ASPECTS OF SPELEOGENESIS IN THE CARBONIFEROUS LIMESTONE OF NORTH DERBYSHIRE.

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

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ABSTRACT.

Karstification of the Carboniferous Limestone of the northern part of the Derbyshire limestone outcrop began to a limited extent prior to deposition of the Namurian, and continued in some areas with the development of a hydrothermal karst system during the mineralisation phases of the Permo-Triassic.

Extensive cavernisation by allogenic streams and by percolating meteoric water began after the final stripping of the cover of younger rocks during the late Tertiary, and the cave systems were extended and modified throughout the Pleistocene. A complex series of erosional events, apparently related to successive glacial phases, gave rise to a series of abandoned cave levels in some areas.

The cavities produced during the Permo-Triassic were of importance in determining the nature and orientation of the later karst drainage systems. Where such pre-existing cavity systems failed to correspond with the hydraulic gradients of the Pleistocene, bedding controlled tube networks developed at preferred horizons in the limestone, often where a fossil horizon gave a relatively higher primary permeability and an underlying clay 'wayboard' arrested downward percolation.

Interbedded impermeable horizons are important in the development of perched groundwater areas. Where such horizons have been breached they often form the upper limits of large caverns, since oxidation of sulphide minerals which they contain has locally increased the aggressiveness of circulating groundwater.

The concentration of large cave systems near the margins of the present outcrop suggests that stripping of the cover during the late Tertiary occurred fast, and was completed prior to the establishment of significant hydraulic gradients within the limestone.
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Chapter 1.

INTRODUCTION.
1. INTRODUCTION.

i) The Aim of the Research.

The study was undertaken with a view to investigating the morphology of the caves of the limestone catchment of the River Derwent and the River Wye above their confluence at Rowsley in order to see whether similar sequences of cave development could be defined throughout the area. Possible relationships between cave levels and the terrace remnants which have been described in the past (i.e. Waters and Johnson, 1958) have also been investigated.

It has been shown that in the Stoney Middleton area a number of cave levels exist, developing in response to a series of erosional events which progressively lowered the local karst base level (Beck, 1975). It was not possible, however, to correlate cave levels with landforms in this area, because mining and quarrying in Middleton Dale have largely destroyed features such as terrace remnants, although caves have in some cases been exposed by these activities (Lord, 1971).

In the course of detailed surveying, much information has come to light regarding the structural and lithological controls over cave development, and this information is also presented.

ii) Methods of Study.

Although surveys of the major cave systems have been published in the past, such as Peak Cavern (Salmon, 1962), Giant's Hole (Eldon Pothole Club, 1972), Nettle Pot (Salmon and Boldock, 1951), many of the small abandoned caves which abound in the valley sides remain unsurveyed and even unrecorded. Much of the work therefore consisted of searching for, exploring, and surveying these caves. During the course of this study, Carlswark Cavern was resurveyed by members of the Eldon Pothole Club (Christopher & Beck, 1977).

Surveys were carried out using either Suunto prismatic instruments
read to 1 degree, or Silva compass/clinometer read to one degree, with fibron tape read to 1 cm. In particularly difficult or dangerous circumstances, rough surveys were carried out, measuring by pacing or body lengths, and taking compass bearings. Stratigraphy was related where possible to the survey. Long vertical sections, such as the entrance shaft to Nettle Pot, and shafts in the Carlswark system, were accurately measured.

Significant advances were made in the exploration of the caves of the Stoney Middleton area during 1973 by excavation, approximately 825 metres of new passage being discovered. Smaller discoveries were later made in other areas (ie. Oxlowl Caverns, Knotlow Mine). The two year drought in 1975/6 permitted access to cavities which are normally flooded, in particular in the Monyash and Wardlow basins. The passing of the sump at the end of Lower Cales Dale Cave revealed a further 400 metres of passage, and Lathkill Head Cave was followed downstream for 150 metres by Eldon Pothole Club members.

In 1977 it was decided to mount an ambitious project to pass 'Big Dig' in Carlswark Cavern, for many questions regarding the hydrology of the cave remained unanswered. This came to fruition in September 1979 with the discovery of 550 metres of new passage, most of it active, and a much better understanding of the drainage of the area was gained.

Most of the accessible soughs within the area were examined, and two were entered for the first time in recent years (Wardlow Sough, and the downstream end of Watergrove Sough). Mining records were consulted in some cases to establish the effects of sough drainage on the natural pattern in areas where the soughs are inaccessible but may still function to some extent, such as Peakshole Sough ('Slop Moll').

A great deal of surface field work was carried out, locating small caves, and establishing their relationship, if any, with terrace remnants in the valleys. A close correlation was found in the Lathkill
Dale area, and in parts of the dry tributary valleys of the River Wye.

In areas where the underground drainage cannot be studied by direct observation, an attempt has been made to predict the courses of major drainage routes on the basis of geological structure, using the criteria established in areas such as Lathkill Dale, Stoney Middleton Dale, and the Bradwell area, where significant amounts of cave passage are known. In some cases this was of value in gaining access to previously unknown cave passages.

iii) Theories of Speleogenesis.

A complete analysis of the research carried out into karst and caves during the past two hundred years is made difficult to the English speaking researcher, for many of the earliest comprehensive accounts were based on observations made in the classical karst areas of eastern Europe, and are therefore inaccessible by virtue of an insurmountable language barrier. Only reviews or translations of such works are available.

Shaw (1979) provides a detailed analysis of the development of cave science up to 1900, and Sweeting (1972) draws extensively on the east European literature, providing a valuable source of information.

A knowledge of the work carried out in the Classical and Dinaric karsts is of great value, for the geological setting often contrasts with that which has influenced ideas in Britain and America. Many of the east European karst areas consist of highly folded and fractured limestones, and work has often been directed towards elucidation of complex hydrological networks by indirect methods such as spore and dye testing of underground flow paths (Drew, 1966).

In America, on the other hand, the relatively flat-lying limestones of some major karst areas have resulted in detailed investigation of the mechanics of cave formation. The concept of a "water table" in limestones
was not questioned in western literature until fairly recently (i.e. Rhoades and Sinacori, 1941). In areas such as Central Kentucky, the evidence to refute the water table concept is less obvious, but in more complex limestone terrains barriers exist to underground flow in the form of interbedded impermeable horizons and structural features, resulting in a complex network of stream courses with which the water table concept cannot easily be reconciled.

The earliest recognition of the connection between limestone country and springs was an observation by Faber in about 1500 (Shaw, 1979), who recognised the fact that water sinking into dolines in the Swabian Alps fed springs in the valley floors. Acceptance of the fact that springs were fed by meteoric water was very slow; there were many who thought that springs were fed by water being forced upwards from the sea, losing salt in the process. This view persisted for a long time, but in Thomas Hobbes' poem 'De Mirabilis Pecci' (1683) we read:

"But by the Sun's hot rays the Sea on high
Mounts up in vapours, which do wandering fly
Drove by the winds, which cooling still as soon
As the heat fails them, or the Sun goes down,
In numerous tears descend unto the earth.
From which collected rivers have their birth".

Hobbes was referring to the stream which issued from Peak Cavern, and to its many small underground tributaries.

Charles Leigh (1700) noted the fact that in the Peak District of Derbyshire were holes which the local people called "Swallows", into which water disappeared, and suggested that the rivulets sinking here were almost certainly the source of the water which rose at Castleton. However, he also stated that "... it is evident continual springs can never be imagined to be caused by rains and dews; it remains therefore that they either proceed from the Ocean, or a subterranean abyss".
As early as 1761, Catcott described Peak Cavern, and referred to it as having been formed by the action of water. The nineteenth century saw the beginnings of detailed and careful observation of caves, and in 1830 Lyell proposed that solution of limestone by water charged with carbon dioxide was responsible for cave formation.

In the early years of the 20th century, the work of Grund and Cvijić began to rationalise the earlier conflicting views. It was suggested by Grund (1903) that groundwater moved from its origin towards the sea, or to its outlet in a valley, the top of the flooded zone having a gradient towards that outlet. Only in the top part of the lower flooded zone did appreciable movement take place, and it was here that caves were formed, to be modified later after uplift.

Cvijić (1918) proposed three zones in the karst. There was, he said, an upper zone in which percolating water moved freely downwards. Below this was a zone not permanently flooded, but into which water rose in flood conditions. The lowest zone was a permanently flooded one, where the water was under hydrostatic pressure, and from which it must rise under pressure to reach a spring. The lowest zone extended upwards in flood due to the inability of the lower conduits to carry sufficient water. Solution in the lowest zone extended right down to the impermeable base of the limestone mass.

The concept of 'phreatic solution' was introduced by Davis (1930). Davis envisaged a water table beneath which water circulated to great depth, and where solution also occurred at unspecified depths. The phreatic cavities so produced were modified, following later uplift, to give the vadose forms we see today. The ideas of Davis were supported and extended by Bretz (1942) with reference to a large number of American caves. Bretz suggested that between Davis' phreatic and vadose stages was a period of relative quiescence, when flow velocities were for some reason very much less, and during which extensive clay filling took
place. The clay fills were reworked after uplift, during vadose modification.

Swinnerton (1932) proposed a model in which water may disperse by many routes below the water table, one being preferentially selected for further enlargement, subsequently to become the 'master cave'. The master cave proposed by Swinnerton developed by enlargement first at the input end, then progressively downstream towards the risings. Entirely the opposite was proposed by Rhoades and Sinacori (1941), who thought that a master conduit was developed first by enlargement in the vicinity of the resurgence of water from the limestone massif, progressively being extended upstream into the karst area.

Many attempts have been made to rationalise the diverse views regarding the concept of a water table in limestones, and the reasons for the selection of particular paths as the preferred route for cave formation. Work in recent years has tended to emphasise the importance of structure in the initiation of cave formation, and to refute the idea of a pre-existing water table (Ford, D.C., 1968; Waltham, 1970; Drew, 1966). D.C. Ford suggested that the water table was defined by the cave, rather than vice-versa, although the cave did not necessarily follow the water table throughout its course. In the situation of the steeply dipping limestones of the Mendip Hills, a series of 'phreatic loops' developed on bedding planes and joints, the peaks of the loops not necessarily ascending to the water surface. Drew (1966) cited the risings of St. Dunstan's Well and Ashwick Grove on Mendip, and questioned the water table concept by pointing out that although these risings lie very close together, they may show completely different hydrological characteristics, and are hydrologically completely separate. Drew cited the work of Mayer & Zötl (1959) in the Dachstein Alps, where it was found that stream courses may cross, and there may be no obvious relationship between underground and surface catchment areas.
American writers have tended to disregard the water table question, accepting the water table in studies of the major cave areas. Kaye (1957) pointed out that solution would be greatest at shallow depths below the water table, where the flow velocities are higher and the water more aggressive. It has been considered, therefore, that major conduits form just below the water table at any one period, the position of that water table varying according to external factors such as stages in the excavation of the major valleys (Miotke & Palmer, 1974).

Thrailkill (1968) referred to this as the 'shallow phreatic zone'.

In areas such as Central Kentucky, the concept of a water table may be valid, or at least, there is no reason to discard a model which satisfactorily explains the disposition of the caves. However, in areas of steep dip, such as the Mendip Hills, or where the limestone sequence contains aquicludes in the form of shales and clays, the water table is untenable as applied to non-karstic rocks. In highly folded and fractured rocks there may or may not be a well defined piezometric surface, depending on the extent of karstification of the area (Warwick, 1976).

Much research has centred on the enlargement of the earliest cavities in a limestone mass into integrated cave systems. Of prime interest has been the problem of how water can remain aggressive at great depths, often deep in a phreatic area, when percolating water is often found to be saturated or even supersaturated, at depths of only a few metres or less beneath the surface. This led to early controversy regarding the relative importance of abrasion and solution; it was argued that since solution could not occur, abrasion must be the main factor.

Bögli (1964 & 1971) described what he called 'mixture corrosion' ('Mischungskorrosion'), demonstrating that when two bodies of water or streams, each saturated with respect to CaCO$_3$, mix, they can produce a solution in which there is still an excess of CO$_2$. Further CaCO$_3$ can
then be dissolved, and in this way solution can take place at depths in
the phreas where a fresh input of water occurs. Larger passages can
start, therefore, where two insignificant ones join.

A further means of increasing the aggressiveness of a cave stream
underground has been demonstrated by Bray (1971, 1972, 1975). Bray has
shown that water entering the Pwll Byfre sink drops in organic content by
the time it enters the Ogof Ffynnon Ddu cave system at Smith's Armoury,
the alkaline hardness increasing. The process continues throughout the
cave, the greatest rate of oxidation of organic matter occurring nearest
to the sink, although this may not be the case in every instance. The
addition of percolation water was considered inadequate to explain the
increase in aggressiveness.

It has been suggested that oxidation of pyrite in clay and shale
horizons (such as those abounding in the limestone sequence in Derbyshire;
Ford, 1976) could provide small amounts of sulphuric acid, which again
increases the ability of percolating water to dissolve CaCO₃ (Howard, 1964).

A useful summary of the chemistry of cave waters is given by
Picknett, Bray, & Stenner (1976).

Abrasion can be an important factor in the enlargement of conduits.
Newson (1971) showed that while solution was dominant in swallet waters
under base flow conditions, abrasion was so important during floods as
to be an important overall factor. Newson records the startling fact that
during the 24 hours of the height of the July 1968 flood on Mendip,
2,000 years worth of suspended calcareous sediment was discharged at
Cheddar, as opposed to one 20th of a year's worth of dissolved calcium
carbonate. He suggested that abrasion became dominant at a specific flow
volume, that volume being well below the limits described as 'flood'.

Early writers (e.g., Swinnerton, 1932; Rhoades & Sinacori, 1941)
tended to disregard structure in their water table cave models, regarding
it as being of little importance except in cases where the structure was
so dramatic that its relationship to cave passages was inevitable and obvious. Later workers began to take structure into account, and detailed studies began to show that the geometry of the joints and bedding planes, and other lines of weakness in the limestone, was of great significance even on the smallest scale (Glennie, 1950; Ford, D.C., 1971; Waltham, A.C. 1970).

The fact that cave streams may migrate to lower horizons in response to lowering of their outlet was recognised as early as the mid-nineteenth century (Lyell, 1863). Boyd Dawkins (1874) realised that streams may flow at a lower level than formerly, but does not appear to relate this to external factors such as valley downcutting. Detailed studies of many areas have now established the relationship of caves to physical features. Droppa (1966) related the Demanova caves in Czechoslovakia to stages in incision of the valley. Sweeting (1950) studied the caves of the Ingleborough district and concluded that they were related to terrace remnants in the valleys. The caves of the Ourthe Valley (Ek, 1961), Central Kentucky (Miotke & Palmer, 1974), and the Bungonia caves (Jennings, 1964) have all been shown to bear a similar relationship to external features. The existence of cave levels in the present study area was first recognised in Middleton Dale by Smith (1964), and expanded in the light of later discoveries (Beck, 1975).

There cannot be an all-embracing theory to explain the formation of caves. The relationship of a cave to its environment has to be considered independently in every case (Warwick, 1976). In the present study area, for example, there are few caves of the type described in the Mendips by D.C. Ford (1968) where 'phreatic loops' form along steeply dipping joints and bedding planes. Instead, phreatic tubes or tube networks extend for long distances, gently graded, along the strike.

In parts of north Derbyshire, the concept of a water table can be useful, but its existence must not be taken for granted everywhere. In
the Wardlow Basin, where an integrated cavity system appears to extend for some distance, a well defined water surface exists over a wide area. Streams are not known to cross, and the allogenic inputs augment an extensive reservoir. In the marginal reef limestones of the Castleton area, the P8 stream crosses the P6/7 stream. Both are in sumps, and are very close together. The juvenile phreatic outlets of Speedwell Cavern pass beneath the active stream of Peak Cavern. Inlets to the Peak Cavern system pass over the top of the Speedwell streamway.

The effect of the veins varies from place to place. In Speedwell Cavern, and in the Crsibwalk of Giant's Hole, veins have acted as barriers to underground flow. The Filthy Five pitches and East Canal of Giant's Hole, however, have formed along veins, probably taking advantage of pre-existing cavities.

In the following chapters, the present state of knowledge of the major catchment areas considered is presented, an attempt has been made to predict the courses of underground streams where no caves are known, and a correlation is suggested between the recognised cave levels and the Pleistocene history of the area.

iv) Previous Regional Speleological Research.

The earliest known account of the exploration of a Derbyshire cave is that of Gervaise of Tilbury (c.1211; Shaw, 1979). He refers to a "castle which the people call Peak... this fortress has in its hillside the entrance to a cavern, which at certain times strongly exhales a wind as if through a pipe". He goes on to relate the story of a swineherd who entered the cavern at a time when it was free from wind, to search for a sow. The swineherd finally came "into a light place, unconfined in a plain of spacious fields". Here, amongst the corn, he found his masters sow.

Although the caves of the Peak must have been well known to lead
miners by the 17th century, the next written account is found in the poem 'De Mirabilis Pecci' (The Wonders of the Peak; Hobbes, 1683). It refers at length to Peak Cavern, and tells the famous story of the poor peasant who was lowered into Eldon Hole;

"And pendulous to hang i' th' midst o' th' cave;
Thence casting stones intelligence to have
By listening, of the depth of this vast hole".

Accounts gradually became more frequent. The earliest reference to Carlswark Cavern is given by Short (1734), and is the first accurate description of a Derbyshire cave. Almost every pillar in the Oyster Chamber (or its shattered remnants) can be recognised as those referred to by Short in his (somewhat extravagant) description of 'Bamforth Hole'. Short's principal concern, however, was to investigate the springs of the county, with emphasis on their medicinal properties.

In 1772, Lloyd and King made the first documented descent and exploration of Eldon Hole, and produced a survey which is still of interest today, when much more rubbish has been thrown down the hole, partly blocking it.

Although the miners had many years of inherited experience behind them, and local knowledge of the geometry of the buried strata was extensive, Whitehurst (1778) was the first to attempt a careful description of the strata. Whitehurst's sections were often described from mines.

Pilkington (1789) visited and described many caves, giving descriptions of Peak Cavern, Pooles Cavern, and a cavern in Chelmorton Dale, which had recently been extended by a miner following a vein. He described a cavern entered via a series of shafts, to the west of Peak Cavern, likely to have been the Assault Course of Speedwell (Ford, T.D., 1966). The main stream passage of Speedwell had been entered and partly explored at this time, and yet Cooke (c.1820) says "Beyond the fissure
(Bottomless Pit) the level has been driven to a similar length... but in this division of its course little occurs to excite observation."

Farey (1811; Vol.1) listed springs and caves, as well as describing the mineralogy and stratigraphy. His appears to be the first reference to Wormhill Springs, and he says these "seem to vent the water of the Dove Holes Swallows". In the same year, White Watson published his 'Strata of Derbyshire', in which a section of the strata from Bolsover to Combs Moss appeared.

From this time on, descriptions of the well known caves such as Peak Cavern are plentiful. The tourist had arrived, and local people would conduct the visitor through Pooles Cavern, Peak Cavern, and Speedwell Cavern. Sir George Head (1836) gave a superb cynical account of his visit to Speedwell Cavern. He was totally unimpressed, saying "the channel is nothing more than an ordinary level, neither a wonder of nature, nor an unusual work of art.... The cascade 'roaring like thunder' is but a dribbling rivulet, artificially secured by a dam, whose sluice is suddenly let loose by the guide; which manoeuvre causes nervous people to start, and thus produces an effect".

Geological mapping of the Derbyshire limestone area began in the mid-nineteenth century, and the first Geological Survey memoir on the area was published in 1869. A second edition appeared in 1887. The reef morphology was not understood, and the concept of the 'Peak Fault' persisted for many years, especially in caving literature. It was finally dispelled by Ford, T.D. (1952), and the 'Peak Fault Swallets' became the Rushup Edge Swallets.

During the late 19th century, the first serious attempts were made to explore, understand, and describe both the cave systems and the details of the geology. Many caves had already been plundered for speleothems by this time (i.e. Water Icicle Close Cavern, Carlswark Cavern, and many smaller caves) but during this period a surge of interest in
archaeology occurred. Bateman (1861) and Boyd Dawkins (1874) gave accounts of barrows and caves which they had excavated. Although most of the results appear to have been published, the material was not given the rigorous examination it deserved (Bramwell, 1977). Archaeologically important caves were excavated, often totally. In the early years of the 20th century, results were better documented (i.e. Storrs Fox, 1906, 1907, 1910).

The late 19th century saw the beginning of organised cave exploration, and some of the early accounts make interesting reading. However, apart from Baker's publication of a plan of Bagshaw Cavern (which appears to have been conveniently twisted to fit the page!), little was found which the miners did not already know, or which had not been described before. During this period, two papers appeared on the origin of the topography of Derbyshire (Fletcher, 1890 & 1891). The second of these concerned the underground drainage. Fletcher described the way in which water finds its way underground, abandoning surface courses, and cited the example of Waterfall Swallet and Linen Dale. He also pointed out the importance of veins in the siting of Waterfall and Little Waterfall ('Pippin') swallows. Interestingly, he also says; "While the erosive action of the water is mainly chemical, it must not be forgotten that, especially in periods of heavy rain, it is supplemented by the mechanical action of suspended particles".

During the 1920's and 30's, the Derbyshire Pennine Club were active in exploring caves, and the significant discovery of Nettle Pot by digging a choked natural shaft occurred in 1937 (Chantry, 1937). Oxlow Cavern was re-opened, miners being employed to stemple the shafts (Winder, 1938).

Caving clubs began to proliferate after the Second World War, and serious exploration began in earnest. Digging began, and by 1960 most of the large extensions to known caves had been made (Giant's Hole, Peak Cavern, Carlswark Cavern etc.). Since that time, the rate of discovery
has slowed considerably, but new caves continue to be found, while extensions to known caves are quite common. Perhaps the most dramatic discovery in recent years was the Winnats Head Cave, with its huge 'Fox Chamber'.

The study of the hydrology of the Derbyshire limestone area has been limited in comparison with some other limestone areas, but the first detailed study of the springs was that of Short (1734) in his 'History of the Mineral Waters of Derbyshire'. Writers after that time did little apart from listing the springs (ie. Farey, 1811). A detailed memoir entitled 'Wells and Springs of Derbyshire' was published by the Geological Survey (Stevens, 1929), and described the water supplies of the county.

Virtually no published research then exists until the Cave Research Group was formed in 1947, and investigations of cave waters began. Pill (1948) investigated the Perryfoot–Castleton cave system, and came to the conclusion that approximately 840 tons of limestone was removed each year from the catchment area. Pitty (1968) estimated that the annual loss from the limestone area amounted to 75 - 83 cubic metres per square kilometre per annum, and assuming that the bulk of this is derived from lowering of the surface, he concluded that the surface was being lowered by 0.075mm per annum.

The groundwater of the Derbyshire limestone was investigated by Downing (1967) and in 1971 by Edmunds, with emphasis on the trace element content. The percolation systems of individual caves have been studied in Pooles Cavern (Pitty, 1966), Peak Cavern (Pitty, 1971), and Waterfall Swallet (Gunn, 1974). The value of the study of potassium / sodium ratios and of the saturation index in determination of the type of cave passage likely to exist behind a particular spring was demonstrated by Christopher (1975) with reference to Derbyshire. Results were encouraging, for in the case of risings behind which a significant amount
of cave passage was already known, the chemistry of the water was to some extent predictable.

Literature on the glacial geology of the limestone area is rather limited, for the evidence of glaciation is limited to scattered erratics and patches of boulder clay. The occurrence of erratics on the limestone was first noted in the Geological Survey memoir of 1887. The recorded erratics were summarised by Jowett and Charlesworth (1929). They suggested that the ice, during the 'Older Drift', had overflowed the watershed of the Pennines at Dove Holes, and flowed down the Wye Valley.

Dalton (1945) supported this view, and collected local erratics from the area around Stoney Middleton, Eyam, and Foolow. He recorded the section in a trench excavated from Calver to Wardlow Mires in 1945, and later described a 'swallow hole' into which he considered that till had been washed in what was then the Derby County Council Quarry in Middleton Dale (Dalton, 1953). Dalton studied the distribution of dolerite boulders, and postulated their likely source (Dalton, 1954) and was able to suggest that two streams of ice passed eastwards, one via Millers Dale to Bakewell, and the other via Eyam, Foolow, and Stoney Middleton.

Sections of tills in the Bakewell area were studied by Straw and Lewis (1962). They again suggested a westerly source for the ice, but also suggested that the drift in the Bakewell area was younger than the till of North Derbyshire.

Burek (1977) considered that the till of the Bakewell area, lying between 525 ft O.D. at Bakewell Cemetery and 800 ft O.D. between Stoney Middleton and Coombs Dale was of Wolstonian age, and that erratics lying up to 1300 ft were representative of an earlier, probably Anglian, glaciation. The Devensian was considered to be represented by the widespread loess, and other periglacial phenomena.
Chapter 2.

TOPOGRAPHIC AND GEOLOGICAL SETTING
OF THE STUDY AREA.
2. TOPOGRAPHIC AND GEOLOGICAL SETTING OF THE STUDY AREA.

i) General Setting of the Peak District.

The Peak District of Derbyshire lies at the southern end of the Pennine Hills, a broad tract of high ground elongated from north to south through Central Northern England. The crest of the Pennines forms the watershed of the country, dividing westward drainage to the Irish Sea from eastward drainage to the North Sea. Large areas of these uplands lie above 1,000 ft (305 m) A.O.D., and small areas such as the Kinderscout Plateau exceed 2,000 ft (610 m) in altitude. Much of this higher ground remains uncultivated and largely uninhabited.

The Pennines consist broadly of an uplifted area of Carboniferous rocks, mainly limestone, coarse grits, and shales, with the Coal Measures providing the coal fields to the east and west (Fig.1.). The Carboniferous Limestone is exposed in two areas, the northern outcrop being by far the larger, and the southern outcrop constituting the "White Peak". A karst landscape is developed on both outcrops, but is spectacularly so only in the north, where large areas of bare limestone pavements testify to the more extensive glaciation which that area has undergone. The karst of the White Peak, or Derbyshire Dome as it is often called, is less well developed, and the extensive cave systems known to underlie much of the Yorkshire limestone outcrop are here much more localised at the limestone margins. It is the predominantly fluvio-karstic landscape of the northern part of the Derbyshire outcrop which forms the subject of this study.

The limestone outcrop of Derbyshire is surrounded by younger rocks, producing the effect of a ponded karst. To the north and west rise the high moors of the Millstone Grit, which become more subdued in the east and south. In the extreme south, Carboniferous rocks are unconformably
THE GENERAL GEOLOGICAL SETTING OF THE DERBYSHIRE LIMESTONE OUTCROP

Fig. 1

After Stevenson and Gaunt, 1971
overlain by Triassic sediments, which directly overlie the limestone to the west of Ashbourne in the Weaver Hills.

ii) Structure.

Only in a very broad sense can the Derbyshire limestone outcrop be referred to as a 'dome'. Its structure is complex, intra-Carboniferous movements having uplifted the area, giving rise to the outward dipping reef masses which fringe the outcrop of massive 'shelf' facies limestone. The pattern is complicated by further folding, the dominant trends being east-west, north west-south east, and north-south. Interaction of these fold axes gives a complex interference pattern of basins and domes, many smaller anticlines pitching eastwards to produce the variations in elevation of the limestone/shale margin (Butcher & Ford, T.D. 1977).

The limestone area is crossed by many mineral veins, which in the north and east of the outcrop have been worked for lead over a period of 2,000 years, and more recently for fluorspar. Most of the veins show horizontal slickensides, and in many places a vertical displacement can be demonstrated. The dominant trends of the veins are north west - south east, north east - south west, and east - west (Fig.2).

iii) Stratigraphy.

The oldest limestones exposed within the present study area outcrop around Peak Forest, on the crest of the Peak Forest Dome, and in the Wye Valley east of Buxton, in Ashwood Dale. A borehole, beginning in these beds (Woo Dale Beds, of S$_2$ age), was sunk in search of the underlying basement (Cope, 1949), and this was thought to have been reached at a depth of 900 ft (274 m). The deep borehole sunk near Eyam (Dunham, 1973) proved 5,913 ft (1803 m) of Dinantian rocks, mostly limestone, underlain by Ordovician shales.
The succeeding $D_1$ limestones, referred to in the area as the Bee Low Limestones, occupy the western part of the area. Where the Lower Millers Dale Lava is present, the Bee Low Limestones are subdivided into Chee Tor Rock (below the lava), and Millers Dale Limestones (above the lava). Evidence from underground localities in the Castleton area suggests that the horizon of the lava may be traceable over a larger area than is possible from surface mapping; it appears to pass north westwards into a tuff of varying thickness, and is important in the development of potholes in the 'massif' facies limestones. The $D_1$ limestones are typically fine grained, relatively homogeneous, pale, and massive.

The overlying limestones are the Monsal Dale Beds, of the $D_2$ zone. Their base was taken as the top of the Upper Millers Dale Lava by Hudson and Cotton (1945), but Stevenson and Gaunt (1971) point out that dark limestones referable to the $D_2$ zone outcrop below this horizon in Monsal Dale. The Monsal Dale Beds show greater lithological variation than the $D_1$ limestones, up to 25 metres of dark thin bedded limestones being developed at the base in the south of the area (Shirley and Horsfield, 1945). Girvanella occurs at two horizons, referred to as the Lower and Upper Girvanella Bands. The top of the Litton Tuff marks the base of the Upper Monsal Dale Beds where it is present, the base being generally taken at the Upper Girvanella Band. The Upper Monsal Dale Beds are paler, fine grained, often cherty, and contain prominent fossil horizons such as the Hob's House Coral Band of Cressbrook Dale, Lower Shell Bed of Stoney Middleton Dale, and the Lathkill Shell Bed. Thin clay wayboards in this sequence, often directly below one of the shell beds, appear to be important speleogenic horizons in the areas of Middleton Dale, Bradwell Dale, and Lathkill Dale.

The Eyam Limestones, of $P_2$ age (Cawdor Limestones in the south; Shirley, 1959), are typically thin bedded, dark, impure cherty limestones. Their base is marked by a non-sequence, often occupied by a clay, and
demonstrably an angular unconformity in Glebe Mine shaft, Eyam. Flat reefs and knolls are often present, a flat reef at Eyam passing westwards into dark grey cherty limestone with reef knolls. The unconformity at the base of the Eyam Limestones is more marked on the western margin of the limestone outcrop (Stevenson and Gaunt, 1971) where pre- \( P_2 \) faulting has occurred, and Eyam Limestones rest directly on limestones of the \( D_1 \) zone.

In the Wardlow Basin, the upper part of the \( P_2 \) beds is represented by a development of shale, lying unconformably on the lower part of the Eyam Limestones.

The Namurian shales rest unconformably on the Dinantian limestones, though with little angular discordance. In many places on the limestone margin, where the shales outcrop at the base of an escarpment capped by coarse sandstone (locally 'gritstone'), landslip has occurred (ie. Eyam Edge, Bradwell Edge). Round the northern margin at Castleton the shales have been shown to be deposited against the fore-reef slope (Parkinson, 1947 & 1953) while in places on the western margin they rest directly on Monsal Dale Beds (ie. Axe Edge).

iv) Drainage.

Only the River Wye flows permanently over the limestone outcrop in the study area. The River Lathkill now dries up in all but the wettest summers, although this may be due to the effect of mine drainage, which has modified the catchment area boundaries. The Derwent, to which the drainage of the north and east of the area flows, lies almost entirely on Namurian sediments, except where it passes through the Matlock Gorge, and is incised into an eastward plunging anticline (Ford, T.D. & Burek, 1976).

The River Wye at Buxton is an allogenic river, having its source on the Millstone Grit moors west of the town. On reaching the limestone recharge from the karst drainage systems is extensive, many risings lying
both north and south of the main river. The volume swells dramatically between Buxton and Bakewell, the largest rising being that of Wormhill Springs. Beyond Bakewell, the river soon leaves the limestone, and is joined by the River Lathkill a short distance before the confluence with the River Derwent at Rowsley.

The apparent disregard of structure in the course of the River Wye may lie in its initiation on a cover of younger rocks, subsequently removed (Linton, 1951). The river crosses a number of north-south folds to the east of Buxton, before turning through a sharp meander in Chee Dale, to flow eastwards roughly parallel to a series of east-west fractures as far as the confluence with Cressbrook Dale.

Many of the tributary valleys of the Wye and the Derwent which lie on the limestone outcrop are always dry (Fig.3), and others carry surface streams only in times of severe flood (Warwick, 1964). In most cases even the flood streams issue from risings, generally close to the valley floor except where lavas carry local perched groundwater which emerges as springs at the margin of the outcrop, as on Wormhill Moor, in Monks Dale, and Millers Dale.

The large land area devoid of surface drainage and the comparatively high rainfall (35 - 50 inches per annum; Edmunds, 1971) suggest the existence of a well developed network of underground drainage systems. Only a few are known to any extent, these lying within comparatively small areas generally close to the shale/limestone margin. Exploration of the Lathkill Head / Cales Dale cave system, which drains the Monyash Basin, is possible due to the activities of the miners in lowering the water table in this part of Derbyshire (Bamber, 1951).

The plateau surface is extensively pitted with dolines. Analysis of these features is complicated by the mining activity in the north and east, for it is likely that the highest doline concentration lay along the veins prior to the mining, so that only the isolated ones now remain
The Derwent-Wye Limestone Catchment: Surface Drainage.

KEY

- Margin of Impervious Cover
- Permanent Surface Stream
- Intermittent Surface Stream
- Dry Valley
- Active Swallet
- Rising
- Boundary of Surface Catchment

Scale

Drawn from Sheet 111 of the Ordnance Survey One Inch to One Mile map (Seventh Series), the published maps of the Geological Survey, and the field maps of the author.

Fig. 3
undisturbed. It is interesting to speculate that when the miners first searched the area for lead, the large rakes were clearly defined in a manner similar to their present appearance, solution dolines or small natural shafts taking the place of the present day rows of mining hollows and mounds. There are places on Bradwell Moor where small dry valleys have clearly led surface drainage into a vein; these dry valleys now end at a mined hollow, possibly originally a natural shaft. There are many mine shafts in the Castleton area which are enlarged natural shafts on veins (i.e. Maskhill Mine, Longcliff Mine).

Many of the natural shafts removed at some distance from the shale/limestone margin are filled with reworked loess and other glacial or periglacial sediment. Since most of the abandoned high level caves in the valley sides are filled with silt, often in turn covered by thick flowstone deposits, these shafts represent what is potentially the easiest means of access to the deep cave systems which undoubtedly underlie at least some parts of the central limestone outcrop. Excavation has so far been well repaid in only one case; Nettle Pot was excavated in 1937, and the shaft led into a deep and spectacular pothole. Other attempts since that time have so far only resulted in abandonment of the dig on diminution of the shaft to a tight fissure.

v) The Catchment Areas.

An attempt has been made in the present study to predict the courses of underground drainage routes on the basis of structure where no cave systems are available for examination (Fig. 4). Investigation of the structural controls over cave systems in the marginal areas has allowed the formulation of criteria by which this might be done. Structural basins such as the Wardlow and Monyash Basins are easy to define, but even here the position is complicated by faulting, lavas and tuffs in the limestone sequence, and minor folding. Complexities
The Derwent-Wye Limestone Catchment: Underground Drainage.

KEY
- MARGIN OF IMPERVIOUS COVER
- LAVA OR TUFF OUTCROP
- DOLERITE OUTCROP
- DIRECTION OF UNDERGROUND DRAINAGE
- FLOW CONCENTRATED ALONG VENTS
- DRAINAGE BY SOUGHS

Fig. 4

AFTER THE 1:25,000 MAPS OF THE GEOLOGICAL SURVEY AND THE AUTHOR'S FIELD NOTES
arise in areas such as the Wormhill Springs catchment area, where extensive development of two lavas results in a widespread perched groundwater area. The underground drainage of a part of the area above the Lower Millers Dale Lava appears to flow to Monks Dale, while water in the limestones below the lava flows to Wormhill Springs.

Surface catchment areas may not always correspond with the known limits of the underground catchment. The prime example in the area is the Peak/Speedwell catchment at Castleton. The surface watershed between drainage southwards to the River Wye and drainage eastwards via the Hope Valley to the River Derwent lies almost across the centre of the known underground catchment area. However Pitty (1968) has shown that close correlation exists between spring discharge and the size of the surface catchment, so that underground and surface catchments may be closely related in more cases than is at first apparent.

Catchment areas have been modified in some cases by the driving of soughs for mine drainage. It is probable that a gradual lowering of the water table in the Monyash Basin has taken place over the last 100 years as a result of the driving of Magpie Sough and the Hubberdale Soughs; these have punctured the lava which formerly acted as an aquiclude to prevent water from the flanks of the basin rising in the River Wye. In the Stoney Middleton area, Watergrove Sough carries water eastwards which would otherwise rise at the head of Cressbrook Dale. In this case the sough has restored the natural drainage by carrying water into the cave system (Carlswark Cavern) which it utilised before capture by Cressbrook Dale.

Most of the catchment areas are delimited by well defined structural features, or their extent is known by dye testing, particularly in the marginal areas. The likely extent of the Lathkill Dale catchment before modification by mining is suggested by the structure of the basin, but other central catchments may be complex (ie. Monks Dale) due to lavas
and tuffs with complex and faulted outcrops. In other cases, such as the catchment area of Wormhill Springs, lack of allogenic streams sinking in the area prevents a detailed analysis on the basis of dye testing.

The major catchment areas considered are as follows;

Stoney Middleton (Moorwood Sough, Watergrove Sough, Carlswark Cavern, Hawkenedge Well).

Castleton (Peak Cavern, Russet Well, Peakshole Sough).

Bradwell (Bagshaw Cavern).

Upper Lathkill Dale (Lathkill Head Cave, Lower Cales Dale Cave, Critchlow Cave).

Wormhill Springs (Considered with Great Rocks Dale).

Monks Dale (Many small risings).

Buxton (Wye Head, Otter Hole, Dog Hole).

In addition to the above, there are many smaller springs, most of which carry only local drainage, and many of which lie at the margin of areas of perched groundwater above lavas and tuffs. The more important smaller catchment areas are;

Ashwood Dale.

Deep Dale.

Brook Head (Tideswell).

Blackwell Dale.

Taddington Dale.

Cressbrook Dale (Lumb Hole).

Calver.

Details of the drainage of the above catchment areas are given in the succeeding chapters.
Chapter 3.

THE STONEY MIDDLETON

CATCHMENT AREA.
3) THE STONEY MIDDLETON CATCHMENT AREA.

1) Previous Research and Exploration.

The area of Stoney Middleton Dale has attracted cavers for many years, and the most extensive cave system, Carlswark Cavern (also spelled Carleswark; King, 1962: or Charleswork; Short, 1734), has been known for several hundred years. The earliest evidence of exploration is a clay pipe found at floor level beneath clay and boulders in 'Big Dig', and dated by reference to Ayto (1979) as late seventeenth century. The earliest written description of the cave is that of Short (1734), who described a visit to the cavern. His account of the Resurgence Entrance is unmistakeable, and his claim that the cavern opened "near Fowlow" (Foolow) appears more likely as more of the cave is explored. It is likely, however, that the westward continuation had become inaccessible shortly before 1730, and that Short did not make the trip.

Early this century, no doubt lured by tales of the great extent of the cave, cavers began exploration. The cave was explored and surveyed from the Resurgence Entrance, then the only access point, to a series of chokes beneath Eyam Dale where progress halted for many years.

During the exceptionally dry summer of 1959, members of the British Speleological Association broke through one of the chokes into what is still often referred to as the 'New Series', excavated the Eyam Dale Shaft to provide a through route, and passed the sump in the Resurgence Entrance passage to complete a circuit through the New Series. In this account, the passages found in 1959 are referred to as the B.S.A. Series, since there have been five more 'New Series' since that time.

At the western end of the B.S.A.Series, a large silted tube was enthusiastically excavated for some distance. It ran gradually downhill, and in the first winter floods, water entered the cave from an unknown
source through the dig, and it filled to the roof with silt once more. Several subsequent attempts here also failed for the same reason.

Following the encouraging progress of 1959, the cave was entirely re-surveyed. It was assumed at this time that the water sinking at the large allogenic swallet to the west of Eyam, Waterfall Swallet, had resurged at Carlswark until sough drainage took over. The Eldon Pothole Club penetrated the swallet to a depth of 43 metres, also in 1959. The work was fully summarised by King (1962) who made the first serious attempt to describe the underground drainage system. A rather speculative account of the development of Middleton Dale had been given by Jefferson (1962).

Smith (1964) considered the development of the dale together with the underground drainage, but no new passage was explored until the Limestone Caving Club attacked a draughting tube at the northern extremity of Carlswark in 1970 (Devoto, 1972). A series of joint-oriented chambers was entered, progress being finally blocked by a tight rift passage. This was finally passed by Sheffield University Speleological Society and South Yorkshire Caving Club, and high level passages were found beyond. The whole is now known as the Dynamite Series.

The present author first gave serious consideration to the area in 1972, and began excavation of Lay-by Pot, a shallow joint-controlled partly natural shaft near the west end of Stoney Middleton Dale. At Easter 1973, at a depth of 15 metres, the dig came to fruition with the discovery of 366 metres of natural passages.

A picture of the speleogenesis of the area began to emerge, and a reinvestigation of the Carlswark system suggested the presence of a buried continuation beneath the solifluxion deposits which had entered the cave through connections with the west side of Eyam Dale. A shaft was sunk, and the important series of passages known as 'Gimli's Dream' was discovered. Further digging established a connection with the nearby
Merlin Mine, where high level cavities existed which could then be genetically related to Carlswark.

The continuation was lost at Merlin, and further digging began. The Merlin Streamway was entered in September 1973, and it was thought that the route from Waterfall Swallet had at last been entered at the eastern end. Dye testing by P.R. Deakin soon showed that the Waterfall Swallet stream, in normal conditions at least, did not pass through the known cave. A hitherto unsuspected drainage route had been discovered.

Attempts to intersect this route further to the west failed, but resulted in the discovery of the 185 metre long Yoga Cave. The cave is developed by solutional enlargement of the same bedding plane as the majority of Carlswark Cavern, and suggests continuity of this phreatic network far to the west of the known cave.

During 1974, members of South Yorkshire Caving Club excavated the silt choke at the end of Ivy Green Cave, finding that beyond that point the cave changed character, with a great deal of flowstone and other fine speleothems. They found roughly 60 metres of new passage trending north westwards, but ending at a solid flowstone choke. An ambitious excavation was carried out during 1975 - 6 in a large northward trending passage near Ivy Green entrance, but the tube ended at an impenetrable choke in the Cliffstile Vein.

The 1975 and 1976 droughts revealed much new passage. Exploration of the Merlin Streamway proceeded as far as Sump Six, which was then pronounced a hopeless prospect as it was full of thick black mud. The downstream sump broke during 1976, with assistance by pumping, but only 20 metres of passage was penetrated.

During 1975, Watergrove Mine was descended by O.M. Mines Research and Exploration, and the Watergrove Pipe was entered. It was found to consist of a very large joint-controlled cavity, extensively silted, and blocked by collapse on a large scale after 60 metres. Blocked side
passages suggested the existence of a network of phreatic cavities lying beneath the shales of the Wardlow Basin, and observation of the water levels over a long period has revealed much about the drainage of the central basin.

The entire underground discharge of the area is by soughs, except in flood conditions when a large rising develops at Wardlow Mires, at the head of Cressbrook Dale (Fig.6.) and a considerable stream flows from the Resurgence Entrance to Carlswark Cavern. Many of the former soughs are lost, but their history was studied in detail by Kirkham (1966, 1967, 1968). A great deal of field work by many authors since that time has revealed more penetrable sough passage. Moorwood Sough, driven from Stoney Middleton to Glebe Mine, Eyam, was cleared by O. M. Mines Research and Exploration between 1967 and 1973. This sough drains actively working mines, and access is not therefore normally permitted.

Excavation of a shaft near the tail of Watergrove Sough during 1975 provided access, and the sough was followed in very difficult conditions for 200 metres to a large scale collapse. The majority of shafts on Watergrove Sough are either blocked at depth, or filled.

The tail of Wardlow Sough, in Cressbrook Dale, was re-driven in 1976 by the Technical Speleological Group. It was hoped that much might be learned regarding the drainage of the area to the south of Stoney Middleton Dale, but results were somewhat disappointing. The sough was hopelessly blocked after 330 metres. Useful sections of the strata were found in a shaft which was climbed upwards from the sough, and natural cavities were inspected directly above the Litton Tuff.

During the exceptionally wet February of 1977, an ambitious project commenced to pass Big Dig in Carlswark. A trench was excavated for nearly 70 metres downstream from the dig, and debris was removed from the base of an old shaft along this stretch of passage. The water level in Big Dig dropped considerably, and during the ensuing two winters, a free flowing
stream cut silt from the dig. A boulder choke had to be timbered before the breakthrough could be made, and access was gained to the Merlin Streamway on the downstream side of the downstream sump in Merlin ("Shag's Sump"). 550 metres of passage were found, including a long stretch of active stream passage. Many previously unanswered questions were resolved by this find, but the stream passage from Waterfall Swallet was still not intersected.

ii) Topographic and Geological Setting.

The first detailed account of the stratigraphy of the area was published by Morris (1929). Morris defined the "Lower and Upper Giganteus Beds"; the lower of these two is an important speleogenic horizon over a wide area.

Shirley and Horsfield (1945) considered the structure and mineralisation of the area, mapping in detail, and producing a structure contour map at the Orionastrea placentata horizon.

All but the southernmost part of the area is included on the 1 inch : 1 mile Geological Survey Sheet No. 99 (Chapel-en-le-Frith), and details are given in the accompanying memoir (Stevenson and Gaunt, 1971). The "Giganteus" beds of Morris (1929) are referred to as the Lower and Upper Shell Beds therein, and these terms are used in this account. Six inches : 1 mile Geological Survey Sheets nos. SK 27 NW and SK 17 NE are now available for the area.

The catchment area occupies the north eastern portion of the limestone outcrop. Its area is approximately 17 km², of which 10 km² is limestone, and the remainder is shale and sandstone. The size of the catchment is somewhat misleading, for in flood conditions water overflows southwards via Cressbrook Dale, and a comparatively small proportion rises at Stoney Middleton. Moreover, two of the streams flowing from the shales to the north have surface courses throughout. Sough drainage has
altered the patterns of underground drainage so that rather than one large natural discharge point, there are several smaller artificial ones.

The limestones of the area consist of Upper Monsal Dale Beds ($D_2$) overlain by the Eyam Limestones ($F_2$). The former occupy the majority of the southern and western parts of the area, and dip northwards beneath the Eyam Limestones, which occupy a broad tract between Stoney Middleton Dale and the shale margin (Fig. 6.). The Eyam Limestones are overlain unconformably by Namurian sediments, which in places overstep the former to rest directly on Upper Monsal Dale Beds.

The Upper Monsal Dale Beds are generally massive, well bedded, often bioclastic limestones of variable lithology. The frequent prominent bedding planes, often occupied by thin clay wayboards, are often of prime importance in determining the position of the successive underground drainage routes recognised in Middleton Dale.

The Eyam Limestones consist of flat-reef limestones in the vicinity of Stoney Middleton and Eyam, with up to 24 metres of dark cherty limestone at the base. They pass westwards into dark cherty limestone with reef knolls, thinning to only 14 metres at Waterfall Swallet. There is often a thick clay wayboard at the base (for example at Waterfall Swallet), and a thin coal occurs at this horizon in Coombs Dale. The wayboard may be of importance in the formation of horizontal passages in swallet caves, but the only instance so far known is the entrance passage to Waterfall Swallet.

To the north of the area, the prominent shale and sandstone escarpment of Eyam Edge rises to a maximum elevation of 1,407 ft (429 m) A.O.D. at Sir William Hill. Allogenic streams accumulating on these Namurian sediments flow southwards to disappear, in most cases, into swallow holes at the limestone/shale margin. The deep limestone gorge of Stoney Middleton Dale lies sub-parallel to the escarpment, and drains to the River Derwent, to the east. At its western end it turns north, and then north east, to
GEOLOGY OF THE EYAM DISTRICT

KEY TO GEOLOGICAL SYMBOLS

1. UPPER MONSAL DALE BEDS (D2 ZONE)
2. EYAM LIMESTONES (P2 ZONE)
3. KNOCK REEF OF P2 AGE
4. SHALES OF P2 AGE
5. MARGIN OF NAMURIAN SHALES
6. VEINS

Fig. 6
To the south of Stoney Middleton Dale, northward dipping Upper Monsal Dale Beds with outliers of Eyam Limestones rise to a maximum elevation of 1,297 ft (395 m) A.O.D. at the summit of Longstone Edge. This upland area is dissected by two dry valley systems, Hay Dale, which drains southwards to the River Wye, and Coombs Dale, which drains east to the River Derwent.

The east-west trending crest of Longstone Edge roughly coincides with the axis of the Longstone Edge Monocline, a structure with a steeply dipping southern limb, and shallow dipping northern limb, which manifests itself at the western end as a fault with downthrow to the south in Cressbrook Dale. Smaller parallel folds occur to the north, and a series of low amplitude north south folds have produced a series of shallow basins and domes. These structures are more pronounced at the western end, and the large topographic basin of Wardlow Mires reflects the presence of a structural basin underneath. The centre of the basin is occupied by an outlier of Visean and Namurian shale.

Topographically, the Wardlow Basin is drained by the deeply incised valley of Cressbrook Dale, which runs southwards to the River Wye. It only carries a surface stream in wet weather except at the southern end, water appearing at various points from natural risings and soughs. Near the southern end, the large rising of Lumb Hole contributes a large volume of water, and is the source of the stream in dry weather. It is unlikely that the rising here has its source in the Wardlow Basin, and it is considered separately.

The catchment area is bounded on the western side by the outcrop of the Litton Tuff, which reaches its maximum thickness of 30 metres to the north of Litton. The horizon provides an impervious floor to the central basin, forming a large reservoir into which percolation water from the
1) Waterfall Swallet during the snow-melt floods of December 1978. The lake is not normally present.

2) Stoney Middleton village during the December 1978 flooding. Moorwood Sough passes beneath the road at this point, and water is forced up through manholes and old access shafts.
surrounding limestone dip slopes may drain. The horizon does not outcrop on the eastern side, but is known from underground localities to thin rapidly and die out. Its function as an aquiclude is taken over by the Cressbrook Dale Lava in the eastern part of the area; the lava thickens eastwards to a maximum of 76 metres (Dunham, 1952) to the north of Glebe Mine, Eyam, and can be seen to die out in Cressbrook Dale (Fig.7.).

The mineralisation of the area has a considerable effect on the patterns of underground drainage. Most prominent are the east-west veins, of which the Hucklow Edge Vein, concealed beneath the shales to the north, was worked until recently in the Ladywash Mine. Although direct observation of their effects is rarely possible in the area, comparison with the Castleton area suggests repetition of the situation in which primary vein cavities have provided an easy passage for the development of underground drainage routes. The breakwater effect noted in the Castleton area by Ford, T.D. (1966) may occur in the case of Middlefield Rake in the present area.

A set of smaller veins with a thickness rarely exceeding a few centimetres has a fairly consistent trend of around 60°. There are very many such veins, or 'scrins', almost every north east - south west joint being mineralised. They display a breakwater effect in some cases, and seem to determine the position of the larger dip tubes in Carlswark Cavern, and also the position of the capture points between cave levels.

More rarely, joints belonging to a set trending at around 320° may be mineralised. Such veins are generally only a few millimetres in width. The mineralisation of these joints appears to have little bearing on cave formation, but the joints themselves are often opened by solution, particularly on the crests of the small north-south folds. They have an important effect on the orientation of the trunk phreatic routes. (Fig.62).
GEOLOGICAL CROSS SECTION FROM CRESSBROOK DALE TO MOORWOOD SOUGH

S 58°W  S 80°E
1932 7654

Fig. 7
iii) Surface Streams.

The western part of Middleton Dale never carries a surface stream, water first appearing at the tail of Watergrove Sough (2106 7583). The sough was driven to drain the inundated Watergrove Mine, which lies just within the eastern rim of the Wardlow Basin. Water from the sough flows eastwards, and is joined at the south end of the Delf, a tributary valley from the north, by the flow from the somewhat mysterious rising of Hawkenedge Well, which is considerable and fairly consistent (2156 7583). The nature of the watercourse is unknown; it has been referred to as Oakenedge Sough (Rieuwerts, 1966; Kirkham, 1967).

Except in very dry weather, surface streams join the brook from the Delf (Jumber Brook) and Eyam Dale (Hollow Brook). The streams flow southwards from the escarpment, through Eyam where they are both culverted, and onto the limestone. Their surface courses may therefore be artificial, swallets in the vicinity of Eyam having been filled in and obliterated. Both streams are seen to seep away into their respective valley floors in dry weather, and these tiny swallets have been dye-tested to Moorwood Sough.

The brook is further swelled at Stoney Middleton by the discharge of Moorwood Sough (2318 7545; Plate 1,2), driven to drain mines between Stoney Middleton and Eyam, notably Cliff Stile Mine and Glebe Mine. The sough runs close to the shale margin, and has captured water from the natural conduits at the western end by intersecting the lowest and most juvenile phreatic cavities of the Carlswark cave system. The sough tail lies at an elevation of approximately 465 ft (142m) A.O.D. The combined streams continue eastwards as the Stoke Brook to the River Derwent.

The only other surface stream on the limestone is that in Cressbrook Dale. At the shale margin on the south western side of the shale outlier is a small swallet which engulfs the small stream that accumulates on the shales. Several similar depressions lie close together, and the valley
floor abounds in open joints and bedding planes for some distance to the south. In flood conditions a pool develops at the swallow, and the water backs up until it overflows down the valley. Nearby depressions quickly fill, and if wet weather continues a very large stream, far greater than the allogetic accumulation of the shale outlier, flows down Cressbrook Dale. This is due to the fact that the water level in the cavities beneath the central basin has risen above the level of the swallow. The swallet here is thus an estavelle, engulfing water in the summer, and discharging a far greater stream during wet winters (Plate 2).

Historical evidence (Kirkham, 1971) suggests that the stream was formerly almost always present, and it is possible that the driving of Watergrove Sough and the pumping operations at the mine lowered the water table to such an extent that the stream now only flows in flood.

The stream in Cressbrook Dale is swelled by the flow from Wardlow Sough (1742 7474), but in recent dry summers this has been inactive for long periods. A stream from the west seeps from the collapsed tail of Arbor Seats Sough. In extremely dry conditions there may be no stream north of Lumb Hole (1726 7315), and the discharge here may become very small, but has not been observed to cease completely. The Cressbrook Dale stream joins the River Wye at Cressbrook (173 726).

iv) The Swallets of Eyam Edge.

The precise location of the western boundary of the catchment area is difficult to define. It is known from dye tests by the Derwent Valley Water Board (recorded in Ford, T.D. 1956) that the stream sinking at Duce Hole at Grindlow flows to Bradwell via Bagshaw Cavern. It appears from the stretch of known passage in the Swevic House Swallet that the small stream here flows either southwards into the Wardlow Basin, or may also flow to Bradwell. On the basis of structure, Bradwell is a more likely destination, for the swallet lies just outside
1) Pressure dome above a large artesian rising at Wardlow Mires. The rising is an estavelle, engulfing a small stream in summer, but discharging a much larger stream in the winter months.

2) A small isolated pressure dome at Wardlow Mires during floods.

3) A large bedding plane rising on the west bank, just downstream from the main rising at Wardlow Mires.
the structural basin. The underground catchment boundary thus lies between Swvic House Swallet and Waterfall Swallet, which is therefore the most westerly locality considered here.

Waterfall Swallet.

The large tree-lined doline of Waterfall Swallet lies at the limestone/shale margin at 1988 7705 (Fig. 8, Plate 1, l), on the north side of the road between Eyam and Foolow. A stream enters the doline from the north west, and falls approximately 9 metres to sink at three points in the doline floor. The entrance to the known cave lies in the north east wall, and takes water only during flood. A joint-controlled cave in the north corner appears to be an early stream sink.

The stream accumulates on Namurian sediments to the north and west, and plunges underground immediately on reaching the limestone. The uppermost beds are the Eyam Limestones, here only some 10 metres thick. The base of the formation is marked by a thick wayboard, and it is by removal of this wayboard that the cave entrance passage is developed. The Eyam Limestones are thin bedded, often bioclastic, cherty beds here.

The underlying Monsal Dale Beds are more massive, less cherty, and with several persistent fossil horizons. The lowest of these seen in the cave, where the stream finally disappears into boulders, is thought to be the equivalent of the Lower Shell Bed of the Stoney Middleton Dale section.

The entrance passage to the cave is very constricted, for little limestone either above or below the wayboard has been removed. A short drop is reached after 8 metres, and the route steps to a lower, thinner wayboard. A small chamber is reached, and the way on is down through a choke of large boulders, now relatively stable due to the passage of many explorers. The choke is found to be perched astride a large rift, Hockenhull's Rift. One of the main fractures on which the doline and cave system are developed has been intersected; the fracture can be
WATERFALL SWALLET, FOOLOW.
East-West Projected Section.

Stream sinks in doline floor.

Prominent wayboard at base of Eyam Limestones

West

Hockenhull's Rift

Westy's Bit.

273.1 m. Entrance

Waterfall Chamber

Showerbath Passage

Eps Aven

230.1m O.D.

Final stream sink.

Fig. 8
seen to the right of the entrance as a fault with a very small throw, which dies out in the uppermost beds, implying syn-sedimentary movement.

The rift is floored with jammed boulders, and there are many ways from here to the bottom of the cave, some in the Hockenhull's Rift fracture, some in parallel fractures, and some in fractures of a set trending north west. The stream in encountered 21 metres below the entrance, and can be followed through a chaos of displaced and eroded blocks to a depth of 43 metres, where it disappears in boulders and mud. The main fracture can be followed beneath the doline floor for a short distance.

The whole of the lower section of the cave floods after heavy rain, but despite the presence of a lake up to 5 metres deep in the doline (Plate 1,1), the maximum water level in the cave has never been seen to rise more than 15 metres above the final choke. The most severe flood in recent years occurred on the 16th July 1973, when 4.6 inches of rain fell in a 24 hour period. At that time the percolation system of the cave was being studied by J. Gunn (Gunn, 1974), and polythene sample bottles had been placed at many points in the cave. Those below the Waterfall Chamber (a depth of 28 metres) were lodged in the roof or strewn about the floor. Those above that point stayed in situ. The flow over the waterfall into the doline was estimated at roughly 1200 litres per second, yet this volume of water was somehow able to escape, suggesting a fairly unrestricted but as yet undiscovered outlet.

The doline owes its location to the intersection of the Crosslow Vein with the limestone/shale margin. The stream has begun to sink on the vein, which at the swallet has a small displacement, and then cut back upstream so that the waterfall now lies a little to the north of the vein. The two major sinks in the doline floor lie roughly on the line of the disturbance. The vein splits into two at the eastern end, the more northerly branch being responsible for the major rifts in the cave. The
most complex part of the cave lies at the junction of the two fractures.

The northern branch passes north eastwards, and is thought to be the vein worked in Black Hole Mine.

**Little Waterfall Swallet.**

The doline here is shallower than that of Waterfall Swallet itself, and lies on the northern branch of the fault/vein system, at 2003 7710. The sink at Little Waterfall Swallet is at present impenetrable, but permission to excavate has never been granted.

**Crosslow Cavern.**

Crosslow Cavern was described by Robey (1964). Access was via a mine shaft on Crosslow Vein (2030 7706). The 18 metre shaft led to a large cavern which had been used as a washing floor for ore, and was largely filled with miners' deads. Water in the cavern was stated to drain towards Waterfall Swallet. The depth of the shaft suggests a repetition of the situation at Waterfall Swallet, where large cavities have developed below the basal wayboard of the Eyam Limestones. The shaft has now been obliterated by the farmer.

**Black Hole Swallet.**

Black Hole Swallet was a shallow doline at 2035 7732. It took a small wet weather stream, but the stream sink was impenetrable, and the doline has now been filled by the farmer. The water was likely to enter Black Hole Mine, where natural cavities were inspected before the unstable shaft was filled for safety in 1976. These cavities were also developed a short distance below the basal wayboard of the Eyam Limestones.

**Hunger Hill Swallet.**

Hunger Hill Swallet lies immediately west of Hunger Hill Farm at 2096 7695. It appears to engulf a considerable amount of flood water, but the outlet is hidden under ancient refuse.
Jumber and Hollow Brook Swallets.

Swallets are unknown in the vicinity of Eyam, for the Jumber and Hollow Brooks are culverted beneath the village where they cross the limestone/shale boundary. There is a short open stretch of the Jumber Brook behind the Rose and Crown Inn at 2053 7654, and small quantities in dry weather. A large quantity of household refuse was dumped here early this century, and swallets may have been blocked. The Jumber Brook flows down the deep valley of the Delf, and sinks at two distinct points, referred to as the Lower and Upper Delf Swallets. In only moderately wet conditions, these small swallets are overpowered, and the stream joins the Middleton Dale Brook. During the flooding of 16th July 1973, the Lower Delf Swallet appeared to discharge, rather than engulf water, and it is possible that the natural stream passage which is thought to lie only a short distance beneath was so overpowered that water was forced back up the swallet.

The Hollow Brook is almost completely culverted, but used to be open for a short stretch in Eyam Dale. In dry weather it could be seen to seep away in several places over a short distance, and entered Carlswark Cavern through tiny open joints.

The juvenile swallets in the floors of Eyam Dale and the Delf are formed by solutional enlargement of joints on the crests of two very low amplitude north-south anticlines which run co-axially with the parallel valleys.

The route by which the water from the Upper Delf Swallet reaches Moorwood Sough is unknown, but it was positively dye tested in 1973. The water from the Lower Delf Swallet was positively dye tested to the Merlin Streamway, thence to Moorwood Sough (Fig. 9).

It is thought that the present eastward route of allogetic swallet water has developed by utilisation of primary vein cavities in the
CARLSWARK CAVERN 
and related caves and mines

SURVEYED BY JOHN-TREVOR CLARK AND THE BRANCH, SCOTTISH CAVES GROUP

Legend:
1. First Recorded Ceiling Passage
2. Feature point between 1 & 2
3. Second Recorded Ceiling Passage
4. Feature point between 3 & 4
5. Subterranean Passage
6. Feature point between 5 & 6
7. Ceiling Passage
8. Local Ceiling Passage
9. Local Ceiling Passage
10. Partial Ceiling
11. Free S. Sandstone
12. Sandstone Cap
13. Sandstone Cap
14. Degree of permanence above 2.0
15. Degree of permanence above 1.0

North
Crosslow Vein. Where the direction of the hydraulic gradient diverges too far from the vein, the route is likely to turn southwards towards Middlefield Rake, to eventually cross White Rake and enter the Carlswark Cavern system. It has now been artificially captured in White Rake by Moorwood Sough, and rises via the sough at Stoney Middleton.


Inspection of the many phreatic caves on the north side of Stoney Middleton Dale and its tributary valleys reveals the existence of a series of cave levels (Fig. 10). These are referred to, in order of development, as:

- The First Remnant Complex.
- The Second Remnant Complex.
- The Carlswark Complex.
- The Lower Complex.

Little correlation with terrace remnants in the valleys has been obtained in the area, but a relationship can be discerned in the Lathkill Dale and Bradwell catchment areas. Multi-level cave systems have been related to terraces on a larger scale in Czeckoslovakia by Droppa (1966) and Miotke and Palmer (1974) in Kentucky.

The First Remnant Complex.

The earliest remnant is seen at the north end of the Delf as a series of interconnected arches in a prominent buttress on the west side of the valley. It appears to be a fragment of a mature cave system, and is likely to have been fed by allogenic swallets at the shale margin at a time when the margin lay further to the south. The cave is known as the Cucklet Church (Plate 3, 1).

