processes (fig. 7.4.1.5.).

The sediments over the Romano - British horizon, and probably those below, have been introduced into the cave by floodwater and were deposited behind the bank of debris which partially blocked the cave entrance before it was removed in the nineteenth century.

7.4.2. Tunstead Quarry

Tunstead Quarry is a large, working quarry to the northeast of Buxton centred on SK 100,740. Well bedded bioclastic limestones of the Bee Low (Asbian(D_1)) and Monsal Dale (Brigantian (D_2)) Groups are extracted from the quarry.

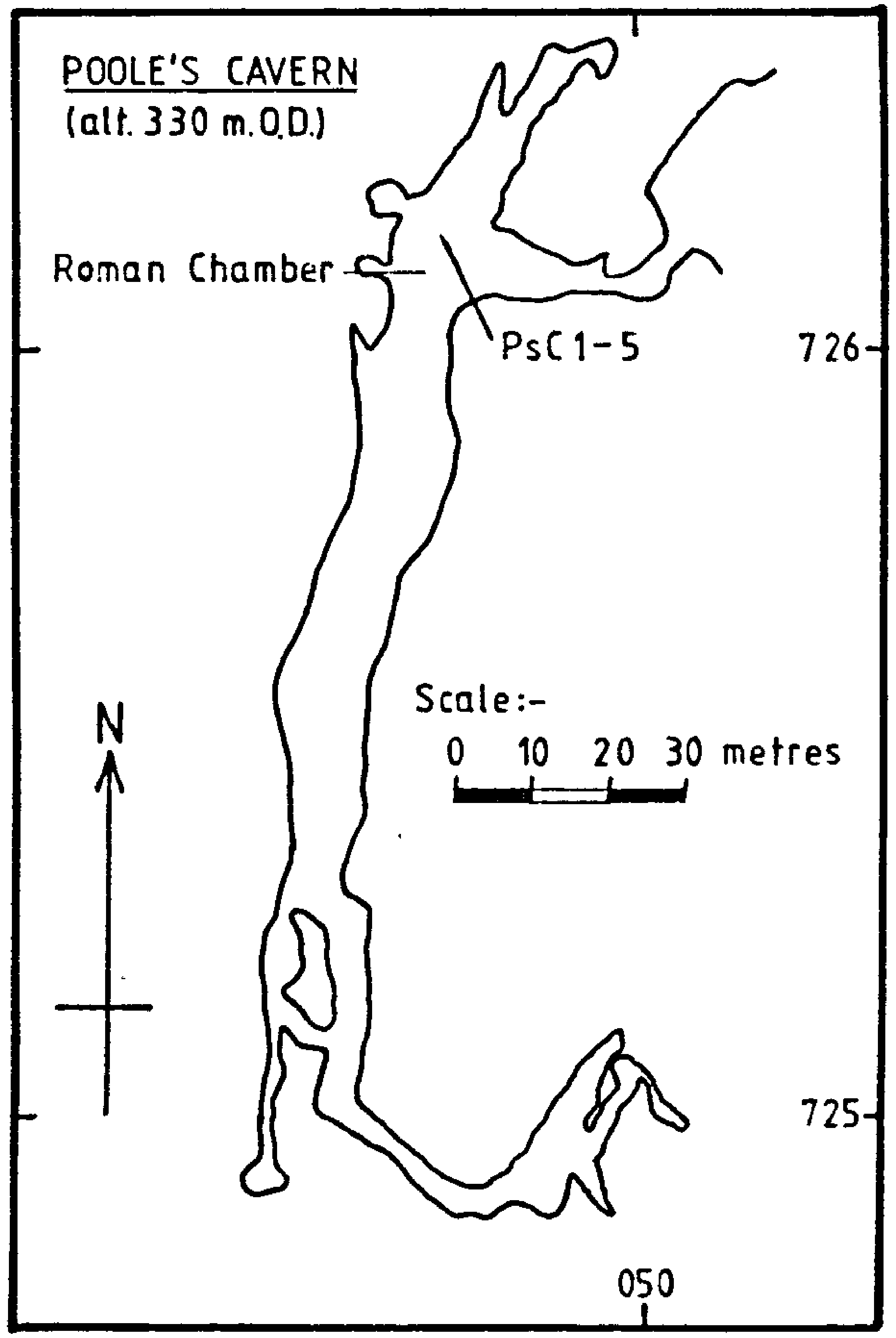


Figure 7.4.1.1. Plan of Poole's Cavern showing sample locations. After Ford and Allsop(1977).

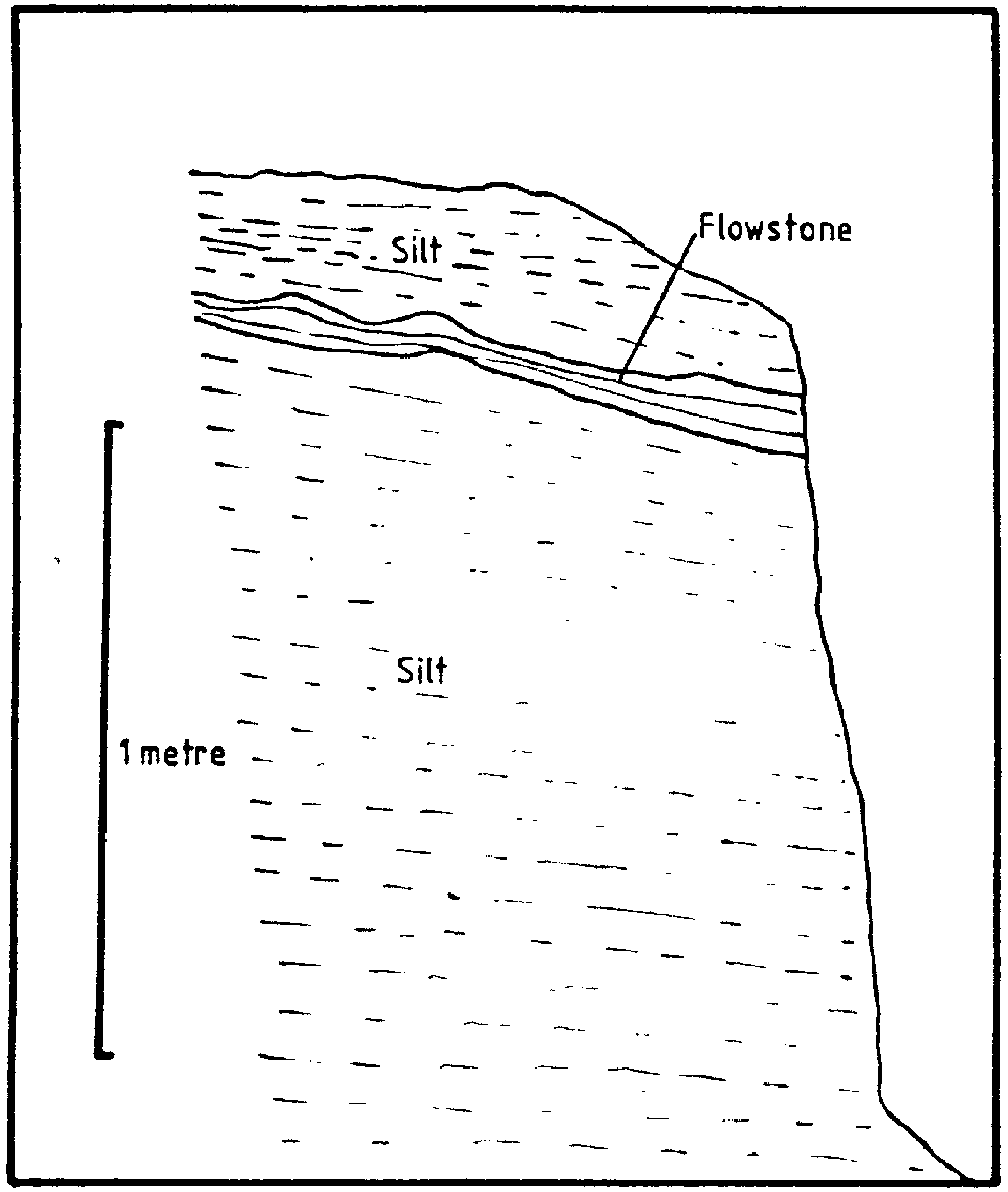


Figure 7.4.1.2. Sediment section, Poole's Cavern.

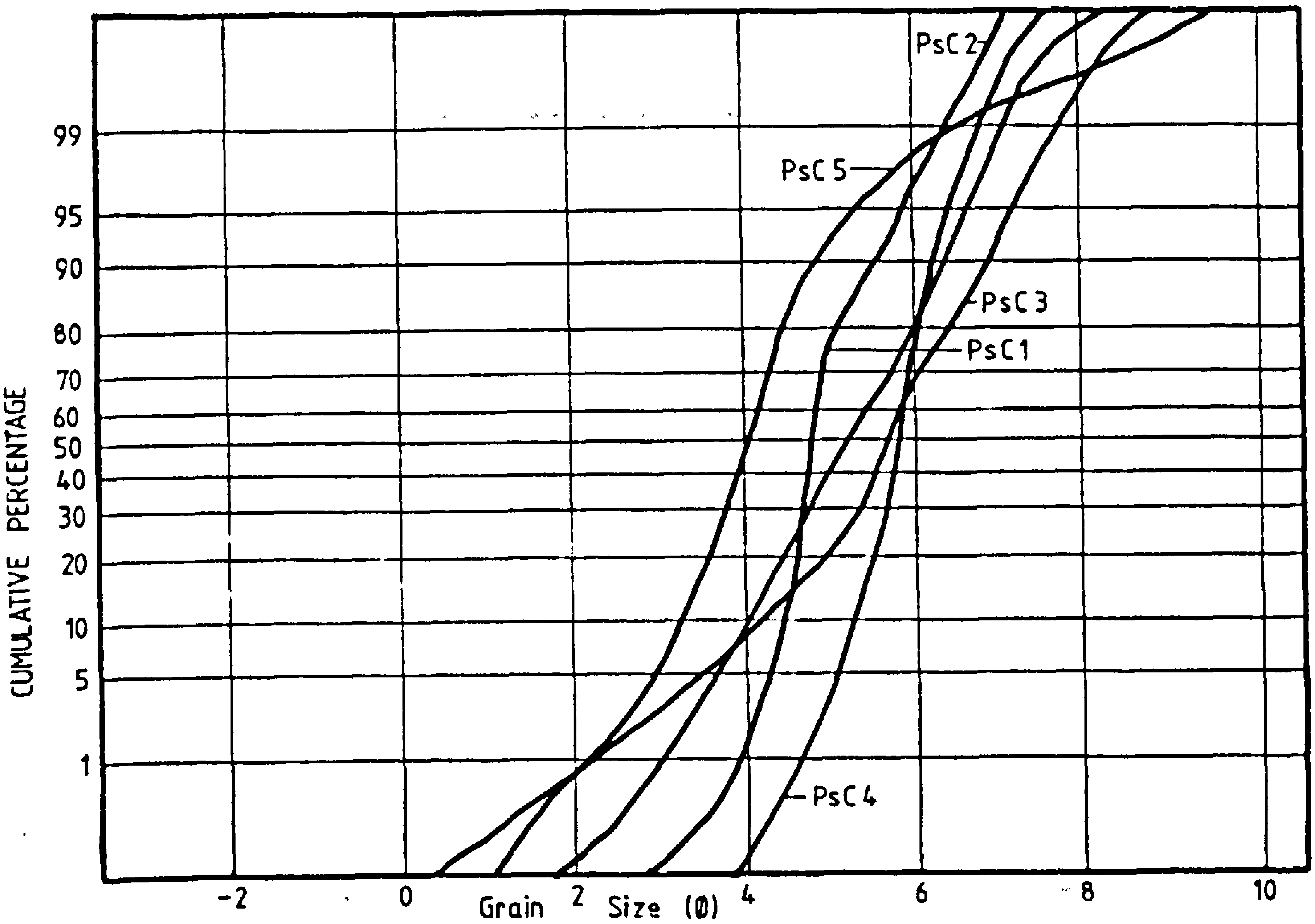


Figure 7.4.1.4. Sediment Size Analysis. Poole's Cavern.

Sample Numbers PsC 1–5

		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	2 — 5
	Silicified fossils	0·5 — 1·5
	Authigenic quartz	1 — 2·5
	Galena	
	Fluorite	0 — 0·5
	Baryte	
	Calcite	0 — 1·5
2	Quartz	47 — 61
	Sandstone	4 — 12
	Feldspar	1 — 4
	Mica	3 — 11
	Shale	1 — 3·5
	Quartzite	
	Balance (mainly clay)	16 — 24

1 Autochthonous 2 Allochthonous

Clay Mineralogy

	%
Illite	46 — 51
Kaolinite	23 — 27
Chlorite	3 — 8
Mixed layer smectites	14 — 19

Figure7.4.1.3. Summary of sediment composition,

Surface Features

Chemical	Euhedral silica		●	●
	Amorphous silica	●		●
	Solution crevasses	◩	◩	●
	Solution pits	●	●	●
	Oriented etch pits	●		◩
Loessic	Dulled surface			
	Smooth surface	●		●
	Rounded	●	●	◩
	Dish-shaped pits			
Fluvial	Subangular	●	◩	◩
	Subrounded	■	◩	◩
	Mechanical V-pits	◩	◩	◩
	Curved scratches	◩	◩	●
	Straight scratches	●	◩	●
Glacial	Chattermarks			
	Angular	●	◩	●
	Fracture plates			
	Adhering particles			
	Imbricate grinding			
	Parallel striations			
	Conchoidals >10µ	●		●
	Conchoidals <10µ	●		●
	Breakage blocks>10µ			
	Breakage blocks<10µ			
General	Euhedral quartz	●	●	●
	Scaling	●		
	High relief	●	●	●
	Medium relief	◩	◩	●
	Low relief	◩	◩	■
	Meandering ridges		●	
	Arcuate steps	●		
	Straight steps		●	
	Edge abrasion	●	●	●
	Grain breakage		●	
	Sample number PsC	1	2	4

■ Abundant – 75%   ◩ Common 25 - 75%   ● Present 1-25%   ☐ Absent – 1%

Figure 7.4.1.5. Summary of quartz grain surface textures, Poole's Cavern.

Sample Numbers TQ 1-2		
		%
1	Limestone	1 — 5·5
	Dolomite	
	Volcanics	
	Chert	0 — 1·5
	Silicified fossils	2 — 4
	Authigenic quartz	17 — 51
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	16 — 25
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	19 — 32

1 Autochthonous   2 Allochthonous

Figure 7.4.2.1. Summary of sediment composition, Tunstead Quarry.

Numerous silty - clay filled, widened joints and bedding planes are intersected by the quarry faces from which samples were obtained at SK 099,736. The overall composition of these sediments is given in figure 7.4.2.1..

Size analysis shows that the sediments are well sorted, slightly coarse - skewed, mesokurtic clayey - silts (fig. 7.4.2.2.). The results of S.E.M. study of quartz grain surface textures show that much of the quartz is euhedral, authigenic quartz derived from the limestones. The remainder of the quartz grains are of loessic origin (fig. 7.4.2.3.).

The composition of the sediments and the results of S.E.M. study show that the sediments are partially derived from the insoluble content of the limestones, which consists mainly of acicular quartz crystals (Harrison, 1981), and partly from former loess deposits on the surface.

7.4.3. Hillocks and Knotlow Mines

These two adjacent mines worked the same series of pipe veins and scrins. The entrance to Knotlow Mine is at SK 144,674 and that to Hillocks Mine at SK 145,672. Both mines have been described by many authors including Gilbert (1952) and Cooper and Westlake (1970).

Each mine intersects a number of natural cavities some of which were partly filled with sediments when they were discovered by the miners. Knotlow Mine intersects part of the local underground drainage network which has been shown to flow to Lathkill Head (Westlake, 1966).

The host rocks are sparry bioclastic limestones of the Monsal Dale Group (Brigantian(D_2)) (Cox and Bridge, 1977).

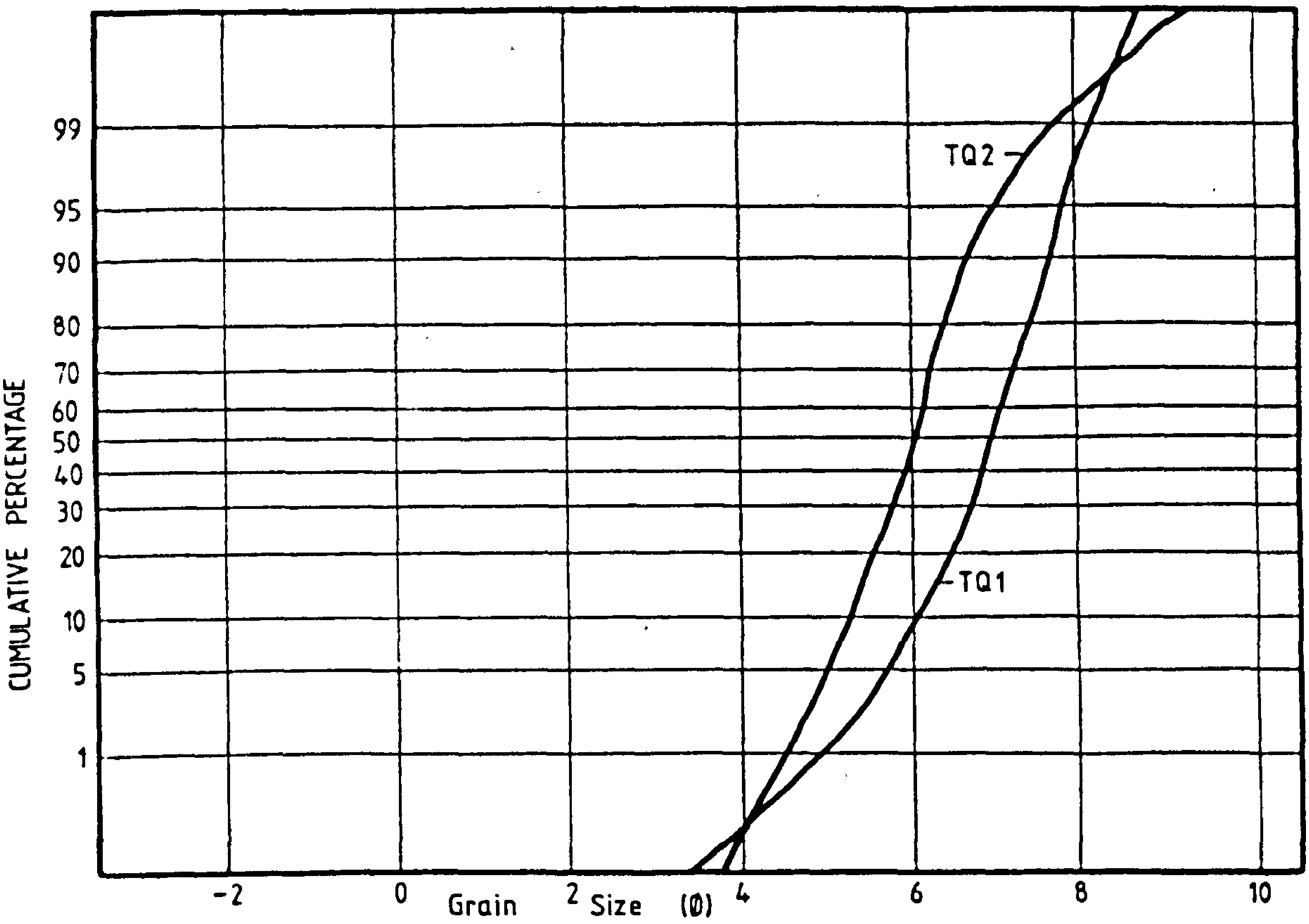


Figure 7.4.2.2. Sediment Size Analysis. Tunstead Quarry.

Surface Features: Chemical	Euhedral silica	●	●
	Amorphous silica		●
	Solution crevasses		
	Solution pits	●	●
	Oriented etch pits		●
Loessic	Dulled surface	■	◢
	Smooth surface	◢	◢
	Rounded	◢	◢
	Dish-shaped pits	◢	●
Fluvial	Subangular	●	●
	Subrounded	◢	◢
	Mechanical V-pits	●	
	Curved scratches		
	Straight scratches	●	
Glacial	Chattermarks	●	
	Angular		
	Fracture plates		
	Adhering particles		
	imbricate grinding		
	Parallel striations		
	Conchoidals >10μ	●	
	Conchoidals <10μ		
	Breakage blocks>10μ		
	Breakage blocks<10μ		
General	Euhedral quartz	◢	◢
	Scaling	●	●
	High relief		
	Medium relief	●	●
	Low relief	■	■
	Meandering ridges		●
	Arcuate steps	●	●
	Straight steps	◢	●
	Edge abrasion	◢	◢
	Grain breakage		●
	Sample number TQ	1	2

■ Abundant – 75% ◢ Common 25-75% ● Present 25% ☐ Absent – 1%

Figure 7.4.2.3. Summary of quartz grain surface textures, Tunstead Quarry.

No sediment accumulations remain undisturbed in Hillocks Mine, all having been removed by the lead miners. Robey (1983) notes that the caverns in Whalf Pipe close to the surface contained limestone, calcite, baryte and galena blocks in a clayey matrix which was worked for lead before galena adhering to the pipe vein walls was extracted.

A large part of the upper sections of Knotlow Mine appears to have contained similar deposits while the caves in the lower part of the system are free from sedimentary accumulations. A number of samples were collected from the upper section of the mine (fig. 7.4.3.1.).

The overall composition of the sediments is given in figure 7.4.3.2.. Size analysis shows that the sediments are poorly sorted, coarse - skewed, very platykurtic silty - gravels (fig. 7.4.3.3.). The results of S.E.M. study of quartz grain surface textures show that the quartz fraction is of loessic origin (fig. 7.4.3.4.).

The composition of the sediments, the results of the size analysis and the S.E.M. study show that the coarse grained fraction is of autochthonous origin, being locally derived from Whalf Pipe and its host limestones and that the finer fraction is reworked loessic sediment brought into the cave from the surface.

7.4.4. Water Icicle Close Cavern

Situated at SK 161,647 Water Icicle Close Cavern was discovered by miners towards the end of the eighteenth century. The present access shaft was sunk into the cave to enable stalagmite deposits to be removed for Chatsworth

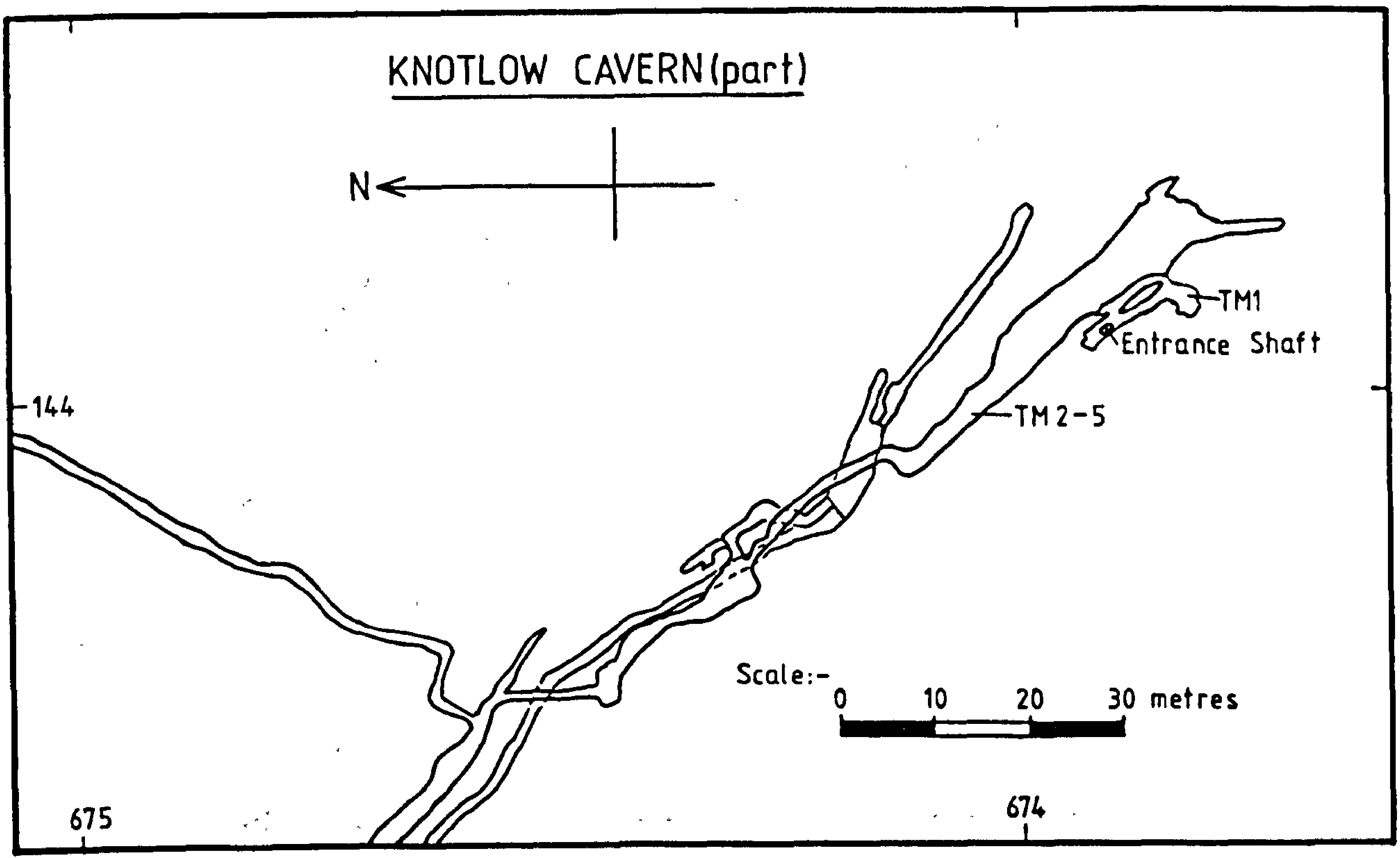


Figure 7.4.3.1. Plan of part of Knotlow Mine showing sample locations. After Cooper and Westlake (1970).

Sample Numbers KM 1—5		
		%
1	Limestone	3 — 21
	Dolomite	
	Volcanics	
	Chert	0 — 1·5
	Silicified fossils	1 — 2
	Authigenic quartz	0 — 0·5
	Galena	0 — 4
	Fluorite	0 — 0·5
	Baryte	1 — 3·5
	Calcite	2 — 6
2	Quartz	39 — 54
	Sandstone	
	Feldspar	
	Mica	0 — 0·5
	Shale	
	Quartzite	
	Balance (mainly clay)	28 — 42
1 Autochthonous 2 Allochthonous		

Figure7.4.3.2. Summary of sediment composition, Knotlow Mine.

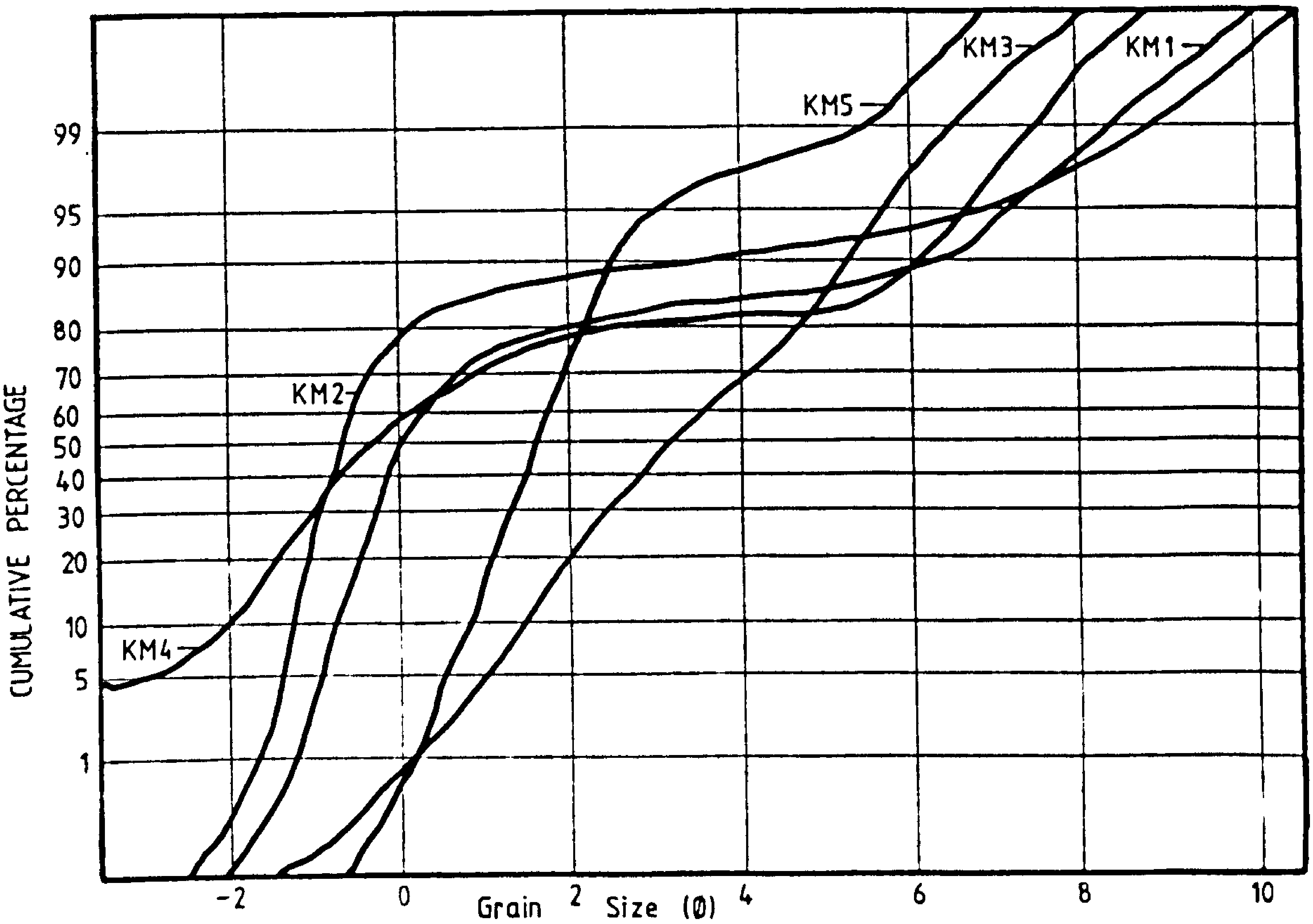


Figure 7.4.3.3. Sediment Size Analysis. Knotlow Mine.

Surface Features Chemical	Euhedral silica	●	●	
	Amorphous silica	●		●
	Solution crevasses	●		
	Solution pits	●	◢	●
	Oriented etch pits		●	
Loessic	Dulled surface	◢	◢	◢
	Smooth surface	◢	■	●
	Rounded	◢	■	◢
	Dish-shaped pits	●	◢	◢
Fluvial	Subangular	●		●
	Subrounded	◢	●	◢
	Mechanical V-pits	●		●
	Curved scratches	●	●	
	Straight scratches	●		
Glacial	Chattermarks			
	Angular			
	Fracture plates	●		
	Adhering particles			
	Imbricate grinding			
	Parallel striations			●
	Conchoidals >10µ		●	
	Conchoidals <10µ		●	
	Breakage blocks>10µ			
	Breakage blocks<10µ			
General	Euhedral quartz	●		
	Scaling		●	●
	High relief			
	Medium relief	◢	●	◢
	Low relief	◢	■	◢
	Meandering ridges			
	Arcuate steps			
	Straight steps	●		
	Edge abrasion	●	●	●
	Grain breakage	●		
	Sample number KM	1	2	3

■ Abundant – 75%
◢ Common 25 - 75%
● Present 1-25 %
☐ Absent – 1%

Figure 7.4.3.4. Summary of quartz grain surface textures, Knotlow Mine.

House soon after (Smith, 1968).

The cave is developed in well bedded and jointed sparry bioclastic limestones of the Monsal Dale Group (Brigantian (D_2)) (Cox and Bridge, 1977).

Dating of stalagmite deposits from the cave which overlie the sediments give ages in excess of 350,000 years B.P., the limit of the U/Th method, for the commencement of stalagmite deposition (Ford, et al, 1983).

Samples from beneath the dated stalagmite layer and from the northwestern extremity of the cave (fig. 7.4.4.1., WIC 1, 3-7) where stalagmite deposits are absent are identical, their overall composition is summarised in figure 7.4.4.2..

Size analysis shows that the sediments are moderately well sorted, slightly coarse - skewed, mesokurtic clayey - silts (fig. 7.4.4.3., WIC 1,3-7). The results of S.E.M. study of quartz grain surface textures show that the silts are of fluvial origin (fig. 7.4.4.4., WIC 1,3-7).

The composition of these sediments shows that they were derived from the Namurian strata. The elevated location of the cave and the speleothem dates indicate that this cave has been abandoned for more than 350,000 years. Sediment deposition occurred before abandonment. The S.E.M. results show that the sediments were fluvially derived.

As the nearest Namurian sediments are now over 5 km. from the cave it is probable that the sediments were derived from a former cover or outlier of Namurian strata in the Monyash area.

The other sample from the cave was taken from a partly filled rift (fig. 7.4.4.1., WIC 2) and may be mine waste. It consists of angular cherty and limestone fragments in a silty

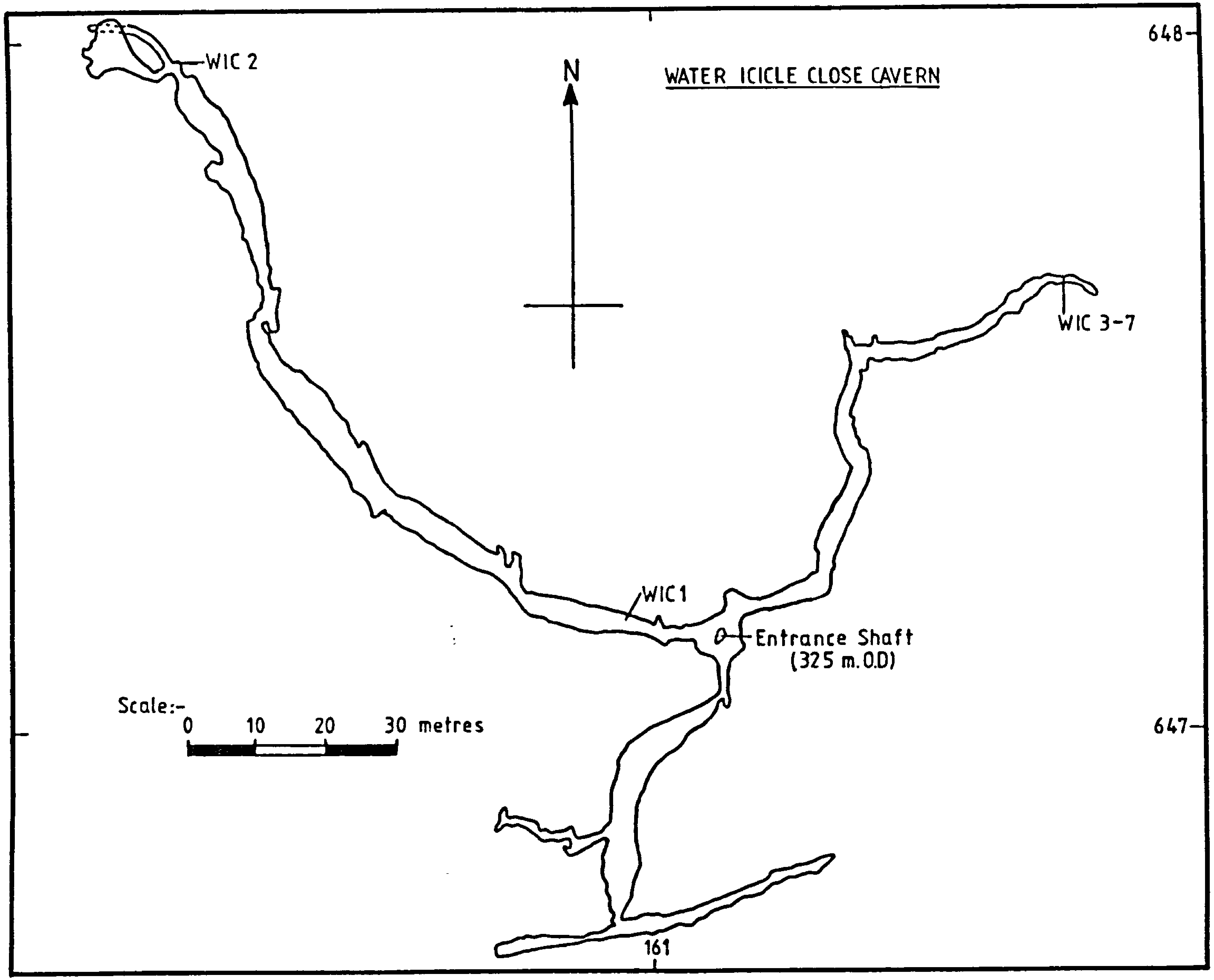


Figure 7.4.4.1. Plan of Water Icicle Close Cavern, showing sample locations. After Westlake (1970).

Sample Numbers WIC 1, 3-7		
		%
1	Limestone	0 — 2·5
	Dolomite	
	Volcanics	
	Chert	0 — 0·5
	Silicified fossils	0·5 — 2
	Authigenic quartz	0 — 1
	Galena	
	Fluorite	
	Baryte	
	Calcite	0 — 0·5
2	Quartz	56 — 78
	Sandstone	
	Feldspar	1 — 3·5
	Mica	0 — 2
	Shale	0 — 1·5
	Quartzite	
	Balance (mainly clay)	17 — 34
1 Autochthonous 2 Allochthonous		

Figure 7.4.4.2. Summary of sediment composition, Water Icicle Close Cavern.

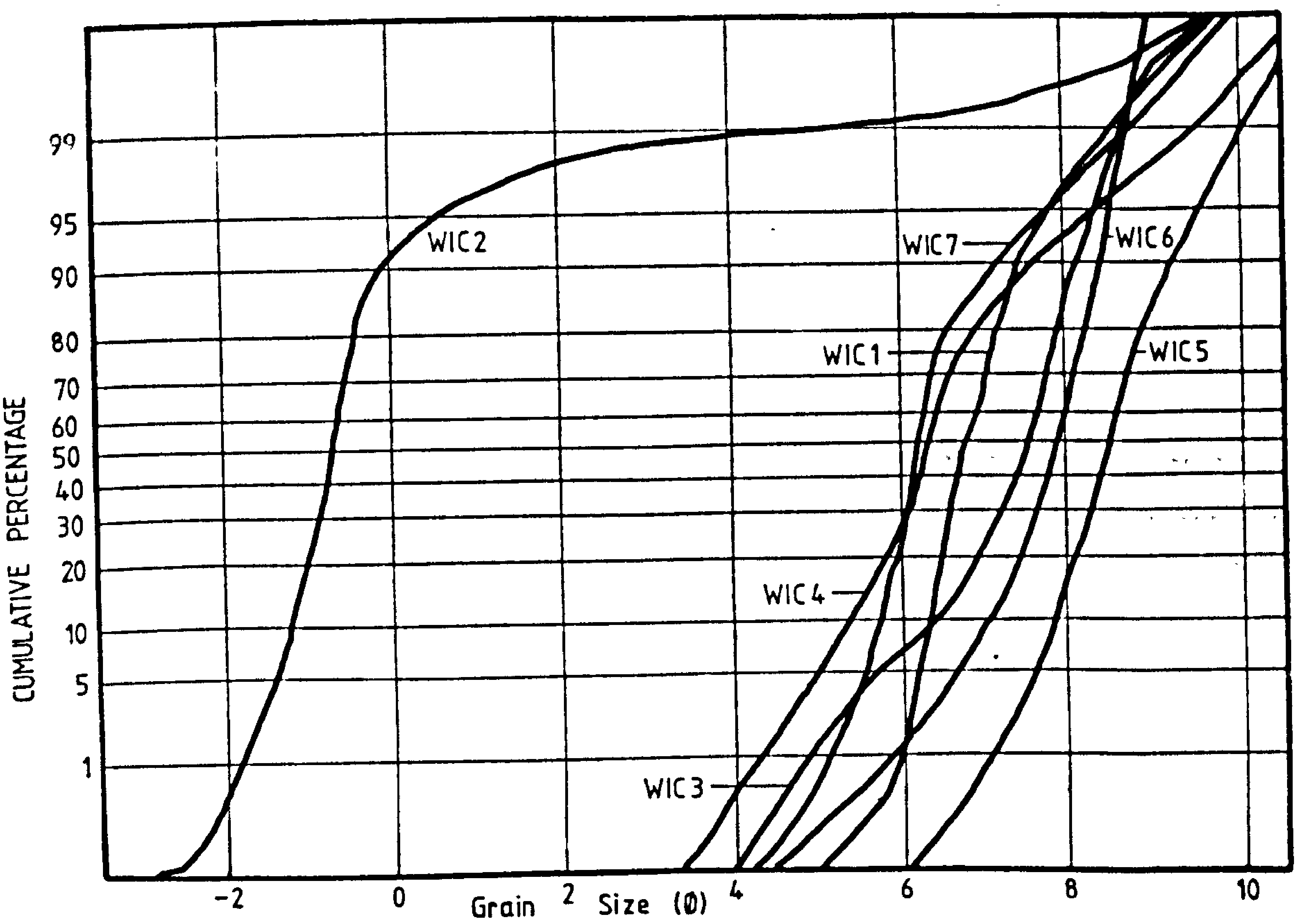


Figure 7.4.4.3. Sediment Size Analysis. Water Icicle Close Cavern.

