Karst and Caves of Great Britain

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Chapter 4

The Peak District karst

INTRODUCTION

The southern end of the Pennines contains the largest unbroken area of cavernous karst in the Carboniferous limestones in Britain (Figure 4.1). A limestone upland roughly 35 km by 15 km lies between Matlock and Chapel-en-le-Frith; it may be referred to as the White Peak, to distinguish it from the Dark Peak of the Millstone Grit moors to the north, the two combining to form the Peak District.

The limestone is of Dinantian age with most of the outcrops, karst and caves lying within rocks of the Asbian and Brigantian stages. Over 500 m of limestones are exposed across the Peak District karst, and another 1000 m of carbonates underlie these but have no outcrop. Thickly bedded, pure limestones of shelf lagoon origins dominate the heart of the Peak District, locally interrupted by dark, thinly bedded, impure carbonates of basinal facies. Massive reef limestones are important. They form a zone of marginal reefs, complete with their own debris slopes of the fore reef facies, which fringe a long-standing positive area; in Carboniferous times they bordered a shelf area of shallow water, and today they lie close to the

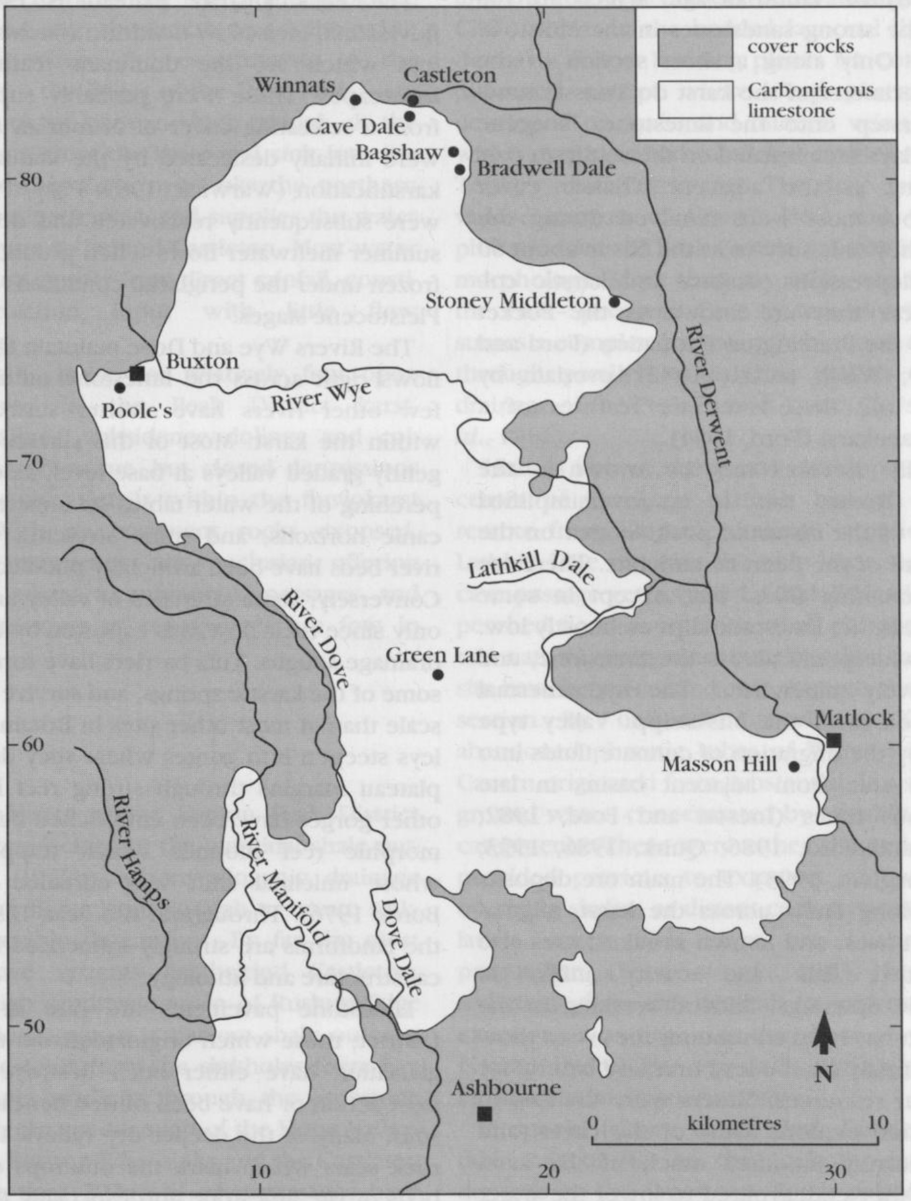

Figure 4.1 Outline map of the Peak District karst, with locations referred to in the text. The cover rocks are Namurian shales and sandstones, and younger stratigraphic units.

perimeter of the main limestone outcrop. Patch reefs occur inside this fringe, and form low reef knolls on the karst plateau. The limestone succession is interrupted by discontinuous basaltic lavas and pyroclastic horizons; many of the latter are heavily altered and weathered, and are known locally as toadstones and wayboards. Secondary dolomitization is associated with some of the mineralized areas in the southern third of the karst outcrop.

Impermeable basement rocks are known only in a few deep boreholes. The cover rocks, forming an annular outcrop around the karst, are shales mostly of Namurian age, which are followed by the strong sandstones in the Millstone Grit Series. Only along a short section of the southern perimeter of the karst do Triassic sandstones overstep onto the limestone. Neogene sands and clays accumulated on the southern part of the karst as the adjacent Triassic cover retreated, but most were removed during the Pliocene. They only survive as the fills in about 60 solutional depressions, dolines and karstic collapses, where they are known as the Pocket Deposits of the Brassington Formation (Ford and King, 1969; Walsh *et al.*, 1972); overlain by Pleistocene till, these sites are features of a Tertiary palaeokarst (Ford, 1984).

Structurally the area may be known as the Derbyshire Dome; this is an oversimplified description of the distorted positive area on the southern end of the Pennine anticline. There are numerous crossing folds, but, except in some marginal areas, the limestone dips are mostly low. Faults are widespread across the limestone, and are extensively mineralized. The hydrothermal mineralization is of the Mississippi Valley type generated by the migration of connate fluids into the domed area from adjacent basins in late Carboniferous times (Ineson and Ford, 1982; Mostaghel and Ford, 1986; Quirk, 1986, 1993; Ixer and Vaughan, 1993). The main ore deposits are in the long faults across the karst, aligned roughly east–west and known as rakes; ores also form bedded flats and cavity infills in palaeokarstic openings. Mineral working in the Peak District has been continuous for over a thousand years, firstly for the lead ores and latterly for the fluorspar resources. Miners were the first to encounter and explore many of the caves, and they significantly modified much of the karst drainage as they endeavoured to lower the water table around their mines by cutting long drainage adits, known as soughs, close to base level.

The karst

The limestone forms a dissected plateau with local relief generally less than 200 m and nowhere more than 300 m, and the entire karst was overrun by ice sheets during the Anglian stage of the Pleistocene. The extent of glacial cover of the plateau by a 'Wolstonian' ice expansion is unknown, but till was introduced into some of the valleys by ice lobes from the west (Burek, 1991). The Peak District karst was not covered by ice during the Devensian, when it was subjected to a long period of periglacial conditions.

The Peak District plateau is essentially a fluviokarst, incised by dendritic systems of dry valleys which are the dominant feature of the landscapes. These were probably superimposed from a retreating cover of Namurian shales, and were initially desiccated by the maturing of the karstification (Warwick, 1964; Pitty, 1968). They were subsequently reactivated and deepened by summer meltwater flows when groundwater was frozen under the periglacial conditions of the cold Pleistocene stages.

The Rivers Wye and Dove maintain their surface flows right across the limestone outcrop, and a few other rivers have shorter surface courses within the karst. Most of this surface flow is in gently graded valleys at base level, aided by local perching of the water tables on impermeable volcanic horizons, and some stretches where the river beds have been artificially puddled with clay. Conversely, some stretches of valley are now dry only since their flow was captured by the miners' drainage soughs. Tufa barriers have formed below some of the karstic springs, and survive on a larger scale than at most other sites in Britain. Some valleys steepen into gorges where they descend the plateau margins through strong reef limestones; other gorges have been entrenched behind stratimorphic reef mounds which trapped valleys whose uniclinal shift was curtailed (Ford and Burek 1976). Throughout the Peak District karst, the landforms are strongly influenced by geological structure and lithology.

Limestone pavements are rare in the Peak District; those which originated from the Anglian glaciation have either been destroyed by later frost action or have been buried beneath younger soils. Many of the deeper dry valleys are lined by rock scars which mark the outcrops of stronger beds of the limestone and especially the massive reef units. Rocky tors have formed by Pleistocene frost action in some of the dolomite outcrops

(Ford, 1963). Most of the karst lies under a veneer of soil, derived from frost action and loess accumulation, both largely in the Devensian periglacial environments (Pigott, 1962, 1965). On the steeper valley sides this is widely soliflucted, and soil creep has initiated the formation of extensive areas of terracettes. Only isolated patches of glacial till have survived the erosion since the Anglian ice cover retreated.

Most of the limestone outcrop stands topographically higher than the surrounding outcrops of the stratigraphically younger shales, which are more easily eroded. Surface drainage is therefore predominantly towards the shale, and allogenic waters draining onto the limestone are limited in extent. Only where the escarpments of the Millstone Grit – the Edges of the Dark Peak – are close enough to the karst and high enough, do the surface streams cross the shale and sink into the limestone. Rushup Edge overlooks the northern tip of the karst perimeter, and supplies the water to the cave systems behind Castleton. Most water enters the karst aquifer from direct rainfall, constituting percolation input with little flow concentration.

Consequently, there are relatively few open sinkhole caves in the Peak District karst. Solutional dolines, subsidence dolines and collapse features do occur, but closed depressions are generally only details within the fluviokarst landscape. With no basement rocks exposed, many of the resurgences are vauclusian, offering only difficult access to submerged passages, and open cave passages at resurgences are few in number.

The caves

The great majority of the known Peak District caves are located close to the marginal shale outcrops (Ford, 1977b), where allogenic drainage creates stream flows large enough to create sinkholes of enterable dimensions. By far the most extensive cave systems lie behind Castleton, where the high sandstone scarp of Rushup Edge supplies drainage across a narrow shale outcrop onto the limestone; from the sinkholes there is a steep hydraulic gradient through the limestone into the deep glaciated trough of the Hope Valley. Between the Rushup Edge sinks and the Castleton risings, more than 20 km of cave passages have been mapped. They constitute an excellent karst drainage system, which exhibits a close control by the geology and reveals a long evolution through successive rejuvenation stages during the Pleistocene (Ford, 1986a). Dated stalagmites and sediments in successive cave levels yield a chronological framework which can be correlated with surface erosion from Anglian times to the present (Ford *et al.*, 1983).

The Castleton caves have developed in all the major environments found in the Peak District karst. They traverse rocks of both the reef and lagoonal facies of the Carboniferous Limestone. In the reef masses, the caves are mostly irregular complexes of chambers, with some extending into the fore-reef boulder beds, notably at Treak Cliff Cavern. In the bedded lagoonal limestones, the caves follow bedding planes for considerable distances, except where deep phreatic loops developed on faults and mineral veins, some of which may have had solutional cavities relict from Tertiary or earlier events. The deep meandering vadose canyon of Giant's Hole and the relict phreatic tubes of Peak Cavern are classics of cave morphology. More than any other site in Britain, the Peak–Speedwell Cave System clearly demonstrates a complex hydrology with flood diversions through parallel routes; this typifies the deep drainage of the Peak District karst (Christopher *et al.*, 1981).

Little is known about cave development in the centre of the karst plateau, beneath outcrops remote from allogenic drainage supplies. Upper Lathkill Dale contains the only large segments of cave passage yet revealed. Lathkill Head Cave is a perched flood route with small passages feeding to a natural resurgence, but the other caves in the site have been revealed only through chance intersection by old mine workings. The large abandoned phreatic tubes of Water Icicle Close Cavern originated from substantial flows of underground water, concentrated by sizeable upstream catchments. These were either allogenic supplies provided previous to extensive removal of the overlying shales, or distant coalescences of percolation water. The caves are known to be pre-Anglian (Ford *et al.*, 1983) but further sediment data are needed to determine their exact origin and the role they have played in the plateau hydrology, especially during periods of Pleistocene meltwater activity.

A special feature of the Peak District caves is their relationship to the hydrothermal mineral deposits in the limestone. Some palaeokarst features predate the late Carboniferous mineralization, which has subsequently influenced the Tertiary and Pleistocene development of the modern caves and karst; large solutional rifts lie along the mineral veins (the rakes) in many cave systems. In the Matlock area, caves intersect and follow some of the mineral orebodies, where mining has re-exposed some of the palaeokarst features (Ford, 1984). Combined with sediment sequences which include fluvioglacial material more than 730 000 years old (Noel, 1987), the Masson Hill caves offer fragmentary evidence covering an exceptionally long timespan of karstic evolution. A second equally long record of Pleistocene events is provided by the fossil caves and sediment fills exposed by the quarry in Eldon Hill (Farrant, 1995).

CASTLETON CAVES

Highlights

The Castleton area contains the most extensive and complex karst drainage system in the Peak District of Derbyshire. It exemplifies a style of drainage unique to this area; draining from both stream sinks and percolation sources, via deep phreatic conduits guided by mineral veins, to linked vauclusian risings. Within the confines of this site are contained a record of nearly one million years of landscape development.

Introduction

The limestone plateau around Eldon Hill is drained by the most extensive cave systems in the Peak District; the resurgences are in the Peak Cavern gorge behind Castleton. The Carboniferous limestone, of Asbian and Brigantian age, forms a reef complex along the northern boundary of the site, with lagoonal carbonates and thin interbedded basalt lava flows to the south. Large east–west mineral veins, or rakes, traverse the limestone and have, in the past, been worked for lead and zinc ores. Both the reef and lagoonal facies are penetrated by the caves, and the mineral veins are also utilized by the underground drainage. Streams flowing from the impermeable shale slopes of Rushup Edge feed a line of sinkholes along the north-western edge of the limestone outcrop. This allogenic water, joined by autogenic input, passes beneath the topographic divide and resurges from vauclusian risings in the Peak–Speedwell cave system in the floor of Hope Valley.

An extensive literature has been published on the caves and hydrology of this area (T.D. Ford, 1966b, 1969, 1977b, 1986a, b; Christopher, 1980, 1984; Christopher *et al.*, 1981; Christopher and Wilcock, 1991; Ford and Gunn, 1992), with other work by Pitty (1971) and Johnson (1967). A thematic issue on the Peak–Speedwell Cave System was published as Volume 18, Number 1 of *Cave Science* (Ford, 1991). Descriptions of all of the caves are given by Gill and Beck (1991), with more detailed accounts of specific parts of the system in Cordingley (1986, 1988, 1989), Ford (1956), Proudlove (1985), Salmon (1956, 1959), Salmon and Boldock (1951a, b), Shaw, R. P. (1983), Smith and Waltham (1973), Westlake (1967) and Wright (1987). Recent major discoveries have been described by Nixon (1991, 1992) and Beck (1991). Data on speleothems and sediments have been published by Ford *et al.* (1983), Thistlewood and Noel (1991) and Murphy (1993), and the underground hydrology is summarized by Gunn (1991) and Bottrell and Gunn (1991).

Description

The caves of the Castleton area represent parts of a single, though complex, hydrological unit (Figure 4.2). The accessible sections of cave passage fall into three distinct groups, which are linked by inaccessible passages, flooded or choked with sediment.

Sinkhole caves below Rushup Edge

Twelve sinks lie along the limestone–shale boundary to the east of Perryfoot. Short sections of accessible cave passage are associated with some of these but only at two can access be gained to more extensive systems. The westerly of these is P8 (Jackpot), with more than 1500 m of passage, while to the east the Giant's–Oxlow system has more than 4700 m of known passage.