The Jumber Brook emerges from a narrow ravine at the head of the Delf, known as the Saltpan (Plate 3, 2). This has the appearance of a vadose stream passage with no roof, and it is probable that it began its
1) The Cucklet Church, a First Remnant Complex fragment near the north end of the Delf.

2) The Saltpan, at the north end of the Delf, has all the features of a vadose cave with no roof, and carries the Jumber Brook.
development as a swallet cave, having been downcut under vadose, and then surface conditions to give the present form. If this is true, then the early stages of development of the Saltpan may be contemporaneous with the Cucklet Church, both being vadose feeders to a system of which very little remains at the input end. Small abandoned passages can be seen at the north end of the Saltpan. The Cucklet Church lies at an elevation of 740 ft (225 m) A.O.D. (2154 7619), and the Saltpan (lower end) at 720 ft (219 m) A.O.D. (2158 7636).

The downstream continuation of the system may be buried beneath scree, but related tubes are seen, intersected by mining, in Delf Hole, on the south east side of the Delf (2163 7598). Large phreatic passages are seen here, but they are filled with sediments consisting mainly of chert and sandstone pebbles in a matrix of sandy clay showing either one or two fining upwards sequences of deposition. The tubes lie at the same horizon, and almost the same elevation, as a cave excavated by South Yorkshire Caving Club during 1973 on the west side of Eyam Dale, and also the highest natural cavities in the Merlin Mine. The group of caves lies between 710 ft (216.4 m) and 690 ft (210 m) A.O.D., and appears to be a fragment of a roughly strike-oriented cave system graded gently to the east.

Further to the north, beneath Eyam Dale in the Dynamite Series of Carlswark Cavern (Figs. 9 & 11), a fragmentary remnant is seen in the roof of the highest joint-controlled chamber. The tube is up to 1.5 m in diameter, and to the west of the chamber shows clear signs of vadose modification. Its eastward continuation beyond the open joint is unmodified, showing that a vadose stream flowed from the western tube and was captured by lower passages by the joint, leaving the continuation dry and silted. This fragment lies at 660 ft (201 m) A.O.D., lying down-dip from the Delf Hole - Merlin fragment, which it may post date.

400 metres to the south east, in Stoney Middleton Dale, Ivy Green
PROJECTED SECTION OF THE DYNAMITE SERIES OF CARLSWARK CAVERN

KEY

1. First Remnant tubes
2. Second Remnant tubes
3. Carlswhark Complex tubes
4. Joint Oriented Passages
--- Prominent Bedding Planes

North

Final Aven
Mined area on Stub Scrin
Fall Chamber
White Bed
Prospect Chamber
Upper Shell Bed
Dynamite Chamber
Porth Crawl
Lower Shell Bed

Elevation above O.D.

feet
metres

Same horizontal and vertical scale

Fig. 11
Cave entrance lies at the same horizon, and almost the same elevation (Plate 4,2.). The survey shows the cave to fall in elevation by only 0.8 m. from the farthest point reached to the entrance, and projected westwards along the strike it is obvious that it represents the downstream continuation of the tube seen high in the Dynamite Series of Carlswark Cavern. It is in places almost filled to the roof with clay, sand, and sandstone and chert pebbles, with occasional flakes of shale large enough to identify *Posidonia* sp. In the farthest part of the cave the sediments are almost totally covered by flowstone, now largely inactive. Bones of sheep, goat, and two species of bird were found encased in the uppermost layer of flowstone; their origin is a mystery, for the locality was almost totally sealed. Transport by flood water seems to be the most likely reason for their presence.

Ivy Green Cave has been intersected by early quarrying and mining operations, and its downstream continuation, Keyhole Cave, is isolated in the next buttress to the east, which it passes right through (Plate 4,1). Beyond here, the cave has been removed by erosion in deepening of the valley, but a small feeder system can be entered at the same horizon and elevation, high on Castle Rock, on a ledge formed by the bedding plane, here an erosion surface, which gives rise to the First Remnant Complex throughout. It is known as Bossen Hole (Plate 4,3).

Near Stoney Middleton small phreatic caves, all silted, are seen in the cliff at an elevation of approximately 600 ft (183 m) A.O.D. They are too isolated to ascribe with certainty to either Remnant Complex, but appear to be later in date that the Ivy Green Fragments.

Projection of the system eastwards suggests an outlet in the region of 650 - 670 ft (198 - 204 m) A.O.D., implying deepening of the valley in the order of 40 metres at Stoney Middleton since First Remnant Complex times.
1) Keyhole Cave, First Remnant Complex.

2) Ivy Green Cave's joint-controlled entrance passage shows considerable vadose incision, suggesting proximity to a capture point.

3) Windy Ledge is formed by the erosion surface which gives rise to the downstream end of the First Remnant Complex. Bossen Hole is at the far end of the ledge.
The Second Remnant Complex.

So little passage can be ascribed to this stage that the definition of a 'complex' is hardly justified. However, the existing fragment, in the Dynamite Series of Carlswark Cavern, is of such a size that a prolonged standstill of outlet elevation is thought to have occurred during its phreatic operation. Moreover, it passes directly under the First Remnant tube, so that the possibility of contemporaneity is ruled out.

The passage is entered at the top of a tight open joint, and is traceable intermittently (through interference by mining) for a distance of 56 metres. Its orientation is strange; it lies parallel to the small vein of Stub Scrin on the east side for some distance before crossing the vein and continuing on the west side. It appears therefore to be a dip tube of some importance. A feeder system can be followed to the north west for roughly 50 metres to the Final Aven (Fig. 11).

The passage lies at an elevation of 615 ft. (187 m) A.O.D., and shows no sign of vadose modification except for a short distance where joints are open in the floor. Attempts to intersect the tube beyond the boulder chokes which block it have so far failed. It is thought that the main strike conduit operating at the time must lie a little further to the north, down dip. It is suggested that valley deepening in the order of 26 metres has occurred since its phreatic operation.

The Carlswark Complex.

The Carlswark Complex is the most extensively known, and the majority of Carlswark Cavern belongs to this level of development. It is certain that a great deal more passage awaits discovery.

The known cave consists of two large conduits lying sub-parallel to the strike, with a slight down-dip component towards the south east. They are developed by solutional enlargement of the prominent bedding plane at
the base of the Lower Shell Bed, a band of silicified *Gigantoproductus* spp. In a few places, such as Nicker Grove Mine, the bedding plane can be seen to be occupied by a thin clay wayboard. It is by removal of the clay that the network of tubes was initiated. Glennie (1954) has suggested, however, that the earliest stage in the initiation of a network of small tubes is removal of the limestone above the clay due to the screening effect of the clay on the underlying limestone. The Lower Shell Bed often displays strong pseudobrecciation, with frequent stylolites; the overall effect has been to increase the permeability of the bed, so that it is relatively easily removed (Beck & Worley, 1977). Removal has proceeded mainly above, but in some cases also below the wayboard, so that we now see every gradation in size from trunk passages up to 3 metres in diameter down to tiny tubes only two or three centimetres high.

The two main strike tubes of the Carlswark Complex are known as Eyam Passage, the more southerly, and Stalactite Passage, running roughly parallel to the former some 50 metres to the north, further down the dip slope. The slight down dip gradient is at an average of 1 in 210 in Eyam Passage to the east of Eyam Dale. The size of Eyam Passage increases dramatically towards the eastern end, partly by removal of the fill of silt and flowstone, and partly by vadose incision on the upstream side of a capture point connecting with the Lower Complex (Plate 5,1). East of the capture point, the tube diminishes rapidly in size, and is eventually blocked with flowstone. A cave in the cliff face at an elevation of 590 ft (180 m) A.O.D. can be followed for a short distance to the downstream side of this blockage. The western end of Eyam Passage is blocked by the extensive cavern breakdown beneath Eyam Dale, but the westward continuation can be reached from the Merlin Mine, where the route can be followed eastwards to the upstream side of the breakdown.

To the west of Stub Scrin in the Merlin Mine, the Carlswark Complex is still active, although as will be shown later this stream is a misfit,
the eastward drainage via Stoney Middleton Dale having been captured by
the risings at Wardlow Mires, then artificially returned to its earlier
route. The westward continuation is known as the Merlin Streamway, and
can only be explored in drought. During the 1976 drought the first five
sumps upstream broke with assistance by pumping, and Sump Six was
reached, a short distance east of the Delf. Sump Six appears to lie close
to Mossley Serin, a vein worked in Nicker Grove Mine, in the Delf, and
its depth may be due to the resistant effect of the vein.

The resistant Stub Serin appears to have determined the position of
a dip tube system, now extensively modified. The stream turns to the
north on the west side of the serin, and plunges to a lower bedding plane.
the dip tube continues, tight and silted, above the drop, and the stream
disappears into flooded passages. The downstream end of this sump can be
reached via Big Dig, in Carlswark Cavern, and the stream continues down-
dip in a large tube, John Smith's Passage, to join the more northerly
strike tube. Under natural conditions, it must then have turned eastwards,
and flowed round the nose of the low amplitude anticline beneath Eyam Dale,
then to flow under vadose conditions to the first capture point with the
Lower Complex, to emerge from the Resurgence Entrance.

However, the westward continuation of the northern strike tube
(Stalactite Passage) runs down towards the axis of the syncline between
Eyam Dale and the Delf. In the axis, in White Rake, the vein worked in
Glebe Mine, Eyam, the extreme western limit of Moorwood Sough intersected
the Lower Shell Bed. All the water in the system now flows towards this
point, to enter the sough through a narrow open joint. The scalloping in
what is now known as the Lower Streamway is eastwards, but a large stream
flows down westwards to a sump. The short period of vadose operation in
this region is demonstrated by the total lack of vadose incision, and the
large clusters of etched out shells, which drop off at a touch (Plate

The two strike tubes are connected beneath Eyam Dale by a second dip-
1) Eyam Passage, Carlswark Complex, the more southerly of the two main strike tubes. Eyam Passage is modified by vadose incision near its eastern end, on the upstream side of a capture point to the Lower Complex.

2) North West Passage, in the Carlswark Complex. This dip-tube displays scalloping indicating up-dip flow, but carries a vadose stream down-dip at present. The parallel dip-tube of John Smith's Passage displays scalloping indicating down-dip flow.
tube, North West Passage. The dip-tube lies roughly on the crest of the anticline, and open joints of the set lying at 320° appear to have contributed to the formation of the network of small tubes in this region of the cave. The elliptical passage cross section is lost in North West Passage; very little solution has occurred beneath the controlling bedding plane. Solution has favoured the main shell band, and the passage is an almost circular tube, slightly higher than it is wide (Fig. 9., Plate 5,2).

Other dip-tubes occur at the eastern end, continuing in Stalactite Passage, as in Eyam Passage, beyond the capture point to the Lower Complex. The main continuation of Stalactite Passage is silted here, and none of the dip-tubes is penetrable. The ultimate destination of Stalactite Passage is unknown.

There are silted tubes leading into unknown regions throughout the Carlswark Complex. Many can be seen to be silted oxbows, some lead on down-dip from Stalactite Passage, while still others lead north westwards along the strike. The abundance of large tubes leading north suggests the presence of at least one more mature strike tube down the dip slope.

Projection of the complex suggests that the outlet of the more southerly strike tube (Merlin Streamway - Gimli's Dream - Eyam Passage) lay at an elevation of approximately 590 ft (180 m) A.O.D. Development of the more northerly strike tube (Lower Streamway - Stalactite Passage) must have proceeded at a time when Eyam Passage was already losing water to the Lower Complex.

Only in the case of the Carlswark Complex is sufficient passage accessible to realise the fact that development of the system has involved several successive passages lying along the strike, the lowest ones maturing while the next one up-dip was carrying a vadose or epiphreatic stream. It is interesting to note that North West Passage shows scallops indicating flow up-dip. The lower strike tubes have thus discharged water into the higher conduits during early stages of their development.
The Lower Complex.

The Lower Complex is very little known, and mainly flooded. The only passage referable to this stage is the Lower (Resurgence) Entrance passage of Carlswark Cavern. It is entered just above road level, and can be followed for 50 metres to a sump. Climbing above the sump leads one into the floor of Eyam Passage at the point where its size diminishes and vadose modification ends. The sump has been passed in drought, and from its inner end it is possible to climb into the northern strike tube where it too becomes restricted and silted. The tube is known to continue beyond Stalactite Passage, but was found by divers to be blocked by mud and boulders.

The Lower Complex is developed by solution along a bedding plane, both above and below the parting, lying 10.2 metres below the base of the Lower Shell Bed, in massive grey crinoidal limestones.

The Lower Entrance lies at an elevation of 553 ft (168.5 m) A.O.D., and discharges a substantial stream in flood conditions. It had certainly ceased to be an active resurgence by 1734, for Short (1734) described the entrance, and the passages within, exactly as they are known today, except that the size of the entrance has been reduced by the tipping of rubbish. The present base margin of the limestone at Stoney Middleton lies at 480 ft (146 m) A.O.D., but apart from the existence of a thermal spring a little above this elevation, there is no evidence that the natural underground drainage adjusted to this lowest level. There may have been a rising between Carlswark and Stoney Middleton which discharged the Waterfall Swallet stream, but there is no historical evidence for this, or any evidence in the field.

Caves of western Stoney Middleton Dale.

To the west of the Delf there is very little evidence of phreatic tube development at any horizon above the base of the Lower Shell Bed, and beyond Farnsley Lane (2105 7580)
there are no known high level caves of significance in the valley sides.

The tiny entrance to Yoga Cave lies on the north side (Fig. 6) just above road level, east of the bend by Eyam Quarry, at an elevation of 645 ft (197 m) A.O.D. (2125 7589). The cave consists of 185 metres of passages developed mainly at the base of the Lower Shell Bed, similar in character to the Carlswark Complex passages further to the east. Trunk passages are generally low, from 1 to 1.5 metres high, but up to 5 metres wide (Fig. 12). The full thickness of the Lower Shell Bed is seen in a chamber close to Streak's Vein, and there are two distinct bands of shells here, separated by 1.3 metres of unfossiliferous limestone. It is likely that upward enlargement of the trunk passages has been prevented by the relatively lower primary porosity of this intervening band.

Passages leading northwards from the chamber are developed at a higher horizon. The large size of the chamber may be a result of the mixing of water from the Lower Shell Bed conduits with water which has become unusually aggressive by contact with oxidising sulphide minerals in the vein. The cave is blocked by large scale collapse in Streak's Vein (Fig. 12), but it is likely to continue northwards to join the active Carlswark Complex route further down-dip.

Small silted tubes are seen at the horizon of the Carlswark Complex further to the west. Stevenson and Gaunt (1971) stated that the Lower Shell Bed was absent in Furness Quarry, but it is very prominent in the lowest cliff on the north side of the road to the east of the quarry. A tube at the base of the bed here shows signs of limited vadose incision, but flow direction could not be determined.

Major cave development is next met at Lay-by Pot (2035 7600; Fig. 6). The entrance shaft is an open joint enlarged by miners for access. The cave is developed along two bedding partings, 3 metres apart (Fig. 12). The passage at the base of the shaft lies on the lower bedding plane, and can be followed eastwards to end at solifluxion deposits in
Figure 12

After surveys by Eldon Pothole Club
the valley floor. A narrow slabbcd mine level continues through these deposits to a complete collapse beneath the road. It is likely that the valley floor has been lowered since the passage was active, cutting into the tube and truncating it, so that the rising was originally further to the east. The passage lies at 770 ft (235 m) A.O.D.

To the north west, the passage ends at a natural collapse, but a short climb gives access to a bedding cave on the higher bedding plane. In contrast to the elliptical phreatic tube, this is a wide low passage with occasional chambers largely caused by extensive breakdown, usually heavily silted and covered with flowstone. It can be followed to the east, rising from an elevation of 785 ft (239 m) to just over 800 ft (244 m) at a large chamber. A poorly developed representative of the Lower Shell Bed is seen here, but does not exert the same influence on passage form as in the Carlswark Complex passages further east. The chamber lies on the crest of a north-south anticline, and the passage beyond is soon blocked by breakdown as it begins to descend. (Fig. 12).

Much of the cave is accessible only because the miner has excavated the fill. A similarly calcited remnant opens into a rock shelter a short distance to the east, and may be part of the same tube network.

A tight climb down an open joint in the floor of the lower passage of Lay-by Pot reveals highly crinoidal limestones with closely spaced chert bands. The lowest of these beds lie approximately 15 metres above the horizon of the Litton Tuff, seen in Earnslow Shaft, on Watergrove Sough, a short distance to the north west. Water enters the shaft from the surface of the tuff, and it is probable that the natural underground drainage in this part of the dale has adjusted to this horizon.

It is possible that Lay-by Pot represents part of a separate cave system to the south of Needham's Rake, the westward continuation of Streak's Vein, for the vein lies between the passages of Lay-by Pot and the area of typical Carlswark Complex development. The vein may have
acted as a barrier, isolating a separate drainage system to the south, and causing water to rise further to the west in Middleton Dale. Yoga Cave does, however, appear to pass through Streak's Vein, and thus at the eastern end the complex appears to be continuous across the vein. Further support is given to this hypothesis by the fact that water from the Victory Mine, to the south of Stoney Middleton Dale, was positively dye tested to the Merlin Streamway. The route is unknown, but it is thought that the natural drainage may lie at the horizon of the Litton Tuff to the south of the dale.

**Caves of the south side of Stoney Middleton Dale.**

The largest cave on the south side of Stoney Middleton Dale is Sarah's Cave (Lord, 1971), now largely destroyed and totally inaccessible. Together with short silted remnants in Eyam Quarry, it suggests down-dip drainage to have become established from swallets at the receding shale margin of Middleton Moor. Unmodified phreatic tubes as high as 690 ft (210 metres) A.O.D. suggest limited speleogenic activity as early as First Remnant times.

It appears from the position of a flood spring in Eyam Quarry at 2106 7516 that present day drainage beneath Farnsley Lane may lie at the Lower Shell Bed horizon. There are few known natural cavities, but a large decorated rift chamber on the west side of the quarry, directly below Farnsley Lane, has a large silted tube running back from it. A tiny rift passage in the same face, at quarry floor level, has a very strong draught, but efforts at penetrating it failed. Dalton (1953) described a cave in this quarry, but it appears to be lost now.

It is possible that an extensive system exists to the south of the dale, but there appears to be no immediate prospect of entering it. The flow times of dye tests from Victory Mine to Hawkenedge Well of four hours, and to the Merlin Streamway of less than nine hours, give scope for further work.
vi) The Wardlow Basin.

The Litton Tuff and Cressbrook Dale Lava, which underlie this structural and topographic basin, act as aquicludes to maintain a large natural reservoir into which percolation water from the flanks may drain. It can be seen from the structure contour map (Fig. 13) that a saddle occurs on the eastern side of the structure, and it was originally thought (Beck, 1978) that the water in the basin overflowed at the horizon of the Litton Tuff to migrate to higher limestone horizons until, in the east, it flowed at the Lower Shell Bed horizon. Recent evidence from the newly discovered stream passage in Carlswark Cavern, however, suggests that only the water from the allogenic swallets of Eyam Edge continued to flow eastwards, the water draining into the basin having been captured by Cressbrook Dale, where it emerged at the 'estavelle' at Wardlow Mires. The process of capture by Cressbrook Dale is shown in Fig. 15.

Descents of Watergrove Mine during the drought of 1975 revealed the presence of an extensive network of phreatic cavities beneath the eastern flank of the basin. Their maximum development occurred at the Lower Shell Bed horizon. Records of the mine show a serious water problem, which became worse as the Watergrove Pipe was followed down-dip into the basin. The sough was the first attempt to lower the water level, but as time went on, the problem became worse, and the mine was abandoned in the 1840's. The pipe continued down-dip.

The cavities are large, up to 5 metres wide, often following major joints, and with an extensive fill of fine silt. It appears to have been the original fill which contained the alluvial lead, for the walls have hardly been touched by the miners. Such cavities appear to occupy a large area near the eastern rim, and response to flooding by the risings at the head of Cressbrook Dale, together with a fast rise in the water level in the mine, suggests hydrological continuity beneath at least the southern
STRUCTURE CONTOURS AT THE TOP OF THE LITTON TUFF HORIZON

- Structure Contours
- Topographic Contours
- Shale Margin
- Outcrop of Tuff

Fig. 13
**Table 1.**

Borehole and other data used in the construction of Fig. 13.

<table>
<thead>
<tr>
<th>Location of section</th>
<th>Elevation of Litton Tuff above O.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>feet.</td>
</tr>
<tr>
<td>1) Milldam Mine (estimated by projection).</td>
<td>600</td>
</tr>
<tr>
<td>2) Hucklow Edge No. 1 Borehole (estimate).</td>
<td>570</td>
</tr>
<tr>
<td>3) Hucklow Edge No. 2 Borehole.</td>
<td>550</td>
</tr>
<tr>
<td>4) Littonfields Borehole.</td>
<td>557</td>
</tr>
<tr>
<td>5) Earnslow Shaft.</td>
<td>697</td>
</tr>
<tr>
<td>6) Middleton Dale Borehole.</td>
<td>688</td>
</tr>
<tr>
<td>7) Eyam Borehole.</td>
<td>601</td>
</tr>
<tr>
<td>8) Wardlow Mires No. 1 Borehole.</td>
<td>355</td>
</tr>
<tr>
<td>9) Burnt Heath Mineshaft.</td>
<td>812</td>
</tr>
<tr>
<td>10) Wardlow Sough.</td>
<td>840</td>
</tr>
<tr>
<td>11) Seedlow Mineshaft.</td>
<td>770</td>
</tr>
<tr>
<td>12) Castcliff Shafts.</td>
<td>850</td>
</tr>
<tr>
<td>13) Waterfall Swallet.</td>
<td>680</td>
</tr>
</tbody>
</table>

Points outside the area of the map;

- Cackle Mackle Mines (195 738) 960 293
- Ladywash Mine (218 775) 135 41

In areas where no data were available, the elevation of this horizon has been calculated by downward extension of the recorded sections (i.e. to the south of Stoney Middleton Dale).
and eastern parts of the basin.

During flood conditions, water rises in the joints and bedding planes at the head of Cressbrook Dale, at Wardlow Mires, until a very large stream flows southwards to the River Wye. The 'estavelle' lies at an elevation of 775 ft (236 m) A.O.D. Maximum water levels recorded in Watergrove Mine were 780 ft (238 m) in January 1976, and 778 ft (237 m) in July 1973. The flow from the swallet appears to lessen dramatically when the water level in the mine falls below 775 ft (236 m) A.O.D., and it is presumed that the eastward route is then able to carry all the water. It is also interesting to note that the highest recorded water level in Waterfall Swallet is 790 ft (241 m) A.O.D., during the 16th July flood in 1973, suggesting that in extreme flood, the stream from Waterfall Swallet may augment the risings at Wardlow Mires instead of flowing eastwards to Stoney Middleton.

The Litton Tuff, dipping northwards into the basin, outcrops in Cressbrook Dale. A large landslip has occurred at Peter's Stone, where a large block of Upper Monsal Dale Beds has slid over the surface of the tuff down-dip into the valley, partly blocking it (Fig.14). The stream is still actively incising the landslip, and a considerable spread of alluvium is dammed behind it to the north. The valley must originally have been blocked to a much higher level at this point, and the level of the outlet of the aquifer must have been raised. It is possible that an early outlet still lies buried beneath the alluvium.

Evidence of very early drainage on the flanks of Cressbrook Dale is limited, but a small cave lies near the top of the cliffs on the west side at 1725 7538. It is known as Dead Dogs Hole. It consists of a small tube, the profile of which suggests vadose incision although its solution features are too corroded to determine the flow direction. It lies approximately 37 metres above the present valley floor, and may represent an early discharge point of water draining down-dip into the
basin, acting in a similar way to the present rising. Lingard's Cave, a little further to the south, has been entered by mining, and is little more than a series of joint-oriented small solution cavities. A cave entrance on the east side close to the risings is blocked with detached rock and flowstone, and may represent an earlier rising. It is worthy of excavation.

vii) Speleogenesis.

Evidence of very early cavity development is provided by the phreatic caverns of Watergrove Mine (Fig. 6), and by a few joint and bedding plane systems in other mines of the area, such as Nicker Grove, Merlin, and short trials on Cliffstile Vein (Fig. 10). Such cavities generally show very low velocity scalloping, with no directional solution features. The limestone walls are often slightly decalcified, and there are often attached minerals (fluorite, baryte, galena, calcite) in isolated pockets, suggesting a pre-mineralisation date for these early cavities. It is not necessary to postulate the existence of a sub-aerial karst for their formation, but early groundwater circulation may have played a part, as well as the solvent action of slowly moving mineralising fluids.

The Namurian cover is unlikely to have been breached until late Tertiary times, and the earliest integrated underground drainage systems may date from that period. The First Remnant Complex (Fig. 10) must have operated at a time when the impervious cover was much more extensive than it is today (Fig. 65). The earliest outlet at Stoney Middleton lay between 650 and 670 ft (198 - 204 m) A.O.D., although whether or not this was then the lowest point on the limestone/shale margin cannot be determined with certainty. The shale cover extended further south in the vicinity of Eyam, and the fragments of the Remnant Complex there may have lain beneath the tongue of shale in the region, the streams
accumulating on the escarpment sinking further to the west. The water flowed south eastwards, strike flow being initiated at an early stage. The main flow was joined by a small amount of water from the south west, and by a large flow from swallets in the region of the present Ryam Dale (Fig. 6). At this time the present valley pattern would have been established, but incision into the limestone would hardly have begun.

To the west of the Delf there is very little evidence of extensive cave development prior to the Carlswark Complex caves (Fig. 6), and it is likely that beyond the tributary valley of Farnsley Lane, on the south side, the limestones were still covered with a veneer of impervious rocks, as were large areas of Middleton Moor and Burnt Heath (Fig. 65). The rarity with which cavities are intersected in the quarries on the south side of the dale does not suggest so mature and extensive a complex as that to the north, but there are caves at the Lower Shell Bed horizon (i.e. Sarah's Cave) which is here at a much higher elevation than to the north. The Lower Shell Bed caves may thus indicate early speleogenic activity resulting from swallets at the shale margin on Middleton Moor.

Lowering of the base margin of the limestone at Stoney Middleton led to capture of water flowing through this early phreatic complex, via open joints, to tubes developing at lower horizons in the limestone. The eastern passages of the First Remnant Complex received very little vadose modification; the only evidence is seen at the entrances of Ivy Green and Keyhole Caves (Plate 4, 1), where it appears that water has been captured by cavities developed in a south west - north east trending vein, which carried water down to a newly lowered phreas. The passages at the eastern end were infilled with sediment derived from the receding escarpment, and as the capture point was abandoned new cavities further to the west, such as the joint-controlled rifts of the Dynamite Series (Fig. 11) carried water downwards. Immediately upstream of each capture point, slight vadose incision occurred, but as the lower routes matured the
tubes were almost completely infilled on the downstream side.

During an early excavation at the end of Ivy Green Cave (prior to the further excavation and discovery by South Yorkshire Caving Club), a number of bones were found in the surface layers of the fill. They were cemented into the flowstone floor, and were deposited there before the initiation of flowstone formation, for they were in contact with the underlying sand. They were of no very great antiquity, being the bones of goat, two species of bird, and a small rodent. The flowstone is therefore not very old, and the discovery suggested that inactive flowstone in other high level caves may be similarly recent in some cases. It also means that flowstone formation may sometimes have begun long after the original phase of infilling of the tube.

It is assumed that the Second Remnant Complex was of some importance between First Remnant and Carlswark Complex times, but since the Second Remnant tube is blocked where it passes beneath the road in Eyam Dale, there is very little material available for study. The position of this large tube suggests lowering in the order of 12 metres of the outlet at this time.

When the Second Remnant Complex was of importance as a major phreatic route, the highest tubes of the Carlswark Complex (ie. those farthest up-dip to the south; Fig. 10) were starting to develop. Middleton Dale became more deeply incised, and the First Remnant Complex was truncated, so that fragments of the system became isolated in the buttresses on the north side of the dale (ie. Ivy Green Cave, Bossen Hole; Plate 4).

The tubes of the Second Remnant Complex became progressively incised on the upstream side of successive capture points as the developing Carlswark Complex increased in maturity, and the downstream ends of the old system were more rarely used as flood conduits. Limestone was now exposed over a wide area, and the new complex, developing by removal of a bed with a relatively high primary porosity (the Lower Shell Bed) and
fed by swallets much further to the west, was very extensive. The Wardlow Mires shale outlier may have been connected to the main Namurian outcrop at this time (Fig. 65), or may just have been isolated, but it is thought that swallets existed in the vicinity of Linen Dale. It is possible that a succession of swallets developed, favouring places where the larger veins emerged from beneath a shale cover. As each doline was abandoned in favour of a new locality further upstream, a shallow and irregular valley would develop gradually, marking the line of headward recession of the engulfment point. During periods of high runoff, such as snow melt conditions, the irregularities would tend to be smoothed, and the steep sided dolines would lose their identity, being infilled and degraded. Frozen ground would also tend to keep a stream on the surface at such times (Warwick, 1964), and eventually a valley such as Linen Dale would result, with the present major swallets, in this case Waterfall and Little Waterfall Swallets, at its head.

While the limestones on the crest of the eastern rim of the Wardlow Basin were covered by shale, underground drainage would flow outward, away from the central basin (Fig. 15). As limestone was progressively exposed in this region, water would tend to sink on the inside of the crest, and flow down-dip into the basin. The elevation of the Litton Tuff in Cressbrook Dale (Fig. 14) controlled the level of the southward overflow, which for a long time may have been higher than the overflow point on the saddle to the east, and throughout the period of development of the Carlswark Complex the open joints and bedding planes on the south side of the basin may have acted exclusively as swallets. It would be interesting to dye the water which sinks here now in summer to determine whether water still finds its way to Stoney Middleton. Dilution in the central basin may be considerable, however, and the quantities of dye needed may be prohibitive.

Middleton Dale was finally deepened to a point which allowed the
Capturing of eastward drainage by Cressbrook Dale on recession of the shale cover.

**Fig. 15**

- Shale
- Limestone
- Lava
- Drainage direction

**Legend:**
- **Shale**
- **Limestone**
- **Lava**
- **Drainage direction**

**Diagram Details:**
- Early swallet at head of Cressbrook Dale
- Allogenic swallet draining eastwards
- Minimum piezometric surface controlled by elevation of Cressbrook Dale Lava
capture of water in the eastern part of the Carlswark Complex by a new outlet at a lower horizon. This allowed slight incision of Eyam Passage to take place on the upstream side of the capture point, with the onset of vadose conditions, while Stalactite Passage still operated under phreatic or epiphreatic conditions. The Carlswark Complex outlets were abandoned, and the strike tubes became silted and covered in flowstone to the east of the capture points.

Several further stages of development can be distinguished during the later stages of capture (Beck, 1975) as shown by a study of the secondary excavation of the sediments in the passages west of Eyam Dale (Gimli's Dream, Fig. 16.)

Phase 1, the period of phreatic development of the tube, must have occurred at a time when the Second Remnant Complex was carrying a vadose stream which fell to the phreas by way of the avens of the Dynamite Series and other capture points further to the west. The eastern end of this higher route was now becoming silted by periodic floods.

Phase 2 (Fig. 16.2) saw a lowering of the water level so that collapse due to removal of hydrostatic pressure began, the broad arch of the roof being rendered unstable. A stream still flowed through Gimli's Dream under epiphreatic conditions, for some of the fallen blocks show sharp scalloping consistent with their new orientation, while the newly exposed roof displays no directional solution features. At this time, the Carlswark Complex outlets at the eastern end may still have been totally flooded, the stream flowing through Eyam Passage under epiphreatic conditions similar to those prevailing in the upstream reaches of the Merlin Streamway at the present time. Stalactite Passage would have been carrying the allogenic flow from the marginal swallets at this time, and discharged water up-dip via North West Passage to join the epiphreatic flow of Eyam Passage.

Phase 3 was a quiescent phase. During this phase flowstone began
STAGES IN THE DEVELOPMENT OF GIMLI’S DREAM, CARLSWARK CAVERN.

1. Phreatic.
A long period of phreatic solution at the base of the Lower Shell Bed.

2. Epiphreatic.
Outlet elevation lowered.
Collapse of roof on removal of hydrostatic pressure.
As the most southerly Carlswork Complex passages were abandoned, periodic floods filled many passages with sediment derived largely from the receding Millstone Grit escarpment.

3. Quiescent.
Very little water flowing underground, probably due to permafrost.
A route further to the west carried the entire flow.

4. Vadose.
The down-dip route was overpowered, and water again flowed through Gimli’s Dream.
A vadose trench was cut through flowstone and sediment.

5. Abandoned.
Drier conditions led to final abandonment of Gimli’s Dream.

Fig. 16
to form in the Merlin Streamway, Gimli's Dream, and Eyam Passage. The stalactites of Stalactite Passage may also date from this time. The latter still carried a stream, which entered from the north west via Big Dig and the other tubes which lead northwards and westwards down-dip. The absence of stalagmites on the floor of Stalactite Passage, and the complete absence of speleothems in the Big Dig area, which would have been flooded, testify to the continued presence of this stream. The end of Phase 3 saw a thick stalagmite floor over the silt and boulders of Gimli's Dream.

The reason for the quiescent phase is uncertain. It is possible that frozen ground, holding water on the surface, was responsible, but it may also be that a southward overflow was becoming established from the Wardlow Basin prior to the landslip at Peter's Stone. The landslip cannot be the whole reason, for it is unlikely that prior to its occurrence the valley floor would have been low enough to allow even the entire present day flow to emerge there. The blockage must at some stage, however, have placed a greater strain on the eastward route, and flow may have been later resumed through conduits left high and dry by the earlier reduction in volume.

Phase 4 (Fig. 16.4) began with an increase in the amount of water flowing in the system. It may be that during Phase 3, water still flowed in the western part of the southern strike tube (the route carrying the overflow of the Wardlow Basin), and that a dip tube system was able to carry the entire flow down to the water surface down-dip to the north. The increased volume was so large during Phase 4 that not only was the unknown dip tube to the west of the known cave overpowered, but the dip tube on the west side of Stub Scrin (John Smith's Passage) was also too small, or choked. Water once more passed the scrin, and continued eastwards through Gimli's Dream. The extensive deposits of sand, silt, and gritstone and chert pebbles, with the thick flowstone cover, were
re-worked, and a deep trench through the whole sequence was the result (Plate 6,1). The stream may not initially have reached Eyam Passage, but may periodically have done so, for a small amount of re-working has occurred, and the vadose features at the eastern end are relatively clear of sediment and flowstone (Plate 5,1).

The major part of the flow at this time left the southern strike tube by way of North West Passage, to enter the phreas in Cockle Passage. This situation persisted long enough for a reversal of the scalloping direction to take place in North West Passage; the features on the roof, where they can be seen, indicate up-dip flow, while those on the floor suggest a vadose stream flowing down-dip. There was, however, no modification of the passage profile (Plate 5, 2). The scalloping of Cockle Passage is from west to east throughout; it is essentially part of the northern strike tube system.

Phase 5 began with another reduction in flow volume, and the dip-tube west of Stub Scrin began to carry the entire flow. Even during what are now considered to be extreme flood conditions, water never backs up at the head of the dip-tube, and water therefore never overflows into Gimli's Dream, where to a limited extent secondary speleothems have begun to form on the floor of the trench.

At what point during the above events the Lower Complex began to function is uncertain, but the resumption of flow for a relatively short period during Phase 4 is unlikely to have been able to create the vadose trench seen at the eastern end of Eyam Passage. It must therefore have occurred during Phase 3, when the passages to the west of Eyam Dale were either permanently flooded or operating under epiphreatic conditions.

It is likely that during Phase 5, the stream retreated almost entirely from the Merlin Streamway, while the allogenic swallet water continued to follow a route through the more northerly system, either via Stalactite Passage, or through less mature strike tubes further down-
1) Gimli's Dream, Carlswark Complex. False floor overlying sand and gravel, later incised by a secondary vadose stream which was finally captured by a dip-tube (John Smith's Passage) further to the west.

2) Oyster Chamber, Carlswark Complex. Two strike tubes, both with former phreatic flow towards the observer, show different profiles, so that removal of limestone below the wayboard may depend on the length of the period of operation rather than flow direction.
Throughout the known stretch of the Merlin Streamway, speleothems are found in places which are now permanently under water, and not static water, but a fast flowing stream which during floods is highly charged with abrasive sediment. Thick flowstone and mature stalactites are found in 'Shag's Sump' at the downstream end of the Merlin Streamway, and stalagmites abound down John Smith's Passage to the point where the stream joins the northern strike tube at the western end of Big Dig, to turn down-dip towards Moorwood Sough. White (1976) points out that re-flooded speleothems are generally etched or partly removed, and it is suggested that the stream seen now in these passages is a misfit of very recent origin.

The present situation was thus established in Gimli's Dream, and the Merlin Streamway route was dry to the south of Big Dig, where the allogenic stream from Eyam Edge flowed from west to east. The valley floor was incised to a depth at which the Lower Complex could discharge water at around 550 ft (167.9 m) A.O.D. The major swallet in the west was established on the Crosslow Fault/Vein system, and water flowed eastwards along the fault, migrating southwards until it crossed White Rake to reach Middleton Dale via Carlswood Complex and Lower Complex passages. Intermediate feeders to the system between Waterfall Swallet and Eyam Dale followed various courses through the higher Remnant Passages, removing the fill in some cases, and being captured via the open joints in the anticlinal regions, to join the main eastward flow.

The recent history of development concerns the complicated series of changes brought about by interference in the natural drainage pattern by the miners. Before the mining, a rising must have existed in Stoney Middleton Dale, but its position is not clear. There is no record of the Resurgence Entrance to Carlswood Cavern having ever been a permanent spring in living memory, yet the indications are that the allogenic swallet streams flowed eastwards through the Carlswood system. It may be
that an as yet undiscovered abandoned rising exists between Carlswark and
the shale margin at Stoney Middleton, but it seems likely that if this
were so the unknown rising would carry flood water in preference to
Carlswark. It is possible that very early sough drainage had modified the
pattern by 1700, but there is now no sign of such an early sough.

Prior to any interference by the miners, therefore, the allogenic
streams of Eyam Edge resurged in Stoney Middleton Dale via the Lower
Streamway, the route being totally flooded on the west side of Eyam Dale.
From that point eastwards a vadose stream flowed. The route may have
lain down-dip from Big Dig, for the miners certainly explored beyond Big
Dig by the end of the 17th century, before any known large scale sough
drainage was established. Once again, it is strange that this route
does not operate now in flood conditions. At this time, John Smith's
Passage was dry, Shag's Sump, which now separates the Carlswark and
Merlin systems, was passable, and there is no reason to suppose that
the sumps of the Merlin Streamway existed. The cave would have been
penetrable for a long distance to the west therefore, and it is remotely
possible that the statement "by another of its grottoes, it opens near
Foolow" (Short, 1734) was true.

The miner expended considerable effort in order to carry out the
early exploration to the west, removing up to a metre of solid rock
from the floor of Dynamite Passage, presumably to drain the area beyond
to the west end of Big Dig. It was also necessary, although the reason
is not yet entirely clear, to block the bedding plane at floor level in
this region with clay and timber and to prevent water from sinking down
it to the north. It may simply be that the miners wanted water to reach
the Resurgence Entrance for ore washing purposes, or this may have
rendered other areas of interest, of which we now know nothing, access-
able.

At this time there appears to have been a permanent stream in
Cressbrook Dale (Kirkham, 1971), derived no doubt from the flanks of the Wardlow Basin, including Litton Edge, the western end of Longstone Edge, and Tideslow. By 1700 the Watergrove Mine was beginning to have serious water problems, and the earliest Watergrove Sough was driven up from Stoney Middleton Dale (Barmasters Book, 1714 - 1730), carrying water eastwards from the basin. The sough may have lain up-dip from the dry southern strike route of the Carlswark Cavern system, and water leaked away through natural cavities intersected by the sough, to invade the cave. The stream flowed eastwards, filling the sumps and rendering the westward continuation inaccessible. It joined the main east - west flow at the upper (eastern) end of the Lower Streamway, and emerged in Middleton Dale. The sudden increase in the volume of water at Stoney Middleton at this time must have been dramatic, and may have put an end to the miner's work in Carlswark.

It is possible that the inundation had already occurred when Short visited the area. The former great extent of the system was well remembered, but much of it was no longer accessible. That the westward continuation was suddenly cut off is borne out by a reference in the 'History and Antiquities of Eyam' (Woods, 1842) to the fact that the Merlin and Carlswark Caverns were no longer accessible to their former extent due to excess water. The 'Merlin Cavern' was discovered in the Merlin Mine, probably after the flooding, and no-one appears to have realised that it was formerly part of the westward continuation of Carlswark Cavern. In most accounts they are referred to as separate caves.

The final significant event was the intersection of the allogenic stream route deep in the phreatic between Eyam Dale and the Delf by the level driven westwards beyond the limit of Moorwood Sough. Had the level been driven five metres lower down, or had the main sough, which lies nearly 20 metres lower, been driven westwards to this point, the flooded area at the northern extremity of what is now known as the Lower Streamway
would have been drained completely. As it was, the main tube was
drained down to a level just above the roof, so that it was effectively
still sealed.

The misfit stream in the Merlin Streamway - John Smith's Passage
route now began to flow via the newly drained Lower Streamway towards the
new outlet, so that we now follow the stream down-dip, while the
scalloping, even at floor level, indicates flow in the other direction.
We therefore see a very modified picture, and reconstruction of the
sequence of events was not possible until Big Dig was passed late in
1979. The picture is still incomplete, and many questions remain. For
example, where did the allogenic streams resurge before sough drainage
took over? Is it possible that even the Waterfall Swallet stream used to
flow south westwards to Wardlow Mires? How did the miner work in the
upper end of the Lower Streamway at Cowlishaw Vein, when the only known
outlet is Big Dig, so that this area ought to have been flooded?

It is certain that only a small proportion of the penetrable natural
caves that exist have been explored. In the past few months, apart from
the Big Dig Series of Carlswark, several small discoveries totalling
more than 200 metres have been made by digging. The major barriers are
Sump Six in the Merlin Streamway, and the Bedpan Sump at the end of the
Lower Streamway. The latter has not yet been subjected to close scrutiny
during the summer months.

Penetrable passages are expected to exist beyond both sumps, for
both strike tubes are expected to rise beyond the Delf. The average
gradient from Sump Six to the crest of the eastern rim of the Wardlow
Basin is greater than 1 in 100, as opposed to 1 in 210 over the known
stretch of the cave, assuming that the active route remains above the
Litton Tuff horizon, which is likely. The gradient from the Bedpan
Sump to the bottom of Waterfall Swallet, at the Lower Shell Bed horizon
throughout, is approximately 1 in 35, and a vadose route is expected
once the tube climbs above the level of the anticlinal crest beneath Eyam Dale. The next few years should see significant discoveries in the area, with a consequent improvement of understanding of this complex hydrological situation, and the history of its development.
Chapter 4.

THE CASTLETON CATCHMENT AREA.
4) THE CASTLETON CATCHMENT AREA.

i) Previous Research and Exploration.

The most authoritative and complete account of the underground drainage of the Castleton area is that of Ford, T.D. (1966), and Ford et al. (1977). The earlier work was summarised in the earlier paper, and many original and valid observations were made. Accounts of the more spectacular cavities of the area go back many hundreds of years; descriptions, of a more or less imaginative nature, of Peak Cavern and Eldon Hole abound. More recently many authors have given detailed accounts of individual cave systems as they were gradually explored. L.B. Salmon and G. Boldock produced many original cave surveys and descriptions, among them Gautries Hole (1948), where new passages had been discovered, and the Perryfoot Caves (1949). In 1950, the same authors described in general terms what were then known as the "Peak Fault Swallets", the line of swallets between Perryfoot and Windy Knoll.

In 1951 Salmon and Boldock produced a comprehensive survey of Nettle Pot, still one of the most difficult descents in the county. Salmon's descriptions of Giant's Hole remain the most complete to date, although the cave, by then connected to Oxlow Caverns, was re-surveyed by the Eldon Pothole Club between 1966 and 1969. Westlake (1967) described the cave, and speculated on its developmental history.

Ford (1954) described Treak Cliff Cavern, and in 1956 produced the only existing complete survey of Speedwell Cavern, to which access is not now normally permitted. Permission for a visit during the course of this study is gratefully acknowledged.

When the far reaches of Peak Cavern were first explored following the passing of the Mucky Ducks in 1949, the British Speleological Association produced a survey, and Salmon (1962) gave a detailed account of the explorations carried out up to 1959.
The P8 (Jackpot) Cave was discovered in 1964, and an excellent survey and description appeared in the Eldon Pothole Club Journal (Cobbet and Westlake, 1972). Smith and Waltham (1973) published a further account of the cave, and produced a series of evolution diagrams documenting the complex process of capture of the two streams of P8 by successive routes.

No full scale attempt has been made to analyse the hydrology of the Castleton area, due to the general inaccessibility of the far reaches of the show caves at the eastern (resurgence) end of the drainage system. Pill (1948) carried out a small amount of dye testing, and analysed the water sinking at the limestone margin, comparing it with that rising at Castleton (Russet Well). Ford (1956) gave details of dye tests carried out by the Derwent Valley Water Board. The flow through times recorded were long; Coalpithole Mine, 7 days, and Giant's Hole, 4 days, suggesting great dilution in long phreatic sections. Dearden (1963) and Edmunds (1971) have touched upon the area, but neither was concerned with the nature of the cave systems.

ii) Topographic and Geological Setting.

The geology of the area was a matter of controversy for many years. The original Geological Survey memoir mentioned the 'Peak Fault', and this term was used for a long period until the existence of an unconformity was demonstrated (Jackson, 1925). The swallets were known as the 'Peak Fault Swallets' for many years, but the name seems now to have been completely dropped.

More recently the problem of interpretation of the Carboniferous succession of the area has centred on the relationship of the reef limestones to the massif facies. The account of Parkinson (1965) and Eden et al. (1964) resolved many of the stratigraphic problems of the Visean, demonstrating that the reef limestones are the stratigraphic equivalents of the limestones of the standard (massif) succession.
Stevenson and Gaunt (1971) gave a detailed account of the geology of the area in the memoir accompanying the 1 inch : 1 mile Geological Survey Sheet No. 99 (Chapel-en-le-Frith). 6 inch : 1 mile and 1:25000 Geological Survey maps of the area are now available (Sheet SK 18 SW).

The area occupies the most northerly portion of the limestone outcrop, and covers an area of approximately 17.5 km$^2$. Of this, 12.5 km$^2$ consists of limestone, and 5 km$^2$ consists of Namurian sediments (Fig. 18). Further subdivision into the Peak Cavern and Speedwell Cavern catchment areas is indeterminate, for their relationship is complex, and in flood conditions much of the drainage of the Speedwell catchment area overflows into the Peak Cavern system. In normal conditions, however, the Peak streamway collects the accumulated percolation of an area, almost exclusively limestone apart from thin lavas and tuffs, of 7.5 km$^2$. The catchment of Speedwell Cavern is larger, and is estimated at 5 km$^2$ limestone, and 5 km$^2$ Namurian sediments.

The limestones of the massif facies belong to the Viséan zones of $S_2$, $D_1$, and $D_2$. These well bedded, relatively homogeneous limestones pass laterally into apron reef limestones of $B_2$ and $P_1$ age (Parkinson, 1965). The Monsal Dale Beds ($D_2$) are present only in the east of the area, and as small outliers to the south of the Winnats Pass. Most of the catchment is occupied by Bee Low Limestones, of $D_1$ age. Further to the south, the Bee Low Group is subdivided into the Chee Tor Rock below, and the Millers Dale Beds above, the junction between the two being taken at the Lower Millers Dale Lava. This is thought to be represented in the east of the Castleton area by the Cave Dale Lava, but no evidence for its presence is seen at outcrop in the north and west. It will be shown that the horizon is represented at several underground localities by the Nettle Tuff.

The Woo Dale Beds ($S_2$) are brought to the surface in the south west of the area in the region of the Peak Forest Anticline. They are
thought to underlie the whole area, and the western reaches of the Peak/Speedwell cave system may penetrate the $S_2$ beds, as may the deepest parts of the Blue John Cavern, the Giant's Hole / Oxlow Caverns complex, and Nettle Pot.

Along the margin of the limestone from a point north east of Sparrowpit to Windy Knoll, reef limestones dip steeply to the north west, north, or north east beneath the Namurian cover. The boundary here was long thought to be a faulted one, and does give this appearance in some of the blind valleys which lead down to the swallets. For this reason the line of swallets was referred to as the 'Peak Fault Swallets'. This account refers to them as the Rushup Edge Swallets.

The entrance passages to many of the swallet caves (ie. P8) pass through crinoidal limestones occupying a position low on the frontal slope of the reef. Deeper into the caves, the dip lessens from up to $40^\circ$ to the north or north west to around $6 - 8^\circ$ to the north, and the limestone contains a more varied fauna of corals, brachiopods, bryozoans, crinoids, and molluscs (Wolfenden, 1958). Further still, the dip may even be southwards, towards the massif, and massif facies limestones predominate. They are generally well bedded, often finely crinoidal, with relatively few but prominent bedding planes, often stylolitic, and often occupied by thin films of clay or shale.

The area is crossed by a number of prominent east-west or north east - south west trending veins, and many smaller veins, or 'scrins'. These have a great influence on speleogenesis, although their effects vary considerably. They may act as breakwaters, deflecting the flow (Ford, T.D., 1966) or may provide preferentially selected channels for the development of important phreatic conduits. It is probable that primary cavities in the veins are a prerequisite for the latter case, and that the selection of a route depends on the correspondence of such cavities with the direction of the hydraulic gradient within the phreas.
A number of north west - south east trending joints, sometimes mineralised, exert a considerable influence, particularly on the siting of potholes in the massif facies limestone. The best known such potholes are Eldon Hole and Nettle Pot. In these cases the presence of the Nettle Tuff is important, as will be shown later. The joints of this set also play an important part in controlling the orientation of the phreatic routes; the East Canal area of Giant's Hole and the sump at the end of the New Series of Oxlow Caverns both lie on these joints. The position of the risings at the western end of the Speedwell Cavern appear to be partly controlled by these joints, although they also lie close to a large east - west vein.

The broad valley between the foot of the escarpment of Rushup Edge and the limestone margin is covered by a thick accumulation of head (Johnson, 1967). The material consists of sub-angular to rounded sandstone pebbles and cobbles in a sand and clay matrix. These deposits mask the entrances to many of the caves, which can be seen to pre-date the solifluxion sheet; many cave passages have been filled with the same material, and the streams are still in the process of re-establishing their courses. The solifluxion sheet is now being actively eroded both on surface and underground, and collapses are frequent. The floods of February 1977 caused subsidence of soliflucted material into cavities excavated by the stream flowing beneath at swallets P 4 & P 5.

The escarpment of Rushup Edge rises to a maximum elevation of 1800 ft (549 m) A.O.D. to the north of the limestone area, and the crest of the escarpment marks the northern boundary of the Castleton catchment area. Precipitation running off the escarpment flows underground by way of the Rushup Edge Swallets to constitute the bulk of the discharge of Russet Well. Whereas the underground drainage system flows from west to east, the surface drainage is in the opposite direction. The highest point on the shale/limestone boundary lies just west of the top of the
Caves of the Peak - Speedwell catchment area


Key:
- Margin of impervious cover
- Other geological boundaries
- Lava or tuft outcrops
- B Bee Low Limestones
- Hi Millers Dale Beds
- Mo Monocle Dale Beds
- W Won Dale Beds
- V Agglomerate
- Cave Passages
- Swallets
- Cliffs

Fig. 18
Winnats Pass, at Windy Knoll. From here the valley slopes gently down to the west, to turn southwards at Perryfoot and continue southwards as Perry Dale, Dam Dale, Peter Dale, and Monks Dale to join the River Wye at Millers Dale. The elevation of the watershed at Windy Knoll is around 1360 ft (414 m) A.O.D., and the valley is gently graded to about 1075 ft (328 m) A.O.D. at Perryfoot.

To the south of the swallet line rise the prominent hills of Eldon Hill and Old Moor. The plateau is divided by the dry valleys of Conies Dale, which runs south westwards to join Perry Dale, and Cave Dale, which runs north eastwards to Castleton. The surface watershed between the two lies at 1375 ft (419 m) A.O.D., where Dirtlow Rake, a prominent vein, crosses the dry valley system.

The present day underground drainage discharges at Castleton via Russet Well, Peak Cavern, and the Peakshole Sough, locally called 'Slop Moll'. All lie close together in the Peak Cavern Gorge (Plate 7, 2), and their interrelationships are complex. Their combined discharge flows eastwards as the Peakshole Water, to join the River Noe at Hope, and the River Derwent at Bamford. Castleton lies at the head of the broad Hope Valley, which ends abruptly at Treak Cliff where the fore reef limestone rises from beneath the Namurian shales.

The south eastern boundary of the catchment is difficult to define, the destination of percolation water in the area between Dirtlow Rake and Moss Rake being rather uncertain. The large discharge of the adjacent catchment area to the south, Bradwell, is surprising, but may be a result of capture of percolation water by down-dip flow, or by vein cavity systems, towards Bradwell. Water in Hollandtwine Mine (Fig. 18) was dye tested to Peak Cavern (see below), but to the south of this locality there are no integrated underground streams known which can be dye tested. Sough drainage has undoubtedly considerably altered the pattern, and may have modified the catchment area boundaries.
The Rushup Edge Swallets have long been known by their number, from P.1 (Perryfoot Caves) to P.13 (the most easterly unnamed swallet). The numbering system is retained here, for there is a very extensive caving literature which uses it throughout. The swallets from Perryfoot to Windy Knoll are listed below.

P.1. Perryfoot Caves (Perryfoot Cave and Dr. Jackson's Cave).

P.2. Sheepwash Swallet.


P.4. Unnamed Swallet.

P.5. Unnamed Swallet.


P.7. Unnamed Swallet.


P.10. Snelslow Swallet.

P.11. Giant's Cave.

P.12. Giant's Hole.


An additional swallet lies just east of the watershed at Windy Knoll in massif facies limestones which are here overlapped by Namurian sediments. It is known as Mam Tor Swallet (Plate 7, 1) and is unnumbered.

The Rushup Edge streams generally sink against a cliff face, many of the entrances themselves being masked by the material of the solifluxion sheet. The cliffs are sometimes overhanging joint planes, and sometimes steeply inclined bedding surfaces. The slow progress of exploration is due mainly to the presence of the reef belt. Access to what is almost certainly an extensive cave system is often prevented by frequent sumps and boulder chokes resulting from the impersistence of bedding partings, irregular jointing, the presence of masses of reef limestone, and the
1) Mam Tor Swallet, the most easterly unnumbered swallet of the Castleton catchment area. It engulfs only a small stream.

2) Peak Cavern Gorge; the Peakshole Water in spate during snow-melt floods of December 1978. The stream here represents almost the entire discharge from the catchment, being the combined streams from Slop Moll, Russet Well, and Peak Cavern.
frequent changes of dip and strike (Ford, T.D. 1976). Moreover, the extensive solifluxion sheet contributes sufficient debris to fill most attempts at deep excavation with the onset of heavy rain.

Consequently only P 1, P 3, P 8, and P 12 can be entered for any appreciable distance. Most of the other swallets have dry caves in the nearby valley walls, some of which take flood water, and almost all of which have been, or are currently being, excavated.

P 1. Dr. Jackson's and Perryfoot Caves.

0989 8127. Alt. 1,035 ft (315.4 m) A.O.D.

Swallet P 1 lies at the foot of a prominent blind valley which carries a stream from the north west (Fig. 19). The valley ends abruptly at a vertical cliff. The stream sinks against this cliff, but although there are two known caves here the stream is not seen underground except in flood. The entrance to Dr. Jackson's Cave lies at the western end of the cliff, and trends west south west in accordance with development from early strike-controlled phreatic conduits. Perryfoot Cave entrance lies at the eastern end of the cliff, and trends eastwards. The stream is known to appear in the workings of Coalpithole Mine (Salmon, 1949), and was reported to be engulfed by an apparently natural cave system at around 800 ft (244 m) A.O.D. This fact suggests that the stream quickly finds its way down to the level of the Speedwell risings by following a relatively easy course down the vein, and that much of its route from Coalpithole Mine to Speedwell Cavern may lie at depth in phreatic cavities in the vein.

P 2. Sheepwash Swallet.

1007 8133. Alt. 1,054 ft (324.2 m) A.O.D.

Sheepwash Swallet consists of little more than a series of open joints, with extensive anastomosis of bedding planes. The stream which sinks at the entrance has been largely artificially culverted there in
order to divert it from swallow P 1, and thus away from Coalpithole Mine (Salmon, 1949). It is assumed, therefore, that the stream sinking at Sheepwash Swallet does not enter the mines, but reaches the main phreatic conduit in the vein by a different route. The cave does lie in its own shallow dry valley. The stream is seen in the cave, but soon sinks into joint-controlled cavities too tight for further penetration.


1015 8145. Alt. 1040 ft (317 m) A.O.D.

The dry valley leading down to the large P 3. doline is a small one, but a comparatively large stream is encountered underground. The stream does not sink in the doline; it enters the cave from a deep sump which lies beneath the doline floor. Its source is uncertain; it is barely possible that it is water sinking at Sheepwash Swallet, following a juvenile course further down the dip slope from the earlier, accessible passages. It is more likely to be derived by a gradual process of accumulation from the area to the north, beneath the solifluxion sheet.

Over the first stretch of stream passage from the entrance, the route lies in the up-dip direction, and successively lower beds are seen. A chamber is reached, and the stream drops through a small eyehole and turns along the strike. Beyond this point there are high level passages developed along the strike of a prominent bedding plane. The strike swings towards the east (Fig. 20), and the stream passage and high level passages follow. The position of the passages is determined by the intersection of inclined joints with the controlling bedding planes in the crinoidal reef limestone. The stream finally sinks into boulders, and surveying on surface has confirmed that this choke lies directly beneath what appears to be a natural but rubbish-filled shaft on the south east side of the main doline.

A mature series of passages leads south westwards from the main
PLAN OF GAUTRIES HOLE, PERRYFOOT.
After Salmon, 1948

Stream rises from deep sump
Stream sinks in boulders

Cliffs
Stream
Pools
Strike, with dash on down-dip side

Scale

Fig. 20
stream route at the First Chamber, migrating to lower limestone horizons as it passes in a direction contrary to the dip. It appears to be an earlier route by which the stream left the known cave, and it is probable that the stream now sinking at Sheepwash Swallet still joins this route beyond the known cave. The route ends at a large chamber with a sump at the bottom. The sump was pumped dry some years ago by the British Speleological Association and found to be too tight for progress.

Swallet P 4.

1016 8154. Alt. 1050 ft (320 m) A.O.D.

The blind valley leading down to Swallet P 4 is fairly prominent, but there is only a stream in very wet weather, suggesting capture by another swallet, possibly Gautries Hole. The stream, when present, flows along the strike of the limestone/shale contact for a few metres before sinking against the limestone dip slope in mud and boulders. The position of the sink is receding upstream. At the foot of the blind valley is what appears to be a dry cave entrance, blocked with clay and boulders, and partly excavated by cavers. The stream used to sink a few metres away, but the floods of February 1977 caused a new collapse upstream from this most recent sink. The stream disappeared in a new place. An attempt at excavation was foiled by the slumping mud.

Swallet P 5.

1029 8163. Alt. 1050 ft (320 m) A.O.D.

A small stream now sinks against a low limestone cliff, some 20 metres upstream from the foot of the prominent blind valley. Its earlier route was into a now dry cave entrance further downstream. Nothing is known of the underground route; the water is not known to have been encountered underground between the swallet and Speedwell Cavern. An attempt has been made to excavate the dry cave, and was foiled by loose boulders, but a vadose passage is suggested by the abandoned dig.
**P 6. Little Bull Pit.**

1038 8167. Alt. 1060 ft (323 m) A.O.D.

Swallet P 6 lies immediately to the north of the large collapse feature known as Little Bull Pit (Fig. 18). The Pit is a roughly circular pothole some 6 metres in diameter, 9 metres deep, with much fractured walls and a floor of mud and boulders. To the north is a large alcove with no apparent continuation but leading back towards the swallow. There is a short swallet cave at the foot of the P 6 blind valley, which passes close to the chamber represented by the Pit, but with no known connection to it. The swallet cave soon ends at a mud and rock choke, where attempts to dig have so far been foiled by heavy silting during wet weather.

The water sinking at P 6, together with the stream from P 7, is seen again in the Lower Streamway of the P 8 Cave. It was dye tested by the Derwent Valley Water Board to Russet Well, taking four days for the journey (Ford, 1956).

**Swallet P 7.**

1051 8173. Alt. 1060 ft (323 m) A.O.D.

Swallet P 7 (Fig. 18) again lies at the foot of a prominent blind valley, but the stream sinks against a limestone cliff in mud and boulders. There are various points in the area at the foot of the valley into which water can be seen to have sunk in the past. A shaft appears to have been sunk in the past against the cliff, but this is now badly degraded, and failed to gain access. The water from P 7 joins the P 6 stream to reappear in the Lower Streamway of P 8 (Fig. 21).

**P 8. Jackpot.**

1079 8179. Alt. 1068 ft (325.5 m) A.O.D.

The P 8 stream (Fig. 18) sinks via a concrete shaft some distance upstream from the foot of the blind valley, where it is thought that the
first engulfment point post-dating the solifluxion sheet lay.

The short concrete shaft leads into a low chamber of irregular shape, where it is necessary to scramble over piles of breakdown. The stream flows through this material, and is rejoined at the head of a narrow winding vadose stream passage. This can be followed via a series of small cascades to Idiot's Leap, a short climb. A prominent vein crosses the stream passage beyond, and the climb results from its resistant effects; a step developed here, and the stream has subsequently removed the vein and incised headwards. The canyon passage continues to wind down to the head of the First Pitch. A high level route continues beyond, nearly horizontal, and the stream falls over short cascades to the head of the Second Pitch.

Beyond the Second Pitch the stream flows into relatively juvenile bedding controlled tubes, and disappears into Sump D/1 (Westlake, 1972). The P8 stream is not seen again in the cave. A short distance before the sump, a small overflow passage can be followed until it breaks into a larger passage carrying the stream from P6 and P7, which emerges from a deep sump. The high level route can be followed from the Second Pitch via Gour Passage (Plate 8, 1) and Mud Hall to intersect the Lower Streamway further downstream.

The Lower Streamway can be followed downstream until it breaks into the large stretch known as "T'Owd Man's Rift", at the end of which the stream disappears into Sump A/V. In most diving reports, this sump is referred to as Sump 1, and the sumps beyond here are numbered, rather confusingly, from 1 to 9.

Westlake (1972) has shown that the early phreatic conduits of P8 are basically strike-oriented, the strike swinging from a north east-south west direction at the present stream sink to a more northerly direction in the far reaches of the system. It is pointed out by Smith and Waltham (1973) that the hydraulic gradient in the system as a whole
1) Gour Passage, a narrow abandoned vadose route in the P8 Cave. (See also Fig. 21).

2) Windy Knoll Cave. The continuation behind the observer is largely infilled with material which has entered via presumed connections with the surface.
from the western swallets to the Castleton risings is from west to east, while the dip in the western part of the catchment is towards the west or north west. An up-dip route must therefore be followed over at least part of the intervening cave system, which accounts for the epiphreatic nature of the far reaches of P 8, which can only be explored by divers.

It is clear from a study of the P 8 blind valley that the present entrance is not the original sink. A branch of the high level route, known as Stalagmite Passage, trends in the direction of the hollows at the foot of the valley, and it appears that here was the earliest sink. The old entrance to the cave, above the present one, must be intermediate in date, the present entrance and stream sink being the most recent. Stalagmite Passage must have become blocked by flowstone since the commencement of incision into the solifluxion sheet, for the valley leading down to the old sinks is prominent.