Surface Features	Chemical	Euhedral silica			●	●		
		Amorphous silica				●		●
		Solution crevasses		●	●			
		Solution pits	●	●				●
		Oriented etch pits		●	●	●		●
	Loessic	Dulled surface	●	●	●			●
		Smooth surface	●	●	●	●		◢
		Rounded	◢	◢	●	◢		◢
		Dish-shaped pits						
	Fluvial	Subangular	◢	◢	●	◢		◢
		Subrounded	◢	◢	■	◢		◢
		Mechanical V-pits	◢	◢	■	◢		◢
		Curved scratches	●	◢		●		●
		Straight scratches	●	●	●			●
	Glacial	Chattermarks						
		Angular	●	●		●		●
		Fracture plates						
		Adhering particles						
		Imbricate grinding						
		Parallel striations						
		Conchoidals >10µ		●				
		Conchoidals <10µ		●	●			●
		Breakage blocks>10µ						
		Breakage blocks<10µ						
	General	Euhedral quartz						●
		Scaling	●	◢	●	●		●
		High relief	●	●		●		●
		Medium relief	◢	◢	●	◢		◢
		Low relief	◢	◢	■	◢		◢
		Meandering ridges			●			
		Arcuate steps		●	●	●		●
		Straight steps	●	●				●
		Edge abrasion	●	◢	●	●		◢
		Grain breakage	●		●			●
		Sample number WIC	1	3	6	7		2

■ Abundant – 75% ◢ Common 25-75% ● Present 1-25% □ Absent – 1%

Figure 7.4.4.4. Summary of quartz grain surface textures, Water Icicle Close Cavern.

matrix which is identical to the other sediments in the cave.

Size analysis shows that the sediment is a poorly sorted, coarse - skewed, platykurtic silty - gravel (fig. 7.4.4.3., WIC 2) The results of S.E.M. study of quartz grain surface textures shows that the silt is of fluvial origin (fig. 7.4.4.4., WIC 2).

7.4.5. Arbor Low Mine

Arbor Low Mine worked the western end of Long Rake. The shaft is at SK 172,640 and the "Old West Decline", the only feasible way into the mine in 1980 and 1981, is at SK 167,640. The mine was worked for calcite (Houston, 1964) and closed in 1975 following an overwind, though calcite reserves were almost exhausted. Following closure tailings were dumped down both the shaft and the decline making access difficult

The vein is hosted in poorly bedded Monsal Dale Limestone (Brigantian (D_2)) (Cox and Bridge, 1977).

A small phreatic cavity developed in vein calcite close to the shaft on the No. 2 Level (fig. 7.4.5.1.) is filled with silt, the composition of which is given in figure 7.4.5.2..

Size analysis shows that the sediment is a well sorted, coarse - skewed, mesokurtic silt (fig. 7.4.5.3.). The results of S.E.M. study of quartz grain surface textures shows that the silt is of loessic origin (fig. 7.4.5.4.).

As the cavity is isolated the loessic silt was probably introduced by the mechanism of translatory flow postulated by Bull (1981b) and derived from surface loess deposits.

Figure 7.4.5.1. Section of Arbor Low Mine showing sample location. After Shaw (1980).

Sample Numbers AL 1		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	1
	Galena	
	Fluorite	
	Baryte	
	Calcite	26
2	Quartz	53
	Sandstone	
	Feldspar	1·5
	Mica	0·5
	Shale	
	Quartzite	
	Balance (mainly clay)	18

1 Autochthonous 2 Allochthonous

Figure 7.4.5.2. Summary of sediment composition, Arbor Low Mine.

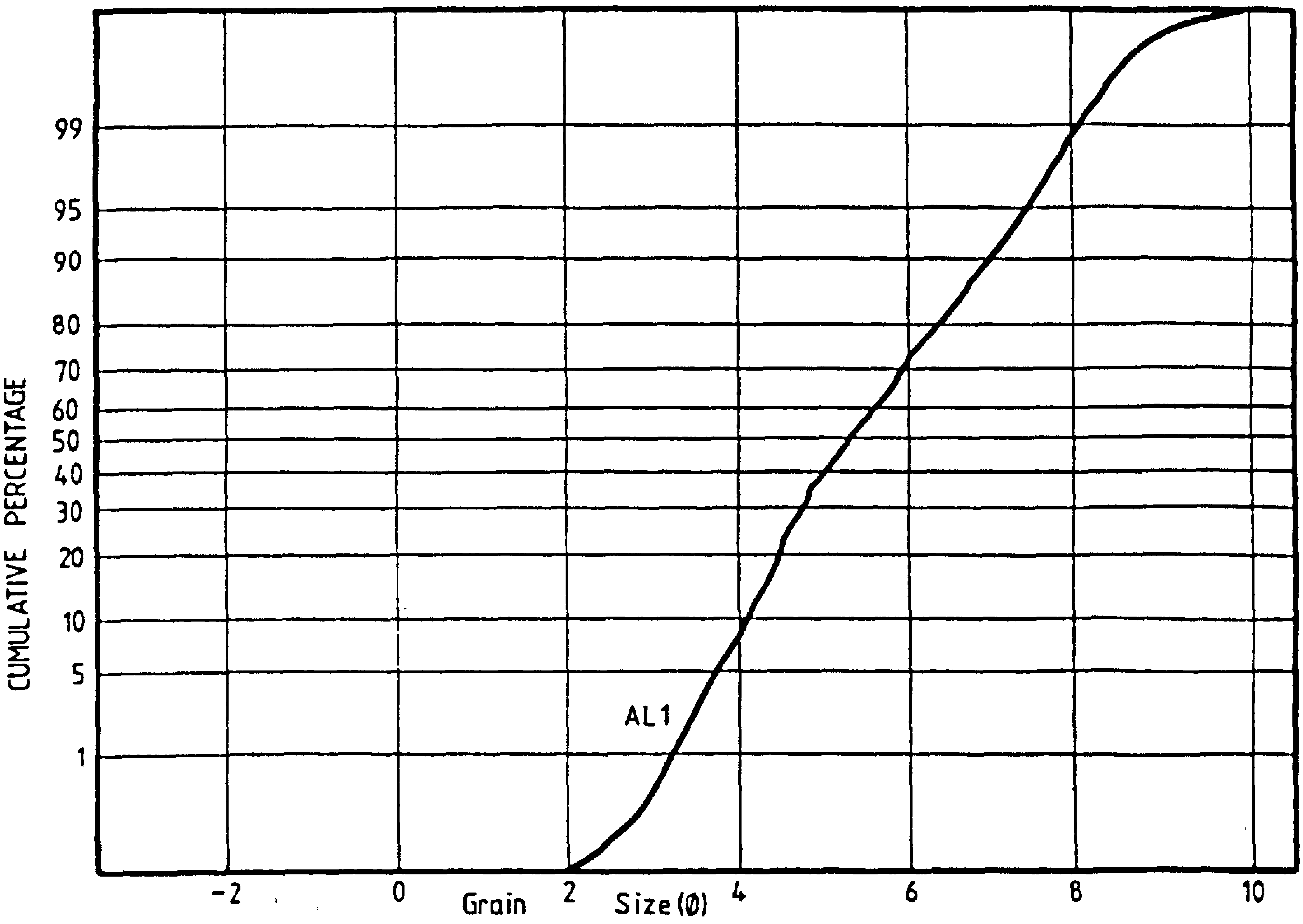


Figure 7.4.5.3. Sediment Size Analysis. Arbor Low Mine.

Surface Features			
Chemical	Euhedral silica		
	Amorphous silica	●	
	Solution crevasses		
	Solution pits	●	
	Oriented etch pits	●	
Loessic	Dulled surface	■	
	Smooth surface	◩	
	Rounded	■	
	Dish-shaped pits	◩	
Fluvial	Subangular	●	
	Subrounded	●	
	Mechanical V-pits		
	Curved scratches	●	
	Straight scratches		
Glacial	Chattermarks		
	Angular		
	Fracture plates		
	Adhering particles		
	Imbricate grinding		
	Parallel striations		
	Conchoidals >10µ		
	Conchoidals <10µ	●	
	Breakage blocks>10µ		
	Breakage blocks<10µ		
General	Euhedral quartz	●	
	Scaling	●	
	High relief		
	Medium relief	●	
	Low relief	■	
	Meandering ridges		
	Arcuate steps	●	
	Straight steps		
	Edge abrasion	●	
	Grain breakage		
	Sample number AL	1	

■ Abundant – 75%
◩ Common 25 - 75%
● Present 1-25%
☐ Absent – 1%

Figure 7.4.5.4 Summary of quartz grain surface textures, Arbor Low Mine.

7.4.6. Long Rake Spar Mine

Long Rake Spar Mine, the shaft of which is at SK 187,643, worked a 2 km. length of Long Rake for calcite until underground work ceased in April 1981 due to depressed calcite prices and low ore reserves. As at Arbor Low Mine the vein is hosted by poorly bedded Monsal Dale Limestones (Brigantian (D_2)) (Cox and Bridge, 1977).

The vein, usually 5 to 6 metres wide, has been almost totally removed from the surface to a depth of about 375 feet over the full length worked by the mine. In the western end of the mine the vein becomes disordered and has not been worked between here and the eastern end of Arbor Low Mine.

Two sediment - filled cavities were intersected in this part of the mine, one on the 300 ft. level and the other on the 225 ft. level.

The first is a phreatic cavity developed below an inclined fracture plane within the vein. The roof of the cavity shows an anastomosing network of phreatic half tubes from which the cavity developed (plate 7.4.6.1.). The composition of the finely laminated sediments (plate 7.4.6.2.) is given in figure 7.4.6.1..

Size analysis shows that the sediments are well sorted, leptokurtic silts (fig. 7.4.6.2.). The results of S.E.M. study of quartz grain surface textures show that the silt is reworked loessic silt (fig. 7.4.6.3., LR 1,4) derived from the surface.

The cavity on the 225 ft. level is an irregular solution cavity developed both in the vein and in the wall rock limestones and is filled with layered silty - sands (plate

Sample Numbers LR 1—5		
		%
1	Limestone	1 — 4·5
	Dolomite	
	Volcanics	
	Chert	0 — 0·5
	Silicified fossils	0·5 — 2
	Authigenic quartz	1 — 3
	Galena	
	Fluorite	
	Baryte	
	Calcite	7 — 15
2	Quartz	61 — 73
	Sandstone	
	Feldspar	1 — 3
	Mica	0 — 1·5
	Shale	
	Quartzite	
	Balance (mainly clay)	17 — 29
1 Autochthonous 2 Allochthonous		

Figure 7.4.6.1. Summary of sediment composition, Long Rake Spar Mine, 300 ft. Level.

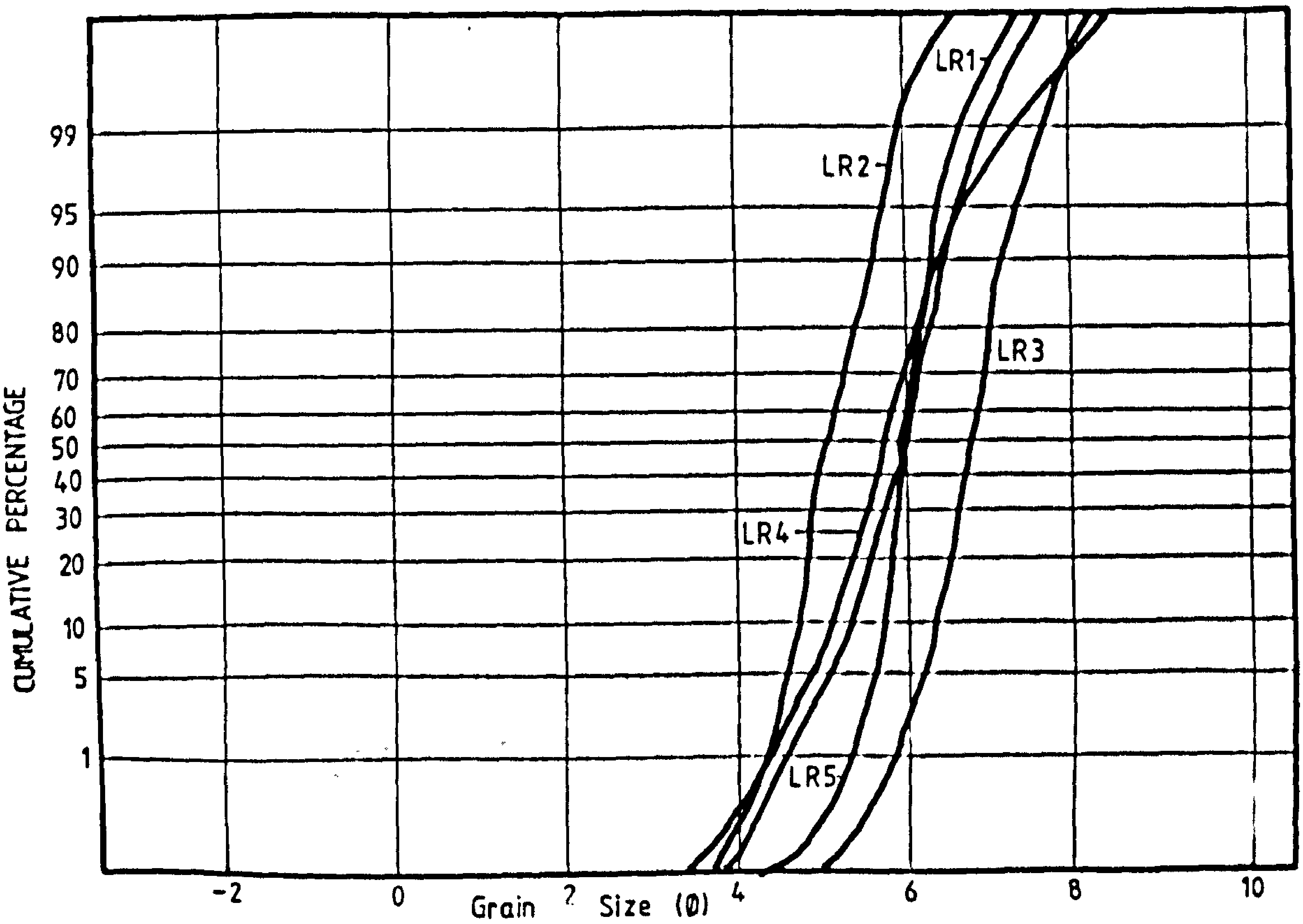


Figure 7.4.6.2. Sediment Size Analysis, 300 ft. level, Long Rake Spar Mine.

Surface Features	Chemical	Euhedral silica					●	●	
		Amorphous silica	●				●		●
		Solution crevasses				●			
		Solution pits	●	●				●	●
		Oriented etch pits				●		●	●
	Loessic	Dulled surface	◢	◢		●	●	●	●
		Smooth surface	◢	■		◢	●		●
		Rounded	◢	■		●	●	●	◢
		Dish-shaped pits	●	◢					●
	Fluvial	Subangular	●			◢	●	◢	◢
		Subrounded	◢	●		◢	■	◢	◢
		Mechanical V-pits	●			◢	■	●	◢
		Curved scratches				●	●	●	◢
		Straight scratches	●	●		●	●	●	●
	Glacial	Chattermarks							
		Angular				◢	●	◢	●
		Fracture plates							
		Adhering particles							
		Imbricate grinding							
		Parallel striations							
		Conchoidals >10µ		●		●		●	
		Conchoidals <10µ					●	●	
		Breakage blocks>10µ							
		Breakage blocks<10µ							
	General	Euhedral quartz	●			●	●	●	●
		Scaling		●		◢	●	●	●
		High relief				●		●	
		Medium relief	◢	●		◢	●	◢	◢
		Low relief	◢	■		◢	■	◢	◢
		Meandering ridges				●	●		●
		Arcuate steps					●		●
		Straight steps	●					●	●
		Edge abrasion	●	◢		●	◢	●	●
		Grain breakage		●			●		
		Sample number LR	1	4		7	8	9	13

■ Abundant – 75%

◢ Common 25-75%

● Present 1-25%

☐ Absent – 1%

Figure 7.4.6.3. Summary of quartz grain surface textures, Long Rake Spar Mine.

10 cm.

7.4.6.1. Anastomosing phreatic half - tubes developed along a parting in a calcite vein, 300 ft. Level, Long Rake Spar Mine.

5 cm.

7.4.6.2. Laminated silts filling the cavity developed below half - tubes in previous plate, 300 ft. Level, Long Rake Spar Mine.

7.4.6.3.). The basal layer in one part of the cavity contains irregular residual galena clasts in the sediments. The composition of the sediments is given in figure 7.4.6.4..

Size analysis shows that the sediment is a well sorted, mesokurtic silty - sand (fig. 7.4.6.5.). The results of S.E.M. study of quartz grain surface textures shows that the sediment has been derived by fluvial processes (fig. 6.4.6.3., LR 7-9, 13).

The composition of the sediments shows that the allochthonous fraction has been derived from the Namurian strata. The results of S.E.M. study show that the derivation has been by fluvial processes. The sediments of this deposit are very similar to those in Water Icicle Close Cavern, which is about 1.5 km. to the northwest, and were probably derived from the same area.

7.4.7. Mandale Mine

The most used entrance to this disused lead mine is at SK 197,661. The mine worked Mandale Rake and a number of associated small scrins. The workings of the mine have been described by Tune (1969) and Worley and Ford (1975).

Mandale Rake is up to 1 metre wide and consists mainly of baryte with minor galena, fluorite, calcite and goethite after marcasite. It is hosted by poorly bedded, dark grey sparry Monsal Dale Limestones (Brigantian (D_2)) (Cox and Bridge, 1977).

A number of small solution cavities occur along the accessible length of the vein (fig. 7.4.7.1.). All contain similar sediments the composition of which is given in figure

Sample Numbers LR 6 -13		
		%
1	Limestone	0 — 4·5
	Dolomite	
	Volcanics	
	Chert	0 — 1
	Silicified fossils	0 — 1·5
	Authigenic quartz	0 — 2
	Galena	0 — 21
	Fluorite	
	Baryte	
	Calcite	1 —· 12
2	Quartz	65 —77
	Sandstone	0 — 3
	Feldspar	0 — 1·5
	Mica	0 — 2
	Shale	0 — 1
	Quartzite	
	Balance (mainly clay)	14 — 27
	1 Autochthonous 2 Allochthonous	

Figure 7.4.6.4. Summary of sediment composition,
Long Rake Spar Mine, 225 ft. Level.

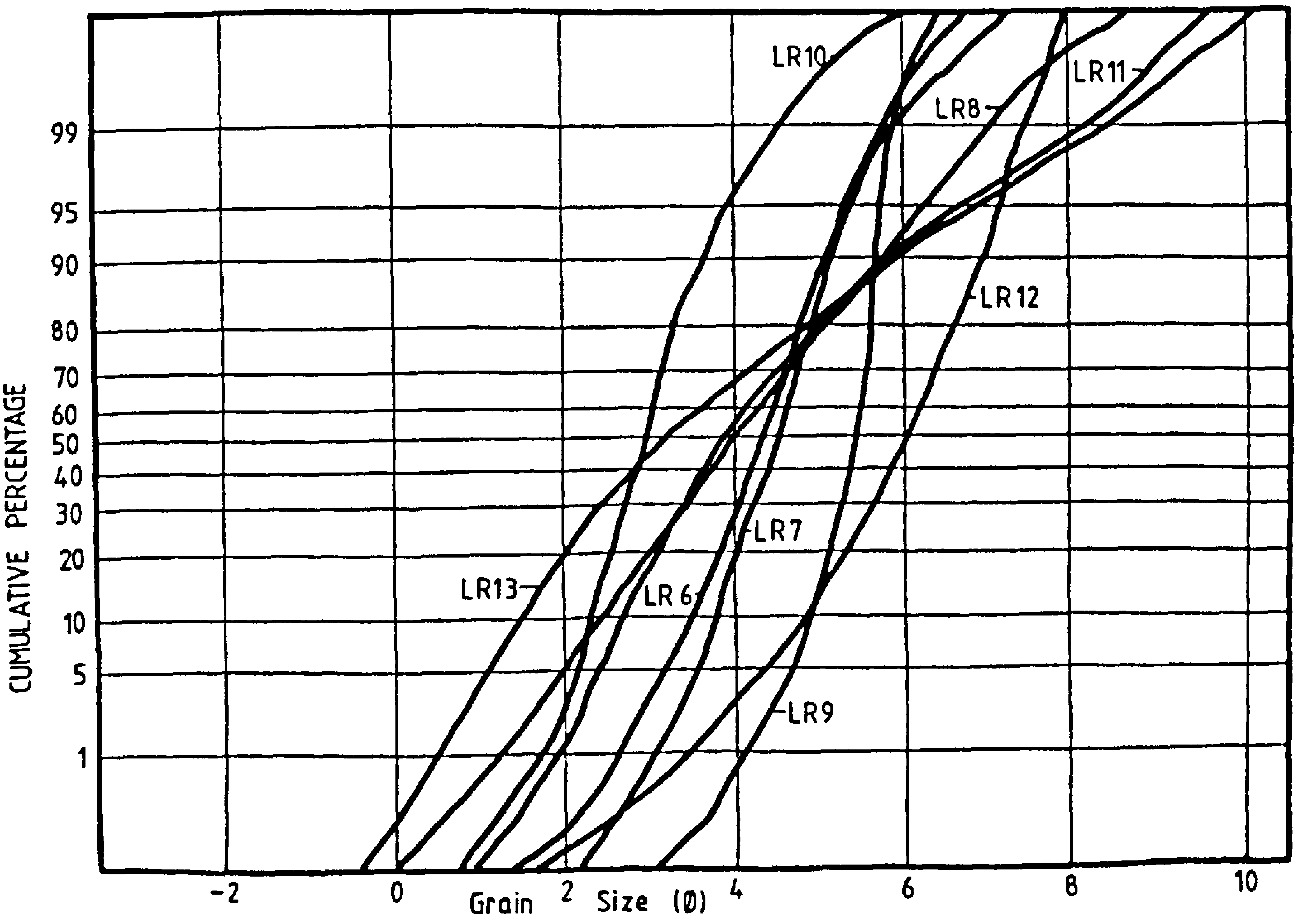
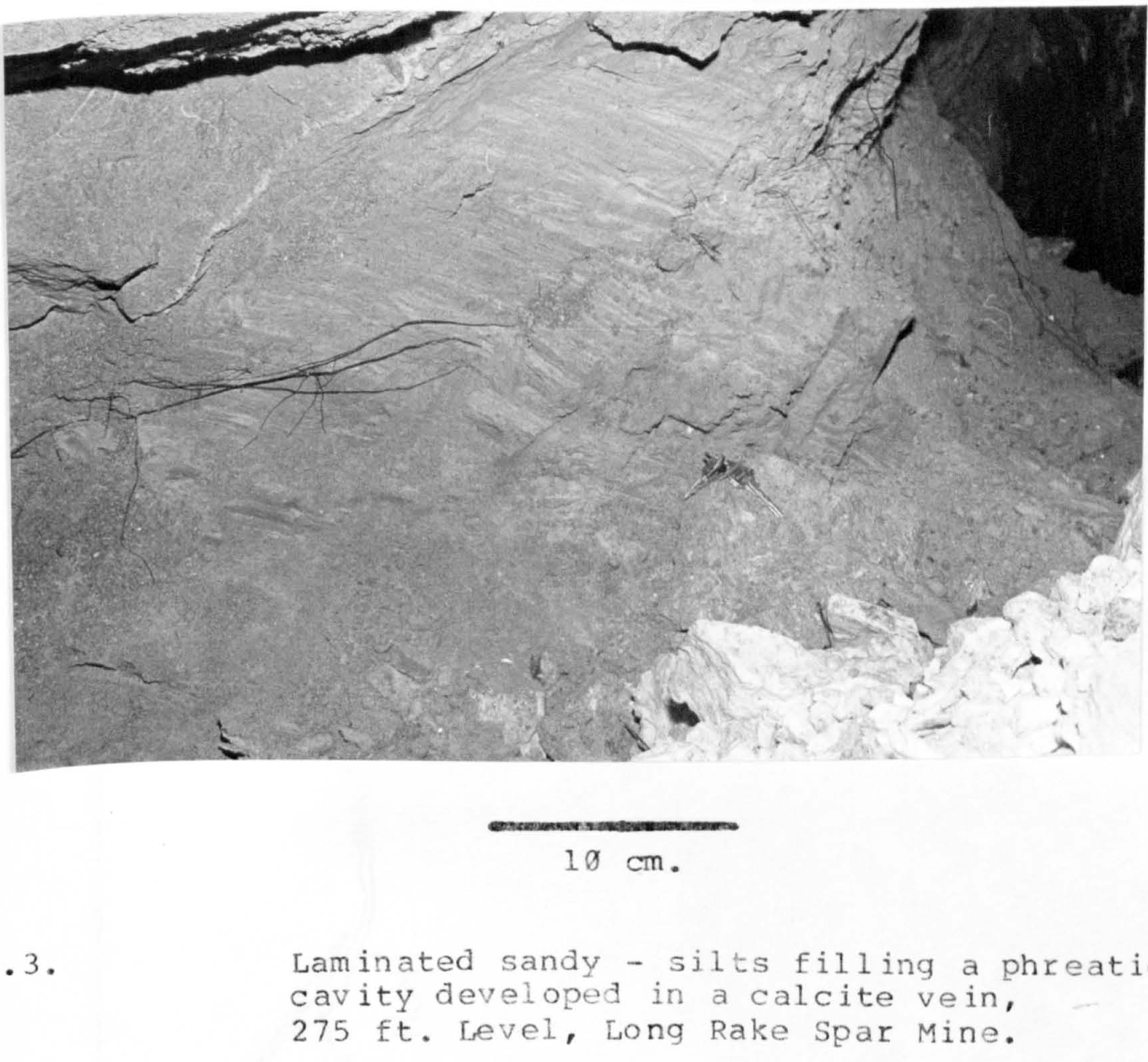


Figure 7.4.6.5. Sediment Size Analysis. 225 ft. level, Long Rake Spar Mine.



7.4.6.3. Laminated sandy - silts filling a phreatic cavity developed in a calcite vein, 275 ft. Level, Long Rake Spar Mine.

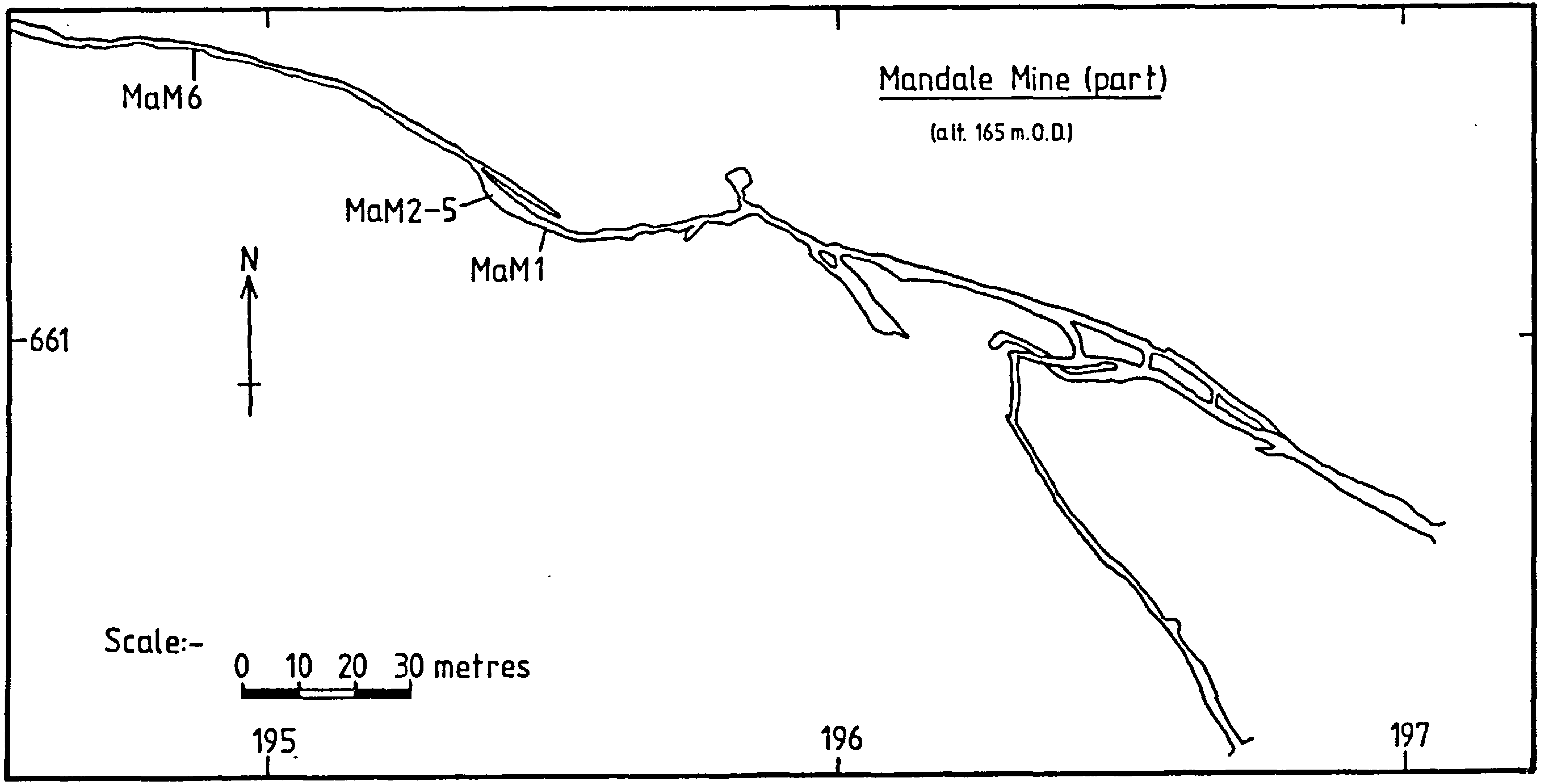


Figure 7.4.7.1. Plan of part of Mandale Mine showing sample locations. After Tune (1969).

7.4.7.2..

Size analysis shows that the sediments are poorly sorted, very coarse - skewed, very platykurtic, silty - angular gravels (fig. 7.4.7.3.). The results of S.E.M. study of quartz grain surface textures show that the silt is of loessic origin with some authigenic quartz derived from the limestone (fig. 7.4.7.4.).

The sediments consist of material derived from two sources. Firstly an angular gravel containing chert, limestone and baryte clasts derived from Mandale Rake and its wall rocks. Secondly the matrix of the gravel which consists partly of autochthonous authigenic quartz and partly of loessic silt derived from the surface.

7.4.8. Shining Sough

This sough was commenced in 1756 to drain mines near Alport and was later superceded by Hillcar Sough (Rieuwerts, 1966). The sough tail is situated at SK 230,647.

The sough is driven through poorly bedded Monsal Dale Beds (Brigantian (D_2)) (Bridge and Gozzard, 1981) following a number of mineralized joints. In several places in the first section of the sough a number of silt - filled joints were cut. The composition of the silt is given in figure 7.4.8.1..

Size analysis shows that the sediments are well sorted, coarse - skewed, mesokurtic clayey silts (fig. 7.4.8.2., SS 1-4). The results of S.E.M. study of quartz grain surface textures shows that the silt is reworked loess (fig. 7.4.8.3., SS 1,4). They occur in widened joints less than 30 metres from the surface and may have been directly washed

Sample Numbers MaM 1–6		
		%
1	Limestone	1 — 3
	Dolomite	
	Volcanics	
	Chert	16 — 45
	Silicified fossils	7 — 12
	Authigenic quartz	1 — 3·5
	Galena	0 — 1·5
	Fluorite	0 — 0·5
	Baryte	3 — 26
	Calcite	0 — 0·5
2	Quartz	31 — 52
	Sandstone	
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	16 — 27
1 Autochthonous 2 Allochthonous		

Figure 7.4.7.2. Summary of sediment composition, Mandale Mine.

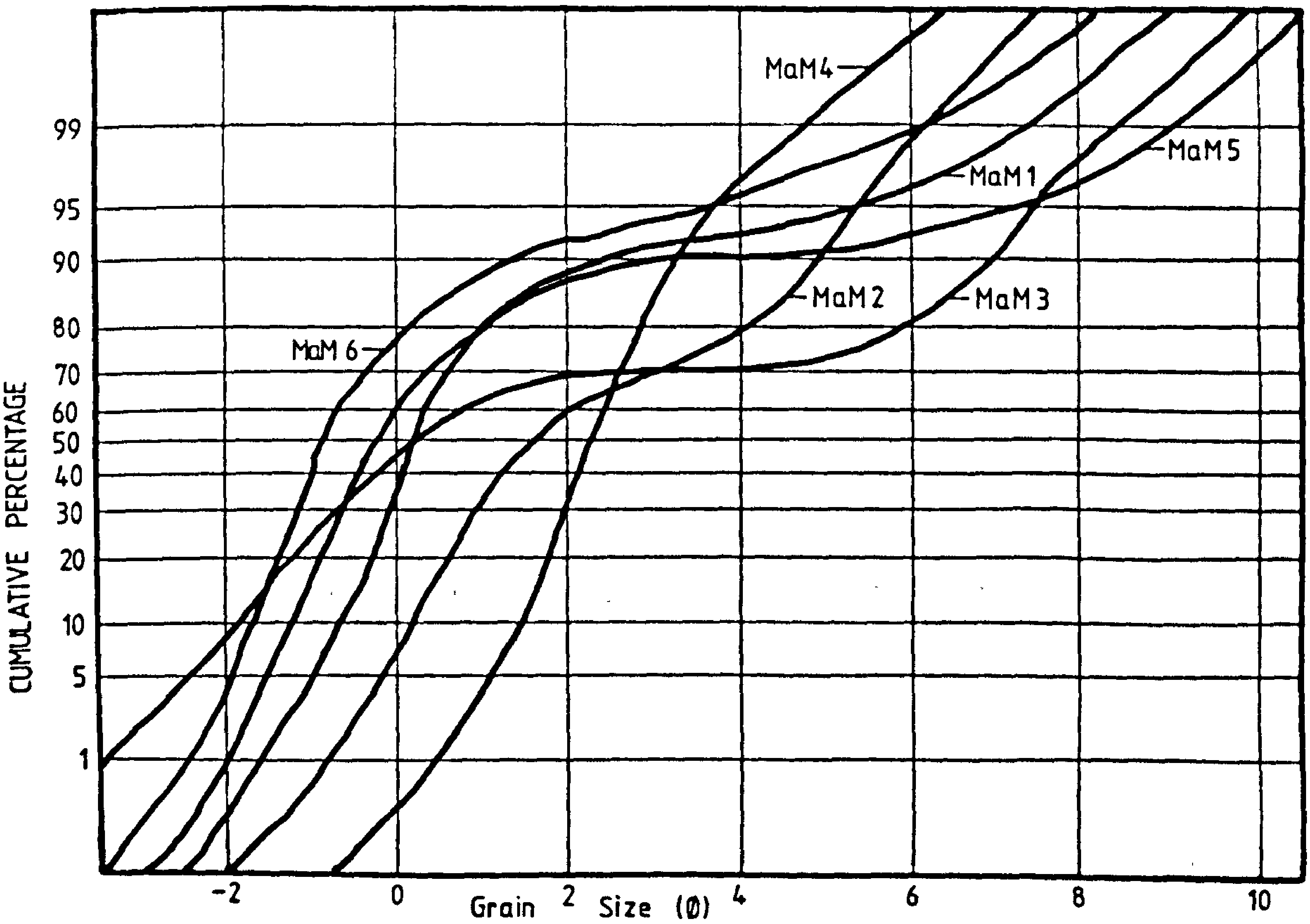
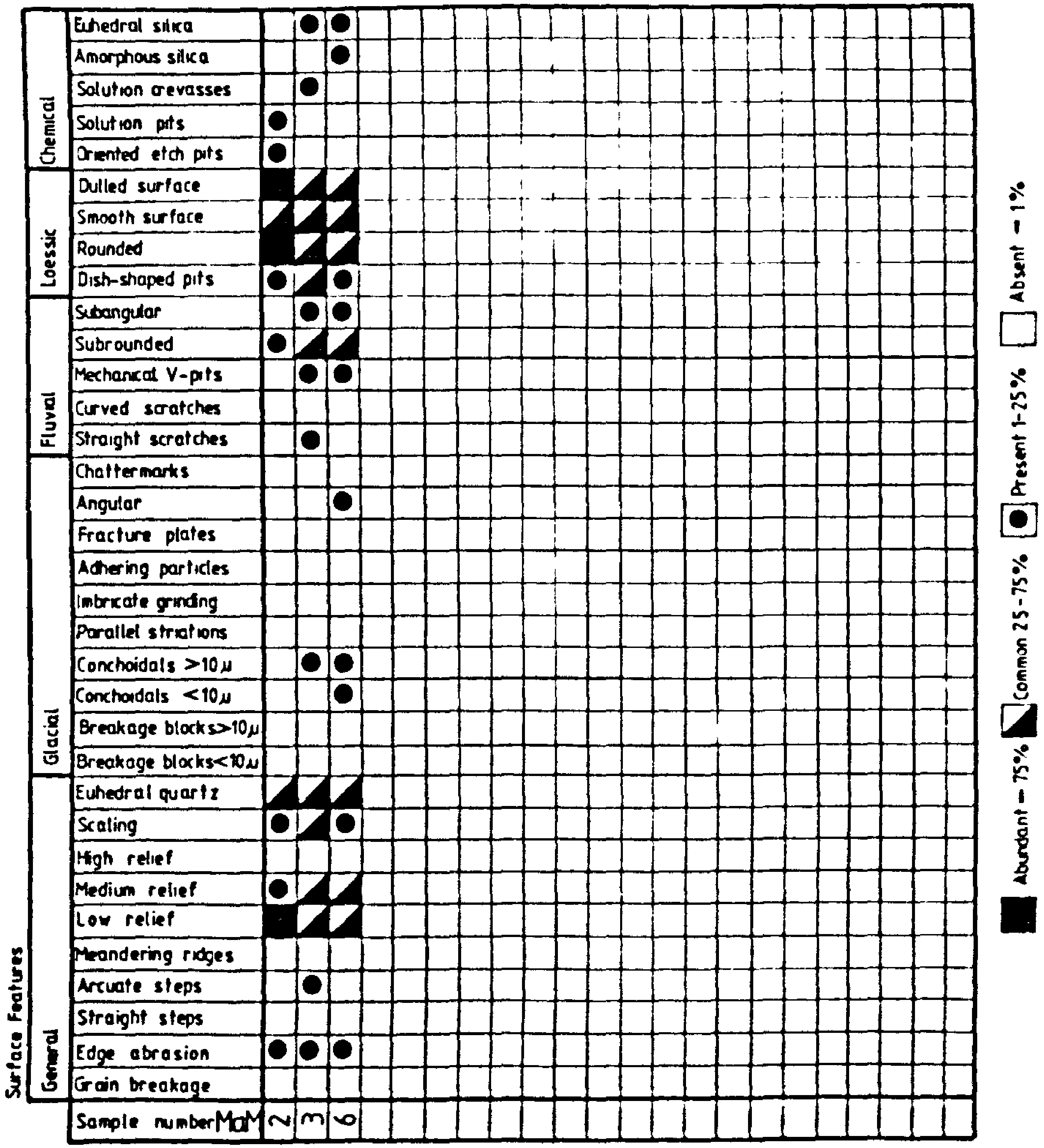


Figure 7.4.7.3. Sediment Size Analysis. Mandale Mine.