The P8 cave (Figure 4.2) is developed mainly in rocks of the Asbian lagoonal facies. It consists of a complex of tall vadose canyons cut into the floor of large, high-level, phreatic passages which are partly fault-controlled (Smith and Waltham, 1973). These lead to a perched phreatic zone where flooded passages are separated by short sections of drained, old phreatic tubes abandoned by the present main stream. Several sumps have been explored in this part of the cave but the main stream is lost beyond sump 6. The explored pas-

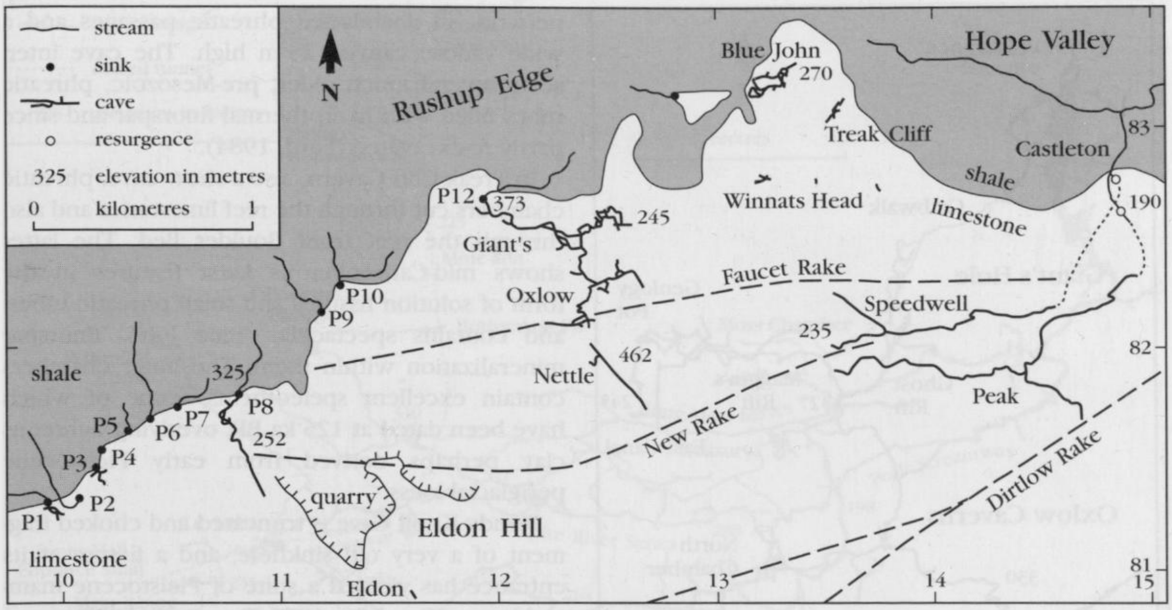

Figure 4.2 Outline map of the Castleton caves, with only the main streamways shown in the Peak and Speedwell caves at the resurgence end of the system. The rakes are mineral veins which carry some of the karst drainage though their fissure systems.

sage has been followed upstream and into a high-level flood route, where sumps 7, 8 and 9 have been passed by divers to enter a short dry passage with two shafts descending to sump 10. This is unexplored; it lies at a level about 18 m above Speedwell Main Rising. At least three separate streams now occupy the passages of P8. The entrance stream sinks into gravel in the upper part of the cave under normal conditions and is not seen again in the known cave. A second stream rises from a sump in the lower part of the cave and flows into the main sumps at the end of the lower streamway. This water is derived from sinks 2–7 (Figure 4.2) and is entirely independent of the entrance stream (Gunn, 1991). A third independent stream is met in the passage between sumps 5 and 6.

The Giant's Hole–Oxlow Caverns system (Figure 4.3) is the deepest in Derbyshire, at 214 m, and the second deepest in Britain (Westlake, 1967). The main stream in Giant's Hole flows eastwards through the reef limestones and into rocks of the bedded lagoonal facies. Here it has cut a meandering vadose canyon, the Crabwalk, more than 1 km long and up to 20 m high, though rarely more than 0.5 m wide; development of the meanders has been influenced by many small mineral veins. Beyond the Crabwalk a complex of phreatic rifts and incised canyons, formed along faults and veins, are now partly flooded and extend below present water level. Abandoned passages in the entrance series contain thick sediment sequences. Other passages, developed along bedding planes in the nearly horizontal lagoonal limestones, extend southwards from the roof of the Crabwalk and from the downstream complex to link with Oxlow Caverns, accessible via a mined shaft from the surface. Oxlow Caverns are a stacked series of phreatically enlarged vein cavities, linked by low or narrow passages. They extend over a vertical range of 150 m on Faucet Rake, and cut through the bedding plane on which lies the abandoned phreatic outlet from Giant's Hole.

Less than 100 m separates the southern end of Oxlow Caverns from the northern end of Nettle Pot (Figure 4.3), a 180 m deep, old phreatic fissure system developed largely along a post-mineralization fault. The deepest point is in parallel rifts in the Red River Series. An extensive series of low, wide chambers is formed by phreatic solution adjacent to thin toadstone lavas, at two levels about 50 m and 60 m from the surface; these extend along the fault, to Gour Passage, reaching towards New Rake, the probable route for water from P8 to the Speedwell stream cave.

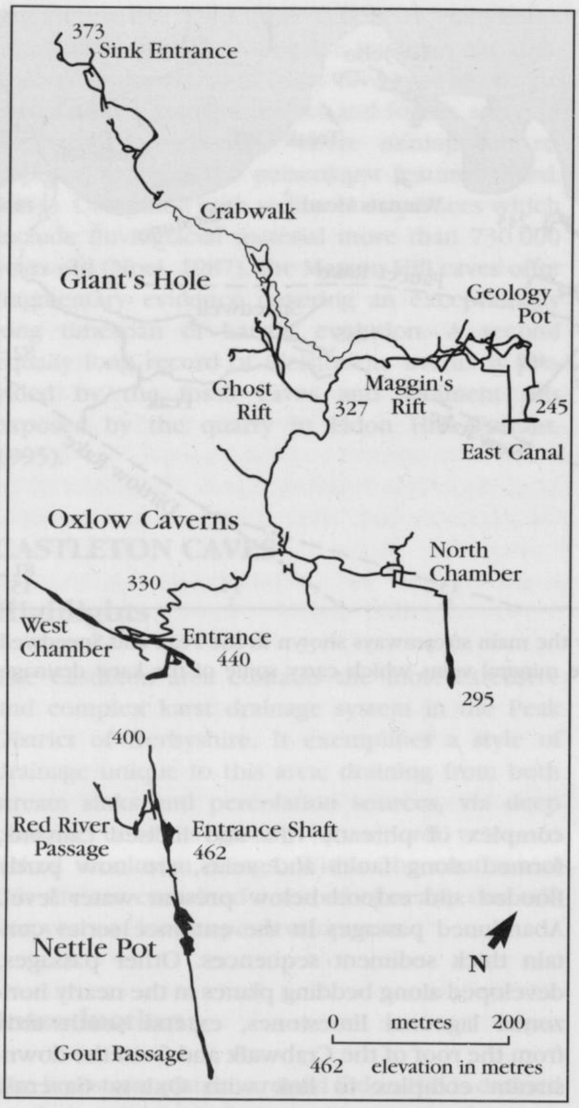

Figure 4.3 Outline map of the cave passages in Giant's Hole, Oxlow Caverns and Nettle Pot (from surveys by Eldon Pothole Club).

Relict caves of Treak Cliff and Eldon Hill

Several almost completely abandoned caves lie in the northern tip of the reef limestone where it forms Treak Cliff, a steep bank at the head of the Hope Valley (Figure 4.2).

Winnats Head Cave, contains high level, phreatic chambers up to 50 m long and 20 m high and wide, from where stalagmite has been dated to 176–191 ka BP (Ford *et al.*, 1983). Small passages and rifts connect with a series of collapse chambers and vadose shafts containing a small stream. These have been descended to a silt choked sump, at a depth of 136 m.

Blue John Cavern, now a show cave, contains a network of abandoned phreatic passages and a wide vadose canyon 25 m high. The cave intersects several much older, pre-Mesozoic, phreatic tubes filled with hydrothermal fluorspar and since partly re-excavated (Ford, 1984).

In Treak Cliff Cavern, also a show cave, phreatic chambers cut through the reef limestones and also through the reef front Boulder Bed. The latter shows mid-Carboniferous karst features in the form of solution fissures and small phreatic tubes, and contains spectacular 'Blue John' fluorspar mineralization within them. The inner chambers contain excellent speleothems, some of which have been dated at 125 ka BP, overlying ochreous clay perhaps derived from early Pleistocene periglacial loess.

Windy Knoll Cave is truncated and choked fragment of a very old sinkhole, and a fissure at its entrance has yielded a suite of Pleistocene mammal bones (Dawkins, 1875; Bramwell, 1977).

A series of sediment-choked swallet caves have been exposed in the faces of Eldon Hill Quarry (Figure 4.2). They contain a variety of facies which can be broadly grouped into four types: (1) very coarse, poorly sorted gravels dominated by clasts of arkosic sandstone derived from the Millstone Grit; (2) finer gravels dominated by well-sorted, well-rounded, decalcified chert pebbles; (3) quartzose sand; and (4) laminated cap muds. The quarry face has also broken into a decorated phreatic tube, roughly parallel to New Rake.

Further to the south, Eldon Hole is an open shaft 30 m long, 5 m wide and 60 m deep enlarged by wall-collapse of a solution chamber bounded by two subparallel joints. A large parallel chamber, decorated with speleothems in the roof, can be entered via a short passage. A downward continuation with a stream at the base, reported by Lloyd and King (1780), is now blocked by debris.

The Peak–Speedwell Cave System

More than 15 km of passages have been mapped in the connected caves of Peak Cavern and Speedwell Cavern (Figure 4.4). All the collected underground drainage of the area flows through the two main streamways towards the resurgences of Russett Well and Peak Cavern gorge. Most of the water from the Rushup Edge sinks reappears at the Main Rising in Speedwell Cavern, while the stream in Peak Cavern is derived largely from percolation water and from flood overflows from Speedwell.

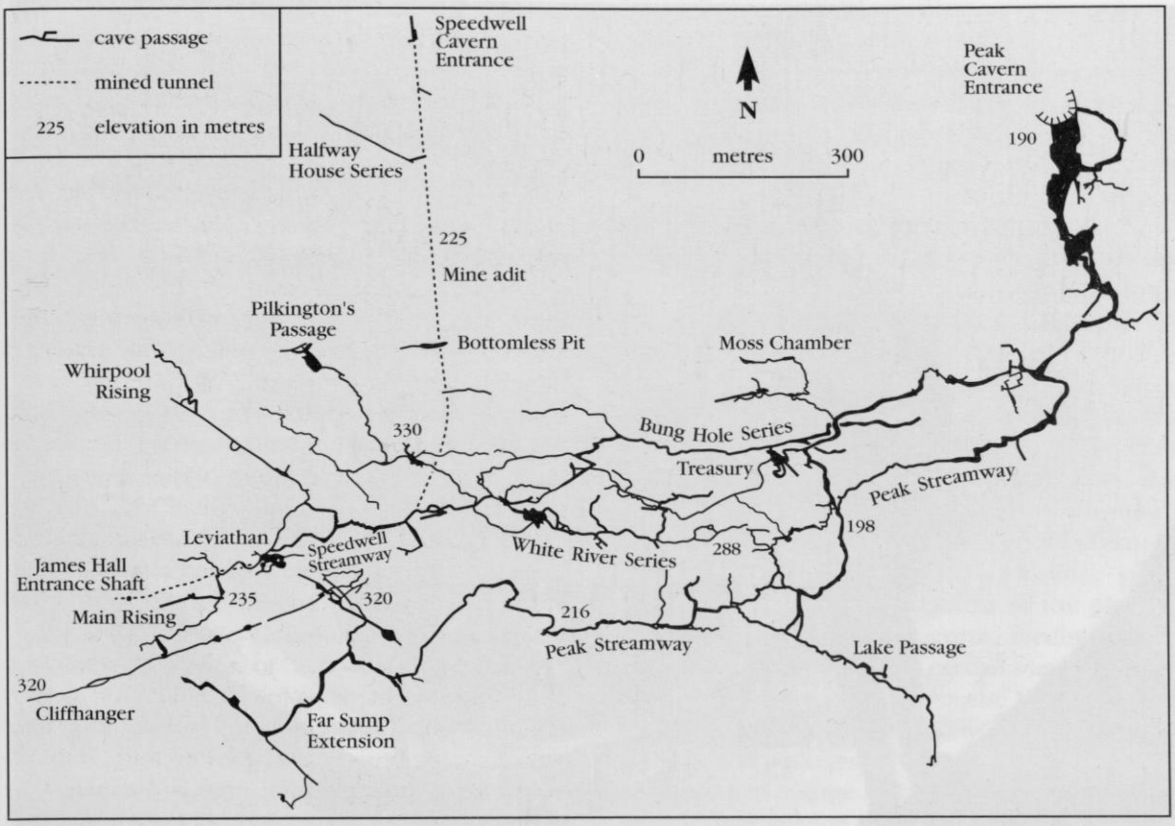

Figure 4.4 Outline map of the Peak–Speedwell Cave System (from surveys by Technical Speleological Group and Cave Diving Group).

Peak Cavern, now in part a show cave, has the largest natural entrance of any cave in Britain, more than 30 m wide and 10 m high. In the passage beyond, several avens have formed by upward solution along joints (Pitty, 1971). The Main Stream Passage, developed entirely in a single bedding plane without significant influence from joints, is a magnificent phreatic tube up to 7 m in diameter (Figure 4.5); it has several sections of vadose canyon, each entrenched where the gradient of bedding and tube is locally steeper. Within the same bedding plane, a series of smaller clay-filled tubes and joints are slowly being re-excavated. From one of these tubes, a series of avens rises 70 m into the White River Series, with more than a kilometre of old phreatic passages (Nixon 1991, 1992). These passages cut through the mineral vein of New Rake, and contain the most extensive and beautiful development of speleothems in the Peak District. At several points the old phreatic passages are breached by vadose shafts which descend 70 m to chokes on the main bedding plane. Lake Passage is a major inlet fed mainly by percolation water derived from the limestone outcrop around Dirtlow Rake (Figure 4.2). At the western end of Main Passage, the Far Sump Extension has several rifts rising more than 130 m above stream level (Cordingley, 1988). Much of the system lies beneath the Lower Lava, an aquiclude which has kept most percolation water and calcite deposition away from the lower levels.

Speedwell Cavern connects to Peak Cavern via several flooded or abandoned routes, but is more readily accessible through a mined shaft and an underground canal, which are now developed as a show cave. The tourist section ends at the Bottomless Pit, a solution cavern developed on Faucet Rake, but the canal tunnel continues south to intercept the main streamway. Most of the water from the sinks to the west usually reappears at the Main Rising, but at times the principal flow may come from Whirlpool Rising; only in flood conditions does it rise from both (Christopher, 1984; Bottrell and Gunn, 1991). Main Rising is the top of a 35 m deep phreatic loop developed along solution vein cavities in New Rake; upstream of the phreatic loop, there are two vertical phreatic

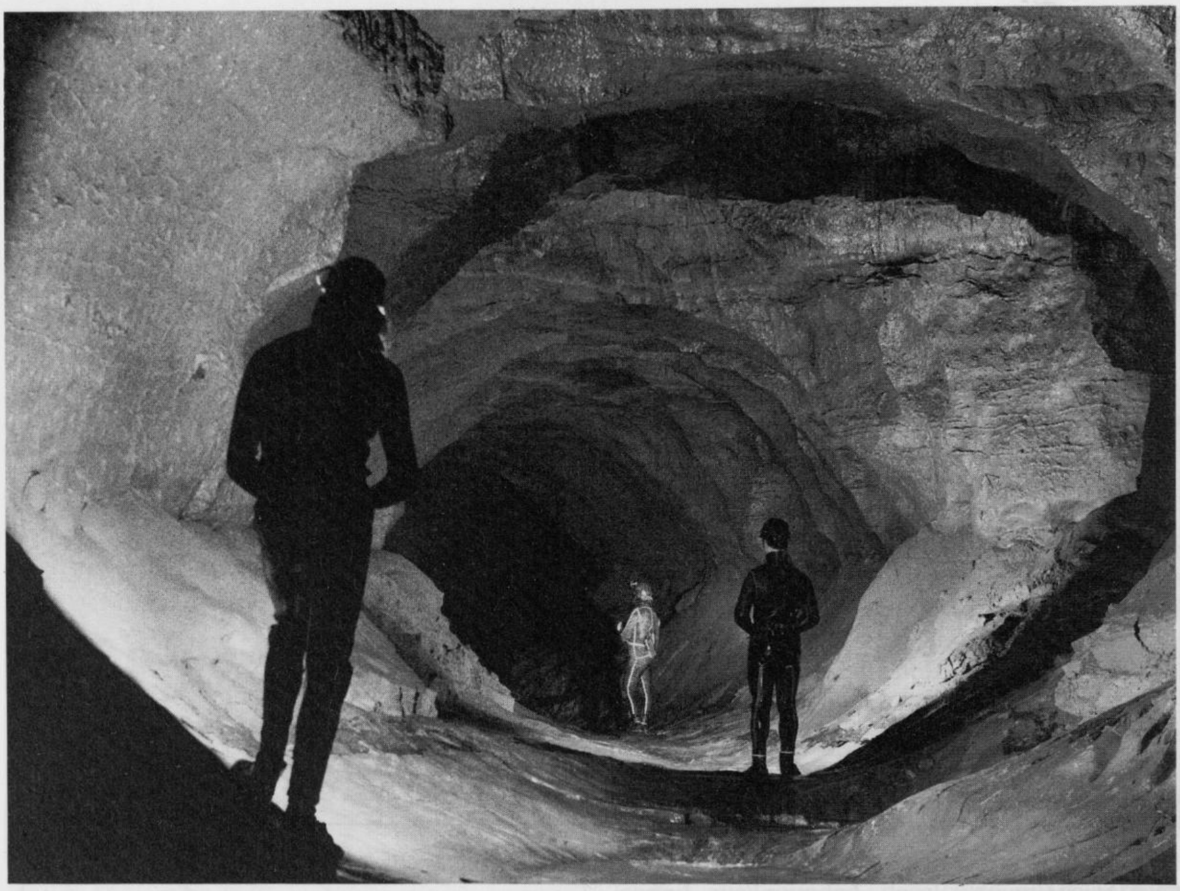

Figure 4.5 The phreatic tube which forms the main part of the stream cave in Peak Cavern. The inception bedding plane is marked by the wall niches, and this section has no vadose trench yet cut in its floor. (Photo: J.R. Wooldridge.)

lifts, and the flow emerges from a flooded rift 70 m below water level. The outlet water flows eastwards and is joined by water from Whirlpool Rising and two other inlets, before entering the long, immature passage to the Downstream Sump. It finally resurges at Russett Well, having passed beneath the Peak Cavern gorge and stream. Several older passages also enter the main upstream passage; some are partly filled with clay while others, originally entered by miners, were once steeply descending vadose inlets (Shaw, 1983). Under flood conditions some of the water from Speedwell Cavern overflows into Peak Cavern through Overspill Passage and Treasury Sump. The main passages of Speedwell are developed on a single bedding plane about 14 m below that which contains most of the Peak Cavern passages. At the western end of the system, Cliffhanger is a high-level phreatic tube, and the Leviathan is a massive and complex vein cavity above the streamway level, with a mined access to its top from James Hall's Over Engine Shaft.