Westlake (1972) suggested a sequence of events in the formation of P 8, but assumed that the stream had always sunk in its present position. The stream must have entered the phreas relatively quickly after sinking when Stalagmite Passage was the main route. Strike-controlled tubes carried the water from Stalagmite Passage, through the flowstone choke above the First Pitch, via Steve's Passage, High Level Passage, and Mud Hall, to continue in the roof of the Lower Streamway (Fig. 21a). Whether this early stream flowed by the present route through the sumps, or whether there is a buried high level continuation hidden above the mud-covered slopes of T'Owd Man's Rift is uncertain. In the vicinity of the 'rift' a second large flow joined the P 8 water from the high level passage which now ends at Christmas Aven; this was probably the water from P 6 and P 7.

The complexity of possible reversals of flow in the Stalagmite Passage/First Pitch route has not been unravelled, but the first passage to be abandoned and covered in flowstone was Stalagmite Passage.
(Fig. 21b). The stream began to sink in the blind valley further upstream, and the initial strike tube which was later to become the Upper Streamway formed, to join the old route amongst the flowstone above what is now the First Pitch (Fig. 21c). The rest of the route was unchanged, which may account for the greater size and maturity of the passages.

Lowering of the water table initiated vadose incision of the tubes along the route from the entrance down to the First Pitch, through High Level Passage, and down to T'Owd Man's Rift. A new downward route was finally established in the region of the present High Level Pitch, and the roof tube of Gour Passage carried the water to rejoin the old route at Mud Hall. Gradual headward incision of this step progressed as far as the First Pitch, leaving High Level Passage dry (Fig. 21d).

Sinks in the floor of this route in the region of the upstream end of Gour Passage now began to carry water to a still lower route, which followed the abandoned oxbow by which one now reaches the upper end of the Lower Streamway. This tube carried water down to meet the old route at the outlet from Mud Hall. Upstream incision of the step began, and has now proceeded to the Second Pitch. An intermediate stage can be seen here, during which the stream first left the Second Pitch by way of the now abandoned vadose trench just above the pitch bottom, and was then captured by the lowest outlet at the bottom (Fig. 21e).

The history of the P 6/7 stream is more obscure. The stream may have originally entered by way of Christmas Aven as stated above. The passage leading to the aven is entered high on the slopes of T'Owd Man's Rift, and the aven lies almost directly above the sump from which the P 6/7 stream now flows. The morphology of the cave upstream from this sump cannot be guessed, but the next stage appears to have been capture by a lower route, of which Sand Passage (Fig. 21d), part of the latest series of phreatic tubes, is the downstream end. At the time of operation of Sand Passage, the P 8 and P 6/7 streams would have united in this area.
The development of the P8 cave.

Fig 21
The P 8 stream found a new route into the present Sump D/1, and the P 6/7 stream began to flow through the present inlet sump. The two streams do not now mix, an unlikely occurrence as the sump into which the P 8 stream flows in wet weather is only 22 metres from that out of which the P 6/7 water emerges. The two streams must cross without mixing, both in sumps.

The cave beyond Sump A/V (Sump 1) is only accessible to divers. The Cave Diving Group have now pushed their exploration to Sump 9, a considerable achievement. Beyond Sump 5 a chamber is reached, into which a stream of unknown source enters from beyond, to join the P 6/7 stream, and to sink with it into a juvenile and impenetrable sump, Sump 6. This stream, the third in the system, can be followed upstream through Sumps 7 and 8 to Sump 9, which has not yet been passed. The route followed by the combined streams from Sump 6 to the rising in Speedwell is unknown. The fall between the two points cannot be more than about 15 metres, so that penetrable passages of great extent are unlikely.

1117 8218. Alt. 1150 ft (350 m) A.O.D.

The swallets to the east of P 8 lie to the north of Faucet Rake, the large east-west trending vein which gives rise to the largest known cavities in the area in Speedwell Cavern, Rowter Hole, and East and West Chambers in Oxlow Caverns (Fig. 18). Westlake (1972) stated that Faucet Rake was present in the Upper Streamway of P 8, just below Idiot's Leap. However, the line of surface workings on the vein passes to the north of the P 8 swallet, so that the vein seen in the cave is a smaller parallel one.

Only Swallets P 9 to P 13 therefore lie to the north of the vein. It is probable, though unproven, that the phreatic route beyond the terminal sumps of P 1 to P 8 lies along New Rake, while the water from
Swallets P 9 to P 13 flows southwards to join an east-west phreatic system in Faucet Rake for at least part of its course.

The P 9 stream sinks against a cliff face against which soliflucted sandstone and shale is banked, with little incision by the stream. A shaft was sunk through this material for 8 metres (Whitehouse, 1967) in an attempt to gain access to the cave, but no entrance was reached. The swallet can engulf a large volume of water.

P 10. Snelslow Swallet.

1125 8231. Alt. 1150 ft (350 m) A.O.D.

Snelslow Swallet has a comparatively large catchment area, and can engulf a large volume of water. It consists of a series of solutionally enlarged joints in a cliff face, which can nearly all take water in flood. The route of the stream between here and Speedwell Cavern is totally unknown, and ambitious excavation by the British Speleological Association failed to gain access.

P 11. Giant’s Cave.

1170 8261. Alt. 1220 ft (372 m) A.O.D.

P 11 is not a separate inlet to the Rushup Edge drainage system. It is a small resurgence cave situated in the valley to the north of Middle Hill. Giant’s Cave is penetrable only for a short distance, and the water sinks only a short distance away at P 13. The stream issuing from Giant’s Cave flows on down the valley to sink finally at Snelslow Swallet.

Swallet P 13.

1170 8269. Alt. 1250 ft (381 m) A.O.D.

Two small streams accumulate on a small area of the solifluxion sheet, and sink into a small cave. Salmon (1950) stated that the stream could be followed underground for "about one hundred feet". It emerges a short distance to the south at Giant’s Cave.
Giant's Hole is the most extensive allogetic swallet cave feeding the Speedwell Cavern stream from Rushup Edge. It has been the object of attention for many years, and is unique among the Rushup Edge Swallets in that its entrance did not have to be excavated. The stream flows into an horizontal cave. However, even at Giant's Hole, adverse dips in the entrance area caused a series of low wet crawls terminating in sumps which took many years of hard work to pass.

The entrance lies in the half-blind valley between Middle Hill and Peakshill. A moderate sized stream enters the cave, becoming large in wet weather. The part of the valley occupied by the surface stream is considerably incised below its continuation down towards Snelslow.

The entrance passages to Giant's Hole were described by Atkinson (1948) at the time when the known cave ended at Backwash Sump, a static pool. Salmon (1956, 1959, 1965) described the far reaches of the system in detail, and Westlake (1967) gave a further account of the cave and speculated on its developmental history. Westlake's work was accompanied by a simplified version of the new survey by the Eldon Pothole Club, which was published in full in 1972.

The stream sink lies on a small fault, the entrance passages lying parallel to this for some way before the effect of the fault is lost and the undulating bedding planes and variable resistance of the reef limestones give a more typical irregular passage form. 80 metres from the entrance, the passage formerly constricted to produce the Curtain, a low wet crawl which was blasted away when the farmer enlarged all the entrance passages. The stream enters the First Stream Sump 120 metres inside the cave. Just before the sump, an oxbow on the left led via low crawls alternating with larger stretches of passage via Pillar Chamber to Backwash Pool, where damming and bailing led to the breakthrough in
1954. This stretch is now enlarged throughout, and the sump at Backwash Pool no longer exists.

From the entrance as far as Base Camp Chamber, and in parts of the farther reaches, there are many patches of fill, consisting of material similar to, and probably derived from the same source, as the solifluxion sheet. One wall of the passage from Pillar Chamber to the site of Backwash Pool is entirely composed of this material, and it is clear that at least some of the entrance passages were at one time almost completely filled.

At Base Camp Chamber, the cave enters much more regularly bedded 'massif' facies limestones, and the passage assumes a much larger and more regular profile. The stream emerges from a bedding slit here, and this can be by-passed to reach the downstream end of the First Stream Sump. The stream passage from here to Garlands Pot, the first pitch, is floored by several thick chert bands, which have halted the vadose incision of the passage from the First Stream Sump to Base Camp Chamber. The chert has been breached 60 metres beyond Base Camp Chamber, and the stream plunges into the roughly circular pothole. The abandoned route above the chert bands can be seen continuing on the far side. The dip in these well bedded limestones is very slight, and the high level complex of tubes can be traced at roughly the same elevation and limestone horizon for a distance of nearly 1 kilometre through to West Chamber of Oxlow Caverns.

Beyond Garlands Pot the stream flows in a tightly meandering vadose canyon incised into the floor of the phreatic tube. It is often up to 20 metres high, but often only 40 cms wide, hence the name 'Crabwalk' (Fig. 22). The Upper Series can be entered by climbing a short distance below Garlands Pot. 200 metres beyond Garlands Pot, the canyon and tube diverge. The Crabwalk continues its meandering course for a further 300 metres to the Comic Act Cascade, at which point the gradient slackens,
the roof lowers, and the passage continues at a lower horizon as an entrenched phreatic tube before narrowing and steepening again to the Second Stream Sump.

The tortuous course of the Upper Crabwalk (above the cascades) is due to the presence of numerous small mineral veins, dominantly of baryte. They are generally less than 1 cm in thickness, but their effect on the course of the canyon is dramatic. There are two sets of such veins, at nearly 90° to each other. The canyon reaches a vein, and turns along it until another vein, of the opposing set, bars its course. The second vein is followed, the passage turning back on itself, until a third vein is reached. One vein must now be breached, and the route turns yet again, to be diverted many times.

A few metres before the Second Stream Sump, a passage on the right (south) discharges a small accumulated percolation stream from the Upper Series. The passage leads to the Lower Siphon Complex, a network of phreatic tubes developed by solution of a prominent bedding plane some 30 metres below that on which the Upper Series tubes and the Oxlow Connection lie. The complex represents an abandoned phreatic route post-dating the Upper Series but pre-dating the Second Stream Sump, and the tubes are now being entrenched by the small accumulated percolation streams.

One tube leads into the wall of the present stream route a short distance below the Second Stream Sump, and the remnant route is followed as a traverse above a canyon until canyon and tube once more diverge, and the stream plunges over boulders into the Third Stream Sump. The tube continues, unmodified, to a short pitch which drops into the head of a canyon incised by a small inlet which enters from the roof. The now incised tube is followed to the head of Geology Pot, a pitch developed by solution along a north west - south east trending vein, and enlarged by headward incision. The tube appears to die out in the roof of this chamber, but a recent climb by Eldon Pothole Club revealed a high level
passage blocked with flowstone, which may represent its original continuation.

The accessible route continues as a bedding controlled outlet at the bottom of Geology Pot, and soon meets the stream downstream from the Third Stream Sump. There is very little tube development at this horizon; the bedding control can be traced for a short distance upstream, and the tube dies out completely above the first cascade downstream. The stream migrates to lower and lower horizons in homogeneous coarsely crinoidal limestones from here, the dominant control over passage form and direction being the north north west - south south east mineral veins rather than the strike of the bedding. The stream finally turns along an east - west vein, and flows into East Canal, a deep sump which has not been dived to a conclusion.

It is interesting to note the absence of high velocity scalloping in the stream passage below Spout Hall. The passages show very large low velocity scallops, except in a few places at floor level, which suggests that a free flowing stream has not existed in these passages for a very long period. If all the surveyed elevations are correct, then the water level at East Canal appears to be controlled, in normal weather, by the elevation of the risings in Speedwell (probably Main Rising). The evidence suggests that only comparatively recently has headward vadose incision of the Speedwell Cavern streamway progressed far enough to lower the water level over the final stretches of Giant's Hole (Fig. 23).

A second route exists from the Lower Siphon Complex to East Canal. One of the tubes of the complex leads to a sump, which can be baled and passed to a series of pitches developed along the same north north west - south south east trending vein that gives rise to Geology Pot. The pitches are known as the Filthy Five Pitches, and intersect the cross vein on which East Canal lies. Descent of the Dog Kennel Pitch then leads down to the canal.
DIAGRAM ILLUSTRATING THE PROBABLE RELATIONSHIP BETWEEN EAST CANAL AND MAIN RISING

Lowest known passages of Giant's Hole carry a vadose stream except in flood, but display no high velocity scalloping.

Lowest water level at East Canal

Water backs up in flood to flow in higher routes

Vadose inlets

Main Rising in Speedwell Cavern

Juvenile deep phreatic vein cavity system

1070 metres

Fig. 23
The most significant inlet to Giant's Hole apart from the main stream is that appearing at Ghost Rift, in the Upper Series. The inlet has incised a canyon into the floor of the Upper Series tube, here known as North East Swallet, and flows down a series of cascades to discharge into the Lower Siphon Complex at the Eating House. The tube is lost in the roof at an 8 metre cascade, but continues beyond, full of clay and sandstone pebbles. It has been excavated by Crewe Caving Club, but was found to re-enter the roof of the canyon before becoming too tight.

A second inlet joins that from Ghost Rift at Maggin's Rift, a large steeply ascending canyon passage blocked at its upper end with boulders. It may have originated as an allogenic swallet cave, for on the surface, close to the shale margin, there are dolines which may engulf water in wet weather.

The Upper Series of Giant's Hole can be followed via Poached Egg Passage and the Chamber of Horrors, relatively unmodified tubes save for the fill of flowstone and silt, which has been partly removed by secondary percolation streams. The connection joins Pilgrim's Way, Oxlow, between Mecca and Rainbow Avens, and the tube continues westwards from this point, still unmodified.

To the east of Rainbow Aven the tube is increasingly entrenched until North Chamber and North Pitch are reached. The roof tube continues, silted, at high level. A series of passages on the Upper Series / Pilgrim's Way bedding plane constitute the bulk of the Main Stream Inlet Series of this region. A low crawl (The Sewer) provides the open continuation at the bottom of North Pitch, and the main stream enters here. Joint control of the passages becomes prevalent, and the main passage again increases in size, finally turning along a north north west-south south east mineralised joint to a sump. The sump was passed by building a concrete dam, but only led to a boulder floored chamber with no obvious way on.
Followed westwards, Pilgrim’s Way leads to a window in the north wall of West Antechamber, a large cavity developed in Faucet Rake. Slight vadose modification of the tube near the window suggests the presence of a stream here after the lowering of the water level in the phreatic cavities in the vein. In 1976 the continuation of Pilgrim’s Way beyond the window was forced past the point at which it crosses the vein, but only opened into the roof of West Chamber, also developed in Faucet Rake, and the largest chamber in the system. From this point the tube was solidly choked. It is expected that digging here would reveal the tube to turn once more from the vein, permitting exploration of the more southerly reaches of the phreatic complex.

At the western end of West Chamber, Maskhill Mine enters. This is largely a natural feeder pothole modified by mining, still in Faucet Rake. A stream enters here from an impenetrable slot. It is possible that this stream once flowed in Pilgrim’s Way complex tubes, but has been captured by the bedding slot, leaving the main tube silted and abandoned. The stream falls into a choked sump.

Chronology of the Giant’s/Oxlow System.

Westlake (1967) has outlined a chronology, postulating four major stages in the development of the system. With some modifications, this is accepted here. A modified version appeared also in Ford, T.D. (1977). Insufficient distinction was drawn in Westlake’s account between the mechanisms of phreatic and vadose flow; rather than envisaging one distinct stream flowing through a single phreatic conduit, one must bear in mind that groundwater under these conditions moves slowly in the direction of the maximum hydraulic gradient through a network of conduits. With the subsequent establishment of vadose conditions, one or more of these early conduits may be developed and incised preferentially in accordance with local conditions.
Stage 1.

There are few penetrable representatives of what must have been a considerable network operating during this stage. Upper East and Upper West Passages (Fig. 22) in the entrance series to Giant's Hole, now extensively choked, are evidently among the earliest passages in the system. The sink at this time lay at the elevation of the valley floor to the west of the present stream entrance. The route continued above the known cave, through passages now choked, and may be represented by the passages found at the top of Ghost Rift (Fig. 22) by climbing above the Upper Series. No tubes above the Pilgrim's Way horizon are known in Oxlows Caverns, and the eastwards continuation of the Stage 1 network is unknown.

Conditions during Stage 1 may have been almost entirely phreatic, vadose incision commencing for a short time towards the end of the period, especially in the passages close to the entrance. Capture by lower routes, both by joints and steeply dipping bedding planes in the reef limestones, occurred at a relatively early stage, so that the passages of Stage 1 never reached great maturity, and were soon abandoned and choked.

Stage 2.

Stage 2 saw the establishment of the stream sink in its present position. The stream followed roughly its present course through the entrance passages, which were largely flooded, but utilised the Pillar Chamber - Backwash Pool route (now blasted away to create a larger passage), and continued through the strike controlled passages of which the Upper Series was the most important route. The Oxlows Connection, Pilgrim's Way, and the tube which continues, silted, beyond the cascades in North East Swallet and at North Pitch (Fig. 24), were all parts of this extensive phreatic network. Whether a swallet fed the upstream end of Pilgrim's Way is uncertain, but the tubes are very juvenile even now
Beyond the intersection with Faucet Rake, and it is likely that there was an inlet of some size in the vicinity. This may have consisted of input from swallets further west, such as Snelslow and Christmas Pot, or it may have been percolation water which reached the phræs down natural shafts and fissures in the vein. The water level in the cavities of Faucet Rake must have stood at around 1150 ft (350 m) A.O.D. A study of the anastomosing tubes at the west end of Pilgrim's Way suggests, so far as the miner's interference permits, that the vein cavities had not reached their present size. The tubes have been truncated, and sections isolated, by subsequent enlargement of the cavities. Some of the important areas have, however, been enlarged by the miners.

During Stage 2, water appears to have flowed from west to east in Pilgrim's Way. However, the scalloping is now confused and anomalous throughout, and some reversals of flow may have occurred since that time. Certainly when the water level in the vein cavities first fell below the tube, water was carried into the cavities by that route, as is proved by the shallow vadose trench in the end of the tube, which inclines towards West Antechamber.

Stage 3.

As free flowing streams became established in the Stage 2 passages with lowering of the water level further east, incision of the preferred route began. The solifluxion sheet is likely to date from this time, and many abandoned tubes were filled with debris washed in from the receding escarpment during floods. The Giant's Hole stream began to find a route through the lower bedding plane on which the Lower Siphon Complex lies (Fig. 24), and incision of Crabwalk began. The water level appears to have stabilised at the level of the Comic Act Cascade (Fig. 22), halting incision below this point. At this time, Maggin's Rift and the inlet at the top of Ghost Rift may have carried allogenic streams down to the
phreas, for the North East Swallet has the appearance of having been incised below the Pilgrim's Way horizon by a large sand-laden stream. To begin with, this incision may have proceeded by the agency of the main Giant's Hole stream, not yet completely captured by Crabwalk. The small passages at the eastern end of North East Swallet lie at the same elevation as the Comic Act Cascade (988 ft / 301.1 m A.O.D.), and are unmodified as a result of the same short halt to downward incision that reduces the size of Crabwalk below that elevation.

The tubes of the Lower Siphon Complex now formed the main phreatic route (Fig. 24). Water moved eastwards through this network until the series of north north east - south south west trending mineralised joints was intersected, and the fractures took over as the dominant control over passage form and orientation. Westlake (1967) stated that it is likely that there was a high level outlet at the elevation of the Lower Siphon Complex in the region of the Filthy Five Pitches. However, the tubes at this horizon die out completely at the head of Geology Pot, and it may be that once the phreatic route intersected the fractures, it utilised them from a very early stage, possibly as early as Stage 1. The large size of the East Canal may result from its having been the main eastward route for a very long time, even before the development of the present day lowest conduits of the known cave.

Stage 4.

The next phase of lowering left the tubes of the Lower Siphon Complex high and dry, and the stream opened the Second Stream Sump, incising the canyon of the Lower Crabwalk below the Comic Act Cascade. Percolation inlets incised small trenches into the floors of the Lower Siphon Complex in places. The inlet from the Corkscrew Shaft, above the climb on the route to Geology Pot, incised the pothole known as the Plug Hole and produced the trench in the passage as far as the head of Geology
Headward incision of the step in the Geology Pot pitch is well displayed. The original route must have been down the vein, and later vadose activity has modified the area to its present form. The water level during Stage 4 must have lain just above the level of the present pitch bottom, so that the outlet was still submerged, as was the lower part of the stream passage to East Canal.

The process of lowering of the water level in the lower part of Giant's Hole since that time seems to have been a gradual one, several short standstills occurring, with a gradual slowing of the process. There may have been a standstill of level below Spout Hall, at 825 ft (251.8 m) A.O.D., but little incision took place between the cascades in the Lower Streamway during that time. It may be that lowering since then has been due to a reduction in the volume of water normally flowing through the system, rather than the removal of physical obstacles and enlargement of the route.

During floods, water still backs up, and may fill the lowest parts of the cave. The deepest route, by which the normal weather stream flows through the phreas to the Speedwell risings may not yet be large enough to carry the entire flood flow. During earlier stages, cavities at a higher level in the vein would have been utilised, and the lower regions, in the static depths of the phreas, would remain relatively undeveloped. Water has to back up for as much as 12 metres now in order to use the higher, larger cavities, which are as yet unknown to explorers (Fig. 23).

In Oxlow Caverns, the standstill which occurred at 988 ft (301.1 m) A.O.D. in Giant's Hole saw the water level at the eastern end of the system at just over 1000 ft (305 m) A.O.D., so that the streams entered the phreas at the bottom of the North Pitch. The route to the final chamber of Oxlow therefore dates from Stage 3, the original route continuing, full of sediment, beyond the pitch at a higher level. The
PROJECTED SECTION OF THE GIANT'S/OXLOW
AND NETTLE POT CAVE SYSTEMS.
Compiled after Atkinson (1948) & Salmon (1956)
from survey figures supplied by P.R. Deakin.

Fig 24
stream passage of 'New Oxlows', as this eastern area is known, became incised during this stage, and headward incision of a series of steps began. The inlet into Faucet Rake at the lower end of West Antechamber is likely to have operated for the first time during this stage.

Subsequent events in Oxlows are obscure, for the lowest levels of development have not yet been observed. Vadose modification of the extreme lower end of the stream passage has occurred since Stage 3, as also has some modification of the West Antechamber inlet. The water entering here now sinks into the boulder floor.

At some point between the shale margin and Faucet Rake, the tuff which represents the Lower Millers Dale Lava has its feather edge. It does not seem to be present near to the margin, with the possible exception of the area around the top of the Winnats Pass, where it may be present in Winnats Head Cave as a series of thin clay wayboards. Possibly the steep depositional dips caused the material to spill over the reef front and to become dissipated on the slope. In Oxlows Caverns the tuff, here referred to as the Nettle Tuff because of its influence on the development of Nettle Pot, is seen at the top of the Second Pitch at an elevation of 1330 ft (405.4 m) A.O.D. The horizon is largely washed out, but may be up to 30 cms thick in Oxlows. It is characteristic of the area in which the tuff is present that joint or vein-controlled cavities increase dramatically in size below it. This is so in Oxlows; the cavities are immense below the tuff. Development of such cavities as West Chamber are a combination of enlargement of primary vein cavities by slow moving water during the early stages of phreatic flow, and, subsequent to lowering of water levels, modification by percolating water rendered more aggressive in its passage over the tuff by oxidation of pyrite, in which such tuffs abound. The present main drainage route, thought to follow Faucet Rake, lies deep below the known cave at Oxlows. The nature of this route is unknown.
iv) The Caves of Windy Knoll and Treak Cliff.

On the eastern side of the watershed at Windy Knoll are a number of significant cave systems, which are surprising in both size and frequency, for the present day surface catchment is not large (Fig. 18).

There is one further swallet, not included among the Rushup Edge Swallets in the past, known as Mam Tor Swallet (Plate 7, 1). The stream has long been considered to be that which appears in the Blue John Caverns, but dye tests in the past have proved inconclusive. The swallet is of little extent.

Very little has been written on the morphology of Blue John Caverns. The cave was fully surveyed by the Eldon Pothole Club (Whitehouse, 1970). The trend of the major passages is in accordance with strike-controlled early phreatic flow from the swallet, with a slight down-dip component. The down-dip component shows an overall increase southwards, although in a few places (in the roof of Crystallised Cavern) up-dip flow prevails for a short distance. A massive vadose canyon is eventually reached (Fig. 25), and this now constitutes the bulk of the tourist route of the cave. The impression gained is of an immense volume of water flowing from a large catchment area, probably during periglacial conditions. The trunk passage constricts suddenly at the lower end, at an altitude of 954 ft (291 m) A.O.D., and the final sump is impassable. The ultimate destination of the Blue John Cavern stream is unknown, but there are small springs round the foot of Treak Cliff which could represent the present-day outlet. It is possible that this stream formerly flowed southwards to cross the present Winnats Pass, to intersect east-west cavities in Faucet Rake, and to rise with the Rushup Edge drainage at Castleton. The stream may now have been largely captured by mine workings, but the Odin Mine lies to the north of the cave, and the natural drainage lies in the opposite direction.
BLUE JOHN CAVERNS.
EXTENDED ELEVATION.
After Westlake 1979.

Fig. 25
Treak Cliff Cavern appears at first sight to be an older remnant. Its deeply incised canyon (Fig. 26) is of comparable size to that in the Blue John Caverns, but is richly decorated with varied speleothems. However, the lower limit of known incision in both caves lies at approximately 955 ft (121 m) A.O.D. It might be argued that lower incision could have occurred either beyond the terminal sump of Blue John, or beyond the terminal boulder choke in Treak Cliff, but the similarity of the lower ends of the canyons seems to be too great a coincidence. Treak Cliff Cavern, further to the south, might be thought to be earlier, but contemporaneity of the two systems is suggested. A stalactite from Treak Cliff was dated at 111,000 ± 5,000 years, suggesting the Last (Ipswichian) Interglacial for the commencement of stalactite formation.

The canyon of Treak Cliff trends south westwards, and at its upper end appears to be generated solely from a small tube. The mined part of the system trends north eastwards, and consists of modified natural phreatic passages with a strong north eastward gradient, suggesting that the passages to the north of the head of the canyon were phreatic in nature, the feeder swallets lying at the margin further to the north. At the time of its operation, it is likely that the Namurian shales were banked up to a much higher elevation on Treak Cliff than they are now, and it is possible that headward incision of the Hope Valley had not progressed beyond the site of the Peak Cavern Gorge. The Namurian sediments could thus have provided a catchment area for these caves in the area now occupied by the head of the broad vale. Headward erosion along the limestone/shale boundary is still progressing at a fast rate, as illustrated by the vain efforts to keep the Mam Tor road in place.

Suicide Cave lies at the foot of the Winnats Pass, on the north side (137 827). It is a logical early outlet for the water from Blue John Cavern and Treak Cliff Cavern. It consists of a low entrance leading to a large abandoned vadose canyon passage with a recently excavated
connection to the hillside far above. The connection was excavated through clay and boulders, and is not the upward continuation of the main canyon. The canyon is likely to continue upwards towards Treak Cliff Cavern. It is interesting to speculate that the canyon may have continued across the Winnats Pass, descending a little until it reached Faucet Rake. The present low entrance may consist only of the top portion of the infilled canyon. The entrance lies at 900 ft (274 m) A.O.D.

Winnats Head Cave lies at the head of the Winnats Pass, on the south side (Fig. 18). The large entrance has long been known, but had little significance alone. Digging by K. Bentham during 1975/6 at the south east side of the entrance revealed a series of cavities developed beneath a prominent bedding plane (Fig. 27), which in places can be seen to be occupied by a thin tuff. The position of this tuff suggests that it may be the most northerly representative of the Nettle Tuff, the probable equivalent of the Lower Millers Dale Lava. Certainly its effect on cave development is similar. The fluting produced by the small percolation inlets is very pronounced, and in the first chamber reached (the 'Main Chamber'), drips have drilled neat round holes approximately 1.5 cms in diameter through boulders in a collapse which does not have an ancient appearance. The extensive cavern breakdown here, and the way in which flowstone is being actively removed from the walls by solution, are reminiscent of areas beneath the tuff in other caves of the area, especially Nettle Pot itself. The bulk of the cave is developed in buff, finely crinoidal limestones with frequent prominent bedding planes, dipping to the south east. There is little evidence of the development of early strike tubes in the uppermost stretch of caves except as early stage anastomoses on the lower surfaces of beds beneath which collapse has occurred.

Early in 1978, C. Fox and K. Bentham discovered a downward route in the boulder choke which floors the 'Main Chamber'. A dangerous descent
WINNATS HEAD CAVE. Simplified section.

Results of water samples

<table>
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<th>Depth (metres)</th>
<th>CaCO₃ content (ppm)</th>
<th>Solution potential (ppm)</th>
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</thead>
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<td>-</td>
<td>-</td>
</tr>
<tr>
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Fig. 27
led to a steeply descending passage which opened into the very impressive Fox Chamber (Fig. 27). At the top of the steep slope (named 'Cornwall Avenue') a thin fluorite flat can be seen, and this lies, as far as can be judged, at the level of the roof of Fox Chamber. The discovery of this much larger chamber showed the system to be an important feeder, formerly at least, to the main drainage system of the area. Water appears to have been engulfed by an entrance now covered by scree at the top of the Winnats Pass where a small north east - south west vein provided a point of weakness. At present, a small stream enters the cave near the entrance, and falls through the boulder choke to Fox Chamber, where it disappears into a further boulder choke. A passage leading northwards from a hole high in the wall of Fox Chamber carries a small stream down a narrow vadose passage to a choked sump.

It would be interesting to dye test the streams in Winnats Head Cave to see if the water emerges at Russet Well, or whether the system behaves in a similar way to the Pickering Series of Peak Cavern, passing over the Speedwell stream, and carrying water into Peak Cavern. A more detailed analysis of the aggressiveness of the small streams might be of value in investigating the role of the wayboards in cavern enlargement; initial results suggested that the most aggressive water was that flowing either directly off a wayboard, or out of cavities in the fluorite vein (Fig. 27).

Windy Knoll Cave appears to be an abandoned allogenic swallet cave of considerable size, and lies just to the west of the surface watershed (126 830). Excavations have been carried out in the past, and nearby fissures yielded many Pleistocene mammal remains (Pennington, 1875). No advances to exploration have yet been achieved, however. The cave consists of a very large passage, descending at a low angle southwards (Plate 8, 2) gaining very little depth below surface, and following the strike over the short known stretch. The rather confused and corroded scalloping appears
to confirm the suspected southward flow. Breakdown of the wide roof has opened holes to the surface, and the run-in material completely blocks the cave. The cave is likely to continue southwards until it encounters southward dipping limestones, at which point the gradient may steepen, and it may continue as an abandoned down-dip feeder to the east–west cavity system of Faucet Rake.

v) Caves and Potholes in Massif Facies Limestone.

There are many natural cavities developed in massif facies limestones at some distance from the shale margin. Those lying just to the south of the reef belt appear to be abandoned swallet caves, consisting largely of enlarged joints and bedding planes, generally too tight for significant penetration. Further to the south, joints have been opened by solution to produce deep fluted shafts, all too often, unfortunately, filled with periglacial debris.

Salmon and Boldock (1950) described the 'Peak Fault Swallets', and included a joint-oriented cave, Christmas Cave, removed at some distance from the shale margin. It lies in a dry valley to the west of Snelslow (111 818). The fissure was penetrated to a depth of 18 metres by digging, but no significant progress was made.

Frog Hole, further to the north east, on the south flank of Middle Hill (121 824) appears to have been similar in character, but is now filled with rubbish. It was excavated to a depth of around 8 metres.

On the north flank of Gautries Hill is a wide open pothole known as Gautries Hill Pot (Elliot, 1975). It is roughly aligned on a major west north west–east south east joint parallel to Coalpithole Rake, and is largely a collapse feature. It may represent part of a remnant swallet cave, and the clay and boulder blockage may be worthy of excavation.

The larger features developed in the massif facies limestones are
commonly aligned on north north west - south south east trending joints. Bull Pit is a massive open pothole close to the margin of the reef belt at 106 814. A fracture is seen in the north end of the hole, and the route down to the bottom lies opposite, presumably down the line of the joint. It is a large collapse doline, and although it is said that digs in the bottom reached short passages, it is unlikely that any significant progress could be made on account of what is probably a great depth of breakdown.

The best known potholes developed on the north north west joints are Nettle Pot and Eldon Hole. The latter is a large open pothole on the south flank of Eldon Hill, while Nettle Pot is a tiny natural shaft on almost the highest point of the moor. The apparent dissimilarity between the two lies in the level of erosion at the two localities (Fig. 28). The top of Nettle Pot lies at the horizon of a thin tuff, close in stratigraphic position to the Upper Millers Dale Lava. The top of Eldon Hole appears to lie at a horizon some 60 metres lower stratigraphically, below the horizon of the Lower Millers Dale Lava.

The many small inlets which drain the tuff-covered surface around the entrance to Nettle Pot amalgamate at depth, 49 metres below the surface, to flow through anastomoses at the top of the Nettle Tuff, the approximate equivalent here of the Lower Millers Dale Lava / Cave Dale Lava. The streams continue down large shafts developed by solution along a major north north west - south south east trending joint. The water flowing over the Nettle Tuff at depth appears to be rendered more aggressive, and cavern breakdown on a large scale has occurred beneath, resulting in the production of large shafts such as 'Elizabeth' in Nettle Pot. A short descent from the Flats, developed by removal of the tuff, leads to a choke of jammed boulders over the top of Elizabeth. A free hanging descent of 55 metres follows, and the shaft becomes blocked by detached rock at a depth of 82 metres below the tuff (161 metres below
the surface). Immediately below the tuff, flowstone can be seen to be corroded by the water now flowing over it.

A passage developed by joint and bedding plane solution 12 metres below the tuff can be followed northwards to the head of a further deep shaft, Beza. The top of Beza is blocked by calcited boulders, and an adjacent shaft, Crumble Pot, provides the downward route for the first 21 metres. The water which falls down the shaft originates from the top of an aven which can be climbed to the Nettle Tuff horizon further to the north. Beza Shaft is blocked by cavern breakdown at a depth below surface of 152.4 metres, but a parallel joint provides a route for a further 12 metres or so, becoming too tight to follow. The water leaves by way of this joint, flowing to the north, and it is therefore likely that the percolation water from this area joins the Faucet Rake system to flow eastwards to Speedwell Cavern.

The wide low area known as the Flats can be followed southwards to further shallower shafts, to more development at the horizon 12 metres below the tuff, and to the Far Flats, developed like the Flats at the Tuff horizon. The flowstone in Boulder Hall, in the lower passage, is again being actively removed by solution by water from the tuff horizon. Here, great slabs of flowstone are almost detached, and the floor is littered with large broken pieces. It suggests that there was a long period during which the percolation water flow was slow enough for the water to become saturated almost immediately below the tuff, so the flowstone was deposited only 12 metres down. The rate is faster now, and small streams develop in wet weather.

Eldon Hole is a large open joint-oriented pothole. The top of the hole lies at an horizon some distance below the Nettle Tuff / Lower Millers Dale Lava, which appears to lie at the base of one of the small persistent scars above and to the north of Eldon Hole. Whether or not the equivalent of the entrance pitch of Nettle Pot ever existed is
uncertain, but the immense shaft appears to equate in its stratigraphic position with the lower, and much larger shafts of Nettle Pot. Eldon Hole therefore appears to be a 'Nettle' type pothole truncated by erosion at a level equivalent stratigraphically to a point just below the top of Elizabeth Shaft.

The origin of the joint-controlled shafts of the massif is in some doubt. It is likely that relatively juvenile shafts formed by simple joint enlargement by percolating water were modified and further enlarged during periods of maximum exposure of impermeable horizons within the limestone sequence. These would provide a temporary and limited catchment area for the pre-existing open joints, which were breaches in the thin impervious cover. When the tuffs were thus exposed, oxidising pyrite would provide very aggressive runoff. Further solution of minor joints close to the master joint was followed by collapse, and the shafts became greatly enlarged, especially below the thicker Nettle Tuff.

Eldon Hole lies in the area between New Rake and Watts Grove Vein (Fig 18), where the boundary between the catchments of the two major streams of the Peak/Speedwell system is in some doubt. The route of the Perryfoot (P 1) water from Coalpithole to the rising on New Rake in Speedwell is unknown, and the affinity of Eldon Hole to either drainage system further to the east cannot easily be determined. The two catchments are known to overlap, for at the eastern end, the Pickerings Series of Peak Cavern carries a small stream from an inlet to the north of the Speedwell Cavern, over the Speedwell Streamway into Peak. The Speedwell stream then flows beneath the Peak stream without mixing with it, but overflows into the Peak stream during floods. It is possible that percolation water from areas underlain by the Nettle Tuff flows southwards at that horizon, crossing conduits which carry allogetic water to Speedwell.

The chambers of Oxlow Cavern have a similar relationship to the
Nettle Tuff to that of the large shafts of Eldon Hole and Nettle Pot. Here, although the cavities are large above the tuff, there is a dramatic increase in size beneath (Fig. 24). East Chamber is roofed by the limestone immediately above the tuff, and a low bedding-controlled passage leads off at roof level towards Nettle Pot (Gill, 1970). Recent traversing by K. Bentham in the roof of West Chamber revealed the presence of the tuff above, and the true nature of the cavity was realised; choked natural shafts continue upwards above the tuff towards the surface, on a smaller scale.

A series of natural shafts at the head of Conies Dale (131 808; Fig. 18) appear to lie at a similar horizon to the top of Nettle Pot. The deepest is penetrable for 10 metres before the controlling joint becomes too tight. North of Watts Plantation (123 808) a natural shaft known as Thistle Pot has been excavated by Pegasus Caving Club to a depth of approximately 20 metres. The top of Thistle Pot lies at a lower horizon than the top of Nettle Pot, but above the Nettle Tuff. Further work may enable the tuff to be reached, and larger cavities may then be found beneath.

vi) The Peak / Speedwell Cave System.

Permission to work in Peak Cavern during the winter months is granted by the Duchy of Lancaster, and this is gratefully acknowledged. The owners of Speedwell Cavern kindly allowed a visit to be made in 1978; access to this part of the system via the Speedwell Level is not normally permitted.

The Peak / Speedwell system occupies a large area between Faucet Rake to the north, and Dirtlow Rake to the south. It is roughly bisected by New Rake, which trends west south west - east north east, roughly parallel to the strike on the north flank of a shallow east - west syncline (Fig. 29). New Rake has halted down-dip flow of allogenic
1) The Bung Series, where vadose incision is relatively slight.

2) The mature canyon passage upstream of the Whirlpool.
swallet streams into the axial region of the syncline, so that two separate streams now flow eastwards, one immediately to the north of New Rake, and one following the axis of the structure to the south of the vein, crossing it only at the eastern end and, in normal weather at least, carrying only accumulated percolation water from a wide area.

The Speedwell streamway is a large mature vadose canyon in its upper reaches (Plate 9.2), incised below a prominent bedding plane bearing a trace of shale (Ford, 1956). It follows the strike fairly closely, parallel to New Rake, with a slight down-dip component. Many smaller veins trend north eastwards or north westwards, or east-west parallel to New Rake, and give rise to cascades in the Bung Series (Plate 9.1) where they cross the passage.

The principal inlets to the Speedwell stream are Main Rising, which lies close to New Rake, Whirlpool Rising, which lies at the end of a north westward trending branch adjacent to Faucet Rake, and two streams which enter from supposedly impenetrable passages high in the walls of Cliff Cavern (Fig. 29).

When the area was being actively mined for lead, a level was driven from the Winnats Pass to intersect the main streamway roughly halfway between Main Rising and the sump at the lower end. A substantial dam was constructed across the stream passage immediately downstream from the point of entry of the level in order to divert water into the level and make possible the use of boats. However, the level intersected the stream passage at roof level, so that the roof had to be removed for some way upstream to give air space above the level of the top of the dam (The Bung). The natural part of the passage immediately upstream of the Bung is thus now silt filled and hidden under water.

The natural floor of the passage rises above water level on the upstream side of the junction with Whirlpool Passage (the Whirlpool is a deeply scoured stretch of passage at the junction, where it is
necessary to swim). Ford (1956) gave an elevation of 742 ft (226 m) A.O.D. for the water level in the canal, and therefore also the Whirlpool. It was estimated on the basis of a dip of 3° that the Whirlpool and Main Risings lay at approximately 800 ft (244 m) A.O.D. However, on the basis of a vertical fall of 4.9 metres over the Bung, and the water level of 226 m A.O.D. where the stream becomes free flowing above the Whirlpool, it is suggested that although 244 m may be valid for the Whirlpool Rising, Main Rising may lie at a slightly lower elevation, possibly 230 - 235 m A.O.D. Even this reduced figure only gives a potential fall in the region of 18 - 30 metres from the 'great swallow' of Coalpithole Mine to the Main Rising.

Below the Bung it is found that the stream passage is less deeply incised below the controlling bedding plane (Fig. 31), which is still prominent. The depth of incision is reduced from around 6 metres between the Whirlpool and Main Rising to a fairly consistent 1.5 - 2 metres below the Bung. The passage height varies somewhat where it intersects major joints, giving extra height, and at one point, where the dip steepens and flattens again, the roof may be submerged in wet weather. A small degree of vadose incision is maintained as far as the second of two low flooded passages on the south side. From this point to the final disappearance of the stream into a sump, the route is a wide bedding plane passage with no trench incision. The lower limit of canyon incision in Speedwell streamway lies at approximately 650 ft (198 m) A.O.D., the same elevation as the lower limit of incision in the Peak stream passage.

The tributaries of the Speedwell streamway are all developed by incision beneath the controlling bedding plane, or are, in a few cases, unmodified bedding controlled tubes. Whirlpool Rising appears to owe its position to early pipe cavities associated with Faucet Rake (Fig. 29) and further study may reveal similar relationships in other north westward trending inlets, for they all have roughly the same orientation. None
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of the inlets are penetrable beyond Faucet Rake; they either become too tight, or are flooded. Main Rising, at the west end of the main stream passage (Fig. 29) discharges a very large stream, and is developed along a small vein trending at 057°; it is of unknown depth.

40 metres downstream from Main Rising, Cliff Passage can be reached by a short climb. The stream from the passage cascades over vein calcite, and this prominent vein is probably one of the main east-west components of New Rake. The passage can be followed, approximately 1.5 metres high and 1 metre wide, for 150 metres to a choke of large boulders at the foot of Cliff Cavern. A steep ascent over the boulders leads to a series of ledges over which the stream falls. Higher still, there can be seen to be two separate streams, falling from high up the continuing aven. They are reputed to flow from tiny bedding-controlled slots too tight for access (Ford, 1956). The cavern is elongated along a master joint, small serins being visible in the walls. A coaly wayboard forms a prominent ledge (Plate 18, 2); this is believed to be close stratigraphically to the bedding plane which has been utilised to produce most of the early tube network of Peak Cavern (Fig. 30). It lies 14 metres above the controlling bedding plane of the lower (Speedwell) network.

The Bathing Pool Passage is reached by climbing a fixed ladder from the main stream passage (Fig. 29). It is a tube on the controlling bedding plane, modified by some incision, and leads shortly to the Bathing Pool, a sump at least 15 metres deep (Ford, 1956). A small stream flows from the sump. A high aven above the sump has not been climbed; it lies directly over the water. The Bathing Pool may have been an early inlet for the main stream, but is now completely isolated from it. The water level stands some 6 metres above Main Rising, although it is only about 35 metres away.

A number of smaller unmodified passages can be seen at roof level further downstream. One is known to connect with Whirlpool Passage, and
STRATIGRAPHIC RELATIONSHIPS OF THE
PEAK SPEEDWELL CAVE SYSTEM.

Horizon of Upper Millers Dale Lava

Cave Dale Lava : Horizon of Lower Millers Dale Lava

Millers Dale Beds

Fault

Reef massif

Moss Chamber

Crystal Inlet

Chee Tor Rock

Wigwam Aven

Top of S2 zone

Peak phreatic network

Speedwell phreatic network

Main Rising

Fig. 30
they were not entered.

The 1978 visit was made after a spell of wet weather, and large amounts of water were the rule underground, yet Whirlpool Passage was carrying only a small stream. This suggested that earlier hypotheses regarding the route of water from Giant's Hole, Snelslow Swallet, and Christmas Pot to the Speedwell risings were wrong. It had been thought that the water from the western swallets flowed southwards, to enter Speedwell Cavern from cavities in New Rake via Main Rising, while that from the more easterly swallets flowed via Faucet Rake to Whirlpool Rising. It is known that Whirlpool Passage can discharge a large stream in flood conditions, but it is impossible that the stream observed on our visit represented the combined waters of the eastern swallets. It must all enter through Main Rising.

Whirlpool Passage is generally between 1.5 and 2 metres in height, and has been extensively prospected by the miners. Short workings can be entered by climbing in the roof. The passage immediately downstream from Whirlpool Rising is filled with 'deads', but these appear to have raised the water in the rising only a little. A mine level has been driven for a short distance beyond the rising, but ends on reaching a vein close to Faucet Rake. The source of the water here is uncertain, but is likely to be the accumulated drainage of the eastern end of the catchment area, around Treak Cliff and Windy Knoll. A short distance to the west of Whirlpool Rising, but roughly 100 metres higher in altitude, lie the deepest cavities of Rowter Hole, also in Faucet Rake.

The Assault Course is a relatively small passage trending north westwards parallel to Whirlpool Passage, accessible from the Speedwell Level. It carries a small stream, which emerges from the continuation of the passage where it becomes too tight. It is likely to be flooded where it intersects Faucet Rake. An aven in the Assault Course is almost certainly the point where a connection was made with mine workings on the
moor west of Castleton (Pilkington, 1789). Pilkington's description of the lower part of the mine and cave system he entered is almost certainly a description of the Assault Course.

The Assault Course passage can be seen to continue across the main Speedwell Level, its downstream continuation being partly walled up to maintain the water level in the canal. Water flows over the wall, and over similar walled swallows. The combined water enters the lower part of the main stream passage (the Bung Series).

There are several branches on the north side of the Bung Series. The first is the entrance to a large oxbow, unmodified at its upstream end, but with a shallow vadose trench where it re-enters the main route, where it discharges the overflow from the canal via the swallows. A smaller oxbow provides a by-pass to a very low stretch of the stream passage which was submerged on our visit.

As the streamway becomes lower and more difficult to negotiate, the first of two southward branches, both flooded, is reached. This is known as Sand Passage in Speedwell, and as the Treasury Sump at its other end in Peak Cavern. In flood conditions, when the main outlet of the Speedwell stream is unable to cope with the volume of water at Russet Well, water backs up until it flows through the Treasury Sump, and out into Upper Gallery of Peak Cavern. The volume of water here can be very large, as during the floods of 16th July 1973, when a large slab of limestone was moved across the Treasury Chamber.

The destination of the second branch, which has never been dived, was a mystery until a small slot in the floor of Upper Gallery (Fig. 29) was investigated in 1977. The slot leads down to a sump, into which a small percolation stream flows under normal conditions. However, the scalloping in the tube approaching the sump indicates an upward and outward flow, suggesting that this sump is another flood inlet to the Peak stream from Speedwell. It is possible that this is the other end of the second
A third major overflow point of the Speedwell stream into Peak is known. Speedwell Pot lies at the end of a short bedding controlled passage on the north side of Upper Gallery, just east of the collapse which creates the 'Mucky Ducks'. In flood, this is the first overflow point to operate at the eastern end, for it is the lowest. The Speedwell end is unknown, for it lies beyond the final downstream sump of Speedwell.

The passages which carry the overflow from Treasury Sump and the slot in the floor of Upper Gallery are deeply incised. The passage which connects Speedwell Pot with the eastern end of Upper Gallery is not. At the time when the principal incision of the Upper Gallery inlet and Treasury Passage was occurring, therefore, the head of Speedwell Pot, and the cave to the east of this point, were below the level of the rising and therefore permanently flooded. The rising therefore lay between 630 ft (192 m) and 660 ft (201.2 m) A.O.D. (the lowest discernible trench incised as a result of Speedwell overflow), suggesting that this incision took place during the standstill of outlet elevation known to have occurred at 640 ft (195 m) A.O.D. from a study of the main stream canyon passages.

The main stream passage of Peak Cavern is large and mature (Plate 10), but is thought now to carry only accumulated percolation water except in times of flood. It was suggested by Ford (1956) that the Vestibule of Peak Cavern once acted as a vauclusian rising, water flowing upwards under pressure from the comparatively deep phreatic network. Progressive lowering of the floor of the Hope Valley allowed downcutting of its lip, and initiated vadose incision of the Peak and Speedwell stream passages. This incision may have progressed even further beyond the breakdown piles which create Far Sump, the present obstacle to further exploration in Peak Cavern. During the earliest phase of incision, one route was selected through the network of phreatic conduits, following the direction...
PLATE 10. The Peak Cavern Stream Passage.

See following page for explanation.
Explanation to Plate 10.

1) The lower end of the Peak Cavern stream passage where it is an unmodified phreatic tube of very regular cross section. The floor of the tube at this point lies just below 640 ft (195 m) A.O.D.

2) Further upstream the main stream passage is deeply incised above the elevation of 640 ft (195 m) A.O.D.

3) The most extreme canyon development in the Peak Cavern system is seen to the south west of Squaw's Junction near Maypole Inlet. The photograph was taken by J.R. Wooldridge during the first ascent to this large roof passage.
of the maximum hydraulic gradient. In some cases, probably due to the undulating nature of the network, the maximum gradient did not co-incide with an existing stretch of tube, and the stream cut across corners to utilise previously undeveloped parts of the controlling bedding plane. Parts of the canyon, therefore, have no roof tube; the tube can be seen to swing away from the canyon at roof level, usually filled with fine brown silt. Some of the tubes have been excavated in search of a by-pass to Far Sump, but have so far only swung back to the canyon, to emerge high in the walls (Fig. 29).

The present Main Stream Inlet to Peak Cavern is a bedding plane (the main controlling bedding plane of Peak Cavern) opened by solution to a maximum height of only 6 - 8 cms. The stream flows from this slot, along an unmodified phreatic tube from which the fill of silt is only partially removed, and falls over a short waterfall into the main stream canyon at Squaw's Junction. No diminution of the size of the main passage occurs upstream from this point, suggesting that this inlet is a recent feature so far as the vadose history of the cave is concerned. The old route must have been from Far Sump, whence the stream still flows in wet weather. Extensive cavern breakdown, behind which sand and gravel have accumulated, forms a barrier which has raised the water level beyond. It is likely that the stream enters the unmodified high level complex, and has cut across the corners to enter the cave through the tiny slit. If the dam resists the action of the stream for a sufficiently long period, it is easy to envisage a new vadose trench forming by incision into the floor of the bedding slot, this stretch of passage then having no true roof tube. The volume of this inlet increases very little even in times of extreme flood, and the route is therefore still small and constricted, almost always carrying its maximum capacity.

Many of the elliptical high level passages carry accumulated percolation streams, but they show either no modification at all, or
occasionally very small vadose slots only a few centimetres deep. All the
deeply incised trenches in the main high level network seem to result
from the action of overflow from the Speedwell stream. In most cases the
small percolation streams have not yet even removed the fill of silt from
the passages.

One inlet which can be followed for a considerable distance is
Pickering's Passage, a small unmodified tube running northwards from
Upper Gallery (Fig. 29). The tube is almost clear of silt for the first
100 metres, at which point an inlet, now dry, enters from the north
east. Beyond, the tube is heavily silted, and was excavated for access,
but does carry a small stream. It can be followed for a considerable
distance to a large cavity, filled with water up to the level of the
entrance passage, down which it overflows. The access tube is known,
over the last stretch, as Cohesion Crawl. Above the sump at the end a
boulder slope rises to the north, and can be climbed to the base of a
large aven, Toadstool Aven, its walls covered by flowstone, and
supplying a small trickle of water. The sump at the bottom of the slope
has been known to drop as much as 10 metres (ie. down to approximately
660 ft (201 m) A.O.D.), at which point the cavity appeared to become
even larger, and there was still no sign of a passage. The presence of
this sump is unexplained; its surface lies to the north of Speedwell
stream, and some 12 metres above it. The lowest point seen in the sump
is believed to be close to the stream level, and recent diving has
almost certainly penetrated below it. The sump is thus completely
independent of any other known water surface.

The north eastward branch of the tube at the 100 metre point can be
followed up steep mud slopes through a chamber to join a narrow vadose
passage which eventually leads into Moss Chamber (Fig. 29), a large
cavity close to Faucet Rake. The route terminates at a second chamber,
Anniversary Hall, where a dangerous and unstable boulder slope
rises to the north, reaching the roof. A high aven has been reached at the top of this slope, but has not been climbed. Upward projection of this system suggests a close relationship with Middle Bank Pot, an abandoned swallet on Longcliff (143 824). The history of this feeder system is hard to determine, but the elevation of the lowest limit of vadose incision suggests that it was flooded below 730 ft (222 m) A.O.D. during its period of operation.

One further important inlet to Peak Cavern may be described. The mature Lake Passage (Fig. 29) discharges a large stream into the main stream passage a short distance upstream of Squaw's Junction. The passage can be followed for 212 metres to Ink Sump. The route plunges below water where it intersects a north west - south east trending vein, and has recently been the site of extensive work by the Derbyshire Section of the Cave Diving Group. The sump has been dived for approximately 275 metres, rising in a series of steps towards the end before entering an area of breakdown and breaking into air space. At this point there was no further way on, but the survey suggests that the final point lies in, or very close to, Dirtlow Rake. Water from Hollandtwine Mine was dye tested to Ink Sump (Kitchen, 1972). A 'great swallow' was recorded in Hollandtwine Mine, and hopes were thus high of reaching an extensive cave system in Dirtlow Rake.

The eastern end of Peak Cavern, near to the entrance, shows no sign of any vadose incision. Capture of the stream by lower phreatic routes has not allowed any modification of the abandoned passages. The stream flows through the inner part of the show cave, and sinks into the Halfway House, an almost circular phreatic tube which can be followed through several ducks and airbells to a long sump. It reappears at the rising in the gorge. During very wet weather the stream backs up in the inner end of the show cave, and eventually begins to rise up the 'Devil's Staircase' to flow out through the tourist route, which is then
inaccessible. It flows out into the Vestibule, and sinks into a large phreatic passage which leads eastwards to a sump. If wet weather persists this passage (The Swine Hole) is overpowered, and water continues to the mouth of the Vestibule. The process of capture by this lower route is thus not quite complete; it is still inadequate during floods. The crest of the overflow route lies at approximately 650 ft (198m) A.O.D., closely corresponding with the lowest level of vadose incision further into the cave.

The Cave Dale Lava / Nettle Tuff overlies much of the Peak / Speedwell cave system. The tuff acts as an aquiclude, preventing a large number of small percolation inlets to the cave from developing. Instead, there are a few streamlets which have passed through the tuff where it is breached by faults or major joints. This 'umbrella' effect has prevented extensive speleothem development in the area overlain by the tuff. Only at the north end of the Pickering's Series, where the reef belt is entered and the tuff dies out, is there extensive flowstone, and in this one locality it is impressive. A large aven a short distance before Far Sump was climbed for a total of 87 metres above the floor of the main stream passage (Kitchen, 1971). At the top a bedding-controlled passage was entered, and although wide, was soon too tight for progress. The passage appears to lie at the horizon of the Nettle Tuff. Fine speleothems adorned the passage, which was named 'Crystal Inlet'.

Ford (1952) suggested that the Peak / Speedwell cave system may penetrate the $S_2$ zone (Woo Dale Beds). Stevenson and Gaunt (1971) give the thickness of the Chee Tor Rock at around 300 ft (91 m) in the north of the area in which it can be recognised as a separate unit. If gradual northward thinning of the succession continues into the Peak / Speedwell area, then the distance from the main controlling bedding plane of Peak Cavern up to the tuff, 87 metres, suggests that the beds below the bedding plane may well be of $S_2$ age. They are certainly pale grey finely
crinoidal limestones similar to those referred to the Woo Dale Beds in the Eldon Hill Quarry borehole (Stevenson and Gaunt, 1971). The main controlling bedding plane of Speedwell Cavern lies 14 metres below that of Peak, and the lowest beds of Speedwell are thus almost certainly in the S^ zone (Fig. 30).

**Chronology of the Peak/Speedwell Cave System.**

The earliest development of which clear evidence remains, apart from the very early pipe cavern development in the Treasury / New Rake region, is represented by the phreatic network beneath which all the subsequent incision has taken place in Peak Cavern. The early network was fed by swallets at the limestone / Shale margin, which may at that time have lain further to the south, and extended up onto Longcliff. Allogenic water thus entered the system by routes such as Pickering's Passage. At that time, the rising at Castleton must have lain at approximately 730 ft (222 m) A.O.D., for this is the lowest level of vadose incision of the canyon in the northward branch of Pickering's Passage. The tube which carried water from that inlet into the main phreatic tube network is unmodified. This elevation was probably controlled by the elevation of the floor of the Hope Valley in the region of the rising, and this would mean that the rising was a vauclusian one. The position of the rising may have been in Cave Dale, where there are phreatic vein cavities which, until they were sealed with concrete, connected with the roof of the show cave of Peak Cavern. The high level cavities in the region of the Peak Cavern Gorge, and in Cave Dale, show no sign of having operated under vadose conditions, and there is no reason to suppose that they were ever feeders to the system.

It was suggested by Salmon (1962) that the Peak Cavern stream passage originally carried water from the marginal swallets to the rising, rather than Speedwell, which may not have existed as an integrated system.
Stages in canyon incision in the Peak-Speedwell cave system.

LONG PROFILES DIAGRAMMATIC, BUT WITH ELEVATIONS AFTER SALMON, 1962; FORD, 1956, AND THE FIELD MAPS OF THE AUTHOR.

Fig. 31
at the time. Certainly the main stream passage of Peak Cavern is so large and the extent of the clastic sedimentary fill so great, that it is difficult to envisage formation by any other than integrated surface streams sinking into the limestone. It has been pointed out that the swallet caves near to the limestone / shale margin tend to consist largely of horizontal stream passages, whereas the known caves further from the margin are generally fluted shafts, therefore they are unlikely to be old swallets. However, the present day swallets lie largely in reef limestones, whereas the caves to the south lie in massive and well jointed limestones. It is unlikely that there were no allogenic swallets when the shale cover was more extensive, but whether they are represented by the fluted shafts we see today is still uncertain.

There is little evidence of standstills in the level of the rising between that at 730 ft (222 m) A.O.D., and that at 640 ft (195 m) A.O.D. However, the stream passage markedly changes character beyond the normally active inlets of Lake Passage and Squaw's Junction (Fig. 29). Below a point 150 metres west of Lake Passage, there is relatively little cavern breakdown, and the stream passage is high and narrow for some way below that point. Upstream from here, there has been extensive cavern breakdown throughout, and the passage contains more ancient flowstone, though this is still scanty. The degree of breakdown increases suddenly, and passing upstream over the boulder piles one approaches the roof of the passage until the roof dips, and progress is barred by Far Sump. The lower limit of the stretch of passage over which extensive breakdown has occurred is approximately 675 ft (206 m) A.O.D., and it is suggested that a standstill in the water level to the east occurred at this elevation.

In the Speedwell Cavern, the main passage is buried deep beneath the silt behind the Bung where its floor lies between 730 ft (222 m) and 740 ft (225.5 m) A.O.D. However, over this stretch, a similar change in the passage profile occurs to that which is seen in Peak at 675 ft (206 m).
Below the Bung, the passage is incised comparatively little below the controlling bedding plane, and is fairly narrow, making it difficult to negotiate against the large stream. Where the natural passage emerges above the artificial water level of the canal, at the Whirlpool, it is wider, more deeply incised, and with extensive cavern breakdown. This suggests that a standstill occurred at a level between these two points, and there is good agreement with the evidence for the 730 ft (222 m) standstill in Peak Cavern.

Further downstream, beyond a large joint-controlled stretch of passage, there is a short stretch of unmodified phreatic tube. Beyond, the passage changes character again. It is still less deeply incised, and the floor is crossed by many ribs of limestone or small veins which the stream has not removed. It has the appearance of a phreatic passage in which a free flowing stream has had insufficient time to remove such obstacles, and even now this stretch must be flooded to the roof during high water conditions. It is difficult to estimate the elevation of the head of this last phase of incision, but it is tentatively correlated with the same stage in Peak Cavern, ie. 675 ft (206 m) A.O.D.

By the time the standstill at 206 metres occurred, the swallets of Longcliff had either ceased to engulf water, or were carrying that water down by new routes to the developing Speedwell stream passage, for the Pickerings Series inlet is nowhere incised below 222 metres.

For a long period after the Peak streamway ceased to carry all the allogenic swallet streams, it is likely that the Treasury Sump was the main downstream outlet for the Speedwell stream (Fig. 31). The acute incision of Treasury Passage persists for some distance along Upper Gallery, but the passage eventually becomes an unmodified phreatic tube. The lower limit of incision here lies at approximately 670 ft (204 m) A.O.D., which suggests that it ceased to operate as a permanent inlet before the incision of the main Peak stream passage down to 640 ft (195 m) A.O.D.
Below the 204 m. level there is no incision of Upper Gallery. The overflow point of Speedwell Pot, at the east end of Upper Gallery, shows no sign of prolonged operation under vadose conditions, and lies at approximately 630 ft (192 m) A.O.D.

A prolonged standstill of the outlet elevation occurred at 640 ft (195 m) A.O.D. This can be clearly defined by the lowest level of incision of both the Peak and Speedwell streamways. The Peak streamway is a very regular phreatic tube (Plate 10, l) below the 195 m. level, to which water may still rise in flood conditions. There is no lower vadose modification, although the stream now flows by a lower route over the last part of its course from Halfway House (Fig. 3) to the rising in the Peak Cavern Gorge. The Speedwell stream flows down a wide low bedding-controlled passage below 195 m. A.O.D. over the last stretch of accessible passage to the final sump.

By the time the 195 m. standstill occurred, the present outlet at Russet Well must have been operating, although Speedwell Pot would still have carried water into Peak Cavern. If Treasury had still acted as a permanent overflow, the trench incised as a result would continue further to the east in Upper Gallery. Flooding from this source must have become less frequent as the Russet Well outlet matured.

The final stage of lowering has seen the floor of the Peak Cavern Gorge lowered to 615 ft (187.4 m) A.O.D. The Five Arches section of the show cave was drained for the first time, and carried a free flowing stream which gradually abandoned its earlier route through the outer part of the show cave. Even now this lower route is only adequate to carry the Peak Cavern stream in normal weather conditions. It cannot take the entire stream in spate, and begins to back up. It used to be assumed that the lower route was somewhere blocked with boulders, but it becomes a wide low bedding slot, with a solid rock floor, too tight for entry by divers. As soon as Speedwell Pot begins to overflow, the Halfway House
is overpowered, and if the flood rises to the level of the Treasury overflow point, the water rises up the steps and flows through the outer chambers of the show cave to the Vestibule. The new route has not carried the main stream for a long enough period for any incision to result from this latest drop in water level. Moreover, the volume of water normally flowing through Peak has probably dropped dramatically with maturation of the lower outlets of the Speedwell stream. Recession of the swallet line to its present position may not have been complete during the early stages of development of Peak Cavern, and allogenic water may have flowed through the canyons in large quantities, charged with abrasive sediment, deepening the canyons relatively quickly.

The only modifications to take place since the last phase of lowering have been those made by the miners. Before the driving of the Speedwell Level laid open the route to the Bottomless Pit, a large cavity intersected by the level in Faucet Rake, backing up in Speedwell may have been more spectacular, and Peak Cavern was probably flooded more often. The sough known as Slop Moll, which discharges into the gorge in wet weather, now acts as a safety valve on the system, although its precise relationship with the natural system has not been directly observed. In flood conditions, the water level at the Inner Styx, a pool near the inner gate of Peak Cavern, rises and falls periodically in very wet conditions. Slop Moll has a similar ebb and flow, but this appears to occur prior to the complete cessation of flow. The tail of the sough is impenetrable.