Surface Features				
Chemical	Euhedral silica		●	●
	Amorphous silica			●
	Solution crevasses		●	
	Solution pits	●		
	Oriented etch pits	●		
Loessic	Dulled surface	■	◪	◪
	Smooth surface	◪	◪	◪
	Rounded	■	◪	◪
	Dish-shaped pits	●	◪	●
Fluvial	Subangular		●	●
	Subrounded	●	◪	◪
	Mechanical V-pits		●	●
	Curved scratches			
	Straight scratches		●	
Glacial	Chattermarks			
	Angular			●
	Fracture plates			
	Adhering particles			
	Imbricate grinding			
	Parallel striations			
	Conchoidals >10µ		●	●
	Conchoidals <10µ			●
	Breakage blocks>10µ			
	Breakage blocks<10µ			
General	Euhedral quartz	◪	◪	◪
	Scaling	●	◪	●
	High relief			
	Medium relief	●	◪	◪
	Low relief	■	◪	◪
	Meandering ridges			
	Arcuate steps		●	
	Straight steps			
	Edge abrasion	●	●	●
	Grain breakage			
	Sample number MaM	2	3	6

■ Abundant – 75% ◪ Common 25-75% ● Present 1-25% ☐ Absent – 1%

Figure 7.4.7.4. Summary of quartz grain surface textures, Mandale Mine.

Sample Numbers SS 1–4		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	0 — 1
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	50 — 64
	Sandstone	
	Feldspar	0 — 0·5
	Mica	0 — 0·5
	Shale	
	Quartzite	
	Balance (mainly clay)	35 — 49
1 Autochthonous 2 Allochthonous		

Figure 7.4.8.1. Summary of sediment composition, Shining Sough.

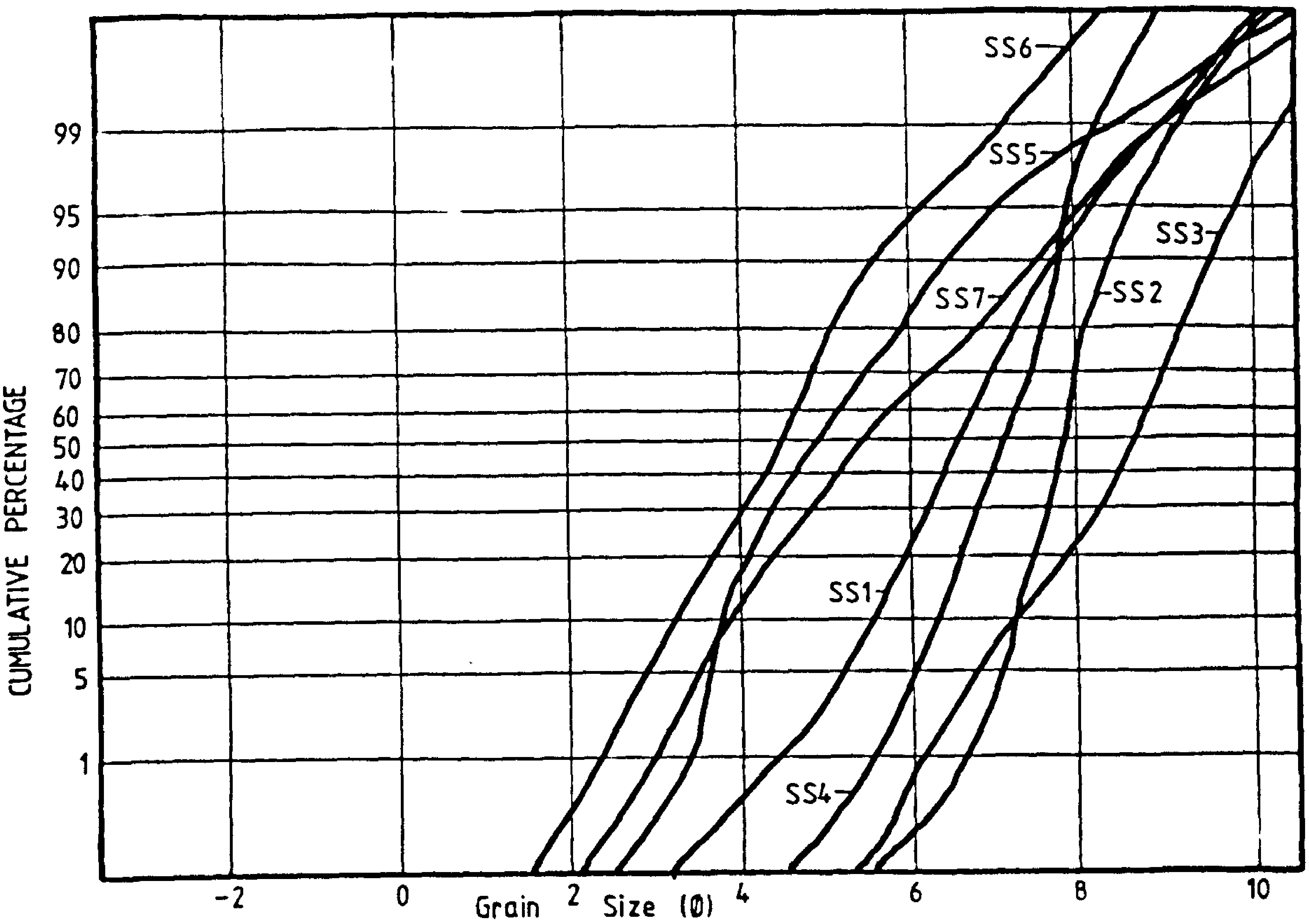


Figure 7.4.8.2. Sediment Size Analysis. Shining Sough.

Chemical	Euhedral silica	●	●			
	Amorphous silica		●			●
	Solution crevasses	●				
	Solution pits	●			●	●
	Oriented etch pits	●			●	
Loessic	Dulled surface	◢	◢			●
	Smooth surface	◢	◢			●
	Rounded	◢	■			●
	Dish-shaped pits	●	◢			
Fluvial	Subangular	●			■	◢
	Subrounded	◢	●		●	◢
	Mechanical V-pits	●			◢	■
	Curved scratches				◢	●
	Straight scratches	●			●	●
Glacial	Chattermarks					
	Angular				●	●
	Fracture plates					
	Adhering particles					
	Imbricate grinding					
	Parallel striations					
	Conchoidals >10µ		●			●
	Conchoidals <10µ	●	●		●	●
	Breakage blocks>10µ					
	Breakage blocks<10µ					
Surface Features General	Euhedral quartz		●		●	
	Scaling	●	◢		●	◢
	High relief				◢	
	Medium relief	◢	●		◢	◢
	Low relief	◢	■		◢	◢
	Meandering ridges				●	
	Arcuate steps					●
	Straight steps		●			
	Edge abrasion	●	●		●	
	Grain breakage				●	
	Sample number SS	1	4		5	7

■ Abundant – 75%
◢ Common 25-75%
● Present 1-25%
□ Absent – 1%

Figure 7.4.8.3. Summary of quartz grain surface textures, Shining Sough.

into the fissures or have been derived by the mechanism of translatory flow.

At the limit of the sough presently accessible (1981) a large pipe vein cavity occurs. It has been modified by phreatic cavernization and contains a solutional collapse breccia overlain by bedded sediments (fig. 7.4.8.4.). The composition of the sediments is given in figure 7.4.8.5..

Size analysis shows that the sediments are moderately well - sorted, slightly fine - skewed, mesokurtic clayey - sands (fig. 7.4.8.2., SS 5-7). The results of S.E.M. study of quartz grain surface textures shows that the sand was derived by fluvial processes (fig. 7.4.8.3., SS 5-7).

The composition of the sands shows that they have been derived from the Namurian strata which overlies the limestone above this locality. The S.E.M. study shows that the derivation was by fluvial processes. Whether the cavity was below the water table until the sough was driven is unknown but it has not operated since.

7.5. Conclusions

Both the Wye Valley and Lathkilldale were cut down to the level of the Hathersage terrace at the start of the Wolstonian glaciation and to their present altitude (that of the Hope terrace) by early Devensian (Beck, 1980). Many of the sites studied are well above the altitude of the Hathersage terrace and were thus formed and probably filled with sediment prior to the Wolstonian glaciation.

The composition of the sediments shows that they were derived from both autochthonous and allochthonous sources.

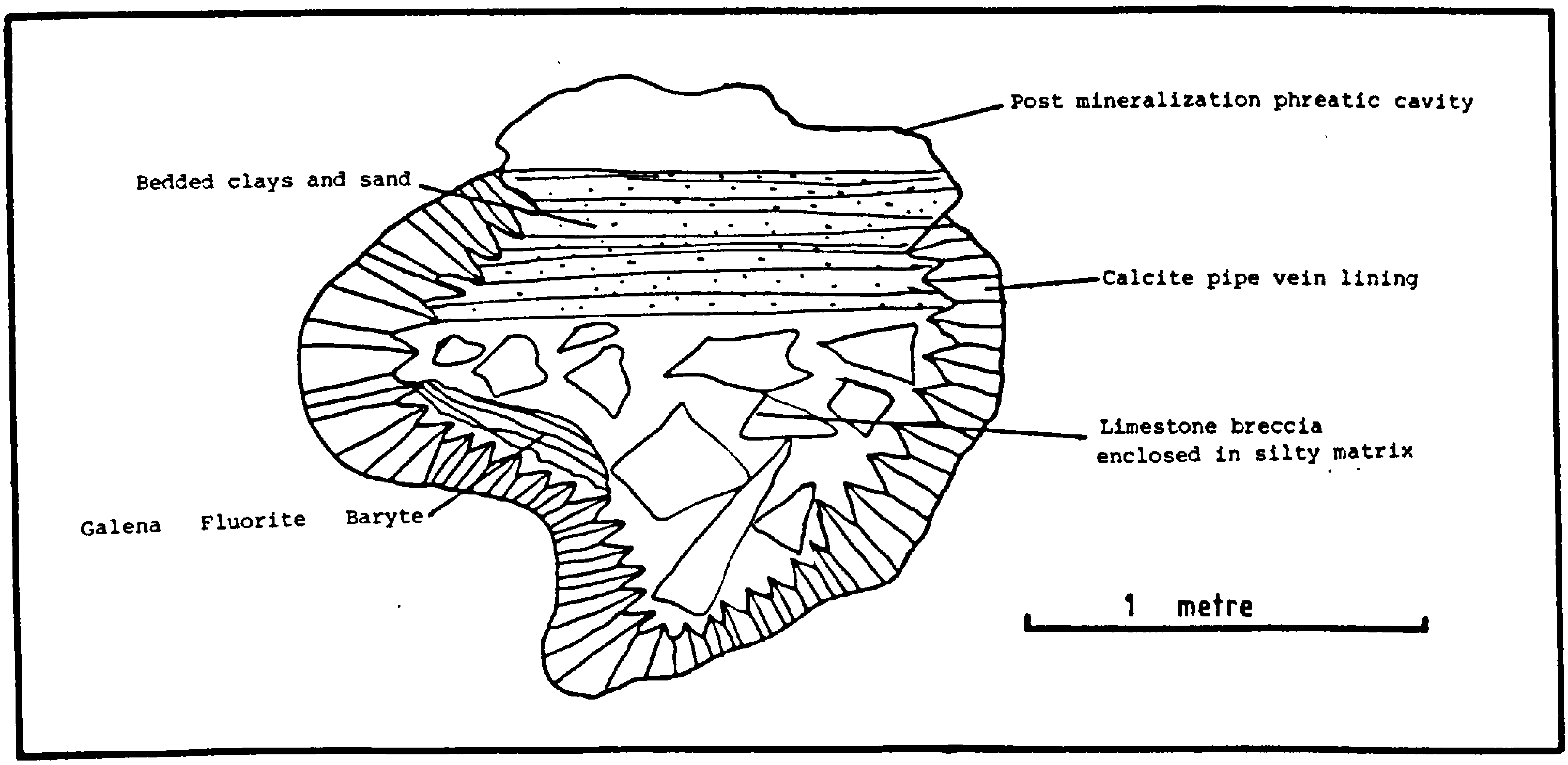


Figure 7.4.8.4. Sediment filled pipe vein cavity, Shining Sough.

Sample Numbers SS 5–7		
		%
1	Limestone	0 — 3
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	0 — 0·5
	Galena	0 — 0·5
	Fluorite	
	Baryte	0 — 0·5
	Calcite	0 — 1
2	Quartz	67 — 85
	Sandstone	
	Feldspar	1 — 3
	Mica	0 — 2·5
	Shale	0 — 0·5
	Quartzite	
	Balance (mainly clay)	11 — 28

1 Autochthonous 2 Allochthonous

Figure 7.4.8.5. Summary of sediment composition, Shining Sough.

The autochthonous fraction of the sediments consists of fluorite, baryte, calcite, galena, limestone, chert and authigenic quartz clasts and some clay.

The allochthonous fraction consists of shale and sandstone clasts, quartz sand, silt and clay derived from a former cover of Namurian sediments. In may of the deposits reworked loessic silt is present.

Size analysis shows that the sediments are highly varied in character reflecting differing autochthonous and allochthonous fractions.

S.E.M. studies show that the sediments have been derived by fluvial and aeolian processes. Fluvio - glacial sediments have not been recognised.

The sediments in cavities in Long Rake Spar Mine and in Water Icicle Close Cavern indicate that at the time that they were deposited the limestone/shale boundary, or at least an outlier of Namurian sediments, existed in the Monyash area from which the sediments were derived by fluvial processes.

The abandonment of these caves as part of the underground drainage network may have occurred when the Namurian sediments were removed by glacial activity and no allogenic streams flowed onto the limestone. All present drainage in the Monyash area is by percolation to deep cave systems eventually draining to Lathkill Head Cave.

The angular chert gravel found in the cavities of Mandale Mine represents the accumulation of the insoluble fraction from the cherty limestone wall rocks. Later introduction of reworked loessic silt filled the spaces between the chert clasts forming the silty matrix.

Many of the sediments studied consist of reworked loessic silt infilling solutionally enlarged joints and pipe vein cavities where it often forms the matrix to a solutional collapse breccia of mineral vein material. The loessic silt has been carried underground by percolating water from surface deposits by the mechanism of translatory flow postulated by Bull (1981b).

The lack of sediments in recently abandoned and active caves systems in the area is explained by the lack of insoluble clastic sediments in the area.

Recent sediments are found in Poole's Cavern which still carries a stream draining from Namurian strata to the southwest of Buxton.

8. THE MENDIPS, YORKSHIRE DALES AND NORTHERN PENNINES

8.1. Introduction

During the course of this study a number of sites in other British Carboniferous Limestone areas were visited to enable comparisons to be made with the deposits in the Peak District. These were the Mendip Hills, the Yorkshire Dales and the Northern Pennines (fig. 8.1.1.).

All three areas have limestones of similar age and lithology to those of the Peak District. In all these areas the limestones host Mississippi Valley type lead - zinc mineralization. The development of karsts has also occurred in all the areas with the extensive development of cave systems.

The glacial history of each area is distinctly different. The Mendips do not appear to have undergone active glaciation in late Pleistocene times though they may have been buried beneath a snow field (Smith, 1975). They may have been covered by ice sheets in earlier Pleistocene glaciations (Green and Welch, 1965). In contrast to the Peak District both the Northern Pennines and the Yorkshire Dales were glaciated during the last glaciation (Edwards and Trotter, 1954).

8.2. The Mendip Hills

8.2.1. Introduction

The Mendip Hills are situated in southwestern England and stretch from Frome westwards to the Bristol Channel as a

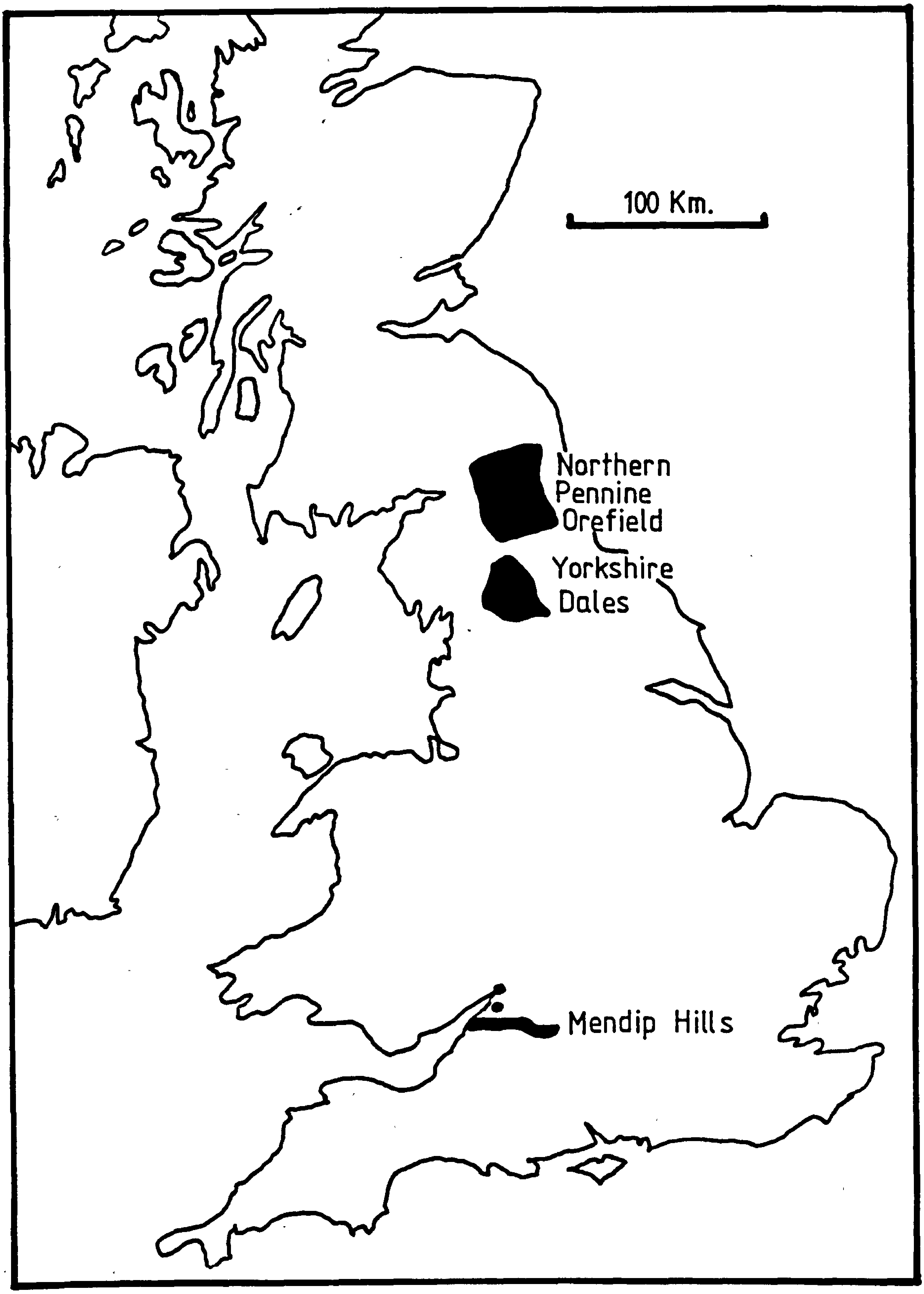


Figure 8.1.1. Location map.

band no more than 10 km. wide (fig. 8.2.1.1.). Between the Mendips and the Avon Gorge at Bristol there are several complex inliers of Carboniferous Limestone.

8.2.2. Geology

The Mendip Hills can simply be described as a series of domal structures arranged en echelon with an east - west trend. The structural history is complicated by thrusts and klippen (Green and Welch, 1965).

The cores of the anticlines consists of Old Red Sandstone (Devonian) varying from mudstones to conglomerates (Smith, 1975b). In total about 500 metres of Old Red Sandstone is exposed but this is reduced to about 400 metres where it overlies Silurian volcanics in eastern Mendip (Green and Welch, 1965).

In these sediments rounded hematite coated quartz sand grains are dominant. Minor feldspar is also present. Some horizons of the finer grained units are micaceous with muscovite mica present.

The base of the Lower Carboniferous succession is marked by the Lower Limestone Shales. These vary from 120 to 150 metres in thickness (Green and Welch, 1965) and mark the transition from a continental to a marine environment. They consist of dark grey shales with interbedded limestone horizons.

The shales are overlain by over 1000 metres of limestones (Kellaway and Welch 1955).

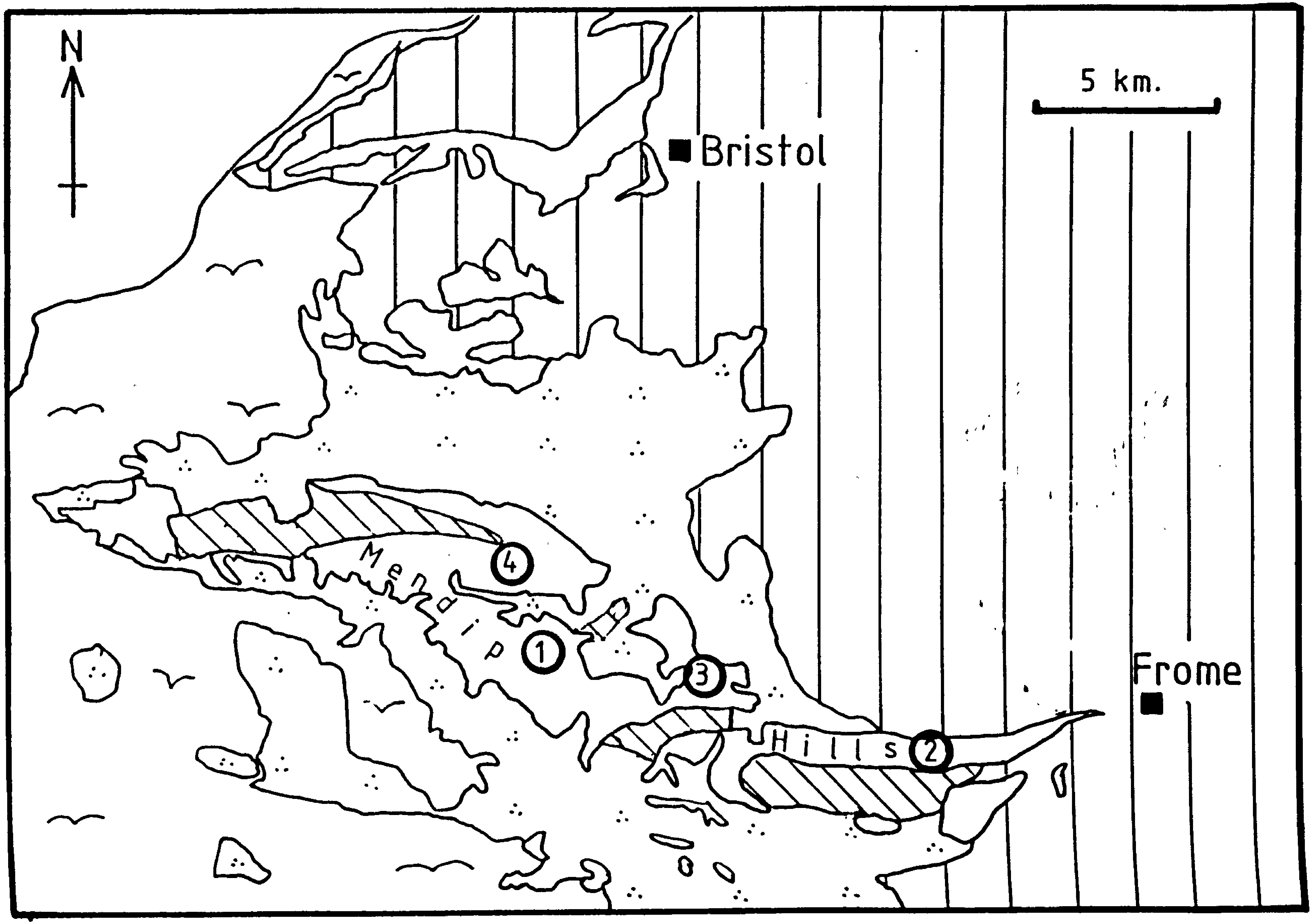
The lowest limestone unit is the Black Rock Group. This varies in thickness from 250 to 300 metres. It is dominantly

Figure 8.2.1.1. Geological sketch map of the Mendip Hills.

⌒	Alluvium
▥	Cretaceous and Jurassic sediments
∴	Triassic sediments
□	Carboniferous Limestone
▧	Old Red Sandstone

Key to localities

1 Swildons Hole
2 Whatley Quarry Cave
3 Lamb Leer Cavern
4 Glebe Swallet


N
5 km.
Bristol
Mendip Hills
①
②
③
④
Frome

composed of dark grey to black bioclastic crinoidal limestone. Locally chert is abundant as beds and irregular bedding orientated masses (Green and Welch, 1965).

Many of the active cave systems of the area are developed in this group because it is the first limestone horizon that streams rising on the higher Old Red Sandstone ground encounter.

The Black Rock Group is overlain by the Clifton Down Group. This group ranges in thickness from 300 to 400 metres. It is lithologically varied. The lower part of the succession (the Burrington Oolite) is an oolitic limestone with few fossils, with occasional calcic mudstone and crinoidal debris horizons (Green and Welch, 1965).

This is overlain by the Clifton Down Limestone which varies in character from oolitic to calcic mudstones. Chert is locally dominant. The limestones are pale to dark grey in colour and usually are massively bedded (Green and Welch, 1965). Locally volcanic rocks are found in this group.

The highest limestone formation is the Hotwells Group which is up to 150 metres thick. It is a massively bedded, pale grey crinoidal bioclastic limestone. Chert is occasionally present.

The limestone is overlain by Upper Carboniferous strata consisting of less than 60 metres of Namurian sandstones and shales and about 3000 metres of Westphalian and Stephanian Coal Measures. Both of these units are poorly represented in the Mendip area, often being obscured by later sediments (Green and Welch, 1965).

Following the deposition of the Coal Measures sedimentation ceased and the area was subjected to marked tectonic activity followed by sub - aerial erosion and deposition (Smith, 1975b). This left the Mendips as a range of hills flanked and partly covered by Triassic deposits and they were not completely buried until the mid Jurassic.

The limestone was deeply incised by steep sided valleys which were filled with the Dolomitic Conglomerate during the Triassic. This conglomerate comprises large angular to sub - rounded limestone boulders in a marly, calcareous matrix. The conglomerate also flanks the hills in many areas and is sometimes found overlying the Old Red Sandstone on the top of the hills (Green and Welch, 1965).

This is overlain by Keuper Marl which is a calcareous mudstone.

To the north and east of the Mendips a thin sequence of Jurassic sediments overlaps the Triassic rocks onto the limestone which was not totally covered until Inferior Oolite times.

Mineralization is widespread throughout the area in the form of lead - zinc - calcite concentrations in joints, both in the Carboniferous Limestone and in the Triassic Dolomitic Conglomerate (Green, 1958). Larger veins and more intense mineralization are more restricted and occur in several distinctive areas in the central Mendips generally at or close to the sub - Triassic unconformity (Green, 1958 and Alabaster, 1982).

The mineralization consists of epigenetic galena, sphalerite and calcite veins often exhibiting a banded structure. These are up to 2.5 metres wide though generally 0.3 to 1.2 metres wide (Alabaster, 1982). Large calcite veins, up to 5 metres wide, are also present in the eastern

Mendips.

Secondary calamine deposits are also present. They were formed by the alteration of sphalerite to calamine and are found in the upper parts of the lead - zinc veins and in solution cavities adjacent to the veins (Alabaster, 1982).

Mineralisation is also present in the Lower Lias and Upper Inferior Oolite where veins pass from the Carboniferous to the Jurassic rocks without break. This indicates that mineralization continued well into the middle Jurassic if not later (Alabaster, 1982).

8.2.3. Types of Deposit

Two distinct types of deposit were examined. Firstly sediment accumulations within an active cave system and secondly, a number of deposits associated with primary mineral deposits.

The active cave systems of the Mendips all take water from catchments on the Old Red Sandstone which sink down swallets close to the base of the limestone, often at the end of a shallow blind valley. Once underground the streams flow down the dip slope at the base of the limestone, to the water table, sometimes eroding into the Lower Limestone shales. When this has been reached, often at depths of over 130 metres, drainage makes its way stratigraphically up the limestone succession to resurgences developed near to the top of the limestone close to the Triassic unconformity.

Some caves were developed close to the surface of the present plateau as the Mendips were exhumed from their Mesozoic cover.

The deposits that are associated with the mineral veins are found in solutionally enlarged veins and adjacent cavities. They consist of residual blocks of vein material in a silty matrix. Many of the lead mines probably mined this type of deposit (Dewey, 1921) and records exist of the discovery of large cavities during mining operations (Gough, 1930), including Lamb Leer Cavern (Tratman, 1975) and Pen Park Hole (Tratman, 1963).

8.2.4. Sites Studied

8.2.4.1. Swildon's Hole

This extensive cave system, consisting of active and abandoned cave passages carries a stream which sinks at ST 5312.5131, the only entrance to the system (Barrington and Stanton, 1977). Samples were collected from both the active stream (fig. 8.2.4.1.1., SW 1 - 5) and now inactive passages (fig. 8.2.4.1.1., SW 6 - 8).

The cave is developed in limestones of the lower part of the Black Rock Group and the stream has occasionally cut down into the Lower Limestone Shale.

The limestones are dark grey to black, thinly bedded, cherty, slightly crinoidal bioclastic limestones. Parts of the cave are developed in locally faulted and folded limestones.

The sediments in the active stream are coarse gravels composed mainly of well rounded limestone and Old Red Sandstone pebbles (fig. 8.2.4.1.2.).

Size analysis shows that the sediments are moderately

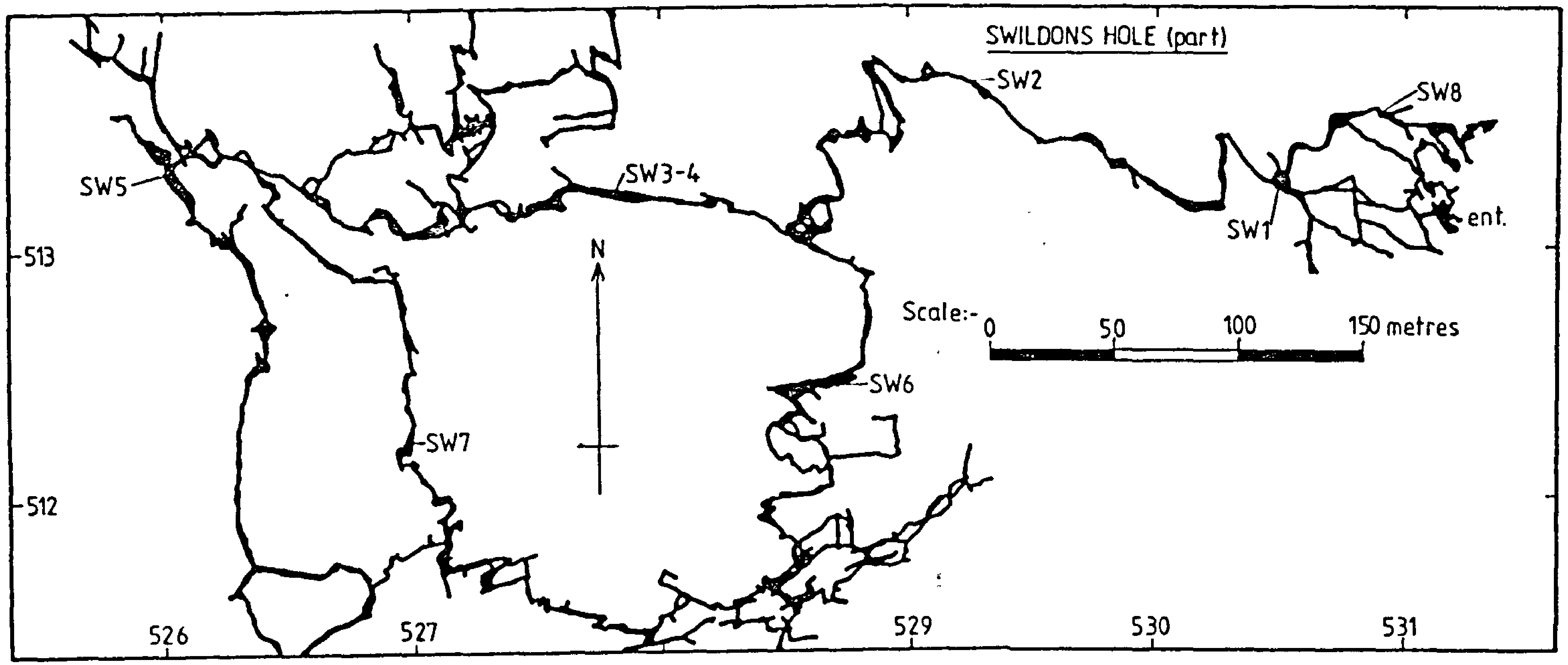


Figure 8.2 411 Plan of part of Swildons Hole showing sample locations

Sample Numbers SW 1– 5		
		%
1	Limestone	48 — 73
	Dolomite	
	Volcanics	
	Chert	9 — 18
	Silicified fossils	
	Authigenic quartz	
	Lower Limestone Shale	0 — 11
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	0 — 15
	Sandstone	15 — 41
	Feldspar	
	Mica	
	Shale	
	Quartzite	
	Balance (mainly clay)	
1 Autochthonous 2 Allochthonous		

Figure 8.2.4.1.2. Summary of sediment composition, Streamway, Swildon's Hole.

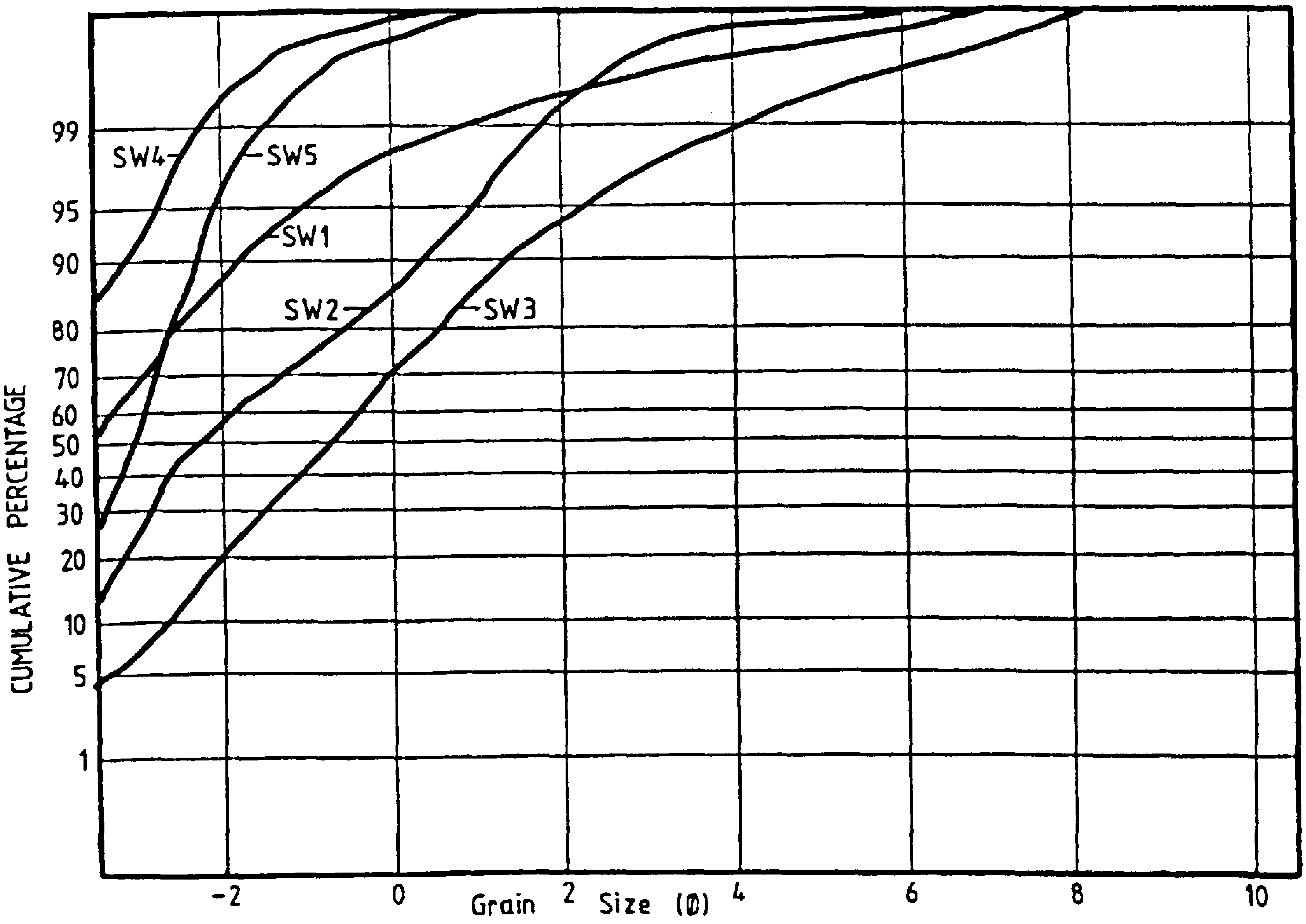


Figure 8.2.4.1.3. Sediment Size Analysis. Streamway Swildon's Hole.

well sorted, fine - skewed, mesokurtic pebble gravels (fig. 8.2.4.1.3.).

The sediments collected from the abandoned parts of the cave system are clayey - silts, the composition of which is given in figure 8.2.4.1.4..

Size analysis shows that these sediments are well sorted, slightly fine - skewed, mesokurtic clayey - silts (fig. 8.2.4.1.5.).

The results of S.E.M. study of quartz grain surface textures shows that they exhibit a well rounded shape but with extensive solutional features and quartz overgrowth (fig. 8.2.4.1.6.). These features indicate that these sediments were derived from the Old Red Sandstone outcrop.

The sediments of Swildon's Hole are derived from two sources. The limestone and Lower Limestone Shale within the cave and externally from the Old Red Sandstone. The fine grained nature of the sediments in the abandoned passages indicates that they were deposited by ponded flood waters, probably as the present streamway was in the early stages of development. The coarse - grained nature of the present deposits is due to winnowing of the finer fraction by the stream.

8.2.4.2. Whatley Quarry Cave

A small cave was revealed by quarrying operations during 1977 in the south side of Whatley Quarry (ST 747,475). The cave was developed in well bedded Clifton Down Group limestones dipping at 45^{o} to the southwest along a small fault of negligible throw (fig. 8.2.4.2.1.). The Jurassic

Sample Numbers SW 6 − 8		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0 — 1·5
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	43 — 68
	Sandstone	0 — 1·5
	Feldspar	1·5 — 2·5
	Mica	0 — 0·5
	Shale	1 — 3
	Quartzite	
	Balance (mainly clay)	26 — 51
1 Autochthonous 2 Allochthonous		

Figure 8.2.41.4. Summary of sediment composition, St Paul's Series, Swildon's Hole.