Interpretation

The caves of the Castleton area constitute a complex integrated karst drainage system; this has been traced from multiple sinks to two adjacent resurgences with parallel feeders at different stratigraphic horizons. The underground drainage penetrates both reef and lagoonal limestones and has utilized mineral veins throughout its evolution. Dye-testing has established that water travelling between the various sinks and the two resurgences follows convergent, divergent, crossing and flood-related drainage routes (Christopher, 1980, 1984; Christopher *et al.*, 1981) and passes beneath the surface interfluve. There is a very long history of karstic development in the area, commencing in the mid-Carboniferous with the solution fissures carved in Treak Cliff beneath the Boulder Bed (Ford, 1984). Deep phreatic caves, probably also of considerable antiquity, developed along mineral veins; they subsequently guided the through drainage from new sinkholes. The caves have been influenced by the distribution of reef and lagoonal facies within the limestone, notably by the extensive development on the bedding planes of the lagoonal facies. The presently accessible swallet and resurgence caves show a history of development, at least as far back as the Hoxnian (Ford *et al.*, 1983). This history must be related to the episodic water table lowering and rejuvenations in response to the incision of Hope Valley through the Pleistocene.

The evolution of the Castleton cave systems is long and complex; it has been discussed in detail by Ford (1986b), and the evolution of individual cave systems has also been reviewed by Smith and Waltham (1973) and by Westlake (1967). The limestone of the Castleton area was first exposed during the mid-Carboniferous, when solution fissures in the bedrock and the Treak Cliff Boulder Bed were formed. Faulting and mineralization in the late Carboniferous and Permian produced a series of east–west mineral veins across the area. A deep, slow phreatic circulation along mineral vein cavities may have been initiated shortly after this, enhanced by the stripping of the late Palaeozoic and Mesozoic cover during Plio-Pleistocene times. With increased runoff, associated with changes of climate in the Pleistocene, a shallower system of swallet and resurgence caves developed along prominent bedding planes, though still draining via the deep mineral vein conduits. Their subsequent evolution was influenced by the incision of the major surface drainage of the area, which controlled local base levels within the limestone. Treak Cliff Cavern, Blue John Cavern and Winnats Head Cave represent former swallet caves draining off a more extensive Millstone Grit cover. The large size of the vadose canyon in Blue John Cavern indicates that it was a major sink at this time. Uranium-series dates from these sites indicate ages in excess of 190 000 BP (Ford *et al.*, 1983).

The modern swallet caves lie along the shale–limestone boundary below Rushup Edge. Their stalagmites give generally younger uranium-series dates, though the complex morphology and abandoned passages, in both Giant's Hole and P8 Cavern, indicate that they are of considerable age and have undergone extensive modification since their initial formation.

The sand infills preserved in the filled caves of the Eldon Hill quarry indicate episodes of aeolian reworking of glaciogenic sediment (Farrant, 1995). By analogy with the currently active swallet caves, the coarse and fine gravel facies may reflect sites of deposition which lie respectively proximally and distally to these ancient swallets. Uranium-series and palaeomagnetic dating of these sediments and the intercalated speleothems indicates a history of development extending back at least 780 000 years; the earliest sediments may date back to more than 910 000 BP, as an episode of normal magnetic polarity precedes the last period of reversed polarity. The caves evidently predate the valley below Rushup Edge, and are probably of early Pleistocene age.

The unusual size of the entrance chambers in Peak Cavern is due to solution and collapse in a lenticular development of back-reef shoal limestones, influenced by major joints. This was further aided by vadose entrenchment through a phreatic lift, which originally fed a vauclusian rising at the site of the modern entrance gorge (Ford, 1986b). The development of the phreatic drainage system in Peak Cavern, feeding to this vauclusian rising, probably predates an episode of incision of surface drainage in the Hoxnian, or in the Anglian glacial, which led to vadose entrenchment of the passages. The main passages in Peak Cavern are too large to have been formed solely by the percolation water which now drains through them; at some time in the past, the main drainage from the Rushup Edge sinkholes flowed through Peak Cavern, before underground capture took the water to the Speedwell Cavern route. A further similar capture appears to be developing now, as seen in the switching of flows between Main Rising and Whirlpool Rising, within Speedwell Cavern (Bottrell and Gunn, 1991). Further incision, probably in the Ipswichian, was responsible for the final draining of many of the phreatic tubes in the Peak–Speedwell system. Subsequent modification has been restricted to the infilling of some passages, by clay derived perhaps from periglacial loess, and by minor phreatic solutional enlargement of some parts of the system as a result of water dammed up by debris.

Conclusion

The Castleton limestone houses a large and important integrated cave system which shows evidence for a history of development longer than at most British karst sites. Caves have formed in different limestone facies and are closely linked with mineralized faults. The scarcity of calcite speleothems in the parts of the Peak–Speedwell cave system underneath an interbedded lava demonstrates the influence on autogenic drainage of minor aquicludes within the limestone aquifer. Speleothems and sediments within the caves have already provided evidence for a history extending back nearly a million years. The great depth range of passages within the system further increases the value of the evolutionary record of the cave and its surrounding landscape through the Pleistocene.

WINNATS PASS

Highlights

The Winnats Pass, often known just as Winnats, is the most spectacular, deeply incised karst gorge in the Peak District and has a complex origin which dates back to the Carboniferous. It is Derbyshire's best example of a fluvially excavated gorge and one of its most famous karst sites. It provides a superb transect through the Lower Carboniferous marginal reef belt.

Introduction

Incised into the northern margin of the limestone plateau 1 km west of Castleton, the Winnats Pass is regarded as one of the finest karst gorges in Derbyshire. It displays evidence of fluvial incision during periglacial events, while additional interest is provided by its complex origins which involves Pleistocene modification to a Carboniferous submarine ravine. The gorge displays a relatively clean section through the Lower Carboniferous (Dinantian) reef belt.

The origin of the gorge has been discussed by several authors, often with little supporting evidence (Sadler, 1964; Warwick, 1964; Broadhurst, 1972; Millward and Robinson, 1975; Ford, 1977a, 1986a), but no comprehensive geomorphological or chronological study of the Winnats Pass had been published until Ford presented a detailed account (1987). The geology is discussed in Broadhurst and Simpson (1973). Several caves exposed in the gorge walls and on the plateau nearby provide additional information on the evolution of the gorge (Beck, 1980; Shaw, 1983). Their relationship to the Winnats is discussed in Ford (1986a).

Description

The Winnats is a narrow steeply graded gorge cut into the steep slope on the edge of the limestone massif at the head of the Hope Valley (Figure 4.6). It drains a relatively small area of the limestone plateau at an elevation of about 400 m near Winnats Head Farm, and debouches onto the floor of the Hope Valley at 250 m altitude about 1 km west of Castleton (Figure 4.7). Less than a kilometre long, the gorge is bounded by cliffs up to

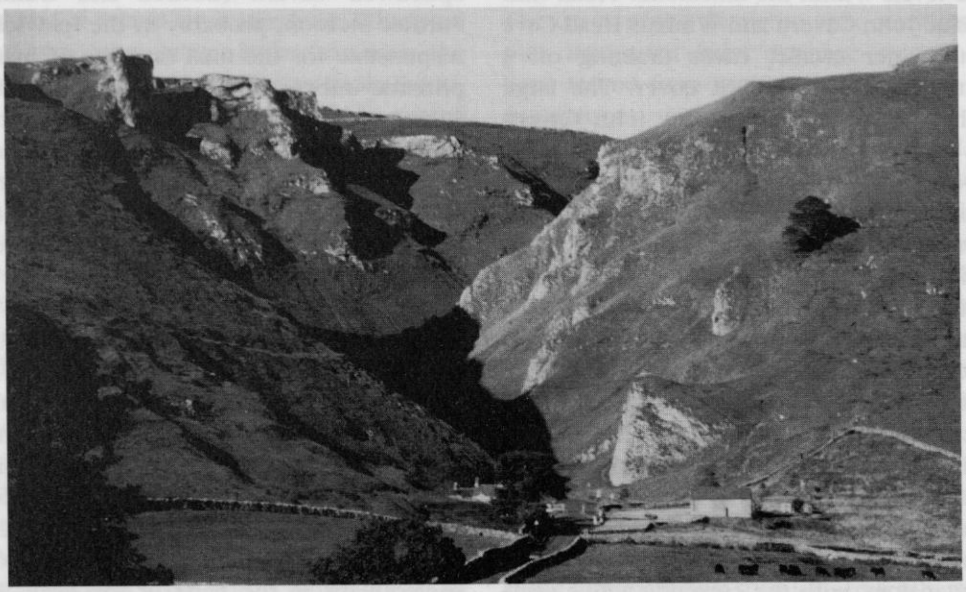

Figure 4.6 The limestone gorge of Winnats Pass, seen from the Hope Valley. (Photo: T.D. Ford.)

100 m high. Its floor is dry, as all the drainage sinks underground, and scree slopes mantle most lower parts of the sides.

Due to its position on the edge of the limestone plateau, the gorge is entrenched into, and reveals a profile through, the Carboniferous reef belt. Behind the reef to the south are the horizontally bedded lagoonal mudstones, while the reef itself is made up of thick algal bioherms. The fore-reef is dominated by two separate facies. The Beach Beds are submarine debris slopes of material transported across the reef by tidal and wave scour. The Boulder Beds are fossil talus slopes derived from pre-Namurian uplift and erosion of the reef, and postdate the beach beds (Simpson and Broadhurst, 1969). The head of the gorge is incised into the back-reef lagoonal limestones, the Bee Low Limestones, while the bulk of the gorge exposes the main algal apron reef, and the boulder and beach beds of the fore-reef.

Several caves occur in the sides of the gorge. Winnats Head Cave contains some old, high-level phreatic chambers, while Suicide Cave consists of largely abandoned passages near the foot of the gorge; an abandoned inlet system to Speedwell Cavern, the Pilkington's Cavern series, lies about 200 m south of the Winnats.

Interpretation

The origin of the Winnats Pass has proved to be controversial and enigmatic. Various ideas have been put forward to explain its origin, most of which were summarized by Ford (1986, 1987). The main theories have involved:

1. Exhumation of an inter-reef channel of mid-Dinantian age, contemporaneous with the deposition of the reef belt.
2. Recent exhumation of an erosional channel cut through the reef belt during a period of uplift in very late Dinantian or early Namurian times, and subsequently infilled with Namurian shales.
3. A collapsed cavern.
4. Superimposition of a drainage network, initiated on the Namurian shale cover, and subsequently incised into the limestone.
5. Fluvial excavation, during stages of periglacial climate within the Pleistocene, followed by underground capture of the drainage to leave the gorge dry.

The first hypothesis (suggested by Broadhurst, 1972), that the gorge was a resurrected Lower Carboniferous sea-floor channel, was discounted by Ford (1987) as he and others (e.g. Parkinson, 1953) noted that the three major lithofacies, the lagoonal, reef and fore-reef facies, strike across the pass in such a way as to preclude the possibility of a significant inter-reef channel having been present. This evidence also precluded Sadler's idea (1964) that the pass was a submarine channel in Asbian times. The Beach Beds survive up to an elevation of at least 300 m, so any channel could not have extended any deeper than that, if it was to be the source of a submarine fan; however, a very shallow channel may have existed. The presence of outcrops of the Boulder Beds in the upper part of the gorge (Figure 4.7) led Ford to suggest (1987) that the site of the Winnats was a moderately shallow channel, eroded during a period of pre-Namurian uplift and subsequently infilled with Namurian shales. The concept of the Winnats gorge originating as a collapsed cavern has been refuted by many authors. Warwick (1964) preferred the superimposed drainage hypothesis, although there is no direct evidence for it at this site.

Both Ford (1987) and Millward and Robinson (1975) advocated the Pleistocene periglacial hypothesis after comparison with other dry valleys in the area; the latter described the pass as 'cut by swift torrents of water passing down during certain pluvial phases at the end of the Ice Age'. The major problem with this hypothesis was the tiny catchment area feeding into the gorge. Ford (1987) suggested that this problem could be overcome if a large mass of stagnant ice filled Rushup Vale and fed meltwater into the valley, thus vastly increasing its catchment. The meltwater runoff during periglacial periods would have accelerated erosion of any shales which may once have filled a pre-Namurian valley. The timing of this must have occurred after the Hope Valley had cut down to the level of the Hope Terrace, as the floor of the Winnats is graded to this level, and the Namurian shale cover has been stripped back. This is interpreted as having taken place during the retreat stages of the Wolstonian glaciation, with perhaps some later modification during the Devensian. The steep initial gradient down the reef front, possibly aided by an easily excavated shale infill, contributed to the deep incision and spectacular morphology of the gorge.

Speleothem dating of several of the Castleton caves (Ford *et al.*, 1983; Ford, 1986a, 1987) has

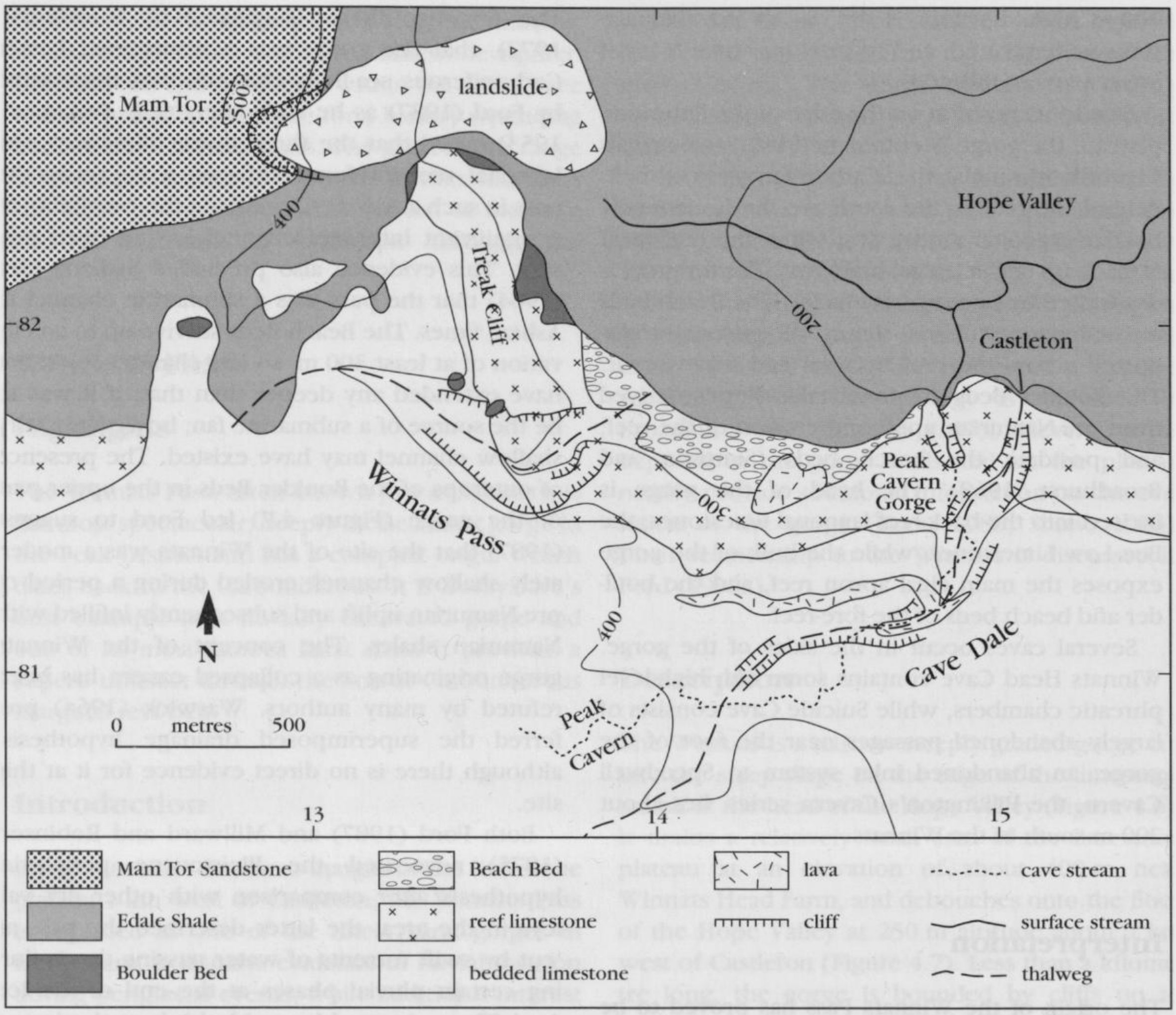

Figure 4.7 Geological map of the Castleton reef belt containing Winnats Pass and Cave Dale.

shed some light on the timing of incision in the gorge. The re-discovery of Pilkington's Cavern (Pilkington, 1789; Shaw, 1983) in Speedwell Cavern, the top of which is only some 200 m south of Winnats Pass, provided key evidence for the timing of incision. To function as an active swallet, Ford argued that the cave must have had a significant catchment area, which almost certainly extended into the area now occupied by the pass. The underground morphology demonstrates that the cave system was active before the Winnats had been cleared of shale and re-established as a gorge, and provides evidence that the shale cover had only been partially stripped back. Pilkington's Cavern therefore pre-dates the gorge incision, and has tentatively been assigned to the Cromerian interglacial (Ford, 1987). However, recent work on some infilled caves at Eldon Hill quarry (Farrant, 1995) suggests the shale cover had been stripped back earlier than previously thought and that significant cave development had begun in the area over 780 ka ago.