The fast reaction of the Peak stream to flooding suggests that there may be another connection with the allogenic swallet drainage system, to the west of the known cave. This overflow point may lie beyond the Main Rising of Speedwell Cavern, and only dye testing of the swallets during flood conditions would prove or disprove its existence. Wind Tunnel (Fig. 29) may be an early overflow point, operating in a similar manner to the Treasury and Speedwell Pot today.
vii) Speleogenesis.

The pattern of superimposed surface drainage shown by the present dry valleys of the area (Fig. 3) demonstrates that the catchment area underwent considerable modification as the impervious cover was removed. The present surface watershed passes through Windy Knoll, across the moor on which Nettle Pot lies, between the heads of Cave Dale and Conies Dale, to the summit of Bradwell Moor. To the west of this line, the surface drainage indicated by the dry valleys is to the south, to the River Wye, while to the east it is eastwards towards the Hope Valley and the River Derwent. It is difficult to determine the orientation of the drainage pattern before the first small areas of limestone were unroofed in the region of the Peak Forest Dome (Fig. 2).

Once there was sufficient relief in the exposed area for karst­ification to occur, the structure, and the presence of dolerite sills, lavas, and clay wayboards tended to divert the underground drainage north eastwards down-dip. The presence of Dirtlow Rake, and its south westward continuation as Oxlow Rake, would facilitate this development, assuming the existence of suitable primary cavities in the veins. The elevation of the lowest point on the limestone/shale margin in the north east to which the water from the earliest karst system could drain cannot be determined, for there are no known representatives of this system available for study. It is sufficient to state that north eastward drainage was soon established, in contrast to the superimposed pattern which appears to cut right across structural barriers (such as the Peak Forest Dome).

In the Castleton catchment area there is no certain evidence for extensive cave development at different stages during the stripping of the shale cover. There are no large remnant high level caves removed from the shale margin comparable with those in the Stoney Middleton and Lathkill areas. The only feature suggestive of an alternative rising to that at Castleton is found in Pindale, where Pindale and Black Rabbit Caves
(158 822) lie at approximately 900 ft (274 m) A.O.D. At some stage it appears that the main underground drainage flowed north eastwards to a rising at this elevation in Pindale, which suggests that that was the elevation of the shale margin there at that time.

The phreatic complex which was to become Peak Cavern may have originated when the outlet was in Pindale. The tract of limestone between Watts Grove Vein and New Rake (Fig. 18) was being progressively stripped of its cover, and the earliest phreatic network to develop may have carried water into Dirtlow Rake instead of away from it as it does now.

By the end of the Middle Pleistocene, the shale cover had receded far enough to expose limestone as far north as the Winnats Pass, for the Winnats Head Cave must have acted as a swallet cave as early as Cromerian times; the flowstone dates for Winnats Head Cave, of \(183,000 \pm 10,300\) years to \(190,000 \pm 15,100\) years suggest that it was abandoned as an active route by the early Hoxnian. The catchment area for the cave lay on the Namurian sediments to the north, and maybe to the north east, for headward erosion of the Hope Valley may not at this time have progressed westwards beyond the Peak Cavern resurgence. This would have provided a much larger area of shale between the head of the Hope Valley and the head of Rushup Vale on which large allogenic streams could collect (Fig. 32).

By the time the large influent caves of Treak Cliff and the Rushup Vale began to function, the lowest point on the limestone margin at Pindale had been lowered to around 800 ft (244 m) A.O.D., and the presence of tuffs in the \(D_1\) limestone sequence prevented further lowering in the position of the risings. The water had begun to find a lower, easier outlet at Castleton. It is probable that the caves now seen high in Cave Dale constituted the new outlets.

Probably contemporaneous with Winnats Head Cave are the abandoned swallets of Longcliff, such as Middle Bank Pot, which lies close to the upper end of the Pickerings Series of Peak Cavern. Their catchment also
STAGES IN REMOVAL OF THE IMPERVIOUS COVER BETWEEN PINDALE AND WINDY KNOLL.

KEY
- MARGIN OF MAM TOR BEDS
- MARGIN OF EDALE SHALES
- CONTOURS (250 ft INTERVAL)
- STREAMS

1. CROMERIAN
   - WINNATS HEAD CAVE
   - CAVE DALE CAVES
   - LONGCLIFF SWALLETS

2. HOXNIAN
   - WINNY KNOLL CAVE
   - TREAK CLIFF CAVERN

3. PRESENT
   - MAM TOR SWALLET
   - WINNATS HEAD CAVE

Fig: 32
lay on the Namurian sediments to the north, and the streams which sank into them flowed southwards to reach the phreas at an elevation above 730 ft (222 m) A.O.D. The present entrance to Peak Cavern may have begun to act as a vauclusian rising before the Longcliff swallets ceased to engulf streams. Headward erosion of the Hope Valley along the shale/limestone margin may have been primarily responsible for the abandonment of these swallets.

The northern extremity of the limestone outcrop included the area of Treak Cliff Cavern by the Hoxnian (Penultimate) Interglacial (See P.122) and Treak Cliff Cavern developed, largely by utilising pre-existing pipe vein cavities and bedding planes. If, as seems likely from the geometrical relationship between the caves, Suicide Cave was the downstream continuation of the Treak Cliff system, the latter may have continued to the south of the Winnats Pass to enter the Peak / Speedwell drainage system. The outlet level of the system was now below 730 ft (222 m), and by this time the Speedwell stream passage was starting to develop. The water in this more northerly eastward route may by this stage have begun to enlarge the pipe cavity which was eventually to become the Treasury overflow point into Peak, or may have been using a higher overflow route, such as Wind Tunnel. Development in the area of Treak Cliff proceeded with further erosion of the cover during the Wolstonian (Penultimate) Glaciation, so that by the Ipswichian Interglacial the Blue John Cavern system was the main drainage route from the area. Where this drained to is uncertain; it is possible that headward erosion along the margin had provided new outlets, but it is more likely that it passed to the south of the Winnats like its predecessors to join the main Peak / Speedwell system. The Devensian saw the virtual abandonment of the Blue John / Treak Cliff cave system on a dramatic diminution of the catchment area, so that it now lies virtually on the watershed between the Hope Valley and Rushup Vale.
Events in the western part of the catchment are difficult to tie into the sequence recognised at the eastern end. Canyon incision and the utilisation of lower bedding planes seems to have proceeded in isolation in Rushup Vale, lagging behind the process at the resurgence end of the system. To begin with, the developing swallet caves carried water through the irregular beds of the reef belt until the first east-west vein was intersected, at which point the route became flooded to the elevation of the upstream sump of the resurgence cave, or the rising, whichever was the higher.

Johnson (1967) suggested that the solifluxion sheet which floors the Rushup Vale and hides many of the cave entrances was of Devensian age, and points out that Giant's Hole must pre-date that sheet since many of its passages, especially near to the entrance, were infilled with the same material. However, Johnson also suggested that the western swallets were far more recent, but this cannot be so because the maturity of some of the passages in Gautries Hole and the P8 Cave, together with a complex story of capture by newer conduits, points to a long history. Parts of the Upper Series of P8 display patches of cemented solifluxion material, often covered in flowstone.

The effects of further lowering of the resurgence level on the Peak / Speedwell system have been described above (p.150). The relationship between events in the swallet caves, and the stages of incision described in the Peak / Speedwell system is hard to determine. It is fairly certain that the Pilgrim's Way horizon of the Giant's / Oxlow system is that of the main controlling bedding plane of Peak Cavern's high level network. However, for the network of tubes at the western (swallet) end to have developed under conditions controlled by the elevation of the rising, it would be necessary to postulate a rising above 1000 ft (305 m) A.O.D. in the early stages of development of the Giant's Oxlow system. It is hard to envisage the necessary topography, and yet to have limestone exposed.
in the area of Giant's Hole.

The answer may lie in the nature of the vein cavities utilised by the allogenic streams from an early date. The lowest open cavity system in the vein would have been used. The position of the phreas on the upstream side would be controlled by the elevation of the highest point along that route. The water in lower unconnected cavity systems remained isolated and static. The establishment of a connection with a lower cavity system would lower the phreas at the western (upstream) end. The stages of incision of the eastern (resurgence) cave would then be governed by the elevation of the resurgence, with successive heads of incision migrating upstream. The successive cave levels in the swallet caves depend on the nature of the intervening vein cavity system. The principle is illustrated in Fig. 23.

The river terraces of the River Derwent were described by Waters and Johnson (1958). They recognised four terraces, the highest of which, the Hathersage Terrace, could not be traced in the Hope Valley at Castleton. The valley here is floored by the Hope Terrace, formed after the 'Older Drift Glaciation', and the Peakshole Water is incised some 3 metres below this terrace. This does tend to support the view that headward erosion of the Hope Valley has proceeded considerably further westwards since the earliest risings began to operate at the eastern end of the cave system. The lowest level of vadose incision in the Peak / Speedwell Cave system therefore corresponds with the elevation of the highest recognisable terrace at Castleton. Earlier terraces, as pointed out by Waters & Johnson, are too fragmentary to be traceable for a meaningful distance. Incision into the Hope Terrace has only comparatively recently proceeded upstream to the cave entrance (Fig. 33).

A great deal of further exploration is necessary before the picture can be thoroughly elucidated. Exploration is slow, but there are still sites along the Rushup Edge swallet line worthy of investigation, and
RELATIONSHIP OF CASTLETON CAVE LEVELS
TO RIVER TERRACES IN HOPE VALLEY.

- Highest unmodified phreatic tubes.
- Deepest canyon incision in western swallets.
- Deepest canyon incision by Longcliff swallets.
- Lowest extensive breakdown.
- Lowest canyons of Peak Speedwell.

Far Sump, Peak Cavern.
Peakshole Water
Hope Terrace
Hathersage Terrace
Not traceable on the Peakshole Water

Fig. 33
prolonged digging here may well be rewarded. Completion of a new survey of the Peak / Speedwell system will allow more accurate elevations to be obtained for the critical incision levels, and may show further relationships between the two major stream passages of the system. Further investigation of terraces in the Hope Valley may reveal higher fragments, but it appears at present that these fragments are not traceable up to Castleton.
Chapter 5.

THE BRADWELL CATCHMENT AREA.
5) THE BRADWELL CATCHMENT AREA.

1) Previous Research and Exploration.

The main rising at Bradwell has the largest discharge of any single rising on the northern margin of the limestone outcrop, but there have been few significant advances in underground exploration since lead miners discovered Bagshaw Cavern from the Mule Spinner Mine on Moss Rake in 1812.

A survey of Bagshaw Cavern appeared in "Moors, Crags and Caves of the High Peak" (Baker, 1903), and various versions have appeared since. The most complete survey, but produced without measurement of vertical angles, was carried out by D.C.Revell in 1964. It is probable that if digging were allowed in Bagshaw Cavern, discoveries might still be made. The western end of the cave offers little prospect, however, and southward trending passages are flooded.

The only attempt to describe the caves fully was that of Crabtree (1964), but the proposed series of articles was never finished. The short published account does, however, cover the important pipe caverns of Hazlebadge, to which access is not normally permitted, and which have been damaged or destroyed by recent open cast fluorspar mining.

Many caving clubs have investigated the caves of Bradwell Dale, but digging has been limited. Quarters Farm Swallet was excavated in 1937 and 1949 (Turner, 1950) but no extension was found. Well Shaft, in the floor of Bradwell Dale, on Earl Rake, was excavated by Eldon Pothole Club (Whitehouse, 1966), and Bradwell Parish Cave (Old Brook Cave) was excavated for a considerable distance in the early 1970's by the Technical Speleological Group.

A great deal of work has been done on the mines of individual rakes by individuals and small groups, but much of this work remains unpublished. Many surveys in the British Speleological Association (now British Cave
Research Association) collection relate to the Bradwell area (ie. Windy Mine, Moss Rake, 1937-8), and the records of QM Mines Research and Exploration contain information on Hazlebadge, Nether Water Mine, and mines on Moss Rake in the vicinity of Batham Gate.

Sheffield University Speleological Society produced a detailed account of the mines of Long Rake, which were shown to contain interesting natural vein cavities. Two deep shafts were opened and descended, and cavities were found which appeared to have a direct relationship with Batham Pot (Lord & Thompson, 1968; Lord & Worthington, 1969).

Moorfurlong Mine was opened by Sheffield College of Technology Caving Club in 1966. A detailed survey was prepared during 1975 (Worley and Beck, 1976), and a study of the geological controls over this mineralised phreatic cave system was carried out.

Berton Pingles Pipe, the entrance to which lies in the quarry in Bradwell Dale, was described by Buckley (1974), when it was shown to be a largely natural system, probably with a close relationship to Bagshaw Cavern. It subsequently became a target for cave diving.

An outline of the development of Bradwell Dale and its caves was given by Ford, Burek, and Beck (1975).

ii) Topographic and Geological Setting.

The area occupies the north eastern portion of the limestone outcrop, between the Castleton catchment area to the north west, and the Stoney Middleton catchment to the south and south east. The Namurian sediments form a north-south trending escarpment to the east of Bradwell Dale, and the limestones rise gently from beneath the shales to form a dip-slope to the west of the valley. The slope flattens out at an altitude of between 1300 ft (396 m) and 1400 ft (427 m) A.O.D. on Bradwell Moor, and it is predominantly this dip-slope, together with a small area of the Namurian sediments, which is drained by the Bradwell
GEOLOGY OF THE BRADWELL DISTRICT
AFTER THE PUBLISHED MAPS OF THE GEOLOGICAL SURVEY

KEY TO GEOLOGICAL SYMBOLS

- APRON REEF
- FLAT REEF OF P2 AGE
- KNOLL REEF OF P2 AGE
- KNOLL REEF OF O2 AGE
- EYAM LIMESTONES (P2)
- MONSEAL DALE BEDS (O2)
- BEE LOW GROUP (D1)
- TUFF
- LANDSLIP
- MARGIN OF SHALE
- VEIN

Fig. 35
risings at the northern end of the valley (Fig. 34). The Bradwell Brook flows northwards to join the River Noe, which joins the River Derwent at Bamford.

The catchment area is a large one, covering an area of approximately 13.5 $\text{km}^2$, of which 11 $\text{km}^2$ is limestone, and 2.5 $\text{km}^2$ is occupied by the Namurian sediments. The catchment area boundaries are sometimes poorly defined, especially to the south in the region of the Hucklow Edge Vein, and to the west in the region of Dirtlow Rake. The southern boundary must lie a little to the south of the Hucklow Edge Vein, for water which sinks at Duce Hole (1814 7767; Fig. 35) was positively dye tested to Bradwell (Derwent Valley Water Board tests recorded in Ford, 1956). Duce Hole lies a little to the south of the surface watershed, which roughly corresponds with the outcrop of the Hucklow Edge Vein in this area. It is just possible that water from Swervic House Swallet, near Foolow, also drains to Bradwell, but it is more likely that this flow augments the natural reservoir in the Wardlow Basin.

From Tideslow, in the south west of the area, the catchment boundary follows the outcrop of the Litton Tuff north westwards. Where the tuff is not present, the boundary may be provided by the outcrop of the Upper Millers Dale Lava. The boundary again becomes ill-defined in the area of Dirtlow Rake, where water in Hollandtwine Mine has been dye tested to Ink Sump in Peak Cavern (see p.146), and therefore flows to Castleton. The boundary probably lies a little to the south of Dirtlow Rake, turning eastwards in the north where the rake is likely to be drained by the Pindale Sough.

Bradwell Dale is a typical deeply incised limestone gorge for 1.25 kilometres south of Bradwell village, at which point it broadens, and continues as the much gentler valley of Stanlow Dale. A number of dry valleys radiate westwards up the dip-slope from this area. To the east of Stanlow Dale streams accumulating on the westward facing scarp of the
Namurian sink into swallow holes close to the limestone margin.

The limestones of the area are dominantly of the D₂ zone, and are generally well bedded, often cherty, with prominent and persistent fossil horizons. They are referred to as the Upper Monsal Dale Beds. They contain a number of interbedded clay wayboards and lavas, the catchment area being bounded by the Upper and Lower Millers Dale Lavas on the west side. To the east, these appear to thin, and are thought to be represented by tuffs in the Long Rake Mines (Fig. 36). Further tuffs were penetrated by the Hope Cement Works Borehole (Stevenson and Gaunt, 1971) but these do not appear to have equivalents at outcrop further to the south and west.

The Monsal Dale Beds are overlain by limestones of the P₂ zone, the Eyam Group, which are more thinly bedded, often very cherty, and often shelly and lenticular. On both sides of the gorge section in Bradwell Dale, flat reef limestones are extensively developed in the P₂ zone, but they die out southwards, giving way to occasional reef knolls.

The area is crossed by many mineral veins, with an east - west or south west - north east trend. Many of the dolines on the margins of the lava outcrops on the boundaries of the catchment appear to have a close relationship to the veins, tending to be concentrated around those areas where a large vein emerges from beneath an impervious horizon. South west-north east trending veins can be seen in Bagshaw Cavern, and here they can be seen to have a strong influence on cavern development. They have provided preferred channels for phreatic routes, especially where they are dominantly of calcite. Direct observation is impossible, but it appears that the more resistant fluorite veins further to the south may have acted as barriers, causing the trunk phreatic route to plunge deep into the phreas, the southward continuation of the main Bagshaw Cavern system being flooded for a long distance.
iii) Surface Drainage.

There is no permanent surface stream in Bradwell Dale. The main rising of the stream from Bagshaw Cavern lies at the foot of the gorge where it begins to broaden onto the flood plain of the River Noe. The many sough tails all lie downstream from the main rising, unlike the nearby Stoney Middleton Dale, where the permanent surface stream in the valley originates at the tail of Watergrove Sough, and where small streams in the tributary valleys flow on the surface throughout their courses over the limestone. Only in extreme flood conditions does water flow down Bradwell Dale (Plate 11,1), and under such conditions the road may be almost impassable. It can be seen that the water level in Bagshaw Cavern, and in natural cavities associated with this drainage system in the vicinity of Earl Rake, easily rises to valley floor level. Low pressure domes appeared twice under conditions of snow melt during the 1978/9 winter, and water forced its way up through the tarmac where Earl Rake crosses the road.

Under these conditions, small risings appear just to the south of Hazlebadge Hall, and water flows northwards down the dale towards Bradwell, sinking, if the water level is not already up to the valley floor, in the vicinity of Earl Rake.

Water may rise in some quantity from the bedding plane on which Bradwell Parish Cave lies; this is thought to be a further overflow from Bagshaw Cavern.

The major surface streams draining the escarpment are those passing underground at Nether Water Farm, Quarters Farm, Deadman's Clough, and at Duce Hole beyond the surface watershed. Smaller streams may accumulate on the shales during very wet weather, and seep away into the fields at the base of the escarpment. Some of the streams at the southern end of the area may remain on surface because old swallets are now buried beneath the extensive landslip (Fig. 35).
iv) The Swallets.

Unlike most of the marginal areas in the north of the limestone outcrop, there are no significant swallet cave systems associated with the swallets of Bradwell Edge. This may be due to the relatively small size of the allogenic streams concerned. The principal component of the Bagshaw Cavern stream is likely to be accumulated percolation water over the large limestone catchment.

Duce Hole.

Apart from the possibility that water from Swevic House Swallet drains to Bradwell, Duce Hole is the most distant sink from the Bradwell rising. It lies at the shale / limestone junction, immediately north of Grindlow, at 1813 7766, at an altitude of 1000 ft (305 m) A.O.D. The stream entering the short cave is often somewhat unsavoury as it consists largely of farmyard effluent. A short stretch of passage leads to a chamber, but the passage constricts beyond, finally becoming too tight after two short drops.

It is possible that the main restriction to the stream is due to a doline which engulfs a small stream approximately 40 metres west north west of the entrance. This doline has been the object of considerable attention by Stockport Caving Club, who gave it the name 'Shod Pot', and sunk a shaft through a fill of rubble, likely to have been dumped there during widening of the road. It appears likely that Shod Pot was the deep open hole referred to by Farey (1811, Vol.1). It appears to lie in the line of the stream passage of Duce Hole.

The Hucklow Edge Vein lies some 400 metres to the north west of the stream sink, and may be a major barrier to the route. However, since the vein has been almost universally worked over this stretch, the water may now enter the workings and flow by a partly artificial route. It is likely that prior to the mining, the route either dropped to depth or
sidestepped on the vein. It is likely that further investigation of this site would reveal much about the effect of a major vein lying at right angles to the maximum hydraulic gradient, while the main flow from a swallet cave is still at a shallow depth.

Swallet below Burrs Mount.

A small stream accumulating on the landslip to the north of Great Hucklow sinks in a rather indeterminate swallet among trees on the north side of the track at 1753 7820. The swallet lies at the foot of the landslip, and is likely to be buried by slipped shale and sandstone. Many small streams can be traced in this area in wet weather, and most soak away into the fields. It is difficult to distinguish between swallets into which routes are becoming re-established and land drains. The lack of well defined swallets along this stretch of Bradwell Edge suggests that the landslip post-dates the establishment of a marginal swallet line.

Quarters Farm Swallet.

The main swallet lies a short distance to the north of Quarters Farm, at 1730 7945. A stream from the shales sinks against a low cliff in a hollow among trees. It is a typical marginal swallet, surrounded by shales, yet close enough to the margin of their outcrop for the shale to have been breached by the stream. It has been excavated in the past (Turner, 1950); but only a tight fissure was reached.

The stream entering Quarters Farm Swallet was dye tested by the Derwent Valley Water Board in June 1952, and a positive result was obtained at Bagshaw Cavern (Ford, 1956).

On the south west side of the farmyard at Quarters Farm is a second small swallet, which although choked with rubbish takes a fair sized wet weather stream. It lies at the shale margin, and engulfs water which accumulates on shales to the south and south east.
Nether Water Swallet.

Nether Water Swallet lies in Stanlow Dale, a short distance to the north of Nether Water Farm, close to the outcrop of the Nether Water Vein. It has never been entered. The stream sinking here was dye tested by the Derwent Valley Water Board (Ford 1956) to Bagshaw Cavern, taking 6\(\frac{1}{2}\) hours to reach the upstream end of the cavern, and 7\(\frac{1}{2}\) hours to reach the resurgence in Bradwell Brook. The period of 6\(\frac{1}{2}\) hours suggests a slow movement through the flooded section upstream from the cavern, while the time of 1 hour from here to the resurgence suggests only relatively short flooded sections between the upstream end of the cavern and the resurgence.

Dead Man's Clough Swallet.

Small swallets exist in the floor of Dead Man's Clough (176 801), east of Hazlebadge. The swallets are indeterminate, and now very little water sinks here due to the construction of a reservoir further up the valley. The overflow from the reservoir is piped into a mineshaft at 1753 8038, and the water is believed to enter the Pic Tor End Sough to resurge in Bradwell Brook. The shaft is blocked at a depth of 27 metres.

The routes from the swallets of Bradwell Edge to the flooded area upstream from Bagshaw Cavern are likely to be dominantly strike-controlled, being modified by vadose activity in the vicinity of the swallets, but consisting largely of strike and dip-tube systems in what may be an extensive phreas. The vertical distance from the swallets to the level of the upstream sump of Bagshaw Cavern is in the region of 45 - 60 metres, and as much as 105 metres in the case of Duce Hole. There may thus be extensive swallet cave systems awaiting discovery in the area, and although the miners reported natural cavities in the Hucklow Edge Vein, it is surprising that more natural passage is not known.
v) Natural Solution Cavities on Bradwell Moor.

The most extensive natural cavities recorded beneath Bradwell Moor are those associated with Batham Pot (1528 8081). They are accessible via the Long Rake Founder Shaft, and by 'Shaft A' (Lord & Thompson, 1969; Lord, 1970).

The open pothole itself lies on the rake, and is believed to have been far deeper before its use as a receptacle for mining waste. Rieuwerts (1969) records that in 1752 it was described as a "remarkable cleft like Eldon Hole". This description hardly fits it at present. By 1957 it had been reduced to a hole "100 ft long, 80 ft deep, and 60 ft wide" (Tottle, 1957), and the process of infilling continues sporadically.

To the north east of Batham Pot lies the Long Rake Founder Shaft. The natural cavities in the mine can be seen to be the likely downward and lateral extension of the same vein cavity system that gives rise to Batham Pot (Fig. 36).

To the west, 'Shaft A' of Lord (1970) also contains natural cavities, one of which is a phreatic tube which crosses the vein but is blocked by clay. The lowest level of this shaft ends at a choke which lies almost directly beneath the open pothole.

It is interesting to note the relationship of these cavities to the wayboards which occur in the area. Two such horizons are intersected by the Long Rake Founder Shaft, at 53 metres and 139 metres below surface (323 m. & 237 m. A.O.D.). The Upper and Lower Millers Dale Lava outcrop 1.6 km to the west, and are likely to be intersected by the mines. The upper tuff in the mine may be the lateral equivalent of the Upper Millers Dale Lava, but if the lower tuff represents the Lower Lava, then the intervening beds, defined elsewhere as the Millers Dale Beds, are twice their thickness at outcrop.

It can be seen from Fig. 36 that that natural cavities increase considerably in size beneath the tuffs, as has been noted in Nettle Pot.
NATURAL CAVITIES IN MINES ADJACENT TO BATHAM POT, LONG RAKE.

Natural cavities shown in solid black.

After surveys by Sheffield University Speleological Society.
Oxlow Caverns etc. to the north west, where the Lower Lava is thought to
be represented by the Nettle Tuff. It is likely that a similar mechanism
has operated, namely the increased aggressiveness of the water in its
downward path in the vein by contact with oxidising sulphides (mainly
iron pyrites) in the tuff.

To the north west of Batham Pot is a shallow blind valley ending
at Crematorium Pot, a natural shaft excavated by cavers to a depth of
12 metres. The top of the shaft lies above the elevation of Batham Pot,
further to the west. The tuff seen at -53 metres in Long Rake Founder
Shaft is expected to lie at approximately 320 m. A.O.D. in Crematorium
Pot, 75 metres below the surface. At this point lateral extensions to
the cavity are almost a certainty.

The general dip direction is to the north east along Long Rake,
so that percolation water reaching the tuff is likely to flow down-dip
in that direction towards Bradwell, migrating gradually across successive
south
north west trending veins until it enters the main drainage system of
Bagshaw Cavern. It is likely that an inlet from the west exists in the
downstream area of Bagshaw Cavern, carrying water from the northern
part of the moor.

Kittycross Mine.

Kittycross Mine shaft lies at 152 803, its collar lying
at 1267 ft (386 m) A.O.D. (Ford, 1951). A natural cavity was intersected
in deepening of the shaft, and appeared to lie at the horizon of the
Lower Lava, for decomposed lava walled the cavity. The chamber was of
considerable size (15 m. x 6 m.) and lay on a calcite vein parallel to
Moss Rake, which showed some displacement, with downthrow to the north.

The chamber lay at approximately 812 ft (247 m) A.O.D. Water sank
in a choked shaft in the floor. Associated joint-controlled cavities
were very narrow, and were of limited extent.
Moorfurlong Mine.

The entrance shaft to Moorfurlong Mine lies at 1683 8120, 0.3 km west of Bradwell village. The shaft is entirely artificial, 13 metres deep, and a level at the bottom leads to the head of a 3 metre winze which gives access to the pipe caverns. The workings were surveyed and described in detail by Worley and Beck (1976).

The north west end of the system consists of a series of bedding plane chambers developed in thinly bedded black bituminous limestones. The highest of these chambers may originally have been very much larger, but extensive cavern breakdown has occurred, and there has been later infilling by clay, miners debris from the pipe vein, and possibly some periglacial debris which entered through open holes to the surface in this region.

Beneath these upper chambers, winzes give access to short and unstable workings in which the lower parts of the breakdown pile can be examined. The fallen limestone slabs are found to be heavily cemented by later fluorite mineralisation, which proves the date of the breakdown, and therefore of the earliest cavities, to be far earlier than the Pleistocene. Shallower phreatic solution during the Pleistocene, and possibly even limited vadose activity, has modified the mineralised cave to give the form we see today, apart from the alterations made by the miners. The absence of high velocity scalloping in most of the system suggests formation of the early cavities by slow deep seated phreatic solution, possibly beneath an impervious cover.

Towards the south eastern end of the workings, the bedding caves give way to low workings in an extensive fluorite flat from 0.25 m. - 0.5 m. thick. A complex series of crawls and short shafts have an overall down-dip trend, but ultimately end at chokes. Draughts can be detected in places at the lower end, suggesting further down-dip continuation.

Bagshaw Cavern.

The entrance to Bagshaw Cavern is an artificial one, high above Bradwell village at 1710 8098, a short distance to the south of the line of workings on Moss Rake. A flight of stone steps descends for approximately 30 metres through stopes in a vein, dominantly of calcite. The stopes continue above and below the steps. The mined area continues along the vein to the west south west at the foot of the steps, and here the walls show large low-velocity scalloping, for a natural passage has followed the vein for some distance before turning to the south. To the west it is lost, and the workings become unstable, but it can be followed to the east, and then southwards beneath the entrance steps as it veers away from the vein. It develops into a well-defined phreatic tube with an extensive fill of cavern breakdown material, chert, and sandstone pebbles in a sand and clay matrix. The whole has been covered with a layer of flowstone, and a trench has been excavated through the sediments to provide a comfortable tourist route.

The tube meanders as it crosses successive veins lying parallel to Moss Rake itself (Fig. 37), turning along the veins for a few metres in some cases before continuing its southward course. The passage is almost level, inclining very slightly to the south. It is developed by solutional enlargement of a bedding plane separating fine grained and highly crinoidal limestones above from grey unfossiliferous beds below.

Calypso's Cave is seen on the right (west) after 120 metres, and is again developed on an east north east - west south west trending vein roughly parallel to Moss Rake. It is possible to climb and crawl through a series of cavities lined with mature flowstone, rising an estimated 10 metres above the main passage, to a choke after 40 metres. The choke is known to be close to a choke in a similar passage in the 'New Series', which is gated, and to which access is not normally allowed.
BAGSHAW CAVERN.
After a survey by D.C. Revell, 1964.

Entrance

Oxbows on higher bedding plane (that of the main route to Hippodrome)

New Series

The Dungeon

Glory Hole

Hippodrome

Stream Passage

Phreatic flow direction.

Present flow direction.

Major calcite vein.

Sump

Fig. 37
The main route joins a prominent calcite vein with a slightly different orientation at the Dungeon, a roughly circular pothole in the floor. The pothole is developed primarily on the vein, having been enlarged by headward vadose incision. The main route follows this vein upstream for some distance, and steps to another vein a little to the west of, and parallel to, the first. The passage is now a large bedding-controlled strike tube, modified by extensive breakdown and a small degree of vadose incision. The vein is often opened by solution in the passage roof, and it is possible to climb up in several places.

This stretch of cave is still developed in thin bedded, often finely crinoidal limestones, the thin bedding having assisted the process of breakdown. There is much vein calcite in situ adjacent to the veins, reminiscent of the Treasury area of Peak Cavern, suggesting extensive influence of primary vein cavities and hydrothermal cavities in the limestone adjacent to the veins in determination of the early route. The dip in this area was estimated to be 8° to the east.

Blockages of breakdown are passed by clambering through open parallel joints, then the route sidesteps to another joint, and the Hippodrome is reached. The Hippodrome is a wide area of breakdown where a joint-controlled inlet enters from the Glory Hole. Glory Hole Passage is developed along a different joint set, and operates under phreatic conditions in wet weather. The reason for the deep sumping of this and other areas at the southern end of the cavern may be the proximity of east-west veins which are dominantly of fluorite. Hartle Dale Rake and Earl Rake cross the dale to the north of Hazlebadge, and may have acted as barriers to disrupt the usual pattern of a strike and dip-tube network just below the level of the phreas.

The Glory Hole must descend to the level of the main stream passage, which is reached by a phreatic dip-tube running eastwards down-dip from the Hippodrome. The tube is roughly 1.5 metres in height, and up to
2 metres wide, and intersects the strike-controlled, rather immature stream passage on an oxbow. The stream flows on through an impenetrable bedding plane in normal weather during the summer, but may back up in wetter conditions to utilise higher routes.

The stream passage may be followed downstream for some distance before becoming too tight by virtue of the accumulation of large boulders, and also upstream to a sump which was dived by the Cave Diving Group to a series of cross rifts beyond which the route dipped steeply to a great depth. The proximity of Earl Rake may be responsible for this sump, which continued to descend steeply at the limit of exploration.

In wet weather, the stream may back up in the 'Top Stream Passage' as it is called, and rise up the dip-tube to the Hippodrome to flow along the main passage to the Dungeon. It is likely to be joined by another inlet from Glory Hole Passage under these conditions. The Dungeon becomes a slowly swirling pool. The water level here appears to be controlled by large breakdown cones in the Lower Series, which is entered by descending the Dungeon for 6 metres. The route from the bottom is north eastwards, and once the breakdown cones are crossed the passage descends obliquely down-dip to two static sumps, reached after roughly 450 metres. A series of joint-controlled chambers in the first stretch of the Lower Series are roofed by the prominent bedding plane which controlled the development of the main passage, and this bedding plane is open over a wide area, providing a series of connections with the main passage in the entrance series.

The passage becomes lower, with many angular boulders of limestone, chert, and calcite, the final stretch to the sumps being very uncomfortable crawling. It appears that the sumps are very close to the level of the resurgence of the stream in Bradwell village. The lower part of the route is developed in very cherty limestones, some of the chert beds being thick and persistent, and having considerable bearing on the shape of the
passages. All the north eastward trending passages are developed along, or parallel to, prominent calcite veins, and the final stretch to the sumps appears to lie on the same vein as the entrance steps (Fig. 37).

The development of Bagshaw Cavern can be seen from the survey to be influenced largely by mineral veins, in particular the east-west set. The position of the New Series on the survey is slightly suspicious; the choke in Calypso's Cave is known by the establishment of voice contact to connect with that in the New Series, and they are likely to lie on the same vein. This being so, the position of the New Series in Fig. 37 has been moved a little to the north, bringing the end closely into line with the entrance. There is likely to be a connection here.

The cave appears, by plotting on the 1:2500 scale (Whitehouse, 1976) to have a close relationship with Outlands Head Quarry Cave (Fig. 35). The two westward trending passages of the New Series would probably connect with the quarry cave if pushed further.

In the absence of a modern accurate survey of the cave, any account of the relationship between Bagshaw Cavern and Bradwell Dale must be speculative. The cave levels seen in the dale cannot be definitely correlated with the two main levels seen in the cave.

The cave itself can be said to have two main levels, each of which has a deep sump at its southern end. Both sumps discharge water in wet weather, and the higher of the two parallel strike-controlled routes is still an important flood conduit. The two are connected at the southern end by the dip-tube from the Hippodrome, and at the northern end by the oblique vein-controlled Lower Series (Fig. 37).

It is tempting, therefore, to equate the level represented by Bradwell Parish Cave in the dale with the upper level of Bagshaw Cavern, and to suggest that the natural cavities in Berton Pingles Pipe, a little further south, may be contemporaneous with the development of the stream passage, which is at present so little known.
Bradwell Parish Cave.

The cave lies on the west side of Bradwell Dale at an altitude of 670 ft (204 m) A.O.D. It is a large phreatic tube with no significant vadose modification (Plate 11, 2). A considerable stream can however flow from the adjacent bedding plane on which the main tube is developed. This suggests that the stream is not overflow from Bagshaw Cavern, but is locally accumulated percolation, for the stream would otherwise surely have removed the fill of sand and clay from the tube.

The cave has been excavated for a considerable distance by the Technical Speleological Group, and is now 46 metres long. It ends where the flowstone floor almost meets the roof, but emits a strong draught. The most likely equivalent to this stage of development in Bagshaw Cavern is the main passage, and the cave may represent the continuation towards the valley of one of the large silted tubes which leave Bagshaw Cavern between the Dungeon and the Hippodrome.

Berton Pingle's Pipe.

Berton Pingle's Pipe workings are entered through a small level in a north eastward trending vein in the Bradwell Dale quarry at 1719 8053 (Fig. 35). The vein lies a little to the south of Hartle Dale Rake. At the bottom of the awkward entrance slope workings run along the pipe to the north west, roughly along the projected line of the Hazlebadge Pipe, known to the south east on the other side of the dale. A low bedding cave, with much cavern breakdown further modified by the miners, is crossed, and a level continues to the head of a shaft to water. Diving at the bottom of this shaft has revealed the presence of water filled levels and chambers (Cave Diving Group Newsletter no. 48). In one level, reported to have the appearance of a sough, a strong flow of water was encountered. It is unlikely that this is any other than the Bagshaw Cavern stream, seen here between the short stream passage at the
1) Water only flows down Bradwell Dale in flood conditions, as seen here during snow-melt floods in early 1979. A large stream originates where Earl Rake crosses the road, being forced up through holes in the road surface.

3) Bradwell Parish Cave. The tube is abandoned and silted, but the controlling bedding plane on the north side (right) may discharge local percolation water in wet weather.
southern end of the cave and the resurgence in Bradwell village. The shaft appears to lie roughly 50 - 70 metres from the downstream sump in Bagshaw Cavern.

The level continues for a short distance beyond the shaft to a collapse, and a small phreatic tube to the west emits a slight draught. It is probable that these workings are close to Bagshaw Cavern, and it is estimated that they lie roughly at the elevation of the Lower Series on the basis of the water levels.

Well Shaft.

Well Shaft lies on the west side of Bradwell Dale, at road level, at 1713 8032 (Fig. 35). The concrete cap lies at an elevation of approximately 790 ft (241 m) A.O.D. The shaft lies on a vein parallel to, and slightly to the north of, Earl Rake.

The shaft can be descended to a fluctuating water surface. In dry weather, very unstable workings can be entered at a depth of 15 m. A considerable draught can be detected at this stage, but no extensive way on has been found (Whitehouse, 1966).

In wet weather, inlets appear on bedding planes 6 metres below surface, and also in a natural rift passage which can be entered at the same level. The water in the shaft bottom begins to rise, though it is impossible that the small inlets observed are responsible for the dramatic rises in level. On 29th December 1978, and 25th March 1979, snow melt caused flooding, and water forced its way up through the tarmac where the vein crosses the road. Collapses here, observed recently from below, have been filled in by the council, and have blocked the continuation of a partly natural passage which may have carried water beneath the road. A large inflow of water must occur to create this head, and there is little doubt that it is derived from the Bagshaw Cavern stream, which under these conditions is backed right up the dip-tube at the southern
end, to overflow via the Hippodrome and the Dungeon. This area of Earl Rake was drained by Pic Tor End Sough, which is known to be blocked in at least one place, at Bradwell Hills (1753 8038; See p. 167), and the poor condition of the artificial drainage levels, together with deliberate infilling of the natural routes, may account for the overflow into the valley floor.

The bedding and joint-controlled passage 6 metres down the shaft leads both eastwards under the road, and westwards to a choke of chert and limestone blocks in a sand and clay matrix. A small inlet occurs here, which may or may not become large during floods. The way on below the road ends at the infill debris below the collapses.

Hazlebadge Cave.

Hazlebadge Cave lies on the east side of Bradwell Dale, near the southern end, a little to the south of Well Shaft at 1711 8019 (Fig. 35). Its entrance is a mine level, and a short descent a few metres inside leads into a natural rift cave. The rift runs roughly parallel to Earl Rake, and ends at a large choke of flowstone where a small stream enters. A short branch to the south from the first chamber near the entrance gradually splits and becomes too tight.

Together with the joint-controlled passages of Well Shaft, Hazlebadge Cave suggests an extensive system of open natural joints associated with Earl Rake. Cave divers have verified this by diving upstream in Bagshaw Cavern, and reached cross rifts, considering those to be close to Earl Rake. The open joints may have carried water up-dip from the sinks near the shale margin into the master conduit at an early stage. The same mechanism may operate at present, water sinking through the Eyam Limestones close to the margin, reaching the phreatic, then moving through fissures in or parallel to the veins, westwards to join strike tubes.
The Mines of Hazlebadge.

The mines of Hazlebadge, on the east side of Bradwell Dale, were not visited. Crabtree (1964) described the pipe workings, and his work suggests that a north westward trending pipe consisting of mineralised open fissures and bedding planes has been worked in several places. The Hazlebadge Pipe crosses Bradwell Dale, passing close to the workings of Berton Pingle's Pipe, which may be associated with it. The cavities intersected in the pipe workings appear to be of wholly phreatic origin, and like the pipe veins in other areas of the limestone outcrop, they appear to pre-date the development of a sub-aerial karst.

Hartle Dale Caves.

Hartle Dale and Intake Dale are tributaries of Bradwell Dale, both joining the main valley at the head of the gorge section at Hazlebadge. Intake Dale runs south westwards, and Hartle Dale drains the south flank of the anticline into the nose of which the gorge is incised.

Hartle Dale is a dry valley, but there were signs of water having flowed on the surface after the winter of 1978/9, and where rubble has been bulldozed into the valley to make a road across it, water appeared to have been ponded behind.

There are many open bedding planes and joints throughout the section of the dale from Earl Rake to Hartlemoor Farm, but only two entrances (see Hartle Dale Caves, Fig. 35) are of any size. Two further bedding caves may be penetrable, but foxes have only recently (1979) been ejected.

Fissure Cave (Plate 12, 1) lies on the south side of the valley at 1642 8033. It is of little extent, consisting of an open fissure, widening upwards, with a bedding plane roof. The fissure curves to the east, becoming too narrow, but an upward extension connects with a low
PLATE 12. The Hartle Dale Caves.

1) Fissure Cave, Hartle Dale.

2) New Cave, Hartle Dale.
tube on a higher bedding plane.

New Cave lies 30 metres to the south east of Fissure Cave on a prominent bench (Plate 12, 2). It is a phreatic tube approximately 1 m. high and 1.5 m. wide, enlarged by breakdown at the entrance to 2 m. by 2 m. The cave trends roughly at right angles to the valley. The fill was excavated by A.L.Pill (Pill, 1963), and possibly in 1872 (Pennington, 1877). Pill (1963) speculated as to exactly which cave was excavated in the 1870's, and concluded that archaeological remains may have been removed from both Fissure Cave and New Cave. Virtually all the fill has been removed, but is said to have consisted of angular limestone fragments in a matrix of sandy clay. No flowstone or other speleothems were recorded.

New Cave has a bedding plane floor, this bedding plane forming the roof of the main cavity of Fissure Cave. The higher bedding plane of Fissure Cave lies in the walls of New Cave.

Both caves lie at an elevation of approximately 905 ft (276 m) A.O.D. This is considerably less than that of 975 ft (297 m) given in "Caves of Derbyshire" (Ford & Gill, 1979). No caves were found where the valley floor lies above 950 ft (290 m) A.O.D.

Fissure Cave, lying close to and slightly below New Cave, suggests a capture point between phreatic levels, but as solution features are almost completely corroded, no flow data can be produced. Whether the fissure in the floor represents a vadose trench, or whether it is merely due to solutional widening of a joint cannot be determined for the same reason. The caves of Hartle Dale may thus be worthy of further study, possibly from an archaeological standpoint, and certainly from the point of view of the speleogenesis of the Bradwell area.

vii) Speleogenesis.

The evolution of Bradwell Dale and its cave was considered by Ford, Burek & Beck (1975). Ford (1976) showed that the
siting of the gorge of Bradwell Dale was due to the presence of the reef mounds, which had halted uniclinal shift of the early stream. The anomalous course of the gorge was determined by the reef mounds rather than in response to the eastward plunging anticline which the gorge cuts through.

At a time when the shales were still being removed from the flanks of Bradwell Moor, and even before exposure of the limestone, the earliest cavities of Long Rake and other veins on the moor were forming by deep phreatic solution. The outlets of such deep systems may be represented at the present time by warm springs such as that at Bradwell at 874 820, and the spring in a similar position relative to the shale margin at Stoney-Middleton.

It is likely that the pipe caverns (i.e., Hazlebadge and Moorfurlong) date from a very early stage in the establishment of a karst drainage system. They are mineralised cavities which have been later invaded by streams under phreatic, and sometimes vadose, conditions. Attached minerals were removed, and were redeposited as part of a cavern fill which consisted also of sandstone and shale debris derived from the receding cover. The date of such events is obscure, but it must have pre-dated the complete removal of the cover from the likely catchment area, i.e., the eastern part of Bradwell Moor.

Typical bedding plane-controlled phreatic cave systems began to form when the hydraulic gradient was sufficiently steep for there to be a significant flow. This would begin to happen as soon as limestone was exposed on the highest ground, but the mature caves are only seen below 910 ft (277 m) A.O.D., and are usually considerably less than this (600 - 700 ft / 183 - 213 m A.O.D. in Bradwell Dale). Extensive development of phreatic networks is unlikely to have occurred until the shale margin receded far enough to give a potential resurgence point in the region of 800 ft (244 m) A.O.D.
The earliest example of what appears to be part of an integrated network is probably New Cave, in Hartle Dale, lying at 905 ft (276 m) A.O.D. It is possible that the cave continues across the valley, but a search did not reveal the continuation, and the presence of a prominent valley bench associated with a knick point further to the north east suggests that the cave may have been close to a rising, although the rising may have been further down the valley, having been truncated by further incision and collapse.

As in other areas where caves are found at high altitude, there is a considerable gap between the Hartle Dale Cave level and the next series of integrated phreatic conduits (Fig. 38). There are several examples of unmodified tubes at approximately 700 ft (213 m) A.O.D. in Hazlebadge Cave, and on the east side of Bradwell Dale near Bradwell village at 174 807.

Little can be deduced regarding the morphology of the highest phreatic systems of Bradwell Dale, for they are fragmentary, and there is no locality where they can be directly genetically related to the later stages. It is likely that high level caves exist in the area of which all surface traces are obscured by screes, or which have been infilled with later fluvio-glacial debris. The lack of significant vadose features in the highest series in Hartle Dale suggests either a rising as high as 900 ft (274 m) A.O.D., or a locally perched phreatic system in which the water was dammed by structural features such as the large east-west veins.

No caves at the 700 ft (213 m) A.O.D. level are seen on the west side of Bradwell Dale. It may be that to the west of the valley there are strike tubes of which we know nothing, and that the main upper passage of Bagshaw Cavern carried water from an early stage, being fed by down-dip flow from the west in tubes such as those of Outlands Head Quarry Cave. It is assumed that Bradwell Parish Cave and the upper passages of Bagshaw Cavern are contemporaneous, and that they represent
THE CAVE LEVELS OF BRADWELL DALE.

Fig. 38
the third phreatic network to develop in the Bradwell area. On the east side of the road lies Walker's Grotto, a large rift chamber to which access is gained via a short passage close to road level. It lies almost opposite to Bradwell Parish Cave, at a slightly lower elevation. Water has been known to back up into the bottom of the chamber in flood, and it is possible that this again results from backing up of the main Bagshaw Cavern stream. The affinity of the rift is in some doubt; there is no associated mature tube which can be correlated with a distinct cave level.

During the third stage of cave formation in the Bradwell area, it appears that the prominent south west - north east trending calcite veins provided preferred channels for the flow, and instead of the passage plan of Bagshaw Cavern indicating flow round the nose of the east - west anticline, passages now began to cut across the nose.

Outlands Head Quarry Cave and the westward trending passages of Bagshaw Cavern appear to constitute a strike and dip-tube system on the north flank of the eastward plunging anticline, carrying water eastwards to join the main conduits where northward flow was caused by the larger veins. These passages have been abandoned in favour of lower routes, and appear to be unmodified phreatic tubes, apart from very small trenches incised by percolation trickles.

The evidence of water flow and levels in Berton Pingle's Pipe, Walker's Grotto, and Bagshaw Cavern suggests that the present route, which remains largely unknown, passes round the nose of the anticline to the east. The veins have been breached, and a lower route has been established further down the dip slope. This route appears to have responded to the anticlinal structure, following the strike, while the earlier routes cut across the structure in response either to the presence of the reef mounds, or to veins which acted as breakwaters. To the south, virtually nothing is known about the present day routes,
but it is likely that dip-tubes exist at the horizon of the Lower and Upper Millers Dale Lava where these lie above the altitude of the barriers at the northern end of the system. These tubes carry water eastwards to the north-south master conduits which discharge into the upstream (southern) end of Bagshaw Cavern. That vadose cavities exist to the south is certain, for there is a drop in the order of 350 ft (107 m) between the lowest point in Duce Hole, the most distant swallet, and the southern end of Bagshaw Cavern.

The picture in the Bradwell area is very incomplete. A great deal more cave passage must await discovery in the large Bradwell catchment area, but the possibilities of entering new ground seem rather remote. It is possible that excavation of the rather juvenile swallets of Bradwell Edge, or the small abandoned caves in Bradwell Dale, may yield results in the future.
Chapter 6.

THE MONYASH BASIN AND LATHKILL DALE.
6) THE MONYASH BASIN AND LATHKILL DALE.

1) Previous Research and Exploration.

The Lathkill area has perhaps received less attention from cavers than it deserves, partly due to its relative inaccessibility, and partly due to the rarity with which the major system of the area, Lathkill Head Cave (Figs. 40 & 41) is dry enough for exploration. However, in the past 60 years a considerable amount of exploration has been carried out, and the outlines of the underground drainage pattern are now understood.

Bamber (1951) drew attention to some of the problems of the drainage of the Monyash Basin, and made suggestions for further work. Some of these suggestions were followed up with useful results. Progress, however, remained very slow.

In 1959, Eccles Caving Club re-opened Knotlow Mine, now known to be in fact Chapel Dale Mine (Robey, 1961). They revealed the only known active part of the system to the north west of Monyash. The water in Knotlow Mine was turned into a natural swallow (Crimbo Swallow), but attempts to push on towards Lathkill Dale from here have met with little success, and it is unlikely that significant progress could ever be made.

Lathkill Head Cave began to receive attention from the Eldon Pothole Club in the dry summer of 1965, and a breakthrough was made into new ground beyond 'Puttrell's Chamber'. The cave was surveyed as far as Fan Chamber, and high water conditions then put an end to further work until 1969, when the survey was continued up to Handshake Chamber (Gasson, 1970). A parallel route to Handshake Chamber, Gasson Passage, was not surveyed until the severe drought of 1976.

A continuation beyond Handshake Chamber was discovered by the Orpheus Caving Club in 1973, but an accurate survey of this section was not produced until 1977, when, surprisingly, for it was a wet summer,
the cave again totally dried out. The aven at the end of 'Gloop Canal' remains the limit of exploration, for the weather broke too early.

Lower Cales Dale Cave, representing the outlet of a separate drainage system, although apparently connected with Lathkill Head Cave, was surveyed by the Eldon Pothole Club (Westlake, 1972) as far as Figures of Eight Chamber, a total distance of 145 metres. It appears to have received little further attention until 1976, when in the course of this study its exploration was pushed in drought for a further 396 metres through normally flooded passages to a large passage which ended at a strongly draughting boulder choke. The extension was surveyed. Digging further was a good prospect, but the cave flooded, putting an end to further work. In 1977, K. Bottoms and T. Jackson again reached this point, but it proved to be a long job, and no further progress was made.

During the same period, members of Eldon Pothole Club explored the 150 metre long Dawkes Crawl, a small southward extension of Lathkill Head Cave. This ended at a boulder choke, which was passed in 1977, but the continuing tube became very tight.

Water Icicle Close Cavern (Fig. 40) was discovered by the Peak District Mines Historical Society in 1968. The cavern was unexpected, and its existence suggests that there may be an extensive high level cave system, at least in the southern part of the catchment area. The cave was surveyed by the Eldon Pothole Club (Westlake, 1970).

Archaeological excavations have been carried out in a number of the high level caves which open into the south side of Lathkill Dale and the west side of Cales Dale. They have been described by Pennington (1875), Storrs-Fox (1906), and Jackson & Storrs-Fox (1913).

ii) Topographic and Geological Setting.

The catchment area of the River Lathkill is centrally placed in the limestone outcrop, and is the most
southerly catchment to be considered. It is estimated on the basis of structure that the catchment occupies an area of about 16 km², of which virtually all is limestone apart from a small shale outlier, and small lava outcrops (Fig. 39). There are thus no allogenic swallet feeders to the underground drainage system, and the discharge of the Lathkill / Cales Dale cave system is entirely composed of accumulated percolation water.

The village of Monyash lies roughly in the centre of a large structural basin, similar in its mode of drainage to the Wardlow Basin further north. It is also similar in that the topography mirrors the underlying structure, and that there is a small shale outlier in the centre, although in the case of the Monyash Basin, this is not large enough for the provision of allogenic recharge of the underground drainage system.

The catchment area is bounded to the west and north west by the outcrop of the Upper Millers Dale Lava, but the area adjacent to the inner margin of this outcrop is drained by small springs round the escarpments of Chelmorton Low, Calton Hill, and Priestcliff Low. These are in the main small, and represent the discharge of very local perched groundwater. The springs generally occur at the top of the lava (Stevens, 1929).

To the south lies the watershed between the catchments of the River Derwent (to which the Lathkill drains eastwards), and the River Dove, to the south west. The precise position of the watershed is indeterminate, but is likely to correspond roughly with the surface watershed, which in turn reflects the structure of the southern rim of the Monyash Basin.

Lathkill Dale begins as a dry valley network in the area of the central basin (Fig. 3). The valleys coalesce, and to the east of Monyash the dale becomes progressively more incised until it is bounded by undercut cliffs of Monsal Dale Beds. On the high ground to the north and south are outliers of Eyam Limestones (Cawdor Group of Shirley, 1959); they are of little extent, the Eyam limestones being more extensively exposed to the north and west.
The valley follows the long axis of the basin (from west north west to east south east) for some distance before cutting through the eastern rim at a low saddle in the structure, which brings lava to outcrop in the valley floor for a short distance near Over Haddon. For nearly five kilometres west of Over Haddon the valley is deeply incised, with high cliffs below which extensive frost screes mask any cave entrances.

It appears that in the past, the River Lathkill may have had its source much further to the west, possibly even beyond Monyash (Bamber, 1951), but the entrance to Lathkill Head Cave (1707 6588; Plate 13, 1) now represents the highest point from which a large stream flows, even in flood conditions (Fig. 40). In lower water conditions, water rises from a series of narrow open bedding planes over a distance of 500 metres between Lathkill Head Cave and Cales Dale, a prominent southern tributary valley. Cales Dale dies out in the region immediately to the north of Long Rake, an important east-west vein which appears to roughly delimit the catchment boundary in this area. Cales Dale is a dry valley, except for the last few metres down to the confluence, where a wet weather stream from Lower Cales Dale cave flows to join the main river.

The gradually accumulating stream can be followed for nearly a kilometre downstream until, by now a river of considerable size in the winter months, it plunges over a tufa dam. In drought, the Lathkill Resurgence Cave, developed entirely in tufa, can be followed from the base of the waterfall for a distance of 90 metres beneath the river bed.

The river is further augmented at Over Haddon by the discharge of the Lathkill Dale Sough, and the bedding plane risings of Bubble Springs. The latter did not completely dry up even during the severe drought of 1975/6, but the river is quite frequently dry to the west of this point, especially in summer. The Lathkill Dale Sough runs for some distance below the river bed, and water from small springs, such as those at
Carters Mill (182 657) soon disappear into the valley floor, almost
certainly sinking into the sough.

The River Lathkill joins the River Bradford at Alport, and the
combined streams join the River Wye 1.5 kilometres west of the confluence
with the River Derwent at Rowsley.

iii) The Active Cave Systems.

Lathkill Head Cave.

Lathkill Head Cave entrance lies on the south side of
Lathkill Dale, 0.5 km north west of the confluence with Cales Dale, at
1707 6588, at an altitude of 680 ft (207 m) A.O.D. It is a large
entrance, but in origin the passage appears to be a wide low bedding-
controlled tube, enlarged by subsequent collapse of a large roof span,
with consequent upward migration of the cavity. The cave discharges a
large stream in flood conditions (Plate 13, 1) and may often be flooded
a short distance inside. In drier weather it is possible to crawl in
for 50 metres to a rift chamber, thence down through boulders to a
lower bedding plane, to join the main passage at what appears to be a
wide sweeping bend, the stream, when present, flowing from right to
left.

The main passage is a wide low phreatic tube (Plate 13, 2) produced
by solutional enlargement of a single prominent bedding plane. Close
examination of the scalloping in this region shows that what appears to
be the 'downstream' passage under low water conditions must in fact
carry water towards the entrance when the phreatic regime is re-established
in the winter months. Direct observation is impossible, but the stream
which flows under vadose conditions in dry weather is thought to leave by
a very small passage trending southwards, Dawkes Crawl, which becomes
too tight to follow after 152 metres. When the passage is accessible,
the phreatic flow direction can clearly be seen to be southwards, towards
PLATE 13.

1. See following page for explanation.

2) The "downstream passage" in Laxmidik Hedc cave in dry

3) One of the large phreatic tubes of water-iricle Close
Explanation to Plate 13.

1) The entrance to Lathkill Head Cave, the source of the River Lathkill in wet weather. It is believed that the cave discharged a permanent stream until the driving of the major soughs such as Magpie Sough during the 19th century (Bamber, 1951).

2) The "downstream passage" in Lathkill Head cave in dry weather. The scalloping in this passage indicates flow towards the observer, and this may be the case in wet weather. The trench on the right of the picture appears to be freshly cut through the sand each time the cave drains, and carries a free flowing stream in the opposite direction.

3) One of the large phreatic tubes of Water Icicle Close Cavern, at approximately 1000 ft (305 m) A.O.D.
LATHKILL HEAD AND LOWER CALES DALE CAVES
After E.P.C. and T.S.G. surveys

Key:
- Cave passage
- Surface stream
- Upper cliff line
- Axis of syncline
- Phreatic flow
- Opposite observed flow

0 100 200 metres
the limit of exploration in the nearby Lower Cales Dale Cave (Fig. 41).

Followed westwards, the passage is soon completely blocked by roof breakdown, but a pothole in the roof can be climbed, and a way found over the fallen blocks. A chamber ('Puttrell's Chamber') has developed here by upward migration of a cavity with a large unsupported span of roof. It is possible to crawl through very tight squeezes to reach the end of the 'downstream' passage from here. The scalloping was not followed through, but it is possible that in high water conditions, when the stream flows from the entrance, water flows through this collapse to arrive at the bottom of the climb to the entrance passage by two routes.

The main route can again be entered by crawling through a series of narrow descending slots beyond Puttrell's Chamber. It is here up to 15 metres wide, but often only 0.5 metre high, continuing on the same bedding plane as before. The floor is sharply scalloped, which gives the passage the name of 'Tiger Passage'. Tiger Passage ends at a chamber of surprising size, Bridge Chamber, which is shortly followed by Fan Chamber. It can be seen from the survey (Fig. 41) that the passage bends sharply through an 'S' before resuming its original direction. This appears to have led to an increase in height and reduction in width by upward development on joints parallel to the overall flow direction. Cavern breakdown has again contributed to the increased size.

Tiger Two follows, again wide, low, and heavily scalloped. A junction is reached, and both branches are narrower and lower, reuniting after 150 metres at the large boulder choke in Handshake Chamber. The majority of the draught emerges from the choke, and it is likely that the main passage will continue beyond the choke, very similar in nature.

Just before Handshake Chamber, a branch leaves the more northerly loop, Gasson Passage, and continues westwards (Fig. 41). It is known as Gloop Canal, and leads to a high joint-controlled aven down which a small stream falls, even in severe drought. The water maintains the
level in the canal, which stabilises, when the rest of the cave dries out, with a minimum air space of about 25 cms. The canal is thus independant of the fluctuating local water table of the region, which must drop considerably below the known cave during drought.

Passages at the top of the aven were found to be blocked either with clay or gravel banks, but it appears that a large stream may enter the cave here. There is no vadose incision of the floor of the chamber surrounding the top of the aven, but an upward continuation, which penetrates a prominent shell bed, is heavily fluted. It thus appears that the normal water level when the Lathkill is flowing from the cave entrance lies at the top of the 'Surprise Aven'.

Gloop Canal does not carry the main stream. The scallops between the aven and the junction with Gasson Passage are large, suggesting a flow of low velocity. Were the entire Lathkill stream to occupy this tube, the scallops would be tiny and shallow. In the main passage the scalloping indicates a strong flow past the end of Gloop Canal, away from the Handshake Chamber boulder choke. In the choke, the scalloping is confused, but in the south branch (Tiger 3) it is again away from the choke. The main inlet therefore lies in the Handshake Chamber choke.

The western end of the cave, at the top of Surprise Aven (Fig.41) is roughly 150 metres short of Ricklow Cave, a series of phreatic tubes at a higher level which now carries a small percolation stream in wet weather. It is expected that further digging here might give access to the westward continuation of the main Lathkill Head system.

The downstream limit of exploration in Lathkill Head Cave, at the south end of Dawkes Crawl (Fig. 41) lies roughly 150 metres short of the upstream limit in nearby Lower Cales Dale Cave. The crawl is thought to act as an overflow between two essentially separate drainage systems, and further work here might connect the two caves.
Lower Cales Dale Cave.

Lower Cales Dale Cave entrance lies immediately below the footpath up Cales Dale, 150 metres from the confluence with Lathkill Dale, at 1738 6539, at an altitude of 650 ft (198 m) A.O.D. (Fig. 40). Two entrances, one blocked with boulders, unite within to form a phreatic passage 1 m. high and from 2 to 2.5 m. wide. This leads after 61 metres to a chamber, from which passages lead north and south. That to the north ends shortly at a calcite choke from which a strong draught issues in hot weather. That to the south (left) leads over large fallen blocks to a second chamber. A tube leads westwards from here to a third chamber, where a climb up one wall leads to a well decorated grotto. A strong draught again enters.

A climb down through boulders in the floor of the second chamber leads into the continuation of the main route, and a fourth chamber can soon be reached by a slippery climb. At the base of the climb, a squeeze leads to what is normally the terminal sump.

In the drought of 1976 the sump was found to be dry, and the cave was explored for a further 396 metres. The main tube led southwards to a choke, beyond which the going became harder until a final dangerous choke was reached. A draught again entered. The southward trending passage appears to supply part of the water which flows from the entrance in wet weather, and is strike oriented, running parallel to the axis of a small subsidiary syncline up Cales Dale (Fig. 41). It is unlikely that this route could ever be followed further from here with safety, but since it runs parallel to the valley, it is likely that entry might be gained further south, up Cales Dale.

A small north westward trending branch, just beyond the normal limit of exploration, was followed for 90 metres to a joint-controlled chamber. Over the first stretch, the tube averaged 0.6 m. in diameter, often further reduced by silting, becoming slightly larger towards the
north west. Digging beyond the chamber revealed a wide low passage, with wide impenetrable branches on the north side. Beyond each branch the passage increased in size until it was a tube 1 m. high and up to 2 m. wide. A 'T' junction was reached, and the passage beyond increased in size to 1.5 x 2 m. The right hand passage was silted, but the left hand route was followed for a short distance to a dangerous choke (Fig.41). The choke draughted very strongly. In October 1977, K. Bottoms and T. Jackson again reached the choke, but were unable to pass it due to lack of time to work, and general instability. Water levels were again rising.

It is thought that under the normal phreatic conditions the northward branches of the main passage (Friday the Thirteenth Passage) take some of the flow from the main route, discharging via the impenetrable bedding planes between Lathkill Head Cave and Cales Dale. Thus, downstream from each branch, the pressure is somewhat relieved, and the passage is smaller. Only in very wet weather does water actually reach Lower Cales Dale Cave entrance. It might have been expected that the routes to the bedding plane risings would have been preferentially enlarged; the fact that they have not suggests that the valley floor has only been incised below that horizon at that point since the trunk routes first became established.

It has often been assumed that the water rising from the bedding planes represents the ultimate destination of the stream seen to flow through Lathkill Head Cave under epiphreatic conditions in fairly dry weather. However, the size of the known downstream passage in Lathkill Head Cave (Dawkes Crawl, Fig. 41) is in no way compatible with that at the upstream end of Lower Cales Dale Cave. They lie on the same prominent bedding plane, both draught outwards in drought, and they undoubtedly connect, but the passage of a large volume of water from one cave to the other during flood is impossible; a pencil, and a length of cable laid on the side of Dawkes Crawl were not displaced during the exceptionally
wet February of 1977. The bulk of the flow out of Lower Cales Dale Cave, and thus also from the bedding plane risings, must originate from an unknown feeder system running sub-parallel with Lathkill Head Cave, but further to the south. The outward draught of both caves suggests the existence of an interesting system between the two exploration limits. That there is a hydrological connection between the caves is proved by the fragments of shredded wetsuits found at the upstream limit of Lower Cales Dale Cave during the first exploration in 1976.