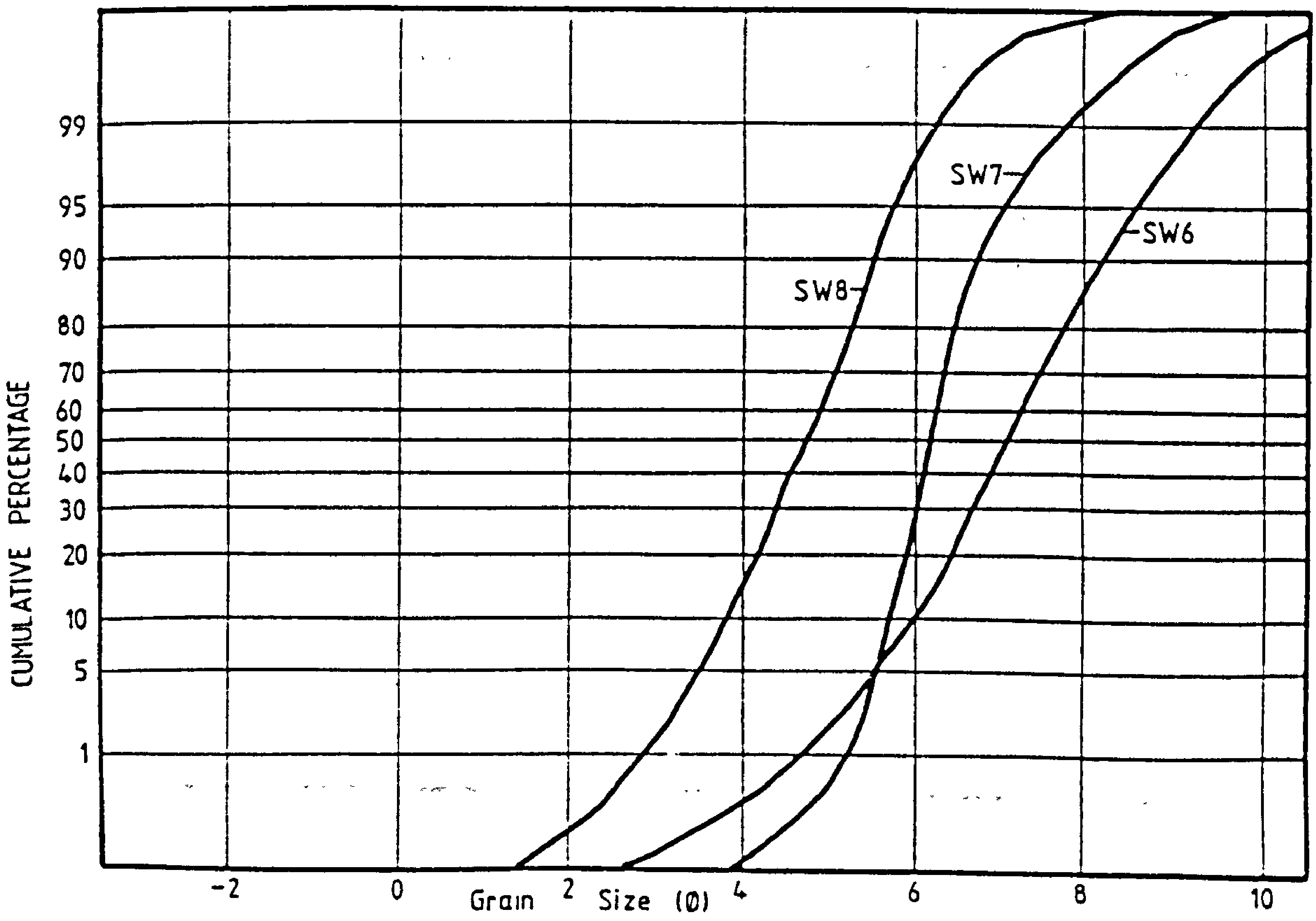
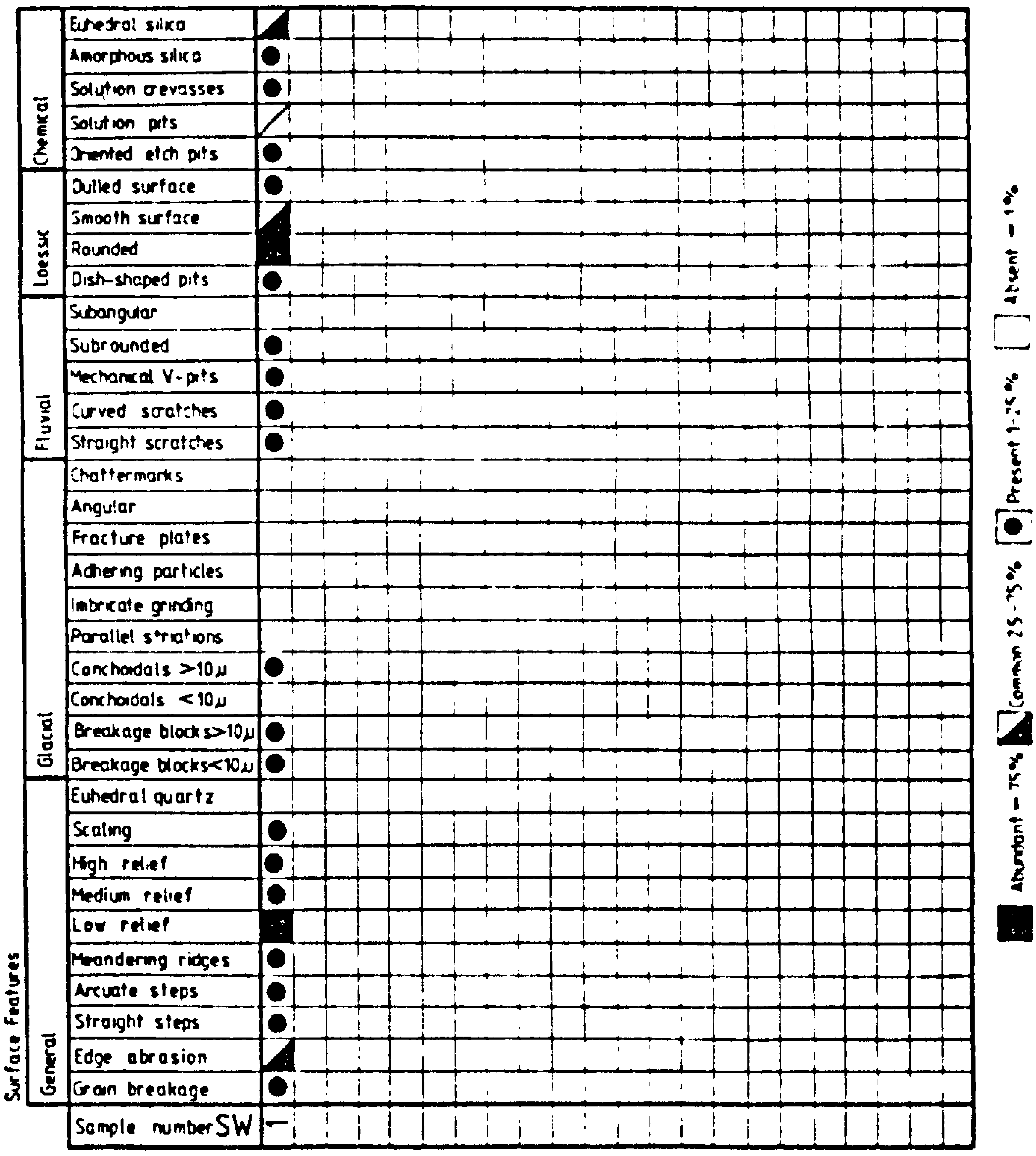


Figure 8.2.41.5. Sediment Size Analysis, St Paul's Series, Swildon's Hole.



Surface Features	Chemical	Euhedral silica	◢
		Amorphous silica	●
		Solution crevasses	●
		Solution pits	◢
		Oriented etch pits	●
	Loessic	Dulled surface	●
		Smooth surface	◢
		Rounded	■
		Dish-shaped pits	●
	Fluvial	Subangular	
		Subrounded	●
		Mechanical V-pits	●
		Curved scratches	●
		Straight scratches	●
	Glacial	Chattermarks	
		Angular	
		Fracture plates	
		Adhering particles	
		Imbricate grinding	
		Parallel striations	
		Conchoidals >10μ	●
		Conchoidals <10μ	
		Breakage blocks>10μ	●
		Breakage blocks<10μ	●
	General	Euhedral quartz	
		Scaling	●
		High relief	●
		Medium relief	●
		Low relief	■
		Meandering ridges	●
		Arcuate steps	●
		Straight steps	●
		Edge abrasion	◢
		Grain breakage	●
		Sample number SW	1

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% □ Absent – 1%

Figure 8.2.4.1.6. Summary of quartz grain surface textures, Swildon's Hole.

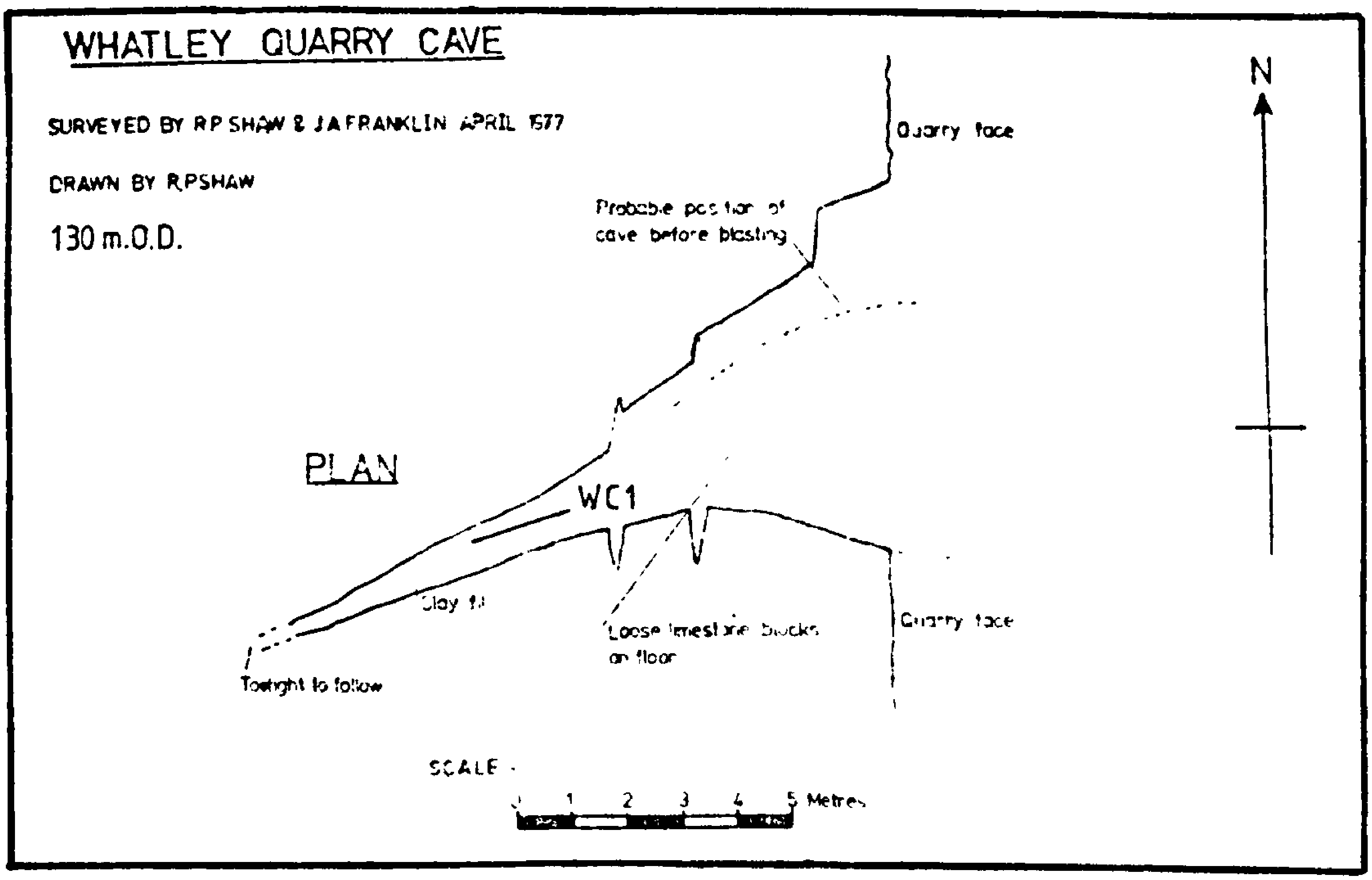


Figure 8.2.4.2.1. Plan of Whatley Quarry Cave showing sample location.

unconformity is exposed in the north face of the quarry and would have been less than 30 metres above the cave.

The cave was of phreatic origin with large scallops indicating a flow direction to the northeast.

The cave is choked with a pale green silty sand, the composition of which is given in figure 8.2.4.2.2.. It contains fossils derived from the Fullers Earth (Jurassic), the nearest present outcrop of which is about 2 km. to the southeast.

Size analysis shows that the sediments are poorly sorted, platykurtic silty - sands (fig. 8.2.4.2.3.).

The derived fossils show that the sediments were derived mainly from the Fullers Earth before it was removed from this area.

8.2.4.3. Lamb Leer Cavern

Lamb Leer Cavern was discovered by lead miners around 1674 (Barrington and Stanton, 1977) working lead veins from a shaft at ST 5432,5505. Old lead workings and some natural passages lead from the shaft to a ledge part way up the Great Chamber (fig. 8.2.4.3.1.) from the floor of which a number of heavily silted natural passages lead.

The floor of the Great Chamber is composed of angular breakdown blocks with occasional loose galena lumps within the smaller debris.

The composition of silts collected from the passages close to the Great Chamber is given in figure 8.2.4.3.2..

Size analysis shows that the sediments are poorly sorted, slightly coarse-skewed leptokurtic silts (fig.

	Sample Numbers WQ 1	
		%
1	Limestone	8
	Dolomite	
	Volcanics	
	Chert	3·5
	Silicified fossils	3
	Authigenic quartz	
	Derived Fullers Earth fossils	7
	Galena	
	Fluorite	
	Baryte	
	Calcite	
2	Quartz	59
	Sandstone	
	Feldspar	1·5
	Mica	
	Shale	
	Quartzite	1
	Balance (mainly clay)	17
	1 Autochthonous 2 Allochthonous	

Figure 8.2.4.2.2. Summary of sediment composition, Whatley Quarry Cave.

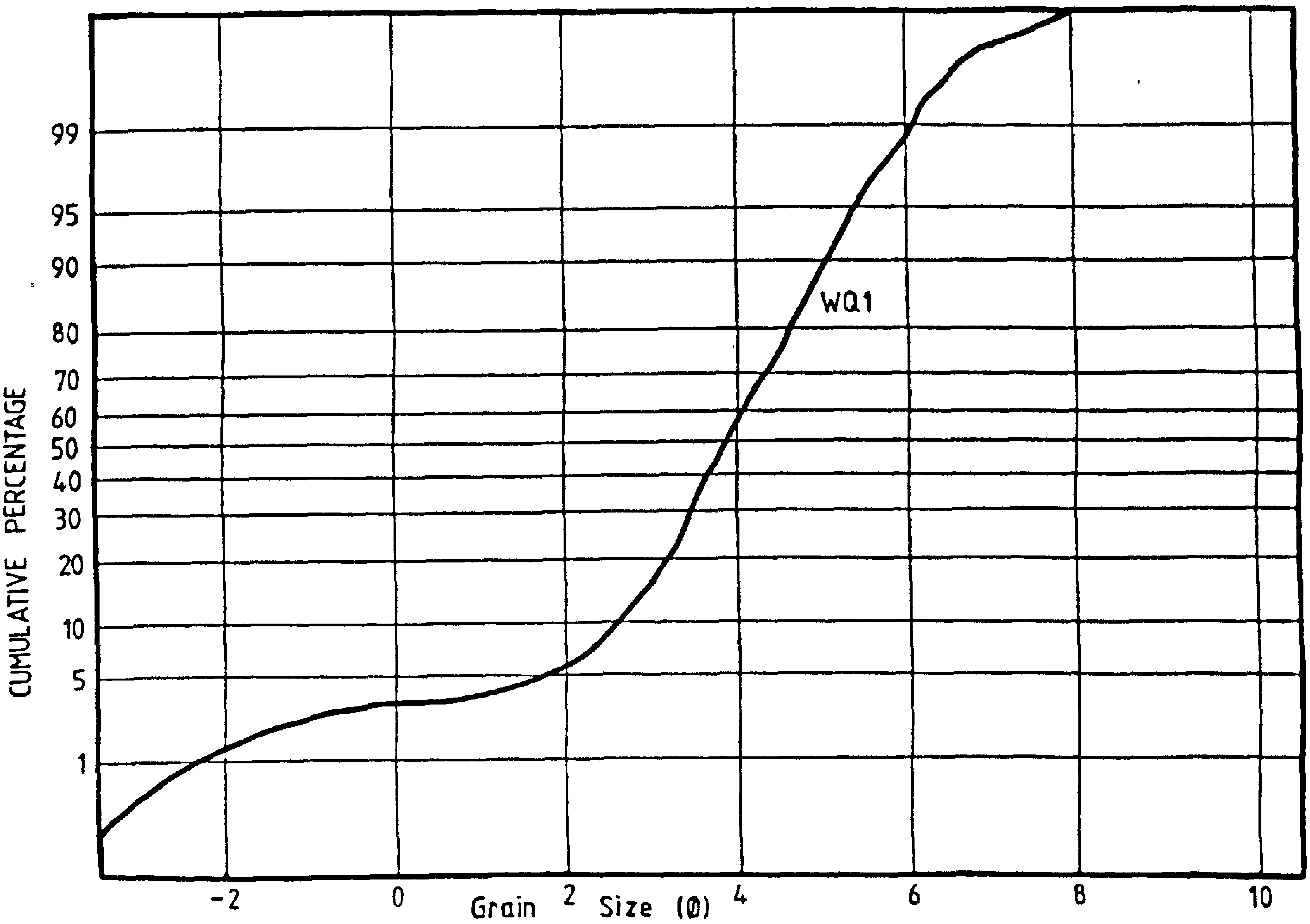


Figure 8.2.4.2.3. Sediment Size Analysis. Whatley Quarry Cave.

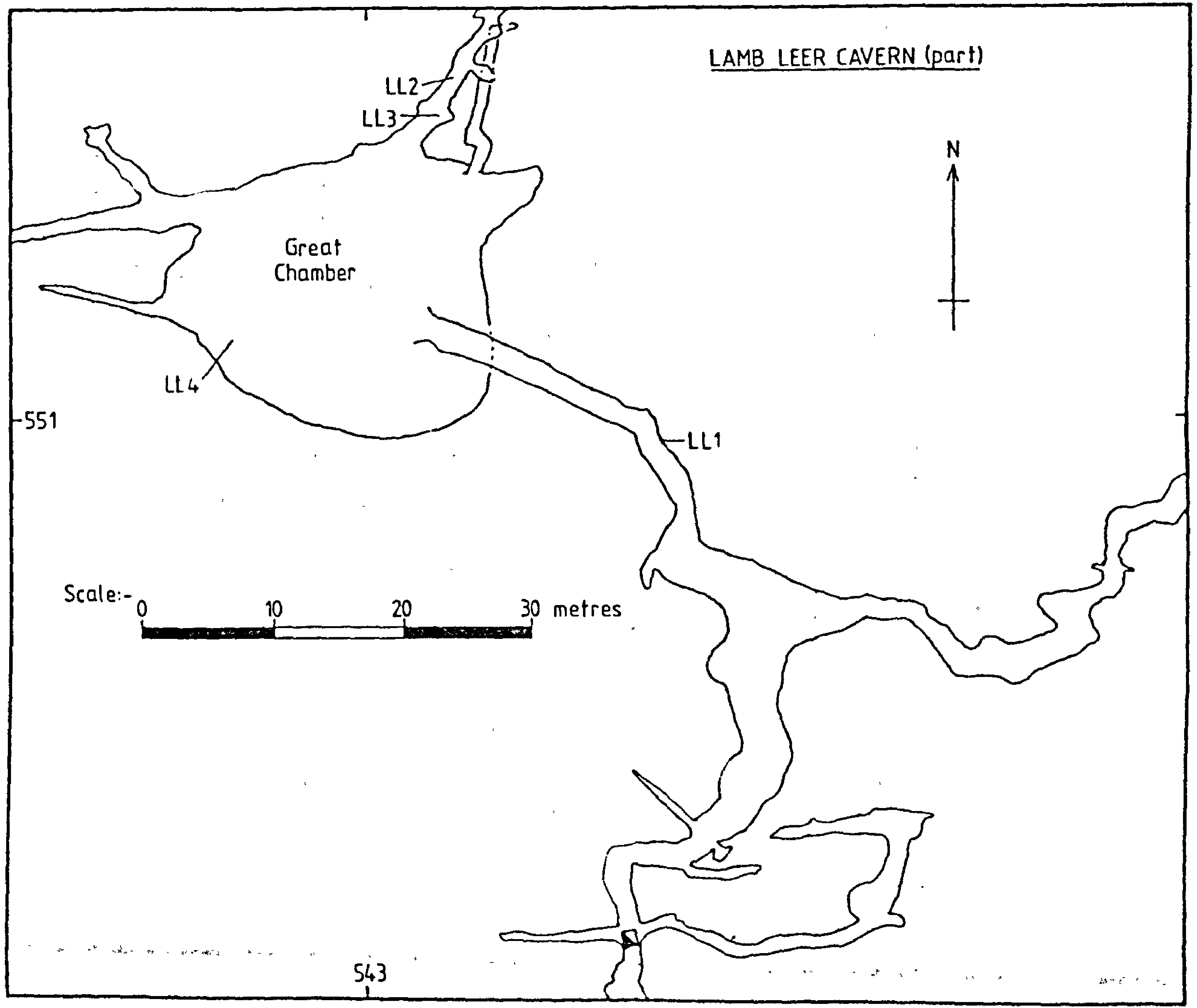


Figure 8.2.4.3.1. Plan of part of Lamb Leer Cavern showing sample locations.

Sample Numbers LL 1–4

		%
1	Limestone	0 — 0·5
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	
	Authigenic quartz	
	Galena	0 — 0·5
	Fluorite	
	Baryte	
	Calcite	05 — 3·5
2	Quartz	67 — 84
	Sandstone	1 — 3
	Feldspar	0 — 1
	Mica	1 — 2·5
	Shale	
	Quartzite	
	Balance (mainly clay)	9 — 29

1 Autochthonous 2 Allochthonous

Figure 8.2.4.3.2.Summary of sediment composition, Lamb Leer Cavern.

8.2.4.3.3.). The results of S.E.M. study of the quartz grain surface structures shows that the sediments have been derived from an aeolian silt (fig. 8.2.4.3.4.).

The relative lack of quartz overgrowth may indicate that the source of this sediment was the Keuper Marl rather than the Old Red Sandstone. The fine - grained nature of the silts also supports this idea.

8.2.4.4. Glebe Swallet

Glebe Swallet, also known as Grebe Swallet, is situated at ST 5044,5550. It was opened up on the 10th July 1968 by severe flooding. It consists of a series of rift passages developed along minor mineral veins which show evidence of past mining activity in the form of sockets cut for stemples.

The rifts, up to 0.6 metres wide, are filled with a silty gravel containing galena. This was the ore worked by the miners (Stanton, pers. comm.).

The alluvial fill consists of a breccia with a silty matrix, the composition of which is given in figure 8.2.4.4.1..

Size analysis shows that the unbedded fill of these rifts is a poorly sorted, fine - skewed, platykurtic, silty-breccia (fig. 8.2.4.4.2.).

The nature of these deposits indicates that they are probably of solifluction origin and that they flowed into solutionally enlarged mineral veins. There is some evidence to suggest that the original location of the mineralization was controlled by neptunian dykes of Triassic age (Stanton, pers. comm.). Remnants of Triassic marl still adhere to the

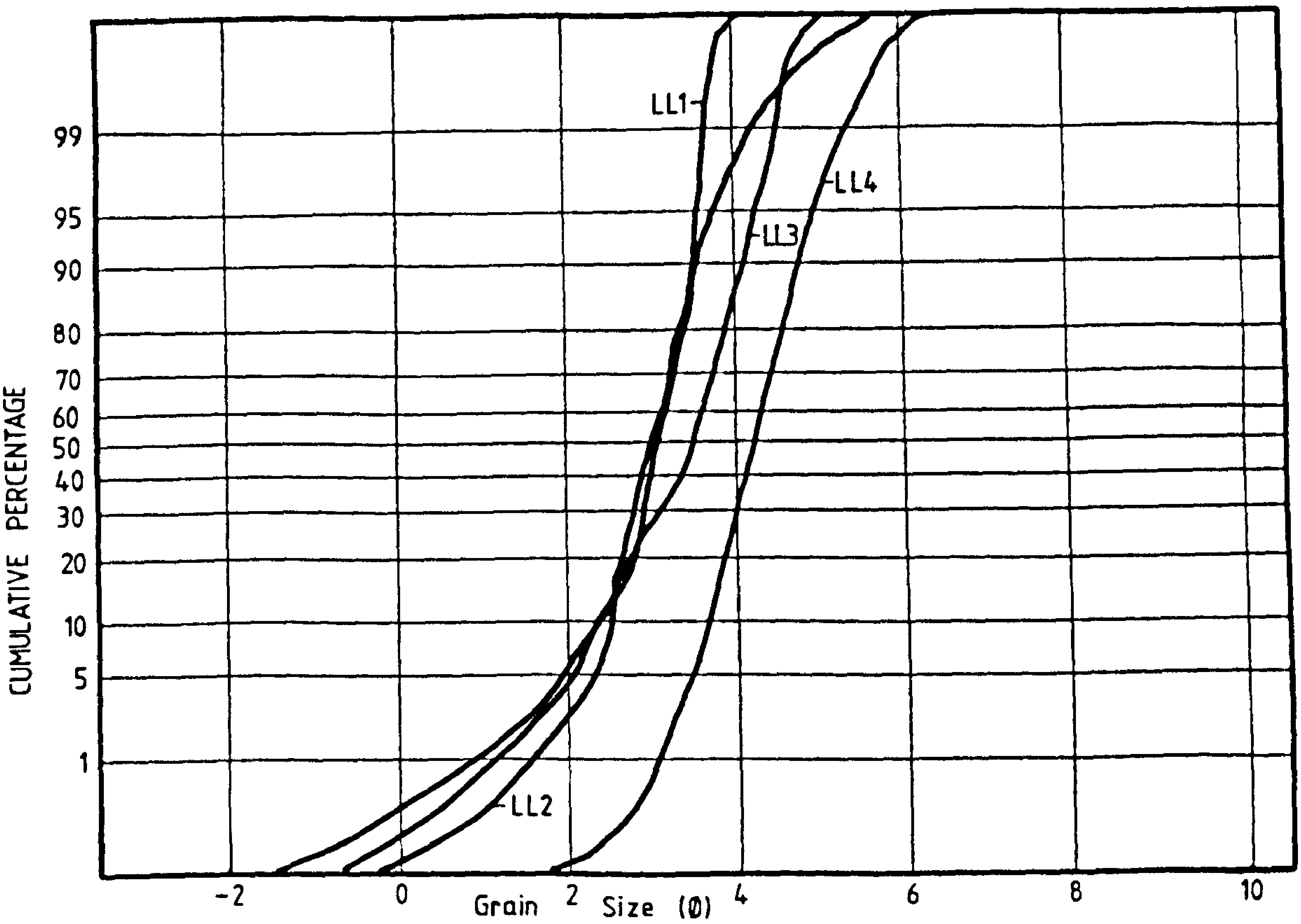


Figure 8 2 4 3 3 Sediment Size Analysis. Lamb Leer Cavern.

Surface Features	Chemical	Euhedral silica	●
		Amorphous silica	●
		Solution crevasses	
		Solution pits	●
		Oriented etch pits	
	Loessic	Dulled surface	◪
		Smooth surface	◪
		Rounded	◪
		Dish-shaped pits	●
	Fluvial	Subangular	●
		Subrounded	●
		Mechanical V-pits	●
		Curved scratches	●
		Straight scratches	●
	Glacial	Chattermarks	
		Angular	
		Fracture plates	
		Adhering particles	
		Imbricate grinding	
		Parallel striations	
		Conchoidals >10µ	●
		Conchoidals <10µ	●
		Breakage blocks>10µ	
		Breakage blocks<10µ	
	General	Euhedral quartz	
		Scaling	◪
		High relief	
		Medium relief	●
		Low relief	■
		Meandering ridges	●
		Arcuate steps	●
		Straight steps	●
		Edge abrasion	●
		Grain breakage	●
		Sample number LL	3

■ Abundant – 75% ◪ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 8.2.4.3.4. Summary of quartz grain surface textures, Lamb Leer Cavern.

Sample Numbers GLS 1—2		
		%
1	Limestone	5 — 27
	Dolomite	
	Volcanics	
	Chert	1 — 14
	Silicified fossils	
	Authigenic quartz	
	Galena	0 — 12
	Fluorite	
	Baryte	
	Calcite	0 — 2
2	Quartz	27 — 41
	Sandstone	17 — 43
	Feldspar	1 — 1·5
	Mica	0 — 0·5
	Shale	0 — 2·5
	Quartzite	
	Balance (mainly clay)	7 — 11
1 Autochthonous 2 Allochthonous		

Figure 8.2.4.4.1. Summary of sediment composition, Glebe Swallet.

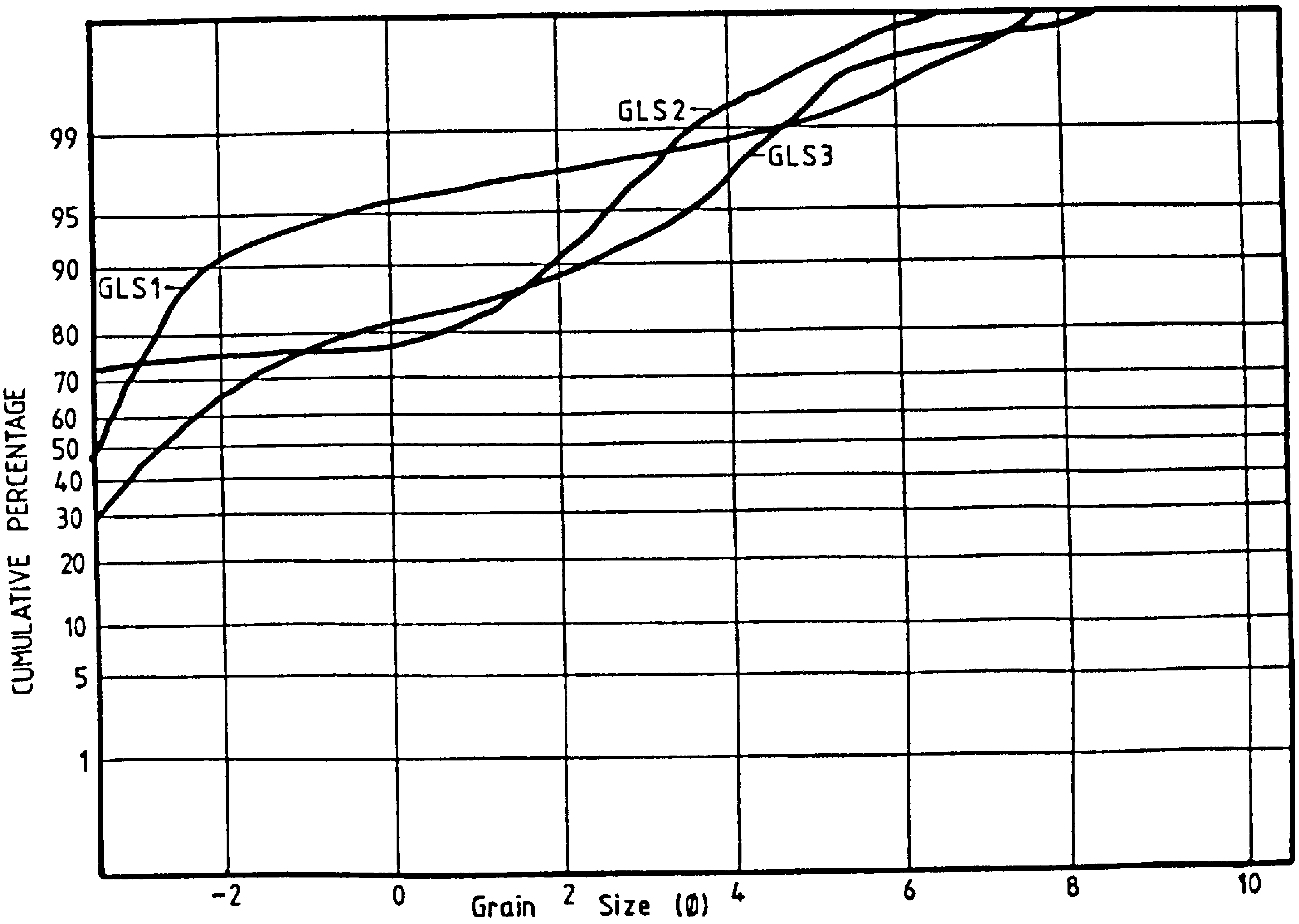
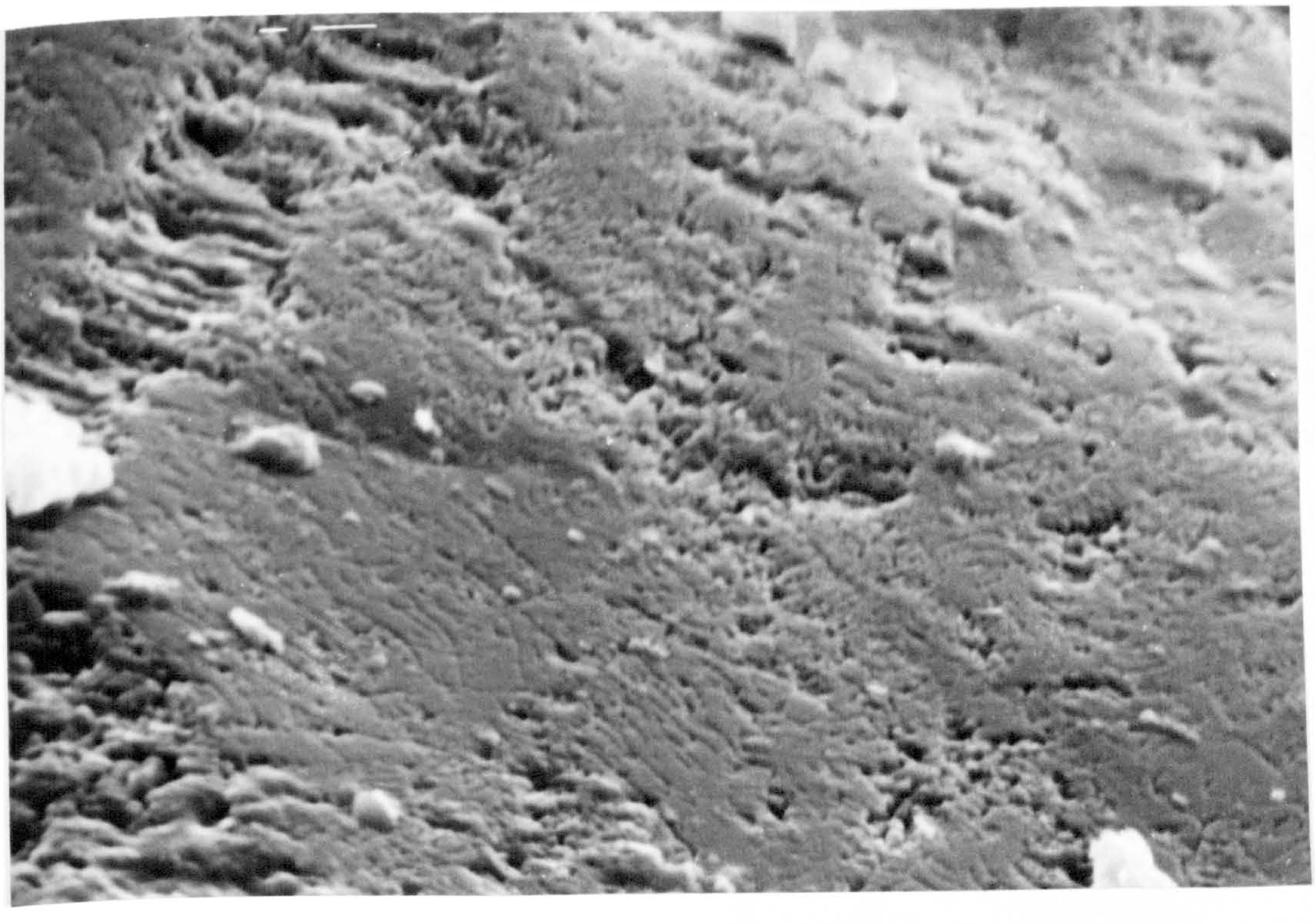


Figure 8.2.4.4.2. Sediment Size Analysis. Glebe Swallet.

100 µm.

8.2.4.3.1. S.E.M. photomicrographs of typical aeolian quartz grains, Lamb Leer Cavern.



1 µm.

8.4.4.3.1. S.E.M. photomicrograph of part of a fluvio - glacial quartz grain, Silverband Mine.

rift walls in a few places.

8.2.5. Conclusions

The sediments found in the caves of the Mendip Hills are highly varied. This is a reflection on the highly varied character of the rocks which underlie and overlie the limestone in this area.

The composition of the sediments shows that they were derived from both autochthonous and allochthonous sources.

Like some of the Peak District deposits, the autochthonous fraction consists of chert, limestone, galena and calcite clasts but it also contains Lower Limestone Shale clasts derived by stream erosion at the base of the limestone.

The allochthonous fraction is unlike that found in the Peak District deposits. It consists of sandstone clasts, quartz sand, silt and clays derived from the Old Red Sandstone which underlies the limestone and the Mesozoic sediments which overlie the limestone.

Size analysis shows that the sediments are highly varied in character reflecting the varied nature of the different source rocks.

S.E.M. studies show that in all cases derivation has been by fluvial processes. Any textures present associated with an aeolian environment are relics from earlier environmental history.

8.3. Yorkshire Dales

8.3.1. Introduction

This region covers an area of the central Pennines from Ingleton in the west to Nidderdale in the east and from Swaledale in the north to Skipton in the south, the southern part of the area is shown in figure 8.3.1.1. The area is sometimes known as the Askrigg Block.

8.3.2. Geology

The basement in this area consists of folded Pre-Cambrian, Ordovician and Silurian rocks. These are only exposed in Ribblesdale, Chapel - Le - Dale and Barbondale where they are similar to rocks exposed in the Lake District (Edwards and Trotter, 1954).

The base of the Carboniferous Limestone is marked by a boulder conglomerate at the unconformity. The unconformity represents a buried landscape with relief of up to 120 metres (Waltham, 1974).

In this area the Carboniferous Limestone is known as the Great Scar Limestone. It varies in thickness from around 100 metres to over 350 metres in the Greenhow area.

Limestones from the Chadian (C_2) to the Asbian (D_1) stages are represented (Waltham, 1974). Lithologically they consist mainly of fine grained, pale grey bioclastic limestones.

Interbedded with the limestones are persistant shale beds varying in thickness up to 0.5 metre and exceptionally

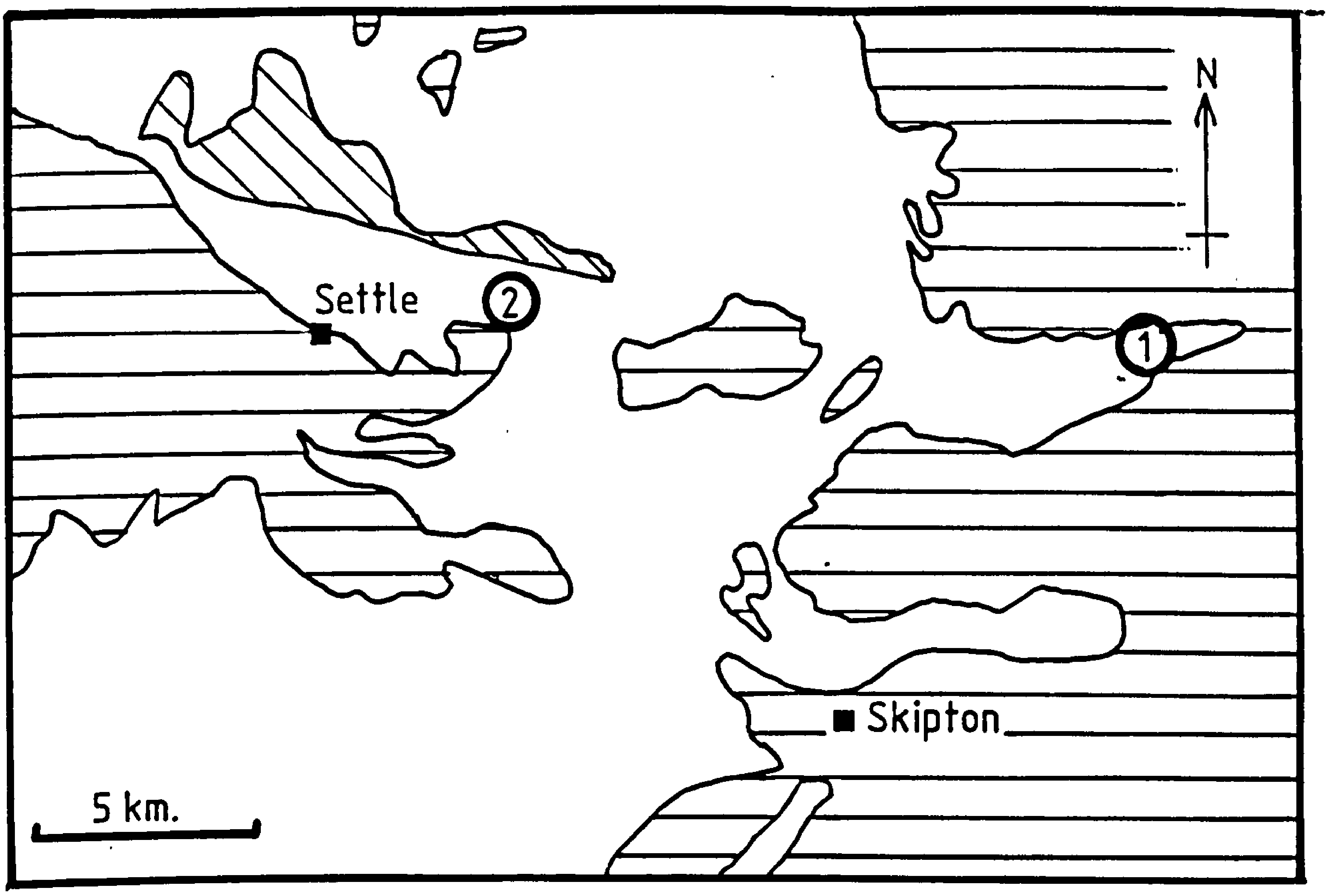


Figure 8.3.1.1. Geological sketch map of the southern part of the Yorkshire Dales.