Ford concluded that the Winnats originated in series of stages, beginning in the Dinantian as an inter-reef hollow. It was then uplifted and excavated subaerially, to form a moderately deep channel during pre-Namurian or early Namurian times, before it was resubmerged and infilled with shales. It was exhumed and reactivated in the mid-Pleistocene when meltwater scoured out the shale fill to deepen the valley, and was further trimmed and modified during the Devensian.

Conclusions

Winnats Pass is the finest meltwater gorge in the Peak District. Its evolutionary history is both long and controversial, with early stages dating back as far as the Carboniferous. Speleothem dating and morphological studies of nearby caves suggests the gorge was mainly excavated by meltwater draining from a stagnant ice mass in the Rushup Vale during a retreat phase of the Wolstonian glaciation. The gorge appears to be located on the line of a Carboniferous ravine which was the product of both submarine and subaerial erosion.

CAVE DALE

Highlights

The deep karst valley of Cave Dale is significant in that it is a deep limestone gorge immediately underlain by a major cave system with which it has no evident genetic link. It was carved by fluvial erosion under periglacial conditions, and its lower end narrows into a rocky gorge. Another, totally separate, gorge has been formed by cavern collapse at the outlet of the underlying cave passage. The juxtaposition of these two gorges, unconnected and of contrasting origins, is unmatched elsewhere in Britain's karst.

Introduction

Cave Dale is a fine example of a dry karst valley, narrowing to a rocky gorge in its lower reaches (Figure 4.8). Immediately adjacent to the valley and underlying it is Peak Cavern, at the resurgence entrance of which is the Peak Cavern gorge. Both gorges are incised into the northern flank of the limestone plateau immediately south of Castleton and provide sections through the Lower Carboniferous reef belt.

The entrance gorge and cave system of Peak Cavern have been described in numerous publications (reviewed by Nash, 1991), but only Ford (1986a, b) has fully described the genesis of the gorge. The formation of Cave Dale has received scant attention, but its origins were debated in a wider argument over the formation of dry valleys in Derbyshire by a number of authors (Warwick, 1964; Knighton, 1975; Ford, 1986a, 1987). Dating of the underlying Peak Cavern was undertaken as part of a larger study of the Castleton caves (Ford *et al.*, 1983).

Description

The Cave Dale valley begins on the limestone plateau near Rowter Farm at an elevation of 440 m and feeds down the steep outer slope of the exhumed limestone reef front before debouching into the Hope Valley at Castleton, 240 m lower (Figure 4.7). In its upper reaches it is a shallow, wide, open grassy valley with one small tributary, incised about 10 m into the plateau. Its floor and sides are pitted with old mining depressions and

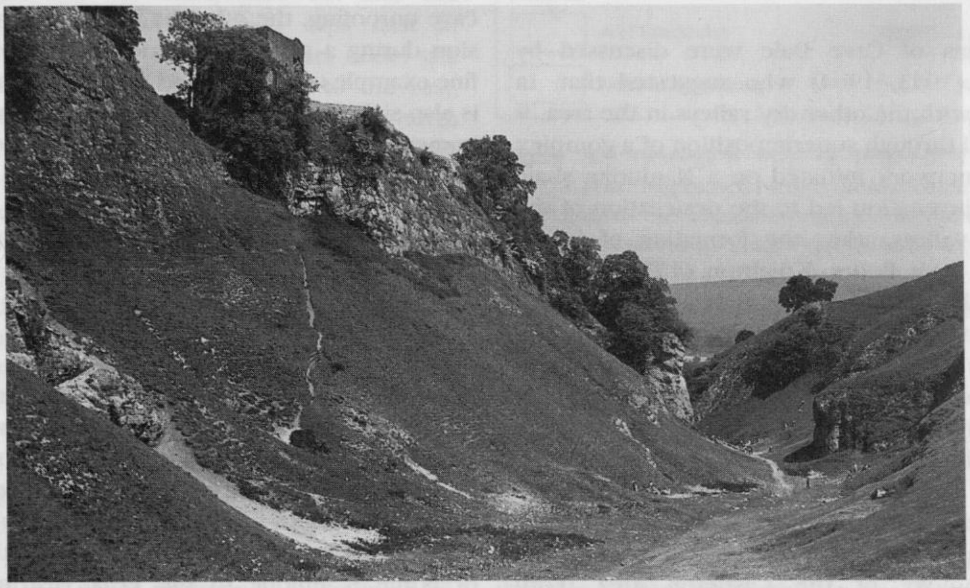

Figure 4.8 The lower part of Cave Dale looking downstream. Peveril Castle, on the left, overlooks the head of the adjacent Peak Cavern gorge. (Photo: A.C. Waltham.)

dolines. Lower down the gradient steepens (Figure 4.8), eventually forming a fine karstic gorge at the foot with cliffs over 30 m high. Resistant bands of limestone form scars along other lengths of the valley sides.

The lower reaches of the dale are graded to the Hope Valley floor which is the level of the Hope Terrace (Waters and Johnson, 1958). An outcrop of basaltic lava (the Cave Dale Lava) occurs in the middle section, creating a positive irregularity in the long profile. A spring occurs where the lava outcrops, as downward drainage through the limestone is impeded. The resulting stream flows a short distance down the valley before sinking into the limestone below the lava flow, to reappear in Peak Cavern almost directly below. Apart from this, the valley is totally dry. Some of the cliffs at the downstream end have been modified by small-scale quarrying.

Underlying much of Cave Dale are the main streamway and tributary passages of Peak Cavern. This has the largest cave entrance in Britain, sited at the head of a short narrow gorge with cliffs over 50 m high. This is also cut into the side of the limestone hill, and its floor is breached by the various resurgences which carry most of the water sinking on the plateau above. The cross-section, long profile and overall dimensions of the Peak Cavern gorge are all in marked contrast to those of Cave Dale.

Interpretation

The origins of Cave Dale were discussed by Warwick (1953, 1964) who suggested that, in common with the other dry valleys in the area, it developed through superimposition of a complex drainage network initiated on a Namurian shale cover. Rejuvenation led to the desiccation of the tributary valleys, after the formation of knickpoints in their floors. Knighton (1975) put forward an alternative interpretation for these knickpoints, advocating that the steepening of the thalwegs was a response to maintain flow continuity where geology imposed constraints on the adjustability of width. Ford (1986a) noted that the step in the Cave Dale profile was probably a structural feature caused by the outcrop of the basalt lavas rather than a true knickpoint. In a series of publications dealing with the limestone geomorphology of the Castleton area, Ford (1977b, 1986a, b, 1987) identified the role of periglacial meltwaters in the formation of the Cave Dale. He suggested an Ipswichian age for the main period of incision based on dating evidence from the underlying Peak Cavern (Ford *et al.*, 1983).

The origins of the Peak Cavern gorge are also discussed by Ford (1977a) and Ford *et al.* (1983), who noted that the gorge showed evidence of having been a vauclusian spring, which was initiated during the phreatic development of Peak Cavern during the Hoxnian interglacial. Downcutting through the lip of the vauclusian spring coupled with roof collapse has created the spectacular gorge seen today. Its roofed-over continuation can be seen in the entrance chamber of Peak Cavern.

The lower part of Cave Dale overlies one of the largest chambers in Peak Cavern. The only connection between the dale and the cave is through a very narrow fissure (now blocked); this is not an old sink, but is a phreatic rift in the cave roof which has been intersected by the valley. This lack of relationship between Cave Dale and Peak Cavern supports the view that Cave Dale is a young valley, excavated when the ground was frozen and the cave below was temporarily inactive (Ford, 1986a).

Conclusions

Cave Dale and Peak Cavern provide a valuable and exemplary site with two genetically unrelated types of limestone gorge, one formed largely by cave unroofing, the other by subaerial fluvial erosion during a periglacial period. Each gorge is a fine example of its type in its own right. Cave Dale is also significant in being a deep limestone gorge immediately overlying a major uncollapsed cave system, to which it is genetically unrelated.

BRADWELL DALE

Highlights

Bradwell Dale and its upstream continuation, Stanlow Dale, lie along the margin of the karst, south-east of Castleton. They are the product of gorge incision caused by reef knolls interrupting the uniclinal shift of a valley excavated along a shale–limestone interface. Within Britain, this type of gorge is unique to the Peak District karst, where these two dales exhibit the clearest morphology of the type.

Introduction

Bradwell Dale and Stanlow Dale (Figure 4.9) form part of a dry valley network which drains north along the east dipping margin of the limestone plateau, immediately south of Bradwell. The valley is incised into the Lower Carboniferous limestones of the Eyam Group, which consist of both bedded, back-reef, lagoonal carbonates and also mounded reef knoll limestones. The gorge is important in demonstrating the role of the reefs in obstructing the downdip uniclinal shift of the valley to the east, instead forcing the valley to incise vertically, creating the gorge seen today. Modern drainage is now underground, so that the gorges, which were developed under periglacial conditions in the Pleistocene, are now dry.

The geomorphic evolution of Bradwell Dale and its associated caves were comprehensively described by Ford *et al.* (1975). These and several other anomalous gorges in the Peak District were further assessed by Ford and Burek (1976) who outlined the role of the reef knolls in the gorge formation, and by Ford *et al.* (1977a) as part of an overview of the karst geomorphology of the Bradwell area. The chronology of Bagshaw cavern, and its implications for Bradwell Dale, was outlined by Ford *et al.* (1983).

Description

The gorges and dry valleys are cut into the Carboniferous limestone, which dips east at 5–10°. The limestone then disappears under the Edale shales a few hundred metres to the east, where a broad strike valley draining to the north has developed along the limestone–shale boundary. The main Bradwell and Stanlow gorges are developed slightly updip along a prominent line of knoll reefs (Figure 4.9). They are incised up to a depth of 40 m into massive limestones, forming steep cliffs and craggy outcrops. The gorges extend some 2 km from Nether Water Farm in the south, north along strike to Bradwell village. Tributary to these are the dry valleys of Hartle Dale and Intake Dale which drain east down the limestone dipslope, meeting the gorge at Hazlebadge Farm. All the valleys are now dry, as modern drainage is underground. Several stream sinks are present along the shale boundary and these feed to a major resurgence in Bradwell village. The largest cave system associated with the gorge is Bagshaw Cavern (Figure 4.9); there are

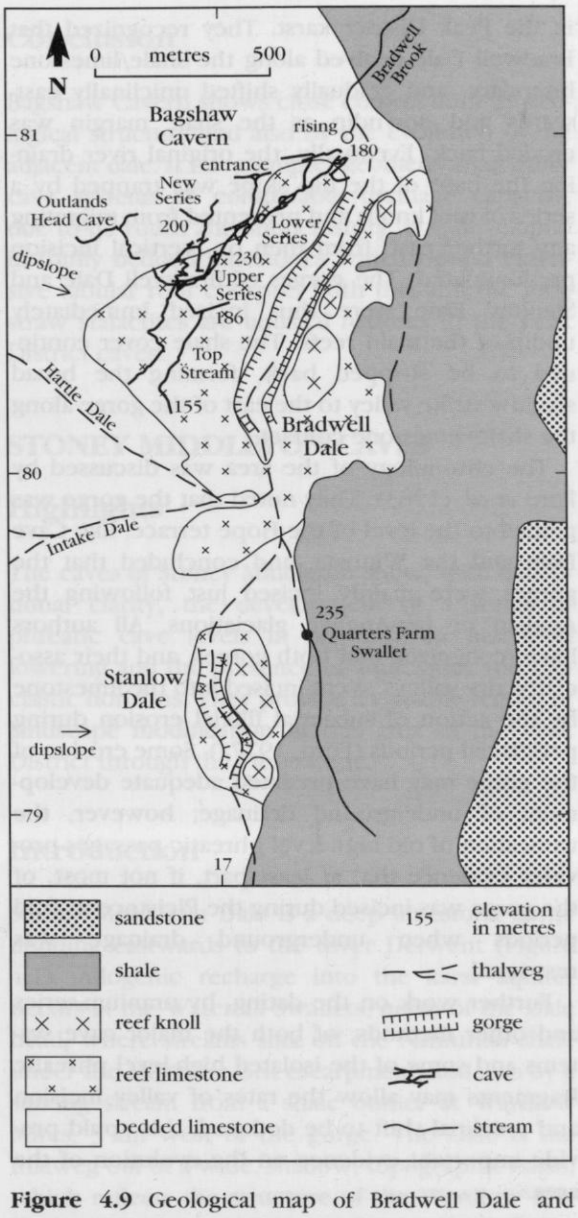

Figure 4.9 Geological map of Bradwell Dale and Stanlow Dale. Bagshaw Cavern is shown in outline, and lies mainly in the bedded limestones beneath the reef knolls (from survey by Eyam Exploration Group).

also other small sinks and cave fragments within the gorge and its tributaries, including fissures which have yielded Pleistocene mammal remains (Ford *et al.*, 1977a).

Interpretation

Ford and his co-workers (1975, 1976) described the role of the knoll reefs in the formation of Bradwell Dale, Stanlow Dale and the various other deeply entrenched valleys, or anomalous gorges, in the Peak District karst. They recognized that Bradwell Dale evolved along the shale/limestone boundary, and gradually shifted uniclinally eastwards and downdip as the shale margin was eroded back. Eventually, the original river draining the base of the dip slope was trapped by a series of reef knolls and prevented from migrating any further east; from then on, vertical incision predominated. The gorges of Bradwell Dale and Stanlow Dale were thus incised immediately updip of the main reefs. The shale cover continued to be stripped back, forming the broad shallow strike valley to the east of the gorge along the shale–limestone contact.

The chronology of the area was discussed by Ford *et al.* (1983). They noted that the gorge was graded to the level of the Hope terrace, like Cave Dale and the Winnats, and concluded that the gorges were mainly incised just following the Anglian or pre-Anglian glaciations. All authors have recognized that both gorges, and their associated dry valleys, were incised into the limestone by the action of subaerial fluvial erosion during periglacial periods (Ford, 1977a). Some erosion of the gorge may have predated adequate development of underground drainage; however, the truncation of old high-level phreatic passages provides evidence that at least part, if not most, of the gorge was incised during the Pleistocene cold periods when underground drainage was restricted.

Further work on the dating, by uranium-series and other methods, of both the major cave systems and some of the isolated high-level phreatic fragments may allow the rates of valley incision and uniclinal shift to be deduced; this could provide important evidence on the evolution of the area.

Conclusions

The site encloses part of a fine karst valley system with two gorge sections, which are the clearest examples in the Peak District where incision is due to the prevention of a valley migrating uniclinally downdip by reef knolls in the limestone sequence. British examples of this phenomenon are found only in the Peak District. The tributary valleys are also good examples of dry karstic valleys in their own right, abandoned by the modern drainage which is underground.

BAGSHAW CAVERN

Highlights

Bagshaw Cavern lies immediately behind a large resurgence, and is developed at a very high stratigraphic level within the limestone sequence. It has a less complex configuration than other cave systems in the Peak District, reflecting its more recent development.

Introduction

Bagshaw Cavern lies west of Bradwell Dale (Figure 4.9), cutting through a gentle anticline plunging with the easterly dip. It lies in thin-bedded limestones of upper Brigantian age, at a stratigraphically higher level in the Carboniferous Limestone than any other cave in Derbyshire. Its development has been influenced by the incision of Bradwell Dale and the presence of reef mounds to the east. The cave stream has a large catchment area of autogenic input from limestone moors, updip to the west, and this is joined by allogenic waters entering sinkholes along the shale boundary east of Bradwell Dale. The Bagshaw resurgence, at the head of Bradwell Brook, is one of the largest risings in the Peak District karst.

The evolution of Bagshaw Cavern and Bradwell Dale has been discussed by Ford *et al.* (1975, 1977a), and aspects of its hydrology have been discussed by Christopher and Wilcock (1991). Description of the cave passages are given by Gill and Beck (1991), and in a brief account by Ford and Gunn (1992).