Knotlow Mine.

The climbing shaft of Knotlow Mine lies at 1438 6 739, north west of Monyash, at an altitude of 960 ft (292.6 m) A.O.D. The mine consists of extensive workings in both veins and pipes, which have intersected a series of natural karst cavities, some of which are bedding controlled phreatic tubes, and which carry a large stream in wet weather (Fig. 42). Dye testing by Westlake (1966) has shown that the water sinking into the Crimbo Swallow of Knotlow Mine reappears at the Lathkill Head rising in Lathkill Dale.

The climbing shaft of Knotlow passes through Cawdor Beds (Eyam Limestones), the base of which is reached at the head of the second pitch, at a depth of 18 metres. A series of mineralised natural cavities trending from north west to south east (Whalf Pipe; Robey, 1963) have been excavated by the miner, and can be followed for some distance to 'The Bung', a squeeze beyond which little attached mineral remains, the passages being typical bedding - controlled phreatic tubes.

The Bung Series can be followed to north and south. To the north, a series of joint - controlled cavities are reached, and higher bedding planes have significant bedding - controlled tubes developed along them. The stream can be heard at a lower level, and at one point has been reached, but could not be followed (Westlake, 1970). To the south, the
NATURAL PASSAGES IN KNOTLOW MINE.
(Excluding mineralised cavities in the Whalf and Crimbo Pipes)

Extended section after Deakin, 1969.

Vertical range of Upper Cales Dale Complex in Lathkill Dale (770 ft - 800 ft/235 m - 244 m)

Eldon Chamber

Crimbo Pipe

Crimbo Swallow

Steeply descending vein cavity system.
Explored in 1975 drought.

--- Elevation of risings below Lathkill Head Cave (670 ft/204 m A.O.D.)

normal water level

bedding controlled phreatic tubes

connections with workings in Whalf Pipe

Fig. 42
tube shortly ends at a tight pothole in the floor of a tiny passage. This was descended with difficulty during the 1975 drought to a chamber from which several passages radiated. These all became impenetrable after a short distance due to banks of gravel, but appear to be the major inlets to the system in wet weather. Westlake (1970) reports the fissure as going down to water, and it appears that the water level is generally above the roof level of the chamber. In the chamber is a choke, through which voice contact was established with the cavities in Whalf Pipe (Fig. 42), at a point where water flows out into the workings in wet weather. This water is thence conducted down the Waterfall Pitch, and flows through coffin levels north eastwards to the Crimbo Swallow. It appears that the stream in the Lower Bung Series also represents overflow from the flooded chamber, and reaches Crimbo Swallow via a mainly natural route, reappearing from an impenetrable slit in the roof of the workings on Crimbo Pipe (Fig. 42). Crimbo Pipe lies to the north east of, and parallel to, Whalf Pipe.

The natural system in Knotlow is roughly strike oriented, with a slight down-dip component. Where the direction of flow corresponds with the orientation of a mineral vein, as has happened in the case of the Crimbo Swallow, the route is still predominantly bedding controlled, but in some places the bedding passage has been abandoned, and the water now falls down a pitch, passing through a sump in vein cavities for some distance (as between Eldon and Aussie Chambers in the Swallow). Phreatic vein cavities above the level of the bedding controlled passage can be inspected above the water level in both chambers of the Swallow, but little progress can be made along them due to their clay fill.

During the 1975 drought, inspection of the sump at Aussie Chamber, the limit of exploration in the Swallow, revealed a series of descending phreatic vein cavities in which the water level had dropped some 15 metres below normal. No sign of horizontal passage was seen at the bottom, and
it is still unknown to what depth the route plunges between here and the Lathkill Dale risings. The normal water level in the Crimbo Swallow appears to lie at roughly 700 ft (213 m) A.O.D. (Westlake, 1970), which suggests a fall of only 10 - 12 metres to the bedding plane risings below Lathkill Head Cave.

The relationship of Knotlow Mine to the Lathkill Head system suggests that there are now lower routes, very juvenile in character, which are only capable of taking the entire flow during periods of extreme drought. Whether these exist at lower stratigraphic horizons, or whether they are down-dip extensions of the main bedding controlled cavities of the Lathkill / Cales Dale system is impossible to tell; future work should be directed at determining the destination of this water during drought. The farthest likely point for detection of tracers placed in the Crimbo Swallow in drought is Over Haddon, for to the east of this point the lava outcrop keeps the drainage on the surface throughout.

The underground drainage is still adjusting to the latest fall in the local base level. The lowest conduits are yet immature, and it is possible that only due to the extensive use of sough drainage is it possible to explore any of the active system.

Critchlow Cave.

The small entrance to Critchlow Cave lies almost opposite Lathkill Head Cave, slightly to the east (Fig. 40), and slightly higher above the valley floor. It appears to lie at almost the same horizon as the entrance passage to Lathkill Head Cave. The cave was first explored by Eccles Caving Club, who produced a survey (D.C.A.Newsletter No. 8). It was apparent that the cave had discharged a large stream following the snow-melt floods of the 1979 winter, but this is rare. A small spring operates a short distance to the west of the entrance, and may discharge more water than is at first apparent; its flow is lost in the large stream discharged by Lathkill Head Cave. There is evidence inside the
cave of a wet weather stream which sinks in the floor, and during the summer of 1977 the strong draught which blew from the entrance ceased within a few days of the onset of heavy rain, suggesting that the route had flooded somewhere within.

Critchlow Cave is likely to represent a separate drainage system, which carries percolation water down-dip on the north flank of the syncline into the axial region, to discharge into the valley first by the known entrance, and then by the small spring following further incision of the valley floor. Cavers appear to have considered that it represents an early downstream continuation of Lathkill Head Cave, but this seems unlikely; it is more probable that the two routes united underground, to discharge the combined stream at one large rising further to the east. They have now been dissected by downcutting of the valley.

iv) The Abandoned Cave Systems.

There are a great many fragments of remnant cave systems in the Monyash area. The most complete sequence is seen on the flanks of Cales Dale (Fig. 44), and to a lesser extent on the south side of Lathkill Dale. There are very many small phreatic caves, not all of which are penetrable, at various horizons and elevations. The abandoned caves are almost all associated with remnant benches, and it is tempting to assume a relationship with earlier valley floors. This area of the Lathkill drainage basin is untouched by quarrying, which has destroyed much of the evidence in dales such as Stoney Middleton Dale and Bradwell Dale. Mining has been carried out on a large scale further to the north and east, but its effect on surface features in the important areas is fairly slight. The highest remnants lie at approximately 1,000 ft (305 m) A.O.D.

Many of the mines of the area intersected natural cave passages, generally of limited extent, but of value in building an overall picture.
Water Icicle Close Cavern.

The cave is entered by a 32 metre deep mine shaft at 1610 6460 (Fig. 40). The shaft top lies at 1,109 ft (338 m) A.O.D., and the cave system at the shaft bottom lies at 1,005 ft (306 m) A.O.D. The shaft is sunk through solid limestone, does not follow a vein, and is dressed by pick axe. It intersects the natural passage at the highest point of a chamber at the junction of three large phreatic tubes (Fig. 43), which makes it unthinkable that the miners did not already know of the cave (Smith, 1968). It has been surmised that the miners sank the shaft in order to remove the flowstone for ornamental purposes, having first intersected the cave through workings in a vein to the south of the present entrance shaft.

The limestones here are almost horizontal, and the cave shows no 'main passage'. The three radiating tubes appear to be of similar importance, representing part of a phreatic network through which water flowed with a very low hydraulic gradient. The flow features are either covered by flowstone, or they are indeterminate, and those that can be seen indicate relatively low velocity flow.

The extent of the fill is uncertain, for nowhere has a complete cross section been excavated. The fill is fine-grained crumbly brown sand and clay, almost everywhere covered with flowstone except in the North Passage (Fig. 43) where it eventually completely fills the tube. Attempts have been made to excavate the continuation here, but have met with no success. A profile drawn through the shaft and the hillside to the north (Fig. 43) indicates that if projected for 300 metres, the tube will reach the surface at a point where there is a pronounced depression at the head of a barely discernible dry valley heading down towards One Ash Grange and Cales Dale. It might thus be suggested that the North Passage represents the 'downstream' direction, but this can only be a tentative conclusion.
WATER ICICLE CLOSE CAVERN,
SURFACE RELATED PLAN AND PROFILE.
After an Eldon Pothole Club survey.

Fig. 43
Further digging in the cavern may reveal more passage, with a consequently increased understanding of the nature of the early drainage of the central limestone area. At present, the North Passage is blocked by a silt choke, and offers little hope of extension, especially in view of the extensive cavern collapse which undoubtedly occurs between the choke and the old exit to the hillside. The North West Passage has been dug over a long period by the Orpheus Caving Club, but cavern collapse has so far baulked all attempts to push further here. The South Passage leads to a mined area in a small mineral vein, and it is here that the miners originally seem to have gained access. The stopes were excavated by the Technical Speleological Group in 1975, and it was found that the passage did not continue straight across the vein as expected. It turns to the east, and further large scale excavation will be necessary to reveal the continuation.

The cave is clearly a very old feature, and must pre-date the deep excavation of any of the valleys in the near vicinity. It cannot be genetically related to any lower levels, or to the active system, since it is as yet seen in total isolation. In order for a phreatic system to operate at this altitude, it is necessary to postulate a local base level standing at around 1000 ft (305 m) A.O.D. The question then arises as to whether Quaternary surface lowering and valley incision could account for such a degree of modification.

Features East of Cales Dale.

To the east of Cales Dale, just below the 1000 ft contour, a small phreatic cave is found at the base of a scar. Again, the phreatic operation of this cave requires the existence of a very high valley floor, and the co-incidence of elevation with Water Icicle Close Cavern suggests that a phreatic network of considerable extent operated at this horizon. The postulated network is referred to as the Water Icicle Complex.
fragment referred to here is of little extent, and is blocked by flowstone.

The Upper Cales Dale Complex.

Both in Cales Dale and in the area of Lathkill Dale between Lathkill Head Cave and the confluence with Cales Dale, there are many phreatic caves at the base of the highest line of cliffs (Fig. 44). They lie between 770 ft (235 m) and 800 ft (244 m) A.O.D. Most are of little extent, but their proximity to the active caves suggests that access might be gained to the further reaches of the lower caves during wet weather by excavation. These tubes all appear to be related to a prominent bench, and constitute a well defined complex when considered as a whole. The most extensive is Upper Cales Dale Cave (1732 6542), which lies directly above Lower Cales Dale Cave entrance. It consists of a branching phreatic tube, which is blocked by clay and flowstone after a total of some 60 metres.

Lynx Cave (Storrs-Fox, 1906) lies beyond the branch to One Ash Grange, 3 metres above the level of the valley floor, at 1723 6509 (Figs. 40 & 44). It yielded many bones, most of which were those of Lynx, from the fill of soft brown loam, which is often covered with a layer of decomposed flowstone.

One Ash Cave is a little further to the south, at a slightly higher elevation. It lies on a distinct bench, which Lynx Cave lies a little below. Lynx Cave is less well defined as a cave level, and its rapidly changing passage profile, lack of a prominent controlling bedding plane, and strange series of three entrances, suggests development under phreatic conditions with no subsequent modification. The proximity of the end of the cave to One Ash Cave suggests that it may be a later outlet for water flowing in the higher cave.

Other small unnamed tubes may be found at almost the same elevation
THE CAVE LEVELS OF LATHKILL DALE AND CALES DALE:

Key to valley floor profiles:

- Lathkill Dale
- Cales Dale
- Cales Dale (hanging south west branch)

Fig. 44
in Lathkill Dale and in the south west branch of Cales Dale, but none are penetrable without excavation.

In Raven Mine (1609 6590) and Cascade Cavern (1574 6638) phreatic passages are found at an elevation of between 780 and 790 ft (238 to 241 m.) A.O.D. (Gee, 1957). One natural passage in Cascade Cavern still carries a small percolation stream, which sinks into boulders and is thought to rise at Lathkill Head.

Ricklow Cave is entered via a small mine level (Fig. 40) on the north side of Lathkill Dale at 1636 6607). The short level leads to a 4 metre scramble down a natural aven which lies over an 'S' bend in a small phreatic tube. To the west, the tube is soon silted, but it can be followed for a short distance eastwards to the head of a climb of 3 metres down an open joint. At roof level in this chamber, three passages radiate, but all soon close down with loose rock and flowstone barring the way. An excavation carried out in the boulders at floor level exposed a very narrow rift continuing down, but this became too tight. A strong outward draught during the 1976 drought suggested a connection with the Lathkill Head system, the westward continuation of which ought to pass close beneath. A percolation inlet in the entrance rift may become a considerable stream in wet weather, and the stream sinks into the westward trending passage.

The tubes of Ricklow Cave lie at approximately 730 ft (223 m) A.O.D., and it is likely that a lower series of tubes lie at the bottom of the joint chamber, at around 710 ft (216 m) A.O.D. This is still some way above the passages at the top of Surprise Aven in Lathkill Head Cave (Fig. 41), and the immaturity of the tubes suggests an intermediate stage during lowering of the main drainage route from the Upper Cales Dale Complex level down to the present Lathkill Head / Lower Cales Dale cave system. It is possible that further excavation in Ricklow Cave could yield worthwhile results.
v) Speleogenesis.

It is clear that there are at least three distinct cave levels in the area, all of which are related directly to early local base levels controlled by the elevation of the River Lathkill. Incision of the valley to its present depth has progressively lowered the water table in the area of the central basin, with consequent development of successive cave systems at lower and lower levels.

The earliest cavities are undoubtedly represented by the sediment filled, joint-controlled chambers and fissures intersected in the mines of the area, particularly on the north flank of the basin, such as Magpie Mine, Mandale Mine, and Hubberdale Mine. As in the case of Watergrove Mine (see p. 69), it is difficult to determine their history, but very early deep phreatic circulation, possibly beneath an impervious cover, may have been responsible for their initiation. There appears to have been little subsequent modification by meteoric percolation water, but at some stage the cavities have been filled with what appears to be periglacial sediment, with accumulations of disaggregated fluorspar, and in some cases valuable concentrations of galena.

The earliest drainage network which can be related to the dry valley system is clearly the Water Icicle Complex (Fig. 43), lying just above 1000 ft (305 m) A.O.D. Development of such a system must have occurred under very different conditions from those prevailing at the present time. It is likely that allogenic streams accumulating on an impervious cover were responsible. If the shale outlier of the central basin, now almost completely removed, were large enough for the provision of integrated allogenic streams, then just such a cave system as Water Icicle Close Cavern would be expected. No corresponding system is known on the north flank of the basin, but since Water Icicle Close itself was discovered by chance, and showed no sign of its presence, this is perhaps not surprising.
The extensive fill of breakdown, clay, and flowstone makes it impossible to determine the nature of the later stages of operation of the Water Icicle Complex; it is not known whether any vadose incision took place. The passages appear to be unmodified phreatic tubes, and if this is the case, it is likely that the outlet lay at around 1000 ft (305 m) A.O.D. The shallow dry valley trending towards One Ash Grange from the area of Water Icicle Close may have been the site for this outlet, and initiation of this valley may have occurred at this time, later collapse of the downstream sections of the cave assisting in its development. The valley dies out once the cave is more than 15 metres below the surface; collapse has not occurred to this depth.

The fragment of the Water Icicle Complex seen on the east side of Cales Dale contributes little. It is unlikely to be a part of the same drainage system as Water Icicle Close itself, for if we assume Lathkill Dale to be a superimposed valley, then it is likely that a valley intervened at the time of operation of the Water Icicle Complex, between the phreatic network draining the south flank of the basin, and any drainage system which drained the area around Calling Low, to the east. This small cave is therefore likely to be part of a separate system, possibly draining down dip on the east flank of the shallow Cales Dale syncline, and discharging into the valley at around 1000 ft (305 m) A.O.D.

The Upper Cales Dale Complex, although more extensively seen, consists of a series of caves with much smaller passages than its fore-runner. It is likely that by the time the valley was sufficiently incised for the outlets of the phreatic systems to lie below 800 ft (244 m) A.O.D., a great deal of the impervious cover had been removed, with consequent decrease of an allogenic catchment area with high relief. In contrast to the Water Icicle Complex, the Upper Cales Dale Complex foreshadows the recent Lathkill Head Complex in its orientation and the position of its outlets. It was fed principally by accumulated percolation water
from an area similar to that drained by the present cave system, that is, the central and southern parts of the Monyash Basin.

The Upper Cales Dale Complex almost invariably shows a relationship with a prominent bench on the valley side (Fig. 44), certainly close to the outlet level of the system.

The progression of drainage from the Upper Cales Dale Complex to the Lathkill Head Complex may have been one of continuous downcutting. The lower cave owes its stratigraphic position to the presence of a series of prominent bedding planes, with frequent shell beds, and possibly originally clay wayboards. The relatively high primary porosity of such fossil beds facilitates and localises the development of the early system of anastomosing tubes which eventually develops into an integrated phreatic drainage system.

In Knotlow Mine, we see passages at the elevation of the Upper Cales Dale Complex which are still active, in the Bung Series (Fig. 42). These phreatic passages show little sign of vadose modification, and lie at around 800 ft (244 m) A.O.D. The stream sinks to the lower level of the Crimbo Swallow, which carries water down to a sump only a few metres above the level of the present risings via vein cavities in Crimbo Pipe. There are phreatic vein cavities in Eldon Chamber, in the swallow, which are unlikely to flood now, at a similar elevation to the tubes of the Bung Series. The system shows the gradual process of capture of the stream by the lower system, the higher bedding plane passages being active further upstream. Again, the close association between the two levels suggests a similar regime in each case.

The position of the earlier risings is not clear, for apart from the low saddle in the structure just to the east of Cales Dale, there is no evidence that any impediment to the development of underground flow existed. It appears that at present, the saddle determines the position of the risings.
The Lathkill Head Complex developed in response to lowering of the valley floor, utilising bedding planes which lay a short distance below that valley floor level due to their susceptibility to enlargement. Two, or possibly three major conduits led water to the risings, connecting passages such as Dawkes Crawl (see p.197) acting as overflow channels between the main trunk routes.

Later lowering exposed the main bedding plane in the valley side, and small springs developed, draining parts of the phreatic network, and allowing streams to flow under vadose conditions in dry weather. The frequency with which this now occurs is largely due to interference by the miners, but would have been possible before, especially in those passages which trend southwards (up-dip) from the main cave (such as Friday the Thirteenth Passage; Fig. 41).

In dry weather, inlets to the Lathkill Head/Cales Dale system which continue to flow can be seen to sink into the cave floor. This water is not seen again in the vicinity, and may flow through developing lower conduits, to rise further to the east. The lead miners modification of the underground drainage of the eastern part of the area makes it impossible to say where this water would appear under natural conditions. A small trickle which first makes its appearance at Carters Mill Pond (183 656) sinks almost immediately, presumably into the Lathkill Dale Sough which was driven beneath the valley floor downstream of this point. The sough discharges near Over Haddon, where a lava outcrops in the valley floor and prevents any underground development further east. The drainage is thus on the surface under all conditions to the east of this point. The maturity of the lowest phreatic system is unknown; it is likely to be very juvenile in character, and no penetrable cavities have been found below the Lathkill Head/Cales Dale system.

The last stage in the process has been the dramatic modification of the underground flow patterns by sough drainage. The River Lathkill
may not have altered a great deal by virtue of the driving of the Lathkill Dale and Mandale Soughs, or any of the smaller soughs which discharged into the river. However, the Magpie Sough was driven southwards from the River Wye to the Magpie Mine, and penetrated lavas which would otherwise have determined the position of the watershed between the Wye and the Lathkill (Fig. 45). The process of capture of Lathkill drainage by the Wye has apparently been a gradual one, as the cone of depression created by the sough extended. The drainage appears to be principally via vein cavities; that on Fieldgrove Vein in Magpie Sough discharges a very large amount of water. The water seen here might not have been flowing to the Lathkill before the driving of the sough; it would probably have been comparatively static. The driving of the sough has merely created an outlet point, so that the vein cavity systems start to be enlarged mainly by the removal of the existing fill. The easy passage out to the Wye has been used to a greater and greater extent as more water which would flow southwards to the Lathkill via the Lathkill Head and possibly the Critchlow Cave systems has been captured by the slowly enlarging routes to the Wye. The dry summers of 1975 and 1976 accentuated the process, and it remains to be seen whether a series of wet summers will restore the situation to that of a few years ago, when Lathkill Head Cave was so rarely accessible.

That the river has been prone to drying up for considerable periods since driving of the sough is known from the initials "J.W.P." and the date "1916" seen in Puttrell's Chamber in Lathkill Head Cave. That it should be possible to reach this point demands a complete absence of a stream in the cave, with the consequent drying of the risings at least as far downstream as Carter's Mill. The situation of capture of the water by the Wye demonstrates how easily such a process can take place in a karst environment.
SECTION ACROSS THE LATHKILL SYNCLINE
AND THE WYE VALLEY


Key to symbols
- Eyam Limestones
- Monsal Dale Beds
- Monsal Dale Beds (dark facies)
- Shacklow Wood Lava
- Bee Low Limestones

Fig. 45
Chapter 7.

THE CATCHMENT OF WORMHILL SPRINGS

AND GREAT ROCKS DALE.
7) THE CATCHMENT OF WORMHILL SPRINGS AND GREAT ROCKS DALE.

i) Topographic and Geological Setting.

The large rising of Wormhill Springs was first referred to by Farey (1811). It lies on the north bank of the River Wye at 123 735, and discharges a large proportion of the flow of the main river below this point (Plate 14, 1). A number of springs constitute the main rising; many small ones lie to the east of the narrow valley which runs northwards to Wormhill village, and a very large rising lies at the foot of Flag Dale, which trends north westwards (Fig. 47).

Structurally, the springs lie to the south of the axis of the Wormhill - Priestcliffe Syncline (Fig. 2), the largest spring lying close to a fault trending parallel to the axis. In the axial region of the south eastward plunging syncline, the Upper and Lower Millers Dale Lavas have concentric outcrops (Fig. 46), that of the Lower Lava not quite closing at the eastern end. To the south west, the complimentary Taddington - Mogshaw Anticline (Fig. 2) brings Woo Dale Beds (S2 zone) to the surface along a 4 kilometre stretch of the Wye Valley.

To the north west, the Wormhill - Priestcliffe Syncline becomes periclinal in nature, and extensive faulting gives rise to the complex lava and dolerite outcrops between Great Rocks Dale and the shale margin from Buxton to Dove Holes (Fig. 46).

The plateau surface is pitted with many dolines, generally close to the margins of lava outcrops, especially round the prominent hills of Bole Hill and Withered Low (Fig. 48) and on the west side of Great Rocks Dale. The area is relatively unaffected by mining, although the quarries of Great Rocks Dale have largely destroyed that valley, and the faults are often marked by lines of dolines which would have been obliterated by extensive mining activity.

There is a notable absence of high level caves in this part of the
1) Wormhill Springs in wet weather. The water soon turns milky, which suggests that the catchment includes the Great Rocks Dale quarries.

2) The sheer cliffs of Chee Dale display widely spaced prominent bedding planes, but there is no known high level cave development.
Wye Valley, suggesting that Wormhill Springs and the risings at the confluence of Great Rocks Dale and Chee Dale (111 726) have been the main outlets of the underground drainage system for a long period. The sheer cliffs of Chee Dale (Plate 14, 2) display hardly any signs of cave development apart from very small scale anastomosis tubes on the relatively few prominent bedding planes.

ii) Underground Drainage.

So little cave passage is accessible or reported in the area that elucidation of the underground routes is speculative. There are large swallets at the shale margin at Dove Holes (076 779; Fig. 46), but the major swallet here has resisted attempts to penetrate it for more than a few metres. Almost directly beneath the swallet, two fissures were encountered in the driving of the Dove Holes railway tunnel. The flow from these was powerful enough to stop construction of the tunnel for many months while the water level in related cavities fell far enough to reduce the flow volume. The water was culverted out to the western end of the tunnel, so that the water now continues westwards instead of flowing to risings in the Wye Valley. The fissures were large enough to enter, but climbing to the source of the water revealed only tiny and impenetrable bedding-controlled inlets. It is likely that before the construction of the tunnel, the fissures lay deep beneath the local water table; they lie at approximately 900 ft (274 m) A.O.D. It is thus possible that lowering of the local water levels has rendered other cavities potentially accessible which would otherwise have been flooded. Further excavation of the Dove Holes Swallet could prove fruitful.

During a short digging attempt at Dove Holes in 1978, it was claimed by a local resident that the local council had, many years ago, dye tested the swallet to the rising at the foot of Great Rocks Dale. The route followed by the water from the swallet is unknown, and since
THE CATCHMENT OF WORMHILL SPRINGS AND GREAT ROCKS DALE.

Key:
- Lava or tuff outcrop. after I.G.S. (1976) and Edmunds (1971).
- Shale margin.
- Perched groundwater margin.
- Swallet.
- Rising.

0 km 1 km

Fig. 48
the Lower Millers Dale Lava outcrops a short distance to the east, the route must either follow the strike parallel to the outcrop, or pass through the lava where it is faulted. It is likely that fault-controlled caves are common in the region, for the underground drainage must pass through the lava in some places to reach either the Great Rocks Dale or Wormhill risings.

Wormhill Springs responds fast to flood conditions (Plate 14, 1), and the water turns milky in colour, which suggests that its catchment area includes the quarry floors of Great Rocks Dale. It might be expected therefore that the route to Wormhill would collect the Dove Holes water on its way from the swallet to the Great Rocks Dale rising, and this seems likely in view of the large discharge of Wormhill Springs, which would need a very large limestone catchment supplying percolation water to account for it. It is then necessary to account for the discharge of the Great Rocks Dale rising, which is large and constant enough to be a viable water supply for the Great Rocks Dale quarries.

The answer may lie in the east-west faults of the area, which carry water eastwards towards Great Rocks Dale, while further faults to the north carry water still further east towards Wormhill Springs. The actual position may be very complex; even the thin tufts present in the Castleton catchment area have a profound effect on speleogenesis, and it is likely that the complexities produced by the presence of two highly faulted lavas will require direct observation to unravel.

An extensive perched groundwater area exists above the lavas. On the flanks of Bole Hill and Withered Low are many small springs (Fig. 48), mostly above the Upper Millers Dale Lava. The springs on the south west side of the ridge discharge small streams which flow over both lavas to sink below the Lower Lava. Those on the north side are smaller, and there is generally an area of boggy ground which extends out onto the flatter limestone area between the lava outcrop and Monks Dale. The water
sinking here is likely to resurge at Wormhill Springs, although it is possible that some of the water from the south eastern sinks enters the Great Rocks Dale drainage system to rise at the Great Rocks Dale risings.

iii) Speleogenesis.

Conclusions regarding the speleogenetic history of the large Wormhill Springs and Great Rocks Dale catchment area rest almost entirely on observation of surface features. The many small dolines on the margins of the lava outcrops, and the existence of one very large integrated flood-prone rising at Wormhill Springs suggest a mature underground drainage system, the position of the present risings having been determined at an early stage.

The fissures of the Dove Holes railway tunnel suggest that a locally developed piezometric surface formerly existed at a comparatively high altitude in the region of the sinks; the fissures would soon have been drained, and their discharge volume reduced, had they been an integral part of a vadose drainage system. The fact that the discharge remained high for a long period suggests that they lay deep beneath the active routes. The volume of water is reported to be still considerable, but dependent on external weather conditions.

A drainage system probably developed soon after unroofing of the limestone, water being able to reach a regional base-level-controlled phreatic relatively quickly by virtue of the faulted nature of the limestone. Water travelled south eastwards towards the Wye Valley, using a network of fault-controlled fissures, to rise in the valley floor at a higher elevation than at present, but at approximately the same locations. The water rose from considerable depths to reach the risings, and may still do so. Boreholes in Monks Dale and Millers Dale are said to have tapped water from deep phreatic cavities (Ford, 1977), and water may still circulate to some depth in the immediate vicinity of the valley.
As the main valleys were progressively incised from the Wolstonian onwards (Burek, 1977), no change occurred in the position of the risings except that they were truncated vertically, increasing the hydraulic gradient, and allowing vadose circulation to occur over a wider area, closer and closer to the risings.

It may be that at Wormhill Springs, we see a situation similar in some respects to that at Castleton, water emerging into the valley floor from depth at a point of weakness. At Wormhill, that weakness is an extensive fault system, whereas at Castleton it is a thinning of the reef belt coincident with a conveniently oriented set of fractures. At Castleton, fracture control was less predominant, and circulation consequently less deep. At Wormhill, bedding control is possibly less important, at least near to the risings, and the valley has not therefore been incised far enough to expose the deeper cave system. Further upstream in the Wormhill system there may be canyon passages comparable in maturity to those in the Peak-Speedwell cave system. If this comparison is valid, then further downcutting may expose a large cave entrance, a hanging valley above it displaying phreatic shafts not modified by later vadose activity, which connect with the main cave, as the small phreatic caves of Cave Dale connected, before they were artificially sealed, with the roof of the Peak Cavern show cave.
Chapter 8.

THE MONKS DALE CATCHMENT AREA.
8) THE MONKS DALE CATCHMENT AREA.

1) Topographic and Geological Setting.

The Monks Dale catchment is ill-defined. The dry valley has different names in different parts of its course. Monks Dale begins at Millers Dale, and extends as far as the Tideswell - Wormhill road (Fig. 49). Beyond this point it is known as Peter Dale, then Hay Dale, then Dam Dale, and finally, from Peak Forest to Perryfoot, it is Perry Dale.

It is immediately obvious on examination of the dry valley pattern (Fig. 3) that the head of the dale lies in the Rushup Vale (see p. 90), where there are swallets which drain to the Castleton risings. It might at first sight seem that the Perryfoot swallets might lead into a cave system lying beneath the Monks Dale dry valley system, but the present day underground drainage has, for structural reasons, turned eastwards.

0.5 km upstream from Millers Dale, where Monks Dale joins the Wye Valley, the Lower Millers Dale Lava, dipping south eastwards on the north flank of the Wormhill - Priestcliffe Syncline (see p. 19) has a 'V' shaped outcrop across the valley. This effectively keeps the drainage on the surface to the south of this point, and means that Monks Dale nearly always discharges a stream into the River Wye, instead of the suspected situation of some other dry valleys, where the risings may be submerged in the river bed.

Southward dipping Chee Tor Rock is then traversed as far as the Tideswell - Wormhill road, immediately south of which lies the Monks Dale Vent (Arnold-Bemrose, 1907; Stevenson and Gaunt, 1971). There is often water on the surface at this point, probably held there by the resistant agglomerate of the vent. The valley then climbs the south flank of the Peak Forest Dome (Fig. 2), passing through older and older strata until it encounters the S zone (Woo Dale Limestones), and
THE MONKS DALE CATCHMENT
After I.G.S. 1976.

Key:
- Lava, dolerite, or tuff
- Vent agglomerate
- Fault
- Swallet
- Rising
- Tufa

Fig. 49
passes onto the dolerite outcrop in the centre of the dome. There is no surface stream further north, in Perry Dale, but a dam at Peak Forest held water on the surface on the dolerite outcrop. In Perry Dale, the northward dipping Woo Dale Limestones give way to the undifferentiated Bee Low Limestones of the northern part of the outcrop (see p. 20), and finally to apron reef limestones at Perryfoot (Fig. 18).

ii) Underground Drainage.

Monks Dale may discharge a very large stream into the River Wye at Millers Dale in wet weather. The stream originates from risings almost throughout the valley as far north as Peak Forest. The most northerly rising lies just south of Mill Cottage (1158 7857), and the stream normally flows over the dolerite outcrop to sink at a choked swallet in Dam Dale (Fig. 49). Dye testing by the Derwent Valley Water Board (Ford, 1956) was negative, no dye being observed anywhere. It is likely that this water flows beneath Dam Dale and Hay Dale, to rise immediately to the north of the Monks Dale Vent.

The largest risings lie to the north of the vent, north of the Tideswell - Wormhill road, at 1290 7540. They consist of a series of narrow bedding planes, too small for entry, on the east side of the valley. The stream which sinks in Dam Dale may occasionally overflow, and a large amount of water may flow over the Tideswell road, rendering it impassable, as occurred in the floods of February 1977.

To the south of the vent, there are very many small risings at valley floor level, most lying on the east bank, and probably fault controlled, though exposures in the region of these risings are poor. Where the Lower Millers Dale Lava begins to 'V' into the valley, there are large spreads of tufa below the lava outcrop, and water appears at valley floor level from cavities in the tufa. Large blocks of limestone have begun to break away from the cliff immediately above the lava on the
IDEALISED CROSS SECTION OF MONKS DALE AT APPROX. 740136

Drainage of extensive perched catchment above lava.

Streams reached down open joints.

Water flows down hillside beneath tufa.

Springs in tufa.

Limited perched catchment to the east, so few high level springs.

Deep drainage of relatively large area to the east, often fault-controlled.

Fig. 50
west side, leaving narrow open fissures at the base of the upper cliff line. One can be descended for a short distance to natural cavities close to the top of the lava. A small stream is reached which sinks into the floor, and this is thought to rise a little further down the valley side. It sinks again, this time beneath the tufa, to finally reappear at the springs at valley floor level. Down an adjacent rift a large volume of water can be heard, but the rift is blocked with boulders. This is yet another stream, and is likely to be that which resurges at the largest spring in the valley floor.

It is likely that before deposition of the tufa, there was a spring line at the base of the upper cliff, above the lava. Tufa deposition has concealed the route of the water down the valley side, so that at first sight the risings appear to lie at valley floor level, and to be controlled by that elevation. However, they are actually controlled by the elevation of the lava outcrop, their courses down the valley side lying through tubes developed in the tufa (Fig. 50).

There is one large rising on the east bank in this vicinity (Fig. 49) which lies at valley floor level and is likely to be fault controlled. The catchment for all the springs on the east side of Monks Dale is likely to encompass most of the high ground between Monks Dale and Tideswell Dale, for there are no large springs in the lower part of Tideswell Dale. This seems strange in view of the eastward dipping lava, which would tend to carry perched groundwater eastwards to Tideswell Dale, but this does not seem to be the case.

The catchment for the springs above the lava on the west bank is likely to be the area of perched groundwater above the lava in the area between Monks Dale and Hargatewall, round the north flank of Wormhill Hill (Fig. 49). This water is guided to the resurgences by the position of the axis of the Wormhill - Priestcliffe syncline, and by small north west - south east trending faults. The water from the southern part of this
perched groundwater area is thought to rise at the head of the small valley leading down from Wormhill to Wormhill Springs (Fig. 47).
Chapter 9.

THE CATCHMENT OF THE RIVER WYE

AT BUXTON.
9) THE CATCHMENT OF THE RIVER WYE AT BUXTON.

i) Topographic and Geological Setting.

Buxton lies on the western margin of the limestone outcrop. The River Wye first encounters limestones at this point as an allogetic stream which accumulates on the shale and sandstone moors to the west of the town (Fig. 51). The stream does not sink, but flows through the town, and augmented by many springs continues eastwards as a surface stream down Ashwood Dale.

The lowest beds exposed in the area are the Woo Dale Limestones, brought to the surface in Ashwood Dale (Fig. 54) by the Great Rocks Dale and Cowdale Anticlines (Fig. 2), and exposed to the north of Harpur Hill on the crest of the Grinlow Anticline (Fig. 51). They are overlain by the Bee Low Limestones (subdivided to the north of Buxton into the Millers Dale Beds and Chee Tor Rock, respectively above and below the Lower Millers Dale Lava). The Eyam limestones directly overlie the Millers Dale Beds to the north, but dark Monsal Dale Beds intervene to the south, and the Eyam Limestones are not exposed. On Stanley Moor (Fig. 51) the Namurian sediments overstep both the Eyam Limestones and Monsal Dale Beds in places to rest directly on the Bee Low Limestones. The limestone / shale boundary is a faulted one over much of its outcrop to the south of Buxton.

The most important structural feature with respect to the underground drainage of the Buxton area is the Grinlow Anticline (Fig. 51). A series of faults lie parallel to the axis, and have a considerable influence on the nature of the Stanley Moor - Poole's Cavern - Wye Head drainage system (Fig. 52).

ii) Underground Drainage.

Swallets abound in the Stanley Moor area, to the south of Buxton (Fig. 51), but to the north, between Buxton and Dove
Holes, there are only small sinks, and the destination of the water is unknown; it is possible that east-west faults here provide a relatively easy passage for the development of underground drainage systems, and that water passes eastwards towards Great Rocks Dale (see p. 226). A surface stream, the Nun Brook, accumulates just west of the limestone outcrop, being joined by streams from the southern flanks of Combs Moss, and joining the River Wye at Buxton.

The known caves of the area lie to the south and west of Buxton. Poole's Cavern (Figs. 51 & 53) has been known since Roman times (Boyd Dawkins, 1874), and consists of a large stream passage running down-dip (northwards) on the north flank of the Grinlow Anticline. The cave carries a stream, which enters through a choke of large boulders at the southern end at around 1150 ft (350 m) A.O.D., and sinks into the floor (Fig. 53) to rise at Wye Head (Glennie, 1953). The passage is deeply incised at the upstream end, the depth of incision being suddenly reduced on the downstream side of the sink. The downstream continuation of the passage was stated by Eldon Pothole Club (1963) to carry water in times of flood, and to discharge it through the present entrance. It appears that the construction of the Stanley Moor Reservoir in 1908 stopped this occurrence.

The present stream sink in Poole's Cavern is restricted, and seems to be a relatively recent feature. Attempts to gain access to the system which must lie between here and the Wye Head resurgence by the Eldon Pothole Club have failed in the past; the whole route appears to be too tight for penetration. The known stretch of passage is very large, and its original resurgence must have been the present entrance, with the possibility of an even earlier entrance at a slightly higher level (Fig. 53). The present entrance lies on a poorly defined bench approximately 16 metres above the present river level at Wye Head. The very restricted size of the downstream section suggests that the period of maximum enlargement of
DIAGRAMMATIC PROFILE OF POOLES CAVERN TO SHOW THE HISTORY OF CAPTURE AND INCISION.
After a survey by Eldon Pothole Club.

Level of early resurgence at approx. 1800ft O.D. Route now silted and flowstoned.

Second stage resurgence active in extreme flood in recent times. 1150ft O.D.

Stream sinks to Wye Head.

Third stage vadose incision upstream of capture point by lower route.

Level of present resurgence at Wye Head. 1000ft O.D.

Fig. 53
the system occurred before rejuvenation led to incision of the upper part of the Wye Valley to its present depth.

It is unlikely that a large cave system exists beyond the upstream choke of Poole's Cavern, for there is very little depth potential (a maximum of 20 metres) between the lowest point reached in the Stanley Moor Swallets and the appearance of the stream in Poole's Cavern. The adverse dips in the region of Stanley Moor, which are probably responsible for the sumps which terminate exploration here, are likely to have given rise to a strike oriented system either in, or parallel to, the north north west - east south east faults (Fig. 51). Once the crest of the anticline is crossed, the stream leaves the faults, and flows down-dip through Poole's Cavern to the River Wye, having emerged at successively lower points with incision of the valley.

The existence of an extensive groundwater reservoir beneath Stanley Moor is suggested by the fact that when pumping is taking place from the Ladmanlow Borehole (0496 7152) the stream in Poole's Cavern may dry up almost completely, even in a fairly wet period during the summer. The Ashwood Dale rising (Fig. 54) is believed to have flowed continuously through the drought of 1959, but dried up completely for several months during the drought of 1975/6, and dried up even during the wet summers of 1978 and 1979. The cone of depression caused by the borehole has been suggested as a reason, but that this should affect a rising so distant and apparently unconnected as that in Ashwood Dale seems unlikely. It is not out of the question that water from the western marginal swallets could rise here, but the volume of the flow from this rising can be accounted for by percolation water from the considerable limestone catchment to the south of the River Wye.

The swallets of Stanley Moor (Fig. 51) give little hope for further exploration. They are generally tight joint-oriented passages or low bedding caves, ending in chokes or sumps. The two most extensive swallet
caves are Axe Hole and Plunge Hole, which lie close together on the north side of the Stanley Moor Reservoir. They lie close to the faulted limestone/shale margin, and are developed by solutional enlargement of joints parallel to the main fault. Other smaller swallets further to the north have a close relationship with the same joint trends.

Brook Bottom Resurgence (Fig. 51) lies in the normally dry valley to the north of Harpur Hill at 061 712. Attempts at excavation have been unsuccessful. The source of the water is unknown; it is possible on structural grounds that water from the swallets to the south of Stanley Moor could find its way to this rising. It is also possible that water overflowing from the higher swallets in wet weather sinks at indeterminate swallets further downstream in the valley, to rise at Brook Bottom. The Brook Bottom stream joins the River Wye from the narrow ravine known as Lovers Leap (Fig. 51).

The other drainage system worthy of consideration is that draining the Shay Lodge area, the tongue of limestone extending north westwards on the crest of the Grinlow Anticline (Fig. 51). Small swallets have been excavated here with partial success. The water is thought to resurge at the Dog Holes Spring (041 727). Very little is so far known about the system, but the limestone dips consistently eastwards towards the rising, so that a thoroughly penetrable cave system is not out of the question.

Otter Hole Resurgence lies to the north west of Otter Hole Farm, on the south bank of the River Wye (here "Ochre Brook") at 046 733. Eldon Pothole Club (1963) state that it is completely separate hydrologically from Wye Head. The source of the stream is not known, but the more northerly swallets between Stanley Moor and Burbage are likely to drain to this rising. A short stretch of tight passage can be entered, and the cave opens to surface for a few feet on the nearby golf course.

Buxton is best known for its thermal springs. It is not proposed to discuss them at length here; they have been described by many authors
(ie. Short, 1734; Stephens, 1929; Edmunds, 1971), but the most important features may be mentioned. It was considered by Downing (1967) that the warm springs discharge meteoric water which has circulated to great depths (as much as 3000 ft; 915 m), rather than connate water. Edmunds (1971) has shown, however, by analysis of the tritium content of the water, that it has been underground for a considerable period. The tritium content was found to be low. Eldon Pothole Club (1963) report that when coal waste was dumped in the Grin quarries, coal dust was found to emerge from the warm springs, suggesting at least some dilution by meteoric water which follows a relatively shallow and unrestricted course.

iii) Speleogenesis.

The large size of the main passage of Poole's Cavern above the sink at around 1100 ft (335 m) A.O.D. is at first sight surprising when the immaturity of the other known caves of the area is considered. However, the fact that this cave is known at all depends on the fortuitous accessibility of the abandoned outlet (the present entrance). The absence of vadose incision below this elevation suggests a relatively recent lowering of the base level represented by the river. Despite a considerable fall in elevation between the stream sink in Poole's Cavern and the rising at Wye Head, no significant penetrable passages have been found.

The Otter Hole and Dog Holes systems similarly show no evidence of the existence of large vadose passages, but it is possible that like the Stanley Moor - Poole's Cavern - Wye Head system, the present outlets are comparatively recent features. It may be that these caves also become far more mature above the elevation of the earlier valley floor (335 metres A.O.D., or a little above), and that further investigation, directed at the discovery of higher abandoned outlets, would be repaid.
Chapter 10.

THE MINOR CATCHMENT AREAS.
10) THE MINOR CATCHMENT AREAS.

The areas described in this chapter are those catchment areas which are either of very small area, or in which so little cave passage is known (sometimes none) that few conclusions can be drawn regarding the speleogenesis of the area. It may be that in the future, with further examination and excavation, catchment areas such as those of Lower Cressbrook Dale (Lumb Hole), Taddington Dale, and Deep Dale may acquire greater significance in the overall speleogenetic picture.

1) Ashwood Dale Resurgence and Pigtor Spring.

Where there are no known allogenic swallet feeders to the underground drainage system, as is the case in Ashwood Dale, it is impossible to define the extent of the catchment area exactly. The closest point on the limestone/shale margin lies on Stanley Moor, nearly 5 km to the west south west.

To the south east of the Ashwood Dale springs (Plate 15, 1) lies Deep Dale (Fig. 54), in the floor of which there are powerful risings in wet weather, and high in both flanks of which there are short sections of large but heavily silted cave passages. The source of the water rising in Deep Dale is likely to be further to the south, but the dividing line between Deep Dale and Ashwood Dale drainage is impossible to define.

Both Ashwood Dale Resurgence (0895 7222) and Pigtor Spring (0867 7230) lie a short distance to the south of a fault (Fig. 54), which crosses Deep Dale below the largest of the risings. Fault control may therefore play an important part in the siting of the risings. Both lie a few metres stratigraphically above the top of the Woo Dale Dolomite (Fig. 54). In very dry weather, Ashwood Dale Resurgence dries up, and has been forced along a tight bedding controlled passage for a few metres (Needham, 1966). During the 1975/6 drought, the passage emitted a very
1) Ashwood Dale Resurgence during snow melt floods.

2) Thirst House Cave, Deepdale.
strong draught, but became too tight.

To the west, towards the swallets of Stanley Moor, the catchment is probably bounded by the outcrop of the Lower Millers Dale Lava horizon, though this is here impersistent, and the outcrop is further fragmented by faulting. If the lava is represented outside the area of its typical development by a tuff, as is the case in the Castleton area, then it may act to some extent as an aquiclude. However, in the Castleton area the tuff has been breached in many places by percolating groundwater, on major joints, and it is therefore possible that water from Stanley Moor could flow eastwards. Unlikely as this seems, it has been observed that pumping from the Ladmanlow Borehole (see p. 240) quickly causes Ashwood Dale Resurgence to dry up. It may be that active pumping causes a cone of depression, so that percolation water which would otherwise flow eastwards flows westwards into the depressed area instead, so that it augments the reservoir of the Poole's Cavern - Wye Head catchment area. The water table contours shown by Edmunds (1971), although generalised, do suggest a hydraulic gradient from the Stanley Moor area towards the Ashwood Dale risings.

ii) Deep Dale.

Deep Dale is a southern tributary of the River Wye, which it joins west of Topley Pike at 1030 7345. It trends southwards for a short distance, then bifurcates, the main valley turning to the south west, and a branch, Marl Dale, continuing to the south. The main valley can be traced for a distance of just over 2 kilometres.

The valley is deeply incised, with extensive scree which may mask both past and present risings. The present day risings lie in the valley floor, water appearing through boulders at many points, aggregating to form a large stream in wet weather. There seems to be little chance of observing the active route behind these risings directly.
Immediately to the west of Deep Dale, the ground rises to between 1000 ft and 1150 ft (305 - 350 m) A.O.D. The catchment area could be quite a large one, but cannot be exactly defined, and is difficult to separate from Ashwood Dale Resurgence (Fig. 54).

The confluence with the main Wye Valley lies just east of the last appearance of the Woo Dale Dolomite (Fig. 54), the lowest beds exposed. The gentle eastward dip carries the dolomite and the overlying Woo Dale Limestones below the valley floor, and they are not seen again to the east. Woo Dale Limestones outcrop in Deep Dale as far as Raven Tor, but dip into the valley floor beyond, to be seen again as a small faulted inlier a little further to the south.

The valley is crossed by several faults and veins, the largest of which can be seen just above the confluence, by Topley Pike Quarry. It appears from the position of the known caves, and the present day risings, that the underground drainage may be largely controlled by these faults in the area.

Deep Dale and Marl Dale have long been the site of archaeological investigation. During the latter years of the last century the largest cave (Deep Dale Cave, Thirst House Cave, or Thirst Hole; Fig. 54) was excavated to reveal Romano British pottery and bronzes (Cox, 1891) and bones of bear, wolf, badger, fox etc. (Salt, 1897). Similar remains were found in Marl Dale, near Churn Hole. Churn Hole was first mentioned by Farey (1811), and then by Salt (1897). Both refer to a larger cave than is now known, and this has prompted investigation by many cavers.

Marl Dale, the southern branch of Deep Dale, displays a prominent knick point 700 metres above the confluence of Deep Dale with the River Wye. At this point an illustration in Turner (1899) shows two caves on opposite sides of the valley. One is still obvious, and consists of an enlarged joint some 3 metres long, but the other, on the west side, appears to have lain beneath the present footpath, and has collapsed.
The latter appears to have been Farey's 'Churn Hole'. When investigated in 1976, two holes could be descended into an unstable small chamber with a boulder floor. The heavily scalloped roof on the west side suggested that the collapse marked the position of an early resurgence at this point, which also helped to explain the position of the knick point above the cave. Beyond the knick point, Marl Dale continues as a shallow dry valley system onto Chelmorton Flat.

Recently, members of Orpheus Caving Club have excavated boulders to reveal approximately 30 metres of low passage which emits a strong draught. Digging is continuing (Drakely, 1979).

Churn Hole lies at approximately 880 ft (268 m) A.O.D., approximately 30 metres above the River Wye at the confluence, at 1054 7186 (Fig. 54).

The two known caves of Deep Dale lie on opposite sides of the valley. Thirst House Cave (Fig. 54, Plate 15, 2) consists of a large entrance on the east side at an elevation of around 915 ft (279 m) A.O.D. at 0970 7124. A large passage can be followed for 22 metres to a short drop into the continuation. This chamber soon narrows, and a small rift passage continues. The flowstone floor of the second chamber has been breached (Turner, 1899) to reveal an unstable descent through boulders. There is often a pool at the bottom, which lies close to the level of the risings near the cave in the valley floor.

The second chamber intersects a vein which crosses the valley a short distance to the north, and the vein is solutionally enlarged for some 5 to 8 metres above the chamber. The second chamber is heavily flowstoned, but this has been breached in several places during excavations. The floor of the cave is solid rock at the entrance, but this is seen nowhere inside.

Deep Dale Cave lies almost opposite Thirst House Cave at a higher elevation (approx. 950 ft; 290 m A.O.D.). It consists of a long low crawl. As noted by Ward (1895), the two caves give the impression of having been one continuous route which has been broken by incision of the
If Thirst House Cave and Deep Dale Cave are considered as one, the question of the position of the resurgence of the system arises. Since the scalloping in these ancient passages is confused throughout, it is difficult to tell in which direction the water flowed, if indeed the caves were continuous. If it is assumed that the cave drained the plateau surface between Deep Dale and Harpur Hill, then Churn Hole, at the head of Marl Dale, seems likely as the rising. It is hard to envisage water moving in the other direction; the geometry of the caves suggests a cave draining to the east. If Churn Hole was the rising, it is likely that the valley floor at the time lay at approximately 900 ft (274 m) A.O.D. at the rising.

The above implies that Deep Dale was almost non-existent at the time of operation of the cave, and suggests that the valley was graded from 900 ft (274 m) at the confluence to above 1000 ft (305 m) at the point where the two caves have now been truncated at Raven Tor. There appears to be no intermediate level between the Deep Dale - Churn Hole system and the present risings in the valley floor.

The time scale involved in the evolution of the present pattern is impossible to determine. There is only one abandoned cave level, with no intermediates between that level and the active system. The answer may be that with deeper incision of the Wye Valley, water from this drainage system was captured by Ashwood Dale Resurgence and Pigtor Spring, so that the water now rising in Deep Dale is only local percolation water except in very wet weather when it may become a large volume. Under such conditions, water levels in the active system further to the west may rise to a point at which the Deep Dale risings act as an overflow. The abandoned Deep Dale system may thus have acted at an early stage, later changes consisting of gradual capture by the risings in Ashwood Dale. It may be that several stages of rejuvenation have produced the present form.
iii) Blackwell Dale.

Blackwell Dale is a southern tributary of the River Wye, joining the major valley at Millers Dale. Topographically it drains an area of 3.5 km$^2$, bordered to the south by the crest of Taddington Moor at 1425 ft (435 m) A.O.D., and to the east by the escarpment which culminates at Priestcliff Low. There is no extensive surface drainage of the area, surface streams being limited to the small springs round the margin of the outcrop of the Upper Millers Dale Lava on the escarpments, and the stream in the lower part of Blackwell Dale (Fig. 55). In flood conditions, Blackwell Dale may become almost impassable due to surface runoff, for in places the road occupies most of the width of the narrow valley floor.

Structurally, the underground catchment appears to be bounded to the south by the Taddington - Mogshaw Anticline (Fig. 2), and to the east by the outcrop of the Upper Millers Dale Lava on Priestcliff Low. To the west the boundary is ill-defined, but little drainage from that direction appears to reach Blackwell Dale.

The Millers Dale Limestones, pale grey and often thinly bedded, occupy most of the area. The Lower Millers Dale Lava lies a short distance below the floor of Blackwell Dale for most of its length, and is exposed for a short distance near the southern end. The Upper Lava forms part of the escarpments of Priestcliffe Low and that which flanks Taddington Moor from Chelmorton Low to Taddington.

In view of the small size of the catchment area, it is perhaps surprising to find so many small tubes, and one quite mature abandoned cave, in Blackwell Dale. The lowest cave entrance lies at an elevation of approximately 660 ft (201 m) A.O.D., close to the River Wye at the north end of the dale. It is a small phreatic tube of irregular shape, silted to the roof after roughly 3 metres, measuring 1 m x 0.8 m is cross section. It now appears to be devoid of a stream at all times. It appears
THE BLACKWELL DALE AREA
Sources: I.G.S.1976 & Author's field notes.

KEY
- Monsal Dale Beds
- Upper Millers Dale Lava
- Lower Millers Dale Lava
- Chee Tor Rock
- Veins and faults
- Geological boundary
- Streams
- Topographic contours
- Caves and springs

Fig. 55
to be associated with the lowest series of caves draining the area to the
west of the dale, and lies at the base of the main river cliff.

The main rising lies on the east side of the valley at an elevation
of approximately 790 ft (241 m) A.O.D. (Fig. 55). The spring emerges from
beneath the road, which has for some time been in danger of collapse.
Repairs to the road during July and August 1980 partly exposed the rock
face from which the water emerges, but no open passage could be seen. The
rising is several metres above the valley floor. Downstream from this
point, tufa has accumulated in the valley floor, forming a series of dams
in several places. Upstream, there are more risings at the same elevation,
and the valley floor rises until the more southerly springs lie at valley
floor level. There is only limited seepage from the west bank.

Above the road, again on the east side of the valley, there is
evidence of a well defined cave level at 830 ft (253 m) A.O.D. The first
lay-by from Millers Dale shows signs of natural cavities blocked with
dumped rubble, but the first well defined and accessible tube lies 4
metres above the road, and can be followed until it intersects the largest
cave in the dale, Blackwell Dale Cave (Figs. 55 & 56). This is clearly
seen from the road, and can be followed as a mature tube for roughly
65 metres to a chamber developed by solution along an east-west fault. The
chamber was discovered by Orpheus Caving Club, and was gated to protect
the fine calcite formations. The side passage which runs back to the
valley side (above) appears to be influenced by a reef like dome which the
valley cuts through (Cope, 1972). The tube passes over the crest of this
structure.

Continuing to the south along the road, a sharp bend is reached, and
the road passes through a sudden narrowing of the valley floor. Two caves
are seen here at an elevation of 885 ft (270 m) A.O.D. (Fig. 55). That on
the east side (Plate 16) is a large rock shelter, probably infilled during
construction of the road, while that to the west is a better defined tube
The large rock shelter on the east side of the road in Blackwell Dale. The roof dips gently into the rubble fill, suggesting that the cave became infilled during construction of the road. A dry cave almost directly opposite is blocked with angular fragments of limestone in a clay matrix almost immediately.
blocked almost immediately with angular limestone fragments in a matrix of brown loam. Whether this was originally one cave, which crossed the valley at this point to be later truncated by rejuvenation, or whether there were two risings at this point, is uncertain, for no solution features can now be distinguished. It is likely that at an early stage there was one large rising here, for there appears to have been a prominent knickpoint before the last phase of incision.

Above the cliff in which the eastern rock shelter lies is an ill-defined bench, on which several small impenetrable cave entrances are found at an elevation of approximately 900 ft (274 m) A.O.D. None has been entered; excavation might be repaid if the foxes were ejected. At the same elevation on the west side of the valley, immediately downstream from the incised knickpoint, further small tubes, none penetrable, occur along a prominent bedding plane (Fig. 55). There is no bench associated with the latter tubes.

The profusion of small caves in Blackwell Dale is inexplicable in terms of the situation along the rest of the Wye Valley, where there are virtually no known caves. In Blackwell Dale, it appears that there are four separate levels, including the currently active one. The small cave at river level does not appear to be directly related to this sequence, and lies on the opposite side of the valley, well below the present main rising.

The earliest level is represented by the fox caves at 900 ft A.O.D. All the tubes so far seen at this level are developed by enlargement of a single prominent bedding plane, on both sides of the valley.

Next there are the two entrances adjacent to the road at an elevation of 885 ft A.O.D., at the foot of what may be an incised knickpoint.

Blackwell Dale Cave lies at 830 ft A.O.D., and again appears to be a part of a mature tube network. No sign of vadose incision is seen in the cave, suggesting, as in many other valleys, that capture by the
lower levels was relatively sudden.

The present day rising, at 790 ft (241 m) A.O.D. lies some 6 metres above the valley floor. There are prominent bedding planes close to the valley floor, yet these have not been utilised, and the stream has not adjusted to the lowest level of valley incision. The active risings appear to all lie at a similar horizon.

Although the caves of Blackwell Dale are only known to a very limited extent, so that conclusions regarding their history are hard to draw, the existence of a series of four distinct horizons of cave development within a relatively small vertical range, so similar to other valleys where caves are available for study, is striking. The outlet level has again been lowered relatively suddenly at least four times, the last stage of lowering having left the present active rising high above the valley floor.

iv) Tideswell Dale.

Tideswell Dale is a northern tributary of the River Wye, the confluence lying at 156 731, at an altitude of 610 ft (186 m) A.O.D. The dale runs roughly parallel to Monks Dale, and is clearly traceable for a distance of 5.5 kilometres, as far as Pittle Mere (134 783), where it becomes shallow and indistinct (Fig. 57).

The drainage of the Tideswell area is kept on the surface by the Upper and Lower Millers Dale Lavas, and by a dolerite which lies below the Lower Lava to the south of Tideswell. Consequently, below Brook Head Resurgence (141 775; Fig. 57) there is a stream throughout. There was formerly an ebbing and flowing spring in Tideswell (Short, 1734), but this is said to be inoperative now.

The only known cave in Tideswell Dale lies just upstream from the confluence with the River Wye at 1555 7319, at approximately 675 ft (206 m) A.O.D. It is known as Tideswell Dale Cave (Gill, 1974), but is of little extent, and is only accessible because the miners have enlarged a tube
which would otherwise be little more than a heavily anastomosed bedding plane. It ends on a small vein, and the continuing tube is too small for access. It lies in Millers Dale Beds, and the same bedding plane is anastomosed over a distance of 0.4 km on both sides of the valley, some tubes at 1534 7347 being up to 20 cms in diameter. A small spring in the valley floor at 1532 7337 has never been observed to discharge more than a trickle.

Passing northwards, a faulted inlier of Chee Tor Rock, overlain by the dolerite and Lower Millers Dale Lava, is crossed. The faulted boundary between the Millers Dale Beds and Lower Monsal Dale Beds is reached just to the south of Tideswell (152 752), and the village of Tideswell lies just south of the axis of the Wardlow Syncline (Fig. 2). The Upper Millers Dale Lava is again brought to the surface 1 km to the north west of the village, and a short distance beyond lies Brook Head Resurgence, its position determined by the outcrop of the Lower Millers Dale Lava.

Brook Head Resurgence is developed in Chee Tor Rock, which outcrops extensively to the north west of the east flank of the Peak Forest Dome. Two considerable outcrops of dolerite occur, and many dolines lie both at the margins of the outcrops, and by collapse of dolerite into solution cavities beneath (Fig. 57). Some of the dolines appear to be worthy of excavation, but the only ambitious attempt was that made at Pittle Hole (1339 7827; Plate 17,1). A shallow but well defined dry valley runs south eastwards on the limestone, to end at a small cliff capped with dolerite. Excavation resulted in the discovery of a series of very tight rifts which were descended with difficulty to a depth of 15.5 metres below the moor, at which point they became impenetrable. It was interesting to note that two prominent clay wayboards occurred about halfway down, and that the shafts enlarged considerably for a short distance beneath them.

The absence of large risings in Tideswell Dale is at first sight
THE RELATIONSHIP OF DOLINES TO LAVA AND DOLERITE OUTCROPS NORTH-WEST OF BROOK HEAD.

After I.G.S. 1976 & author's field maps.

0  500 metres

- Dark limestone
- Other limestone
- Upper lava
- Lower lava
- Dolerite
- Tuff
- Head
- Doline
- Wet weather swallow
- Rising
1) Pittle Hole, Tideswell Moor, lies at the foot of a small blind valley. It was penetrated to a depth of 15.5 metres by digging. Collapse of overlying dolerite into solution cavities is responsible for many of these dolines.

2) Lumb Hole, Cressbrook Dale, the rising for the drainage of the west end of Longstone Edge.
surprising, but it is likely that the north eastward dipping Monsal Dale Beds in the region of Tideswell village carry water into a large compartment bounded to the east by the Cressbrook Dale Lava and the Litton Tuff. This water may then pass south eastwards to Cressbrook Dale (Fig. 4), or even northwards to enter the Bradwell catchment area. Faults puncturing the Litton Tuff may allow some water to enter the reservoir of the central Wardlow Basin (see p. 64).

To the west of Tideswell Dale, water may be carried through the lava horizons where they are punctured by faulting. The drainage of this area then rises in Monks Dale, either through fault-controlled risings (Fig. 4) or bedding controlled risings at the southern end where the Chee Tor Rock begins to dip towards the valley on the north flank of the Wormhill-Priestcliffe Syncline (Fig. 2).

v) Lower Cressbrook Dale.

The risings at the head of Cressbrook Dale have already been considered (Chapter 3, vi) since they have an inseparable relationship with the Stoney Middleton catchment area. The large rising at Lumb Hole and the associated springs are therefore considered separately.

Cressbrook Dale joins the River Wye at 173 726. A small outcrop of Upper Millers Dale Lava occupies the valley floor at the confluence. To the north, Bee Low Limestones floor the valley and form the line of cliffs in the narrow gorge through which the stream flows. The large rising of Lumb Hole (Fig. 58) lies at 1725 7313, at an altitude of 600 ft (183 m) A.O.D. (Plate 17, 2). A large entrance discharges a large stream in wet weather, but the passage within soon becomes a crawl between blocks of breakdown, eventually becoming too tight. The stream flows through the bottom of the breakdown. In dry weather the stream above Lumb Hole may dry up completely, and smaller risings in the region can then be observed. The Lumb Hole stream can still be heard at a lower level in the cave.
entrance, and rises on the west side of the stream bed. On the same
side as Lumb Hole, small risings occur on narrow bedding planes. The
rising appears to lie on a steeply inclined fault plane, the stream having
incised downwards along the plane of the fault, and the upper part having
collapsed behind this incision as the roof span became unstable.

A short distance upstream from Lumb Hole, a prominent calcite vein
crosses the valley, and there is a powerful resurgence on the line of the
vein in the valley floor. Features above the stream on the vein have the
appearance of run-in mineshafts, and it is possible that there was an
early sough at this point. Workings in the vein can be entered higher up
the hillside at 173 732, but are of little extent. The rising on the
vein usually dries up in summer.

Almost opposite Lumb Hole is Old Cressbrook Cave (Ford, T.D. 1974).
It consists of a large entrance which soon closes down to a muddy crawl
leading to a tiny chamber. It is likely that further excavation might be
repaid, as little is known of the caves of the west side of Cressbrook
Dale, but much of the system appears to be silt-filled. It is possible
that the water rising below the cave, thought to come from Lumb Hole (see
above) includes some separate drainage from the west, and there may thus
be an unknown active system.