▤ Namurian sandstones and shales

□ Carboniferous Limestone

▨ Ingletonian

Key to localities

1 Gillfield Level
2 Pikedaw Calamine Mine

up to 2 metres (Waltham, 1974).

In the southeast of the area where the limestone is thicker it is more varied because it was deposited on the margin of the Bowland Trough (Black, 1950).

The limestones are overlain by the Yoredale Series (Namurian). These are a succession of repetitive cycles of limestones, shales and sandstones (Moore, 1958). Continuous limestone deposition was brought to an end earlier in this area than the Peak District by the incursion of the Namurian deltas from the north. Relatively thin limestones are interbedded with the Namurian sandstones and shales which overlie the Great Scar Limestone.

Throughout the area the limestone has a dip of a few degrees to the north except where it is disturbed by the Craven Fault System. It is well, though massively, jointed and has a number of minor faults.

Mineralisation is widely dispersed throughout most of the area but is more concentrated in the Great Scar Limestone in the Greenhow and Grassington areas. In Wensleydale and Swaledale mineralisation occurs in the Yoredale Series.

In the Greenhow - Grassington area mineralisation consists of joint and fault controlled veins, up to 2.5 metres wide, carrying galena, fluorite, baryte and calcite (Dunham and Stubblefield, 1945).

The area has been glaciated on several occasions and was finally de-glaciated about 12,000 years B.P.. As a result the area still exhibits numerous glacial features.

8.3.3. Types of Deposit

The Yorkshire Dales contain many caves and potholes, most of which are developed in the Great Scar Limestone.

All of the sites studied were in the south of the area close to the Craven Fault and were associated with mineral veins or contained secondary mineral deposits. They were developed in the Great Scar Limestones and all were totally or partly filled with allochthonous sediments though they do not contain active streams at present.

The Grassington area is noted for its "gulphs". These are potholes formed on some of the mineral veins and filled with residual ore minerals and surface derived sediments (Varvill, 1920; Dunham and Stubblefield, 1945; Anon, 1965a and 1965b). None of the recorded gulphs in the Grassington area are accessible today (1982).

8.3.4. Sites Studied

8.3.4.1. Gillfield Level

This is a crosscut level driven from SE 115,648 which intersects a number of veins and a sediment filled solution cavity.

The cavity is developed close to the top of the Asbian (D_1) Coldstones Limestone below a cover of Namurian strata. It is filled with unbedded sediments, the composition of which is given in figure 8.3.4.1.1..

Size analysis shows that the sediments are poorly sorted, coarse - skewed, platykurtic silty - sandy gravels (fig. 8.3.4.1.2). The results of S.E.M. study of quartz grain

Sample Numbers GL 1-6		
		%
1	Limestone	
	Dolomite	
	Volcanics	
	Chert	0 — 1·5
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	0 — 0·5
2	Quartz	67 — 74
	Sandstone	3 — 16
	Feldspar	0 — 0·5
	Mica	1 — 25
	Shale	0 — 1
	Quartzite	
	Balance (mainly clay)	15 — 27
1 Autochthonous 2 Allochthonous		

Figure 8.3.4.1.1. Summary of sediment composition, Gillfield Level.

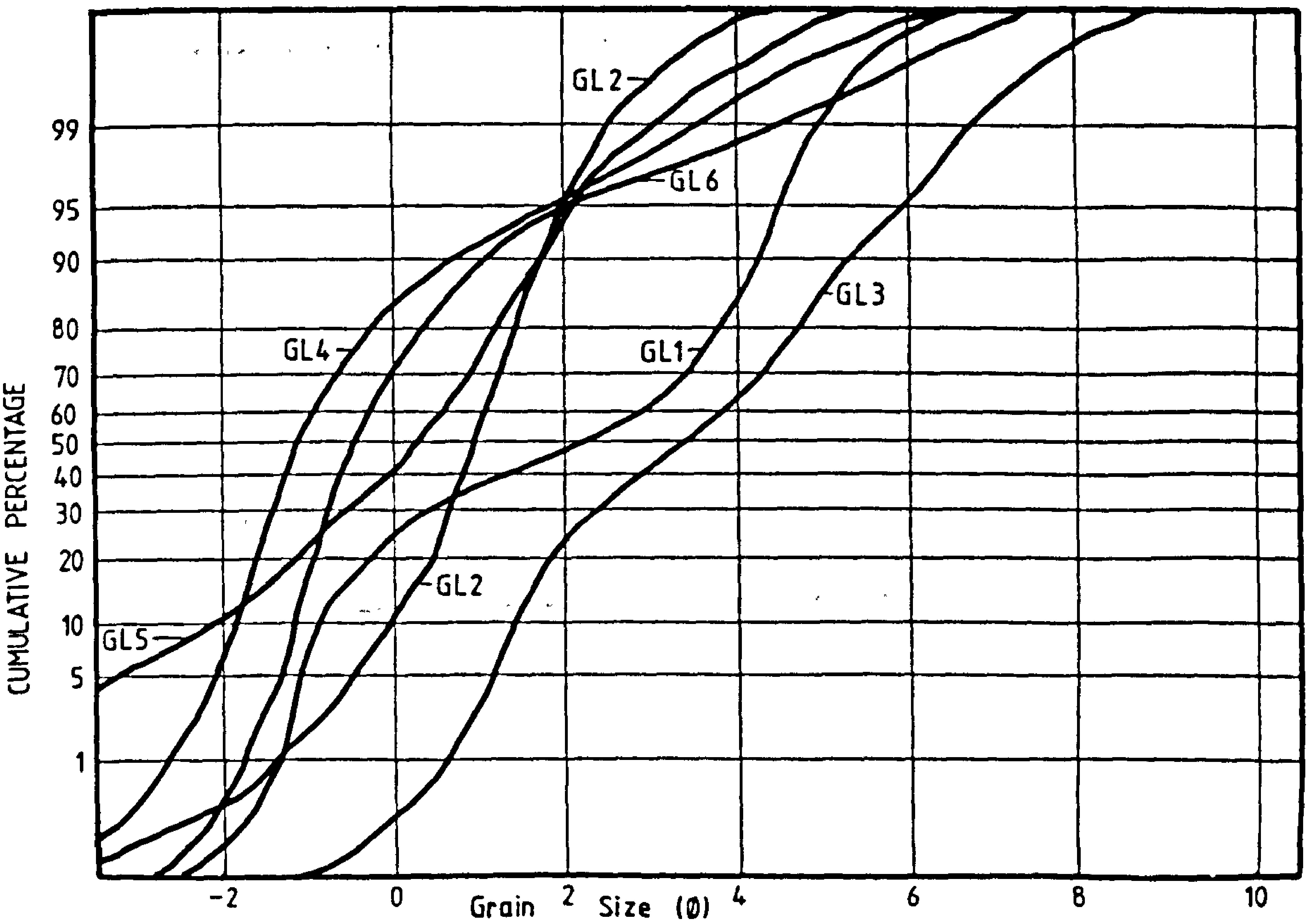
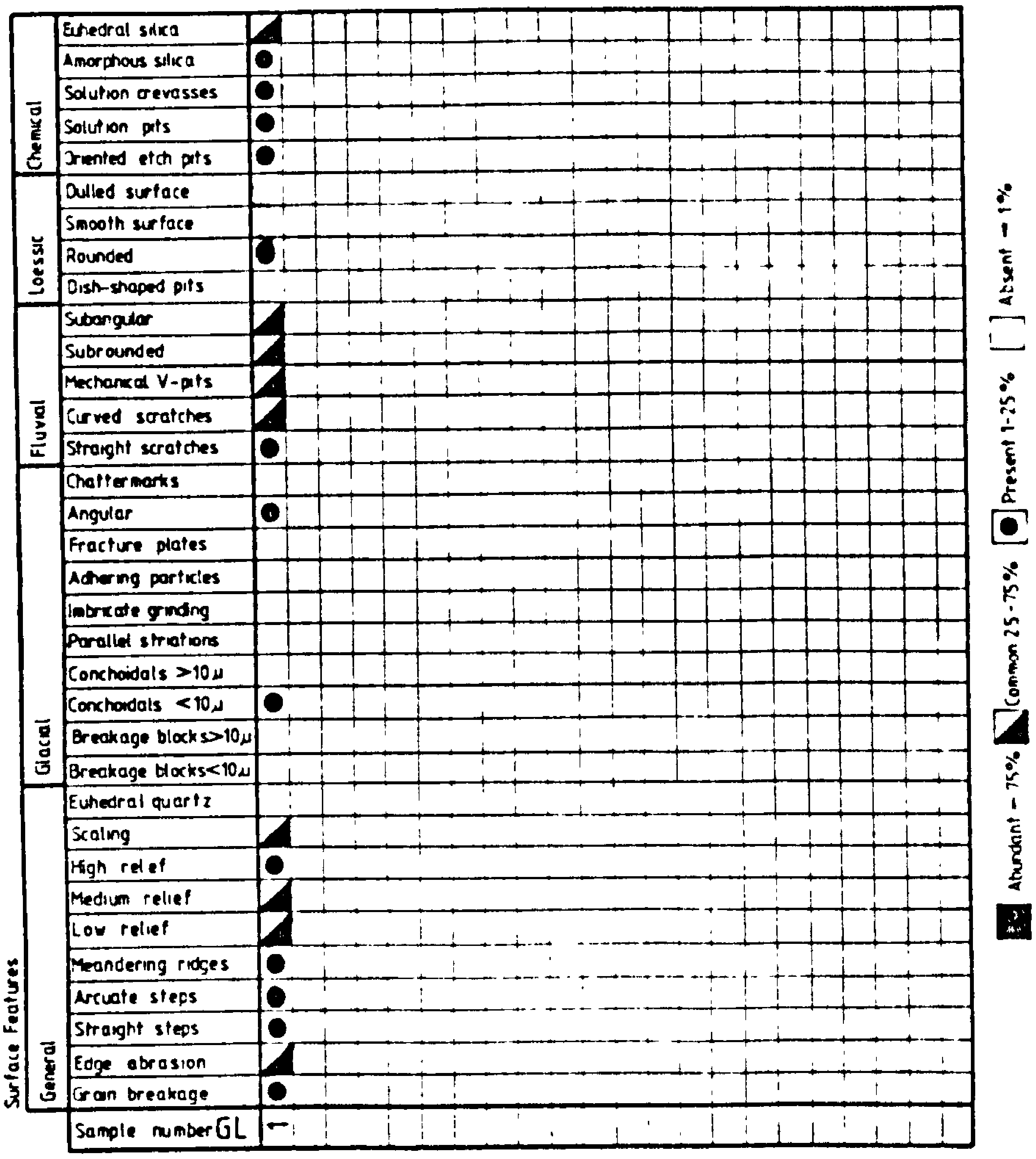


Figure 8.3.4.1.2. Sediment Size Analysis. Gillfield Level.



Surface Features		
Chemical	Euhedral silica	◢
	Amorphous silica	●
	Solution crevasses	●
	Solution pits	●
	Oriented etch pits	●
Loessic	Dulled surface	
	Smooth surface	
	Rounded	●
	Dish-shaped pits	
Fluvial	Subangular	◢
	Subrounded	◢
	Mechanical V-pits	◢
	Curved scratches	◢
	Straight scratches	●
Glacial	Chattermarks	
	Angular	●
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10µ	
	Conchoidals <10µ	●
	Breakage blocks>10µ	
	Breakage blocks<10µ	
General	Euhedral quartz	
	Scaling	◢
	High relief	●
	Medium relief	◢
	Low relief	◢
	Meandering ridges	●
	Arcuate steps	●
	Straight steps	●
	Edge abrasion	◢
	Grain breakage	●
	Sample number GL	1

■ Abundant - 75% ◢ Common 25-75% ● Present 1-25% [ ] Absent - 1%

Figure 8.3.4.1.3. Summary of quartz grain surface textures, Gillfield Level.

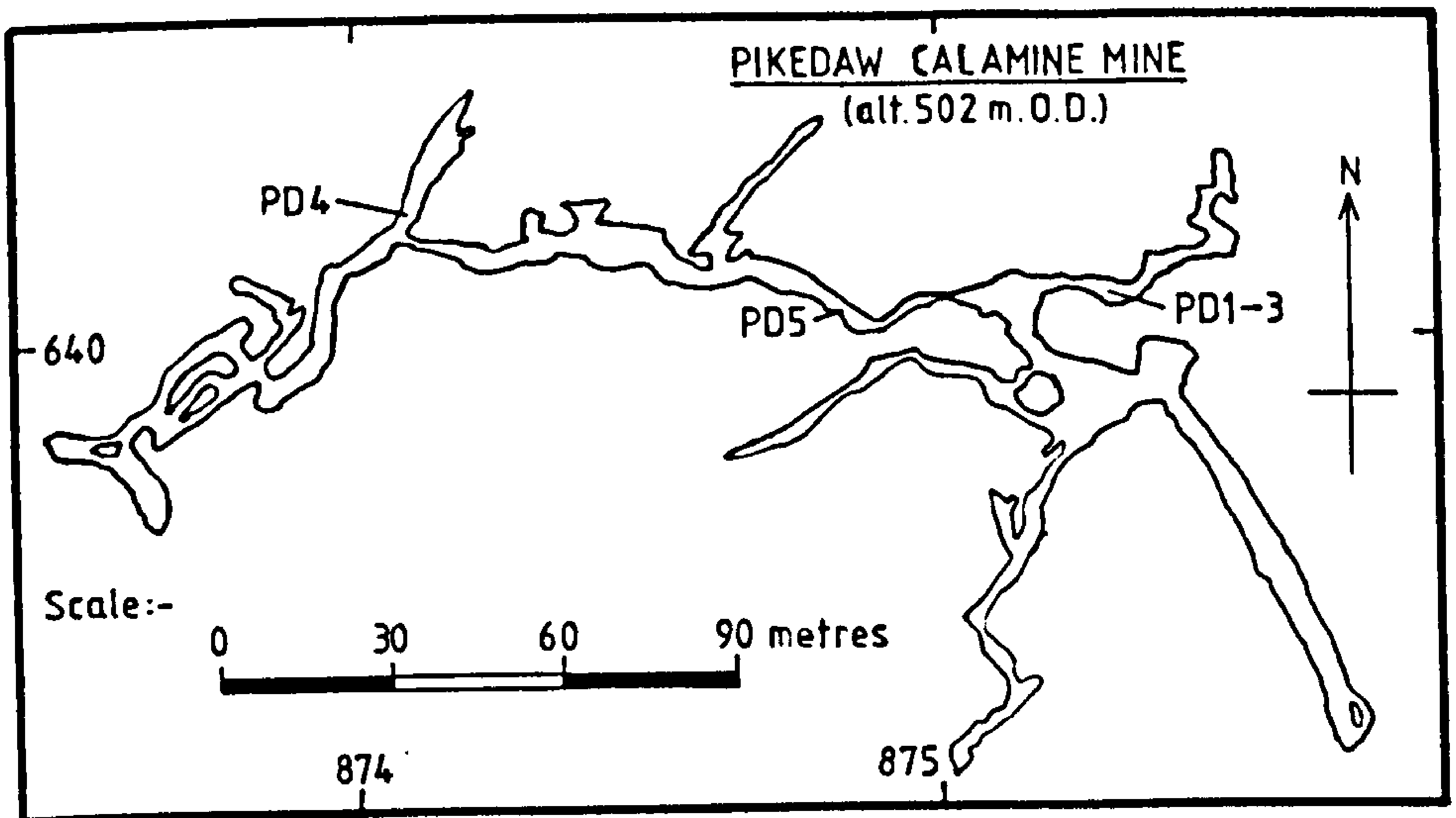


Figure 8.3.4.2.1. Plan of Pikedaw Calamine Mine showing sample locations. After Gemmell and Myers (1952).

surface textures shows that they have been derived by fluvial processes (fig. 8.3.4.1.3.).

The composition of these sediments shows that they have been derived from the Namurian strata in the locality. Despite the proximity of this cavity to a number of major mineral veins it contains no derived ore minerals.

8.3.4.2. Pikedaw Calamine Mine

Situated to the west of Malham Cove at SD 875,640 Pikedaw Calamine Mine consists of a series of passages which contained deposits of calamine. The mine was probably working before 1750 and continued well into the nineteenth century (Simpson, 1967).

The caverns are developed towards the top of the Great Scar Limestone about 30 metres below the surface of the moor and consist of a number of phreatic passages (fig. 8.3.4.2.1.).

The sediments contained in the cavern have been greatly disturbed by mining activity though a section is exposed beneath a 20cm. thick stalagmite layer (fig. 8.3.4.2.1., PD 1-5). The section (fig. 8.3.4.2.2.) shows that the calamine deposits occur as the matrix between angular limestone blocks and are intermixed with allochthonous sediments.

The composition of these sediments is given in figure 8.3.4.2.3. which shows that the allochthonous fraction was derived from the Namurian (Yordale Series) sediments which overlie the limestones.

Size analysis shows that the sediments are moderately well sorted fine - skewed, mesokurtic silts (fig.

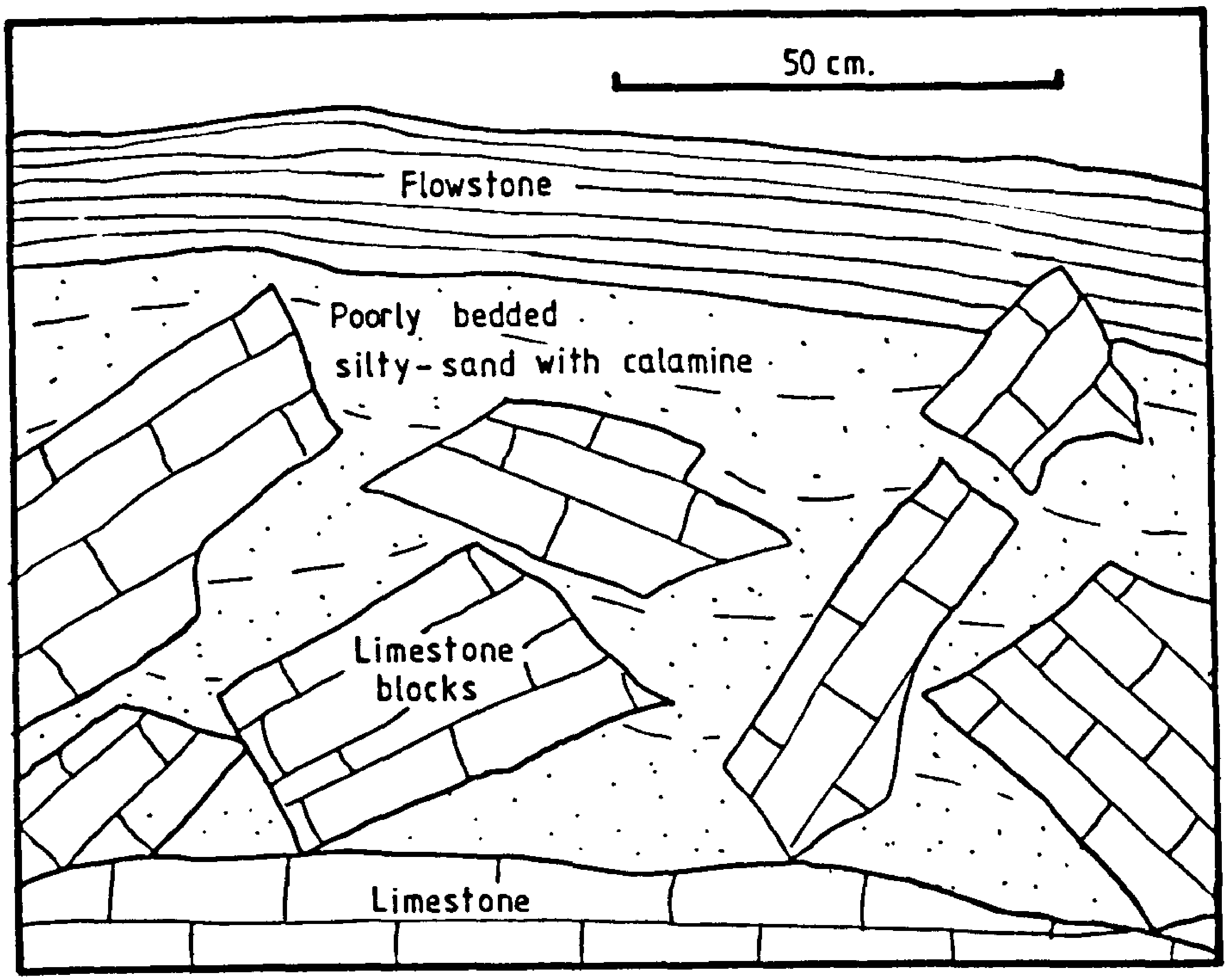


Figure 8.3.4.2.2. Sediment sequence, Pikedaw Calamine Mine.

Sample Numbers PD 1—5		
		%
1	Limestone	1 — 37
	Dolomite	
	Volcanics	
	Chert	
	Silicified fossils	0 — 1·5
	Authigenic quartz	
	Galena	
	Fluorite	
	Baryte	
	Calcite	
	Calamine	0 — 49
2	Quartz	16 — 34
	Sandstone	1 — 7
	Feldspar	0 — 2·5
	Mica	1 — 3·5
	Shale	0 — 0·5
	Quartzite	
	Balance (mainly clay)	3 — 17
1 Autochthonous 2 Allochthonous		

Figure 8.3.4.2.3. Summary of sediment composition, Pikedaw Calamine Mine.

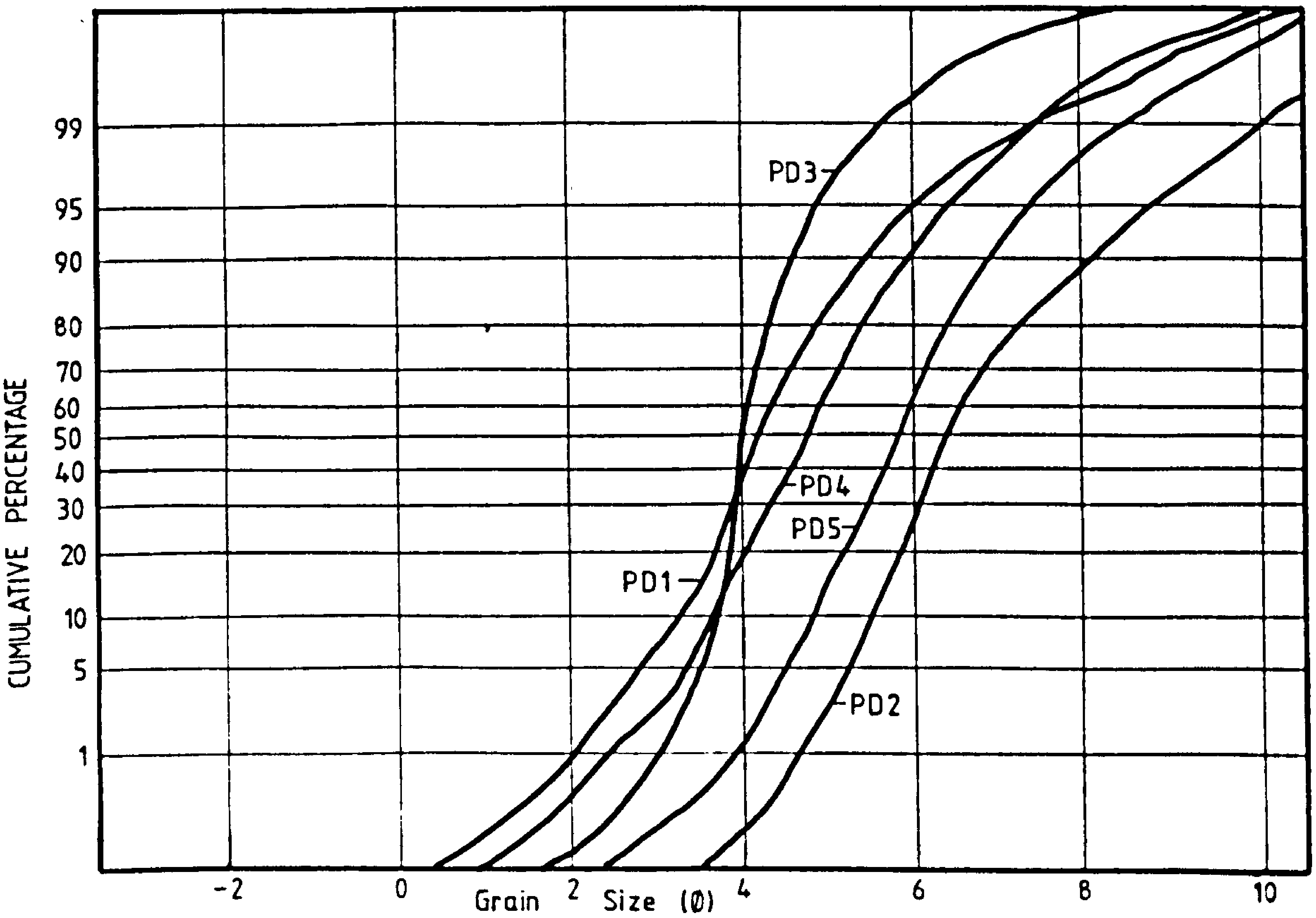


Figure 8.3.4.2.4. Sediment Size Analysis. Pikedaw Calamine Mine.

Surface Features		
Chemical	Euhedral silica	◩
	Amorphous silica	◩
	Solution crevasses	●
	Solution pits	●
	Oriented etch pits	●
Loessic	Dulled surface	●
	Smooth surface	●
	Rounded	●
	Dish-shaped pits	
Fluvial	Subangular	◩
	Subrounded	◩
	Mechanical V-pits	◩
	Curved scratches	●
	Straight scratches	●
Glacial	Chattermarks	
	Angular	●
	Fracture plates	
	Adhering particles	
	Imbricate grinding	
	Parallel striations	
	Conchoidals >10μ	●
	Conchoidals <10μ	●
	Breakage blocks>10μ	
	Breakage blocks<10μ	
General	Euhedral quartz	●
	Scaling	◩
	High relief	●
	Medium relief	◩
	Low relief	◩
	Meandering ridges	●
	Arcuate steps	
	Straight steps	●
	Edge abrasion	●
	Grain breakage	●
	Sample number PD	3

■ Abundant – 75%
◩ Common 25-75%
● Present 1-25%
□ Absent – 1%

Figure 8.3.4.2.5. Summary of quartz grain surface textures, Pikedaw Calamine Mine.

8.3.4.2.4.). The results of S.E.M. study of quartz grain surface textures shows that they are derived from by fluvial processes (fig. 8.3.4.2.5.).

The calamine appears to have been derived by the reworking of oxidised primary zinc deposits by the groundwater which formed the caverns. This water also carried the allochthonous silts into the cave.

8.3.5. Conclusions

Both the sites studied in this area are close to or within the Craven Fault system and are associated with primary mineralisation in the Great Scar Limestone.

The composition of the sediments shows that they were derived mainly from allochthonous sources, with a smaller contribution from the limestone and its' mineralization.

As in the Peak District the allochthonous fraction consists of sediments derived from the overlying Namurian strata. S.E.M. studies show that this derivation has been by fluvial processes.

The higher altitude and the thick stalagmite layer above the deposits in Pikedaw indicates that they may be of considerable, possibly pre-glacial, age.

8.4. Northern Pennines

8.4.1. Introduction

This area covers the Northern Pennine Orefield, also known as the Alston Block, (fig. 8.4.1.1.). It extends from

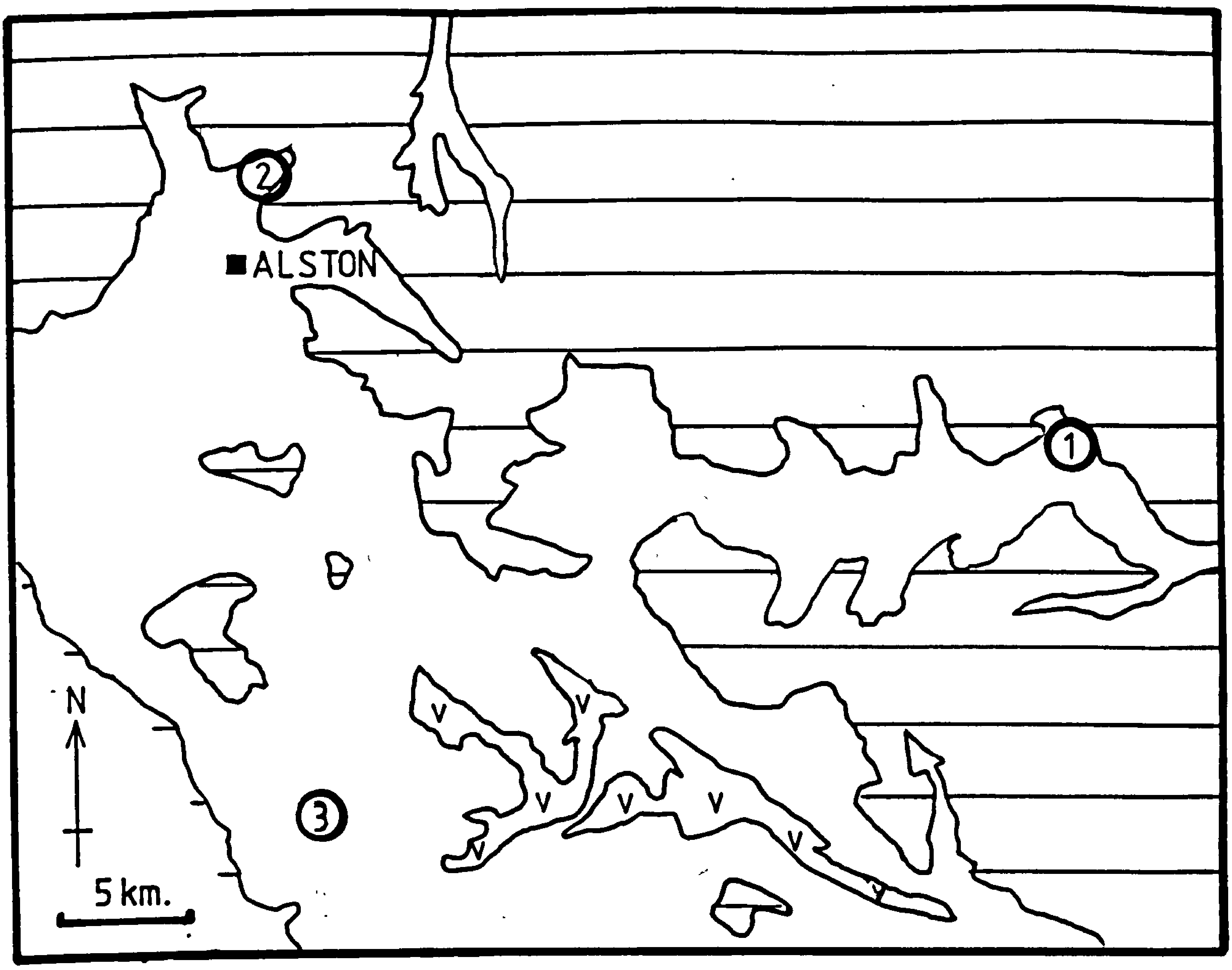


Figure 8.4.1.1. Geological sketch map of part of the Northern Pennine Orefield.

▤	Namurian sandstones and shales
☐	Great Scar Limestone
V V	Whin Sill

Key to localities

1 Hope Level 4 Fathom Limestone Cave
2 Ayleburn Mine Cavern
3 Silverband Mine

Middleton - in - Teesdale in the south to Hexham in the north and from Wolsingham in the east almost to Penrith in the west. Lead mining has been carried out in this area for many centuries. During this century zinc ores became more important but today it is generally fluorspar which is mined in this area.

8.4.2. Geology

Geologically the area is similar to the Yorkshire Dales though the limestone units are thinner.

The basement in this area consist of folded Silurian and Ordovician sediments (Dunham, 1948) and the Weardale Granite. The Lower Carboniferous strata lie unconformably over this basement and consists of an alternating succession of limestones, shales and sandstones of variable thickness sometimes with coal seams at the top of each cyclothem (Dunham, 1948). In the lower parts of the succession limestone horizons are dominant but they become few and thinner higher up the succession.

Many of the limestone and sandstone beds, and some of the shale horizons have local names attached to them by the lead miners who could correlate individual beds over considerable distances.

Mineralisation is widespread throughout the area. It is more common in the sandstone and limestone horizons which retained open spaces formed by fault movement.

Both fissure veins and replacement flats are represented and both formed important lead, zinc and/or fluorspar deposits.

Galena is present throughout the orefield but baryte, fluorite and sphalerite occur in more distinct zones (Dunham, 1948).

8.4.3. Types of Deposit

All three sites studied in this area were caves or solutional cavities associated with primary mineral deposits. Many similar caves have been noted in the literature but were found to be inaccessible including Hudgill Burn Caverns (Sopwith, 1833) and Lunehead Caverns (Dunham, 1948 and Anon, 1976), both of which were discovered by lead miners.

8.4.4. Sites Studied

8.4.4.1. Hope Level

The portal to this lead mine level is at NY 990,398. The level was driven to intersect Red Vein close to the Stanhope Burn Mine in Weardale to allow deeper working. Recently it was reopened to allow the vein to be examined for fluorspar reserves.

The level intersects a phreatic cave system, which is now drained, developed in the Four Fathom (Undersett) Limestone about 600 metres from the portal (Anon, 1967) (fig. 8.4.4.1.1.). The cave contains a small stream which now flows down the level, its former resurgence being unknown. The cave has thick accumulations of silt in parts and the floor of the stream contains numerous sandstone pebbles derived from the local sandstone horizons.

Figure 8.4.4.1.1. Plan of part of Hope Level 4 Fathom Limestone Cave showing sample locations

Sample Numbers HL4FM 1—4		
		%
1	Limestone	0 — 1·5
	Dolomite	
	Volcanics	
	Chert	1 — 12
	Silicified fossils	
	Authigenic quartz	
	Galena	
	Fluorite	0 — 1·5
	Baryte	
	Calcite	0 — 0·5
2	Quartz	37 — 91
	Sandstone	3 — 39
	Feldspar	0 — 1·5
	Mica	1 — 2·5
	Shale	0 — 1
	Quartzite	
	Balance (mainly clay)	2 — 17

1 Autochthonous 2 Allochthonous

Figure 8.4.4.1.2. Summary of sediment composition, Hope Level 4 Fathom Limestone Cave.

The composition of the sediments is given in figure 8.4.4.1.2..

Size analysis shows that the sediments are moderately well sorted, fine - skewed, platykurtic, pebbly - silts (fig. 8.4.4.1.3.).

The composition of the sediments indicates that they have been derived from the strata above and below the Four Fathom Limestone from either surface or underground exposures. The small amount of fluorite present shows that the stream has intersected mineralization. Mineralized joints are present in the walls of parts of the cave which could have contributed part of the fluorite.

8.4.4.2. Ayleburn Mine Cavern

This is another stream cave found by mining activity. The cave was entered from a level driven from beside Ayleburn at NY 724,497, in 1824 (Anon, 1970).

The cave is developed in the Great Limestone where it is disturbed by the presence of Ayleburn Vein. The vein carries sphalerite, galena, witherite, baryte and calcite.

Size analysis shows that the sediments are moderately well sorted, very fine - skewed, platykurtic, gravelly - silts (fig. 8.4.4.2.1.).

The composition of the sediments (fig. 8.4.4.2.2.) indicates that most of the material is derived from the strata overlying the Great Limestone and has been brought into the cave via sinks in Ayleburn. The remainder of the sediment consists of chert and vein minerals eroded from the cave walls.

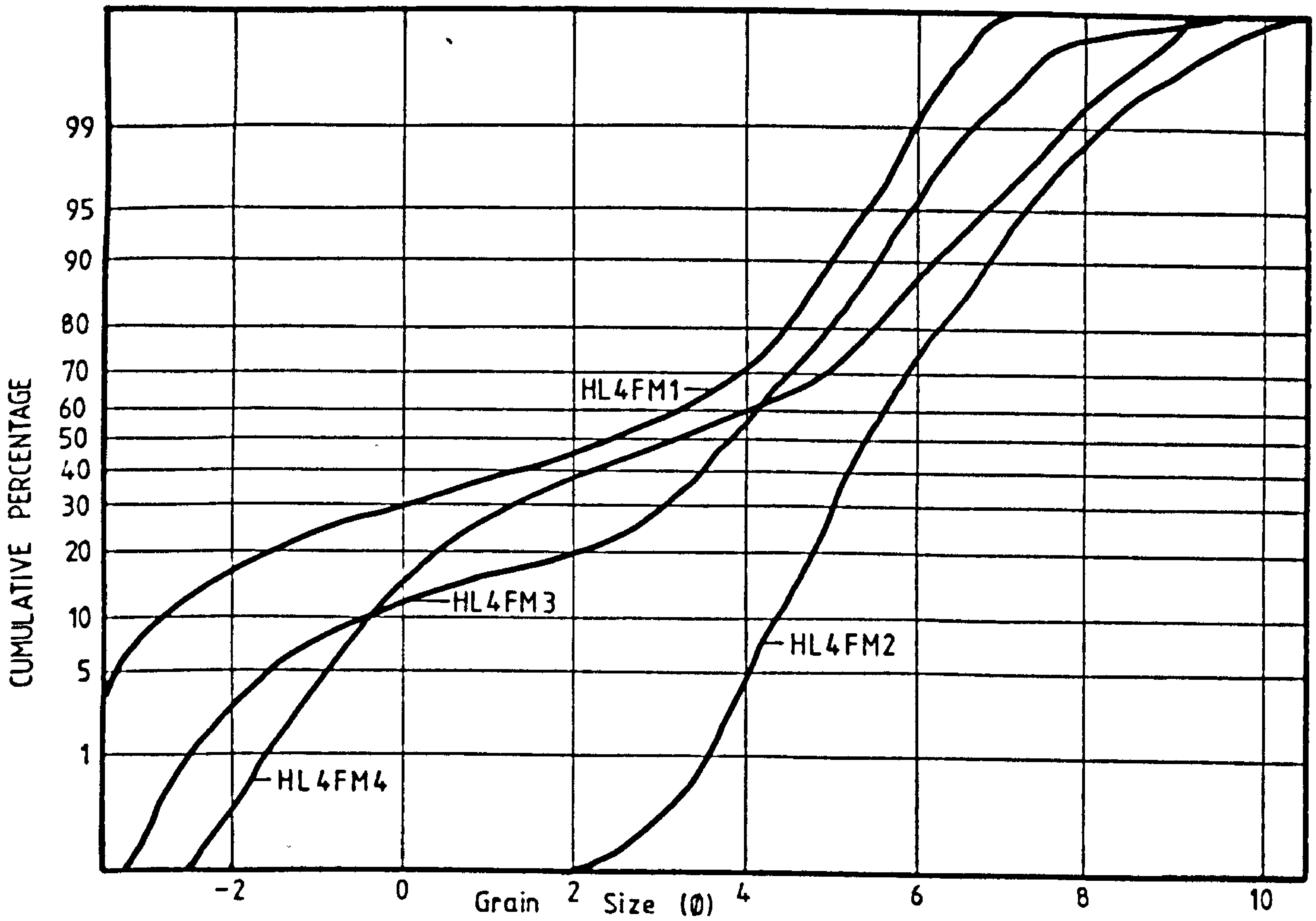


Figure 8.4.4.1.3. Sediment Size Analysis. Hope Level 4 Fathom Limestone Cave.