Description

Bagshaw Cavern is entered via a staircase in an old mine working. At the foot, a phreatic tube partly full of sediment leads south to join the main cave at the Dungeon, a 6 m deep pothole. From the bottom of this, a lower series of intermittently active passages trends north-east towards the resurgence (Figure 4.9). Above the Dungeon, an upper series of abandoned passages trends south-west along the strike. Both upper and lower series display fine vadose downcutting in phreatic bedding tubes up to 4 m high and wide. The system is developed in thinly bedded limestones, and many passages show good examples of tabular collapse of roof blocks. The active stream is normally seen only for short distances at the two ends of the system between flooded sections of its route; upstream in Top Stream Passage, the water rises for over 30 m through flooded caverns. Much of the flow comes from the Quarters Farm Swallet (Figure 4.9).

The western end of the main passages approaches the abandoned phreatic tubes and rifts of Outlands Head Cave. The New Series of Bagshaw, discovered in the 1930s, extends into a calcite pipe vein and contains chambers decorated with straw stalactites up to 2 m long. An aven rises from it into Batham Gate, a high-level passage almost directly above the main series and extending south parallel to Top Stream.

Interpretation

The Bagshaw Cavern drainage system is unusual in crossing a limestone anticline close to a major dry valley. Its development was closely linked to the formation of Bradwell Dale and the erosion of the limestone plateau to the west. As the shale cover was progressively removed eastwards, unroofing of the limestone allowed entry of sinking water and the development of phreatic circulation. Surface drainage experienced a uniclinal shift downdip until trapped by reef mounds, at which point Bradwell Dale began to form immediately to their west; it therefore cut down through a gentle eastward-plunging anticline, instead of following the strike round the nose of the fold. Most of Bagshaw Cavern was a late development, largely postdating the initial excavation of Bradwell Dale during the Hoxnian or Ipswichian interglacial. The cave is a young system, of relatively simple geometry, which has not developed to the same extent as those around Castleton or Stoney Middleton, despite having a comparable throughflow of water. The main passages lie at altitudes of 190–210 m, and the older conduit of Batham Gate is at the 230 m level, maintaining its level by following the strike. With continued incision of Bradwell Dale the underground drainage has migrated downdip; downstream of its phreatic lift in the Top Stream sump, the present streamway lies close to the 180 m level, just above the resurgence. Both the upper and lower series of Bagshaw Cavern exhibit classic vadose trenching of phreatic bedding passages, while permanently flooded passages represent the youngest part of the system.

Conclusion

Bagshaw Cavern shows close control both by geological structure and also by the evolution of the adjacent dale. It has a simpler geometry than other cave systems of comparable drainage capacity, due to its youth and short history. It is developed in thinly bedded limestones which permit extensive tabular roof collapse; both this and the long straw stalactites are unusual features in the Peak District caves.

STONEY MIDDLETON CAVES

Highlights

The caves of Stoney Middleton show, with exceptional clarity, the development of a series of phreatic cave levels in response to base-level lowering and the presence of aquicludes and bioclastic horizons. They provide a valuable record of landscape modification in this area of the Peak District through the Pleistocene.

Introduction

Stoney Middleton Dale is a deep limestone gorge draining eastwards to the River Derwent (Figure 4.1). Allogenic recharge into the karst aquifer occurs at the Waterfall Swallets, north of the Dale head, where streams sink off the Namurian shale under the Millstone Grit escarpment, and also by a sinking stream from a shale outlier at Wardlow Mires, 3 km west of the gorge. The Dale is the thalweg out of a wide, shallow, topographic basin, which reflects the structure of the Wardlow syncline with the shale outlier at its centre. The catchment is bounded to the west of the basin by the outcrop of the Litton Tuff, which acts as an aquiclude, maintaining a large groundwater reservoir within the basin. Several large phreatic cavities, possibly of considerable age (Beck, 1977), lie beneath the southern and eastern flanks of the basin. The catchment area for the risings at Stoney Middleton covers 17 km^2, with 60% on limestone. The discharge is now entirely by mined drainage soughs, except in flood conditions, when the estavelles at Wardlow Mires and Carlswark Cavern discharge large streams.

The geological setting, evolution and hydrology of the caves of this site have been discussed by Beck (1975, 1977), Christopher and Beck (1977)

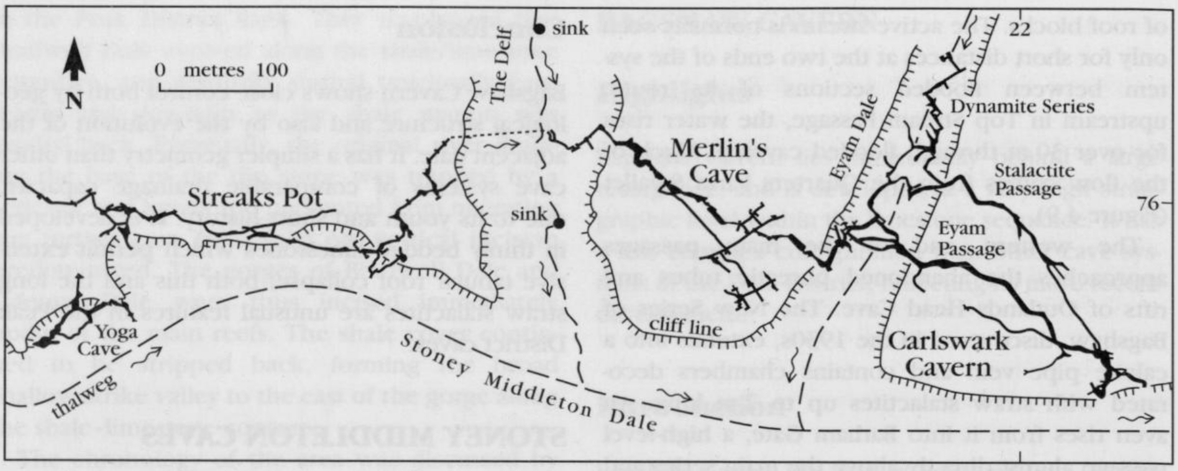

Figure 4.10 Outline map of the cave systems under the northern flank of Stoney Middleton Dale (from survey by Technical Speleological Group).

and Ford and Gunn (1992). The caves are described by Gill and Beck (1991), with an account of Streaks Pot and Merlin Mine in Beck (1990).

Description

Waterfall Swallet is the largest of the sinks on Eyam Edge. It lies in a large doline which fills in flood and overflows into the adjacent cave system of Waterfall Hole. This cave reaches 43 m deep in a series of rift caverns, extensively modified by collapse, which enlarge beneath the wayboard at the base of the Eyam Limestone. Little Waterfall Swallet lies on the same fracture system a short distance to the north-east. Sinkholes at Eyam are largely hidden by the culverts which carry the Jumber and Hollow Brooks through the village, but one has been followed to a depth of 100 m in vein cavities. These brooks continue southwards via the Delf and Eyam Dale respectively, seeping into their valley floors in dry weather, or joining the Dale Brook in wet conditions.

Stoney Middleton Dale exposes an almost continuous section, 3 km long, through the Brigantian Monsal Dale limestones of the Carboniferous. Within this sequence several important speleogenic horizons have been recognized (Beck, 1975). A number of caves are developed, mainly along the strike on these horizons (Figure 4.10); they form a series of levels which reflect external erosional events.

The highest and oldest part of the cave system is the First Remnant Complex, represented by a series of tubes at levels of 210–216 m (Figure 4.11). Vadose feeders to the system are represented by Cucklet Church Cave and The Saltpan with their isolated fragments of passage in crags west of the Delf. The Second Remnant Complex is seen only as a large phreatic tube in the Dynamite Series of Carlswark Cavern; it lies directly beneath the First Remnant tube, which it clearly postdates.

The Carlswark Complex is the most extensive level of the system, with the majority of Carlswark Cavern, Streaks Pot and Yoga Cave developed at a level of about 180 m. Carlswark Cavern has two main relict phreatic tubes. Eyam Passage lies to the south and Streaks Pot represents its truncated

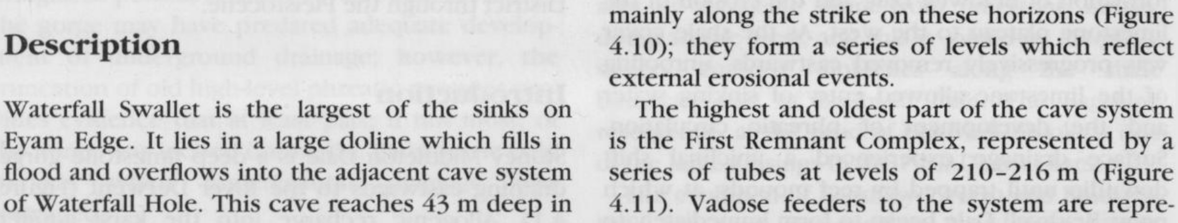

Figure 4.11 Long profile through Merlin's Cave and Carlswark Cavern showing the development on four levels (after Christopher and Beck, 1977).

continuation west of the Delf. Stalactite Passage is the northern tube downstream of the joint-controlled phreatic rifts of the Dynamite Series. The entire Carlswark Complex is developed at the base of a limestone bed crowded with silicified *Gigantoproductus*, where a thin clay bed has arrested vertical percolation and initiated development of the network of tubes. Eyam Passage has a spectacular roof formed in the Lower Shell Bed, and also reveals excellent examples of bedding plane anastamoses. The Lower Complex is little known since it lies mostly below the thalweg and is largely flooded.

Interpretation

Cave development in the Stoney Middleton area has been influenced to an unusual degree by a combination of stratigraphic and surface topographic controls. The Lower Shell Bed is a bioclastic horizon, directly underlain by a clay wayboard aquiclude, which acted as an important inception horizon for the phreatic caves. Joint control is also conspicuous within the caves, both at the speleogenic horizons and as rifts linking them vertically.

The sequence of four cave levels represents a succession of shallow phreatic networks developed in response to intermittent rejuvenation and incision of the River Derwent upstream of the Matlock knickpoint (Beck, 1977). Each cave level was formed where favourable inception horizons lay just below the contemporary water table which was gently graded towards base level at the river. The minimal vadose trenching within the phreatic tubes suggests that each new level captured the entire drainage and fossilized the upper levels very rapidly (Ford *et al.*, 1983). The higher-level passages tend to be larger than those lower down, perhaps reflecting the formerly greater extent of the shale cover, and hence larger catchment area of allogenic water, at the time that they were active. Similarly, the position and vadose character of Cucklet Church Cave also suggest a more extensive shale cover at the time of initiation. Sedimentary fills in the abandoned levels demonstrate several stages of infilling and re-excavation; correlations with terrace levels suggest that the old highest level in the caves was active in pre-Anglian times, but stalagmite dating has not yet provided a chronological framework for all the levels (Ford *et al.*, 1983).

Conclusion

The Stoney Middleton caves provide excellent examples of the influence of aquicludes on the level of passage development. The successive levels of passage development also record, with exceptional clarity, the effect of lowering of surface drainage on underground drainage levels.

POOLE'S CAVERN

Highlights

Poole's Cavern is a large section of cave passage with an underfit stream fed by karst drainage from the south. A proven hydrological link with nearby thermal springs provides valuable information on the nature of recharge to such phenomena. Stalagmites which have developed on gas pipes within the cave provide important data on the growth rate of speleothems.

Introduction

Poole's Cavern lies north-east of Stanley Moor, and represents the only significant length of accessible cave passage within the catchment of this upland karst (Figure 4.1). Several sinkholes lie close to the boundary of the overlying shale on Stanley Moor. All drain to a series of resurgences in the floor of the Wye Valley at Buxton, and several drain via Poole's Cavern in all but very low flow conditions. Although the flow route is confirmed by dye tests, passage sizes at the sinkholes are small and none of the cave streams can be followed far underground. Poole's Cavern is the only large cave in the area. Coal fines were formerly stored in the Grinlow quarries, midway between Stanley Moor and Poole's Cavern, and have appeared in Poole's Cavern and at the Buxton hot springs, suggesting that some of the cave stream joins the hydrothermal system after leaving the cave.

The caves and hydrology of the area have been discussed by Ford (1977c), Gunn and Edmans (1989) and Ford and Gunn (1992), and the passages in Poole's Cavern were described by Gill and Beck (1991).

Description

Poole's Cavern is currently operated as a show cave. Though only 240 m long to a boulder choke, it has an impressive main passage up to 20 m high and wide; this is an excellent example of solutional enlargement in a dense system of beddings and joints, with solutional undermining and collapse. Subsequent vadose erosion has removed most of the fallen blocks. The cave contains good examples of stalactites and a massive bank of flowstone with large gour terraces. Pitty (1969) has used this site to ascertain the difference in response times of percolation water and stream water in order to distinguish contrasting residence and through flow time of different components of the karst groundwater. The entrance passages contain thick sediment sequences, yet to be documented in detail, which have yielded Pleistocene mammal bones and include undisturbed stalagmite layers; Romano-British material lies on the Pleistocene silts. Further sediments were excavated from the cave entrance by Victorian archaeologists, but the finds were poorly recorded and preserved.

Interpretation

The phreatic origins of Poole's Cavern and its position adjacent to the modern Buxton valley suggest a considerable age for the cave and a history which may extend as far back as the Anglian glaciation. The undisturbed bone deposits and stalagmite layers provide a record of Pleistocene events and climatic change in this area, with the possibility of absolute dates being obtainable from the stalagmite layers. An unusual feature is the stalagmite columns, which have been deposited up to 100 mm high on a century-old gas pipe; they provide data on the growth rate of speleothems, but their development may have been influenced by lime-burning in Grin Woods above. Some of the stalagmites have unusual colouring distinguished by their resemblance to poached eggs.

Poole's Cavern represents a former resurgence for the area. The main underground drainage now takes a different route, probably via Green Lane Pot (SK 050726), to the resurgences at Otter Hole (SK 046733) and Wye Head (SK 050751), both about 45 m lower. Although the hydrology of the area appears fairly simple, the connection with the Buxton hot springs suggests that some of it follows a much deeper phreatic route which is probably fault-guided. Alternatively, the shallow drainage from the Stanley Moor sinkholes has intercepted an independent, deep phreatic system. Tritium contents of the Buxton spring water shows that it has been underground only for 15–20 years; it appears to be meteoric water which has passed through unusually deep systems of karstic fissures (Ford, 1977c).

Conclusion

Poole's Cavern is an isolated segment of large cave passage containing clastic sediment deposits which incorporate both vertebrate remains and stalagmite layers. This sequence preserves a valuable record of climatic and geomorphological change in this area through the Pleistocene. The karst hydrology of the area encompasses both the shallow drainage from moorland sinkholes and also the deep recharge to thermal springs.

LATHKILL DALE

Highlights

Lathkill Dale is a dendritic dry valley system deeply entrenched into a karst plateau; it is the best developed in the Peak District, and among the finest in Britain. The River Lathkill emerges from several springs at the lower end of the Dale, and has some of the most important examples of barrage and sheet tufas in Britain. The complex hydrology has been considerably affected by mine drainage.

Introduction

A dendritic network of shallow dry valleys incised into the limestone plateau drains eastwards from around the village of Monyash, and feeds into the head of Lathkill Dale (Figure 4.12). The upper part of the valley network is guided by the synclinal geological structure and is dry above Lathkill Head Cave, which is an active resurgence in wet weather. Below this cave, the surface stream is intermittent and seasonal until Pudding Springs are reached below the junction with Cales Dale, where the stream is permanent except in extreme drought. The surface flow is maintained in part due to toadstones (Carboniferous lavas) and less permeable limestones exposed in the valley floor.

The dry valley network was studied by Warwick (1953, 1964), while Ford and Beck (1977) expanded on his work, studying the chronological relationship of the downcutting of the dale to

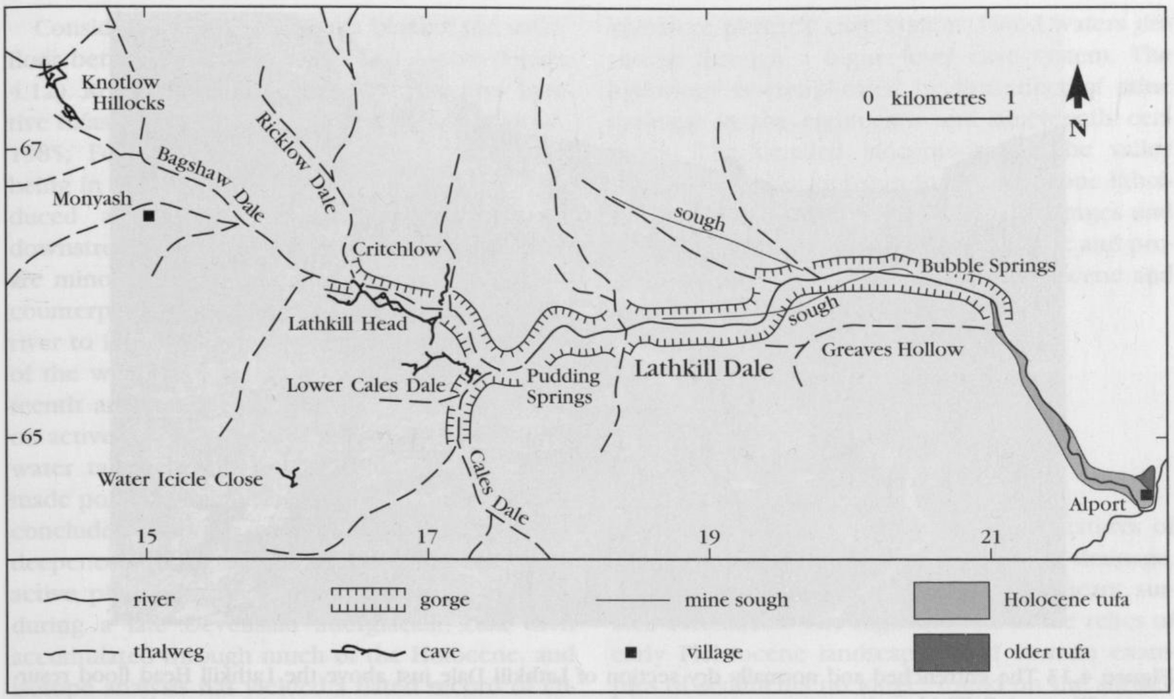

Figure 4.12 Outline map of Lathkill Dale, its tributary dry valleys and its associated cave systems.

glaciation. In the lower part of the dale, thick deposits of tufa occur, some of which are still actively growing and form a series of barrages across the river (Towler, 1977; Aitkenhead *et al.*, 1985; Ford, 1989b; Pedley, 1993). These have enabled Pedley (1993) to deduce part of the Quaternary history of Lathkill Dale, but this is complicated by the considerable modifications imposed on the dale by past measures to affect mine drainage (Bamber, 1951; Robey, 1965). A comprehensive study of the dale's geomorphological history is awaited, though Ford *et al.* (1983) outlined a tentative chronology based on cave levels related to the Derwent terraces. The many caves in the dale are described by Gill and Beck (1991).