230 metres to the north of Lumb Hole the stream plunges over a
waterfall into the head of the gorge section of its course (Fig. 58). The
stream has incised headwards beyond a large east-west fault, which
represents the westward expression of the Longstone Edge Monocline (Fig. 2).
The fault has a downthrow of approximately 60 metres to the south; the
beds seen in the gorge section at Lumb Hole form the topmost line of
cliffs at Ravensdale Cottages (172 737). The valley floor immediately
south of the cottages is occupied by the Ravensdale Tuff, which forms a
broad meadow, and springs derived from local accumulated percolation above
the tuff occur just above the knickpoint. There are no further significant
risings until Arbor Seats Sough (1746 7461) and Wardlow Sough (1742 7474) are reached.

High level caves are limited to Ravencliffe Cave (1739 7356) and Bull Tor Cave (1742 7313). Ravencliffe Cave consists of a large chamber partly infilled with cemented scree, with a short crawl at the back. It has been archaeologically excavated (Storrs-Fox, 1910 & 1928) and many human remains found, together with those of Bear, Ox, Deer, Boar, Rhinoceros, and many others. An enormous volume of material has been excavated both from inside the cave and from the terrace outside, as shown in two photographs in Storrs-Fox (1910).

Bull Tor Cave lies at the base of a small crag some distance to the south of the faults (Fig. 58), and is reputed to consist of a long crawl (Ford, 1974). It appeared to be occupied by badgers, and was not entered during this study.

Both Ravencliffe Cave and Bull Tor Cave lie at approximately 1000 ft (305 m) A.O.D., and the similarity of elevation suggests the existence of an early drainage network at this elevation. There is then no evidence of integrated cave development until the elevation of Lumb Hole is reached. Whether intermediate levels existed cannot be determined with certainty, for the valley sides are almost uniformly covered by scree.

The present day drainage system is likely to continue eastwards on the south side of the fault system, draining the southern flank of Longstone Edge. Small swallets occur on the crest of the edge in wet weather, engulfing streams which accumulate on a large spread of chert gravel and peat to the north of Watersaw Rake (193 734 to 202 734). Attempts at excavation were unsuccessful; the whole area appeared to be highly fissured, the heavy fluting of the closely spaced joint-controlled cavities reflecting the acidic nature of the groundwater. Unsupported excavations soon collapsed.

To the west of Cressbrook Dale there is only a limited catchment area,
much of the drainage flowing southwards to emerge as small springs on the north bank of the River Wye. It is possible that there is a large rising opposite Lumb Hole, but in wet weather this is masked by the large flow from Lumb Hole itself, and by the surface stream. The abandoned caves on the west side, at roughly the same elevation as Lumb Hole, suggest the existence of an unknown cave system to the west.

The two final catchment areas have been little studied, for their drainage is considerably modified by soughs. The drainage of Taddington Dale is little known, and the risings are intermittent; water may have been pirated by the soughs which drained the Hubberdale Mines. The drainage of Coombs Dale is virtually unknown, and the water emerges through the Calver Sough system.

vi) Taddington Dale.

The catchment area for the risings at the foot of Taddington Dale and those in Dimin Dale (Fig. 59) occupies the north flank of the Taddington-Mogshaw Anticline (Fig. 2) and the axial region of the Wormhill-Priestcliffe Syncline. Apart from the area around the confluence of Taddington Dale and Dimin Dale with the Wye Valley there is very little evidence of cave development in the area, although a series of newspaper articles appeared in 1937 describing a cave supposedly found during the construction of the Taddington by-pass.

A major rising is seen in the south side of Taddington Dale, a short distance above the confluence, at 166 708 at an elevation of approximately 580 ft (177 m) A.O.D. Water emerges from cemented scree in several places, and accumulates to form a large stream which flows beneath the road to continue on the north side to join the River Wye. The risings lie immediately above the horizon of the Lees Bottom Lava (Geological Survey, 1976).
The other major rising lies in Dimin Dale at a slightly higher
elevation (about 600 ft; 183 m A.O.D.) at 1689 7045. It is known as
Demon's Dale Cave, or Taddington Dale Resurgence Cave (Ford & Gill, 1979).
It consists of a large rock shelter, archaeologically excavated (Ford, T.D. 1974). At the back of the shelter, breakdown obscures the continuation,
but during wet weather water flows over the breakdown slabs forming quite
a large stream in the lower part of Dimin Dale. If the approximate
horizon of the rock shelter is followed into the narrow gorge section,
small caves are found on the north side at 1687 7037, also at around
600 ft (183 m) A.O.D. Both caves lie a short distance above the horizon
of the Lees Bottom Lava (Fig. 59), and this may have prevented adjustment
in the position of the risings relative to the latest valley floor level.

Defined on the basis of structure, the catchment area is apparently
quite a large one, larger than one would expect from the size of the
known risings. It is possible that the use of mine drainage has captured
water from the natural system, or it may be that there are risings in the
river bed. The Whale (Wheal) Sough, driven to Nether Hubberdale Mine from
Dimin Dale (Robey, 1965) is unlikely to have had a great effect on the
risings at the foot of Dimin Dale and Taddington Dale, for the sough was
driven to drain mines further to the south. The only sough likely to
drain any part of the area is the Maurey Sough (Robey, 1965). The tail
lies at 151 731, and is reported to still discharge water. This is also
unlikely to have an important bearing on the drainage of the area, for
its catchment cannot be large.

It is interesting to speculate on the likely existence and location
of the cave reported in newspapers in 1937, and referred to by Brindley
as "Puttrell Cavern, Taddington Dale" (Ford, 1980). It was rumoured to
have been found during construction of the Taddington by-pass, which runs
from 1534 7132 to 1365 7130, although the road was improved for some way
to the west of this point. There are cuttings on the south side of the
road where what appear to be open joints filled with loose rock can be found, and it is quite likely that open cavities could have been entered here. There is no other evidence of high level caves within the area. If the cave was indeed found on this stretch of the road, it would place it at around 1000 ft (305 m) A.O.D., which is consistent with caves such as Water Icicle Close Cavern, Ravencliffe Cave etc. which appear to be related to a regional base level at around 1000 ft which climbed gradually westwards. Such a cave system would have been likely to drain north westwards towards Blackwell Dale, however, unless the Upper Millers Dale Lava is breached where it is faulted.

d) Calver.

Calver lies on the eastern margin of the limestone outcrop, the River Derwent flowing just to the east of the village on Namurian sediments. To the west a tongue of shale in the axis of an east-west syncline extends up onto the eastern end of Middleton Moor (Highfields, Fig. 60).

The axis of the Longstone Edge Monocline passes immediately to the south of Calver. The outcrop of the shale margin turns to the south over the plunging nose of the structure, and runs south westwards towards Great Longstone. Although small springs occur along the shale margin between Calver and Hassop, there is no expression of former outlets of an integrated underground drainage system draining the eastern end of Longstone Edge.

The major limestone dry valley considered in the catchment area is Coombs Dale (Fig. 60) which runs west south westwards from a point roughly midway between Calver and Stoney Middleton. The drainage of this valley is complex, and is certainly very much modified by mining. It is likely that two of the soughs which discharge at Calver, Calver Sough and Brightside Sough, have captured water which would otherwise have flowed
through a cave system beneath Coombs Dale to rise at the foot of the dale where it broadens onto the flood plain of the Stoke Brook.

Only one significant cave is known in Coombs Dale. It lies on the north side of the valley at 2268 7485, at an altitude of 600 ft (183 m) A.O.D. It is known as Fatigue Pot (Fig. 61). The entrance passage is a bedding controlled crawl which breaks into the top of an open joint. The joint can be descended for a total of 16 metres until it is possible to traverse horizontally where the rift widens on a prominent bedding plane beneath a prominent band of silicified corals. Two low passages lead to the north east. One can be followed for 80 metres to a series of joint-oriented chambers, where the tube divides into passages either too tight for further penetration, or silted. A strong draught blows outwards in cold weather. There is mature flowstone at the lowest point of Fatigue Pot, which is surprising when one considers the elevation of 520 ft (158 m) A.O.D., and that the lowest possible local outlet on the shale margin only lies some 6 metres below, at the foot of the valley.

A little to the west of Fatigue Pot, a narrow steep gully leads up onto the shale-covered fields of Highfields (Fig. 60). In the floor of this gully a small stream sinks, and the word "Hole" appeared here on a map of 1758 (Kirkham, 1966). The place was known as Booth Hole, and Kirkham (1966) suggests that this may have been an open pothole.

Still further to the west, water sinks, or used to sink, into a hollow where Shepherds Vein crosses the valley (Fig. 60). It seems unlikely that mining took place far below the valley floor here, and it is possible that there was a natural swallet on the site.

The adit entrance to Sallat Hole Mine lies on the south side of the valley at 2191 7411, and discharges a stream which flows for varying distances down the valley, to seep away between Shepherds Mine (2234 7437) and Wren Park Mine (2335 7438). In the Wren Park Mine, it is said that a large volume of water was suddenly encountered at a depth of around 30 m.,
FATIGUE POT, COOMBS DALE, DERBYSHIRE.

PLAN

PROJECTED SECTION FACING NORTH EAST

Entrance

Prominent bedding plane.

Cherty limestone much obscured by flowstone. Thin shell bed near base.

Persistent chert bands.

Many corals, often silicified.

Prominent bedding plane.
and a branch of Calver Sough was driven along Peakstone Rake (Fig. 60), on which Wren Park Mine lies. The depth of 30 metres seems unlikely, for the Wren Park shaft collar lies at 510 ft (155 m) A.O.D., and the water level would have been below the lowest point on the limestone margin, and almost as low as the River Derwent.

Little is known of the drainage of Upper Coombs Dale, beyond Sallet Hole Mine, but the valley is always dry except for a short stretch beyond the mine, where a stream may emerge from bedding planes on both sides of the valley in wet weather. A shaft was descended in a short adit on the south side, and water flowed out of bedding planes to the west, to sink into similar ones on the east side at the bottom. This suggested that the drainage of the upper part of the valley was shallow; the water level may drop suddenly at Shepherds Vein (2234 7437).

High on the hillside above Sallet Hole is a short cave. A deep mineshaft has been sunk at the end, and is reputed to have connected with Sallet Hole. This cave, the only evidence of a connective cave system at a higher elevation than Fatigue Pot, lies just above 900 ft (274 m) A.O.D.

It is therefore certain that prior to the mining, the underground drainage had adjusted closely to the lowest possible elevation of the outlet at the limestone/shale margin. Coombs Dale was a totally dry valley except for the minor seepages from the shales at the eastern end, streams which accumulated on the shale of Highfields flowing southwards into the valley to disappear into poorly defined swallets. It is possible that risings existed along the shale margin between Calver and Hassop, but there is no sign of these now except for very minor springs. The drainage of the eastern end of Longstone Edge has been effectively captured by Brightside Sough (Fig. 60) which runs southwards and south westwards from its outlet at Calver.
Chapter 11.

CONTROLS OVER UNDERGROUND DRAINAGE

IN NORTH DERBYSHIRE.
11) CONTROLS OVER UNDERGROUND DRAINAGE IN NORTH DERBYSHIRE.

Evaluation of the controls over the nature and orientation of the drainage systems is complicated by the mining activity of some 2000 years in the northern and eastern parts of the study area. Most of the large cave systems lie in the main orefield, where modification of natural flow patterns by sough drainage is at a maximum. On the other hand, soughs have often lowered water levels so that previously inaccessible phreatic cavities can be reached and studied (ie. Watergrove Mine, p. 64; Knotlow Mine, p. 204).

The following conclusions are therefore often based on a reconstruction of the pre-mining pattern. The most obvious example is the Stoney Middleton area, where water has been brought eastwards by sough drainage to re-invade an abandoned cave system. Once this is realised, however, the Stoney Middleton area provides some of the best examples of structural control of cave development in Derbyshire.

i) The Impervious Cover.

The major known cave systems owe their orientation to the altitude of the impervious cover of Namurian shale. In the north and north east of the limestone area, and in the Buxton area, the large allogenic swallets lie at the highest elevation of the limestone/shale boundary, where there is a steep hydraulic gradient to the floors of the major valleys. The resurgences for these swallets generally lie at the lowest elevation of the same boundary (ie. Russet Well, Bradwell) or upstream from the boundary in the valley floor (ie. Carlswark Cavern, Lathkill Head Cave). The presence of the shales, overlain by grits which form high moorland, allows the formation of many small allogenic streams. It is these streams, often charged with abrasive material, that are responsible for the major cave systems of the north.

Precipitation over the limestone area rarely forms integrated streams
except where there is either an extensive lava or dolerite outcrop, or a superficial cover of chert gravel or peat. The swallow holes by which access might be gained to the cave systems which undoubtedly exist have therefore either not developed, or are choked and inaccessible.

ii) Structure.

Where phreatic systems are available for study, it appears that flow within the phreas followed the strike of the beds wherever possible, particularly in areas of shallow dip. Once the groundwater has found its way to the local water table, the flow consists of a body of water moving relatively slowly over a wide area in a network of conduits. Flow will probably be fastest, and the water most aggressive, just below the water table. With any given water table, therefore, cave passages tend to develop along the strike of preferred bedding planes, just below the intersection of such bedding planes with the water surface. A network of phreatic passages may then develop from swallow to resurgence (although complicated by other factors in most cases; see below). The principal conduits will lie roughly parallel with each other, sub-parallel to the strike, with a slight down-dip component, and will be connected at 90° to the strike by smaller tubes. A fall in the water level due to external erosional events will lead to the development of new conduits, either further down the dip slope on the same bedding plane, or at a lower favourable horizon. The smaller down-dip conduits ("dip-tubes") then carry water up-dip in flood conditions, to re-utilise the higher abandoned routes, which may show signs of vadose incision (i.e. Eyam Passage, Carlswark Cavern; Plate 5, 1).

An allogenic stream entering the limestone at a high elevation on the margin may often encounter a totally adverse dip, as in the western part of the Castleton catchment area (p. 87) and on Stanley Moor, Buxton (Fig. 52). In Derbyshire, penetrable caves are rare under such conditions,
for water can neither flow along the strike for any distance, nor flow down-dip. A combination of bedding planes and joints is utilised to give a zig-zag long profile to the passage, with frequent sumps, the depth of which will depend on the frequency of favourable joints. The situation is similar to that described in the Mendips by Ford, D.C. (1968).

In situations where the steep dip is favourable, such as the dip slope on which Poole's Cavern is developed (Fig. 53), a large vadose passage may develop at $90^\circ$ to the strike. The stream will eventually reach the phreatic close to the outlet level, and strike flow will occur towards the outlet if this is favourable. Otherwise the stream must cross the bedding to give a zig-zag profile as before.

In the absence of other factors, therefore, the plan of a phreatic network will reflect the fold structures it encounters (Fig. 62). The course of the stream passage of Ogof Ffynnon Ddu round the noses of plunging anticlines has been pointed out by Charity & Christopher (1977). If the fold amplitudes are relatively large, a high degree of divergence from the direction of the maximum hydraulic gradient is necessary if a stream is to flow round the nose of a fold, and the passages may then utilise joints to cut across the structure. Gently plunging folds of very low amplitude and long wavelength will be reflected in the cave plan. This can be demonstrated by the phreatic networks of Carlswark Cavern (Fig. 62), Peak Cavern, and the Lathkill/Cales Dale system (Fig. 41), but only detailed surveying may often reveal the presence of such low amplitude structures.

Once the higher conduits become abandoned to flood water only, the passages developing at lower horizons in the limestone sequence begin to capture water from the now vadose passages above. Such capture takes place on strong joints, faults, or occasionally mineral veins.

iii) Joints and Faults.

In Derbyshire, a succession of erosional events
RELATIONSHIP OF CARLSWARK COMPLEX
PASSENGES TO JOINTS AND SCREINS

KEY

- Scrin
- Major Joint
- Axis of anticline
- Cave passage
- Blocked or impermeable routes

Fig. 62
gave rise to a progressive lowering of the base levels to which the caves could drain, with development, during each period of relative stability, of one of a series of cave levels. Capture between cave levels takes place almost exclusively on joints and faults, but there is little evidence that cave passages follow joints for any significant distance.

The routes generally lie on bedding planes, for a bedding plane, extending in every direction from the point of entry of water to the phreatic, is bound to extend in the direction of the resurgence. That a master joint or fault may trend in the direction of the maximum hydraulic gradient is far less likely. At Waterfall Swallet, and at Castleton, the large veins and faults trend favourably, and it is thought, though not proven, that the phreatic routes may follow the fractures for a large part of their as yet unknown courses.

A series of joints disposed at a low angle to the direction of the maximum hydraulic gradient may have a marked effect on passage plan. The joints may give rise to a zig-zag plan. The route follows the line of extra weakness where bedding and joint intersect. When the joint direction diverges too far from the hydraulic gradient, the route again becomes bedding controlled until another joint is reached. Bossen Hole, Middleton Dale (Fig. 63) is a good example of control of a phreatic tube system by three joint-sets.

In the marginal areas to the west of Castleton, the difference between caves in the irregular reef limestones and those in the well jointed massive Bee Low Limestones further south is marked. The streams of Rushup Edge generally enter horizontal passages with frequent sumps and few pitches. The known potholes further south are exclusively deep shafts, with little known horizontal development except at considerable depth. The strong north north west - south south east trending joints in the Bee Low Limestones have provided an easy passage for swallet water in the past, and percolation water at present, to plunge straight down

Bedding plane forms prominent bench

Major joints

10 metres
almost to the level of the risings before strike flow commences in the phreas. Such shafts are Eldon Hole, Nettle Pot (Fig. 24) and Thistle Pot.

iv) Mineral Veins.

Apart from the strong east-west veins of the area, many of the minor joint sets are mineralised, and are known as "scrins". A mineral vein lying at right angles to the flow direction, either in a vadose canyon or at depth in the phreas, may have differing effects. In many cases, a stream passage may cross a vein or scrin with no disruption of its course or change in passage cross section. The vein is then seen in section in the walls, with no sign of differential solution. Where such a vein is seen in an unmodified phreatic situation, it generally contains a low proportion of relatively insoluble minerals such as baryte and fluorite. In other cases, where the vein is more susceptible to solution than the surrounding limestone, the passage may still not be diverted, but a small aven develops on the vein. The vein may on the other hand be resistant to solution, and although still not disrupting the flow, may stand out in relief from the passage walls. Many small veins in the Lower Streamway of Carlswark Cavern (Figs 9 & 62) are dominantly of baryte, and stand out as much as 20 cms, although only a few millimetres thick.

A vein disposed at a low angle to the passage direction may divert the flow parallel to the vein for some distance. The route will then either breach the vein at a point of weakness, or turn away from it. In some cases, such as the large calcite vein below Idiot's Leap in P 8, it may be hard to tell whether the water has followed the vein because the vein is comparatively soluble, or offered a weakness in the form of pre-existing cavities, or whether the stream has been diverted along the vein due to its greater resistance, breaching it at a suitably weak point. The Speedwell Cavern streamway has formed parallel to New Rake, the down-dip
feeders responding to the barrier by turning eastwards (Ford, 1956), so
that the route is now obliquely along the strike (see p. 135).

The Crabwalk, Giant's Hole (Fig. 22), is a good example of the
varying effects of small scrins. The route meanders tightly as it
encounters a network of tiny veins, dominantly of baryte. It may be
diverted by one, and follow it until another is reached. Then either the
first vein is breached, or the stream turns away, until a third bars the
way. The passage abruptly turns again, and continues to do so until the
network is passed.

The Lower Siphon Complex of Giant's Hole (Fig. 22) demonstrates the
development of capture points between cave levels, and pitches at which
a phreatic tube may end with no high level continuation, on veins. Here,
both east - west and north north west - east south east trending veins
have considerable influence. The spectacular pitch of Geology Pot
first developed by phreatic solution downwards on encountering the vein,
A lower bedding plane provides the continuing route at the bottom. Once
the water level in the region dropped, the water now flowing over the
pitch under vadose conditions cut back upstream to give the present round
shaft.

It appears that this may often happen under phreatic conditions, a
resistant vein diverting water downwards to a point at which either the
existence of primary cavities in the vein, or a change in its mineralogy,
allows the water to pass through. It may sometimes happen that the
controlling bedding plane is displaced, so that a continuation at the
same level may not be possible.

The situation in the Peak/Speedwell cave system is a fine example of
combined effects. At a time when the rising was at a higher altitude,
prior to downcutting of the Hope Valley to its present depth, the Speedwell
streamway developed obliquely down dip until it was easier for the water
to rise upwards to a higher horizon, that of the Peak controlling bedding
plane. This it did by utilising primary cavities in New Rake at lower and lower levels as the outlet elevation dropped, first at the head of Wind Tunnel, at Rift Chamber, where an aven was climbed during February 1980 by the Cave Diving Group. Later, in the Treasury area (Fig. 31) the water opened a route through "pipe" type cavities into the tube network of Peak, which it still uses in flood. Later still, Speedwell Pot was opened, and finally the stream emerged through cavities in the vein which crosses Peak Cavern Gorge at Russet Well. It is interesting to speculate on the reason for the many siphons which appear to operate in the system. Lumbago Walk, in the tourist cave of Peak Cavern, fills with water at a certain stage of flood, and suddenly empties down a boulder filled tube, to emerge in the Swine Hole. Slop Moll (Peakshole Sough) will, with falling water conditions, dry totally, and then flow strongly again several times in 12 hours. Window Sump is reported by the Cave Diving Group to discharge an intermittent stream, but this may be water let out of the canal by the Speedwell guides. Whirlpool Passage can suddenly discharge a large stream powerful enough to wash away cavers. During February 1980 it was observed that the Main Rising had almost dried up, while Whirlpool Passage was in full spate. Cohesion Sump may vary in level from week to week despite settled weather.

The reason may lie in the extensive use of vein cavity systems. At certain critical flow levels, small tubes become overpowered, and cavities fill to certain levels at which the complexities of the vertical maze allow siphons to operate. Some such siphons may operate continuously through a certain flow range, and may explain the Main Rising / Whirlpool phenomenon; it may be that almost the entire stream is siphoned across, through bedding controlled connections, from New Rake to Faucet Rake. Under normal conditions, the stream in each cavity system is separate and contained in its own route.
v) Lavas and Clay Wayboards.

The effect of lavas and clay wayboards in the limestone sequence is best seen outside the study area at Matlock (Worley & Nash, 1977), where they are often seen in the natural cavities found during mining. Here, the many tiny tubes by which water moved within an earlier phreas can be seen, left high and dry either naturally, or as a result of mine drainage.

Wayboards arrest the downward flow of percolation water, which then begins to flow along the wayboard surface, either flowing down-dip under vadose conditions, or along the strike in the phreas. The wayboard may in some cases be completely removed over a wide area (as in Carlswark Cavern), leaving an extensive network of interconnected cavities. These have great lateral but little vertical extent along the horizon formerly occupied by the clay. Once such cavities carry vadose water, vertical routes begin to form on joints until either a lower wayboard is reached, or the water enters the phreas. A three dimensional network may result. In many Derbyshire caves we see such a network, later modified by the enlargement of preferentially selected tubes in accordance with the factors governing bedding-controlled flow within the phreas.

In the Castleton area, the Lower Millers Dale Lava is represented by a clay up to 1.5 metres thick, seen to best advantage on the 'Flats' of Nettle Pot, and hence referred to here as the Nettle Tuff. The entrance shaft to the pothole is narrow, enlarging below the first of a series of prominent bedding planes which appear to have formerly been occupied by lenticular wayboards. The Flats is a wide low area formed by removal of the tuff, and the pothole enlarges dramatically beneath. It is likely that the oxidation of pyrite, in which such tuffs abound, renders the water more aggressive below this horizon. Such a situation may have been important in the formation of Eldon Hole, East and West Chambers in Oxlow Caverns (Fig. 24), Cliff Cavern in Speedwell, Crystal
Inlet in Peak Cavern, and Winnats Head Cave (Fig. 27). All lie below the horizon of the Nettle Tuff, closing to almost nothing above it.

Several important areas of perched groundwater occur as a result of the presence of lavas and tuffs. Around Bole Hill and Withered Low, near Wormhill (Fig. 47), and in Monks Dale (Fig. 50), there are many small springs high above the valley floors above the Lower and Upper Millers Dale Lavas. Those rising above the Upper Lava flow over both lavas, to sink again below. Many such springs occur above these horizons throughout the Wye Valley.

The spring in Cave Dale, Castleton, lies above the Cave Dale Lava, the probable equivalent of the Lower Millers Dale Lava and Nettle Tuff. The horizon forms an effective umbrella over most of the Peak / Speedwell cave system (Fig. 30). Water enters the cave as discrete streams rather than a large number of drips, passing through the lava or tuff only where a major joint or other fracture permits. The tuff is thought to die out towards the reef belt, the material having spilled over the fore reef slope, and where the reef limestones are intersected, in the Pickering's Series of Peak Cavern, calcite formations are suddenly abundant. It has been observed (Butcher, N; personal communication) that the reef limestone contains many small pieces of green tuff.

The Litton Tuff and Cressbrook Dale Lava have contributed to the formation of a natural underground reservoir in the Wardlow Basin (Fig. 15). High ground flanking the basin forms a large catchment area, and water is thought to pass down-dip into the basin on the surface of the Litton Tuff to the west and south, and possibly the Cressbrook Dale Lava to the east. Water first left the basin to the east, where the lava is at a low elevation on the rim, and was then captured by Cressbrook Dale, to the south. Sough drainage later punctured the aquiclude at a lower level on the east side, so that water only flows down Cressbrook Dale in flood.

The lavas and tuffs of the area are thus of prime importance in
establishing the direction of groundwater flow. The formation of water compartments bounded by a tuff or lava is more common in the south of the area where these horizons are more extensive (Oakman, 1979), but any borehole in search of water in the limestone area must be sited on the basis of close study of the extrusive igneous rocks in the limestone sequence.

vi) Limestone Lithology.

The position of caves in north Derbyshire is governed by factors such as structure, the disposition of the overlying impervious rocks, the orientation of joints and faults, the presence of interbedded lavas and tuffs, and the nature of local mineralisation. The extent to which large trunk passages will develop, and the form they will eventually take, depends largely on the lithology of the limestone.

In the phreatic situation under which the majority of the caves of the area are thought to have been initiated, underground routes developed at those horizons in the limestone sequence where permeability was relatively high, provided that a favourable bedding parting or other plane of weakness existed to assist the establishment of the early flow paths.

Within the shelf facies limestones are many such horizons. Many of the bedding planes are, or were formerly, occupied by thin clay wayboards or shales. The effect of such horizons acting as aquicludes to downward percolation has been discussed above. Where the lithology of the adjacent limestone was suitable, phreatic passages began to develop by removal, at first, of the limestone above the impervious layer (Glennie, 1954). Later, on removal of the clay or shale, limestone will be removed below the bedding plane.

Probably the most spectacular unmodified phreatic tubes occur in the Peak / Speedwell system (Plate 10, l), in particular in the main
stream passage immediately upstream from Buxton Water Sump. The bedding parting on which the passage developed is quite tightly closed, containing only a thin film of shaly material. This has prevented lateral extension of the profile, but the perfectly circular cross section of the tube (Fig. 64) results from the uniformity of lithology of the limestone, which is massive and fine grained both above and below the bedding plane. This has meant that solution could occur all round the cross section to an equal degree. Because the bedding plane was so tightly closed, the film of insoluble material was soon removed once a flow was established. In the high level complex of the cave further to the west, the bedding plane lies below the mid-point of the cross section in some areas (Fig. 64, 2). Limited solution below the bedding plane is probably due to the screening effect of a locally thicker clay or shale.

The sequence of cave levels developed in the Stoney Middleton area (Chapter 3) demonstrates a variety of passage profiles. The highest complex is developed at the base of the White Bed, a pale cherty calcilutite (Stevenson and Gaunt, 1971). Beneath Eyam Dale, tubes of the First Remnant Complex are roofed by chert bands in the upper part of the White Bed (Fig. 64, 3). The passage cross section is therefore an oval one, with curved floor, and a flat roof where the chert has slowed upward solution.

The Second Remnant Complex of Middleton Dale is developed by solutional enlargement of a bedding plane at the horizon of the Upper Shell Bed, and can be seen in the Dynamite Series of Carlsuark Cavern. Below the bedding plane lie limestones with abundant corals, and the massive limestones above have received comparatively little solution. The corals and frequent stylolites of the lower bed have given it a relatively high primary porosity, and it has been removed to a far greater extent (Fig. 64, 4). The bedding plane is therefore seen above the mid-point of the cross section; this is undoubtedly due in places to vadose incision, but
a short unmodified stretch of this tube is available for study.

The existence of a prominent bedding plane, occupied by a thin clay, at the base of the Lower Shell Bed of Stoney Middleton Dale has contributed to the formation of an extensive network of tubes referred to as the Carlswark Complex (Fig. 62). In most of the complex, solution has only occurred to a significant degree above the controlling bedding plane (Fig. 64, 3-7). Here, the limestone is packed with fossils (Plate 18, 1), often pseudobrecciated, and often displaying prominent and persistent stylolite seams of high amplitude (Beck & Worley, 1977). The massive fine-grained limestone with few fossils which lies below the bedding plane has only been removed to any great extent where vadose modification of the tube has occurred (ie. on the upstream side of the capture point to the Lower Complex in Eyam Passage; Fig. 64, 7). The dip-tube beneath Eyam Dale (North West Passage; Fig. 64, 6) lies almost entirely above the bedding plane. The screening effect of the clay seam has prevented solution of the underlying limestone until a late stage in development, while the porous shelly limestone above the wayboard has been removed. The keyhole profile of the tube is not due to vadose action; a small thickness of unfossiliferous limestone separates the wayboard from the main shell bed, and this part of the profile is constricted.

The Lower Complex of Middleton Dale formed under conditions similar to those of the Peak Cavern stream passage, but here, although the beds above and below the bedding plane are of similar lithology, the bedding parting was occupied by a clay which was quickly removed. This may have been due to a high hydrostatic head in the earliest selected tubes of the network, for the entrance passage now carries water obliquely up-dip to the the Resurgence Entrance (Fig. 10). Limestone was removed equally above and below the parting, and also laterally along the bedding plane. The result is a wide low tube (Fig. 64, 8). Had this bedding plane been tightly closed, it is likely that symmetrical round tubes would have formed.
THE EFFECT OF LIMESTONE LITHOLOGY ON THE FORM OF PHREATIC TUBES.

1. PEAK CAVERN: UNMODIFIED STRETCH OF THE MAIN STREAM PASSAGE. TIGHTLY CLOSED BEDDING PLANE. HOMOGENEOUS MASSIVE LIMESTONES ABOVE AND BELOW.

2. PEAK CAVERN: MAIN STREAM INLET SERIES. BEDDING PLANE OCCUPIED BY RESISTANT SHALY WAYBOARD. LOWER BED SCREENED UNTIL LATE STAGE.

3. CARLSWARK CAVERN: FIRST REMNANT COMPLEX. "WHITE BED" (PALE CALCIUTITE) WAYBOARD. PALE MASSIVE LIMESTONE.

4. CARLSWARK CAVERN: SECOND REMNANT COMPLEX. MASSIVE LIMESTONE WITH OCCASIONAL SHELLS. WAYBOARD. PALE LIMESTONE WITH MANY CORALS AND PROMINENT STYLOLITES.

5. "LOWER SHELL BED" WITH MANY SILIFIED BRACHIOPODS. EARLY CARLSWARK COMPLEX WAYBOARD. PALE MASSIVE LIMESTONE. SCREENING EFFECT OF WAYBOARD CLAY PROTECTED LOWER BED. TUBE WAS ABANDONED EARLY.

6. CARLSWARK CAVERN: NORTH WEST PASSAGE. "LOWER SHELL BED" WAYBOARD. DENSELY PACKED BRACHIOPODS. CARLSWARK COMPLEX DAY-TUBE. FINE GRAINED LIMESTONE WAYBOARD. LOWER BED SCREENED BY WAYBOARD.

7. CARLSWARK CAVERN: EYAM PASSAGE. "LOWER SHELL BED" WAYBOARD. FINE GRAINED LIMESTONE WAYBOARD. MATURE CARLSWARK COMPLEX STRIKE TUBE WITH SOME VADOSE MODIFICATION. PALE MASSIVE LIMESTONE. BECOMING CRINOIDAL IN LOWER PART.

8. CARLSWARK CAVERN: LOWER COMPLEX WAYBOARD. HOMOGENEOUS MASSIVE CRINOIDAL LIMESTONE ABOVE AND BELOW WAYBOARD.
1) The Lower Shell Bed of Stoney Middleton Dale as seen in the Lower Streamway of Carlswark Cavern. Shells stand out in large clusters from the walls, often falling off at a touch since they are decalcified, mud filled, and very fragile.

2) A thin coaly wayboard in Cliff Cavern, Speedwell Cavern. The wayboard lies close to the horizon of the controlling bedding plane of the Peak Cavern phreatic network.
The dark crinoidal cherty limestones in the Lower Series of Bagshaw Cavern have another effect. Solution of the limestone has proceeded to a relatively small degree. Joints close to the original tube have been enlarged, the water taking advantage of many small calcite veins, and removing small lenticular patches of clay or shale. Breakdown has occurred, and the passage has enlarged by this method, the sub-rectangular joint-bounded breakdown products being gradually abraded and removed. Large residual chert nodules, or pieces of continuous chert beds, litter the passage.

The swallowt-cum-risings on the margin of the Wardlow Mires Shale outlier have resisted attempts to enter them. The limestone here, just below the Namurian shales, is dark, muddy, often cherty, with very frequent prominent shale partings. Solution has taken place along the many thin horizons where high primary porosity and higher solubility were combined. This accounts for the many small tubes and enlarged joints which constitute this complex rising. Only when this system is explored to a point at which the underlying more massive Upper Monsal Dale Beds are reached (Fig. 14) is readily penetrable passage likely to be found.

In the Lathkill area, much of the catchment is occupied by limestones of dark basinal aspect which are unsuitable for cave development by virtue of their high content of insoluble material. However, water percolating to saturation level has produced a mature system in the Monsal Dale Beds (= Upper Lathkill Limestones). As in Middleton Dale, the major cave system follows the strike of a prominent bedding plane, and again there is a prominent shell bed just above, which has provided a medium of relatively high primary porosity for cave development. The dark Monsal Dale Beds in the eastern part of Lathkill Dale (Fig. 39) may contribute to the maintainance of a surface stream in this part of the valley, although lavas exposed for short distances in the valley floor may also play a part.
The reef limestones of the northern limestone margin to the west of Castleton are yet another case. Relatively high primary porosity allowed water to penetrate easily, but the northerly dip, variations in the dip over reef mounds, and the impersistent nature of bedding partings has meant that in the western part of the catchment area the caves are very irregular in plan and cross section, with extensive breakdown on steeply dipping joints, and with frequent sumps. As soon as the caves enter the more massive Bee Low Limestones, particularly when the dip swings to the north east in the eastern part of the area (Fig. 18), the phreatic tube networks from which the deep canyons developed become better defined, the gradient of the cave becomes more regular, and caves may be penetrable for long distances. The best example is Giant's Hole, where it took many years before explorers passed the reef belt, but once passed, it was possible to follow the stream right down to the level of the Speedwell risings.

The vertical shafts of the Bee Low Limestones stand in marked contrast to the present day marginal swallet caves of the reef belt. The vertically jointed massive limestone with frequent wayboards has given rise to percolation inlet potholes which allow water to fall to a deep saturation level before strike flow and phreatic tube formation commence.

It is therefore difficult to say that a particular lithology will not give rise to cave development at all. The dark Monsal Dale Beds seem to rarely, if ever, contain integrated cave systems, but groundwater has been able to use shelf-facies limestones nearby. At Wardlow Mires, even the muddy thin-bedded Eyam Limestones have some penetrable cavities within them. The greatest degree of cavern enlargement, however, takes place in massive, generally fine grained limestones, provided that suitable paths exist for the establishment of early flow patterns. Enlargement will tend to occur to a greater extent where fossil horizons are present, such as the Lower Shell Bed of Stoney Middleton Dale, the Lathkill Shell
Bed, and the coral bed of Fatigue Pot, Coombs Dale. Such horizons are often pseudobrecciated, and are more readily attacked by solution than the surrounding homogeneous limestone.

vii) Mines and Soughs.

In north Derbyshire, mining has interfered with the natural patterns of underground drainage to such an extent that its effects must be considered carefully in any study of the caves. It is often difficult to determine to exactly what extent the natural drainage has been altered by the mine drainage levels ('soughs') which abound in the mineral field (Rieuwerts, 1966). The position would be complicated even if all the major soughs were available for study, but many are known only from old mining records and their exact courses are unknown. In such cases there may be no obvious rising, but the existence of a sough, however poor its condition, may still interfere with the natural drainage. Round the northern margin of the limestone outcrop are many examples of modified catchment areas, phreatic systems artificially drained, greatly lowered water tables, and mysterious risings whose origin may be either natural or artificial (ie. Hawkenedge Well; p. 39). In the case of soughs long operative there may be no trace of the original natural outlet, as in the case of Moorwood Sough (p. 79).

In many places in Derbyshire, natural cavities obviously formed beneath the water table have been emptied and entered during deep mining. The phreatic cavities reached during the 1976 drought in Watergrove Mine (p. 64) are unlikely to be seen again for many years, but had been entered by the miners during the last century. In the Matlock area, mining and mine drainage have allowed studies of the effects of wayboards and lavas on drainage and mineralisation in places which would otherwise have been totally inaccessible (Worley, 1978). It is interesting to note places where the provision of free air space in mine levels and nearby
natural cavities has allowed deposition of flowstone at a comparatively high rate. Also, the breaching of clay wayboards which, until the mining, carried almost unbroken perched water tables has initiated vadose downcutting which would otherwise not have occurred.

The most spectacular effects of the mining can be seen where the miner has intersected large natural cavities, such as Speedwell Cavern, Oxlow Caverns, and the large caverns of Watergrove Mine. The existence of Bagshaw Cavern at Bradwell would probably be unsuspected if it had not been intersected by chance in the Mulespinner Mine. The frequency with which natural cavities have been intersected in the mining areas suggests that with persistence, large cave systems may be found further to the south and west, where there has been less human intervention in the past.
Chapter 12.

CONCLUSIONS.
i) Intra-Carboniferous Karstic Features.

The earliest karstic features to be recognised are those of Viséan date, resulting from short periods of uplift during which sufficient relief existed for the development of extensive potholing of limestone surfaces. In most cases there is very little angular discordance at such horizons. Walkden (1974) has demonstrated that the axes of the potholes are perpendicular to the bedding, even in dipping beds, and suggested that the possibility of modern solution is ruled out since this would demand that the potholes were vertical. It is possible that solution on joints normal to the dip could produce such features, but it is more likely that they are of Viséan age, for the requisite joint patterns are unlikely to exist in every case. The breaks in the depositional sequence are often occupied by thin films of clay, shale, or even coal (Plate 18,2), and these 'wayboards' are often important in the initiation of later karst drainage channels.

It has been suggested that a great deal of limestone was removed before the deposition of the Namurian. Certainly the relief must have been considerable, for neptunian dykes in the region of Treak Cliff have a vertical range of more than 200 ft (60 m) (Ford, 1964). At least this depth of karstification appears to have occurred here, but evidence from other areas is not forthcoming.

Simpson and Broadhurst (1969) described the boulder bed which underlies the Namurian shales on the steep frontal slope of the apron reef at Treak Cliff. They attributed the bed to the erosion of considerable quantities of limestone, which moved down the steep frontal slope to be covered by the accumulating shales. Stevenson and Gaunt (1971) suggested an $E_7$ age for the bed. Its existence again points to the development of considerable relief before Namurian deposition commenced.
Hudson (1931) described the pre-Namurian landscape of the Dovedale area. Here, deep erosion of the limestone occurred before the valleys were infilled with shale. The thickness of limestone removed may have been as great as 90 metres. It is likely, therefore, that the large-scale morphology of the limestone outcrop was determined to some extent during the mid-Carboniferous.

ii) The Permo-Triassic.

That some limestone was exposed during the Permo-Triassic is demonstrated by the presence of Carboniferous Limestone pebbles in Permian sediments in Warwickshire, but it is unlikely that the unroofing was of very great extent, and little modification of the surface is thought to have occurred. It has been suggested that the dolomitisation of the limestone may have occurred during the Permian, and it is possible that some of the large cavities found in this area had their origin at this time, to be later modified by groundwater circulation prior to collapse and infilling during the Tertiary by the sediments of the Brassington Formation (Ford, 1964; Ford & King, 1969; Walsh et al., 1972).

On both structural grounds, and on the basis of the K/Ar dates obtained for hydrothermal alteration of toadstone clays (Ineson & Mitchell 1973), the mineralisation is thought to have occurred during the Permian and Triassic. If, as seems likely, the areas of dolomitisation represent the areas of Permo-Triassic unroofing, then it is possible that for limited periods the hydrothermal fluids responsible for the mineralisation were able to escape at surface in some areas. In the north, and indeed over most of the rest of the limestone area, rising solutions would be ponded beneath a cover of Upper Carboniferous and later formations. Circulation would be slow, and solution of the limestone would either be lessened, or cavities would fill with the precipitates derived from the fluid. Where the fluid could escape, however, an inverted karst system
developed, which may or may not have been infilled by later phases of mineralisation. This may be the origin of the 'pipe' in the truest sense; the term is used here to infer a cavity, or more usually a series of interconnecting cavities, displaying very low-velocity solution features, and none of the characteristics of a cave system developed in a sub-aerial karstic regime save by later modification by descending groundwater. Such a system may be wholly or partially sediment filled, often with some attached mineral, and often with concentrations of re-worked mineral deposits.

There are many such pipes in and adjacent to the areas of dolomitisation (Worley, 1978), and relatively fewer in the north of the area. The pipes of the northern part of the limestone outcrop are rarely pipes in the sense of an inverted karst system. Mines such as Moorfurlong, and the associated Hazlebadge and Smalldale Pipes, are of relatively limited extent, and are flat lying deposits which have been later modified by meteoric karst processes (Worley & Beck, 1976). It is likely that the large caverns of Watergrove and Hubberdale Mines have reached their present size by later phreatic solution; both lie on the flanks of large structural basins which collect groundwater from a large area. Some hydrothermal cavernisation has occurred, but there is no sign of the large ramifying mineralised cavern systems of the south of the orefield.

iii) The Late Tertiary and Quaternary.

The impervious cover is unlikely to have been breached until late Tertiary times, and the earliest phreatic cave networks indicating groundwater movement may be expected to date from that time. With rejuvenation of the river system responsible for the braided river sediments of the Brassington Formation (Boulter et al., 1971), limited relief became available for slow phreatic solution to take place. With lowering of the water table in the areas of limestone which were
unroofed first, removal of hydrostatic pressure in the Triassic caverns initiated upward stoping, at last breaching the top of the limestone, and allowing the subsidence of Tertiary sediments into the cavities. The details of the Brassington Formation and associated caverns have been discussed by Ford (1964), Boulter et al. (1971), Walsh et al. (1972), and the work summarised by Ford, (1977).

Many areas of perched groundwater exist (i.e. Wormhill Moor, Fig. 48; Priestcliffe, Fig. 55; Brook Head, Fig. 57) above lavas and tuffs within the limestone sequence, and these springs often lie well above 1000 ft (305 m) A.O.D. Their elevation is stratigraphically controlled, however, and the highest remnants of large drainage systems developed where no such aquiclude exists are such as Water Icicle Close Cavern and Ravencliffe Cave (1000 ft; 305 m), and the phreatic outlet of Pooles Cavern (1150 ft; 350 m). A valley floor rising is likely in all three cases, for none shows signs of vadose activity. The outlet of Pooles Cavern (the present entrance) may be a later development, for it is said to have discharged water in flood conditions until comparatively recently (see p. 238). If it was related to the '1000 ft' surface, rising to 1100 ft (335 m) in the Buxton area, then a very long standstill in the deepening of the upper Wye Valley is implied, for the present outlets are juvenile in nature (Fig. 52).

Although fragments of cave passages do occur in the northern part of the limestone outcrop at high altitude (i.e. the high level phreatic network of the Giant's/Oxlow system), they are seen in isolation, and cannot be related directly to external factors. It is possible that limestone was exposed in these areas, but it is unlikely that sufficient relief was available for the development of mature systems at this time.

During the early Pleistocene, therefore, the central portion of the present limestone outcrop was drained by cave systems whose outlets lay at around 1000 ft (305 m) A.O.D. in the east, and up to 1100 ft (335 m) A.O.D.
near what was then the western margin of the outcrop. The position of the risings was related directly either to base level, or to the local base level controlled by the elevation of the shales at the lowest points on the eastern margin. Most of the northern area lay beneath a cover of younger rocks, and only limited shallow phreatic circulation took place, with possible enlargement of primary vein cavities, and development of local bedding controlled tube networks on a small scale.

The most complete sequence of cave levels below the elevation of the '1000 ft' surface is to be found in the Stoney Middleton catchment area (Chapter 3). There are no representatives of a drainage system associated with highest local base level of 1000 ft (305 m), but the majority of the limestone of the area lies below that level, and the areas likely to be exposed would have very low relief and small extent.

It is unfortunate that Stoney Middleton Dale has been so extensively quarried; this has rendered it impossible to determine any terrace remnants in the valley sides. The phreatic caves provide a great deal of evidence, however. The highest complex, the First Remnant Complex, lies between 660 ft (201 m) and 680 ft (207 m) A.O.D., with fragmentary vadose inlet caves between 680 ft (207 m) and 740 ft (225 m) A.O.D. The group of caves can be projected eastwards, and appears to have operated when the outlet elevation lay between 650 ft (198 m) and 670 ft (204 m) A.O.D., implying lowering of the base margin of the limestone at Stoney Middleton by some 40 metres since the time of phreatic operation of the complex.

The Second Remnant Complex tube in the Dynamite Series of Carlswark Cavern (Fig. 11) has recently received further attention from A.L.Buckley, and its continuation located. It continues as a very large tube leading north westwards. The passage lies at an elevation of 615 ft (187 m) A.O.D. The process of capture from the First Remnant Complex is well demonstrated; upstream from the capture point, the First Remnant tube displays a vadose trench. Downstream from the capture point, it is unmodified and silted.
Access to the far reaches of the Dynamite Series is by way of a series of narrow joint and bedding controlled passages, which have carried water down from the Second Remnant to the Carlswark Complex (Figs. 9 & 11). At a later stage, capture has taken place further to the north and west, leaving the higher passages in this region dry.

The Carlswark Complex, the most extensively known, is still active in its western reaches, though the eastern outlets to the valley side, at an elevation of 590 ft (180 m) A.O.D., are always dry. The most easterly passages show no sign of vadose activity, but only a short distance to the west are capture points to the little known Lower Complex (Fig. 9), the present active flood resurgence level. Upstream from these capture points vadose incision is apparent to a limited extent (Plate 5, 1). The route was quickly abandoned in response to a falling outlet level, in favour of capture points further west. The present rising lies at 550 ft (168 m) A.O.D. at valley floor level, some distance upstream from the present limestone / shale margin at Stoney Middleton, at 500 ft (152 m) A.O.D.

The cave levels at Stoney Middleton are thus as shown in Table 2.

<table>
<thead>
<tr>
<th>Complex</th>
<th>Vertical range of phreatic tubes</th>
<th>Outlet elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Remnant Complex</td>
<td>660 ft (201 m) to 680 ft (207 m)</td>
<td>650 ft (198 m) to 670 ft (204 m)</td>
</tr>
<tr>
<td>Second Remnant Complex</td>
<td>615 ft (187 m)</td>
<td>610 ft (186 m)</td>
</tr>
<tr>
<td>Carlswark Complex</td>
<td>590 ft (180 m) to 605 ft (184 m)</td>
<td>590 ft (180 m)</td>
</tr>
<tr>
<td>Lower Complex (active)</td>
<td>550 ft (168 m) to 560 ft (171 m)</td>
<td>550 ft (168 m)</td>
</tr>
</tbody>
</table>
The apparent abruptness of capture by lower cave levels in the Stoney Middleton catchment suggests response to a series of erosional events which lowered the level of the outlet relatively quickly. It is likely that in the cases of the most abrupt capture, a halt to cave development was associated with considerable deepening of the valleys. On resumption of favourable conditions, caves were able to develop at lower levels, leaving old routes dry. The blocking of caves by ice and till during glacial advances, and the development of permafrost under cold periglacial conditions provide a likely explanation. The latter case would allow deepening of the valleys to occur, because the frozen ground would maintain meltwater streams on the surface, and such streams would be charged with the abrasive derivatives of till sheets in the source area (Warwick, 1971).

It has not proved possible to relate the cave levels of Stoney Middleton Dale directly to the terraces of the River Derwent described by Waters & Johnson (1958). Breaks of slope in the floor of the dale are masked by quarrying and mining debris, but there do appear to be breaks at 540 ft (165 m) and 650 ft (198 m) A.O.D. The Hathersage Terrace lies between 480 ft (146 m) and 500 ft (152 m) A.O.D. along the Stoke Brook to the east of Stoney Middleton, but cannot be projected with confidence into the gorge section. If the lowest outlets of the underground drainage system were related to the Hathersage valley floor (of Wolstonian date or earlier at Bakewell), it would imply that no adjustment in outlet level had occurred throughout the Ipswichian and Devensian.

On morphological grounds (depths of vadose incision, the extent of cave levels, and the abruptness of capture), the longest stillstands appear to have occurred during First Remnant and Carlswark Complex times. Both are very extensive within the areas of their development. If little or no limestone was exposed in the area until the end of the Tertiary, it is tempting to suggest the sequence of events shown in Table 3 and Fig. 65.
Table 3. Development of Successive Cave Levels at Stoney Middleton.

<table>
<thead>
<tr>
<th>System/Stage</th>
<th>Base Margin Elevation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower &amp; Middle Pleistocene.</td>
<td>680 ft (207 m)</td>
<td>Initiation and development of First Remnant Complex as significant hydraulic gradient was established.</td>
</tr>
<tr>
<td>Cromerian.</td>
<td>660 ft (201 m)</td>
<td>Some capture at eastern end of system. Vadose incision down to 660 ft. Easternmost tubes silted and abandoned.</td>
</tr>
<tr>
<td>Anglian Glacial.</td>
<td>-</td>
<td>Lowering of base margin during later stages to 610 ft. Partial choking of First Remnant Complex during recessions of ice.</td>
</tr>
<tr>
<td>Hoxnian Interglacial.</td>
<td>610 ft (186 m)</td>
<td>Second Remnant Complex becomes important. Development of large conduits of limited areal extent. Eastern First Remnant abandoned.</td>
</tr>
<tr>
<td>Wolstonian Glacial.</td>
<td>-</td>
<td>Some base margin lowering during recessions; till deposited on eastern slopes of limestone down to 600 ft (Dalton, 1945).</td>
</tr>
<tr>
<td>Ipswichian Interglacial.</td>
<td>590 ft (180 m)</td>
<td>Carlswark Complex widespread. Large strike tubes developed with down-dip connections. Extensive flowstone deposition in heavily silted Remnant Complexes. Drainage of western area isolated by Streaks Vein. Capture of part of headwaters of Middleton Dale by Cressbrook Dale on isolation of Wardlow Mires Shale outlier (Fig. 15).</td>
</tr>
<tr>
<td>Devensian Glacial (no glaciation in area).</td>
<td>-</td>
<td>Base margin lowered towards 500 ft under periglacial conditions. Carlswark Complex still active, but extensive silting of highest tubes as vadose incision begins at eastern end. Lower Complex initiated. Stages 2 - 5 of Gimli's Dream (Fig. 16) represent changing conditions in the Devensian.</td>
</tr>
<tr>
<td>Post Glacial.</td>
<td>500 ft (152 m)</td>
<td>Lower Complex matured. Head of incision of Hope Terrace now at Stoney Middleton at 500 ft. Incomplete adjustment of caves to this level.</td>
</tr>
</tbody>
</table>
STAGES IN REMOVAL OF THE IMPERVIOUS COVER IN THE STONEY MIDDLETON CATCHMENT AREA.

1. Cromerian

Early Pleistocene, First Remnant Complex initiated.
By Cromerian some vadose incision of the most easterly routes occurred; some minor tubes silted.
Rising at 660 ft (200 m) A.O.D.

2. Ipswichian

Second Remnant Complex became important after Anglian Glacial. Wolstonian saw further lowering and till deposition prior to formation of Carlswark Complex.

Rising of strike-controlled Carlswark Complex, route at intersection of Lower Shell Bed with the valley floor 590 ft (180 m) A.O.D.

Rising of Carlswark Complex passages isolated by the barrier of Streaks Vein at 650 ft (198 m) A.O.D.

3. Present

Valley floor lowered by 90 ft (27 m) during Devensian, and major swallow established on the newly exposed Crosslow Vein Lower Complex rising at 550 ft (168 m) A.O.D.

Fig. 65
It is difficult to relate the deductions shown in Table 3 to stages of cave development in other areas, for only at the margins of the limestone outcrop, and in Lathkill Dale, are extensive cave systems available for study. The sequences are often poorly defined and incomplete.

An important clue is provided by the dates of $111,000 \pm 5,000$ years and $183,200$ to $190,000$ years for flowstone from Treak Cliff and Winnats Head Cave respectively (see p. 122). Dates for flowstone from Peak Cavern have recently been obtained by M. Gascoyne (Ford, T.D., personal communication). The earliest date, from Upper Gallery (Fig. 29) was $73,200 \pm 2,000$ years, and dates indicating flowstone formation during the Chelford Interstadial ($58,000 \pm 2,500$ years and $50,800 \pm 1,800$ years) were obtained from the lower part of the Main Stream Passage on the upstream side of Buxton Water Sump. However, it is uncertain whether the last two samples had fallen from the roof of the canyon, or split away from the canyon walls.

The flowstone dates from the Castleton region, some of which are associated with phreatic tube networks, may provide a basis for correlation between areas when combined with the striking series of cave levels seen at Stony Middleton. In the Peak / Speedwell system at Castleton, a series of outlet levels can be defined on the basis of the stages of incision of the Peak and Speedwell main stream passages. Both systems are flooded below $615$ ft ($187$ m) A.O.D. The streams flow in an unmodified phreatic tube (Peak; Plate 10, 1) and an unmodified bedding plane passage (Speedwell) between $640$ ft ($195$ m) and $615$ ft ($187$ m) A.O.D. Shallow incision appears in both routes above $640$ ft ($195$ m), becoming more pronounced above $650$ ft ($198$ m), and in Speedwell there is a definite change to a more mature canyon above approximately $675$ ft ($206$ m). Similar changes occur in the Peak stream passage (Fig. 31).
We conclude from the caves at the eastern end of the Castleton catchment area that there were at least three stages in lowering of the outlet at Castleton from 730 ft (222 m) to the present level of 615 ft (187 m). It is known that flowstone formation in the lower parts of the high level phreatic network of the Peak / Speedwell system had commenced by the Chelford Interstadial, and that Upper Gallery had free air space, and had probably been incised below 675 ft (206 m) by the late Ipswichian.

The presence of the large east-west veins, and the smaller north-west-south east mineralised fissures is likely to have led to isolation of the swallet caves further to the west so far as the incision stages were concerned, response to lowering of the outlet elevation taking some time. Some conclusions may be drawn, however.

Johnson (1967) suggested a Devensian date for the formation of the extensive solifluxion sheet which floors the Rushup Vale, and pointed out that Giant's Hole must pre-date that sheet (see p. 158). Emplacement of the material must post-date the incision of the upper part of the canyon to within 2 metres of its present depth. A pre-Devensian date is therefore likely for the commencement of incision, and the swallet cave must have been initiated much earlier, possibly during the later stages of the Anglian or Wolstonian.

It was suggested by Johnson (1967) that the western series of swallets post-dated the last period of intense cold. However, the relative maturity of some of the entrance passages (ie. P8; Fig. 21) and complex series of abandoned high level routes suggest a long period of development. It is possible that they were abandoned at times during the Devensian, and later re-excavated by the redistributed streams from the escarpment. The lack of extensive penetrable cave systems in the western part of the Rushup Vale is due rather to structural considerations than to immaturity. The dip is to the north west, while the hydraulic gradient is to the south east, towards Castleton. Water is prevented from flowing southwards to the River Wye by
the structural barrier of the Peak Forest Dome (Fig. 2), and caves therefore generally end in sumps. Some of the western influent caves are undoubtedly of recent origin (ie. Sheepwash Swallet, Fig. 18), but others (ie. Gautries Hole, Little Bull Pit, and Jackpot P8) are associated either with mature high level passages or with well defined surface features which appear to have been infilled with soliflucted material, and are now being re-excavated.

The relationship of the incision stages of the Castleton caves to the river terraces of the Derwent (Waters & Johnson, 1958) is obscure, for only the rejuvenation head responsible for the Hope Terrace has progressed upstream to Castleton. Waters & Johnson (1958) showed that the Hathersage Terrace was not traceable in the Hope Valley above Hope, and it appears that the rejuvenation head of incision into the Hope Terrace has overtaken that of the Hathersage Terrace on the Peakshole Water as it has on the River Noe.

Boulder clays reputed to be of Wolstonian date lie on the Hathersage Terrace at Bakewell (Burek, 1977). Waters & Johnson (1958) refer the gravels which lie below this terrace to the closing stages of the same glaciation (' Older Drift'), so that the Hope valley floor existed by the early Ipswichian. It is possible on this basis that incision of canyons below 675 ft (206 m) in the Peak / Speedwell system occurred during the Ipswichian, which would suggest that incision down to 640 ft (198 m) A.O.D. had already occurred by the Devensian. This implies that a considerable rise in outlet level occurred in the Devensian due to the choking of the Peak Cavern Gorge with scree, preventing further incision down to the level of the present rising at 615 ft (187 m) A.O.D. While this last point may be true, it appears that the flowstone dates may be more reliable indices of stages in the drainage of the phreatic tube network than the projection upstream of the thalwegs of former valley floors. A suggested chronology of cave development in the Castleton area is given in Table 4.
Table 4.  Chronology of Cave Development in the Castleton Area.

<table>
<thead>
<tr>
<th>System/Stage</th>
<th>Base Margin Elevation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower &amp; Middle Pleistocene</td>
<td>900 ft? (274 m)</td>
<td>Limited exposure of limestone to north of Peak Forest. Highest tubes initiated (ie. Giant's/Oxlow). Outlets may have been where Dirtlow Rake passed beneath the shale in the region of Pindale, down to 900 ft (274 m) by end of Middle Pleistocene; development of Black Rabbit Cave etc.?</td>
</tr>
<tr>
<td>Cromerian</td>
<td>above 800 ft (244 m)</td>
<td>Outlets established near Castleton (Cave Dale?) utilising vein cavity systems. Swallets at Winnats Head and on Longcliff, and at shale margin further west, to the south of the present shale margin/swallet line. No Winnats Pass except for shallow flood channel.</td>
</tr>
<tr>
<td>Anglian Glacial.</td>
<td>-</td>
<td>Base margin of limestone at Castleton lowered towards 720 ft (219 m). Some stripping of shale from Winnats Head/Windy Knoll area. Deepening of Winnats Pass on retreat of ice.</td>
</tr>
<tr>
<td>Hoxnian Interglacial.</td>
<td>730 ft (222 m)</td>
<td>Winnats Head Cave abandoned as a swallet. Some flowstone formation. Treak Cliff (and Windy Knoll?) became important swallet caves. Treak Cliff drained via Suicide Cave into the east-west system in the rakes. The outlets in Peak Cavern Gorge began to function. Speedwell streamway matured, discharging entirely through Wind Tunnel and Treasury into Upper Gallery. The Pickering's Series and upper parts of main stream passages were incised down to 730 ft (222 m).</td>
</tr>
<tr>
<td>Wolstonian Glacial.</td>
<td>-</td>
<td>Headward incision of Hope Valley along the shale margin. Shale stripped northwards from Treak Cliff. Base margin approached 675 ft (206 m) at Castleton. Deepening of Winnats under periglacial conditions. Peak Cavern Gorge largely choked with scree; temporary rise in outlet level led to some clay filling of tubes, and choking of higher parts of the large stream canyons.</td>
</tr>
</tbody>
</table>
Table 4 (Contd.).

<table>
<thead>
<tr>
<th>System/Stage</th>
<th>Base Margin Elevation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipswichian Interglacial</td>
<td>675 ft (206 m)</td>
<td>Flowstone formation in Treak Cliff as Blue John became important. Russet Well outlet initiated by enlargement of primary vein cavities. Upper Gallery incised down to 675 ft (206 m) by the Speedwell overflow; some flowstone formation. Incision of main stream passages down to 675 ft (206 m). Longcliff swallets abandoned as shale was stripped.</td>
</tr>
<tr>
<td>Devensian Glacial (early) (no glaciation in the area)</td>
<td>-</td>
<td>Onset of periglacial conditions led to choking of the marginal swallets with solifluction material. Considerable modification and incision may have occurred. Outlet level in Peak Cavern Gorge was lowered and lowest routes of Peak (Swine Hole and Halfway House to Resurgence) became more mature.</td>
</tr>
<tr>
<td>640 ft (195 m)</td>
<td>Chelford Interstadial.</td>
<td>Rising at 640 ft (195 m) in Peak Cavern Gorge. Flowstone formation in roof tube of main stream passage below 675 ft (206 m) and incision down to 640 ft (195 m).</td>
</tr>
<tr>
<td>Middle &amp; Late Devensian (no glaciation in the area)</td>
<td>-</td>
<td>Final deepening of the valleys by periglacial meltwater. Deep incision of Winnats Pass before headward erosion of Perry Dale into Rushup Vale, and of the Hope Valley, reduced the catchment area.</td>
</tr>
<tr>
<td>Post Glacial</td>
<td>615 ft (187 m)</td>
<td>Base margin of the limestone at Castleton stands at 615 ft (187 m). Lowest outlets of Peak / Speedwell system mature, but still inadequate in flood, and still partly choked with the products of late Devensian re-excavation of passages further west. Extensive re-excavation of swallet caves. Very little canyon incision below 640 ft (195 m) in Peak / Speedwell and level of phreas between swallet and resurgence caves stabilised at 800 ft (244 m).</td>
</tr>
</tbody>
</table>
The development of the present underground drainage systems of the Bradwell area was considered by Ford et al. (1975) who concluded that the closing stages of either the Anglian or Wolstonian glaciation marked the beginning of utilisation of underground routes consistent with a hydraulic gradient towards the Hope Valley. This can be refined by reference to the various phreatic cave levels seen in Bradwell Dale.

The sequence of cave levels in the Bradwell area has been discussed in Chapter 5 (vii). The limestone at present exposed on Bradwell Moor (Fig. 34) rises to a much greater altitude than that at Stoney Middleton, and it is likely that limestone was exposed here much earlier. The highest cave level (the Hartle Dale Complex) may thus have developed at a time when no significant hydraulic gradient existed in the Stoney Middleton area. It is remotely possible that the Hartle Dale Caves are contemporaneous with the development of the very highest fragmentary caves of Stoney Middleton which are insufficiently preserved to group into a 'complex'. Even if this is so, however, a far greater degree of lowering must have occurred at Bradwell in between the first two cave levels. It is likely that an unknown cave level exists, albeit poorly developed, in the Bradwell area, or that the very early system operated here for a much longer period than elsewhere without the development of intermediate levels.

The polycyclic nature of the long profile of the River Derwent (Waters & Johnson, 1958) would suggest that less altitudinal discrepancy might be expected between the older contemporaneous cave levels of the Bradwell and Stoney Middleton areas. This again does not support the contemporaneity of the Hartle Dale Complex (at around 900 ft (274 m) with the earliest integrated phreatic network (the First Remnant Complex) at Stoney Middleton. At Bradwell, as at Stoney Middleton, the terraces of the River Derwent cannot be traced into the limestone gorge, and it appears that the present active rising lies close to the elevation of the
Hope Terrace, although even this conclusion can only be reached by projection of the thalweg of the Hope valley floor.