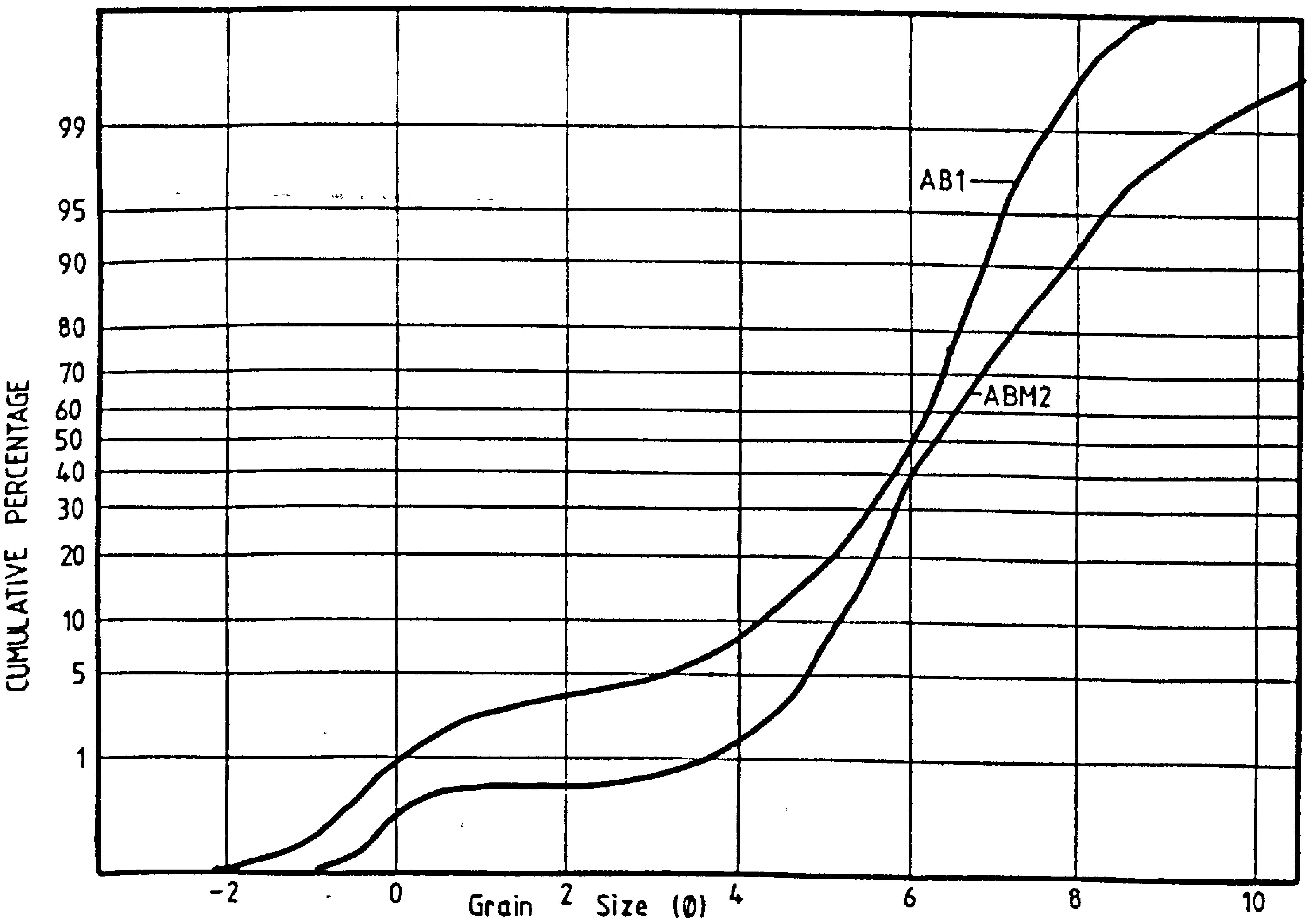


Figure 8.4.4.2.1. Sediment Size Analysis. Ayleburn Mine Cavern.

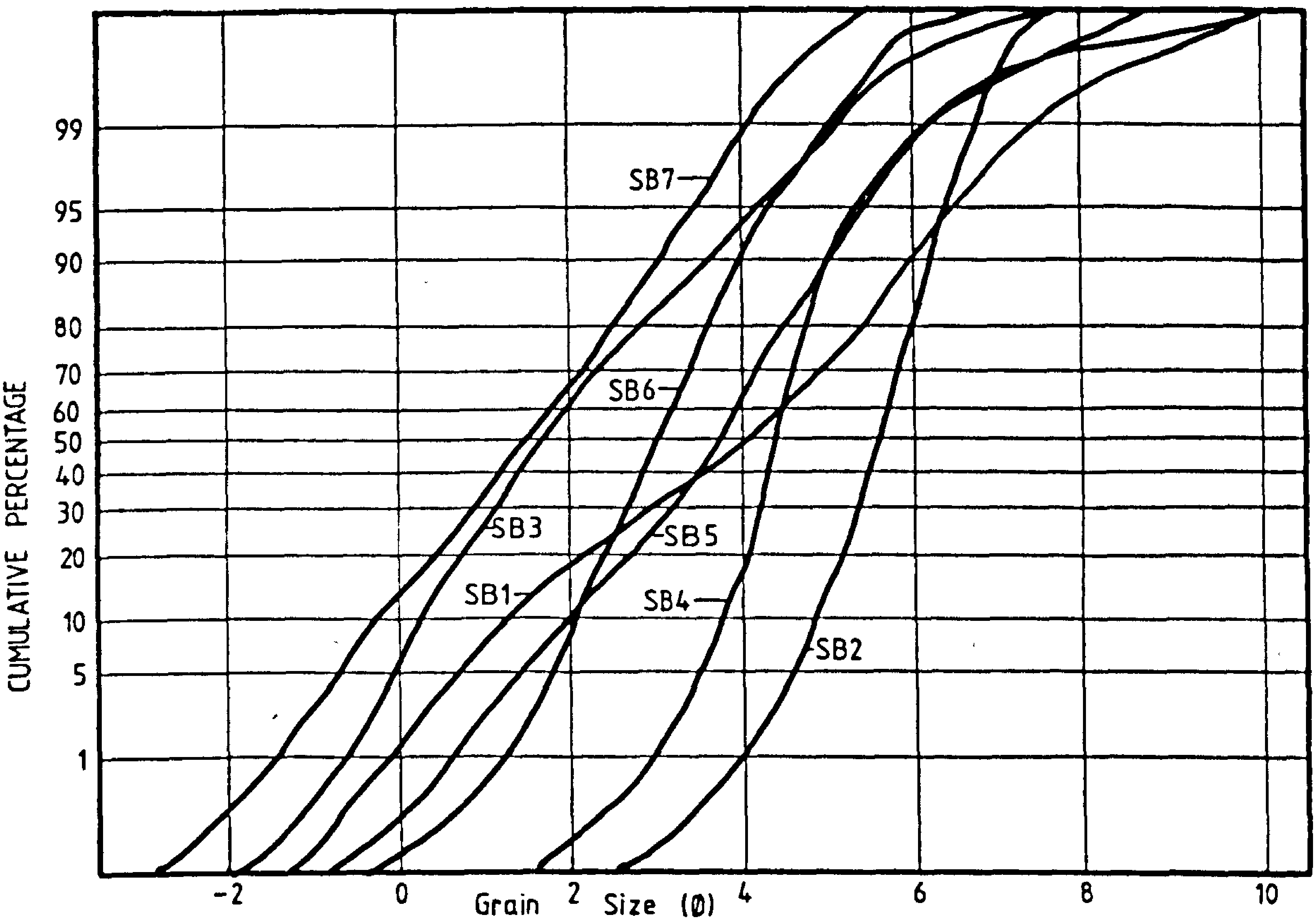
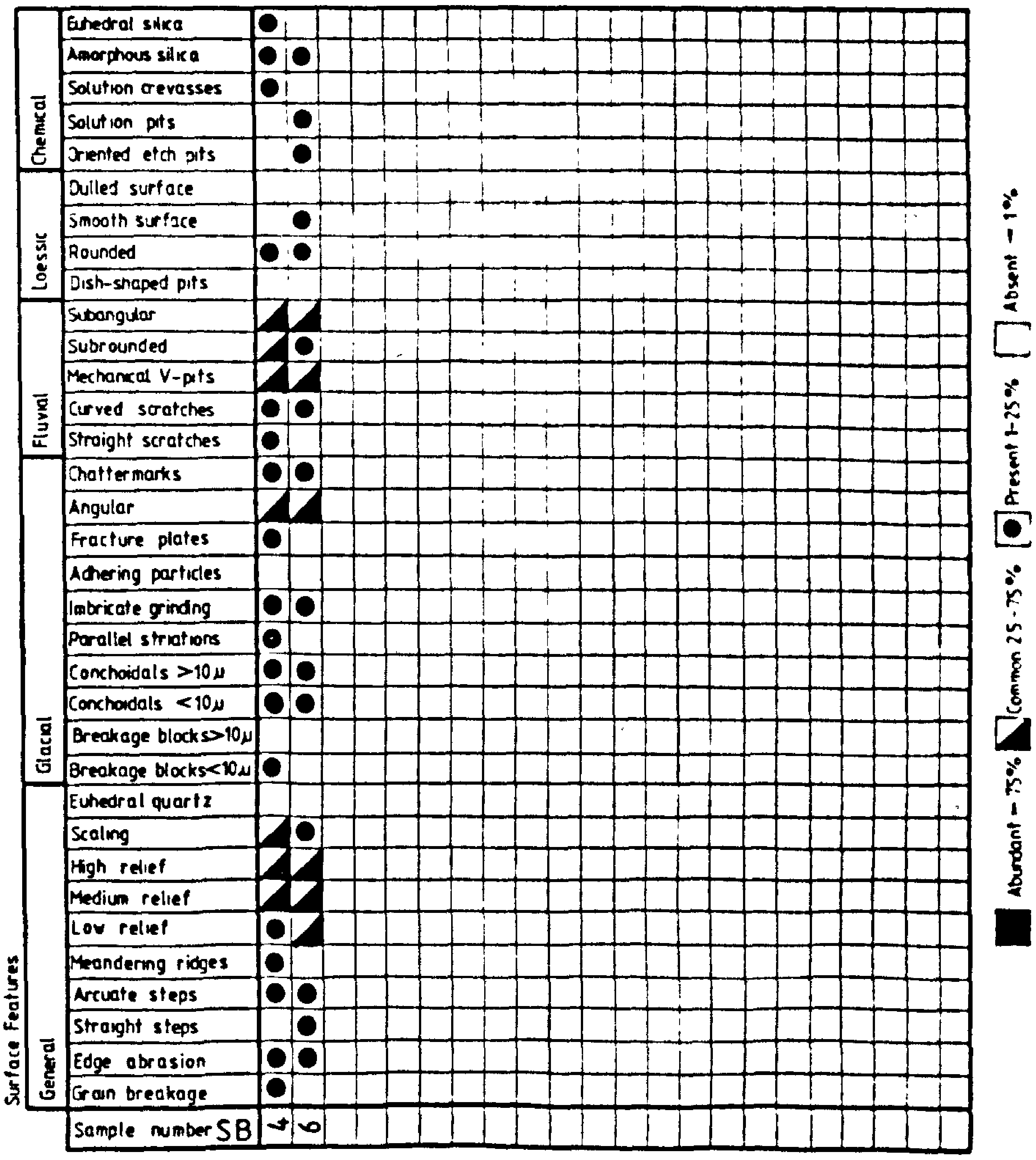


Figure 8.4.4.3.2. Sediment Size Analysis. Silverband Mine.



Surface Features	Chemical	Euhedral silica	●	
		Amorphous silica	●	●
		Solution crevasses	●	
		Solution pits		●
		Oriented etch pits		●
	Loessic	Dulled surface		
		Smooth surface		●
		Rounded	●	●
		Dish-shaped pits		
	Fluvial	Subangular	◢	◢
		Subrounded	◢	●
		Mechanical V-pits	◢	◢
		Curved scratches	●	●
		Straight scratches	●	
	Glacial	Chattermarks	●	●
		Angular	◢	◢
		Fracture plates	●	
		Adhering particles		
		Imbricate grinding	●	●
		Parallel striations	●	
		Conchoidals >10µ	●	●
		Conchoidals <10µ	●	●
		Breakage blocks>10µ		
		Breakage blocks<10µ	●	
	General	Euhedral quartz		
		Scaling	◢	●
		High relief	◢	◢
		Medium relief	◢	◢
		Low relief	●	◢
		Meandering ridges	●	
		Arcuate steps	●	●
		Straight steps		●
		Edge abrasion	●	●
		Grain breakage	●	
		Sample number SB	4	6

■ Abundant – 75% ◢ Common 25 - 75% ● Present 1-25% ☐ Absent – 1%

Figure 8.4.4.3.3. Summary of quartz grain surface textures, Silverband Mine.

8.4.4.3. Silverband Mine

Formerly worked underground for lead and later baryte, Silverband Mine, at NY 702,317, is now (1982) worked for baryte by open pit methods.

The baryte - galena mineralization is in the Great Limestone and consists of a complex of small veins and flats (Burgess and Wadge, 1974).

Extensive post - mineralization cavernization has occurred with the formation of an extensive network of phreatic caves and numerous isolated cavities. Only those exposed in the open pit could be examined because no underground workings were accessible

The cavities are filled with sediment the composition of which is given in figure 8.4.4.3.1..

Size analysis shows that the sediments are well sorted, slightly coarse - skewed, mesokurtic to leptokurtic silty - sands (fig. 8.4.4.3.2.).

The results of S.E.M. study of quartz grain surface textures shows that the sediments have been derived by fluvio - glacial processes (fig. 8.4.4.3.3. and plate 8.4.4.3.1.).

The composition of the sediments shows that they have been derived from the local sandstone and shale horizons and from the reworking of the baryte mineralization. The S.E.M. study shows that the allochthonous fraction of the sediment was derived fluvio - glacially, probably into pre-existing cavities.

8.4.5. Conclusions

The composition of the sediments shows that they were derived from both autochthonous and allochthonous sources. Because sandstone and shale may have been derived by erosion of underground exposures in this area allochthonous is applied to any sediment derived from outside the limestone horizons.

The autochthonous fraction, which consists of limestone, chert, fluorite, baryte and witherite clasts derived from the limestones and their mineral deposits, is very similar to the deposits of the Peak District.

Again like the Peak District, the allochthonous fraction consists of sandstone and shale clasts, quartz sand, silt and clay derived from the overlying sediments.

Size analysis shows that the sediments are of similar character, the major variation can be attributed to the varied autochthonous fractions present.

S.E.M. studies show that the allochthonous fraction has been derived by, in the case of the active stream caves, entirely fluvial processes and, in the case of Silverband Mine, fluvio - glacial processes.

9. CONCLUSIONS

9.1. Sources of sediment

Detailed mineralogical studies have revealed that the sedimentary accumulations in the Peak District caves and karstic cavities are principally of two kinds: firstly autochthonous material consisting of clasts derived from the Carboniferous Limestone or its epigenetic mineralisation; secondly allochthonous material derived from the overlying Namurian sediments and superficial surface deposits. In many of the deposits studied the sediments are a mixture of both allochthonous and autochthonous material in varying proportions.

The autochthonous fraction can be composed of any combination of clasts derived from the limestone or epigenetic mineralisation. From the limestone itself the clasts may be either of limestone or dolomite, both often having a partially de-calcified crust. The limestone also contributes any insoluble residue that it may contain. This residue consists of chert, silicified fossils, authigenic quartz and a small quantity of clay. The autochthonous fraction has been partly derived from interbedded volcanic horizons (wayboards and toadstones) and shale beds.

Considerable proportions of the autochthonous fraction have been transported by alluvial processes and contains alluvial and residual clasts derived from primary mineralisation. Such internal cavity alluvial deposits usually consist of degraded fluorite, baryte and calcite with occasional galena as clasts of varied sizes. When present the galena often has an approximately 1mm. thick cerussite coating which has formed in situ.

The autochthonous fraction may occur as discrete layers within a deposit or may be distributed throughout the deposit. It may be derived from surface or underground exposures of the host rocks.

The allochthonous fraction has been derived from the surface either from former loessic cover, or the Namurian strata which overlie the limestone. In the south of the Peak District some of the allochthonous fraction has also been derived from the Triassic sediments to the south and the Pliocene Brassington Formation. Occasionally till and solifluction deposits have contributed to the sediments.

The reworked loess found in many of the caves in the Peak District is a yellow clay-silt composed mainly of quartz grains. When studied using a scanning electron microscope they show numerous features characteristic of an aeolian environment.

Sediments derived from the Namurian strata are largely composed of quartz grains re-worked from the sandstone units. Also present are clasts of sandstone and shale which become smaller the further from the source area that they have been transported.

Muscovite mica and feldspars occur in small quantities but are widely distributed in sediments derived from the Namurian succession.

Where Triassic and/or Brassington formation sediments have contributed to the deposits in the south of the area it has not been possible to establish whether they were derived directly from the Triassic escarpment or via the Brassington Formation deposits.

X.R.D. studies of the clay fractions of the sediments have proved to be of limited value.

No contemporary pollen or other fossil remains have been identified during this study.

9.2. Grain Size Studies

Grain size studies often confirm that many of the sediments are a mixture of autochthonous and allochthonous sediments by their platykurtic nature. Other sedimentological studies can be used to distinguish between sediments derived by different processes as well as from different sources.

Grain size studies of wholly autochthonous sediments or the autochthonous fraction of mixed sediments normally show that they are poorly to moderately well sorted, often coarse skewed and platykurtic gravelly silts. This reflects the coarse grained nature of the detrital limestone, chert and epigenetic mineral vein clasts and the clayey nature of the insoluble residue from the limestone and the tuffs which contribute to most of these sediments.

Grain size studies of wholly allochthonous sediments or the allochthonous fraction of mixed sediments reflect the environment of the source and transportation of these sediments.

Fluvially derived sediments, whether from the Namurian or Triassic strata, are usually moderately well to very well sorted, fine or coarse skewed, mesokurtic sands and gravels. Occasionally more poorly sorted sediments occur.

Fluvio - glacially derived sediments have very similar sedimentological characteristics to those from the fluvial environment but are often less well sorted. Distinctive coarse and fine units are also usually present in sequences of fluvio - glacial sediments.

Reworked loessic silts are moderately sorted, usually fine skewed, leptokurtic silts and silty clays.

9.3. Processes of Derivation

There are four processes of derivation recognisable from the study of the sediments. These are:- collapse and slumping, solifluction, fluvial and chemical weathering. The latter is predominant. S.E.M. studies of quartz grain surface textures are invaluable for distinguishing between medium to fine grained sediments derived from fluvial and chemical weathering processes.

9.3.1. Collapse and Slumping

Collapse and slumping occur when the walls or roof of a cave passage become unable to support themselves. The resulting deposit is an open angular breccia which may be cemented by speleothem deposition. Other sediments may be introduced following the collapse and form a matrix to the breccia. Collapse and sedimentation may be synchronous as at Bonsall Moor and Portway pits.

9.3.2. Solifluction

Solifluction flows down surface slopes may enter open caves or potholes and flow underground a short distance. They have only been recognised underground in two or three localities (Brightgate Cave, Giants Hole and perhaps Pilkington's Cavern of Speedwell Cavern). These consist of poorly sorted sediments composed of subangular to rounded cobbles in a silty matrix.

9.3.3. Fluvial

Fluvial processes of derivation are of three distinct types:-

9.3.3.1. Streams

Streams flowing from the Namurian strata and onto the limestone carry with them the products of normal weathering processes. These may be mixed with sediments derived from underground erosion and the solution of the limestone and may be deposited at sites within the underground drainage network. S.E.M. studies show that these sediments exhibit surface features characteristic of a fluvial environment superimposed on those found on weathered grains from the same source.

Deposition of the sediments occurs where passage gradients are reduced, passage widths enlarged or at some form of constriction, such as a collapse, which reduces flow rates causing ponding and deposition.

The sediments are usually irregularly bedded, often with channelling features, and sometimes exhibiting fining upwards sequences indicating deposition from flood inputs.

9.3.3.2. Glacial-outwash Streams

Superficially, deposits from glacial outwash streams are very similar to those from temperate streams. When examined underground they often exhibit distinctive bedding with fining upwards sequences which may be of varied character reflecting seasonal or storm inputs, some possibly due to meltwater runoff.

S.E.M. studies show some features remaining from the source rocks with substantial characteristic glacial and fluvial features superimposed.

Causes of deposition would have been similar to those of temperate stream sediments.

9.3.3.3. Translatory Flow

Many apparently isolated solution cavities are filled or partially filled with surface derived sediments. This can only satisfactorily be explained by the mechanism of translatory flow postulated by Bull (1981b). In this process fine-grained sediments are transported underground via joint and bedding planes by filtering groundwater. If the routes are less than 1mm. wide then filter caking will probably occur preventing sediment transport. Where they are greater than this size considerable quantities of sediment may be carried down joints. It may then accumulate in any cavities present including vein and solutional cavities when further migration is prevented.

All of the cavities studied containing sediments derived by this process are filled with reworked loessic silts which can only have been derived from the surface. S.E.M. studies show that the surface textures resulting from an aeolian environment are not modified by fluvial activity.

Many of these deposits occur in localities where loess is no longer present on the surface, having been removed by erosion.

For any sediment accumulations to be preserved the passage in which they were deposited must be abandoned soon after final deposition. If this does not happen re-erosion occurs leading to the removal of the accumulation as is happening in the Far Stream Passage of Peak Cavern. In active cave systems sedimentary accumulation can only be considered as transient.

9.3.4. Chemical Weathering

Chemical activity on surface or underground exposures of limestone or dolomite eventually removes the soluble carbonates leaving an insoluble residue. This may consist of clasts of chert and silicified fossils, clay, authigenic quartz and minerals from the epigenetic mineral suite.

The residual accumulations may remain in the depression or cavity in which they formed or may be reworked and mixed with other sediments.

9.4. Characteristics of Peak District Karstic Sediments

Sedimentary deposits which have been derived from different sources and by different processes have a number of characteristic features which may be used to distinguish between them. These vary from differences in the colour of the sediments to those of composition and grain size.

Sediments consisting totally or partially of reworked loessic silt are distinctively yellow/brown in colour with a marked absence of sand sized or larger particles. Sediments of this type occur throughout the Peak District in a number of situations. True loess deposits occupy surface depressions, as at Portway Pit.

Fluvially reworked loessic silt is abundant in the Castleton area where it has been deposited on ledges in the higher parts of active stream cave passages. In Peak and Speedwell Caverns most abandoned phreatic passages are filled almost to the roof with fluvially reworked loessic silt.

Throughout the Peak District numerous isolated vein cavities and small solutional pockets have been filled with surface derived loessic silt by the process of translatory flow. In many examples of this type of deposit a proportion of the sediment is insoluble autochthonous material.

The variation of sediments derived by fluvial and fluvio - glacial processes is more dependant on the characteristics of the source rocks than on the process of transportation.

In central and northern areas of the Peak District these sediments are almost exclusively derived from the Namurian shales and sandstones. In all cases sediments derived from this source are mottled dark brown to grey and black gravels, sands and silts. In the larger grained sediments abundant shale and sandstone clasts occur which have not been reduced to their individual grains. The grain size of these deposits is controlled by the flow velocities of the stream from which they were deposited. The faster flowing vadose streams depositing sand, gravel and cobbles close to the inlet to a cave system and slower moving phreatic streams depositing finer sand, silt and clay. Many of the active caves in the Castleton, Bradwell and Stoney Middleton areas are at present depositing or reworking this type of deposit.

Without the use of S.E.M. techniques it is impossible to distinguish between fluvial and fluvio - glacial sediments which have been derived from the same source rocks.

In the Matlock and Wirksworth areas these sediments are of similar nature but in addition to clasts derived from the Namurian contain material derived from the Sherwood Sandstone (Triassic) either directly or via the Brassington Formation. The sediments usually are light brown or red/brown in colour.

All the sediments studied in the Matlock and Wirksworth area are fossil, occurring in caves that are no longer part of the active drainage network whereas in the Castleton and Stoney Middleton areas they occur in active cave systems.

Muscovite is common in all sediments derived from the Namurian strata in the northern part of the Peak District but it is absent or rare in the south. This reflects the relative abundance of muscovite in the source rocks and this may be useful in determining where the cave sediments have been derived from.

Deposits derived by solifluction processes, chemical weathering and collapse are highly varied in character. In many cases sediments from other sources and introduced by

<table>
<tr><th></th><th>SOUTH</th><th>NORTH</th></tr>
<tr><td>Fluvial & fluvio-glacial</td><td>Light brown/red brown gravels, sands and silts consisting of derived Namurian quartz sandstone and shale, derived Sherwood sandstone and Brassington Formation quartz sand & pebbles.
Mica rare.</td><td>Brown/grey/black gravels, sands and silts consisting of derived Namurian quartz sandstone and shale.
Mica abundant.</td></tr>
<tr><td rowspan="2">Re-worked loess</td><td>-</td><td>Yellow/brown silt filling abandoned phreatic and vadose cave passages</td></tr>
<tr><td colspan="2">Numerous isolated cavities filled with re-worked loess by process of translatory flow</td></tr>
<tr><td>Collapse</td><td colspan="2">Collapse breccias of limestone, shale and igneous rock ± sediment matrix ± stalagmitic cement</td></tr>
<tr><td>Solifluction</td><td colspan="2">Sub-rounded cobbles of Namurian sediments, limestones and lavas in a poorly sorted matrix fills some caves close to present or former swallets.</td></tr>
</table>

Table 9.4.1 Summary of similarities and differences between northern and southern Peak District cave sediments.

other processes form the matrix to collapse breccias.

9.5. Chronology

In many cases it is not at present possible to date the deposits other than to indicate relative ages by use of the law of superimposition. No spores or pollen have been found in this study which could be used to date any of the deposits palaeontologically. Some dates have been provided by the dating of overlying speleothems using U/Th methods (see Ford et al, 1983). Where palaeomagnetic studies have provided data which can be correlated with known palaeomagnetic sequences this has also provided some information on the age of the sediments and there is considerable scope for the development of this technique.

Palaeomagnetic studies in the Masson Cavern - Youd's Level Complex give consistently reversed remnant magnetism of the sediments. In the Clay Shaft of Youd's Level a complete sequence of samples was taken which show that a reversal to normal remnant magnetism occurs approximately one metre from the top of the sediments exposed. This can be tentatively correlated with the inversion to normal magnetic polarity between the Matuyama and Brunhes polarity epochs at 690,000 yrs. B.P. (LaBrecque et al, 1977). It is also possible that this event may correlate with the end of other, shorter, reversals during the Brunhes palaeomagnetic epoc (Rampino, 1981), though the consistent reversed remnant magnetism of the sediments and their position close to the top of Masson Hill makes this less likely.

Similar studies of the silts remaining in the Far

Years B.P.	
330,000,000	Pre-Edale Shale cavernisation (Windy Knoll, Treak Cliff Cavern, Smalldale Pipe).
250,000,000 to 33,000,000	Mineralization and hydrothermal cavernisation throughout the Peak District.
7,000,000 to 10,000,000	Brassington Formation laid down in the southern part of the Peak District followed by sagging into solutional depressions.
1,000,000 to 1,500,000	Exposure of the Carboniferous Limestone in the southern part of the Peak District.
630,000	Deposition of fluvio-glacial sediments in cave systems close to the top of Masson Hill.
350,000 to 600,000	Exposure of the limestone in the Monyash area, formation of Water Icicle Close Cavern and partial filling with fluvial Namurian sediments.
90,000 to 350,000	U/Th dating suggests that the present underground drainage systems evolved during this period.
75,000 to 90,000 and ?17,000 to 45,000	Introduction of solifluction and loessic deposits into cave systems
75,000 to date	Re-working and deposition of loessic silt, fluvial sedimentation and re-erosion.

Increasing exposure of limestone and development of a complex sub-surface drainage net-work

Table 9.5.1 A suggested chronology for Peak District cave sediments.

Stream Passage of Peak Cavern show that the sediments have normal remnant magnetism. Comparison of these results with those of Turner and Thompson (1981 and 1982) for British lake cores show close correlation over the period from 5,000 to 1,000 yrs. B.P.. The sediments have been partially re-eroded since that time owing to the removal of the constriction causing the ponding. One speleothem date for a stalagmite overlying these sediments gives an age of 1,000 to 1,200 yrs. B.P. (Ford et al, 1983) which supports the palaeomagnetic results.

There is considerable potential for the continuation of the study of remnant magnetism in cave sediments of the Peak District and more positive dating may be possible by this method.

The only other correlation that can be made between sediments is that based on their composition. Those containing loess - derived silt have probably accumulated since the Devensian I glacial (75,000 to 90,000 yrs. B.P.) when most of the loess was introduced into the area by the reworking of surface loess deposits. It is possible that some of the loessic silt is pre - Devensian in age though it is not possible to recognise any such deposits.

Fluvio - glacially derived sediments can only have been derived during the waning phases of a glaciation, the last of which to affect the Peak District was the Wolstonian which ended 145,000yrs. B.P..

Fluvial sediments could have been derived during any of the temperate periods.

9.6. Implications on the Pleistocene Geology of the Peak Disrtrict

In the Matlock area the downcutting by the River Derwent began in early Pleistocene times leading to the formation of phreatic, mineral - vein - oriented, drainage networks in the higher parts of the limestone. Further down cutting led to the abandonment of these cave systems which may also have lost any allogenic stream input by the removal of the overlying sediments. At a later period invasion by glacial or snowfield meltwater streams led to the filling of many of these phreatic caves with fluvio - glacial sediments. These sediments were derived from a source predominantly composed of material derived from the Namurian strata.

As palaeomagnetic evidence suggests that these sediments are nearly 700,000 years old and as S.E.M. studies indicate that these sediments have a glacial history they are thus the earliest evidence of glacial activity in the British Isles though not in Europe.

Further phases of high runoff caused by glacier and snowfield melt led to rapid, but intermittent, deepening of the Derwent valley and gorge down to 122 metres O.D. by the close of the Wolstonian Glaciation. This is the lowest level at which sediment filled cavities are developed in this area, indicating that the cavities had been formed and many of them filled with sediments by this date.

The sediments found in Water Icicle Close Cavern and Long Rake Spar Mine were derived from a Namurian source fairly close to them, probably in the Monyash area. Ages for stalagmite deposits overlying these sediments are beyond the range of the U/Th method at greater than 350,000 yrs. B.P. (Ford et al, 1983). From this data it is reasonable to conclude that an outlier or former cover of Namurian strata existed to the west of the Water Icicle Close Cavern area in early to mid Pleistocene times before the incision of Lathkilldale. It may have been removed during a glacial phase leading to the abandonment of this high level drainage network.

In the Castleton area there is radiometric evidence to suggest that the present underground drainage system at least dates back to the Devensian I (Ford et al, 1983) and may well have been substantially as it is today as long ago as the end of the Wolstonian.

At Earle's Quarry, and probably over the rest of this area, the post limestone cover had been stripped off by the end of the Wolstonian since the limestone is cut by sub-glacial or marginal drainage channels which cannot be of more recent age.

Loess and reworked loessic silt occur throughout the Peak District. The distribution of derived loessic sediments in subsurface cavities throughout the area shows that surface loess deposits were considerably more widespread than at present. The surface loess deposits have been attributed to the Devensian (Piggot, 1962) and there is no evidence to suggest that the reworked deposits found underground have been derived from loess deposits of a different age.

9.7. Residual and Alluvial Ore Deposits

Throughout the Peak District the fill of solutional cavities and the sediments in some cave systems once formed important lead ore deposits and it is probable that a considerable proportion of the early lead production came from this source. In view of the almost total removal of these galena - rich sediments little can be deduced further.

Of those deposits that have survived their character is highly variable, varing from small fissures along scrins to large cavities many tens of metres in diameter. The composition of the ore fraction varies according to the location of the cavity in relation to the zonation of the orefield.

Any of the cave - forming and sediment transport processes can introduce "ore" minerals into the sediments. Some may be derived purely by mechanical erosion of surface or underground exposures of primary mineralization. Due to the friable nature of most of the vein minerals in the Peak District most of the clasts of these minerals found in the sediments are fine - grained. If allochthonous sediments are present in the cavities the "ore" minerals may form discrete layers within the deposit or may be more or less uniformly distributed throughout the deposit.

Galena, usually with a coating of cerussite, is present in many of the deposits, but usually only in small quantities as the richer deposits have been worked out. It occurs either as lumps extracted from its original matrix by solutional processes and accumulated as a residual deposit or as stream

- worn pebbles throughout fluvial deposits and in active streams.

Fluorite occurs in many of the deposits in the fluorite zone of Dunham (1952) where it tends to retain its cubic crystals, without rounding, indicating very limited removal from its original source. Baryte is found in a similar condition when it is present. If calcite is present it is deeply etched by the effects of solution.

These "ore" minerals may form all of the sediments in a cavity or may be mixed with other autochthonous material in the form of chert, authigenic quartz and toadstone clay as well as with variable quantities of allochthonous sediments.

Comparison with the deposits in the Mendips, Yorkshire Dales and the Northern Pennines shows that these areas have similar deposits, of similar age, but with local differences resulting from different local geology and environment.

In the Peak District fluorite - bearing deposits are potential sources of fluorspar but their erratic distribution, limited size and the fact that the high clay content of some of these deposits interferes with the sink/float cells of the dressing plants (Fletcher, pers. comm. (1979)) renders them of little commercial value at present. This is especially the case as there are considerable reserves of fluorspar in primary mineral deposits in the area.

9.8. Further Research

This study has demonstrated that the sedimentological history of karstic cavities and cave systems of the Peak

District is highly complex and has occurred over a considerable period of time. The sediments have been derived from a number of sources and by a variety of processes.

Further palaeomagnetic study may be able to to provide more information on the chronology of sedimentation and perhaps relate sediments from cold and warm phases to known time periods.

In the Castleton and Stoney Middleton areas detailed sedimentological investigation of individual cave systems or underground drainage basins, similar to that undertaken by Bull (1976c) on Agen Allwedd in South Wales, may provide more information on the speleogenesis of those areas.

A study of the problems associated with the mineral dressing of the secondary fluorite deposits will be of importance if these deposits are ever to be used as sources of fluorspar.

PAPERS PRESENTED IN SUPPORT OF THIS THESIS

ARBOR LOW CALCITE MINE

Notes and comments resulting from
a descent of the mine, 10/2/80.

R.P.Shaw, 19/2/80

This report is intended to supplement the information contained in the O.M. Mines Research and Exploration report of July 1978, which describes the location, geology and the 1976 condition of the mine.

Description of the Mine

The mine was entered at the western end of the property by means of the "Old West Decline", and its ladderway, which was, no doubt, one of the old emergency exits. Recent dumping of rubbish and former dumping of tailings into the decline has made the descent rather unpleasent. A combination of ladders and steep stopes gives access to the western end of the mine.

The first level encountered is the No. 1 Level a few metres from its western forefield. The level is stoped out above and below, leaving about two metres of calcite as a floor. Progress to the east is prevented by semi - liquid tailings which are continually slumping from above. Continuing down the ladderway at the west end the No. 2 Level is reached. The ladderway continues to the No. 3 Level but progress along that level is prevented by dumped tailings.

The No. 2 Level can be followed to the east, via a number of "holes in the floor" passed by catwalks, to the shaft and, beyond, to the eastern forefield.

Ladderways near the shaft go both up and down. that down gives access to large stopes between the No. 2 and No. 4 Levels (No. 3 having been removed) which is flooded to above the No. 4 Level.

The ladderway up gives access to the No. 1 Level and on to the surface. At this level, before further progress is prevented by tailings slurry, is an old timber hand winch.

Throughout the mine the stopes are generally between 5 and 8 metres in width and almost the full height between levels (~30 metres), with just one or two metres of vein left as level floors. In some cases this was removed in tha last stages of mining.

Ladders and chains on the ladderways are in fair condition; most ladders being constructed entirely of steel. Most of the timbering in the mine is still in good condition with the exception of a few limited areas. At present the major hazards are the vast ammount of semi - liquid tailings in the western end of the mine and the condition of some of the catwalks. There is evidence to suggest that in periods of wet weather a stream flows down the decline and ladderway to the bottom of the mine carrying with it rubbish dumped in the entrance.

Recent footprints indicate that the mine is sometimes visited via the Old West Decline.

The Vein

Throughout the length of the mine, except at the east and west ends, the vein has been almost entirely removed. It is generally between 5 and 8 netres wide and composed almost exclusively of white calcite and a little galena. The galena is concentrated into narrow, patchy strings close to each wall and rarely in the centre. Where slickensides are present they are roughly horizontal.

At the east end, on all levels where it was exanined, the vein breaks up into a limestone breccia with strings and pockets of calcite. This is also the case in the west end of Long Rake Spar Mine which is to the east of Arbor Low Mine.

At the west end the vein appears to narrow rapidly to a width of about one metre and assumes the banded nature typical of multi - phase mineralization. Here it also contains small (2 - 3 cm.) pockets of soft, red hematite.

Little calcite remains in the existing mine and evidence suggests that the vein pinches out both east and west. Evidence here and along the rest of Long Rake suggests that the vein is no a simple wrench fault as had previously been thought. The only possible reserves of calcite are below the existing workings where they have not been tested and where water would be a major problem.

R.P.Shaw 19/2/80

Additional Note

A further descent of the mine was made on the 10th. August 1981. On this occasion it was found that the western end of the No. 3 Level was passable with care. After about 70 metres the tailings "flow" descended to flooded stopes below the level. the shaft area at the bottom of the Main Shaft was reached where more tailings, up to 1 metre deep, were encountered. From here a decline, flooded part way down, led to deeper stopes.

East of the shaft the level sole has been removed leaving a large stope, flooded towards the bottom, with an unstable catwalk along one wall. The character of the mine on this level is the same as the higher levels with almost total extraction of the calcite vein.

R.P.Shaw 12/8/81

Bulletin of the Peak District Mines Historical Society, Vol. 7, No. 6 pp.342-344
Autumn 1980

A SURVEY AND THE GEOLOGY OF PUTWELL HILL MINE, MONSAL DALE

by R. P. Shaw

Some information has previously been published on this mine, especially on the recovery of two steam pumping engines from the mine by members of P.D.M.H.S. (Thompson, 1971 and Amner, 1974). A brief description and sketch survey have been produced by Bird (1972). Since then the accessible parts of the mine have been considerably extended by somebody digging through the fill at the end of the last stope on Bird's section.

The present article is intended as an up-to-date description of the accessible mine workings and is accompanied by an accurate survey, which was carried out using Suunto compass and clinometer (read to a quarter of a degree) and Fibron tape read to the nearest centimetre. The initial line survey was plotted by computer.

The mine is situated at SK 179 718 beside the disused railway just east of the old Monsal Dale station site. Part of the strong calcite vein is exposed on the south side of the railway where it enters a cutting. The concrete plug over the old easy entrance can be seen beside the vein. Entry to the mine nowadays is via an open stope surrounded by a fence just above the exposure. 15 metres of ladder and a 6 m belay to nearby trees are needed for the descent. An alternative entrance is via a small level on the east side of the open cast workings higher up the hill. This gives access to a 8 m deep shaft (ladder required) connecting to the inner workings of the mine.

The bottom of the stope is littered with scrap iron and fallen trees. Back towards the railway a small hole to surface can be seen. The stope ends at a well built drystone pack probably built at the time of the railway to support its foundations. In the other direction beyond the open stope, a large mound of deads has to be climbed, giving an impressive view of the stope. The vein here is about two metres wide and composed almost entirely of calcite (for which the mine was worked earlier this century). On its south side the vein carries some galena and baryte which was worked by t'owd man in a slit about 0.5 metre wide containing rotten stemples and deads, now partly calcited over.

From the bottom of the mound the size of the stope increases to about 15 metres high and 3 to 4 metres wide. Slickensides are clearly visible on both walls and indicate a horizontal movement along the vein. About half way along the stope a false floor has collapsed but this can be bypassed by climbing up on the left hand wall.

Near the shaft from which the steam engines were recovered the stope closes down to a level which ends overlooking a short drop to the bottom of the 30 metre deep shaft from the surface. Where the stope ends a climb up a rotten wood and iron ladder leads to an upper level and a traverse around the side of the shaft. The large level beyond the shaft contains some stacked deads and ends abruptly at a fall. Here a short climb up leads to another stope with one end composed of fallen and washed in material. At roof level this has been dug through to give access to more large stopes beyond. Immediately at the inside end of the crawl a climb up through boulders leads to a number of short, fairly modern levels with a climb up a steep slope to an unstable connection to daylight in the open cut beside the limestone quarry. The alternative entrance to the mine is via a short level and a ladder down an 8 metre deep shaft into this section of the mine.

A steep slope down from the crawl leads to the head of a 7 metre pitch, where a ladder 8 m long is necessary and can be belayed using a long rope to boulders at the top of the slope. From the bottom of the pitch the stope continues for about 30 metres and contains some massive fallen blocks; it eventually ends at a major fall.

Back under the pitch some stoping has been carried out but it is blocked by an extensive fall of fine grained tailings, possibly from the surface. Part of a level through deads with drystone walls and timber roof remains. This level obviously continued through the fall but the timbers have given way.

Throughout the mine the vein is 2 to 4.5 metres wide consisting mainly of calcite with some earlier galena and baryte on the south cheek. The easterly workings and the upper part further west are in limestone but in the western end at depth toadstone forms the walls. The toadstone is slightly altered and is weathered to a grey clay where exposed in the workings. This toadstone may be the continuation of one of the Millers Dale lavas. When in the toadstone the vein has irregular walls with pockets of calcite, sometimes with traces of sphalerite and galena. In the limestone the vein walls are smooth and often show nearly horizontal slickensides. Since the contact between the toadstone and the limestone is almost in the same position on both the north and the south sides of the vein there has been very little relative movement between the two sides.

July 1980

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Karstic sediments, residual and alluvial ore deposits of the Peak District of Derbyshire

Richard Peter Shaw

Abstract

Detailed sedimentological studies of both surface and underground karstic sediments from the Peak District have been undertaken.