Description

The upper part of the Lathkill catchment consists of an elongate bowl centred on the village of Monyash, with a group of shallow dry valleys leading out to the east. These coalesce into a dry gorge with steep rocky sides incised up to 75 m below the level of the plateau surface. The gradient of the valley steepens markedly into the gorge section, and the steep rocky sides are fringed by coarse screes (Figure 4.13). At the lower end of this gorge, Lathkill Head Cave is the wet weather resurgence of the River Lathkill; in flood conditions this discharges a very large flow (Gill and Beck, 1991). Directly opposite is Critchlow cave which also discharges water in flood. Below this several more springs add to the stream, depending on the stage of flow, with water emerging from a spring at Holme Grove, from the Lower Cales Dale Cave, from Pudding Springs a kilometre downstream, and from Bubble Springs 3 km from Lathkill Head Cave. During severe drought, there may be no flow above Bubble Springs.

The general trend of Lathkill Dale is eastwards along the line of a gently plunging syncline. The dale exposes the Monsal Dale Limestones; these are mainly pure calcarenites with coral bands, but they include a lower facies of dark limestones which are rich in shale partings, thinly bedded and less permeable. Ford and Beck (1977) suggest that the dark limestones would have helped to maintain a surface flow along the dale, if the mine drainage had not artificially lowered the water table and captured much of the tributary input. At Bubble Springs, faults bring a bed of lava to the surface.

For much of its length below Pudding Springs, the floor of Lathkill Dale is covered partly by the remains of artificial dams, placed to improve the fishing, and partly by a large sheet of tufa. The tufa

Figure 4.13 The entrenched and normally dry section of Lathkill Dale just above the Lathkill Head flood resurgence. (Photo: A.C. Waltham.)

is most extensive at the lower end, and two tufa phytoherm barrages occur between Bubble Springs and Alport (Figure 4.12), with pool deposits in between (Pedley, 1993). The fossil tufa deposits further upstream are now being eroded by the stream or grassed over, and that at Pudding Springs has been modified by quarrying. An older, massive tufa sheet forms a cliff up to 8 m high and 150 m long immediately north-east of Alport (Figure 4.12).

Interpretation

Warwick (1964) described the Lathkill valley network in some detail and was convinced that the majority of the valley evolved from a complex drainage pattern initiated on overlying, impermeable shales, and that rejuvenation had led to progressive elimination of the tributary valleys. Ford and Beck (1977) suggested the main development of Lathkill Dale took place during the Pleistocene cold phases when periglacial conditions allowed surface flow of glacial meltwater and valley incision. They suggest that incision was initiated during the Last Interglacial, and followed the axis of the syncline; remnants of glacial till survive on the plateau. Initial incision was greatest at the downstream end and was via Greaves Hollow, which is now truncated and dry. Subsequently, the river was offset to the north (Figure 4.12), probably by some form of river capture (Ford and Beck, 1977), to follow the line of the mineral veins.

The role of rejuvenation appears to have been more limited in Lathkill Dale than it was in the Dovedale and Manifold valleys. None of the tributary valleys in the upper section hangs above the main valley floor (Warwick, 1964). Only lower down do some of the tributaries hang, and then they do so only by a few metres. One hanging tributary lies immediately south of Lathkill Head Cave (Warwick, 1964), but this may be a structural feature where contrasting limestone lithologies are juxtaposed across a mineralized fault (Ford and Beck, 1977). In other cases the tributary valleys may be partially infilled, thus apparently hanging above the main valley from where any infill has been removed.

The hydrology of Lathkill Dale is complex, has been much affected by mine drainage (Bamber, 1951; Ford and Beck, 1977), and is far from being fully understood. A natural phreatic cave system drains the upper part of the dale; Lathkill Head, Critchlow and the Lower Cales Dale caves represent the flood overflow or epiphreatic parts of the system. Below the Cales Dale junction, the Lathkill Dale and Mandale soughs were cut to drain the mines and have altered the flow regime, so that the main water now reappears at Bubble Springs.

Considerable deposits of tufa blanket the valley floor between Bubble Springs and Alport (Figure 4.12). Reference has been made to the now inactive tufas above Bubble Springs (Aitkenhead *et al.*, 1985; Ford, 1989), the most detailed account being in Towler (1977), while Pedley (1993) produced a detailed study of the active tufas downstream of Conksbury. These modern tufas are minor in extent compared to their Holocene counterparts, due in part to the ponding of the river to improve fishing and the general lowering of the water table by mine drainage in the eighteenth and nineteenth centuries. The restriction on active tufa formation is due to both the falling water tables drying up the river and also man-made pollution inhibiting the algal growth. Pedley concluded that the pre-tufa Lathkill gorge was deepened during the earlier Devensian, with active phytoherm development causing ponding during a late Devensian interglacial. Tufa then accumulated through much of the Holocene, and isotope analysis has yielded a dated record of climatic and environmental changes from 10 000 to 4000 BP (Andrews *et al.*, 1994; Taylor *et al.*, 1994). Mean temperatures reached a maximum around 8000 BP, and the forest cover was largely cleared in two stages by 5000 and 4000 BP. The tufa in the cliff above Alport was probably deposited during the Ipswichian interglacial.

Ford *et al.* (1983) suggest that the earliest phase of cave development was that associated with Water Icicle Close Mine, which has been dated in excess of 350 ka. The next phase was the development of Upper Cales Dale Cave, followed by renewed incision and the formation of Lathkill Head Cave. Limited incision of the dale occurred during the Devensian, followed by calcite deposition in the caves. Further dating of the speleothem sequences within the Lathkill caves is needed to confirm this chronology, and dating of the travertines could provide further data on Quaternary environments. Further dye tracing is required to resolve the complex hydrology of the karst.

Conclusions

Lathkill Dale is one of Britain's finest examples of a dendritic dry valley system. It was largely developed under periglacial conditions during Pleistocene cold phases. Surface flow occurs over differing lengths of the river bed depending on stage, with partial parallel drainage through an immature phreatic cave system. Flood waters discharge through a higher-level cave system. The hydrology is complicated by the effect of mine drainage in the eighteenth and nineteenth centuries. The detailed morphology of the valley shows a close relationship to the limestone lithology and structure. Several fine tufa barrages and sheets occur in the lower part of the dale and provide some evidence for the Late Pleistocene and Holocene development of the valley.

UPPER LATHKILL DALE CAVES

Highlights

The caves of Upper Lathkill Dale are features of abandoned or intermittently active karst drainage, which now lie isolated from any significant surface catchment. The high-level caves are relics of early Pleistocene landscapes, and contain examples of sediments no longer found on the surface here. The intermittently active caves demonstrate the nature of karst drainage fed entirely by percolation sources.

Introduction

The limestone basin at the head of Lathkill Dale contains isolated fragments of large phreatic cave passages at Lathkill Head, Water Icicle Close and Knotlow Mine (Figure 4.12). All the caves lie in the bedded, lagoonal facies of the Monsal Dale Limestones, and are far from any allogenic drainage sources; they are believed to be fed solely by autogenic input. The River Lathkill flows from one of the largest areas of riverless terrain in the Peak District karst, and it represents a classic example of a river flowing on or beneath the limestone valley floor depending upon the amount of preceding rainfall. After periods of wet weather, the river flows from Lathkill Head Cave, though at other times the dale may be dry as far down as Bubble Springs (Figure 4.12). This situation is no longer entirely natural, as the regional water table has been lowered by Hillcarr Sough to the south and also by Lathkill Dale Sough driven below the valley floor and Mandale Sough beneath its northern flank (Oakman, 1979). Whether the river flowed permanently on the surface before the construction of these drainage adits is uncertain. In historical times the river flowed from as far up as Monyash, and was restricted to flowing from

Lathkill Head Cave only in times of drought (Bamber, 1951; Oakman, 1979).

The caves and karst of Upper Lathkill Dale have been discussed by Bamber (1948, 1951), Ford and Beck (1977) and Ford and Gunn (1992); the cave passages are described by Gill and Beck (1991).

Description

The large open entrance of Lathkill Head Cave discharges a powerful stream in winter, but dries out allowing access to the cave system in summer. The main passage is a bedding-guided phreatic tube, typically 1 m high and 5 m wide, which can be followed upstream to high, solution-enlarged joints, with a series of large chambers well decorated with speleothems. Further low passages have been followed north-west, and a series of small phreatic tubes pass beneath the dale floor to link with the lower levels of Ricklow Cave, with its entrance on the north side. A low, sediment-filled distributary extends downstream to within 150 m of Lower Calesdale Cave. Critchlow Cave lies directly opposite Lathkill Head, and has 800 m of low, partly sand-filled, phreatic passage, with several small chambers decorated with speleothems. Lower Cales Dale Cave is the third major cave in the immediate area; it has more than a kilometre of passage trending north-west through low phreatic tunnels and small chambers. Like Lathkill Head and Critchlow, it acts as a flood resurgence during prolonged periods of wet weather. Two other small cave fragments in Cales Dale have yielded late Palaeolithic remains (Jackson and Storrs Fox, 1913).

Water Icicle Close Cavern is entered only via a 32 m mine shaft which intersects the junction of three drained phreatic tubes, each up to 3 m in diameter. They have only very minor vadose entrenchment. All are blocked after short distances by collapse or fluvioglacial deposits partly derived from the Millstone Grit, the nearest outcrops of which are now 7 km to the west. Stalagmite from these phreatic passages has been dated to earlier than 350 000 BP (Ford *et al.*, 1983).

The limestone north of Monyash contains natural caverns which are accessible through the artificial shafts of Knotlow and Hillocks mines (Figure 4.12). Constricted phreatic tube complexes and some large, fracture-guided caverns have been partly modified by mining, but still retain their main morphological features. Large banks of fluvioglacial sand are present in the Hillocks chambers. The caves are largely relicts and lie at a height intermediate between those of Water Icicle Close and Lathkill Head. There has been some invasion of the passages by vadose water, which flows into sumps before reappearing at Lathkill Head.

Interpretation

The Upper Lathkill Dale caves encompass successive levels of partly drained and totally flooded phreatic caves situated beneath the central part of the Derbyshire karst plateau. The origin and destination of the water which formed Water Icicle Close Cavern is unknown; the passages clearly represent a dissected remnant of a former high-level, phreatic system which pre-dates the present cave drainage at Lathkill Head, and is probably older than the incision of Lathkill Dale. Speleothems dated by the uranium-series method can only indicate abandonment more than 350 000 years ago, and the cave is probably very much older than this. These old, high-level cave passages, in Water Icicle Close and Knotlow, appear to have been invaded and modified by glacial meltwater streams; these flowed from more extensive, contemporary outcrops of the impermeable cover, or from spreads of glacial till since removed. Either bedrock or till could have been the source of the Millstone Grit sand and gravel preserved in Water Icicle Close Cavern.

The active sections of Lathkill Head Cave, Critchlow Cave and Lower Cales Dale Cave are fed mostly by, and may have been formed partly by, percolation water; there has been little allogenic input other than seepage from the few small lava outcrops in the area. They represent fine examples of epiphreatic systems, formed within the zone of water table fluctuation, which have become accessible only in recent times through lowering of the water table by sough drainage.

The ancient and active drainage patterns within the caves therefore relate to the progressive incision of Lathkill Dale well back into the Pleistocene, when the impervious cover may have extended further across the limestone plateau. A tentative chronology by Ford *et al.* (1983) recognizes sporadic new cave development from the early Pleistocene through to the Holocene, but awaits confirmation by further dating of cave sediments. Data from Lathkill Dale may provide an evolutionary model for dry valleys in the Peak

District karst where associated caves are not accessible. The sequences of clastic and speleothem deposits within the caves provide an important, if incomplete, record of Pleistocene events in the southern Pennines.

Conclusion

Lathkill Dale has an important series of isolated cave fragments preserved in the heart of the limestone plateau. These are significant as indications of the extent of karst drainage development remote from the present shale margin. The truncated relict caves, and the underlying active phreatic drainage, far from any impermeable catchments, make Lathkill Dale unique within Britain's karst.

GREEN LANE PITS

Highlights

The Green Lane Pits are four collapse dolines which were infilled with Pliocene, or very late Miocene, sands. These large-scale Tertiary karst features are unique to Derbyshire, and the Green Lane Pits are notable as they admirably show the geomorphology of the depressions. The deposits are of major importance in elucidating the Tertiary history of the area.

Introduction

Over 60 solution collapse dolines occur across the southern end of the Derbyshire limestone plateau. Many of these contained sediments of the Tertiary Brassington Formation, and have been worked for the manufacture of refractory bricks. The quarrying of the sand has revealed the limestone morphology of these dolines (Figure 4.14). The Green Lane Pits are notable in that the rock walls may now be seen with uncommon clarity, and little backfilling has taken place. The dolines all occur in dolomitized Carboniferous limestone, and are infilled with clays, sands and gravels from a fluvial depositional environment. These deposits have been preserved because solution of the underlying limestone caused collapses, into which the sediments sagged or slumped.

The dolines and their deposits are of major importance in elucidating the Tertiary history of upland Britain, and also provide evidence of the scale of Pliocene uplift in the southern Pennines. The 'Pocket Deposits' (Howe, 1897) were worked at least as early as the eighteenth century (Pilkington, 1789). They were once considered to be Triassic palaeokarstic features (Kent, 1957), but more recent studies have revealed the true nature of the deposits (Ford and King, 1969; Boulter, 1971; Boulter *et al.*, 1971; Walsh *et al.*, 1972, 1980; Wilson, 1979; Ford, 1984). The earlier work is reviewed by Ford (1977a).

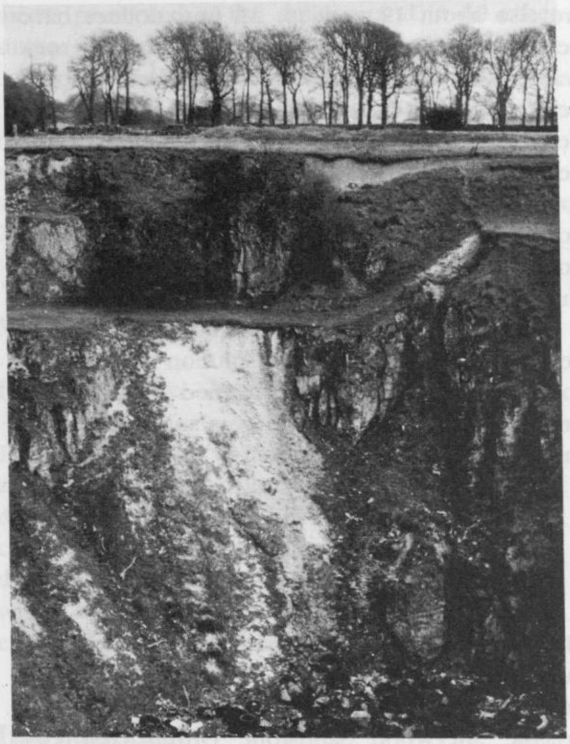

Figure 4.14 Limestone walls and some remnants of the Pliocene sediment fill left after quarrying of the northwestern of the Green Lane Pits. (Photo: T.D. Ford.)

Description

The four dolines at Green Lane, in the centre of the Peak District karst (Figure 4.1), have had most of their sand infillings removed by commercial operations. All lie in dolomitized facies of the Carboniferous limestone, at an altitude of 335 m, adjacent to the floor of a dry valley which feeds into Long Dale. The southern doline is a circular pit 90 m across and 25 m deep, with almost vertical sides in limestone. The largest of the northern dolines is elliptical in plan, over 150 m long and 12 m deep; the two smaller dolines adjacent to it are also about 12 m deep. All four dolines have been almost totally excavated, to reveal rock walls, with rock saddles and pinnacles exposed between them (Figure 4.14). Some of the original Tertiary sands and the overlying Quaternary loess deposits remain preserved in the walls of the southern doline and along the margins of the northern dolines. The floors of the dolines are now obscured by vegetation, tyre dumps or slumped sediment.