A suggested correlation of the cave levels of Bradwell and Stoney Middleton is given in Table 5.

Table 5.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower - Middle Pleistocene.</td>
<td>Hartle Dale Complex.</td>
<td>905 ft (276 m)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cromerian.</td>
<td>-</td>
<td>-</td>
<td>First Remnant Complex.</td>
<td>660 ft (201 m)</td>
</tr>
<tr>
<td>Hoxnian.</td>
<td>Hazlebadge Complex.</td>
<td>690 ft (210 m)</td>
<td>Second Remnant Complex.</td>
<td>610 ft (186 m)</td>
</tr>
<tr>
<td>Ipswichian.</td>
<td>Bradwell Parish Complex.</td>
<td>670 ft (204 m)</td>
<td>Carlswark Complex.</td>
<td>590 ft (180 m)</td>
</tr>
<tr>
<td>Late Devensian to Recent.</td>
<td>Lower Complex.</td>
<td>600 ft (183 m)</td>
<td>Lower Complex.</td>
<td>550 ft (168 m)</td>
</tr>
</tbody>
</table>

The only other major catchment area in which a series of cave levels can be defined to any extent is Lathkill Dale, but the position here is made complicated by the fact that the structure to the east of the main discharge points does not favour adjustment to the lowest base margin of the limestone, and part of the valley floor consists of lavas which render further lowering of the underground drainage routes impossible (See Chapter 6, v).

Below the Water Icicle Complex (Fig 43) there are no well defined phreatic caves above 800 ft (244 m) A.O.D. Then, between 770 ft (235 m) and 800 ft (244 m) there are a large number. One Ash Cave, Upper Cales Dale Cave, Lynx Cave (Fig. 44) and the phreatic tubes of Raven Mine and Cascade Cavern all lie within this range of elevation. Some, especially in Cales Dale, are associated with a prominent bench, partly stratigraphically controlled, on the valley side, and all appear to have been
related to an outlet level at around 800 ft (244 m) A.O.D. The passages of the Bung Series in Knotlow Mine represent a part of the Upper Cales Dale Complex which is still active in the distal catchment. Water flowing through this route falls to a lower elevation on Crimbo Pipe (Fig. 42), and continues down the Crimbo Swallow to a deep sump which was penetrated during the 1976 drought almost to the level of the risings in Lathkill Dale.

The Lathkill Head Complex normally carries all the drainage of the area. The cave entrance, which is now only active in flood conditions, lies well above the main controlling bedding plane of the cave, which lies below the valley floor except in the eastern part of the known cave system. The valley has been incised below the lines of springs (Fig. 41) but further adjustment in the level of the outlet has been prevented by the saddle in the structure, which brings dark Monsal Dale Beds to the surface to the east. It is possible that prior to complete capture by the Lathkill Head Complex, there was an intermediate level, represented now only by the tubes of Ricklow Cave. They lie at approximately 730 ft (223 m) A.O.D., just below the top of a steep knick point.

Again, the terraces recognised on the River Derwent are untraceable into the area of maximum development of the four cave levels. The nearest locality to Cales Dale at which boulder clay can be seen resting on a terrace is more than two miles downstream, north of Conksbury, and the terraces are lost in the screes and mine workings of upper Lathkill Dale. It is possible that an intensive study of the underground drainage of the lower part of the valley prior to the mining activity might reveal significant relationships here, and Bradford Dale contains risings close to the limestone/shale margin which would be worthy of investigation.

Correlation of the cave levels of Lathkill Dale with those of other areas is speculative, but the sequence of events shown in Table 6 is suggested.
Table 6. Stages in Cave Development in the Monyash Basin.

<table>
<thead>
<tr>
<th>System/Stage, Outlet Elevation,</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower &amp; Middle Pleistocene</td>
<td>1000 ft?</td>
</tr>
<tr>
<td></td>
<td>(305 m)</td>
</tr>
<tr>
<td></td>
<td>Limited exposure of limestone on the flanks of the Monyash Basin. Large allo-genic source area for integrated streams. Strike flow initiated parallel to the long axis of the basin. Water Icicle Complex began to develop, a mostly phreatic system with limited vertical range.</td>
</tr>
<tr>
<td>Cromerian.</td>
<td>1000 ft</td>
</tr>
<tr>
<td></td>
<td>(305 m)</td>
</tr>
<tr>
<td></td>
<td>Some lowering of the outlet elevation by the removal of shale to the east gave rise to enlargement and extension of the complex. There is no evidence for any vadose activity.</td>
</tr>
<tr>
<td>Anglian.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Deepening of the valleys by meltwater in later stages.</td>
</tr>
<tr>
<td>Hoxnian.</td>
<td>800 ft</td>
</tr>
<tr>
<td></td>
<td>(244 m)</td>
</tr>
<tr>
<td></td>
<td>The size of the allo-genic catchment was reduced. Upper Cales Dale Complex became important, but although extensive, passages were smaller in size than the earlier Water Icicle Complex.</td>
</tr>
<tr>
<td>Wolstonian.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Deepening of valleys. Deposition of boulder clays now seen on terraces up to 600 ft (183 m).</td>
</tr>
<tr>
<td>Ipswichian.</td>
<td>730 ft?</td>
</tr>
<tr>
<td></td>
<td>(223 m)</td>
</tr>
<tr>
<td></td>
<td>Water may have begun to utilise the horizon of the Lathkill Shell Bed, but rose from depth via phreatic networks such as Ricklow Cave to discharge at a higher elevation further west than now.</td>
</tr>
<tr>
<td>Devensian.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>No glaciation. Lathkill Head Cave outlet?</td>
</tr>
<tr>
<td>Post Glacial.</td>
<td>660 to 680 ft</td>
</tr>
<tr>
<td></td>
<td>(201 to 207 m)</td>
</tr>
<tr>
<td></td>
<td>The lower risings began to discharge water, but despite incision of the valley below this elevation, incomplete adjustment has occurred due to adverse dip on a saddle in the axis of the syncline. The long period of operation of the Lathkill Head Complex has given one large conduit which discharges through higher outlets in flood conditions.</td>
</tr>
</tbody>
</table>
With the exception of the caves of Blackwell Dale, other areas do not display a sequence of cave levels, and evidence consists of isolated caves. In Blackwell Dale, four cave levels are indicated between 790 ft (241 m) and 900 ft (274 m) A.O.D., with a small and probably unrelated cave on the south bank of the River Wye at 660 ft (201 m) A.O.D. Any correlation with other areas is difficult, for the rest of the Wye Valley displays virtually no significant penetrable cave systems below Buxton, and the stages of its incision are hard to relate to the known chronology of the Pleistocene. The similarity of the Blackwell Dale situation to other areas lies solely in the number of cave levels present, but their vertical range is limited. If the sequence bears any relationship to the cave levels further north, slow downcutting is implied down to 790 ft (241 m) A.O.D. before the end of the Devensian. Rapid deepening must then have occurred during and after the Devensian, not allowing complete adjustment of the cave levels to the latest base level represented by the main river. Correlation with the recognised terraces of the river system is again difficult, for the knick point associated with the highest (Hathersage) terrace is considered by Waters & Johnson (1958) to lie at around 720 ft (219 m) in Chee Dale. The present Blackwell Dale rising therefore lies considerably above this terrace, but the absence of boulder clays on terraces in this part of the Wye allows no conclusion to be reached regarding the date of upstream migration of the knick point.

In the case of the Wormhill catchment, it appears that the rising has occupied the same site, though at a progressively lower elevation, for a long period (see p. 227) and only entry to the cave system will reveal the sequence of stages of downcutting.

Still further to the west, at Poole's Cavern, a mature cave system exists at an elevation of 1150 ft (351 m) A.O.D., passages below that elevation being very juvenile so far as is known, and carrying the cave stream to the Wye Head rising 150 ft (46 m) below on the south side of the
Wye Valley. Although three stages of lowering of the outlet (and the consequent incision of the floor of the cave; Fig. 53) can be recognised, the cave is seen in isolation and cannot be readily related to other areas. That some degree of karstification occurred at an early date is shown by the Victory Quarry Fissure (Dawkins, 1908; Bramwell, 1977). The maturity of the Poole's Cavern stream passage suggests that the cave may have been initiated at an early stage, but it must also be remembered that an allogenic underground stream charged with the abrasive material derived from receding sandstone escarpments would incise a deep trench into the floor of a dip-tube faster than an accumulated percolation stream could achieve the same degree of enlargement.

Further exploration and study of the caves of the area are yielding new information constantly. During the writing of this chapter (June, 1980), nearly 900 metres of new cave passage has been found at Stoney Middleton, mostly belonging to the Carlswark Complex, and largely confirming the conclusions already reached regarding structural and stratigraphic control of the cave systems. It is possible that in future, other areas will reveal sequences of cave development, allowing caves such as Ravencliffe, Fatigue Pot in Coombs Dale, small disjointed cave segments in Monks Dale, and the few caves of the Wye Valley to be fitted into an acceptable chronology.

iv) The Development of the Plateau Surface and Initiation of the Drainage Pattern.

It has been demonstrated that a great deal of limestone was removed from the Derbyshire area before the deposition of the Namurian (Hudson, 1931; Ford, 1964), and it is likely that the broad features of the limestone topography were developed during that period, and to a lesser extent in the Permo-Triassic (Fearnside, 1932). There is both theoretical and field evidence to suggest that a considerable thickness of
limestone was removed after unroofing of the limestone in the early Pleistocene however. Pitty (1968) suggested, on the basis of rates of solutional surface lowering calculated by various workers that the limestones near the margin had been exhumed for between 3 and 6 million years, and that the surface was being lowered by between 75 and 83 mm per 1,000 years. The rate of lowering may actually be less than Pitty's estimate (Drew, 1974), and it has been demonstrated that 40% of the calcium carbonate discharged at Russet Well, Castleton, enters the sinks with the allogenic water (Christopher, Beck, & Mellors, 1977). The truncation of potholes such as Eldon Hole, and dissection of caves in the valley sides (i.e., Cucklet Church Cave) which were certainly formed after exhumation in the Pleistocene, supports the removal of a considerable thickness of limestone nevertheless.

The earliest evidence from which an absolute date can be obtained is the case of the bones from the Victory Quarry Fissure Cave, which suggest a period in the order of 1 million years since the infilling of the cave (Bramwell, 1977). The absence of extensive high level caves removed from the present limestone/shale margin suggests quite rapid unroofing, which was largely completed prior to the development of a sufficient hydraulic gradient to allow the formation of integrated underground drainage systems, and without the lapse of sufficient time for integrated allogenic streams to form caves which took advantage of the small gradients that did exist. No direct evidence has been found to indicate that remnant caves lay abandoned in the valley sides earlier than the Hoxnian (see p. 301) and even these lie at the highest altitudes in the north. The lack of significant relief during stripping suggests that the limestone had been subjected to considerable peneplanation at an earlier stage, and at least partly negates Pitty's hypothesis.

It was first suggested that the present drainage pattern of the area was superimposed from an impervious cover by Farey (1811) with reference
to the Derwent at Matlock. It was suggested by Fearnside (1932) that the Derwent had developed by headward erosion, largely following the strike of the Namurian shales, but this view was challenged by Linton, (1951). Linton's explanation of superimposition is now widely accepted, although Clayton (1953) suggested that the drainage originated on the "upland surface". Warwick (1964) supported the view that the present dry valley pattern had originated on an impervious cover, and showed that the present situation, in which so few of the valleys carry streams, was a result of gradual lowering of water tables with rejuvenation of the main rivers. This in turn led to progressive dessication and elimination of tributaries. Warwick's findings also supported a lack of significant relief during the early stages of stripping of the cover, the successive rejuvenations of rivers which cut through the shale seal to the south and east of the limestone mass leading to the development of progressively greater hydraulic gradients.

v) The Overall Pleistocene Chronology.

The picture which emerges from a study of the available speleogenetic evidence is one of gradual exposure and dissection, throughout the Pleistocene, of a limestone area which already possessed, in some areas, an extensively developed hydrothermal karst. A succession of halts in the process of cave formation, each accompanied by aggradation of the upper reaches of some valleys followed by knick point recession and a resumption of underground drainage, led to the development of a succession of cave levels.

During the early Pleistocene, comparatively large areas were exposed, but low relief was available for the formation of extensive cave systems. That some karstification occurred at a very early date is illustrated by the Victory Quarry Fissure (Dawkins, 1903), but absolute dates from this period are rare. The highest phreatic tube networks of the Castleton area,
at 1050 ft (320 m), beneath Bradwell Moor (1100 ft/335 m), on the flanks of the Lathkill Syncline (1000 ft/305 m), to the south of Buxton (1180 ft/360 m) and in the northern tributaries of the River Wye (1000 ft/305 m) may have been initiated during the early Pleistocene. Development was not contemporaneous in all these areas, and the exact sequence cannot be determined, but Johnson (1954 & 1957) has recognised remnants of former valley floors along the River Wye. The fragmentary caves lying at 1000 ft (305 m) A.O.D. in the central Wye Valley may be related to the lower Topley Pike surface, and the highest outlets of Poole's Cavern are close to the elevation of the highest surface defined by Johnson (the Hall Green stage).

The earliest networks of which clear evidence remains lie between 680 ft (207 m) in the east, and 1100 ft (335 m) further to the south west and north (Table 7). It is likely that by the Cromerian there was sufficient relief for important underground drainage routes to be operating. The lowest outlets were near to the eastern margin, at 660 - 680 ft (201 - 207 m) at Stoney Middleton, rising to around 900 ft (274 m) at Bradwell, and to above 1150 ft (351 m) at Buxton.

The Anglian Glaciation saw the area at least partly overridden by ice, with deposition of till on the high ground between 1000 ft (305 m) and 1300 ft (396 m) A.O.D. (Jowett & Charlesworth, 1929). The later stages of this glaciation saw local base levels lowered to 610 ft (186 m) near to the eastern margin at Stoney Middleton, 690 ft (210 m) at Bradwell, 720 ft (219 m) at Castleton, and as high as 850 - 900 ft (259 -274 m) in the central part of the Wye Valley.

The Hoxnian interglacial saw the operation of a new suite of underground drainage routes related to lowered local base levels. The recession of the shale margin during the later stages of the preceding glaciation saw the Winnats Head Cave abandoned as a swallet cave, with large streams sinking at the new influent caves of Treak Cliff and Windy
Table 7.
Suggested Correlation of Developmental Stages in the Major Catchment Areas.
(Figures in brackets indicate probable outlet elevation).

<table>
<thead>
<tr>
<th>System/Stage</th>
<th>Stoney Middleton</th>
<th>Bradwell</th>
<th>Castleton</th>
<th>Lathkill Dale</th>
<th>Blackwell Dale</th>
<th>Buxton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cromerian.</td>
<td>First Remnant Complex important. (660 ft)</td>
<td>No evidence.</td>
<td>Cave Dale outlets. (above 800 ft)</td>
<td>No evidence.</td>
<td>(900 ft)</td>
<td>Poole's Cavern route initiated? (above 1180 ft)</td>
</tr>
</tbody>
</table>
Knoll, and possibly also along the present line of swallets in Rushup Vale. The Second Remnant Complex at Stoney Middleton, its outlet lying at around 610 ft (186 m) A.O.D., now operated beneath the truncated earlier system from which it differed little in extent and orientation. The allogenic catchment for the caves of Upper Lathkill Dale had been considerably reduced, and the Upper Gales Dale Complex was a phreatic network of generally smaller proportions, but of greater extent, than the earlier Water Icicle Complex. Again, the position in the Wye Valley is hard to determine. Waters & Johnson (1958) were able to trace the Hathersage Terrace up to a knick point in Chee Dale at 720 ft (219 m), but boulder clay of probable Wolstonian date lies at 720 ft (219 m) at Cressbrook, nearly 6 kilometres downstream from Chee Dale, and lies on the Hathersage Terrace at Bakewell at 525 ft (160 m) A.O.D. This suggests that recession into the limestone of the knick point at the head of the Hathersage valley floor had not progressed far by the Wolstonian, and it follows that the present risings of the upper Wye Valley (ie. Blackwell Dale and Deep Dale) must have originated at a much later stage.

The ice which overrode the northern part of the limestone during the Wolstonian (Straw & Lewis, 1962) deposited boulder clay on terraces belonging to earlier episodes. This is found down to 600 ft (183 m) at Stoney Middleton, and 525 ft (160 m) A.O.D. at Bakewell. Waters & Johnson placed the rejuvenation responsible for the creation of the Hathersage Terrace at the end of the Wolstonian, and a further phase of abandonment and capture by lower cave levels followed.

During the Ipswichian interglacial, extensive phreatic networks operated in the area. The Carlswark Complex became widespread at Stoney Middleton, Russet Well first operated at Castleton where the cave systems were incised down to 675 ft (206 m) A.O.D., and the Lathkill Head Complex was initiated, although the principal outlets to the system lay at a higher elevation (730 ft / 223 m A.O.D.) than the present ones, and were
further to the west. By now the Lathkill cave system carried mainly percolation water, for the shale cover must have been reduced almost to the present tiny patch in the centre of the basin.

There was no glaciation in the area during the Devensian, but there is widespread evidence of periglacial activity. With frozen ground maintaining meltwater streams on the surface (Warwick, 1964), modifications occurred to the valleys which resulted in capture, in some instances, by the lowest, generally flooded, cave levels. At Castleton, solifluxion of material from the slopes of Rushup Edge largely choked the swallet caves (Johnson, 1967), and the material can now be seen, often calcite cemented, in the higher parts of the cave systems (see p. 108). The extensive mantle of loess which covers the limestone plateau surface dates from the Devensian (Burek, 1977), and it is material derived from this loess cover, together with residual chert gravels (Pigott, 1962), which infills many of the cave systems which would otherwise be available for study. Choking of outlets by scree may have temporarily raised water levels, so that many higher conduits were infilled with fine material.

Most of the resurgences of cave streams now lie at valley floor level. In some cases, incomplete adjustment has occurred to the latest local base levels, although there is often a structural feature to account for this. In Lathkill Dale, the presence of lavas has prevented further lowering of the underground drainage route. At Stoney Middleton the rising (only now active in flood due to sough drainage) lies well upstream from the shale margin, adverse dips having forced the water to rise at the point where the controlling bedding plane of the cave system dips beneath the valley floor for the last time. The Blackwell Dale rising lies above the valley floor, which is perhaps surprising as it lies well above the horizon of the Lower Millers Dale Lava. It may be that the reef mound in Blackwell Dale has produced additional complexities.

There are many areas in which a chronology cannot be guessed. The
principal rising behind which a large cave system may yet be discovered is that of Wormhill Springs. The sequence of downcutting here may yield important information regarding the geomorphological history of the Wye Valley through the Pleistocene. The picture remains highly speculative in some areas, and will no doubt be considerably modified in the future as more information allows adjustments to be made to the overall chronology.
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THE CAVES OF THE FOOLLOW-EYAM-STONEY MIDDLETON AREA, DERBYSHIRE, AND THEIR GENESIS
by John Beck

SUMMARY

An outline description of the caves and the present state of exploration is presented. The caves are shown to have developed by the successive utilization of lower bedding plane and joint systems becoming active as the base level of resurgence fell owing to surface denudation. The caves or passages within them can be separated into (a) the active swallets, (b) the first and second remnant complexes, (c) the Carlswark Complex, and (d) the Lower Complex.

INTRODUCTION

Lying on the northeast flank of the Carboniferous Limestone outcrop in Derbyshire, the Foolow-Eyum-Stoney Middleton area has attracted cavers for many years, but few attempts have been made to analyse the evolution of the underground drainage systems. Outline accounts, rather speculative in places, have been presented by Jefferson (1961) and by King (1962) though these were concerned with development of the dales rather than the cave systems.

The caves of the area lie within the zones D2 and P1 zones of the Carboniferous Limestone, here comprising the top 100 metres beneath the cover of Edale Shales of the Millstone Grit Series. Details of the stratigraphic succession may be found in the Geological Survey Memoir for the Chapel-en-le-Frith sheet No.99 (Stevenson & Gaunt 1971) and in Orme's contribution to Neves & Downie's Geological Excursion guide to the Sheffield area (1967).

The evolution of the cave systems is undoubtedly controlled by the sequence of events in the Pleistocene Ice Age, but as yet no fixed points by which the cave evolutionary sequence can be linked to stages in the surface development have been found. All that can be said at present is that the area was glaciated in the Penultimate advance and that the dry valley system, presumably including Middleton Dale, has been incised since then. This incision progressively exposed lower beds of limestone and thus potential resurgence points to which the successive levels of the caves could drain.

This paper describes the general form and relationship of the caves and shows that a sequence of events can be worked out underground. It is hoped that future research will be able to relate this sequence to one worked out on the surface.

TOPOGRAPHY

The villages of Foolow, Eyam, and Stoney Middleton lie on the northern margin of the limestone outcrop. To the north, the prominent shale and gritstone escarpment of Eyam Edge rises to a maximum height of 1,407 ft. OD at Sir William Hill. Streams accumulating on the gritstone moors flow southwards to disappear, in most cases, into shallow holes on, or near, the limestone margin. A deep limestone gorge, Middleton Dale, drains eastwards, sub-parallel to the escarpment. It turns at its western end to run north eastwards as Linen Dale, dying out in the vicinity of the largest sink, Waterfall Swallet, at the shale/limestone boundary (Fig. 1).

To the south of Middleton Dale, the limestone rises to a maximum height of 1,297 ft. OD at the summit of Longstone Moor. This upland area is dissected by two dry valley systems, Hay Dale, which runs southwards to the Wye Valley, and Coombs Dale, much larger, and descending eastwards to the Derwent near Calver.

The deeply incised valley of Cressbrook Dale runs north-south along the western edge of the area. At its northern end, springs occur at the margin of a shale outlier at Wardlow Mires, and water flows southwards across the shale. It may often be seen to sink at various points, and in wet weather the stream is augmented by the flow from various artificial drainage levels, or soughs. Near the southern end, the large resurgence of Lumb Hole discharges a considerable volume of water.

The western part of Middleton Dale carries no surface stream, water first appearing at the tail of Watergrove Sough, at the bottom of Farnsley Lane. The sough was driven to de-water the inundated Watergrove Lead Mine, at the western end of Middleton Dale. Water from the sough flows eastwards as the Dale Brook, to be joined by water from resurgences both natural and artificial, and by water from two streams which flow for some distance over the limestone, the Jumber Brook, and the Hollow Brook. These streams flow from the shale, through Eyam, and continue southwards via the Delph, and Eyam Dale respectively. Both may often sink at various points in the valley floors, although the Hollow Brook in Eyam Dale has almost been completely culverted.

Opposite the Delph, on the south side of the road, the somewhat mysterious resurgence of Hawkenedge Well discharges a considerable and very consistent flow into the brook. The nature of this watercourse is unknown; it has been referred to as 'Oakenedge Sough' (Rieuwerts, 1966, Kirkham, 1967).

At Stoney Middleton, the brook is swelled by the water from Moorwood Sough, driven to de-water mines between Stoney Middleton and Eyam, principally Glebe Mine at Eyam. The sough runs close to the shale margin, and has captured water from the natural conduits via small phreatic tubes and joints. The sough tail lies in the grounds of Stoney Middleton Hall at a height of approximately 465 ft. OD (SK 2318 7545).
The Northern Swallets

The most westerly swallet to be considered is Duce Hole, at Grindlow (1812 7767). This was penetrated by members of the B.S.A. into a choked stream passage, and it is said that the water flows westwards, to resurge at Bradwell via Bagshaw Cavern.

Swevic House Swallet lies half a mile north west of Foolow, at 1869 7746. Permission to visit the swallet is rarely granted, and rubbish is said to have been dumped there. The destination of its water is uncertain, but it is remotely possible that this is the most westerly swallet whose water flows to Stoney Middleton.

Waterfall Swallet lies half a mile north east of Foolow, in a large tree-lined shakehole at 1988 7705. A considerable stream enters the shakehole on the north west side. This normally sinks at three points in the shakehole floor, but during severe floods, as on 16th July 1973, water may back up above these small choked fissures and escape into Waterfall Hole, a cave system with its entrance in the north east wall. The stream is normally encountered 21 metres below the entrance, and can be followed through a chaos of displaced and eroded blocks to a depth of 43 metres, where it disappears among boulders and mud.

Waterfall Swallet is developed on an east-west fault plane, in places mineralised and mined. The fault divides into two components at the swallet, the more northerly branch passing eastwards through a smaller shakehole. This is Little Waterfall Swallet (2003 7710), but the water outlet here is impenetrable. Present attempts at further exploration are directed towards the probably union of the two streams underground. The water from Waterfall Swallet, and probably from the other swallets along the shale margin between here and Eyam, has long been known to reappear in Moorwood Sough.

Robey (1964) described Crosslow Cavern, which lay adjacent to the road a short distance to the east at 2030 7706. An 18 metre shaft led to a large cavern which had been used as a washing floor for ore, and was largely filled with miners ‘deads’. Water in the cavern was stated to drain towards Waterfall Swallet. The entrance has now been obliterated by the farmer.

Black Hole Swallet was a large depression at 204 772, which took a small stream. The stream sink was impenetrable, but the depression has now been filled with rubble.

Hunger Hill Swallet lies closer to Eyam, immediately north west of Hunger Hill Farm, at 2096 7695. It appeared to have taken considerable water after the flood of 16th July 1973, but the stream sink is hidden under farm rubbish.

The small swallets in the floors of Eyam Dale and the Delph are very juvenile in character, the water having, comparatively recently, found routes down joints into cave passages beneath. These passages are part of the Carlswark Complex, a network of phreatic conduits developed at the base of a bed of limestone packed with large silicified brachiopods (Gigantoproductus) known as the Lower Shell Bed. During the 16th July flood, the Delph stream appeared to swell at the more southerly swallet, rather than diminish. It is possible that the main streamway, which lies only a short distance below the valley floor, was so overpowered that water was forced back up the swallet.

Carlswark Cavern and Ivy Green Cave

Close inspection of Carlswark Cavern, and of the other smaller phreatic caves in the sides of Eyam Dale, the Delph, and Middleton Dale, reveals that there have been several periods of cave development, resulting in a succession of cave levels. These may be referred to, in order of development starting with the highest, as the First Remnant Complex, the Second Remnant Complex, the Carlswark Complex, and the Lower Complex. The Carlswark Complex is the most extensively known, and the majority of Carlswark Cavern itself belongs to this level.

There are several entrances to Carlswark Cavern, those most frequently used being the Eyam Dale Shaft (opposite the electricity sub-station) at 2185 7595, and a mined joint on Wonder Scrin, a small north east — south west trending vein, at 2208 7582. An easy scramble down the latter leads into the main phreatic passage (Smith 1971). The Lower Shell Bed is prominent here, walls and roof of most of the passages being covered with etched out fossil shells. This is Eyam Passage leading eastwards from the bottom of the Scrin entrance back towards the cliff face. To the west, it soon enlarges, and a hole in the floor leads via a tube and a joint-oriented rift down to a passage of the little known Lower Complex. A long deep sump at the bottom of the rift must not be free dived; its other end can be reached through higher passages. A phreatic passage leads out to the original Lower Entrance, which is also a flood resurgence, at 2207 7580.

Eyam Passage can be followed eastwards to a large boulder choke, beyond which a right turn through a low and partly flooded passage brings one to a further junction. To the left is the large collapsed area at the foot of the Eyam Dale Shaft. Beyond the collapse, the passages continue, but the western section can only be reached by the nearby Merlin Mine. To the right access is gained to what is still known as the ‘New Series’, although it was entered by the B.S.A. in 1959. The major passage of the New Series is the large and vandalised Stalactite Passage, reached by a duck, and lying roughly parallel to Eyam Passage, lower down the dip slope. The passage ends at a rift, where a scramble down leads to the inner end of the sump in the Lower Entrance Passage.

A very tight series leads northwards from Stalactite Passage. Known as the Dynamite Series, it consists of a series of avens lying on joints trending north-west to south-east. The avens are connected by phreatic tubes of varying size, but generally very small. The Lower Shell Bed is left behind, and one progressively climbs through the limestone sequence into passages developed at higher and higher horizons.

A large passage containing an extensive fill of miners ‘deads’ is reached at the top of a tight climb, and soon leads to mine workings on Stub Scrin. The choked bottoms of shafts can be seen; their tops are
close to, or under, the Eyam Dale road. The workings soon rejoin the natural passage, and three more aven
can be reached before the connecting tubes become too tight. A constricted dig is possible here.

The natural passages at high level in the mine workings lie at a similar horizon to
that on which Ivy Green Cave is developed. The entrance to the latter lies at the eastern end of 'The Gin' in
Middleton Dale, above mine workings at 2224 7580. The cave consists of a phreatic passage trending north­
westwards. It is heavily silted, but dedicated digging would probably connect it with the high level passages
of the Dynamite Series of Carslawaik. These passages are part of the Second Remnant Complex.

An even higher development can be reached by climbing into a high level passage in the fourth
aven of the Dynamite Series. Traversing diagonally upwards through (in places) rather unstable looking
boulders gives access to a large passage at the top of yet another aven. This passage is referred to the First
Remnant Complex, and lies at the base of a limestone unit containing three persistent and closely spaced
chert bands. Below, the limestone is fine-grained, and contains many corals, and the bedding plane between
forms a useful marker horizon. The passage ends rather ludicrously, however, at a boulder choke through
which traffic can clearly be heard bumping over the oft-repaired bit of road halfway up Eyam Dale.

The bedding plane on which the passage lies can be seen plunging steeply below the road by a small
pull-in at 2192 7606. It shows extensive bedding anastomosis, and a small cave entrance lies at this horizon
a short distance to the south.

The Merlin Mine

The entrance to the Merlin Mine lies high on the west side of Eyam Dale, just above the junction
with Middleton Dale, and it is from here that the more westerly passages of the Carslawaik Complex can be
reached. The mine follows a pipe vein northwesterns, soon crossing Sycamore Serin, on which levels run
to right and left. To the left are natural cavities at the level of the Second Remnant Complex, leading to a
15 metre blind pitch.

Stub Serin is reached approximately 50 metres from the entrance. To the l eft are more Remnant
cavities, while to the right three shafts are found in the floor. The second shaft is 9 metres deep, and a
further descent down a pile of boulders which were once, it seems, stamped into to roof, gives access to
several hundred feet of passages at the level of the Carslawaik Complex. This series includes the very active
Merlin Streamway. Through most of the year, all that can be seen is a forbidding sump pool, and the stream
can be heard, through an impenetrable bedding plane above water level, crashing into a rift. The route to
the stream is obvious at the bottom of the stopes, for it can nearly always be heard, to the west.

The right hand (downstream) sump is eight feet long, but silted, and with a constricted entrance.
It leads to a low bedding cave, which the stream crosses before falling into a permanently flooded rift. The
outlet of the rift is tight, heavily silted, and dangerous.

The upstream sump is tight, deep, and sixty feet long. When the streamway was first discovered, a
boulder choked rift in the main stream beyond this sump was able to take all the water, and there was just
air space enough to wriggle through. Since that time, the weather has never been so dry, and the water has
never receded. The main streamway was followed to another sump, which was subsequently dived to more
encouragingly large streamway. The water from the Merlin Streamway reappears, like that from Waterfall
Swallet, in Moorwood Sough.

The largest component of the flow of this stream is almost certainly accumulated percolation water
over a long stretch of cave, for there are no large allogenic sinks to account for it. Dye testing revealed that
the water from Waterfall Swallet does not pass through the known streamway, suggesting the presence of a
separate system to the north. The water from the more southerly of the Delph Swallets was proved to
enter the streamway, and its point of entry was believed to have been reached by divers.

Prospects for further exploration are good, for there are high level passages in the Sump Pool
Chamber which are above the maximum water level. These are silted, but excavation would almost certainly
by-pass the sumps. Care would have to be taken not to block the 'eight foot sump' with silt.

To the east of Stub Serin, passages can be followed back to the blockage at the foot of the Eyam
Dale Shaft. This stretch shows features which are clearly indicative of the cave's history; the developmental
phases are shown in Fig. 2. During Phase 1, the water flowing at Lower Shell Bed level formed an elliptical
passage by phreatic solution. Retreat of the water led to the removal of hydrostatic pressure in the conduits,
and roof collapse began. The blocks being covered with the accumulating silt, as seen in Phase 2. Phase 3
represents a period of quiescence, when little water was flowing underground. A glacial phase is suggested
as a reason; this would account for the high rate of flowstone formation. When the ice sheets retreated,
extensive flooding took place, and the resultant secondary stream excavated a deep channel through the
layers of silt and flowstone. This phase was followed by retreat of the water to the present Merlin Streamway
route, and the passage was finally abandoned. Flowstone began to form on the remnants of earlier episodes,
and also on the floor of the new channel. Clean sections through this material can now be seen, with large
projecting cornices of flowstone. The stretch of well decorated passage was christened 'Gimli's Dream'.

The Delph

The small valley running parallel to, and west of Eyam Dale, known as the Delph, or Cucklet Dale,
has many small cave passages and mine levels in its walls. The largest system is Nicker Grove Mine
(incorrectly referred to as Great Cucklet Mine by Pearce [1974]) high on the west side at 2155 7595. Like
the Merlin Mine, a pipe vein was followed northwesterns. This intersects a solution cavity developed on a
north west — south east trending joint, and continues to a choke of sticky mud. A 'vein' such as this is not
a pipe in the usual sense; it is essentially an open joint infilled with sediment. A large proportion of this
sediment in some cases may be derived from in situ hydrothermal veins, and is thus a valuable source of lead.
The Merlin Pipe, and the Watergrove Pipe are similarly developed.
Fig. 1. Gimli's Dream, Carlswark Cavern.

Fig. 2. False Floor in Carlswark Cavern.

Fig. 3. Sarah's Cave, Stoney Middleton - now destroyed.
A shaft in the floor of the main level, roughly 75 metres from the entrance, leads to levels 8 and 16 metres lower. The lowest level leads to solution cavities close to the horizon of the Carlswark Complex. These show confused directional scalloping, and may be abandoned and silted portions of the Carlswark Complex, up-dip from the present streamway. The -8 metre level leads via another large solution cavity to a short shaft to daylight, with its top just above the valley floor.

Delph Hole (2163 7598), opposite Nickers Grove, shows Remnant Complex tubes intersected by mining, though it is of little extent. A cave in Eyam Dale, almost directly above the Eyam Dale Shaft, was recently excavated by members of the South Yorkshire Caving Club, and may represent the eastward continuation of the Delph Hole tubes.

High on the west side of the Delph is the Cucklet Church, a series of through arches in a prominent buttress, used by the Rector of Eyam, William Mompesson, for church services during the plague of 1665. This is a very high development, and is probably a part of the First Remnant Complex, although it lies a little above the exact horizon. Its appearance of vadose modification suggests that it may have lain near the head of that system, being fed by sinks at the then more southerly shale margin.

The stream emerges from a narrow ravine, known as the Saltpan, at the head of the Delph. This has all the features of a vadose streamway, with no roof. Its origin was probably as a stream passage, which was downcut under vadose, and then surface conditions, to give the present form.

Halfway down the Delph, on the west side, some 5 metres above the valley floor, is a small cave developed partly on the joint pattern. This may represent an early route by which the stream sank in the valley floor, or may have originated as a capture point by which water sank from the Second Remnant Complex into the Carlswark Complex which was developing below. The water has now found new routes in the present juvenile swallets.

Upper Middleton Dale
To the west of the Delph there are fewer high level caves, and beyond Farnsley Lane there are none in the valley walls. Passages of the Carlswark Complex are still present, and may be quite mature. The tiny entrance to Yoga Cave lies a few feet above the road, on the north side, just east of the sharp bend by Eyam Quarries (2125 7589). The Lower Shell Bed is obvious in this cave, and some passages are very similar in character to those of Carlswark Cavern itself. A tight entrance crawl leads after just over 50 metres to larger passages, including two large chambers. From here, the way on is blocked by mine workings in Streak's Vein, so unstable that they should not be touched.

A few small blocked tubes are found at the same horizon further to the west, but no major caves are found until Lay-by Pot is reached. The 15 metre entrance shaft lies north of the road, opposite the second lay-by west of Furness Quarry, at 2035 7600. The shaft intersects an abandoned stream passage at the bottom, which runs east and west. To the east, the passage soon ends at a deposit of clay and boulders in the valley floor, through which a narrow slabbled mine level continues for 60 metres to a complete collapse. To the west, access can be gained to a bedding cave at a higher level. This can be followed eastwards for a considerable distance to two large chambers. The crawl beyond the second chamber is silted to the roof. The total length of the cave is approximately 350 metres. The Lower Shell Bed appears to be poorly developed in the first large chamber, but does not exert the same influence over passage shape and size as in the Carlswark Complex passages further to the east.

Beyond Lay-by Pot, the dale rapidly becomes shallower until it turns northeastwards as Linen Dale. The only known cave here lies at the northern end of the valley, just south of the road to Foolow, at 1989 7696. It may be referred to as 'Linen Dale Cave'. A tight crawl was dug out for 13 metres to a small chamber, where the way on is hopelessly blocked with boulders and mud. It is probably an old engulfment point for water draining from the shale.

The south side of Middleton Dale reveals few caves. The most significant find here was Sarah's Cave, exposed by quarrying, and now removed. A well-decorated passage was found, lying close to the level of the Lower Shell Bed (Lord, 1971).

A mineshaft above the quarries, on Middleton Pasture, intersects a natural passage at the horizon of the Second Remnant Complex, but this is hopelessly blocked with 'deads' and run in workings.

Coombs Dale
Coombs Dale has many small caves and mine workings in its walls, as well as the still functioning Sallet Hole Mine. The only natural system of any size is Fatigue Pot (Collier's Peril Cave), which lies on the north side of the valley at 2249 7473. Here, a tiny bedding controlled passage leads to the head of a tight pitch, which can be descended in three steps to a passage developed along the bottom of the rift, running north-westwards into the hillside. This ends at a choke of huge boulders, but two crawls lead off to north west and south east. The north west crawl is only 27 metres long, and turning is a considerable problem. The south east crawl leads for nearly 100 metres to a small rift chamber, with further crawls to a well decorated grotto, and a boulder choke in a small passage through which a draught emerges in hot weather. The level of this choke is approximately 17 metres below the valley floor, and would be a good but exhausting prospect for digging, as the crawls are very arduous.

The Lower Shell Bed cannot be recognised in Coombs Dale, and a coral band appears to have taken over its function as the principal horizon of cave development. It lies at a similar level, and is close to the Lower Shell Bed stratigraphically. It is unfortunate that insufficient cave passages are known to allow a sequence of events to be constructed.

Further west in Coombs Dale, at the confluence of two valleys, a large volume of water sinks in wet weather in the vicinity of old workings. It was thought that this water flowed through immature
passages close to the surface, but a careful survey of Fatigue Pot showed that passages at a considerable depth are not flooded, and that the water table is much deeper than one would expect. The water table has not been artificially lowered to this depth by mining, for there is mature flowstone in the lowest parts of Fatigue Pot.

Other Areas

Longstone Moor is devoid of known caves or potholes. Abandoned swallows can be seen in a few places where opencast fluor spar workings have exposed them, but all are full of glacial detritus. Just north of Watersaw Rake, at 1925 7337 and 1928 7338, two small swallets take a considerable amount of water in wet weather. East of the open cut on the rake, another small swallet lies in a small but pronounced depression. The swallets appear to derive their water from the extensive cover of 'head' and peat. Current excavations here may reveal something of interest. Whether this drainage flows eastwards below Coombs Dale, or westwards towards Lumb Hole, in Cressbrook Dale, is uncertain. Percolation tests are needed to determine the extent of these two catchment areas.

Hay Dale has no known caves, but the valley sides are covered with a thick scree, and any entrances are likely to be buried.

Cressbrook Dale has a few small high level caves, but everything is either tight, mined out and collapsed, or heavily silted. Lingard's Cave lies high on the west flank near Litton, at 1706 7506, and consists of a chamber from which short descents into blocked mined sections may be made. This is part of a phreatic system long abandoned, collapsed, and silted.

Bull Tor Cave and Ravencliffe Cave lie high on the east side above Ravensdale Cottages. Neither is of great extent, but Ravencliffe Cave has been archaeologically excavated, and yielded interesting Palaeolithic implements. These were associated with remains of woolly rhinoceras, horse, reindeer, and bear (Fox, 1910; Brailsford, 1959; Bramwell, 1973). The finds are among the oldest archaeological remains in the Peak District.

Abandoned resurgence passages are found opposite Lumb Hole, at 1723 7312. Digging here in the past has been unrewarded. These caves appear to be controlled by the presence of an underlying lava, in the same way as the active resurgence of Lumb Hole. The structure of the apparent catchment area makes it difficult to form any conclusions regarding the nature of this watercourse, and a very ambitious project would have to be mounted to penetrate it, judging by past efforts. When the water is low, it is possible to crawl into the lower entrance of Lumb Hole for a short distance, but the way is blocked by large boulders. The upper entrance, a few feet above, can be followed for some way to an uncomfortable end, again among large boulders. The stream can be heard here, at a lower level.

The dip in the northern part of Cressbrook Dale is to the north, into the basin of Wardlow Mires, and it is probable that the drainage of the moors on either side of the valley is down-dip into the basin. The centre of the basin is occupied by a shale outlier, and the water resurges at its margin, collects to form an integrated stream, and flows down the dale to the Wye. It appears that this down dip drainage may have been responsible for the large amount of water encountered in Watergrove Mine, which now flows eastwards via Watergough Sough. It is also possible that the large flow of the Merlin Streamway may originate on the dip slope.

SPELEOGENESIS

Developmental conclusions can only be drawn at present for the caves of Middleton Dale, where it appears that four distinct periods of phreatic solution occurred. During the earliest period, the shale cover was far more extensive, and only a relatively small area of limestone was exposed. A large catchment area gave rise to streams which sank, in the vicinity of Eyam, into swallets at the head of the First Remnant System, now represented by the Cucklet Church, probably the Saltpan, and the highest levels of Carlswark Cavern. The high level passages of Carlswark represent development just below the water table of this time, and the resurgence of this system probably lay in the region of the mouth of Middleton Dale.

The second phase occurred after more shale had been removed, diminishing the catchment areas, and lowering the base level of the limestone massif. The downstream passages of the first system began to degrade as the water was pirated by juvenile passages at a lower level, and shallow valleys began to form on the limestone. Their position was determined partly by the position of cave networks, and partly by the influence of a drainage pattern developed on the now removed shale cover. More sinks opened towards the west as the shale cover receded, and the passages of the Second Remnant Complex were initiated. Ivy Green Cave, the majority of the Dynamite Series of Carlswark Cavern, and the highest natural passages of the Merlin Mine belong to this level.

A further phase of erosion left the second system above the water table, and filled its passages with varying amounts of debris derived from the surrounding shale and gritstone. The Wardlow Mires outlier was probably at this time still connected to the main shale outcrop, so that the active allo genetic sinks lay as far west as Linen Dale, migrating northwards with the shale margin, and giving rise to the present irregular valley as successive shakeholes degraded. Water now flowed eastwards along developing conduits at the level of the Carlswark Complex, and reappeared at base level, in Middleton Dale, just west of Stoney Middleton.

The shale cover retreated further, and the main sink finally established itself in its present position on the Crosslow Fault System, so that some of the more easterly passages of the Carlswark Complex were abandoned. The Lower Complex began to carry water to the resurgence, which is likely to have been the present Lower Entrance to Carlswark Cavern. The majority of this complex is still flooded, and attempts to explore it further have so far failed.
Surface Relationships
Delphi: Approximate Eyam Dale and the Caves and Mines of

KEY
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INFERRED\r
LOWER ENTRANCE\r
LOWER ENTRANCE (MINE 2)\r
REMAINING CAVES 2-5\r
ORIGINATING MINE FLOW\r
REALIZED SURFACE FLOW\r
PRESENT UNDERGROUND FLOW

NOTES
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THE DELPH
STRAWM CEMENT
FROM THIS
PARKER INGER
WEATHER ONLY
BROAD HEAD HOLE
ALT. 850 B.E.
ALTERNATE HOLES
ALT. 850 B.E.
ALT. 850 B.E.

THE DELPH
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BROAD HEAD HOLE
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THE DELPH
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WEATHER ONLY
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ALT. 850 B.E.
ALTERNATE HOLES
ALT. 850 B.E.
ALT. 850 B.E.
Caves and Mines of Eyam Dale and the Delph; Approximate surface relationships.
Developmental Phases
of 'Gimli's Dream',
Carlswark Complex (Merlin Mine).

1: Phreatic.

2: Paraphreatic.

3: Quiescent.

4: Vadose.

5: Abandoned.
It has often been assumed that the pre-Moorwood Sough resurgence of the Waterfall Swallet stream was the Lower Entrance to Carlswark Cavern, but Short (1734) described the entrance, and the passages within, exactly as they are known today, except that the size of the entrance had been reduced to the present grovel by rubbish tipping.

Short’s description runs as follows: “A little west of this is Charleswork, this has a Majestic Appearance, lies at the Foot of a very steep Rock, ninety three Yards High, and five Yards above the Level of the Brook, its Entry is six Yards high and eight wide, here you walk on for forty two Yards and a half, where you arrive at an unpassable deep stagnant Lake, this Cave reaches quite through the Mountains and opens into Eynedale, which is above half a Mile; by another of its Grottoes, it opens near Fowlow which is a Mile and a half, passing quite under Eyan church.”

The entrance could not then have been a resurgence, for water must flow up-dip to reach it, and the passages would certainly have been completely inaccessible. Moorwood Sough was not carrying this water in 1734, and the stream must therefore have already abandoned Carlswark’s Lower Entrance. No definite conclusions can yet be drawn regarding the position of the actual resurgence, but it is hoped that further work will help to complete the picture.

All the phreatic passages in the area which are of any size lie roughly parallel to the strike of the beds, sloping very gently towards the east. Scalloping generally indicates flow from west to east, except in the smaller passages which may connect larger passages at 90° to the strike. Since it appears that phreatic passages are formed only a short distance below the water table, this is what might be expected; the main conduits would develop on the dip slope of a preferred bedding plane, just down dip from the intersection of the bedding plane with the water table of the time. As the water table was lowered by erosion, a succession of parallel passages would develop at lower and lower positions on the dip slope. Lower bedding planes would also be opened, and later lowering of the water table would allow formation of a new complex at a lower horizon in the limestone sequence. As each passage was abandoned, most of the ‘dry’ passages would be silted by flood waters which re-invaded them via the smaller down-dip connections. One route generally remains open to cope with such floods. Further exploration of Carlswark may reveal the latest passages in the succession.

If high level passages should be discovered in the other smaller valleys of the area, and the active routes finally explored, it may be possible to construct similar sequences of events for them.

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THE EVOLUTION OF BRADWELL DALE AND ITS CAVES, DERBYSHIRE
by Trevor Ford, Cynthia Burek and John Beck

Summary

A preliminary study of the interrelationships of the limestone structure, the stripping of shale cover, evidence of glacial and periglacial weathering, the form of Bradwell Dale, the dry valley pattern, the phreatic potholes of Long Rake, the pipe caverns of Smalandale and Hazlebadge, and the stream cave system of Bagshaw Cavern, suggest a sequence of events in the Pleistocene which can be correlated in part with the various phases of the Ice Age elsewhere.

Lying along the northeast boundary of the Carboniferous Limestone outcrop of Derbyshire, Bradwell Dale drains northwards into Hope Valley, where Bradwell Brook joins the River Noe, a tributary of the Derwent. The central part of the Dale is a deeply incised limestone gorge without a stream, making it a striking dry valley. The “upstream” part of the Dale is the more gentle dry valley of Stanton Dale which serves as the focal point for a number of smaller dry valleys. There is one choked swallet near the head of Stanton Dale taking a little water underground at Nether Water, close to an old mine and a present day mineral processing plant. Another swallet at Quarters Farm also takes a stream in one of the tributary dry valleys, but it is so unstable that digging attempts have failed to penetrate more than a few feet.

To the west of the Dale rises Bradwell Moor, a dip slope some 2 km long topped by a flat area at about 1300-1400 feet O.D. The limestone beds here are in the D₂ zone and dip at slightly more than the average slope, so that the beds highest stratigraphically outcrop lower down the slope and in the Dale. The main part of the D₂ zone is composed of fairly regularly bedded rather cherty limestones referable to the Monsal Dale Group (Stevenson & Gaunt 1971); these are overlain by the limestones of the Eyam Group (the latter were called the Nunlow Limestones by Shirley & Horsfield (1940) and correlated with their Eyam Limestones in 1945). These beds are more irregular, lenticular and contain many bioherms or reef mounds, giving the highly variable lenticular limestones on the east side of the Dale. The reefs are composed of calcilutite (algal mudstone) or of crinoidal debris, or sometimes of banks of coarse calcarenite.

To the east of Bradwell Dale there rises the long escarpment of Millstone Grit rocks of Bradwell and Hucklow Edges. Capped with sandstones, the lower slopes are composed of Edale Shales. Drainage from the scarp face forms a series of short surface streams disappearing into choked swallets, as at Quarters Farm and Deadman’s Clough, or simply fading away in their alluvium not to be seen again. A shale-floored valley lies along the extreme margin of the limestone about 0.5 km east of the gorge section of Bradwell Dale, but it carries only a wet weather trickle of a stream which flows north to join Bradwell Brook in the village. A low col lies between the head of this valley and the gorge section of Bradwell Dale at Hazlebadge.

The regional dip of the limestones and Millstone Grit is eastwards but there is a slight anticlinal warp plunging eastwards roughly across the central part of Bradwell Dale. A complimentary syncline plunges southwards through the area of Little Hucklow.

The limestones on both sides of the Dale are cut by a number of mineral veins, mainly fissure veins or rakes with a WSW - ENE trend through there are a few pipe veins with a NW to SE trend. Mineral vein cavities occur in both. Toadstones (basaltic lavas) are present in the area but at considerable depth, so that they nowhere outcrop, but with the dip carrying them eastwards beneath the Dale, some 100 metres or so below its floor, they form a western boundary to the underground catchment, with outcrops on the western edge of Bradwell Moor. To the north there is no clear demarcation of either surface or underground catchment from that of Castleton, though it probably lies roughly along a line extending southwards from Earle’s Quarry. To the south the catchment, both surface and underground, seems to be roughly along the line of Hucklow Edge rake, west of Great Hucklow.

Previous studies of this area have been very limited in scope. Only Crabtree (1964) has considered the mines and cave together, but only two instalments of his article have been published, and it is as yet unfinished.

The Underground Drainage System

Bagshaw Cavern has the only underground stream accessible in the area (Baker 1903). The cavern is entered through a mined-out vein, once known as the Mule Spinner Mine, west of Bradwell Village. From the foot of the entrance stairway a phreatic tube still partly full of sediment leads southwards to the main cave, which is reached after a short descent at the Dungeon, a 6 metre pitch. Below this a U-tube rises into the downstream section of the cave which can be followed through a series of static pools and ox-bows to within 50 metres or so of the Bradwell Brook resurgence at the south end of the village. The running stream is not seen in this part of the cave though it clearly uses the cave in times of flood. Upstream from the top of the Dungeon the cave can be followed in a generally south to southwest direction along the strike in a vadose trench cut into the floor of a phreatic tube, both somewhat affected by the collapse of roof blocks. Turning eastwards down dip brings to the active stream, flowing northwards. Downstream the passage is impenetrable owing to boulders, but the survey (Fig. 2) (of unknown accuracy) shows it to be close to a small series of pipe caverns in Bradwell Dale — Burton’s Pingle Pipe, entered via a hole in the old quarry floor.

Upstream the roof gradually lowers into running water in an alluvium-filled cave, but it has been dived for more than 100 metres through a series of low bedding cave sections into some east-west rift passages with “canals”, and two further sumps (Cobett 1971). Adding on the divers’ grade 1 survey suggests that the west-trending rift section could have been in the chambers developed in Earl Rake, and it is notable
Fig. 1. Sketch-map of the Bradwell area showing the limestone outcrop, reefs, mineral veins, dry valleys, caves, swallets, and the resurgence.
that if the line of this is continued it would reach the Hartle Dale bone caves, some distance to the west. Sump 3, however, returned to bedding plane conditions, presumably extending southwards along the strike, becoming a larger passage at the furthest point reached.

The stream in Bagshaw Cavern has been traced by dye testing from Quarters Farm and Nether Water swallets, and not unexpectedly its floor contains much alluvium of sand and silt derived from the Millstone Grit of Bradwell Edge. Halfway along the strike passage from the Dungeon a "New Series" extends up dip into a nicely decorated grotto partly formed in a mineral vein, which is also seen in Calypso’s Cave close to the Dungeon. Two passages lead off beyond the grottos: one is a low phreatic tube with cross-joints trending more or less along the strike back towards the foot of the entrance staircase, while the other goes up dip westwards, in the general direction of Outlands Quarry Cave, with which it may once have linked.

Plotting the survey of Bagshaw Cavern on the topographic map shows that its general course lies parallel to and at roughly the same altitude as the floor of the gorge section of Bradwell Dale. A low tube completely choked with stalactite-cemented alluvial gravel leads down dip from near the entry to the New Series and may well have a link with the short Bradwell Parish or Old Brook Cave in the Dale. This too is choked with cemented gravel, though water is said locally to appear here in times of flood. Clearly at present the known cave is largely a recently abandoned predecessor of the present stream system, which must lie down dip of the present cave, closer to the Dale, but slightly lower than its floor. The grottos and associated passages suggest the former presence of a parallel phreatic system higher up the dip, though largely still in the same beds as both the accessible cave today and the hidden present stream course.

Other caves in the Bradwell area are mostly small, but not without significance in trying to work out the evolution of the drainage pattern.

To the east of the gorge are a series of Pipe Vein caverns. Cow Hole overlooks the gorge from high on the cliff, and is but a single chamber, modified by mining, but still showing good phreatic features. It is a horizontal ore-pipe developed in a crinoidal reef. To the southeast, on the hill top is a line of opencast fluorspar workings which have partly removed Noulton, Revel’s and Hazlebadge Pipes. However, sufficient cave survive to show that these are a complex of phreatic enlargements of mineral vein cavities, mostly in crinoidal mound facies. While no vadose features can be seen, some are filled with sediment, and one in the former site of Revel’s pipe has yielded bones of a Late Pleistocene cold mammal fauna. Mr. Tim Riley of Sheffield City Museum has kindly informed me that these included mammoth, reindeer, bison or large bovid, hyaena and numerous small mammals. The nature of the matrix and the form of the fissure suggested that washing into an open fissure was chief mode of accumulation, though no swallet morphology can be made out.

The spur of the Dale side north of Hazlebadge Hall contains the mine-cum-cave of Hazlebadge Cave. Partially solution-enlarged vein fissure, it seems to be an isolated phreatic segment breached by mining, though the stalagmite-cemented choke at the end may well conceal interesting cave passages.

Much lower in the eastern side of the gorge close to the road is Walker’s Grotto, a short single chamber phreatic cave developed on a small NE - SW fault. Burrowing down some 10 metres below road level amongst the boulders at the back of the Grotto has failed to reach water. A number of very short phreatic enlargements higher in the same cliff barely merit the title of cave.

The dip-slope rising to the west of Bradwell Dale has a number of Caves, as well as numerous mines. A high-level phreatic tube system has been entered from Outlands Head Quarry (not accessible at present), and the survey shows that it trends down dip towards the New Series extension in Bagshaw Cavern.

In the dry valley of Hartle Dale two small caves are close to a vein parallel to Earl Rake and may have phreatic connection with fissures in the veins. A fissure and the mouths of two phreatic tubes on the south side have yielded Late Pleistocene and Post-glacial mammal faunas as well as evidence of early human occupation. (Pennington 1875, 1877; Pill 1963; Turk 1964; Turk 1966). Now that the archeological material has been removed it should be possible to continue the digs inwards, provided the foxes and badgers can be ejected. The tubes appear to have been truncated by the incision of the Dale so that continuation tubes may lie concealed beneath the scree and soil on the north side, possible once forming part of a phreatic feeder system to Bagshaw Cavern.

To the northwest of Bradwell lies the Moorfurlong-Small Dale pipe vein with a northwest - southeast trend like most of the pipe veins of the area, as seen in the Noulton - Revel’s - Hazlebadge Pipe across the Dale. The northwesterly Smalldale, section of the pipe is still being worked open cast for fluorspar and small pipe-vein cavities lined with fluorspar and barytes are common as well as phreatic solution enlargements along the same line. These can also be seen in Moorfurlong Mine, unaffected by modern mining. The main mineralization in both is in crinoidal mound facies limestones, with some evidence of bedding plane control, particularly along shale partings. The upper end of Moorfurlong Mine penetrates a cone-shaped plug of fill in what must have been pothole open to the surface. The fill, which still requires proper excavation and examination, is a heterogenous mixture of clay, sandstone pebbles and limestone blocks, some of which carry glacial striation. Thus, although not yet proven it seems that there is at least a component of glacial boulder clay in the fill. It might conceal bones but none have yet been found. Striated erratics of Gritstone have been uncovered in fissures in the top of Earl’s quarry about a kilometre to the northwest of Moorfurlong Mine.

Higher on Bradwell Moor is a group of open potholes of which Batham Pot or Pigeon Hole is best known. Although only a few metres deep it is close to the series of phreatic "rift" caverns encountered in Long Rake Mines. These descend to a total depth of about 150 metres (Lord & Thompson 1968; Lord & Worthington 1969). Little but local percolation water is seen in them. The presence of similar phreatic
solution caverns in the nearby parallel New Venture mine (Wright & Worthington 1971) suggests that many more of the veins and mines high on Bradwell Moor may have phreatic caverns in them, though no longer accessible. Kittycross Mine on Moss Rake to the south of these penetrated a single phreatic chamber at a depth of 135 metres, cut into a floor of toadstone. Puddles suggested that water seeped away down dip, though no water course was seen. Still higher on the moor are a scatter of dolines and a few of them have short blind valleys leading in, taking a little storm drainage.

To the south of the area under consideration and beyond the apparent surface watershed at Great Hucklow, the small swallet of Duce Hole has been dye-tested to resurge in 4 days at Bradwell Brook, and presumably the nearby Shodpot does also. High Rake mine shaft, west of the village, also drains to Bradwell but takes a long time, several weeks in fact. Nothing is known of the underground drainage connections.

Physiographic Evolution

Since the drainage system cannot be understood without fitting the observations to the surface morphology, this must be discussed first.

The limestone dip slope with its gentle anticlinal warp once trended right across the present site of Bradwell Dale. The reefs projected above the regional dip slope, perhaps by 10 metres or so. In late Tertiary and probably early Pleistocene times the whole was still covered with the Edale Shales and at least part of the sandstones of the Millstone Grit. A drainage pattern was developed on these rocks, converging on the River Derwent, either by its tributary River Noe to the north or to the River Wye on the south, with the Hucklow monocline as a topographic divide at an early stage. The southern drainage need not concern us here. As time progressed in the early Pleistocene the rivers cut down through the shale cover to bare the limestone. At first this was probably in the Bradwell Moor area where the streams were incised and thus superimposed on to the limestone. With little relief available only slow deep-seated phreatic circulation could take place through the limestone and the solutional activity was probably restricted to forming the enlarged vein cavities of Long Rake mines at first, with later phreatic solution taking place in the Smalldale-Moorfurlong Pipes and still later in the Revell's-Hazlebadge Pipes. Each of these three phreatic pipe systems, at Long Rake, Smalldale, and Hazlebadge, may represent separate stages in the unroofing of the limestone: so long as there was sufficient limestone exposed, with enough relief to have a hydraulic gradient, a deep phreatic circulation could be established via primary vein cavities. There was probably insufficient flow to establish a true swallet-resurgence system, but a catchment of residual shale cover could supply aggressive percolation water to be channeled through a phreatic system.

The later solution caves probably formed soon after the limestone crests on either side of the gorge section of the Dale were bared, and thus they may post-date an important aspect of the story, the initial siting of the gorge.

The present position of Bradwell Dale's gorge section is anomalous, like the Derwent gorge at Matlock, in that it cuts through an anticline of relatively hard limestone when it might have been expected to go round the nose of the anticline to the east. Both can be explained broadly as the result of superimposition from the shale cover by the rivers cutting down directly into the limestone. But this generalization does not explain the immediate problem of the failure for the river's course to migrate down dip until it went round the nose of the anticline instead of through it. The answer, not previously proposed, lies in the presence of the reef mounds.

A series of such reefs, flanked by coarse crinoidal limestones, forms the crest line high on the east side of Bradwell and Stanton Dales, though there is little evidence of them on the west side. By projecting above the dip-slope of the limestone, any uniclinal shift down dip of the river's course was blocked so that in immediate vicinity of the reefs it was "trapped" with limestone on each side. This focussed the superimposition of the river's course across the limestone both in Bradwell Dale and at Matlock where High Tor, Pic Tor and Cat Tor form an analogous series of obstacles in the way of simple uniclinal shift.

Before the gorge of Bradwell Dale had been incised far, glaciation overtook the area. The evidence of glaciation is limited to the silty drift with striated blocks in fissures in Earle's Quarry and the striated blocks in the fill of Moorfurlong Mine's old pothole. From evidence in surrounding areas it can be deduced that the glaciation was older than the Devensian (Late Pleistocene) probably Wolstonian, and even possibly the earlier Anglian glaciation. No dating evidence is available in the Bradwell area yet.

Even if it is uncertain whether the Anglian or the Wolstonian glaciation was responsible, perhaps both, the waning stages show a marked phase of run-off of both precipitation and melt-water under periglacial conditions, causing the final stripping of the shale cover from the present limestone dip-slope, with progressive incision of the dry valley network while the ground was still frozen (Warwick 1964). The Hoxnian (Penuitima) and most likely the Ipswichian (Last) Interglacial saw the establishment of normal run-off and the beginnings of utilization of phreatic solution conduits, some along the present site of the gorge and some to one side. Such conduits could have been both bedding and vein cavities or large joints, whichever was the most favourable for a hydraulic gradient towards Hope Valley by now incised to something approaching its present depth.

The mouths at least of the early phreatic caves were almost certainly choked with till or solifluction material during the Wolstonian glaciation, but they were cleaned out to a large extent by the run-off during the Ipswichian interglacial and the succeeding Devensian periglacial activity. Some such early pots are still choked, and representatives are seen in the fissures in Earle's Quarry.
Fig. 3. Diagrammatic sections to illustrate the evolution of Bradwell Dale and its caves. B.C. = Bagshaw Cavern; OQC = Outlands Quarry Cave; LRC = Long Rake Caverns; MF = Moorfurlong Mine; RP = Revell's Pipe; HP = Hazlebadge Pipe; BD = Bradwell Dale.

Stage 1. Early unroofing of part of the limestone permits phreatic circulation via primary vein cavities, and develops the Long Rake Caverns. Probably Pre-Anglian or Pre-Wolstonian glaciation.

Stage 2. Further unroofing of the limestone permits development of phreatic circulation via Smalldale and Moorfurlong Pipes, while surface drainage is trapped by uniclinal shift down the main dip slope until impeded by the reef mounds on the east side of Bradwell Dale. The Dale itself is initiated. Hoxnian or Ipswichian interglacial.

Stage 3. Phreatic systems all abandoned. a, b, and c represent the Bagshaw Cavern drainage system: (a) the old up-dip cave passage parallel to the main cave, with a feeder tributary from Outlands Quarry Cave; (b) the presently accessible and intermittently active cave; and (c) the inaccessible down-dip active stream passage, probably still mostly flooded. The system developed mainly during the Devensian.
The return of a cold climate in the Devensian glaciation did not result in glaciation in the Peak District but in much periglacial activity. Owing to frozen ground meltwater streams were maintained on the surface and the dry valleys were incised to their present depth, some, as at Hartle Dale, breaching phreatic caves. Frost opened a few fissures and mammal bones were washed in together with a loam derived from a widespread loess cover.