Mineralogical examination shows that the allochthonous fraction of the sediments have been derived mainly from the Namurian strata which surround, and once overlay, the area. The remainder of the allochthonous fraction has been derived from the Triassic sediments to the south of the area and from superficial loess deposits, many of which were introduced into the area during the Devensian Glaciation.

Many of the deposits contain an autochthonous fraction consisting variably of chert, authigenic quartz, limestone and dolomite, fluorite, baryte, calcite and galena clasts released from the host rocks by phreatic solution and having suffered only limited transport.

Scanning electron microscope (S.E.M.) studies of quartz grain surface textures show that many of the allochthonous sediments have been transported under fluvio-glacial conditions.

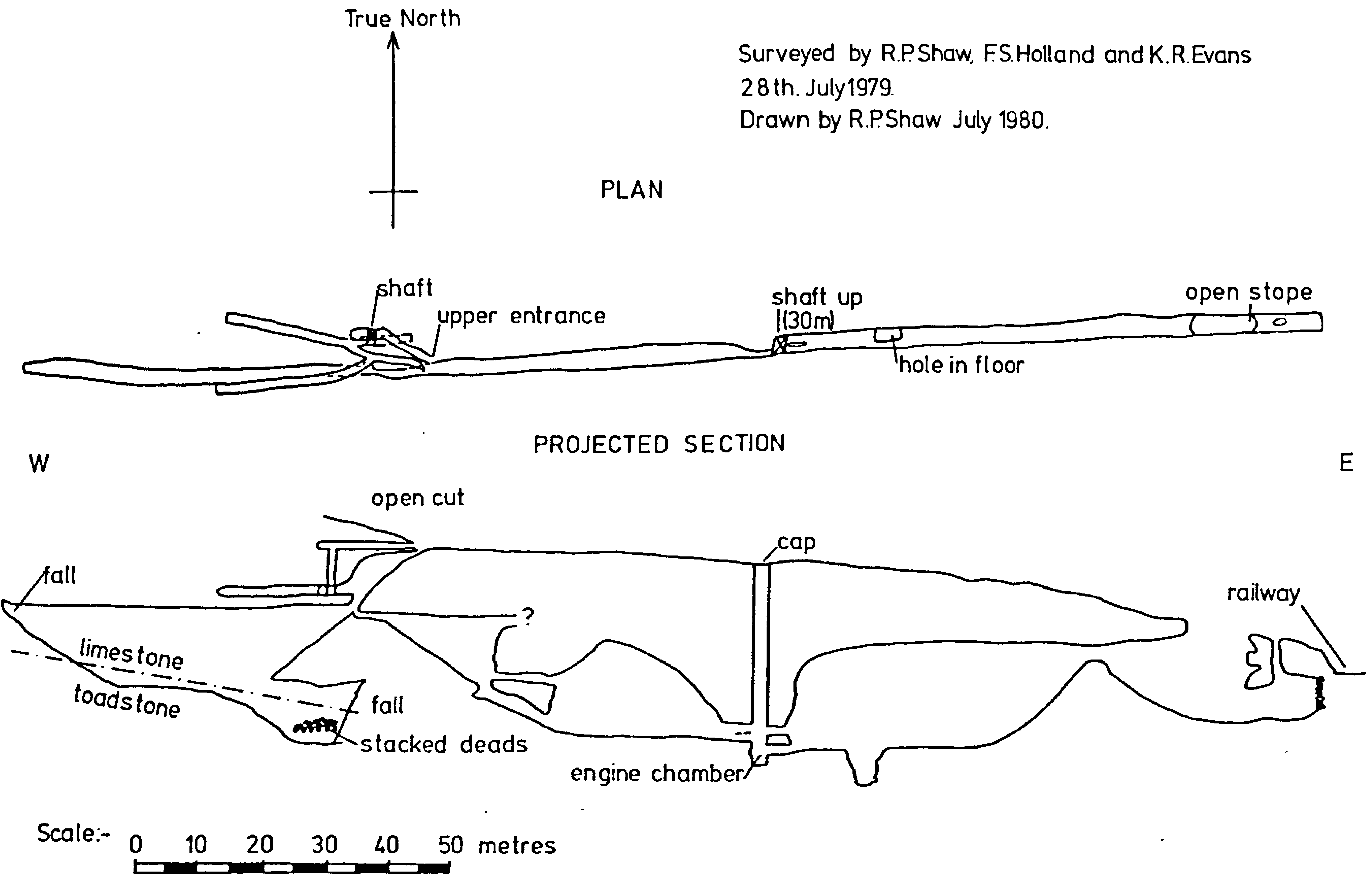
A number of sedimentary accumulations in isolated cavities consist of reworked loessic silt which has been carried underground via joints by the mechanism of translatory flow.

Palaeomagnetic studies of sediments in the Matlock area show that they consistently have a reversed remanent magnetism which may indicate that these fluvio-glacial sediments have an age in excess of 690,000 years b.p.

The "ore" fraction of some of the deposits studied may form important sources of fluorspar when other, larger and more easily worked, deposits have been worked out, if the dressing problems can be overcome.

Putwell Hill Mine

Surveyed by R.P.Shaw, F.S.Holland and K.R.Evans
28th. July 1979.
Drawn by R.P.Shaw July 1980.



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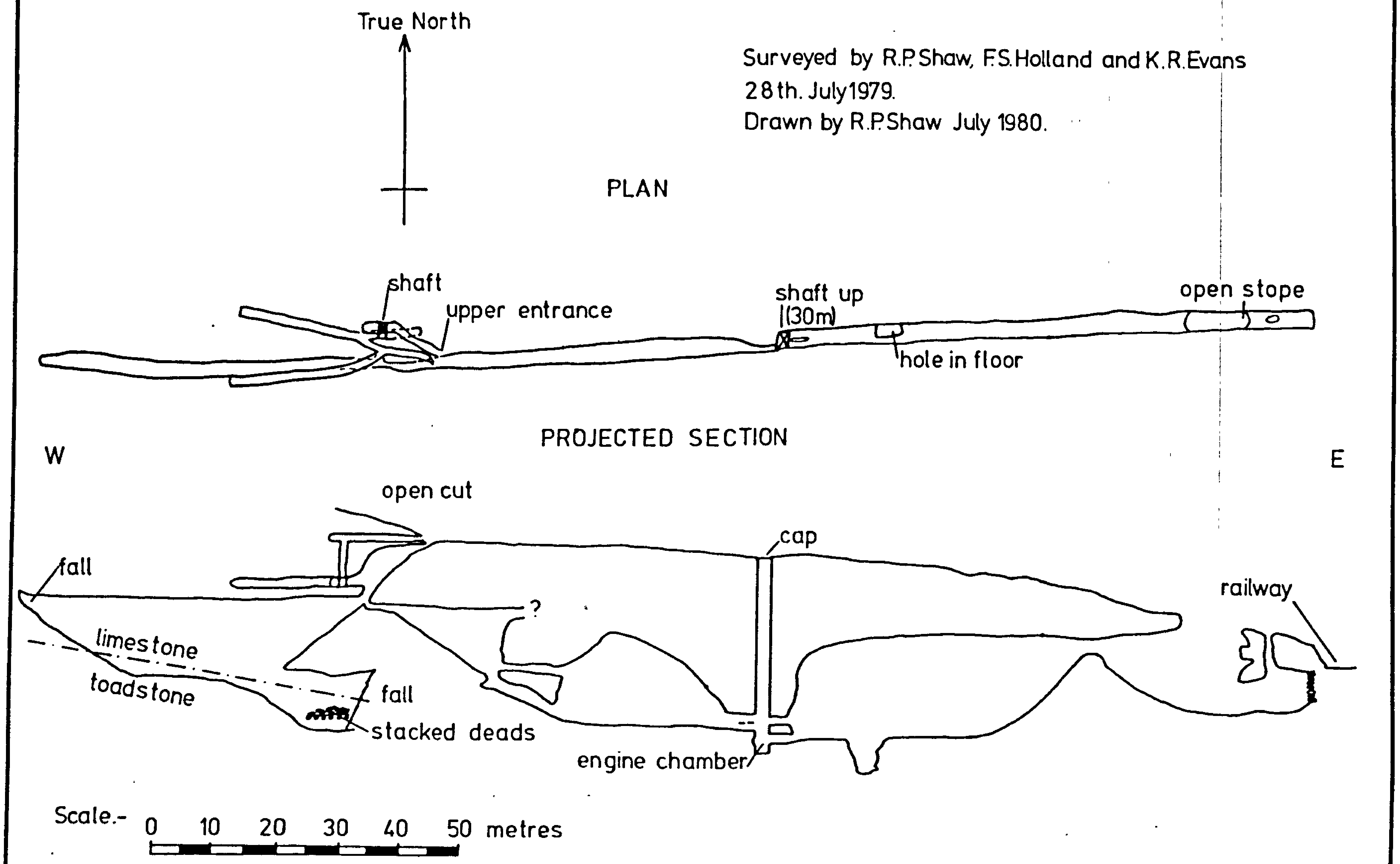
Putwell Hill Mine



Surveyed by R.P.Shaw, F.S.Holland and K.R.Evans
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CAVE SCIENCE

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REDISCOVERY OF THE LOST PILKINGTON'S CAVERN, CASTLETON,DERBYSHIRE

R. P. Shaw

ABSTRACT

Climbs totalling 58 metres, with linking passages totalling 536 metres long, have led into cave passages which fit Pilkington's description of 1789. Originally found by lead miners around 1770-1780, this part of Speedwell Cavern appears to have given access to the stream caves before the canal was driven to intersect the stream system so that a number of mineral veins could be worked. The total vertical range of the Speedwell Cavern System is 182.6 metres, very close to the English depth record.

Speedwell Cavern is a show cave cum mine at the bottom of the Winnats Pass west of Castleton, Derbyshire. The previously known cave has been described by Ford (1956). It consists of a mine level driven as a canal to utilize boat haulage for ore and waste removal which intersects an extensive active and abandoned stream cave system taking swallet water from the Perryfoot/Giants Hole area to Russet Well.

During 1981 a number of pitches were climbed in part of the system using self-drilling bolts. Bolting started in the cavern discovered in the Assault Course part of the system some 100 metres west of the Far Canal by T. D. Ford in 1944. This contained the remains of climbing stemples from which Ford deduced that it might be the bottom of the lost cavern described by Pilkington in 1789.

BRIEF HISTORY

That the "Old Man" knew about the stream cave system of Speedwell Cavern before the canal was driven has been regarded as certain, but hitherto unproven.

The Speedwell Canal, commenced in 1771, was driven to intersect the cave system, which it reached 11 years later, to enable the working of a number of mineral veins therein. Boat haulage was to be used for waste and ore (Rieuwerts and Ford, 1983), though why it did not reach the surface as a level is in doubt. All waste rock (until the Bottomless Pit was reached) was boated back to the bottom of the shaft and then wound to the surface.

The route by which the "Old Man" entered the cave system before the level was driven was described by a number of contemporary tourists. Though most of these accounts were published after the canal reached the stream caves the visits were made before the break-through. The first of these was Sulivan in 1780 (second edition 1785) who described an arduous descent to the stream caves via climbs totalling some 420 feet.

Pilkington (1789) described the descent in a much more detailed account and with a fair degree of accuracy, giving depths of descents and rough lengths traversed but unfortunately no bearings so that it was impossible to work backwards when the presumed bottom was found in 1944.

Another description was by Milne (1813) (noted by Anon, 1947) though this is an almost perfect repetition of Pilkington's account without acknowledgement.

From these descriptions several people have tried to locate the lost passages, usually wrongly assuming that they entered the Bottomless Pit Cavern.

The Assault Course series of the Speedwell system was discovered in 1944 by T. D. Ford who dug through a silt-filled passage from the Far Canal (Ford 1956; Simpson, 1953). Some 100 metres from the canal a circular cavern was entered containing stacked deads and the remains of climbing stemples on the floor and a few wedged in the walls. The remains of a wooden platform could be seen above. It was estimated as 50 feet high and this fitted with the last vertical of Pilkington's descent at 16 yards, and so the chamber was provisionally named Pilkington's Cavern.

The last part of Pilkington's account describes a passage "one hundred and twenty yards long, two feet high and two wide and at the end you discover another 150 long, six feet high and two wide". This does not correlate with the present flat-out crawl entrance from the canal, but it does correlate with the downstream end of the Assault Course streamway, which now ends at a sump created when the canal was completed and flooded.

Fig.1.

The Lost PILKINGTON'S SYSTEM, Speedwell Cavern.

Surveyed by R P. Shaw, J.D. Harrison and J. Tomlin.
B C.R.A. grade 5C.
Drawn by R P. Shaw 31/12/82
Passage sections at twice scale of plan
Spot heights (→123) in metres above Canal
100 metre grid

Fig.2. PROJECTED PROFILE OF PILKINGTON'S CAVERN

Inset - Pilkington's Cavern reconstructed from his description.

EXPLORATION

Pilkington's Cavern was climbed, using self-drilling bolts, in January 1981, giving access to about 160 metres of passage trending northwards to a second climb (Round Pitch). This was climbed in late February giving access to some 70 metres of steeply ascending passage including a free climbable third pitch (Galena Pitch) of 7 metres to the fourth pitch (Chain Pitch). This was climbed in November 1981 to a further 250 or so metres of passage including two further pitches (Waterfall Pitch and Boulder Pitch), each of 8 metres, making six pitches in all.

DESCRIPTION

Pilkington's Cavern is circular in plan and about 5 metres in diameter. This first pitch is a climb of 12 metres, the ladder hanging under the small stream that cascades from the passage above. Originally the cavern had climbing stemples and a stemple-supported platform over the top. Deads are stacked at the bottom.

From the head of the climb Pilkington's Passage extends some 160 metres generally northwards. The passage is developed in one bedding plane (probably the same one as the controlling bedding plane of the Peak Cavern streamway) as a vadose canyon. Initially this is 2.1 m high and 0.75 m wide but soon reduces in height and width. In many places it was enlarged by the miners who removed sharp corners to enable them to get the long stemples through. Where the passage height allowed the rubble from this operation was packed onto the floor. The surplus was taken back to the bottom of the Round Pitch. Towards the northern end the passage intersects a number of small scrins and a calcite pipe vein, none of which were investigated by the "Old Man". A number of artifacts were found in the passage including the end of a pick, a brass button and buckle, the remains of a pair of boots, a rope and a number of nails.

The chamber at the north end of Pilkington's Passage and the passage immediately above are partly developed in a calcite pipe vein . Beyond the top of the 11 m Round Pitch the passage is a phreatic tube about 1.5 m in diameter developed in the pipe vein. A short distance beyond this the passage becomes a high vadose rift to a climb of 7 m (Galena Pitch) into a chamber.

Here there is evidence of the presence of the miners in the form of an ore-washing floor of rotten planks with a little galena on them, though there is no evidence of mining. Above the dressing floor is a cluster of large stalagmites.

A series of climbs leads to the bottom of the third pitch (Chain Pitch), a climb of some 12 metres. The pitch is covered with massive flowstone, a hole in which was found to contain a length of iron chain (Pilkington noted that a chain was used on this pitch). Above the pitch the passage is again developed in a calcite pipe vein to a lofty chamber, Waterfall Cavern.

Just before the cavern is reached are the remains of another ore-washing floor, but again no evidence of mining. The cavern is at least 20 metres high with water entering from two points, one in the roof of the cavern and the other down two stempled climbs. The cavern is adorned with stalactitic formations, some of which were broken in mining days but have since partly regrown.

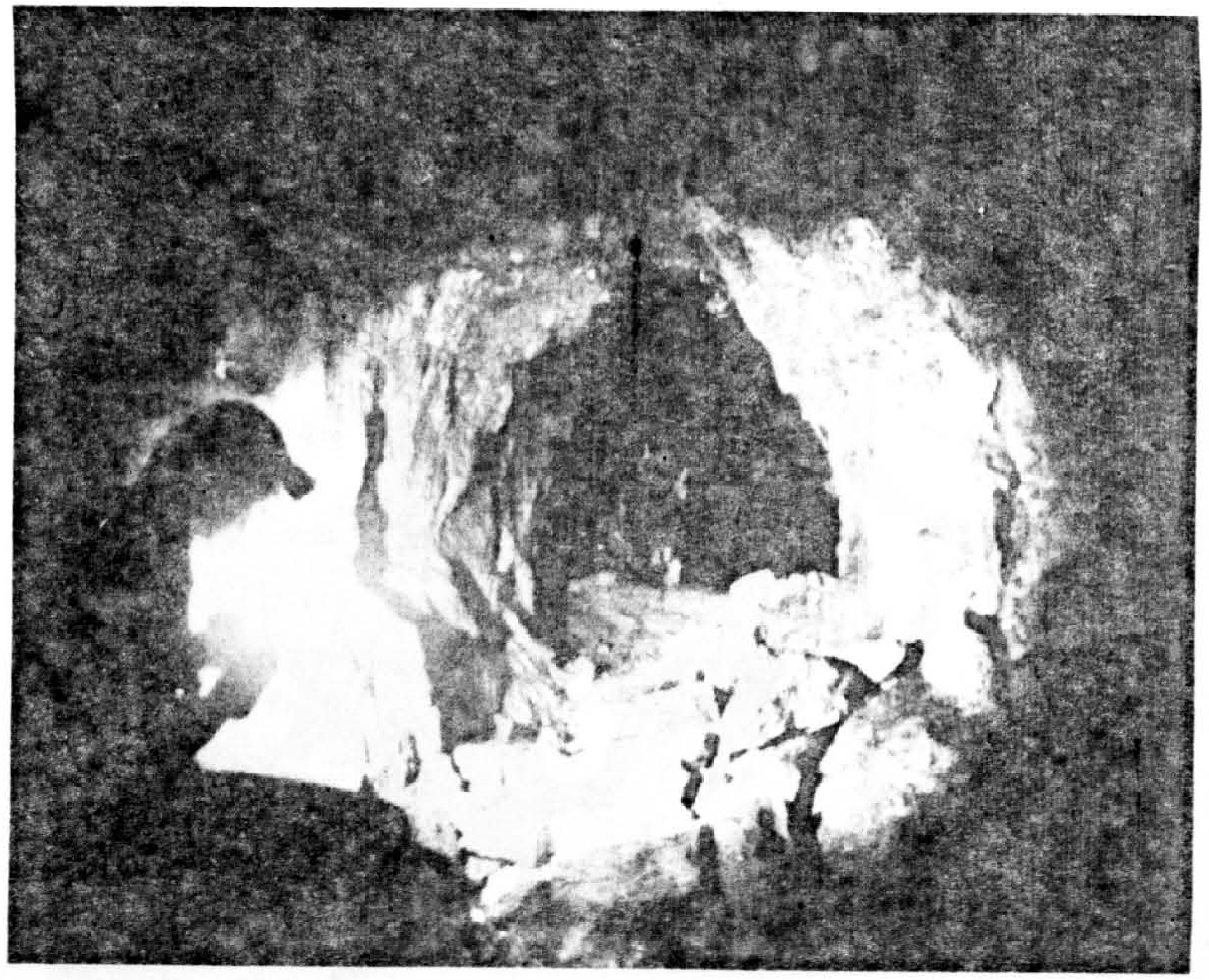
From Waterfall Cavern two difficult free climbs (Waterfall and Boulder Pitches) up a formerly-stempled section, each of 8 metres, led via a short low passage to the bottom of a stempled shaft through boulders. The top of this shaft is in a large chamber named Mud Hall. This chamber is not as large as Pilkington described it but it is certainly impressive. It has a bedding plane roof and a floor of boulders buried in mud, the chamber being up to 5 metres high and 15 metres wide.

At the east end, the chamber reduces in height to a bedding plane about 0.35 metre high but the miners made an easier route by digging a trench in the floor. Beyond this, over a partly collapsed dry-stone wall, which may have marked a property boundary, is another chamber which Pilkington described. Named Watricle Chamber, this was beautifully decorated before being stripped by the miners. The stalactite stumps are starting to regrow but two hundred years is not long enough for total recovery. Pilkington described it thus:-

"When the miner first broke into it, it appeared beautiful beyond description. Upon introducing his candle thro' the hole, which he had made, he was struck with astonishment. But when he entered the cavern, it in beauty exceeded his highest expectations. The roof and sides were covered with water icle, almost as white as snow. But now it is in a great measure stripped of its ornament by those who have passed through it".

To the east this chamber extends 20 or so metres to a fall, caused by the

1. Climbing Pilkington's Cavern; remains of miners' wooden platform above.

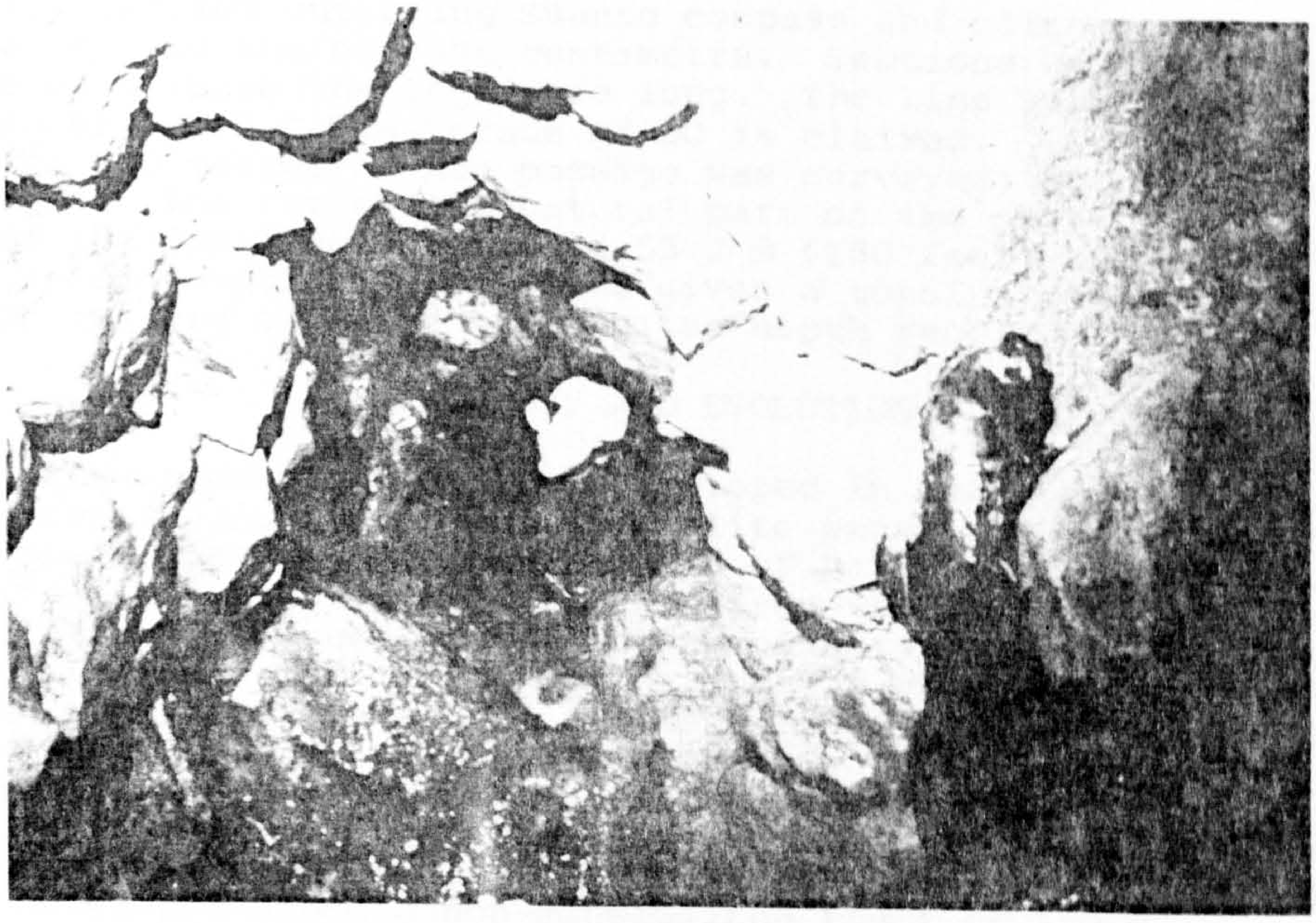


2. Watricle Cavern looking west; ore-dressing bench on right.

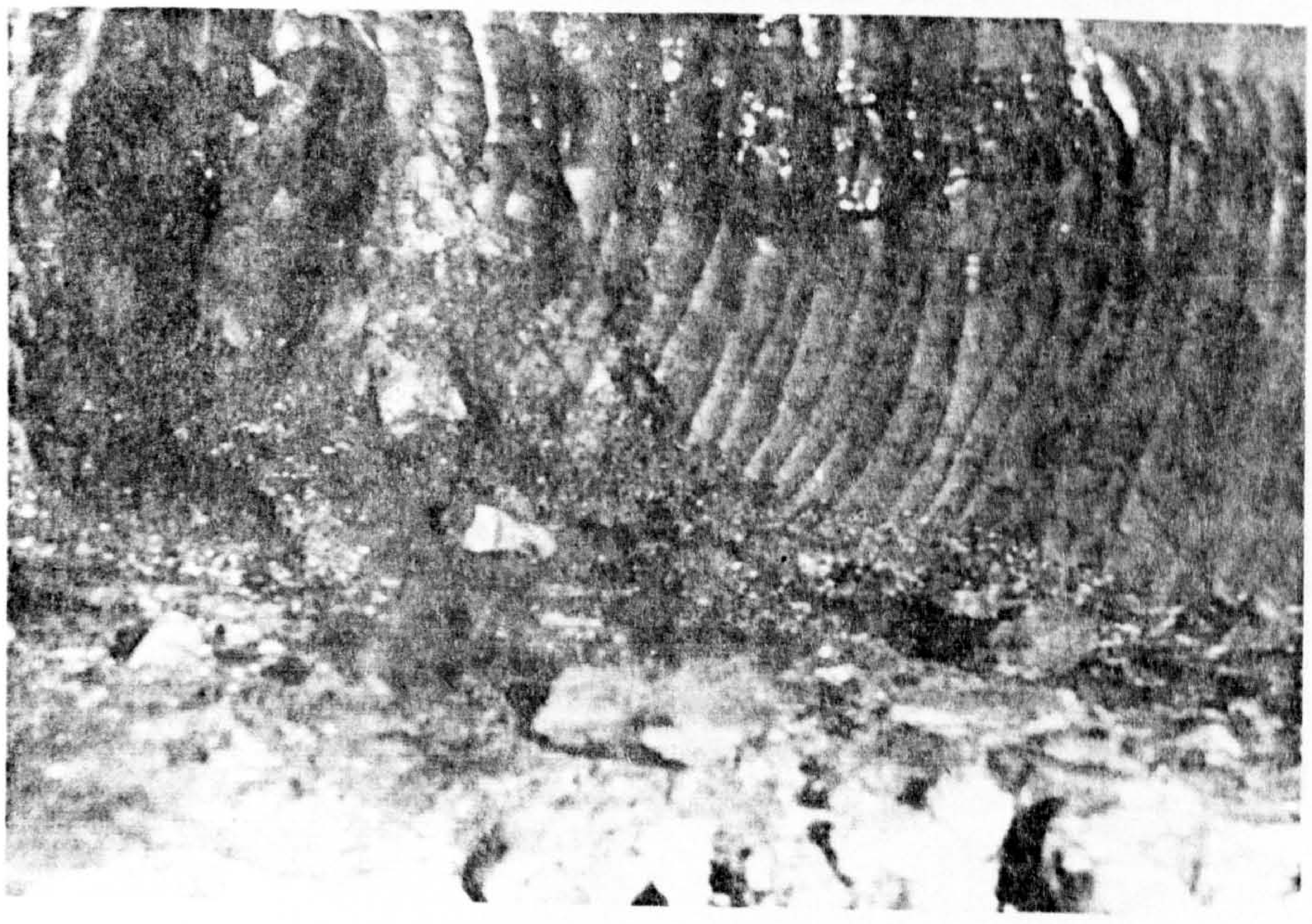
PILKINGTON'S CAVERN

3. Broken stalactites in Watricle Cavern.

4. Miners' trench cut in floor from Mud Hall to Watricle Cavern.



5. Climb through boulder shaft into floor of Mud Hall.



6. Remains of washed galena on rotten boards above Galena Pitch.

collapse of sandy gravel fill from a phreatic cavity into the mine workings. The chamber has been extensively used for ore dressing which must have been carried out dry for there is no water available here. The sorted ore was then taken down 3 or 4 pitches, for some 50 m to the bottoms of the wetter pitches for final cleaning, and was then apparently carried back out to the surface via a shaft which appears to be back-filled or totally run-in now.

From Watricle Chamber lead a number of partly natural, partly mined passages and mine workings. Most of these are levels driven in Faucet Rake or branches to the north. Only in two places are the workings continued below the bedding plane controlling the roof of Mud Hall in the form of flooded, partly back-filled stopes. Where present, stopes on the vein above this level are 0.5 to 0.8 m wide extending irregularly upwards for up to 7 m. All shot holes made for mining are about ¾ inch in diameter. To the west a passage mined through sediment fill leads to a small, cleanwashed phreatic chamber with a 10 cm. high bedding plane with solid rock floor and roof being the only exit.

A number of artifacts were found in this section of the system including a wooden kibble with iron bands, tallow dips, a leather harness and chain for dragging corves, iron banding from a corve, a broken wedge and a clay pipe (1750 to 1790 in style).

On the surface above this area, about 50 m above, is a large natural depression close to Faucet Rake which probably represents the surface location of the natural part of the cave system. Any cave between this point and the top of that explored appears to be filled with loess and solifluction sediments.

THE SURVEY

The survey was carried out using Suunto compass and clinometer, read to 0.25° and Fibron tape read to the nearest centimetre. Sections were made at all stations and between where the legs were long. The line survey was initially plotted by computer. A B.C.R.A. grade of 5C is claimed.

In total about 500 metres of new passage was surveyed; of this only about 40 m is mine level. The top of the natural part of the system is some 127.1 m (416 feet) above the canal which is some 55.2 m (180 feet) above the downstream Bung Hole sump in Speedwell cavern. This gives a total altitude range of 182.6 m (596 feet) which is very close to the English depth record for natural cave passage.

GEOLOGY AND EVOLUTION

This part of the Speedwell system is developed in well-bedded limestones of Asbian (D_1) age containing a number of stylolite seams. The limestones are cut by a number of small, less than 1 cm., scrins of baryte and fluorite and irregular calcite pipe veins as well as the large veins of Faucet Rake.

The mineralization in Faucet Rake consists of void fillings in veins of banded fluorite, baryte , calcite and galena up to 0.8 m wide though generally less. In Watricle Chamber there is a sedimentary deposit containing derived fluorite, baryte, calcite and galena which has also been worked.

Pilkington's Passage is a sinuous vadose trench developed from a prominent shale-filled bedding plane with a thin (2 to 3 mm) coal seam which has also been recognised in Speedwell's Cliff Cavern and in Peak Cavern. The passage below the Chain Pitch is developed along a non-mineralized fault of 1.5 m throw down to the south, as shown by upturned limestone beds in the roof. Mud Hall and Watricle Cavern are associated with a prominent bedding plane, probably a clay wayboard. In the case of Mud Hall this horizon forms the roof while in Watricle Cavern it forms the floor. This wayboard may represent the Cave Dale Lava in this locality.

Development of Watricle Cavern has also been controlled by Faucet Rake which runs along its length but has only been worked in the floor at this point.

Most of the system is vadose in origin connecting short sections of formerly phreatic passage developed in Faucet Rake and associated pipe veins. The vadose incision indicates that it formed as an inlet swallet to a system already drained at least to the level of the canal and thus Hope Valley was in existence when this inlet system was last active, though it seems unlikely that the Winnats Pass could have been present so close to such a swallet at that time.

The limited phreatic development at the top of the cave system probably considerably pre-dates the vadose development perhaps representing early cavernization in Faucet Rake and associated pipe veins. Watricle Cavern is partially filled with a silty gravel, similar to that in the entrance series of Giant's Hole, probably of solifluction origin, containing large rounded clasts of Millstone Grit and shale. It is likely that this material was introduced into the cave during a periglacial phase totally blocking the former swallet. As the vadose passages are not very large this cave was an active swallet system only for a limited period of time before the Wolstonian glaciation. Today all water in the system is of percolation origin.

CONCLUSIONS

Pilkington's lost cave system for which cavers have been searching for nearly a century has been found. The early accounts of arduous and long caving expeditions have been shown not to be as exaggerated as some have thought and the route by which the "Old Man" found his way to the stream caves before the canal was driven has been traversed again. Considering that a return trip from the canal to the highest point reached at the bottom of Pilkington's shaft takes at least four hours one has to admire the miners who worked in these passages and shafts fitting stemples on the pitches whilst hanging by ropes under wet conditions without the protection of modern clothing. It must surely have been an achievement just to keep their candles burning on some of the pitches.

ACKNOWLEDGMENTS

The exploration and survey described has only been possible due to access to the Speedwell system via the show cave being allowed by the owners, the Harrison family. Especial thanks go to the manager and staff at the shop for changing room and the supply of hot drinks etc., when emerging after a long day underground. Also to the vast amount of willing assistance given by numerous people who helped in bolting, surveying and photography, including John Harrison, Rod Branson, Richard Acton, Jon Reading and John Tomlin. Gratitude must also be extended to Trevor Ford for floor space and continued encouragement as well as for introducing the author to the cave system as a whole.

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Squear of the great rods at the top 12 by 8½ Inch squear Bottom of the great rods 8½ by 6 squear
Sept^{r} 22 1792, I made a trial of Coales for 24 houers the Engine working at the rate of 9 Stroakes per minute Consumed 2T 5 h (cwt) of Coales in 24 houers ________ without the slide rods
Dec^{r} 15 Coales consumed in 5 days working with the Slide rods 16T 10h the Engine working at the Rate of 5 strokes per minute.
Account of the Coales consumed at Gregory new Engine in 6 weeks the Engine working at the rate from 6 to 9 stroakes per minute.

1792		T	h	s
Dec^{r}	10	4	8	0
	11	2	6	0
	12	6	19	0
	13	2	17	0
	15	10	12	4
	17	3	4	0
	18	3	8	0
	19	3	3	0
	20	4	5	0
	21	7	16	0
	22	6	8	0
	26	9	13	4
	28	3	8	0
	29	3	3	0
1793,	31	4	4	0
Jan,y	1	6	19	0
	4	9	18	0
	7	4	10	0
	8	7	8	0
	9	9	13	0
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		127	18	4

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PILKINGTON'S CAVERN, CASTLETON

with comments on Bray's cavern and Stemple Highway

Richard P. Shaw

ABSTRACT

The long-lost Pilkington's Cavern of 1789 is now known to have been entered via a mine shaft on Faucet Rake and to have descended a series of natural caverns to reach the Speedwell Mine's Far Canal at a total depth of some 600 feet. Lead ore was mined at upper levels and taken down some 150 feet for washing.

A marathon caving-cum-mine descent in the hills near Castleton was described by Sulivan (1780 and 1785, vol. 2, 65-70 and 81-89) as leading into a wild underground torrent, generally assumed to have been the Speedwell Cavern's stream cave system. Sulivan's account is based on letters written in August 1778, before the Speedwell canal tunnel had reached the stream caverns. A few years later Pilkington (1789, vol. 1, 73-75) gave a much more factual account, also apparently written several years earlier. He gave depths and distances but unfortunately no bearings and no exact location, though he did refer to the "level driving from the Winnats". A plagiarized version of Pilkington's description was published in a pamphlet by Richard Milne in 1813 with sundry errors introduced (see Warwick, 1947). In spite of searches in various places estimated by working backwards from assumed points of entry into Speedwell, and to the entrance shaft being "400 or 500 yards" west of Peak Cavern", it was not until 1944 that a breakthrough was made when Ford dug through a silt choke on the side of the Far Canal into what became known as the Assault Course series of passages (Ford 1956). In these a high cavern was found with stemples still in the walls, and the remains of a wooden platform some 50 feet up in the roof. This fitted the description of Pilkington's last descent. However, it was not until 1981 that this was climbed using self-drilling bolts. After traversing 160 metres of narrow winding passage a series of five further pitches was climbed and it was quite clear that these fitted Pilkington's account of 1789. A full description has been given by the author (Shaw 1983) and only an outline of the features relevant to mining is given here. The description is given moving upwards as explored and so is in the reverse direction to Pilkington's account.

After the first stempled climb in the 1944 cavern, the narrow passage showed clear signs of the miners having blasted off corners to get long timbers through. Shot-holes were driven in both directions, and the rubble was either bedded into the floor or transported to the bottom of the next cavern. Artefacts found in this passage included the end of a pick, a brass button, a buckle, the remains of a pair of boots and some nails.

At the top end of this passage a small calcite pipe vein was found but the miners seemed to have ignored it. Close by was the bottom of a natural rift chamber which was bolt-climbed, Round Pitch. This was soon followed by Galena Pitch, into a chamber with the remains of a washing floor in the form of a few rotten boards with washed galena on or between them and against the wall, where a trickle of water fell. A series of short climbs up natural rifts was followed by Chain Pitch, well decorated with flowstone. Pilkington noted the use of a chain and a length was found in a crevice here. Above this was another washing floor of boards with washed galena, but little sign of mining except stemple holes. Above, two stempled climbs led via a short passage to a climb amongst boulders into a large chamber, Mud Hall. Though not as large as Pilkington's account it is impressive, with a flat bedding plane roof and sloping muddy sides. At the upper end a trench had been dug through a thick clay by the miners to ease the otherwise flat-out crawl. The trench led to a partly collapsed drystone wall, which may have marked a mining boundary. Beyond the wall is Watricle Cavern, which Pilkington described thus:

> "When the miner first broke into it, it appeared beautiful beyond description. Upon introducing his candle thro the hole which he had made he was struck with astonishment. But when he entered the cavern, it in beauty exceeded his highest expectations. The roof and sides were covered with water icle, and almost as white as snow".

The stalactites were stripped and sold as curios and have now started to grow again.

Watricle Cavern is developed on Faucet (= Foreside) Rake, west of the Bottomless Pit Cavern, and for the first time in the present exploration there is abundant evidence of mining activity. There are three veins, two close together and the third a few yards to the north. The veins converge westwards and all have been worked, though the stopes are very narrow, rarely more than 15 inches wide. The veins contain galena, fluorite, baryte and calcite, and they were blasted out, leaving ¾ inch diameter shot-holes. A bench built of limestone blocks is on one side and was used as a dressing bench, though the process was carried out dry as there is no water here. Presumably the partly dressed ore was then carried down two or three pitches to where there was sufficient water; then it had its final washing and the final product was carried back up. This section of the mine-cum-cave yielded a number of artefacts; a wood and iron kibble, tallow dips, a leather harness and with chain attached for dragging corves, iron banding from a corve, a broken wedge, and a clay pipe of late 18th century style.

Pilkington's original entrance shaft, which he recorded as 50 yards deep, was not certainly located as there were heaps of boulders suggestive of a run-in or back-filled shaft in several places.

The lost cave system of the 18th century has thus been re-discovered. From a shaft on Faucet Rake the miners escorted Sulivan and Pilkington on different occasions (and apparently others, though the surviving accounts are too vague to be much use). They descended to a total depth of around 600 feet and entered the stream cave system somewhere in the vicinity of its intersection with the canal. Pilkington's account fits the downstream end of the Assault Course streamway, which became sumped when the canal was flooded, leaving the present flat-out muddy crawl of the Assault Course entrance passage as the only link. This of course means that, though Pilkington's account was published in 1789, it may have been written concerning a visit 12 years earlier as the canal was completed and flooded at least since 1777.

Two interesting points arise from this discovery and analysis: one is that mining records and archives say virtually nothing about the existence of a major stream cave system and its ramifications, and we would have known very little about them if it had not been for Sulivan's and Pilkington's 'tourist' descriptions. The second point is that the miners found it worthwhile to carry partly dressed ore down some 150 feet of stempled pitches in natural caverns for final washing before carrying it out to the surface again, instead of doing the washing on the surface.