Boulter *et al.* (1971) examined the Tertiary deposits preserved in the solution hollows of south Derbyshire and termed them the Brassington Formation. This was subdivided into three members:

Kenslow Member	plant-bearing clays	c. 6 m
Bees Nest Member	coloured clays	c. 7 m
Kirkham Member	sand and gravel	c. 30 m

The Kirkham Member consists largely of white, fluvial, cross-bedded sands with many quartzite pebbles, reworked from the conglomerates of the Triassic Sherwood Sandstone Group (formerly known as the Bunter Pebble Beds). The Bees Nest Member is dominated by red, yellow and white clays, and the Kenslow Member is mainly grey clays, with abundant fossil plant debris. The sediments are generally folded into small synclines, as a result of sagging into the collapsing dolines in the limestone. Commonly these fluvial deposits are underlain by remnants of the Namurian Edale shales and up to 5 m of angular chert gravels, derived from solution of the chert-rich limestones. Parts of the Brassington Formation are present in at least 60 of the limestone depressions, but there is no complete sequence in the Green Lane Pits. A small thickness of glacial till covers the Pliocene sands in some of the Brassington pits, and this shows evidence of sagging through continued subsurface solution.

Interpretation

The doline deposits were long regarded as features of a fossil karst surface with Triassic sands unconformably overlain by Tertiary clays (Kent, 1957), until Ford and King (1969) recognized that the Kirkham Member was a Tertiary deposit derived from Triassic conglomerates. The stratigraphy and paleobotany of the deposits were examined by

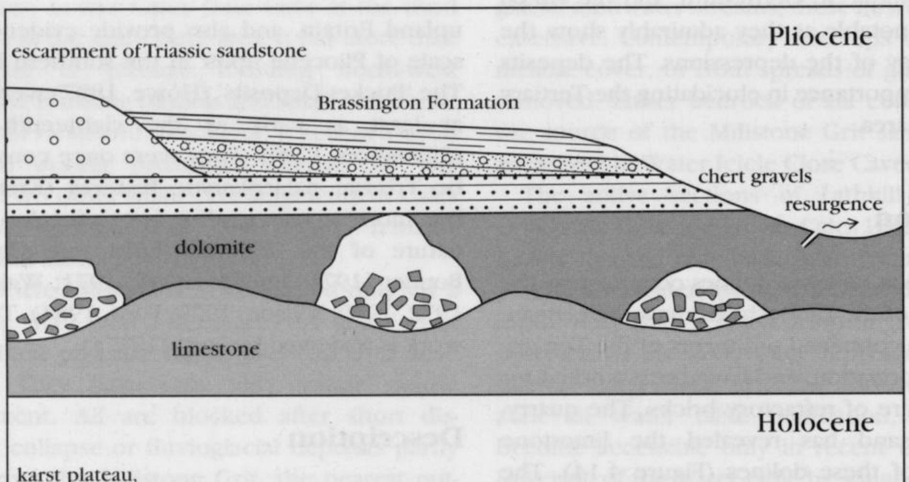

Figure 4.15 Diagrammatic sections of two stages in the formation of the Brassington Formation and their preservation in the collapse dolines in the limestone (after Ford, 1984).

Boulter (1971) and Boulter *et al.* (1971), who recorded 60 species of plant from the Kenslow Member, including *Sphagnum* and logs of *Sequoia*; they inferred an early Pliocene environment of a sandy heathland with scattered ponds.

The implications of the doline deposits for the paleogeographic history of upland Britain were recognized by Walsh *et al.* (1972), who regarded the subsidence outliers as small relics of a once continuous sheet of sands and clays. They calculated that subsidence of the Brassington Formation into collapse dolines, such as those at Green Lane, was in the order of 200 m. This indicated that the highest beds of the Brassington Formation were deposited at an altitude around 460 m. Thus the limestone block has been uplifted, during the Pliocene, by up to 250 m relative to the Triassic source areas at elevations around 240 m to the south; the uplift was probably much less than 250 m as the source could have been Triassic rocks once overlapped onto higher parts of the limestone upland. Paleocurrent structures in the Kirkham Member confirm the southerly provenance of the sands (Walsh *et al.*, 1980), while SEM analysis of the quartz grains suggested a short distance, low-energy fluvial regime with little chemical weathering (Wilson, 1979).

The synclinal bedding in the sediments preserved in the Green Lane Pits indicates that most of the limestone solution was underground, and was followed by progressive collapse and upward stoping of the voids (Figure 4.15). The Neogene sediments subsided into the dolines when the cavity roofs finally failed and dropped onto the accumulated piles of fallen debris. At some sites, they were later covered by glacial till which has been slightly disturbed by subsidence, indicating continued solution at depth. The collapse must postdate the initiation of a major karst drainage system, which produced the solution cavities. This was probably initiated following the incision of a major valley which provided the hydraulic head needed to start underground circulation. The dolines at Green Lane admirably show the nature of the solution during late Tertiary times.

Conclusions

The dolines exposed in the Green Lane Pits show the limestone morphology better than any other similar feature in Derbyshire. They provide an excellent example of this type of large-scale Tertiary solution and collapse feature. The sediments preserved in the dolines, and in 60 other similar pocket deposits, represent an important component in the Tertiary geomorphic evolution of Derbyshire. They provide evidence of Pliocene rivers draining a receding Triassic scarp in the south, and indicate that the limestone block has subsequently undergone perhaps as much as 250 m of relative uplift.

MASSON HILL CAVES

Highlights

The Masson Hill caves pre-date and post-date mineralization in a deep phreatic zone, subsequently drained by incision of the Derwent Valley. They are critical to an understanding of vein-guided karst drainage elsewhere in the Peak District. Sediment within the caves contains evidence for some of the earliest Pleistocene glacial episodes in Britain.

Introduction

The caves lie beneath the northern and eastern slopes of Masson Hill, immediately west of the anomalous limestone gorge at Matlock Bath where the River Derwent has entrenched updip of the limestone reefs (Figure 4.16). Most are sections of very ancient, partially choked, phreatic passages. These have been modified to some extent by lead and fluorspar mining, which has destroyed some natural features, but has allowed access to many more. The geology and mineralogy of the caves are uniquely complex within the Pennines. The hydrothermal mineralization is directly related to the cave development, as the mineralizing fluids both utilized and created solutional cavities within the Carboniferous limestone.

Descriptions of various parts of the cave system are given by Flindall *et al.* (1981), Gill and Beck (1991) and Warriner *et al.* (1981). The karst and cave development is discussed by T.D. Ford (1964a, 1984), Ford *et al.* (1977b) and Worley and Nash (1977), and the processes of mineralization are reviewed by Ineson and Ford (1982) and Quirk (1993).

Description

The Carboniferous limestone exposed at Masson Hill forms a gentle flexure over an anticline which

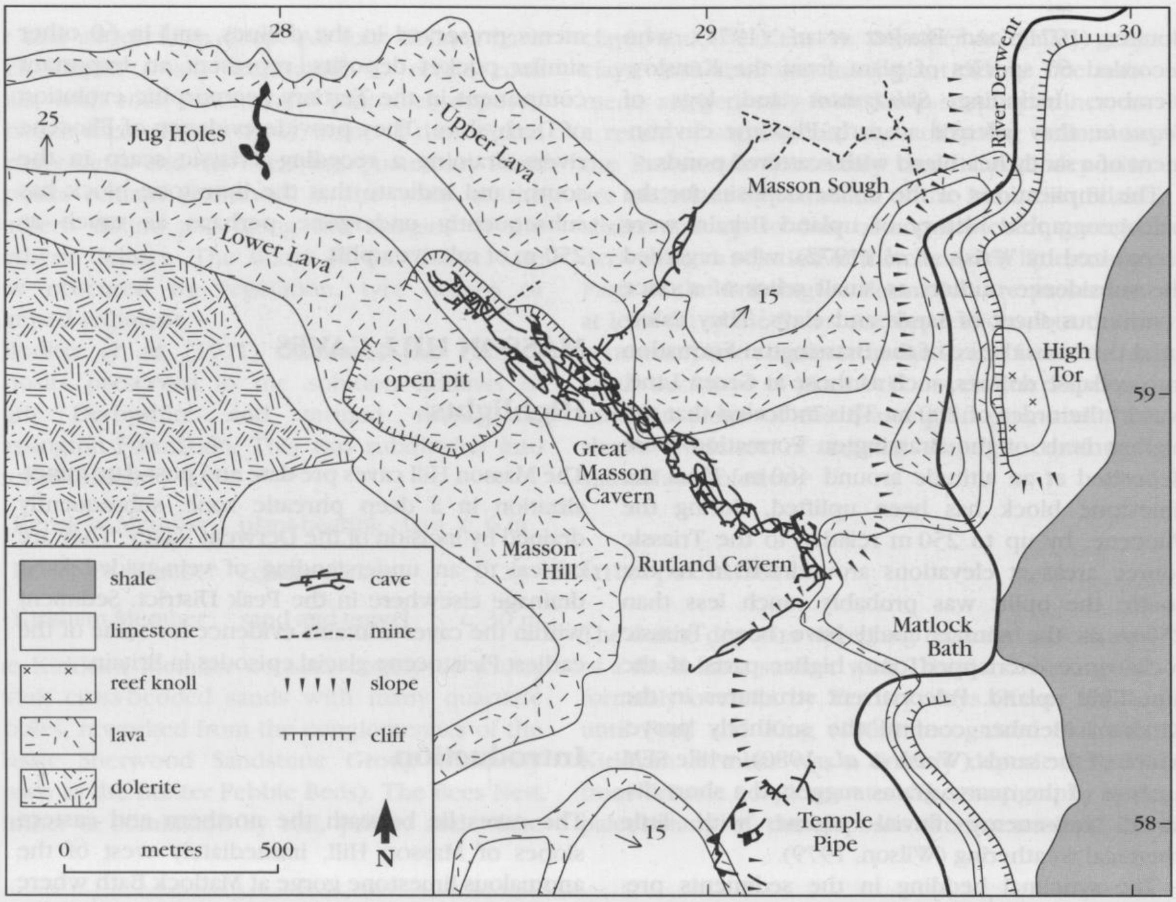

Figure 4.16 Geological map of Masson Hill and its cave passages, in relation to the Matlock Bath gorge. The mine workings in solid rock and the re-excavated natural caves are complexly interwoven; the symbols for cave and mine are generalized. The caves within the open pit have all been destroyed.

plunges steeply with the regional dip to the east. The carbonate sequence is broken by two basalt lavas – the Matlock Lower Lava and the Matlock Upper Lava – and by several thin wayboards of volcanogenic clay. Between the lavas, about 40 m of limestones contain the major caves.

Most of the known cave passages interconnect to form the Masson Cavern system, where pre- and post-mineralization phreatic solution caverns are linked by old mine workings into a single underground complex with more than 2000 m of natural passage (Figure 4.16). The north-western part of the system has been destroyed by surface mining on the hilltop, leaving two elongate networks, just separated by the open pit. One descends south-east, obliquely downdip, through Great Masson Cavern (Figure 4.17), and on to the disconnected fragment of Rutland Cavern; the other descends almost straight downdip, north-east to the old Masson and Ringing Rake Soughs at river level. Individual cave chambers are up to 20 m high or wide, and the whole cave system has a vertical range approaching 200 m.

Pre-mineralization caves are filled or lined with hydrothermal fluorspar and other minerals. Further solutional enlargement of these old caves by meteoric groundwater occurred in the late Tertiary and early Pleistocene, at the same time as new caves were formed. Much of the phreatic network has been filled with complex sediment sequences, comprising both locally derived vein minerals and also inwashed glaciofluvial material. Interbedded stalagmite layers are sparse, and evidence for a major vadose episode of cave excavation is lacking. Magnetostratigraphic analysis of sediment sequences in three separate parts of the system has established that fluvioglacial material was deposited during an interval of reversed magnetic polarity, indicating an age in excess of 780 000 years (Noel, 1987; Noel *et al.*, 1984).

Temple Pipe (Figure 4.16) shows similar pre-

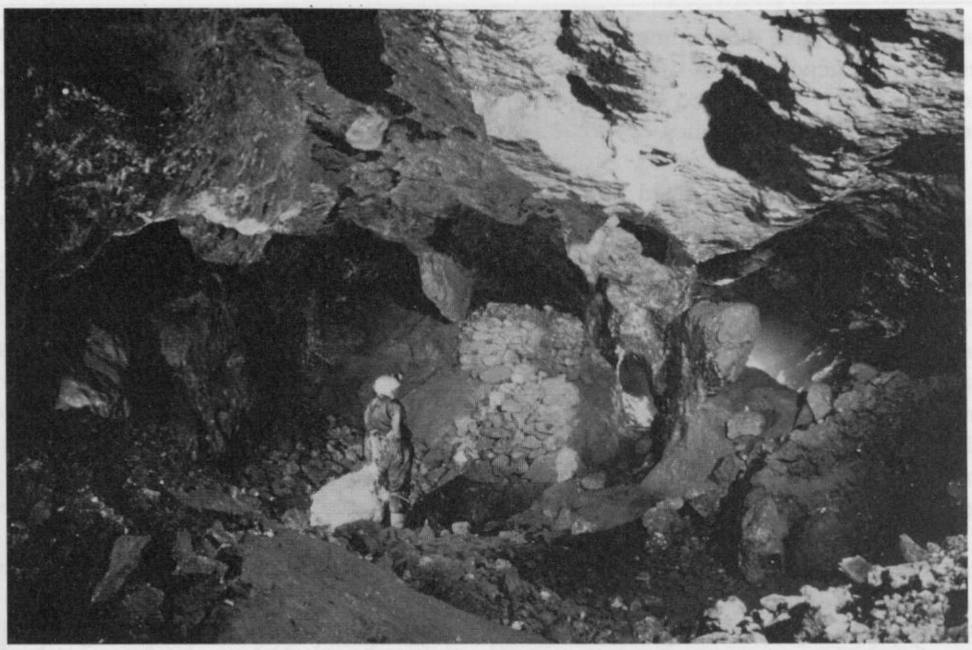

Figure 4.17 Ribs of limestone left around solution cavities which were filled and then re-excavated by miners in the Black Ox Mine workings in Great Masson Cavern. (Photo: T.D. Ford.)

and post-mineralization cavern development to that seen in Masson Cavern. Some excellent sediment sequences are preserved in its two fossil phreatic chambers; it is now a show cave. A number of other cave passages are intersected by the other mines in the area, of which the longest are in Devonshire Cavern.

Jug Holes (Figure 4.16) consists of an isolated series of phreatic cave chambers. These were formed by limestone solution both before and after the hydrothermal mineral infilling. Factors controlling cave development are clearly recognizable, and the site is typical of a Derbyshire pipe vein system. The cave was developed downdip in about 40 m of Asbian limestone sandwiched between the Upper and Lower Matlock Lavas; subsequently the cave has been partly filled with sediments, which were derived from the mineralized cave walls, from the lava flows, and from inwashed glaciofluvial material. There are extensive stalagmite deposits in parts of the cave; some of these rest directly on the altered top of the Matlock Lower Lava which forms the cave floor.

Interpretation

The three cave systems reveal a complex history, with the development of pre- and post-mineralization phreatic solution caverns separated by an episode of hydrothermal mineralization and a considerable timespan (T.D. Ford, 1964a, 1984; Ford *et al.*, 1977b; Worley and Nash, 1977). The earliest episode of cavern development was associated with the initial phase of hydrothermal mineralization in the late Carboniferous. Solution voids within the limestone were excavated by meteoric water which had travelled distances up to 100 km through Namurian clastic rocks at depth, where it was enriched in minerals before rising into the limestones on the Peak District block (Quirk, 1993). There is no definite evidence for limestone solution by locally derived meteoric water influence at this time. Many of these cavities were then filled partly or wholly with fluorspar and other hydrothermal minerals. Voids remaining within these veins, pipes and flats were then utilized by meteoric karst water as the limestone was exposed by erosion in late Tertiary and Pleistocene times; this new phase of solutional activity both enlarged some of the old caves and also developed new ones.

Cavern development was strongly influenced by the geology. The lavas acted as confining aquicludes, and the patterns of solutional opening were determined by the irregular dolomite/limestone interface, early diagenetic solution of the lower part of the limestone, the presence of several thin wayboard tuffs, and a NNE–SSW joint system. The presence of sulphide minerals may have contributed to cave development, by acting as a source for the generation of sulphuric acid, in the style now widely recognized as inception in karst limestones (Ball and Jones, 1990; Lowe, 1992).

Most of the caves were filled with both autochthonous and allochthonous sediment, prior to the downcutting of the River Derwent which caused the change from phreatic to vadose conditions. Chatter marks on the sand grains indicate a glacial meltwater origin for some of the allochthonous material, and the age of 780 ka indicates that they date from one of the pre-Cromerian cold stages (Noel *et al.*, 1984). There is little evidence for significant vadose modification following draining of the phreas. This suggests that the vadose stream phase was brief and overloaded with fluvioglacial sediment, quickly choking the system, perhaps indicating that it was directly associated with an episode of glacial incision. Since then the surface catchment has been insufficient to allow significant drainage into the cave system. The scarcity of speleothems probably reflects the position of the system beneath the Upper Lava aquiclude.