As climate ameliorated in post-glacial times, the frozen ground thawed and run-off, doubtless still high, went underground via the phreatic systems causing modification to vadose conditions at least in parts of Bagshaw Cavern. A lower phreatic system, down dip of Bagshaw Cavern, now takes the normal flow, though Bagshaw Cavern is still active in flood times. The higher parts of the limestone plateau, west of Bradwell, which earlier had had phreatic drainage via the Long Rake cavities, via Moorfurlong Pipe and the tubes of Outlands Head quarry cave, now had their percolation taken directly to depths of 150 metres or more, to a new deep phreatic circulation of which very little is known. With a relative lack of impervious strata such as toadstones or wayboards, water was not held high up and vadose stream caves apparently did not develop. An additional factor is that Bradwell Moor has no allogenic streams draining on to it, as in the Rushup Edge swallets of Castleton.

It is possible that some of the present day deep phreatic drainage resurges at the Warm springs behind the New Bath Hotel, at Eden Tree, north of Bradwell village (Edmunds 1971). The high temperature (12°C) and tritium content suggest that the small quantity of water resurging here is of meteoric origin but has been underground as much as 15 years, and it is possible that it has been warmed by the exothermic reaction of the oxidation of pyrite in volcanic rocks such as underlie Earle’s Quarry. Though still small the conduits concerned may be the fore-runners of phreatic “rift” caverns like those of Long Rake, but which are still buried beneath the Edale Shales.

Soughs

A number of lead miners’ soughs discharge small quantities of water into Bradwell Brook more or less in the centre of the village. Rieuwerts (1966 & 1969) gave the details of the discharge points but unfortunately little is known of their courses or of their effect on the natural drainage system. Pic Tor End Sough was driven more or less southwards to Pic Tor End Mine, a 200 ft. shaft, close to the south end of the Hazlebadge Pipe workings. A planned extension to continue this sough more than a mile to the south to unwater mines at Great Hucklow was never carried out. Two other short soughs are said to go to mines on Moss Rake, and this is quite reasonable as road discharge from near the quarries there apparently reappears in the Brook in the village. An unlikely sough is supposed to go to Moorfurlong Mine, but as the known conduits concerned may be the fore-runners of phreatic “rift” caverns like those of Long Rake, but which are still buried beneath the Edale Shales.

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MOORFURLONG MINE, BRADWELL, DERBYSHIRE
AND ITS GEOLOGICAL EVOLUTION
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Summary
The Moorfurlong Mine is developed in the Viséan Monsal Dale Beds of D2 age. An early system of small interconnecting phreatic pockets were developed in favourable stratigraphical positions, such as prominent bedding planes and along shale partings. Later mineralization filled in many of the cavities and replaced the wallrocks, favouring the pale grey stylolitically bedded calcirudites. During the Pleistocene phreatic circulation produced a series of bedding plane caves which re-utilized the earlier mineralized plumbing system. The downcutting of Bradwell Dale subsequently lowered the water table leaving Moorfurlong Mine as an abandoned phreatic system. Fluvioglacial sediments then filled in the cave system and were re-excavated by the old miner. Flowstone then developed in the spaces provided by mining.

Introduction
Moorfurlong Mine lies on the Moorfurlong pipe 0.3 kms west of Bradwell village (SK 1683.8120). Little is known about the history of the mine and prior to the present survey no adequate survey existed. A crude plan was produced by Marsh (1954) which appeared to be incomplete and inaccurate. The mine was mentioned by Rieuwerts (1969, p.130), who suggested that a sough might exist to drain the Moorfurlong pipe. No evidence of the existence of a sough was found during the survey.

The present work was undertaken to determine the geological nature of the pipe and its relationships to the other caves and pipes of the Bradwell area. This shows that the pipe trends northwest-southeast lying in the Upper Monsal Dale beds of the D2 zone. These have been folded into a gentle syncline whose axis trends roughly north—south. Later karst processes have cut across the earlier fluoritized pipe-vein system producing a series of extensive bedding plane chambers.

Description of the Mine
The mine is entered via the narrow entrance shaft which lies at 287.6 m AOD. This was reopened by Sheffield College of Technology Caving Club in 1966 who installed a fixed ladder. The entrance shaft is 13 metres deep and leads via a small level to a 3 metre winze. A low cross cut from the winze leads to the main workings. For convenience the workings can be divided into four: the upper bedding plane chambers, the lower bedding plane chambers, the lower pipe workings, and the main flat and pipe workings. (Fig. 1).

The upper bedding plane chambers are a series of low but laterally extensive caves. They are developed in thinly bedded black bituminous limestones with shale partings dipping at up to twenty degrees to the southeast. The lowest of these chambers has a steeply inclined floor with two small partially collapsed winzes sunk through coarse muddy gravel. This coarse gravel seems to have come from a former surface shaft, and probably represents old miners' washings mixed with glacial infill. A narrow flat-out crawl at the top of this large chamber leads into a similar series of bedding plane chambers with collapsed winzes in the floor. A small dome-like antcline with an amplitude of approximately 2 metres is the only structural feature in horizontally bedded limestones which form the roof to the caves. The numerous winzes in the floor of the upper bedding plane chambers suggests that the old miner was searching for the strongly mineralized pipe-vein which lies directly beneath.

The lower pipe workings are entered by a short level which has been driven from the downdip end of the upper bedding plane chambers. This leads to a short climbable winze 4.2 metres deep. The passage leading from the winze intersects an intensely mineralized series of cavities developed in thinly bedded dark grey limestones with cherts and shale partings. These limestones appear to have undergone solution collapse in this vicinity producing a massive breccia of large slabs of limestone cemented by later fluorite mineralization. Beyond this, the workings extend to the north and consist of a series of fluorite, galena, baryte, and calcite-lined cavities developed in the dark grey limestone. These are linked by thin replacement fluorite flats developed between shale partings. A complex of narrow passages and rather unstable winzes may be followed for a further 10 metres in mineralized ground of a similar nature.

The lower bedding plane chambers are the natural downdip extension of the upper bedding plane chambers. They reach 2 to 3 metres in height and are developed in horizontally bedded dark grey to black cherty limestones. Small phreatic pockets are present along minor joints in the bedding plane roof. The small Buddie Chamber is entered by a small winze in the southern wall of the passage. This was used by the miner to empty washings from a small square huddle which rests on the lip of the winze. A similar square shaped huddle is still intact in the extensive bedding plane chamber 20 metres to the southeast. This large chamber terminates abruptly. However, a small tight crawl may be followed through a boulder choke into a small rift chamber forming the connection to the main flat and pipe workings. The connection is developed in pale grey coarse crinooidal biosparrudite limestones, which form the wallrock to all the main flat and pipe workings. These can be followed for a further 100 metres through very tight flat out crawls in muddy pools. The northwestern part of the workings are in a fluorite flat up to 0.5 metres thick but more usually 0.25 metres thick. The mineralization changes in character after 30 metres to the southeast into a series of elongate cavities lined with purple fluorite, which is banded in a similar fashion to Blue John [incorrectly identified by Marsh (1954) as sphalerite (zinc blende)].
Fig. 2.
THE STRATIGRAPHY OF THE MOORFURLONG MINE

D 2 UPPER MONSAL DALE
BEDS

Metres

0

0

Dark grey thinly bedded cherty limestone

Pale grey thickly bedded calcarenites with cherts

Thinly bedded very dark grey cherty bitumenous limestones with shale partings

Pale grey stylolithically bedded crinoidal biosparrudites.

Fig. 3.
A DIAGRAM SHOWING THE DEVELOPMENT OF THE REPLACEMENT FLAT IN THE FLAT AND PIPE WORKINGS MOORFURLONG MINE

1
Crinoidal biosparrudite with prominent stylolite seams

2
Fluorite replacement occurs along stylolite seams

3
Replacement proceeds and replaces the limestone adjacent to the stylolite seams

4
Replacement complete with crinoid ossicles remaining as pseudomorphs
Stratigraphy

The stratigraphy of the mine is illustrated in figs. 1 and 2. This shows that the main bedding plane chambers and lower pipe workings are developed in thinly bedded very dark grey bituminous limestones with shale partings. Approximately 9 metres are exposed in the workings. These pass laterally to the southeast into slabby, pale grey, crinoidal biosparrudites; numerous stylolite seams are developed in them at intervals of less than 1 cm. A thin clay wayboard (volcanic ash) is also present. The dark grey thinly bedded limestones pass gradationally upwards into pale grey thickly bedded cherty calcarenites with numerous small Productid brachiopods. This type of limestone is exposed in the lower half of the entrance shaft where the thickness reaches 10 metres. About 4 metres of very dark grey thinly bedded cherty limestones are seen resting on top of the pale grey limestones in the top of the entrance shaft.

The lithofacies described closely resemble those described as Upper Monsal Dale Beds by Stevenson and Gaunt (1969) and Orme (1974), who ascribed an upper D3 age to the limestones.

Structure

The section (Fig. 1) shows that the mine is developed in a shallow syncline, whose axis trends roughly north-south. A number of smaller undulations are present and appear to be superimposed on the main structure. They are probably associated with "drag" effects due to faulting. A series of faults cut the deposit. These are principally confined to the main flat and pipe workings. They have displacements of up to 4.2 metres with well developed mineralized breccia zones. Two sets of faults and major joints are recognised; those with a northwest-southeast trend and, those with a southwest-northeast trend probably forming a shear pair.

Mineralization

The principal minerals present in the lower pipe and the main flat and pipe workings, are, in order of abundance: Fluorite, Baryte, Calcite, Galena, and small amounts of quartz. Two types of textures are developed: fibrous textures, and saccharoidal, sometimes vuggy textures. The fibrous textures occur as a lining in a series of phreatically produced interconnecting cavities usually 0.2 to 0.5 metres in diameter. From a study of these cavities an order of crystallization or paragenesis has been deduced for the orebody. This is generally as follows:

1. Formation of the cavities
2. Infilling by (a) purple zoned fluorite and partial replacement of the cavity walls, (b) white fibrous translucent calcite, (c) thin whitish yellow powdery baryte.
3. Final stage of pervasive metasomatic fluorite replacement. The fluorite is generally orange but may be clear or purple-coloured. Galena is present as large inclusions reaching 1 to 2 cms across. Quartz is sometimes present in small vugs.

The final phase of fluorite mineralization extensively replaced the wallrocks producing a vuggy saccharoidal texture in the form of a replacement flat. Within the flat unreplaced chert nodules and fossil fragments are common. The development of both types of texture appears to be lithostatigraphically controlled, with mineralized cavities and replacement flat being most strongly developed in the coarse crinoidal biosparrudite type of limestone.

The final fluorite phase alters the host wallrock by initial replacement along stylolitic interfaces. Finally the intervening limestone is entirely converted producing a continuous replacement deposit (fig. 3). In the other lithofacies, thinly bedded dark grey cherty limestones with shale partings, prominent bedding planes and shales exert a strong control, with mineralized cavities developed within them sometimes displacing the intervening shale. Similarly, fluorite replacement is preferentially developed in thin limestone beds between shale partings.

Cave development

The "natural part" of the mine consists of a series of bedding plane caves which have developed across the existing pipe-vein system. Solutional features are not particularly well developed but small pockets are present along the stronger joints and a little scalloping can be seen in the roofs of some of the chambers. From the available evidence it appears that for most part the caves were developed under phreatic conditions. The influence of lithology is apparent in the cave development as the thinly bedded black limestones contain numerous prominent bedding planes and shale beds which have provided suitable channelways for solutional enlargement.

Coarse sub-angular gravel fills and brown silty clays cover most of the cave floors and in many cases completely fill the passages, the old miner appears to have cut through these in search of lead ores. Quite a significant proportion of this infill consists of fluorite, calcite, and barytes which probably originated from erosion of the earlier mineralized pipe vein. Later mining activity precludes any reliable analysis of the fills as they have been confused by ore-washing processes being carried out underground as well as on the surface.

The speleogenetic evolution of the Moorfurlong Mine has been considered in detail by Ford, Burek, and Beck (1975) who suggested that it was developed under phreatic conditions. They estimate that this occurred during the pre-Anglian or pre-Wolstonian stages (of the Pleistocene). Later Devensian downcutting of Bradwell Dale and removal of the shale cover, lowered the water table and produced abandoned phreatic systems such as those in Moorfurlong Mine. The lack of flowstone and other formations suggests that the
caves were then completely filled by later fluvio-glacial sediments. Only after excavation by the miner was there sufficient room for the later development of flowstone.

Notes on the Survey
Equipment used: Silva Compass read to one degree with clinometer read to within two degrees, and a Rabone Chesterman 'Fibron' tape read to within one centimetre.

Acknowledgements
Both authors acknowledge the receipt of NERC studentships and the co-operation of Mr. Brown of Within House Farm on whose land the mine is situated.

References


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NICKER GROVE MINE, EYAM, DERBYSHIRE
by John S. Beck and Noel E. Worley.

Introduction
Nicker Grove Mine is situated on the west side of the Cucklet Delf, ¼ mile south of the village of Eyam, at an altitude of approximately 715 ft A.O.D. (N.G.R. SK 2155 7595). It has often been confused with Great Cucklet Mine in the past, but careful comparison of old plans with the modern '6 inch' map shows that Great Cucklet Mine shaft lies just west of the valley at 2151 7609 (Gunn, 1974). No historical records exist, but Barmasters' books for the area for the mid 18th century refer frequently to 'Never Fear Mine on the west side of Mr. Wright's Delf.' Never Fear Mine may be another name for Nicker Grove.

A plan of Nicker Grove was published by Pearce (1974). The subsequent discovery of a third entrance, and the excavation of a shaft to lower levels, threw new light on the relationship of the mine to the postulated upstream continuation of the Merlin Streamway, and a detailed survey was deemed necessary. Close study of the mine proved useful in understanding the function of the Lower Shell Bed in the control of speleogenes is and mineralization in the area.

General Description:
1) The Main Level. The grid reference given is for the adit entrance, high on the west flank of the valley. Other entrances are via a shaft to the north of, and higher than, the adit, and by a shaft still further north, a short distance above the valley floor.

The adit is driven along a scin close to the Cowlishaw Vein, probably that named as 'Chitterling Venture' on a plan dated 1863. After 90 ft, the level turns to the north west along a fissure with a sedimentary fill.

Old Grove Scrin is soon reached, and a short trial can be followed eastwards to a tiny hole from which a strong draught issues in hot weather. The hole was enlarged slightly until a small person, semi-clad, could pass through into a level which led to the bottom of a 40 ft shaft to surface. It is certain that the miner never passed through this hole; work was stopped when the connection was made.

Continuing along the Main Level, a shaft 75 ft deep in the floor is reached. There are levels at -25 ft, -50 ft, -60 ft, and -75 ft, which are described later. The shaft lies on Mossley Scrin.

The level continues, and the fissure becomes ill-defined until a large rift chamber is reached. The chamber is 80 ft long, roughly 30 ft high at its highest and up to 8 ft wide. Its size has been considerably reduced by the piling of 'deads'. The chamber is completely natural and at the north end a small amount of water enters from the roof in wet weather to sink in the floor. The roof of the chamber has been investigated and there is no way out above.

The level continues at the lower end of the chamber, and a 15 ft deep shaft has been sunk on to the Lower Shell Bed, presumably in search of the 'flat' mineralization present elsewhere at this horizon.

A further shaft is encountered 90 ft beyond the chamber. The shaft has only two solid walls; the other two consist of the fissure fill. It is probable that its depth has been reduced by collapse; it is at present 35 ft deep. Digging was attempted, but the shape of the shaft made removal of spoil difficult.

Small trials have been made on scins between the last shaft and the end of the level, which lies 770 ft from the adit entrance. The level ends at a fall of sludge where water enters in small amounts in wet weather. Digging was attempted, but the fall became dangerous, and the attempt was abandoned.
2) The Lower Levels. A safe descent of the Main Shaft on Mossley Scrin can be made if tackle is hung down the north or west walls, which are heavily flowstoned. The iron ring on the south side should not be used. The level at -25 ft leads shortly to a climb down. A level at the bottom leads to a tiny chamber, where climbing through a hole in the roof leads to a natural rift chamber on a fissure parallel with that along which the Main level is driven. The rift chamber has been climbed in the past, and no way out found above. A shaft offset from the chamber in an alcove is fifteen feet deep, and provides a slippery climb down to a junction of three levels. The level to the north follows the fissure, which can be seen here to be a washed out vein, for 110 ft to a forefield, where the vein splits into three small stringers. The level to the west becomes too small to follow after a few feet. The level to the east leads through stopes with interesting mineralisation at the Lower Shell Bed horizon to the Lower Shaft Entrance. Although the level enters the shaft only twelve feet below the surface, the climb should be previously laddered if exit is to be via this route. The last part of the level, and the shaft, are driven along a natural joint-oriented cavity at the horizon of the Lower Shell Bed. A level may have existed at the bottom of the shaft, but it is now hidden beneath debris.

Levels at -50 ft in the Main Shaft lead to north and west. There was a short level to the south but this was backfilled during our excavation of the shaft below -50 ft. The level to the west is blind, ending at a very small partly natural chamber. The north level leads to a fairly large natural clay-filled chamber, where the Lower Shell Bed is again seen. The wayboard at its base appears again to control development of the natural cavity. The chamber appears to have been excavated to its present size by the miner, and the level may have continued beyond. It is now hidden beneath tons of collapsed clay. A small vein thought to be Green Scrin forms the south wall of the chamber, and a slippery climb up the east wall leads into a small short level. A shaft on the hillside, driven on this vein, was excavated during 1974 to a depth of 65 ft but was blind.

Excavation of the Main Shaft below -50 ft was undertaken when it was realised that a small stream sank in the floor in wet weather. The stream originates at a small natural rift in the Main Level near the shaft top. The shaft had become filled with packs of 'deads' which had fallen from above. The remaining packs are now largely flowstoned.

A level was soon entered at -60 ft. This ran eastwards for 30 ft to a forefield. It was backfilled as digging continued.

A level was entered at -75 ft, trending southwards. A prominent bedding plane at this level, 40 ft below the Lower Shell Bed, had some natural solution cavities developed along it, but none was penetrable. The level ended at a bad fall after about 20 ft, but it was interesting to note that the shotholes had been driven towards the shaft. Either a natural fissure was followed first, and later enlarged, or the miner had another point of access.

The water sank to the north, and a level was soon uncovered here. This had the appearance of a drainage level, and contained 18 inches of water. It ended disappointingly at a fall, at a point where the fissure became wider. The fall is directly below the natural chamber on Green Scrin, on the -50 ft level. This passage is estimated to be only a few feet above the level of the Merlin Streamway, and to be heading towards it. Digging was attempted, but it was almost impossible to support the roof, and the excavation continually filled with sludge.

Although our excavation failed to open a way to the streamway, it is thought there may be a buried connection.

Stratigraphy and Structure

The mine lies entirely within the D_2 zone of the Upper Monsal Dale Beds
(Stevenson and Gaunt, 1971), and largely above the Lower Shell Bed of Middleton Dale. Most of the limestones are grey to medium grey in colour, generally thickly bedded biomicrites, often cherty. Fossils are abundant, and consist of brachiopods, crinoids, and corals. Many of the bedding plane surfaces show development of stylolite seams, which are frequently coated with hydrocarbons, and are often solutionally enlarged.

Petrological investigations have been carried out on the Lower Shell Bed as this horizon seems to have exerted a major control on the development of the caves and mineral deposits of the area (Beck, 1974). This prominent horizon consists of a metre or so of medium to dark grey limestone, crowded with specimens of Gigantoproductus edelbergensis (Stevenson and Gaunt, 1971). A prominent bedding plane is frequently developed at the base of the shell bed, and in Nicker Grove Mine this is occupied by a clay wayboard several centimetres thick.

Examination of polished slabs of the shell bed has shown that it has a mottled appearance due to strong pseudobrecciation probably caused by burrowing organisms. Stylolite seams frequently develop adjacent to areas of pseudobrecciation, and have amplitudes of up to 2 centimetres. The stylolite seams are highly porous and act as lines of weakness along which the bed readily breaks down into small fragments.

It may be concluded that the shell bed was deposited in shallow marine conditions consistent with a 'shelf' environment. The occurrence of extensive pseudobrecciation and the presence of a basal clay wayboard implies that a temporary slowing in the rate of sedimentation had occurred, probably associated with regression and shallowing of the sea. Overall, the effect of these processes was to increase the porosity of the limestone and reduce its mechanical strength, providing a horizon of weakness along which the cave development took place.

The limestones are folded into a shallow anticlinal structure whose axis trends NWW-SSE and plunges north at 5°. A number of mineralised joints ('scrins') cross the anticline from north east to south west, and two solutionally enlarged master joints lie parallel to the anticlinal axis. This joint pattern is reflected by the shape of the survey. The principal scrins worked in the mine are Green Scrin, Old Grove Scrin and Mossley Scrin. The two north west trending fissures have, subsequent to their mineralisation, formed the basis of important early drainage routes. They have then been filled with debris derived both from the fissure walls and from erosion of the gritstone escarpments to the north.

Mineralisation
The mineral deposits of the Stoney Middleton area are characterised by a number of 'pipe' deposits, which trend north-westwards; these include Merlin Pipe, Carlswark Pipe, Paul Pipe, Ashton's Pipe, Bull Hole Pipe and Phillips Pipe. The fissure veins of Nicker Grove are typical of these pipe deposits, developed at right angles to the general trend of the major rakes and veins, which is east-west. The pipe deposits consist of prominent fractures or master joints which have been solutionally enlarged forming a series of cavities which are interconnected in a vertical sense by the master joint.

The mineralisation is of two types, replacement, and cavity lining. Replacement occurs most extensively at the horizon of the Lower Shell Bed, where the walls of a series of pre-mineralisation phreatic cavities up to 5 metres in diameter have been replaced by greyish purple fluorite. This replacement largely occurs along the bases of the cavities, and has a laminated texture representing development by a series of pulses of mineral fluids. Finally, later barytes and galena, sometimes in the form of octahedral crystals, crystallised forming concentric layers partly infilling some of the cavities.

Similar processes occurred in the joints, where wall rock replacement by fluorite has occurred, usually with later infilling by galena and barytes.

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The mineralized joint and cavity system provided a convenient channelway for subsequent underground drainage, and the flow of water has consequently eroded many of the friable minerals from the walls. In many cases the joints and cavities have also been solutionally enlarged, especially in the vicinity of the Lower Shell Bed, producing the Carlswark-Merlin cave system as we know it today.

The effect of this erosion of the minerals, and mixing with other material, has resulted in deposition of a sediment which fills many of the fractures, and which has been excavated by the miner. This feature is typical of the pipe deposits as being "distinguished from a vein by its irregularity in width. In the widest parts, a pipe is usually filled with soft clays or loose loamy soil in which the ore lays in loose lumps. A pipe generally runs in a contrary direction to the veins nearby".

Analysis of these sediments indicates that they consist of rounded gritstone pebbles, angular barite, fluorite, chert, and silicified fossil fragments. This suggests that they were partly derived from erosion of the Upper Carboniferous gritstone escarpment, to the north. The clays probably have a similar source. Fluorite and barite were derived from erosion of the mineral veins which we re-utilised by the drainage system.

Conclusion

Excavations carried out in various parts of the mine revealed previously unknown passages in two cases, suggesting that much has been lost through collapse. The lowest level found in the Main Shaft carried a small amount of water in wet weather, and this flowed away to the north. The geometry of the Lower Shell Bed in the mine suggests that if the Merlin Streamway follows this horizon beyond the farthest point known, it will lie some distance to the north of the blockage, at roughly the same level. The level may, either by chance or by design, have intersected the streamway and thus acted as a drainage level. Future work may uncover the connection.

Examination of the Lower Shell Bed has thrown new light on its function as an important horizon for cave development and mineralization. The discovery of a clay wayboard at the base, connected with the increased porosity of the horizon, explains the presence of a network of phreatic passages at the base of the bed, and the frequent 'flat' and 'pipe' mineralization in the area of its development. Future work on other important speleogenic horizons, for instance that of the Remnant System of Middleton Dale (Beck 1974), may reveal similar reasons for cave development along preferential bedding planes.

Acknowledgements

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References


A SURVEY OF CARLSWARK CAVERN, STONEY MIDDLETON, DERBYSHIRE, WITH GEOLOGICAL AND HYDROLOGICAL NOTES

Noel Christopher and John Beck.

(a) The Survey

The survey was begun on 25.11.73 when the connection between Carlswark Cavern and Gimlis' Dream was about to be blocked, and having surveyed, that day, as far as the crawl half-way along the new extension, we decided to survey the rest of the cave!

Work proceeded at a steady pace until Easter 1974, when it languished until the Autumn, with apparently only a few trips necessary to complete the work, but the pace was not pushed until the following year when after a mere 17 trips the field work was apparently completed. A few short trips to survey parts of the cave found since the original survey work were made later.

The survey was carried out with a hand-held Suunto compass, a Suunto clinometer or calibrated Abney level, and a Fibron tape. The compass was checked for gross errors, but individual daily calibrations were not carried out. The method of using the instruments and the precisions obtained conform to a poor BCRA Grade 5 for the centre line. The passage detail was measured or estimated, if warranted, at the survey stations and wherever else necessary to ensure a reasonably detailed outline to conform to BCRA Grade C. The cave contains only one closed internal traverse, but this unfortunately can only be made through the lower sump which even during the exceptionally dry summer of 1975 remained flooded so the traverse could not be closed.

There are three entrances to the system and these were closed by P.R. Deakin using a theodolite and conventional land surveying techniques to give National grid references accurate to one metre. These were taken as accurate and the cave survey was closed to these points. A level survey was not carried out and the only vertical closure possible was from altitudes given in a previous survey (King, 1962) which were checked for gross errors from Ordnance Survey maps, and used to assess the vertical misclosure.

The survey was calculated by coordinates using initially a Hewlett Packard HP 35 pocket calculator, and subsequently a Texas Instrument SR 51A calculator. These considerably reduced the tedium of this method, and the internal computation to 13 significant figures was more than sufficiently accurate for the purpose. A magnetic declination of 8° was incorporated. The main closed loops were calculated twice to check for mechanical errors, which proved to be few. Traverse misclosure information is given in Table 1. The survey was plotted on 0.5 x 0.8 metre sheets of graph paper, at a scale of 1: 500 (2mm = 1 metre) using the Gin entrance as base point. A permanent tracing was made on one sheet of permatrace 1.2m x 0.75m using Rotring Variant pens of 0.5mm thickness for the main outline and 0.3 or 0.25mm for the detail. For parts of Dynamite series and some side passages a 0.4mm pen was used for the outline to improve the appearance.

Contrary to present recommendations (Ellis 1976) it was decided not to Grid the final tracing as it was already sufficiently cluttered, but grid marks are provided around the margin of the plan for anyone who so desires to draw in a plan grid.

Extended elevations of the whole cave were drawn in three sections and, due to its complexity, a projected elevation insert of the Falls Chamber Porth Crawl was added as an insert at a scale of 1 to 200 (5mm = 1m).

The survey was primarily carried out by four persons, Noel Christopher, Paul Deakin, Dave Gill and John Beck, NC was present on 15 of the 17 trips accompanied by one or more of the principal surveyors; in addition, 6 people helped with one trip each, these were, Jim Burton, Joe Cooper, N. Smith, H Mares, O C Lloyd and Ron Bridger, all of these people were/are or have subsequently become members of the Eldon Pothole Club.

Tables 1 and 2 give details of traverse misclosures and passage lengths respectively.

Table 1

A. Horizontal Misclosures of Principal Traverses

<table>
<thead>
<tr>
<th>Traverse</th>
<th>Misclosure in Metres</th>
<th>Traverse Length</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance on Gin to Eyam Dale Shaft</td>
<td>-3</td>
<td>8.5</td>
<td>354.8</td>
</tr>
<tr>
<td>Entrance on Gin to Merlin’s Entrance</td>
<td>-8</td>
<td>15.3</td>
<td>586.9</td>
</tr>
<tr>
<td>Eyam Dale Shaft to Merlin’s Entrance</td>
<td>-5</td>
<td>7.1</td>
<td>154.4</td>
</tr>
</tbody>
</table>

B. Vertical Misclosure

<table>
<thead>
<tr>
<th>Underground Survey</th>
<th>Surface Difference</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Entrance to Eyam Dale Shaft</td>
<td>25.2 m</td>
<td>26.5 m</td>
</tr>
<tr>
<td>Lower Entrance to Merlin’s Entrance</td>
<td>35.5 m</td>
<td>36.9 m</td>
</tr>
</tbody>
</table>
Lower Sump at End of Stalactite passage - 16.7 m below Gin Entrance
Lower Sump at Downstream Side - 22.8 m below Gin Entrance

Misclosure = 6.1 m or 0.93%

Traverse Length = 655.1 m

Table 2
Passage Lengths

<table>
<thead>
<tr>
<th>Passage Length</th>
<th>Length in Metres</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carlswark Cavern</strong></td>
<td></td>
</tr>
<tr>
<td>Gin Entrance to Eyam Dale Shaft</td>
<td>354.5</td>
</tr>
<tr>
<td>New Series from Junction with Northwest passage to Lower Sump</td>
<td>323.8</td>
</tr>
<tr>
<td>Dynamite Series</td>
<td>322.2</td>
</tr>
<tr>
<td>Lower Entrance Series</td>
<td>76.8</td>
</tr>
<tr>
<td>Side Passages</td>
<td>749.1</td>
</tr>
<tr>
<td><strong>Total Carlswark</strong></td>
<td>1826.4 = 5992 ft</td>
</tr>
<tr>
<td><strong>Merlin Mine</strong></td>
<td></td>
</tr>
<tr>
<td>Merlin Entrance to End of Gimli’s Dream</td>
<td>234.0</td>
</tr>
<tr>
<td>Streamway from Junction with Gimli’s Dream</td>
<td>171.1</td>
</tr>
<tr>
<td>Minor other side passages</td>
<td>462.9</td>
</tr>
<tr>
<td><strong>Total Carlswark + Merlin</strong></td>
<td>868.0 = 2848 ft</td>
</tr>
<tr>
<td><strong>Total Carlswark + Merlin</strong></td>
<td>2694.4 m 8840 ft</td>
</tr>
</tbody>
</table>

(b) Geological and Hydrological Notes

It has been shown (Beck, 1975) that the underground drainage system of the Stoney Middleton—Foolow area has developed in response to a series of erosional events, which progressively lowered the base level in the Derwent Valley. Four principal cave levels have so far been recognised within a 40 m thickness of the Upper Monsale Dale Beds. They are defined as the First Remnant Complex, the Second Remnant Complex, the Carlswark Complex, and the Lower Complex. Each of the four levels has been recognised in Carlswark Cavern, and it is here that their relationships can best be studied.

The majority of the cave passages belong to the Carlswark Complex, a network of phreatic tubes developed by solution at the base of a band of silicified *Gigantoproductus spp.* (Lower Giganteus Bed of Morris, 1929; the Lower Shell Bed of Stevenson and Gaunt, 1971).

The known cave, including the natural passages of the Merlin Mine, represents the eastern end of what is undoubtedly a large system, which carries both allogenic swallet water and accumulated percolation water eastwards along the strike of the Carboniferous Limestone to a now-abandoned resurgence, in the vicinity of Stoney Middleton. The position of this resurgence is not clear, for the water is now carried over the last part of its underground course by Moorwood Sough whose tail (= outfall) lies in the grounds of Stoney Middleton Hall at an altitude of roughly 465 ft O.D.

It has been shown by dye tests that there are two parallel and separate stream courses. The more northerly carries water from the Millstone grit shales eastwards via the allogenic swallets of Eyam Edge and the more southerly carries the underground overflow from the reservoir of the Wardlow Basin along a parallel strike-oriented course. An analogy may be drawn with the Peak-Speedwell system at Castleton, where New Rake Act as a barrier to separate allogenic from autochthonous stream passages. In the case of the Stoney Middleton system, Middlefield Rake may perform the same function, though there is as yet no direct supporting evidence.

The two streams enter Giebe Mine, Eyam, as one, and must unite in the region beyond the second sump downstream in Merlin Mine. The Merlin Streamway turns to the North between Eyam Dale and The Delf, to flow along the axis of a shallow Northward plunging syncline.

It is convenient to describe the four cave levels in reverse order of development, for none of the Remnant passages open to surface in Carlswark Cavern.
The Lower Complex

The Lower Complex is very little known. The lowest entrance to Carlswark Cavern lies at the foot of a cliff, just above road level, half a mile west of Stoney Middleton. The entrance passage was described by Short whose account (1734) shows that the level of the Lower Sump has not changed since that time. There are two passages leading from the entrance chamber. The smaller tube closes quickly, but a larger passage can be followed for 58 metres to the Lower Sump. The large phreatic passage has been followed into the sump in times of drought, and disappears into a boulder choke in a rift chamber in the middle of the sump. It could never be followed beyond here, for even in drought the northward dip carries the choked continuation below water level. The passage has been located by divers in the rift sump below Aladdin’s Crawl, where it is again choked. The inner end of the Lower Sump is a joint-oriented fissure enlarged by miners.

The Carlswark Complex

Above the entrance end of the Lower Sump is a rift on a joint of a set bearing 320°. This can be climbed, passing tubes at levels intermediate between the Lower Complex and the Carlswark Complex. The highest tube opens into the floor of the large Oyster Chamber, from which Carlswark Complex Passages, their roofs covered with etched out silicified fossil brachiopods, radiate. To the east, the passage soon diminishes in size, and chokes of flowstone prevent further progress, though the tube beyond the choke opens into the cliff face above and to the east of the Lower Entrance. The reason for the diminution in size is the capture of water flowing eastwards through the Carlswark Complex by the open joints which connect it to the Lower Complex.

To the west of Oyster Chamber, the large Eyam Passage can be followed for roughly 200 metres to Noughts and Crosses Chamber, where the passage divides into three. This region lies on the axis of a low amplitude north-south anticline, which plunges to the north, and small inlets from the stream in Eyam Dale join to flow via North West Passage, roughly parallel to the plunging axis. North West Passage can be followed down dip to join Cockle Passage, where another small stream enters. The water used to leave via Big Dig, a heavily silted northwest-trending passage, but has been diverted into a sump during efforts to clear the silt. During flood conditions, water rises in Big Dig until a large stream flows out into the known cave. Once over the crest of the anticline, the watershed of the cave is crossed, and the stream is free-flowing eastwards to the inner end of the Lower Sump. The sump rises up to the entrance passage in times of flood and the Lower Entrance may then become a powerful resurgence.

Cockle Passage may be followed eastwards to intersect the much larger Stalactite Passage. This junction is again on the axis of the anticline, and beyond this point, the water flows eastwards to the Lower Sump. The connection between Carlswark Complex and Lower Complex is again made by way of an open joint of the 320° set, and by a tube on the same intermediate bedding plane as that leading into the floor of the Oyster Chamber. Beyond the capture point, the Carlswark Complex passage continues, but soon becomes silted to the roof.

Dynamite Passage is an obvious northward branch of Stalactite Passage. It appears at first sight to be a phreatic tube with a vadose trench incised into the floor. However, although percolation streams are in places cutting such trenches, none are incised to this degree. Close inspection reveals that the trench is an artificial cut-through fluvo-glacial fill: comparison of levels suggests that the miner drove it in order to lower the water level in the passages on the far side. Were the trench excavated to its original depth, it would be impossible for silt to settle in Big Dig, and it is thought that the purpose of their work was to pass Big Dig and investigate the vein of Stub Serin, which lies a short distance to the west. The floodwater flowing from Dynamite Passage emerges from the downstream end of the sump near Big Dig, into which the small percolation stream has been diverted.

Eyam Passage and Stalactite Passage are large strike-oriented conduits which carried phreatic flow from west to east, and during the later stages of their development lost their water to the Lower Complex by way of the connecting rifts at the eastern end. Eyam Passage, higher up the dip slope, shows evidence of vadose modification at the eastern end, while Stalactite Passage, probably still paraphreatic in character at the time of capture, does not. The smaller passages running north-south are down dip connections, carrying percolation water down dip to the phreas, and carrying floodwater into the higher vadose conduits.

Carlswark Complex passages to the west of the Eyam Dale Shaft can only be reached from Merlin Mine. Eyam Dale shaft is a convenient western entrance to Carlswark Cavern through an enlarged natural fissure. The Carlswark Complex continues westwards as Gimli’s Dream, a stretch of passage with an extensive fill of gravel debris, partly reworked, and extensively flowstoned. The area at the base of the shaft has become complicated by extensive cavern breakdown, and it is probable that the thick deposits of silt beyond have built up behind the piles of blocks.

The access point to this western portion of the Carlswark Complex is by a squeeze at the bottom of the deepest stope in shaft S 3, on Stub Scrin, in the Merlin Mine. Below the squeeze, a small passage on the east side leads back to Gimli’s Dream. To the west, the large stream can usually be heard, but on reaching the streamway, all that can be seen is a swirling pool in Sump Pool Chamber. The downstream sump, although small, is free-diveable with care except in flood, when its length increases to about 4 metres, and the current would prevent a return. Beyond the sump, the stream crosses a wide bedding chamber, and plunges over a short pitch. Climbing and squeezing through boulders with the stream leads shortly to ‘Shag’s Sump’. This was passed in the 1976 drought to a cross rift, where there would normally be an air space, after 8 metres. The passage is very restricted, with small stubby projecting stalactites and stalagnmites. The passage turns through a right angle
at the cross rift, and was followed, in places with minimal air space, for a further 8 metres until it again sumped. The stream flows down dip from here, to reappear in Glebe Mine, Eyam, from a deep sump. Between Shag's Sump and Glebe Mine, the Waterfall Swallet Stream must join the Merlin Stream. Dye testing in 1973 showed that the Waterfall Swallet stream, although it appears at Glebe, does not flow through the Merlin Streamway.

The upstream Sump 1 must not be free-dived. It is 20 metres long, and is often silted amost to the roof. It is restricted at the upstream end. The stream passage was followed in the 1975 drought to the rather evil Sump Five, after 130 metres. This was passed by pumping in the 1976 drought to Sump Six, which followed almost immediately and was too tight for further progress. There is a slim possibility that when the stream is flowing, enough silt may be removed to make the passage penetrable. When the water stops or slows down, silt slumps back down the slope, hopelessly blocking the sump.

Sumps Five and Six lie in the vicinity of Mosaic Wire Mine, on which vein there are extensive workings in Nicker Grove Mine. The vein may have acted as a dam, causing the stream to sump. The effect of a vein, acting as a dam can be seen on the upstream side of Sump Two, where a small stringer of fluor spar and barytes crosses the passage.

The total drop throughout the Carlswark Complex, from Sump Five in Merlin to the opening in the cliff near the Resurgence Entrance, is in the order of 6 metres, a low gradient considering the long stretches of passage that are penetrable.

The Remnant Complexes

Remnant Complex passages are seen in the system in two areas. There are high level tubes and chambers in the Merlin Mine, and there are many high level fragments in the Dynamite Series of Carlswark Cavern. The entrance to the Merlin Mine lies high on the west side of Eyam Dale, south of the Eyam Dale Shaft. Natural cavities are reached by turning left after 12 metres, along the vein of Sycamore Serin. A tube leads to the head of a 17 metre pitch, which may have acted as a capture point of Remnant Complex water by the developing Carlswark Complex below. The remaining tubes and chambers are heavily silted, and blocked by flowstone.

Continuing along the main level on Merlin Pipe, a short climb leads to a further chamber. The tubes leaving this chamber are also soon blocked by silt. They lie on a bedding plane 24.75 metres above the base of the Lower Shell Bed.

Stub Serin is reached, crossing the pipe, 60 metres from the entrance. To the left at the junction are more natural cavities, principally open joints. To the right, two shafts descend to lower levels. The second shaft provides the access to the Merlin Streamway and Gimmil's Dream. A third shaft can be reached, and digging is in progress here. A level continues along the pipe to a shaft on Cowlishaw Vein. The shaft is blind in solid rock, and the base of this shaft is known to lie only 5 metres above the streamway, where there is a short upward trial on the vein.

The Remnant Complex passages of the Dynamite Series are more extensive. Dynamite Chamber is entered from the north end of Dynamite Passage, via an upward squeeze among boulders. Dynamite Chamber is a large cavity developed on a joint of the 320° set. The Carlswark Complex passage is thought to continue beyond the boulder choke, but may be silted for a long distance. The continuing passage lies on a bedding plane 5.1 metres above the base of the Lower Shell Bed. A small joint-oriented chamber follows, and the continuation again lies on the + 5.1m bedding plane. The third chamber (Midnight Chamber) is larger, and the continuing crawl again lies at + 5.1m.

The fourth chamber is Prospect Chamber, and is the largest. Several prominent bedding planes can be followed along its walls, and at the north end, a bedding plane at + 12.80 m forms the roof. A tube leads off at roof level on this parting to a fifth joint chamber, Fall Chamber. Fall Chamber can again be followed northwards, and climbing between jammed boulders, and traversing in the roof, leads to two passages lying on a bedding plane at + 26.48 m. These highest tubes lie directly below the road in Eyam Dale, and the chokes which block them should not be touched. Traffic can be clearly heard. The tube on the west side shows evidence of vadose modification, while that on the east, where there is more extensive cavern breakdown, does not. This suggests that water flowing at this level was captured by the joint-oriented cavities, and carried down to the Carlswark Complex. The western tube was therefore modified and enlarged, while the eastern one deteriorated.

Returning to Prospect Chamber, a tube can be followed by the determined caver on a bedding plane lying at + 8.70 m. This is the notorious Porth Crawl, partly a joint controlled rift, partly a bedding controlled tube. It is only just penetrable. A tight climb at the northern end of Porth Crawl opens into the floor of a large phreatic tube at the +12.80 m level. The passage has been reduced to its present uncomfortable size by the dumping of miners' deads during excavation of the continuation by cavers. In the downstream (southerly) direction, the tube ends at a choke of large boulders, where prospects for digging seem remote. To the north, the tube is again lost among boulders (though here the choke is of miners' debris) and access can be gained through loose boulders to a mine level. This is Clog Passage, and lies on Stub Serin. Choked shafts from surface can be seen.

Isolated fragments of the +12.80 tube can be reached by climbing down shafts in the floor of Clog Passage, and the final descent leads into a small chamber from which two passages lead on. The right-hand (east) passage again ends at a choke, but that to the north follows the vein, and its fill has been excavated by the miner to gain access to the vein continuation. Two shafts in the floor lead nowhere; they are unstable, and should be carefully passed. The tube is finally lost in more chokes at the base of a large joint-oriented aven, and a small feeder system can be followed to the north west. An awkward keyhole-shaped passage leads to yet
another joint-oriented cavity. Two tubes continue from here. The right fork is soon impassable due to silt and flowstone, although there is an air space. The left fork is very small and awkward to pass, but leads into the Final Aven, which is well named, for it is impossible that the tiny tubes beyond this point could ever be followed by cavers. The silted right fork could be excavated, but the nature of this feeder system suggests that it will eventually become too tight. The journey from the Eyam Dale Shaft to the end of the Dynamite Series is so arduous that digging is almost out of the question.

The principal levels of the system are thus as follows;

1) First Remnant System;
   1a; +26.48 m Top of White Bed?
   1b; +19.83 m Bedding plane below Upper Shell Bed.
2) Second Remnant System;
   2a; +12.80 m Base of unit with isolated Lithostrotion sp.
   2b; + 8.70 m
   + 5.10 m
3) Carlswark Complex;
   3a; 0.00 m Bedding plane/wayboard at the base of Lower Shell Bed.
   3b; - 6.00 m (app).
4) Lower Complex;
   4a; - 12.63 m Prominent Bedding plane in lowest crinoidal limestones.

The four cave levels appear to be directly related to terrace levels in the valleys, and further work will clarify the correlation of these terraces in different areas of the limestone outcrop.

Prospects for further exploration from the Merlin Streamway seem remote, but the Remnant Complexes are obviously far more extensive than is known. The westward trending “dry” tubes of Carlswark Cavern are silted, but the silt is of recent origin, and is now being slowly removed.

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THE CAVES, MINES AND SOUGHS OF THE WARDLOW BASIN AND
CRESSBROOK DALE

by John S. Beck

SUMMARY: The uppermost limestones of the Wardlow area form a structural basin and an aquifer perched c. the Litton Tuff. Drainage patterns vary according to weather conditions with flow going (a) via Watergrove Sough to the east, (b) via Wardlow and other short soughs in Cressbrook Dale, or (c) via surface drainage down Cressbrook Dale. Holes on the dale floor near Wardlow Mires act as swallets in dry weather but as artesian overflow resurgences in wet weather. The route of natural pre-sough drainage is uncertain but was probably eastwards to the Merlin Mine - Carlswark system, though some may have gone southwards to Lumb Hole.

Cressbrook Dale is a northern tributary of the River Wye, trending roughly north - south. Topographically, the dale appears to drain the Wardlow Basin, centred on Wardlow Mires, but the underlying structure suggests that the underground drainage of the basin now passes eastwards towards Stony Middleton. Only in flood conditions, when the water table in the central basin rises to valley floor level at the head of Cressbrook Dale, does a surface stream flow down the upper part of the valley. It is joined by the flow from a very small rising near Peter’s Stone (SK 175 753), which is likely to consist of local percolation above the Litton Tuff. A larger seepage flows from the east bank at SK 173 751, and a considerable stream flows from Wardlow Sough (SK 174 748).

A small stream flows from Arbor Seats Sough; there are small springs in the Ravensdale Tuff at Ravensdale Cottages, and a large rising occurs to the south of a large east - west fault, at Lumb Hole. In wet weather, the stream joining the River Wye at Cressbrook can be a very large one.

Recent excavations carried out in the valley have revealed little natural cave passage, but the evidence provided has been of great value in elucidating the natural drainage of the area.

GEOLOGY

The regional dip is to the north or northeast in Cressbrook Dale, but the basin at the head of the valley is structurally completely enclosed (Figure 1). The Litton Tuff functions as an aquiclude, maintaining a large reservoir of groundwater in the overlying limestones beneath the central basin.

The outcrop of Upper Millers Dale Lava at the southern end of Cressbrook Dale may assist in keeping the drainage on the surface over this stretch even in dry weather. Progressively younger beds are encountered as one passes northwards up the dale, and Bee Low Limestones floor the valley for some distance, with dark Monsal Dale Beds above. The large rising of Lumb Hole lies a short distance to the south of a large fault, and the considerable downthrow to the south results in the Bee Low Limestones forming all but the highest line of cliffs on its north side. The valley floor here is occupied by the Ravensdale Tuff, which forms a broad stretch of meadow at Ravensdale Cottages.

The Bee Low Limestones dip steadily northwards until the dark Monsal Dale Beds reach the valley floor at SK 174 746. A small faulted inlier of the Bee Low Limestones occurs in Tansley Dale, further north.

From this point northwards, the Litton Tuff forms a marked bench in places on the east side of the valley, and dips into the valley floor at Peter's Stone. The landslip here appears to result from a large mass of Upper Monsal Dale Beds having slid down-dip over the lubricated surface of the tuff. To the north of the landslip alluvium floors the valley, dammed to some extent by the slip itself. The limestones disappear beneath the shales of the Wardlow Mires outlier at SK 179 756.

The basin is a structural, as well as a topographic one, and the shale directly overlies Upper Monsal Dale Beds to the south, having overstepped the Eyam Limestones, which outcrop to the north and east of the outlier. The limestones finally dip northwards beneath the Namurian of Pyam and Hucklow Edges.
CAVES, MINES AND SOUGHS OF THE WARDLOW BASIN.

KEY:
1. Shad Pot.
2. Duce Hole.
4. Waterfall Swallet.
5. Watergrove Mine.
7. Seedlow Mine.
8. Wardlow Mires Swallet.
10. Unnamed Mine.
15. Lumb Hole & nearby risings.
16. Lingards Cave.

- Limestone.
- Shale.
- Litton Tuff.
- Landslip.
Several veins cross the valley. The most important are White Rake, and the westward continuation of Watersaw Rake, at the southern end. The veins are dominantly of calcite and baryte, slowly becoming richer in fluorite to the east. There are many smaller east-west serins, worked for lead in the past to varying degrees.

THE CAVES

Shod Pot

This small swallet (1) lies in a prominent hollow. Recent excavation by Stockport Caving Club has revealed it to be full of road-widening debris, and it is possible that this is the 'Duss Pit' referred to by Farey (1811) as a 'deep open hole in 1st lime'.

Duce Hole

This short swallet cave (2) lies very close to Shod Pot, and is penetrable only for a short distance. Drainage of both swallets is thought to flow north to Bradwell.

Swevic House Swallet

The destination of the small stream sinking at Swevic House Swallet (3) is unknown. It is possible that it passes southwards to augment the reservoir in the central basin.

Waterfall Swallet

A large tree-lined doline (4) into which a large stream sinks. An overflow cave in the north wall of the doline can be descended to a depth of 140 ft, where the stream sinks in boulders and mud. In normal conditions the stream flows eastwards, to emerge through Moorwood Sough, but it is thought that in extreme flood it may flow southwards to the Wardlow Basin, adding to the flow emerging at the head of Cressbrook Dale. Waterfall Swallet was first described by King (1962) and a survey was published by Yonge (1973). A re-survey is in preparation by the Technical Speleological Group.

Wardlow Mires Swallet

In summer the small stream draining the shales of the Wardlow Mires Outlier sinks into a small swallet (8) a few yards south of the road. This stream may back up in the swallet, and in wet weather water appears in adjacent hollows. As the flow increases, these hollows overflow, and water begins to flow down the valley. If wet weather continues, the volume of the stream flowing from the shales does not increase significantly, but the volume of water flowing from the swallow becomes very large. Pressure domes appear on the surface, even in places where the water is up to three feet deep. Bedding planes further down the valley discharge large amounts of water, and in extreme flood, tubes up to 20 ft above the valley floor may discharge water.

Digging was attempted during 1977. The most prominent rising, a bedding plane on the west bank some distance downstream from the swallet, was first selected. A hard day's work revealed collapse of the bedrock, and it was decided that a prolonged excavation would be necessary. The dig was backfilled.

A tiny overflow tube above this rising emitted a rumbling noise when not actually flowing. The entrance was cleared, but it became too tight in solid limestone. During the past two winters it has at times flowed quite strongly, and the bedding plane on either side of the tube has been cleared of turf by the floods.

The artesian risings near the swallet were then cleared of turf and topsoil, and the water was found to well up a series of boulder-filled rifts. Digging in the most southerly of these soon revealed a tight lateral extension along the joint, but it soon became too tight, and a deeper excavation has recently begun, halted so far by wet weather.

The main rising (not the 'swallow') was cleared to a depth of 5 ft, at which point the joint closed, and a tight bedding plane led northwards. A strong draught was present. The dig became too constricted, and was completely backfilled. This rift is not worth re-opening.

The other openings became too tight immediately, and the swallow is too evil and smelly to be considered.
Dead Dogs Hole

Dead Dogs Hole (9) lies in the uppermost line of cliffs, close to the stile on the Litton - Wardlow Mires road. It is partly joint-controlled, partly bedding-controlled passage, excavated by the Technical Speleological Group for some way during 1977. There is little evidence as to whether it is an old swallet cave, or an old rising. Whichever is the case, it is a very old remnant. It lies above the Litton Tuff, which suggests that it may have operated in a similar way to the present swallet-cum-rising, which takes water down dip into the basin in normal weather, and discharges water in wet weather. Deepening of the valley by about 120 ft has occurred since the time of its operation.

Lumb Hole

Lumb Hole (15) is a large rising in wet weather. Despite the large entrance, it is only penetrable for about 100 ft owing to extensive breakdown of the wide bedding roof. The stream flows through the bottom of the breakdown pile. In dry weather, water can be heard flowing at a lower level near the entrance, and wells up in the stream bed a short distance to the south. In drought, water may not be seen or heard here, but still flows from bedding cracks between here and the River Eyre at Cressbrook.

A large entrance lies directly opposite Lumb Hole. It has been suggested that the cave originally ran straight across, and has been incised into by downcutting of the valley. However, it is more likely that the same structural controls over underground drainage development influenced drainage on both sides of the valley, so that two risings opposite each other is a logical development. This situation is frequently found in Derbyshire, and in very few cases is it likely to be one truncated cave system.

It is likely that Lumb Hole is the western outlet of a cave system draining the area of the Longstone Edge Monocline. The cave is likely to be largely vein controlled, but there is no evidence of natural cavities of any size being intersected by mining on Longstone Edge.

Lingard's Cave

Lingard's Cave (16) lies high on the west side of the valley, a short distance to the north of Tansley Dale. It consists of a single natural chamber, often occupied by foxes. A rift was descended at the back of the chamber for some way, but became too tight. Mine workings in the floor near the entrance are soon blocked. The cave is a very old remnant, and lies a short distance below the Litton Tuff.

THE MINES

Watergrove Mine

No attempt is made to fully describe Watergrove Mine here, but some observations made during both drought and flood are of value. The Forefield Shaft (5) was descended in the 1975 drought by O.M. Mines Research and Exploration, and the 1846 section was found to be essentially correct. The shaft is normally flooded far above the workings, but towards the end of the drought a very large natural cavity was entered at a depth of 220 ft. A great deal of movement had taken place on removal of the normal hydrostatic pressure, gigantic cubes of limestone sliding along clay wayboards and bending the supporting tree trunks. Deep fresh grooves scarred the mud-coated walls, and the floor was of thick mud of unknown depth. Most people arrived back at the shaft minus boots.

Watergrove Sough lies above the roof of this cavity, and water was pumped up to it in the Fairburn Engine Shaft nearby.

It is probable that the Watergrove Pipe was only a small part of a series of interconnected cavities beneath the shales of the Wardlow Basin, and it is these cavities which form the reservoir. They may be of hydrothermal origin, having been modified by later karstic solution processes as the limestone surrounding the outlier became progressively exposed. Hydrological continuity between the cavities of Watergrove Mine and the risings at the head of Cressbrook Dale is suggested by careful monitoring of the water levels in the mine, and flow from the risings. The swallet-cum-rising lies at 785 ft AOD, and the artesian risings do not normally flow when the water level in the mine lies below this elevation.
'Castcliff Mine'

A group of four shafts close to the Watergrove - Hay Dale road was investigated by the Technical Speleological Group in 1975 (Fig. 2). The shafts were covered with timber, and with limestone slabs from the ruined coes (6).

Shaft 1. Shaft 1 was found to be only 35 ft deep, at which point the wall of the shaft had completely collapsed, totally blocking it. It was in a dangerous condition, and a cone was built over it on leaving. The size of the spoil heap suggests that it may have been much deeper.

Shaft 2. This shaft has the largest spoil heap of the four. Much work was required to make the top safe for a descent, but it was found to be collapsed, as Shaft 1, at 30 ft. The collapse had left a large cavity in the south wall, and it was in a dangerous condition. It was re-covered with a cone.

Shaft 3. Shaft 3 was descended for approximately 70 ft. A small level led off at the bottom to the west, and was followed for 80 ft to a collapse. A squeeze led to a further 60 ft passage, at which point Shaft 4 was intersected 50 ft down. When exploration was complete, one member, heavily clad, could not return through the squeeze, and exit had to be made through Shaft 4, laddered by those on surface.

Shaft 4. The shaft is 80 ft deep to a rubble slope, where the shaft sidesteps to the head of a pick-dressed shaft 15 ft deep. A turntree was in place at the head of this second pitch. The level at the bottom was large, and immediately forked. The left fork was followed for 50 ft to the head of a third pitch. The right fork was partly flooded, and has been backfilled after 30 ft.

The third pitch was descended for 25 ft, and was a partly natural bell-shaped cavity. It was very wet, water entering from a tiny natural cavity above a clay wayboard. A flat crawl at the bottom led after 20 ft to a cavity excavated in a baryte flat, at approximately the same horizon as one seen further east on the moor. A collapsed winze led upwards in the flat for about 8 ft. Beyond, the water sank in a choked and floored rift. A wet crawl led back to the bottom of the third pitch, the passage beyond being too tight for progress.

At the head of the third pitch, a blocked level was noticed on the west side. Mud and rocks were removed, but the level ended after 20 ft.

Ascending Shaft 4, it was seen to be intermittently ginged throughout, and was rather unstable in places.

A return was made to survey and photograph the mine, and the various tools and turntree were removed via Shaft 4 by Peak District Mines Historical Society.

The shafts were closed with cones.

Seedlow Mine

Seedlow Mineshaft lies on White Rake at SK 192 748 (7). It is a large ginged shaft, about 240 ft deep. It was descended by O.M. Mine Research and Exploration in 1975.

The shaft is ginged for the first 6 ft, then enters solid rock. The beds are thin bedded cherty limestones for an estimated 40 ft, then there is a prominent bedding plane/wayboard, which may mark the base of the Eyam Limestones.

The beds become more massive. The shaft suddenly bells out on a baryte flat at a similar horizon to that of Castcliff, though evidence for correlation is scanty. Below the flat, a massive stope extends into the distance. The state of the packs in the stope, supported on massive tree trunks of doubtful vintage, makes any lateral exploration impossible. The end of the stope cannot be seen. The descent of the lower shaft is through this stope, but there are patches of intact pack which separate 'levels'.

Both solid walls show slickensides, and there are large vugs lined with calcite and fluorite, with later barytes and a small amount of galena. The vein appears to have been completely removed.

At approximately 150 ft a prominent shell bed occurs. At 180 ft is a band of very dark limestone which may be tentatively correlated with the Black Bed of the Middleton Dale Section. A prominent shell bed, with the double accumulation of shells typical of the lower Shell Bed of Middleton Dale occurs at a depth estimated at 200 ft.

The shaft continues to 240 ft, where collapsed packs create a hopeless choke.

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Unnamed Mine in Tansley Dale

The only mine of any extent remaining open in Tansley Dale is entered via a small adit at valley level on the south side at SK 171 747 (10). A shaft in the roof is concealed on the surface where no trace can be seen. The level ends shortly at a shaft in the floor, reported by A. Broadbent to be 120 ft deep, and to lead into dangerous workings of little extent.

Unnamed Mine above Lumb Hole

This mine lies on the westward continuation of Watersaw Rake. It consists of a series of small stopes, with blocked workings down short shafts in the floor. A shaft at the end leads nowhere. More workings may remain to be found in this area, for the spoil heaps on the hillside are large. The entrance is an adit (14) almost directly above Lumb Hole, high on the hillside. Where the vein crosses the stream, there is a persistent rising, and the area has the appearance of a collapsed sough tail, although there is no known record of this.

THE SOUCHARS (Fig. 3)

Wardlow Sough Mine

The tail of Wardlow Sough was excavated in 1976 by the Technical Speleological Group. The old tail had completely collapsed, and water flowed from the base of the scree. A new level was driven through scree under the direction of A. Broadbent, following as nearly as possible the line of the old one. The level, although silted, was penetrable beyond this point of entry into solid limestone. A shaft was passed in the tail, and another had to be forepoled through after roughly 200 ft. A third was negotiable; the fill had jammed fortuitously a few feet above the level. A short crosscut led to the fourth shaft. Surveying revealed a large mound on the surface, but we learned that access was likely to be denied. The shaft then became '200 ft high', and climbing began. D. Williams reached the base of the Litton Tuff 80 ft above the level, with a band of rubbly limestone at the approximate horizon of the Cressbrook Dale Lava. The route sidestepped at the base of the tuff. Maypoles were used to scale the unstable shaft through the tuff, and small natural cavities were found, with fine stalactites. A short crawl led to the base of the upward continuation, which appeared to have been filled.

An exploratory level led northwards for 200 ft along the base of the tuff, and ended at a complete collapse. The floor showed sled marks. Beyond the fourth shaft, the level progressively deteriorated until a complete collapse was reached. There was evidence of some natural solution along the line of the vein in this final stretch. A considerable quantity of water falls down Shaft 4 in wet weather, but the bulk of the flow is thought to come through the complete collapse at the end. It is thought that at this point, stopes exist, which penetrate upwards into the tuff, for there is much green tuff strewn along the level downstream.

The water flowing from the tail does not all come from the sough. The digging was carried out in exceptionally dry weather, and when normal flow was resumed, a large flow was noted emerging from the base of the spoil heap. Inspection of the sough left this flow completely clear, the main flow from the tail being muddy. It was also noted that when the sough dried up, the flow from the spoil heap continued for some time afterwards. There may have been two separate drainage levels discharging at this point.

The sough is known to have continued eastwards through the tuff, beneath the village of Wardlow, and to have drained mines as far to the east as Seedlow.

Neptune Mine

Neptune Mine (12) was found by chance. Rails were found on the hillside by the use of a metal detector, and appeared to lead into a collapsed adit. Technical Speleological Group members dug avidly until a distant echoing splash, and a dark hole between the rails, betrayed the true nature of the entrance.

The 6 ft square shaft subsequently uncovered was flooded at a depth of 65 ft. The main cartgate lay above water level, and was followed back to the hillside, where an oil-drum-lined shaft was constructed through the scree to give an easier entrance. The shaft was re-covered.
The main shaft of the mine passes into dark Monsal Dale Beds, in which the rest of the mine lies. In the 1976 drought the shaft dried and was found to be blocked by collapse at a depth of 100 ft. A shaft further along the cartgate was descended by A. Broadbent, and was flooded at a depth of 90 ft below the level, roughly 80 ft below the valley floor. Water throughout the mine stands at valley floor level in normal weather, but since it never flows out along the cartgate, there may be a natural outlet.

A branch level to the south of the main cartgate led to a small natural rift down which a small stream entered. This had been dammed from the main cartgate, and sank in the floor. A small rift, just before the forefield, has been filled with deads, and is a possible dig.

Neptune Mine is still something of a mystery. The purpose of the very large shaft is obscure; it is possible that it was a pumping shaft, but no trace of pumping installations has been found.

 Arbor Seats Sough

The entrance to Arbor Seats Sough (13) lies on the westward continuation of the Neptune Mine vein. The tail of the sough has collapsed, but a fissure in the cliff above leads over the collapse into water. The level has square section rails in the floor, some of which were removed during the digging of Wardlow Sough. Progress is barred after roughly 300 ft by a collapse. More collapses can be seen beyond, and it is likely that this point lies below some large dangerous open stopes in the field above.

The flow from Arbor Seats Sough is small but quite persistent even in dry weather.

CONCLUSION

It is probable that much more open passage, both mined and natural, remains to be found. The size of the risings at the head of the valley in flood conditions suggests drainage down-dip on both sides of the valley into the central basin. The passages entered here so far have been very small, but sufficient progress may be made into the risings to reach junctions with other cavities. It has often been said that the water from the Wardlow Mires Swallet, when it is acting as such, flows to Lumb Hole. So far as I know, this has never been dye tested, and in view of the adverse dip over the entire route, it is very unlikely.

Much remains to be investigated, and several surveys are still in preparation.

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26th. Feb. 1977

Photos by John Beck

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WITH THE COMPLIMENTS
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Karstification of the Carboniferous Limestone of the northern part of the Derbyshire limestone outcrop began to a limited extent prior to deposition of the Namurian, and continued in some areas with the development of a hydrothermal karst system during the mineralisation phases of the Permo-Triassic.

Extensive cavernisation by allogenic streams and by percolating meteoric water began after the final stripping of the cover of younger rocks during the late Tertiary, and the cave systems were extended and modified throughout the Pleistocene. A complex series of erosional events, apparently related to successive glacial phases, gave rise to a series of abandoned cave levels in some areas.

The cavities produced during the Permo-Triassic were of importance in determining the nature and orientation of the later karst drainage systems. Where such pre-existing cavity systems failed to correspond with the hydraulic gradients of the Pleistocene, bedding controlled tube networks developed at preferred horizons in the limestone, often where a fossil horizon gave a relatively higher primary permeability and an underlying clay 'wayboard' arrested downward percolation.

Interbedded impermeable horizons are important in the development of perched groundwater areas. Where such horizons have been breached they often form the upper limits of large caverns, since oxidation of sulphide minerals which they contain has locally increased the aggressiveness of circulating groundwater.

The concentration of large cave systems near the margins of the present outcrop suggests that stripping of the cover during the late Tertiary occurred fast, and was completed prior to the establishment of significant hydraulic gradients within the limestone.