STEMPLE HIGHWAY AND BRAY'S CAVERN

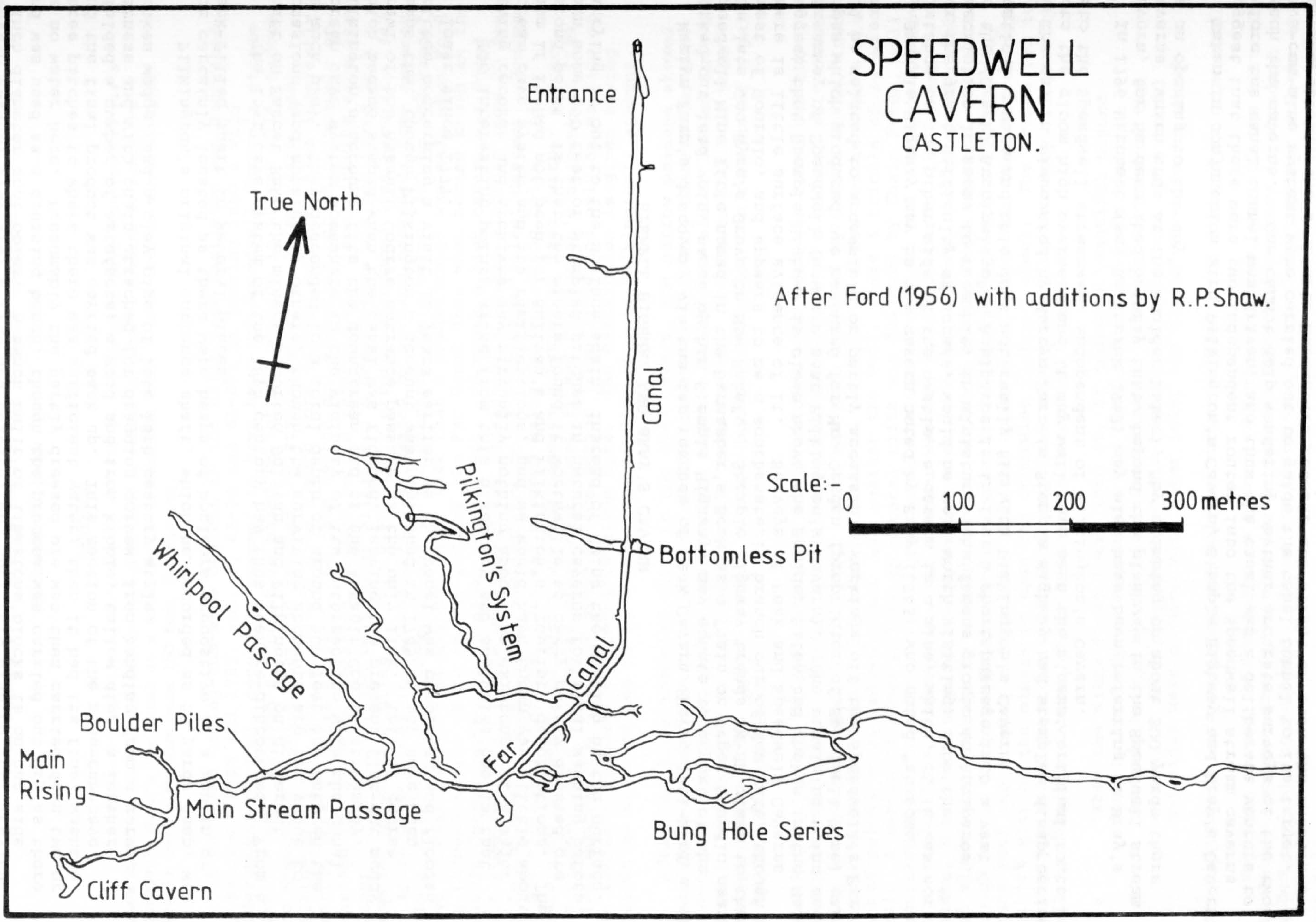
Martyn Farr's discovery via the far reaches of Peak Cavern (Farr, 1981-2) of a worked-out lead vein, named by him Stemple Highway, may equate to a part of the Speedwell Mine Title named in the Barmaster's Book as a "vein on Upper Hourdlo near the late Jno Eyre's Grove on New Rake". Stemple Highway trends NW-SE close to the crest of Hourdlo, and appears to be a southeasterly branch out of New Rake, though there is little surface evidence of it. Surveys of Peak and Speedwell Caverns suggest that Stemple Highway is close above the Boulder Piles and chokes in the Main Streamway of Speedwell (nowhere near Pilkington's Cavern). The remaining veins and pipes which produced ore measured for Mr. Oakden (proprietor of Speedwell Mine) can all be related to accessible or partly accessible workings off the Speedwell's Far Canal.

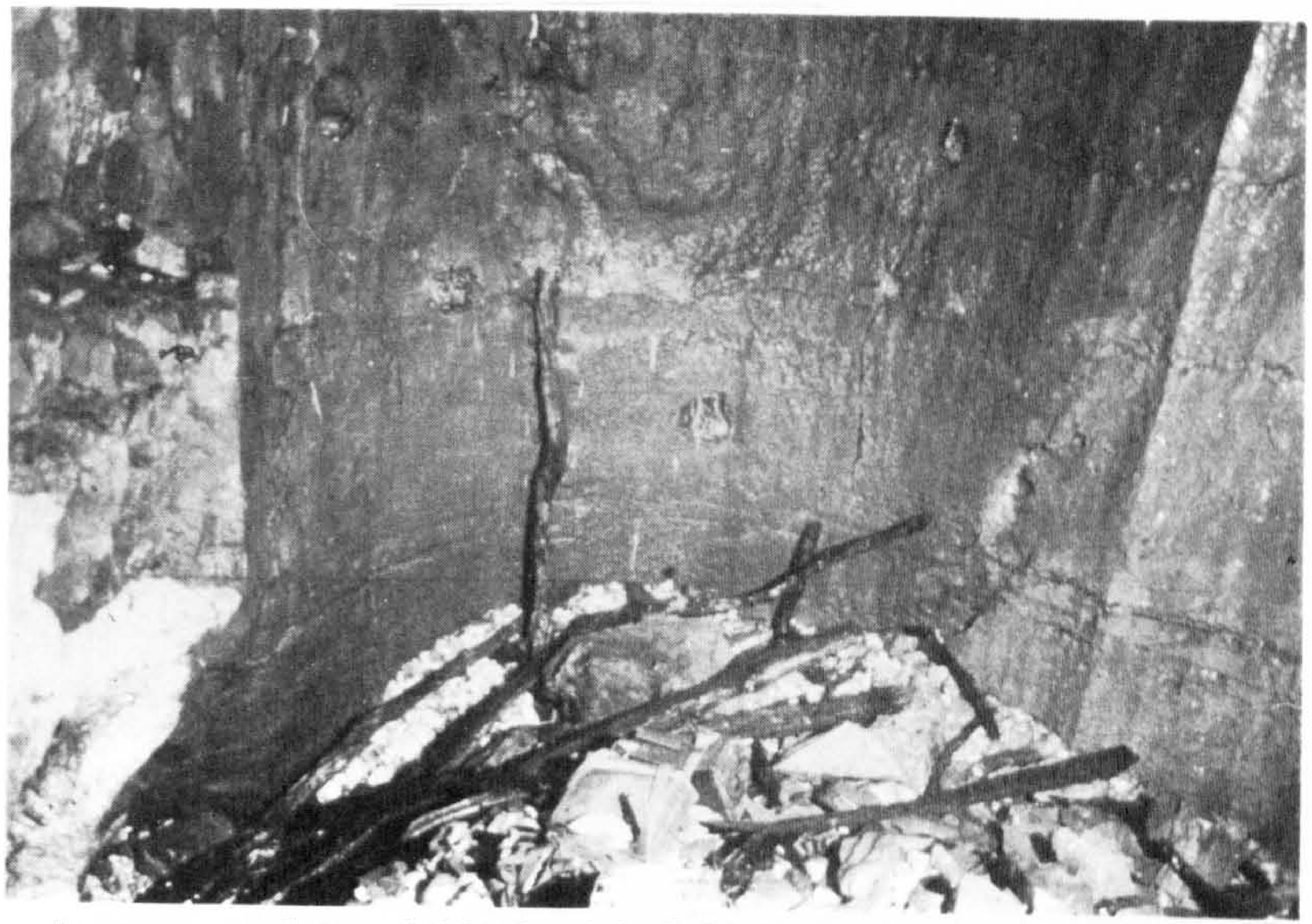
Stemple Highway may be the cavern noted by Bray (1783) who noted "at some distance on the other side of the castle, a cavern in a mine, which, if it was not for the great difficulty of access, would be well worth visiting; from the description it seems to resemble, in miniature, the famous grotto in Antiparos, in the (Greek) Archipelago". Antiparos is in fact a short passage into a vast vertical cavern and this does not really fit with Pilkington's Cavern.

The cavern discovered by Martyn Farr in Stemple Highway had stemples disappearing into the gloom high overhead and it may well have been the miners' original route into the Speedwell streamway, independent of Pilkington's Cavern.

In 1796 Hatchett (see Raistrick 1967) may also have been referring to Bray's Cavern, for he described briefly that, beyond the plankway in the Speedwell stream caverns (which ends at the Boulder Piles), "by climbing up about 300 yards there is an opening to the day".

Taken in conjunction with Pilkington's Cavern, Stemple Highway and Bray's Cavern suggest that there were two independent routes into the Speedwell stream caverns before the canal tunnel was driven, and thus the canal was a deliberate venture to reach the caverns. One cannot help wondering whether accurate surveys of the two-cave-cum-mine systems were carried out to guide the canal tunnel to its target, but regrettably the available Barmasters records are silent on even the existence of the stream caverns.


SPEEDWELL
CAVERN
CASTLETON.
After Ford (1956) with additions by R.P.Shaw.
Entrance
True North
Canal
Scale:-
0
100
200
300 metres
Pilkington's System
Bottomless Pit
Whirlpool Passage
Canal
Far
Boulder Piles
Main
Rising
Main Stream Passage
Bung Hole Series
Cliff Cavern



1. Bottom of Round Pitch with fallen stemples on miners' debris and washings with stemple sockets in wall behind.

2. Above Galena Pitch. Remains of ore stockpile on boards at ore-washing floor.

3. Remains of leather harness for dragging corves.

ACKNOWLEDGMENTS

The exploration and survey described has only been possible due to access to the Speedwell system via the show cave being allowed by the owners, the Harrison family. Especial thanks go to the manager and staff at the shop for changing room and to many willing assistants, including John Harrison, Rod Branson, Richard Acton, Jon Reading and John Tomlin. Gratitude must also be extended to Trevor Ford for floor space and continued encouragement. Thanks are due to Jim Rieuwerts for historical data and discussion.

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January 1983 R.P. Shaw, Geology Department, University of Leicester, Leicester LE1 7RH.

Karstic residual fluorite-baryte deposits at two localities in Derbyshire.

R. P. Shaw

SUMMARY: Various karst processes may rework primary mineralization producing secondary ore deposits in a variety of karstic cavities both on the surface and underground. Two surface localities, on Bonsall Moor, near Matlock, and near Castleton are filled with sediments containing locally derived fluorite and baryte clasts, in sufficient quantity to be worked as ore deposits. The associated clastic sediments are of Pleistocene fluvioglacial origin.

The lead-zinc-fluorite-baryte mineralization of the area has been described by Carruthers & Strahan (1923), Dunham (1952), Ford (1967b), Ford (1976), Worley (1978), Worley & Ford (1977). The mineral deposits consist of fissure and cavity fills, and depositional textures show evidence of episodic phases of mineralization (Ineson & Al-Kufaishi 1970; Firman & Bagshaw 1974; Bagshaw 1978).

Karstic cavities including cave systems, solution hollows, solution pipes and pre-existing 'pipe' cavities are associated with some of the mineral veins. The cavity fillings consist of locally derived minerals with allochthonous clay-silt-sand deposits; the processes of cave formation have been described by Ford (1964, 1971, 1972, 1977), Ford & Worley (1977a), Beck (1980). This type of ore deposit containing easily worked and dressed galena has been worked by Derbyshire lead miners who knew it as 'gravel ore', and it has been responsible for the 'bonanzas' found in some mines in Derbyshire.

The two localities considered are on Bonsall Moor, west of Matlock, (SK261 586) and the Portway 'Gravel' Pit near Castleton (SK127 812) (Figs 1 & 2).

At Bonsall Moor the open cast pits have or are being worked for fluorspar and the Portway Gravel Pit is being worked intermittently for nodular baryte.

Cavities and residual ores

In karst areas the formation of cavities occurs both on the surface and underground.

On the surface these cavities may take several forms including:

(1) widening of joints and other lines of weakness;
(2) differential solution of limestone at joint intersections to produce surface depressions;
(3) the development of 'swallow' holes engulfing allochthonous streams;
(4) collapse of underground cavities and the formation of surface depressions.

These depressions may become filled with sediment by a combination of processes including wind, water and ice transport, and slumping of the depression walls. Filling of the depressions and subsidence collapse may be contemporary producing slump structures in the sedimentary fill. When primary mineralization is present in the area, derived fragments may be incorporated into the sedimentary fill of the depression as insoluble residue or by mechanical erosion of an outcrop of epigenetic mineralization. In some cases the mineral vein may protrude into the cavity but usually it becomes disaggregated and locally distributed.

The 'ore' minerals may form discrete layers within the deposit or may be uniformly distributed throughout the sediment.

Description

Bonsall Moor

The host rocks are partially dolomitized Carboniferous Limestone of the Matlock Group which are Brigantian (D_2) in age. They are massive, well-jointed and contain layers rich in both crinoid and coral remains. Interbedded with the limestone are numerous 'wayboards' (altered volcanic tuffs) from 2 to 35 cm thick. The wayboards are variously composed of chlorite, kaolinite, smectite and illite (Walters & Ineson 1980).

Two rake veins have been worked in the pit, each up to 3 m wide. Both consist mainly of fluorite with minor galena and traces of sphalerite. Late calcite is present in vugs. Numerous scrins (small fissure veins) up to 3 cm wide and many mineralized joints are also present.

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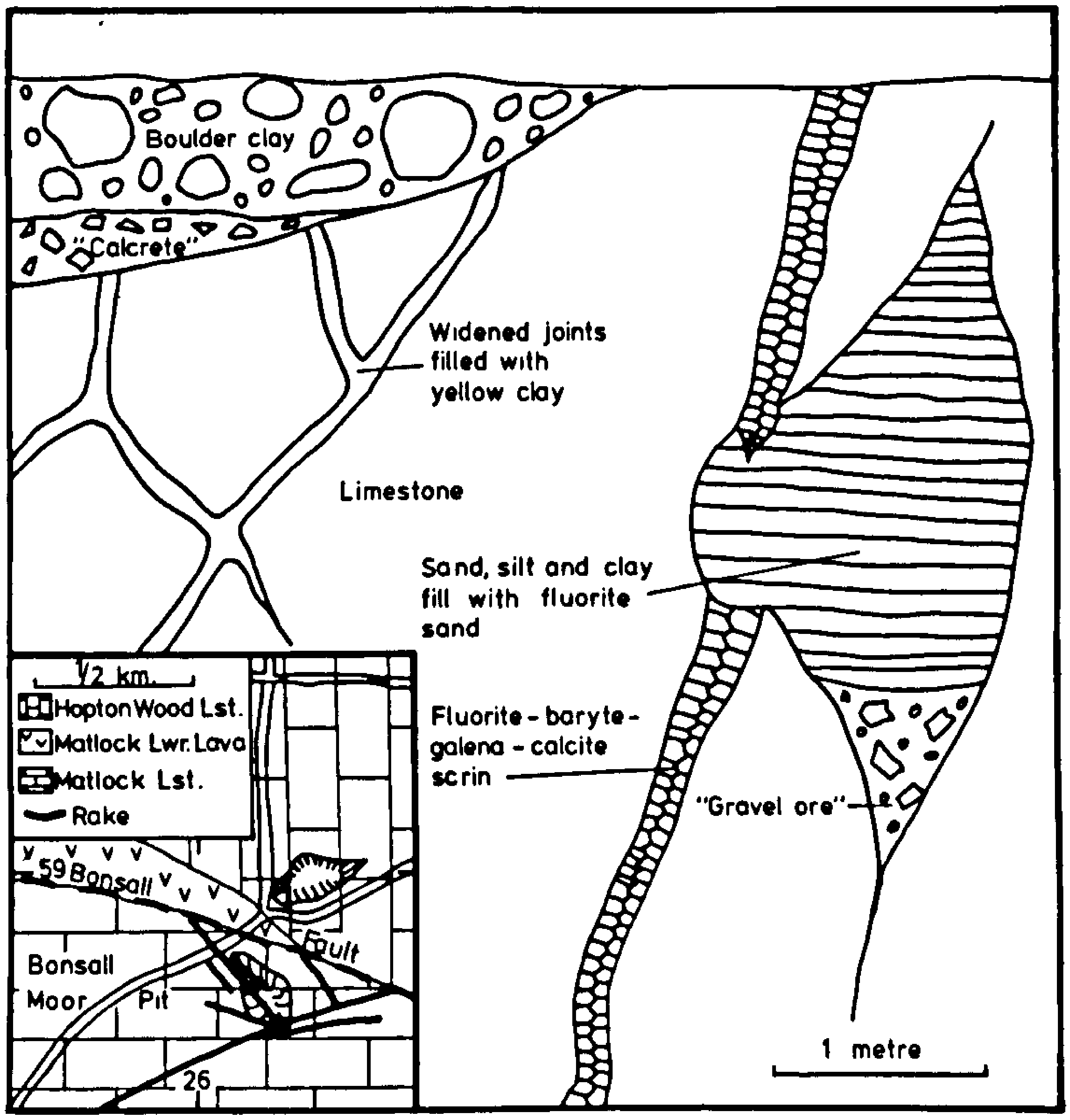

FIG. 1. Schematic section of the residual ore deposits at Bonsall Moor. Boulder clay and 'calcrete' overlying widened clay filled joints and a cavity intersecting a mineral vein containing residual ore overlain by layered sands, silts and clays.

The area has undergone deep weathering, under warmer conditions than prevailing today, prior to glaciation producing a soil layer containing a calcified horizon resembling 'calcrete'. This is overlain in places by quartz sand, derived from the Millstone Grit. In turn this is overlain by up to 6 m of boulder clay, nearly all locally derived, containing boulders up to 0.75 m across, of Millstone Grit sandstone and shale, Carboniferous Limestone and basalt with a few smaller exotic erratics (some of which are from the Lake District) (Fig. 1).

The deep weathering of the limestone has widened many of the joints to a considerable depth (over 10 m below ground level) in some parts of the pit. These joints are now filled with 5–8 cm width of stiff yellow clay of loessic origin. Any insoluble residue, such as fluorite, has accumulated in small lenses within the clay.

In places limestone solution has produced cavities, up to 2 m high and 1.5 m wide, oriented along scrins. All are filled with sandy sediments which, when finely layered, represent suspension settling from ponded waters. As well as accumulations of remnant and residual blocks of mineral vein present in the bottoms of these cavities the sand also contains derived fluorite, up to 70% by volume. The fluorite grains, up to 5 mm in length, still retain their crystal faces and show no signs of abrasion.

The non-ore-mineral fraction of the sands consists mainly of quartz (50–95%), feldspars (0–10%) and muscovite mica (2–10%). Scanning electron micrographs of quartz grain surfaces show textures associated with glacial transportation. The source rock is probably the peripheral Millstone Grit escarpments, having been derived by glacial erosion and outwash. X-ray diffraction (XRD) analysis shows the clay fraction to be composed of kaolinite and illite, with lesser chlorite and mixed layer smectite. Like the coarser fractions the source is the Millstone Grit shales with a contribution from local wayboards.

The ore-mineral fraction, which varies from 0 to 70% of the cavity fill, can be divided into two types: firstly, remnant and residual ore which consists of relatively insoluble vein material accumulated in the bottoms of the cavities. It comprises lumps of euhedral fluorite, with baryte and/or calcite. In one cavity galena is present with a ~1 mm coating of cerussite, and secondly a fluorite sand. It consists of euhedral fluorite grains (0.5–5 mm) showing no signs of abrasion indicating a local derivation. It occurs interbedded and intermixed with the quartz sand.

The deposits containing fluorite are potential fluorspar reserves, with fluorite contents of between 20 and 75%, but their clay content interferes with the froth flotation circuits of the dressing plants.

Portway 'gravel' pit

The limestones in this pit, of the Bee Low Group, are of Asbian (D_1) age. Unaltered limestone is not exposed in the pit itself but an old quarry to the north shows it to be a well-bedded, slightly crinoidal limestone. Chert nodules are well developed as layers within the limestone. Epigenetic mineralization is largely present as 'pipe' veins, linings of pre-existing cavities.

Within the pit the limestone has undergone intense silicification to produce a patchy 'quartz rock' (Ford 1967a). Two varieties of the quartz rock are present: first, partially silicified limestone containing as much as 50% acicular quartz crystals up to 0.5 mm long; secondly, the 'maggot' rock which was originally a fossiliferous limestone composed mainly of compound corals. The matrix was selectively replaced by crystalline quartz, but the corals were resistant and remained as calcite. Later decalcification has removed the corals leaving a porous quartz rock full of coral moulds or 'maggot holes'.

In parts of the pit both types of silicified limestone have been completely decalcified and disaggregated producing a white sand composed of acicular euhedral quartz. At the margins of the silicified area unaltered limestone has silicified joints, in places decalcified to yield quartz crystal 'sand' veneer. The quartz replacement of the limestone is thought to be associated with epigenetic mineral fluids having attacked basaltic rocks lower in the stratigraphic sequence thereby extracting silica (Ford 1967a). At this locality silicification was complete before the deposition of any epigenetic minerals.

The pipe veins are solution cavities up to 3 m in diameter, lined with baryte, fluorite, galena and late calcite, often as corroded scalenohedra. Remaining voids in the pipes are filled with laminated clays and silts. The pit is worked for numerous baryte nodules present in both the epigenetic and residual fractions.

Karstification at this locality consists of enlargement of pipe vein cavities and of the

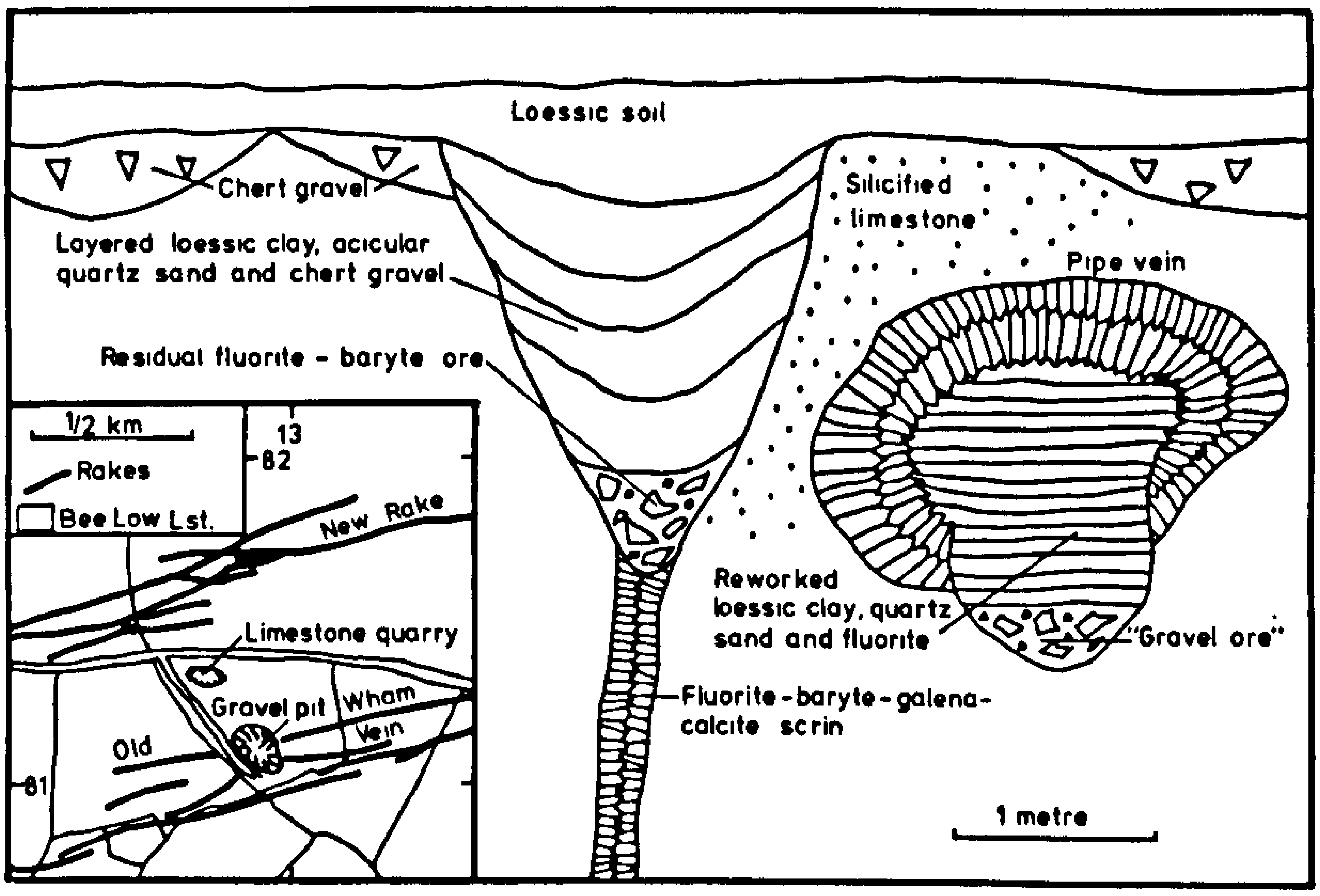

FIG. 2. Schematic section of the residual ore deposits at Portway 'Gravel' Pit. Loessic soil and pockets of chert gravel overlying partially silicified limestone containing a solution hollow developed on a mineral vein with a residual ore and layered sedimentary fill and a pipe vein with later solutional modification containing 'gravel ore' and layered sedimentary fill.

formation of solution pipes from the surface. The solution pipes are filled with surface-derived loess (40–70%) and chert gravel (0–50%) and insoluble residue from the limestone which consists of chert nodules, derived quartz rock and 'sand' (5–95%) and derived blocks of the epigenetic mineral suite (0–20%). Collapse structures and mixing caused by slumping as the limestone was dissolved are evident. Patches of laminated clay have been caught up in the collapses indicating that the process is still in operation.

In both pipe veins and solution collapse structures the 'ore' fraction consists of angular residual lumps of epigenetic pipe vein mineralization. Baryte is dominant with fluorite and some deeply etched calcite crystals present. Secondary goethite, after marcasite, is also present both in joints in the quartz rock and as small derived lumps in the fills.

Conclusions

The cavities, apart from pre-existing mineral vein and pipe cavities, were probably formed and filled with sediment during periglacial conditions when ground water circulation was restricted. The textures of the limestone walls of these cavities indicate that some solution of the limestone has occurred during the Pleistocene and recent weathering cycles. At the Bonsall Moor pit some of the joint widening occurred before glaciation.

The deposits are mainly allochthonous sand and clay fills variably containing derived limestone, galena, fluorite, baryte and calcite clasts showing no evidence of transportation. The source of the sand and clay is from the surface, probably from the Millstone Grit series via glacial action. Some of the loess may be derived from further afield.

Distinct contrasts occur between these two localities. The nature of the Pleistocene overburden is markedly different, being boulder clay at Bonsall Moor and loess at Portway. The high degree of silicification of the limestone at Portway is an important contributor of insoluble material to the cavity fills, while at Bonsall Moor silicification is insignificant. There is no evidence of much redistribution of ore minerals at the Portway pit but at Bonsall Moor redistribution has occurred though not in all the deposits and only on a local scale.

Similar deposits are known over much of the Derbyshire Orefield, such as those at Masson Hill, Matlock (Ford & Worley 1977b; Warriner, Willies & Flindall 1981), and at Hubberdale Mines, near Monyash (Worley, Worthington & Riley 1978), where they formed important lead ore deposits. Today they are of importance as numerous though small potential fluorspar reserves if the problems of mineral dressing can be overcome.

ACKNOWLEDGMENTS: I would like to thank the University of Leicester for financial support to undertake this research, which forms part of a PhD project, and Clyde Petroleum (Minerals) Limited for financial support for field work and for access to their pit on Bonsall Moor (the pit has since changed ownership). I am especially grateful to Dr T. D. Ford for his critical examination of the original manuscript and for his constructive suggestions for its improvement.

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PALAEOMAGNETISM OF THE CAVE SEDIMENTS IN MASSON HILL,MATLOCK

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Scanning electron microscope (S.E.M.) studies of sediments in phreatic caverns in Masson Hill, Matlock reveal that some of them are of fluvio-glacial origin. Palaeomagnetic studies have shown that at one of the sites these sediments are probably 690,000 years old.

Geological Setting

Masson Hill lies on the east side of the Dinantian Limestone massif of the Peak District. Varied limestones of the Griffe Grange (Holkerian), Hopton Wood (Asbian), Matlock (Brigantian) and Cawdor (late Brigantian) Groups are exposed in the Matlock area (1). At the crest of Masson Hill limestones of the Matlock Group have been irregularly dolomitised forming a porous dolomite (Ford, 1967). Two lava flows are interbedded with the Matlock Limestones and between the flows up to five thin altered tuff horizons occur (2).

Structurally Masson Hill is a plunging anticline with dips to the north, east and south.

The area has been intensely mineralized resulting in a large number of near vertical veins with an east - west trend and associated pipe and flat veins (3).

Beneath the slopes of Masson Hill lies a complex system of disused lead and fluorspar mines. The mines worked ore deposits, in the form of fissure, pipe and flat veins, hosted in the Matlock Limestone sandwiched between the Upper and Lower Matlock Lavas and partially controlled by the presence of the tuff horizons. The mine workings have broken into many natural caverns where speleogenesis has occurred enlarging the existing voids left by the mineralizing fluids which acted as channel ways for groundwater movement (4).

Most of this phreatic network was subsequently filled with a mixture of autochthonous and allochthonous sediments. Many of these sediments contain alluvial galena and have largely been removed by past mining activity but some still remain undisturbed.

Three sequences of sediments exposed in different parts of the mine and cavern complex, one in Clay Cavern (N.G.R. SK 289,589) accessible from the Masson Cavern show cave (SK 292,586) and the others in the Clay Shaft and Climbing Shaft of Old Jant Mine (SK 290,594) accessable from Rining Rake and Masson Soughs (SK 295,594).

The sediments exposed in Clay Cavern consist of a basal layer of limonitic silts containing large residual clasts of galena, baryte and fluorite in a matrix of silt and clay derived from the altered tuffs and lavas with a small contribution from the insoluble content of the limestone.

Overlying this basal layer is a succession, 1.1 metres thick, of alternating dark sandy and light-brown silty horizons of a varved nature totalling 17 couplets. Both the coarse and fine grained units of these fining upwards sediments consist largely of sediment derived from the

Namurian strata which formerly overlay the limestone. Scanning Electron Microscope (S.E.M.) studies of quartz grain surface textures indicate that these sediments have been transported by fluvio - glacial processes.

Overlying the rhythmite sequence is a less well bedded succession of silty clays and sands approximately 1 metre thick. The composition of these sediments again shows that they were largely derived from Namurian strata but they also contain up to 15 percent of fluorite, baryte and galena derived by the collapse of the mineral lining on the roof of the cavity.

Clay Shaft is a small shaft sunk through sediments nearly 5 metres thick filling a calcite-lined pipe vein cavity. The sediments are well bedded and vary from coarse sands to clays which have horizontal or slightly inclined bedding.

The basal layer consists of a residual limonitic silty clay, 20 to 30 cm. thick, identical to the basal layer in Clay Cavern.

This is overlain by a succession of sands, silts and clays consisting of clasts derived from the Namurian strata. S.E.M. study indicates that these sediments were also derived by fluvio - glacial processes.

Climbing Shaft is another mine shaft sunk through cave sediments, here over 8 metres thick. The base of the sediments is not exposed in the shaft.

The sediments are well bedded with a steep sedimentary dip to the northeast and consist variably of sands, silts and clays derived from the Namurian strata. S.E.M. study indicates that these sediments are of fluvio-glacial and fluvial origin.

Palaeomagnetism of the cave sediments

124 orientated sediment samples for palaeomagnetic analysis were obtained from sites in Clay Cavern, Climbing Shaft and Clay Shaft. The aim of this study was to investigate whether the cave sediments contained a stable, accurate record of the ancient geomagnetic field, the changing direction of which could provide evidence for the absolute age of these deposits.

Cave sediments are ideally suited to palaeomagnetic studies of the Earth's magnetic field since they are usually preserved under conditions of constant temperature, high humidity and negligible bioturbation. Consequently, the minerals responsible for natural magnetisation are relatively undisturbed mechanically and unaltered chemically, when compared, for example, with sediments from lakes or the deep ocean (5). Furthermore, cave sediments are formed under conditions which are similar to those produced artificially in laboratory flumes intended to study the magnetisation processes in sediments (6). Consequently, it is possible to apply laboratory-determined criteria to the magnetic results from these natural materials (5).

The palaeomagnetism of cave sediments have been reported for sites in Spain (7), the Lebanon (8), Sarawak (9), the U.S.A. (10), Norway and Britain (11). A stable magnetisation of geomagnetic origin has been found to exist in stalagmite (12).

The majority of unlithified cave sediments have aquired their magnetisation during deposition due to a systematic alignment of suspended magnetic particles by the Earth's magnetic field. This alignment is largely maintained by the magnetic grains when they settle and become incorporated in the sediment matrix. The resulting deposit thus retains a weak depositional remanent magnetisation (13).

The presence of water flow during deposition causes the magnetic particles to rotate slightly away from their geomagnetic alignment as they pass through the laminar fluid shear layer immediately above the bed. This phenomenon can be detected in a sediment by comparing the direction of magnetisation (mainly controlled by the magnetic field) with the linear lineation direction of the magnetic grains (mainly controlled by the flow). The latter is measured in terms of the anisotropy of magnetic susceptibility in the sediment. The principle of this flow measuring technique was outlined by Rees (6) and applied successfully to cave sediments by Noel (5).

This note describes both the palaeomagnetism and susceptibility anisotropy of the cave sediments. The results have important implications concerning the age of deposition and indicate the palaeoflow direction through part of the cave system.

Field and Laboratory Methods

Samples were obtained by pressing 5x5 cm. plastic cylinders horizontally into a prepared vertical sediment surface at each of the locations. The orientation of the cylinder axis in a horizontal plane was recorded using a magnetic compass before each cylinder was withdrawn and sealed with a plastic disc. Orientations are considered accurate to 1^{o} in all directions. Samples were stored at $6^{o}C$ prior to measurement.

The natural remanent magnetisation of all specimens was measured using a Digico fluxgate spinner magnetometer (14). The results were then corrected for the field orientation and local magnetic variation. The remanence vector direction is described in terms of the horizontal declination and the vertical inclination.

In order to study the stability of the magnetisation, pilot samples of typical lithology were selected and partially demagnetised in alternating magnetic fields up to a peak intensity of 500 Oe. The change in the remanence vector direction at each stage in the demagnetisation was measured. From a inspection of the results it was decided to partly demagnetise the remaining samples ia an alternating field of 150 Oe. This field was the optimum level required for the removal of secondary components of magnetisation acquired since deposition. The remanence of the samples was then remeasured in the spinner magnetometer.

For the purposes of examining the palaeoflow through the cave a number of 2.54 x 1.85 cm. subsamples were removed in plastic cylinders from the centres of the larger samples. The field orientation was transferred to the new specimens and their anisotropy of magnetic susceptibility measured using a modified spinner magnetometer (15). This instrument detects the direction of maximum susceptibility within the specimen which reflects the lineation direction of elongated magnetic particles.

Using a hand magnet a small quantity of magnetic minerals was extracted from the cave sediments and identified using a thermomagnetic balance. This instrument detects the Curie temperature in the sample which is accurately diagnostic of the magnetic mineralogy.

Results and Discussion

The cave sediments were found to have natural remanent magnetisation intensities of around 5×10^{-5} Gauss. cm^{3}. g^{-1} which is typical for a cave deposit (5). Scattered directions of magnetisation were found in the vertical suite of 34 samples obtained in Clay Cavern and in the two sampling locations near the base and top of the Climbing Shaft (12 samples. This scatter may have arisen from the disturbance to the sediments during mining operations, the proximity of magnetic miners tools or diagenetic changes within the sediments. The demagnetisation characteristics also indicated low magnetic stability for these materials. A Curie temperature of 530°C in the magnetic extract suggests that the mineral responsible for the remanence is magnetite.

In contrast, a high-quality palaeomagnetic record was obtained for the 78 specimens in the Clay Shaft. Figure 1 shows the vertical profile of remanence intensity, declination and inclination for each specimen after partial demagnetisation in an alternating magnetic field of 150 Oersteds. The good grouping of directions within repeatedly sampled layers is good evidence for the high magnetic stability of this material and this is supported by the results of the demagnetisation tests. The grouping is particularly good for sample sets at depths of 135 cm. and 283 cm.. In view of this evidence and the susceptibility data (described below) there is good reason to believe that this palaeomagnetic profile is a record of the ancient geomagnetic field.

A striking feature of the magnetic profile is the evidence for a geomagnetic reversal occurring at around 130 cm. depth. Sediments from 0 to 120 cm. have remanent magnetisation directions which are consistent with normal geomagnetic polarity and the site latitude (53.1°N). Samples below 129 cm. have negative (i.e. upward) remanence inclinations and declinations which are directed south. The transition from the reversed to normal polarity seen here is similar to records which have been obtained from deep sea cores (16) but this is the first observation of a geomagnetic reversal from unlithified sediments in Britain.

The inclination reversal is quite abrupt and occurs over an interval of only 20 cm. in an homogenous clay layer. If the rate of deposition is assumed to be similar throughout the section and the cyclic changes in direction near the base of the section are assumed to arise from geomagnetic secular variation (approximately 500 yrs.) then we can infer a period of about 800 yrs for the reversal to have occurred.

The directions shown in figure 1 have been transformed to virtual geomagnetic pole positions and their movement over the globe examined. It was found that the pole crosses the equator at a time represented by sediment at a depth of about 132 cm.

In the absence of radiometric dating evidence on interbedded speleothems the geomagnetic reversal recorded in these sediments can be used to infer a possible date based on the established geomagnetic timescale. A further refinement in this procedure is to relate the oxygen isotope palaeoclimate record for deep sea sediments to the magnetic timescale and hence search for an episode with the appropriate simultaneous geomagnetic and palaeoclimatic parameters.

The geomagnetic timescale for the Pleistocene has been built up from palaeomagnetic studies of lake and marine sediment cores, marine sediments exposed on land and rapidly deposited lava sequences. Supportive evidence is provided by marine magnetic anomalies in the neighbourhood of young, fast spreading sea-floor. The geomagnetic timescale has been reviewed by La Breque et al (17).

Sensitive measurements of the O^{18}/O^{16} ratio in benthic foraminifera in deep sea cores have resulted in a record which reflects continental ice volume from the upper Pliocene to the present (18). Within this record it is possible to identify at least 23 warm (i.e. interglacial) stages which alternate with cooler (i.e. glacial) stages. Since the cave sediments described here are of probable periglacial origin, as shown by the results of S.E.M. study of quartz grain surface textures, it seems likely that they were deposited during the termination of a glacial stage since this would then provide the required meltwater influx.

The oxygen isotope record shows that the continental glacial/interglacial cycles assumed their maximum ampliteud after glacial stage 22 (~0.8 m.y.), in other words shortly before the reversal which marks the onset of the present Brunhes, normal polarity epoch. The evidence suggests that the Jaramillo normal polarity event (~0.9 m.y.) is an unlikely contender for the Clay Shaft reversal.

The Matuyama (reversed) to Brunhes (normal) polarity transition is dated to around 0.73 m.y. and is probably contained within interglacial stage 19 (18). The preceding glacial stage 20 was of similar intensity to the ensuing glacial events, although of shorter duration and hence could have resulted in the ice reserves required for flooding of the cave system during glacial retreat. This geomagnetic polarity change has been recorded in Mammoth Cave, Kentucky (10).

A second contender for the geomagnetic reversal is the Blake event (19) which occurred at around 0.11 m.y.. This brief reversal event may thus correspond to a period immediately before or during the Ipswichian Interglacial which has been identified, in Britain, as matching warm stage 5 (20). During the Ipswichian, temperatures were equal to or above those of today and meltwater may have been sufficiently abundant initially to flood the cave system before the valley floor was completely free from ice and the hydrological base level became too low for continued sedimentation. The geomorphological history of the Matlock Gorge makes this an unlikely date for the Clay Shaft reversal.

A conclusive identification of the Clay Shaft Reversal will await further palaeomagnetic studies in this area and a comparison of the polar wander path with records from other, dated, geomagnetic events.

The susceptibility anisotropy results revealed a clear magnetic lineation in the bedding plane which confirms a depositional origin for the remanent magnetisation. By combining the remanence vector direction and lineation directions for the multiple sample groups it is possible to identify the flow direction during sedimentation (5,6). The results indicate that water flowed consistently from a bearing of 287.9°, in other words the flow was down the dip of the limestone from the crest of Masson Hill.

Conclusions

The most likely date for the Clay Shaft reversal is that of the onset of the Brunhes normal polarity epoch at around 690,000 yrs. b.p.. If this is the case, the fluvio-glacial character of the sediments shown by the S.E.M. studies indicates that a glacial episode was waning at this date, the earliest Pleistocene glaciation yet determined in Britain.

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