Conclusion

The Masson Hill site is the best example in Britain for demonstrating the relationships between mineralization of the limestone and cave development. It is important for understanding aspects of the hydrology of other cave systems associated with mineral veins, where the phreas remains largely inaccessible. Sediments in Masson Cavern include fluvioglacial material deposited during an episode of reversed magnetic polarity, more than 780 000 years ago. They are of comparable age to the material in the fissure caves of the Eldon Hill quarry, and are considerably older than most Pleistocene glacial deposits proven on the surface in Britain; these caves therefore provide incomparable evidence for the Pleistocene history of the area extending back beyond the Anglian glaciation.

DOVE DALE

Highlights

Dove Dale is perhaps the finest example in Britain of an allogenic river cutting through a limestone massif. It forms an extensive and spectacular gorge with many notable karst features, and admirably demonstrates the nature of fluvial erosion within a limestone terrain.

Introduction

The River Dove crosses the Carboniferous limestone outcrop in a deeply entrenched gorge. It maintains its flow over the entire limestone outcrop, a distance of 10 km, and provides a clear example of river superimposition onto a limestone outcrop. The river, fed by a large shale catchment, is too large to sink underground, and erosion has continued until the present. The gorge morphology shows excellent adjustment to the different lithologies and structures within the limestone, and the walls contain various karst features, including Dove Holes and Reynard's Cave.

Warwick (1953, 1964) first studied the geomorphology of the Dove and Manifold valleys. Ford and Burek (1976) discussed the importance of the geological structure and the position of reef-knolls in determining the river course. An overview is documented in Ford (1977a). Rowe *et al.* (1988b) and Atkinson and Rowe (1992) discussed the geomorphic evolution of the area and commented on the age of the relief using uranium-series dating of caves in the neighbouring Manifold valley. The caves in the valley sides are described in Gill and Beck (1991), and the area is described in a field guide by Ford and Gunn (1992).

Description

The River Dove maintains its course across the south-eastern corner of the limestone outcrop (Figure 4.1), cutting a meandering valley north to south up to 150 m below the limestone plateau level. The headwaters of the river lie on the Millstone Grit, and it flows onto the limestone at the head of Wolfscote Dale. For the next 10 km the river is deeply entrenched into the undulating limestone plateau, descending some 70 m to emerge from the mouth of Dove Dale (Figure 4.18). A series of tributary valleys, notably Biggin Dale and Hall Dale, feed from the limestone plateau into the main valley; all are now dry, and many hang above the main valley floor. The valley rim is characterized by sharp breaks of slope at levels around 300 m. The lower section of the valley sides are thickly wooded, but are broken by

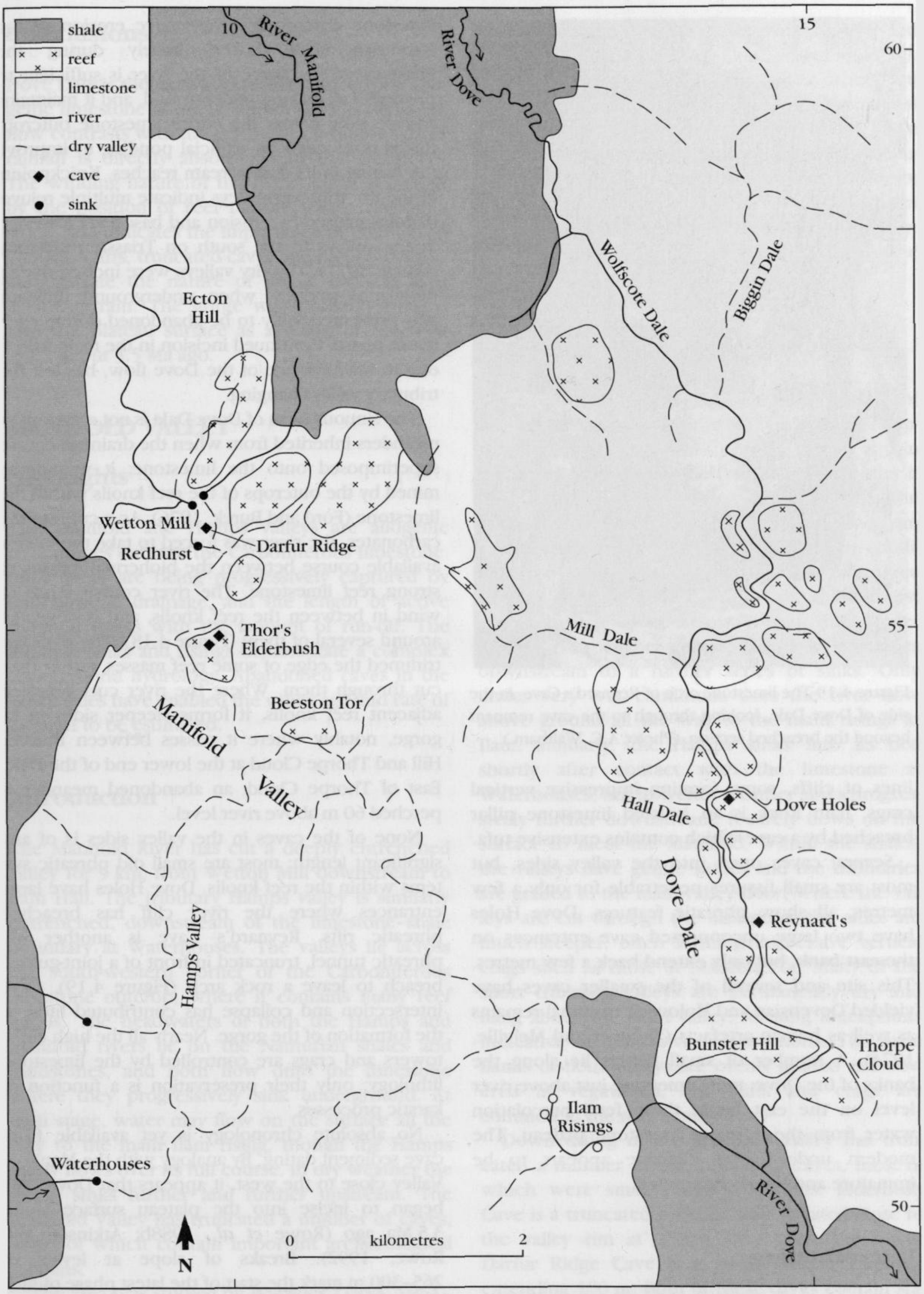

Figure 4.18 Geological map of the active and dry valley systems of Dove Dale and the Manifold River in relation to the reef knolls in the Carboniferous limestone (partly after Ford and Burek, 1976).

Figure 4.19 The limestone arch of Reynard's Cave, in the side of Dove Dale, looking through to the cave remnant beyond the breached section. (Photo: A.C. Waltham.)

lines of cliffs, some forming impressive vertical crags. Ilam Rock is an isolated limestone pillar breached by a cave which contains extensive tufa.

Several caves open into the valley sides, but most are small fissures penetrable for only a few metres; all show phreatic features. Dove Holes have two large unconnected cave entrances on the east bank, but only extend back a few metres. This site and several of the smaller caves have yielded Devensian and Holocene mammal remains as well as human artefacts (Spencer and Melville, 1974). A number of small risings lie along the banks of the Dove, most emerging just above river level on the east bank; these feed percolation water from the adjacent limestone plateau. The modern underground drainage appears to be immature and poorly integrated.

Interpretation

The gorge section of Dove Dale owes its origins to the superimposition of the River Dove onto the limestone outcrop by progressive erosion of the Namurian shale cover, largely during the Pleistocene. Discharge of the river is sufficient to prevent it all sinking underground, and it maintains surface flow across the entire limestone outcrop; this is now aided by artificial ponding to improve the fishing in its downstream reaches. Knickpoints in the dry tributary valleys indicate multiple rejuvenations, caused by erosion and base-level lowering in the valleys to the south on Triassic mudstone (Burek, 1977). The dry valleys were incised during periglacial periods, when underground drainage was prevented, only to be abandoned during each warm phase. Continued incision in the main valley, due to maintenance of the Dove flow, has left the tributary valleys hanging.

The sinuous form of Dove Dale is not a pattern of meanders inherited from when the drainage course superimposed onto the limestone; it was determined by the outcrops of the reef knolls within the limestone (Ford and Burek, 1976). As it cut into the carbonates, the river was forced to take the lowest available course between the biohermal masses of strong reef limestone. The river course tends to wind in between the reef knolls, and is deflected around several of them (Figure 4.18). The river has trimmed the edge of some reef masses, rather than cut through them. Where the river cuts between adjacent reef knolls, it forms steeper sides in its gorge, notably where it passes between Bunster Hill and Thorpe Cloud at the lower end of the Dale. East of Thorpe Cloud, an abandoned meander is perched 60 m above river level.

None of the caves in the valley sides is of any significant length; most are small old phreatic systems within the reef knolls. Dove Holes have large entrances where the river cliff has breached phreatic rifts. Reynard's Cave is another old phreatic tunnel, truncated in front of a joint-guided breach to leave a rock arch (Figure 4.19). Cave intersection and collapse has contributed little to the formation of the gorge. Nearly all the high cliffs, towers and crags are controlled by the limestone lithology; only their preservation is a function of karstic processes.

No absolute chronology is yet available from cave sediment dating. By analogy with the Manifold Valley close to the west, it appears that Dove Dale began to incise into the plateau surface about 3.5 Ma ago (Rowe *et al.*, 1988b; Atkinson and Rowe, 1992). Breaks of slope at levels of 265–300 m mark the start of the latest phase of incision into an older landscape of low relief (the '1000-Foot surface' of Clayton, 1979).

Conclusions

Dove Dale is the most spectacular and longest allogenic limestone gorge in Britain, and its allogenic flow contrasts with the dry tributary valleys where rainfall is directly absorbed into the limestone. The winding nature of the river course is guided by the position of reef masses within the limestone, and indicates the importance of lithological control. Cliffs, truncated caves and natural bridges demonstrate the nature of fluvial incision in a karstic terrain. The gorge was probably incised into the plateau surface as a result of renewed uplift about 3.5 Ma ago.

MANIFOLD VALLEY

Highlights

The Manifold and Hamps valleys are allogenic river gorges cut into the Carboniferous limestone. Both rivers are being progressively captured by underground drainage, and the length of active riverbed varies with the amount of run-off. The multiple sinks and risings demonstrate a complex underground hydrology. Abandoned caves in the valley sides have enabled the valley age and rate of incision to be estimated.

Introduction

The Manifold River has cut a deeply entrenched valley for 9 km, from Wetton Mill downstream to Ilam Hall. The tributary Hamps valley is similarly entrenched, downstream of the limestone–shale boundary at Waterhouses. The valleys lie across the south-western corner of the Carboniferous limestone outcrop, where it contains many reef knolls. The headwaters of both the Hamps and Manifold rivers lie on the Namurian shales and sandstones, and both flow onto the limestone where they progressively sink underground. At high stage, water may flow on the surface all the way to the main Ilam rising, though the Hamps rarely flows over its full course. In dry weather the water sinks further and further upstream. The Manifold Valley has truncated a number of caves, some of which contain important archaeological remains.

The area was studied by Warwick (1953, 1964), and Ford and Burek (1976) examined the role of the reef knolls in determining the form of the valley. The caves are discussed by Potts (1977), and are described by Gill and Beck (1991). Excavations at Elderbush Cave, among others, are described by Bramwell (1964, 1977). Sediments from the same cave and also Darfur Ridge Cave have been dated using uranium-series and paleomagnetic techniques (Rowe *et al.*, 1989b; Atkinson and Rowe, 1992) which give estimates for the rate of incision and the age of the valley. Ford and Gunn (1992) provide a field guide to the Manifold Valley.

Description

The headwaters of the Manifold drain an area of Namurian shales below the Millstone Grit escarpments. The river flows onto the limestone, and in dry conditions sinks at Wetton Mill, shortly after it encounters the first reef knoll. Downstream, the river bed may be dry for 9 km, as far as the Ilam risings (Figure 4.18). Under slightly wetter conditions the water continues to flow over the surface to sink by the Darfur bridge or at Redhurst Swallet, about 400 m below Wetton Mill. Under progressively higher stages, the flow continues downstream to a further series of sinks. Only under very wet conditions does the river flow above ground all the way to the main risings at Ilam. Similarly, the Hamps sinks into its bed shortly after contact with the limestone at Waterhouses, but in wetter weather sinks progressively further downstream; it rarely flows on the surface to meet the Manifold. Within the shales, the valleys have gentle slopes and the tributaries are graded to the main valley floor. Where the valleys are cut through the limestone, the sides are much steeper, often forming impressive vertical crags such as those at Beeston Tor. Many of the short tributary valleys are permanently dry and hang above the main valley, forming knickpoints indicative of successive rejuvenations. The main flanks of both valleys are evenly graded and covered in vegetation, but cliffs and crags are common in the reef limestones.

Downcutting of the Manifold Valley has truncated a number of old, high-level caves, most of which were small phreatic systems. Elderbush Cave is a truncated phreatic tube located close to the valley rim at 275 m OD, while the lower Darfur Ridge Cave is a small phreatic passage extending 100 m. Both of these caves contain stalagmites which have proved suitable for dating (Rowe *et al.*, 1988; Atkinson and Rowe, 1992).

Thor's Cave has a massive entrance, but its phreatic rifts reach back less than 50 m. There are more remnant rift caves in Beeston Tor. A new cave system is presently developing under the valley floor, gradually capturing the surface flow. Fragments of this system can be entered at a number of locations. Darfur Pot, just downstream of the main sink at Wetton Mill has 360 m of very flood-prone passage, while further downstream, Redhurst Swallet extends for some 280 m in a series of tight joint and tube passages (Potts, 1977). Ladyside Pot is another fragment where 450 m of passage extends under the river bed. All the water resurges at a series of large springs at Ilam Hall; diving in the main rising has revealed only 250 m of submerged passage reaching a depth of 54 m.

Interpretation

Remnants of former valley floors can be identified from knickpoints in the dry tributary valleys, Warwick (1953, 1964) used these to deduce that the valley had been deepened in six successive stages. This was almost certainly in response to base-level lowering in the valleys on the Triassic mudstone to the south, aided by more vigorous phases of downcutting during the Pleistocene cold phases. The influence of the limestone lithology is important, as the river course has been dictated by the position of the reef knolls (Ford and Burek, 1976). The river has been diverted round each reef, as at Beeston Tor and Thor's Cave Crag; other bends on the river, around Ecton Hill, have been influenced by the strong folding of the limestones. The sinuous course of the river was not superimposed from a former shale cover, as suggested by Warwick (1953); it developed as a result of lithological contrasts as incision progressed, concomitant with falling base levels to the south.

Nearly all the high-level caves are developed within the reef knolls, and they provide evidence of karst development which predates incision of the gorge. They represent earlier generations of caves developed at or below the contemporaneous valley floor, and are comparable to the phreatic system that is developing today beneath the river bed. To investigate the chronological development of the Manifold Valley, Rowe *et al.* (1988b) dated a suite of speleothems from Darfur Ridge and Elderbush caves using magnetostratigraphic and uranium-series methods. Uranium-series dating proved the stalagmite from Elderbush Cave to be older than 350 ka, while the presence of reversed-polarity stalagmite overlying normally magnetized stalagmite indicated a minimum age of 1.87 Ma. Elderbush Cave appears to have been drained by downcutting in the Manifold Valley, by or soon after 2.0 Ma. The cave lies 110 m above the present river bed, giving a maximum rate of valley incision of 5.5 cm ka^{-1}. Similarly, Darfur Ridge Cave was shown to be about 300 ka old, and gave an incision rate of 4.1 cm ka^{-1}. Extrapolation of these rates to the plateau surface at 265–300 m OD leads to the tentative estimate that valley incision began in the Pliocene about 3.5 Ma ago (Atkinson and Rowe, 1992).

The modern hydrology of the Hamps and Manifold valleys is complicated. The multiplicity of sinks and risings makes the underground flow patterns very complex. The resurgences at Ilam consist of 12 separate springs, which appear to have different catchment areas. The lowest two springs discharge only autogenic percolation water, while the next three are fed by the Manifold sinks. The Hamps water emerges from the Upper rising (taking about 3–6 days to flow from Waterhouses). Dye tracing has shown that the flow is transmitted via a complex conduit system, but with no mixing of the Hamps and Manifold waters (Ford and Gunn, 1990). The Hamps drainage system falls about 70 m over 4 km, which suggests there may be a significant vadose component, and is close to total underground capture. The underground Manifold drainage has a lower gradient, is more likely to be phreatic, and is less mature in that it is less able to transmit flood flows.

Conclusions

The two limestone valleys of the Manifold and Hamps provide fine examples of allogenic river gorges undergoing progressive capture by a developing underground drainage network. The river beds can be active or dry depending on stage, and the karst hydrology of the area is complex with a multiplicity of sinks and risings. Knolls of strong reef limestone defined the sinuous course of the Manifold Valley as it was entrenched into the karst plateau. The valley has truncated earlier cave development, recording a history of incision spanning about 3.5 Ma.