Ingleborough caves

[SD 71 73]–[SD 74 78]–[SD 77 76]–[SD 75 71]

Highlights

The caves of Ingleborough include examples of almost every type of cave morphology. They include the finest group of deep potholes and shafts in the country, as well as the largest cave chamber and the highest waterfall in Britain. The caves form a complex and varied system of underground karstic drainage, which is an essential component of the spectacular glaciokarst of the Ingleborough surface landscape.

Introduction

Ingleborough forms a magnificent block of karst between Chapel-le-Dale, Ribblesdale and the Craven Fault scarp (Figure 2.1). It has a plateau, nearly 10 km across, formed on the top surface of the Great Scar Limestone at an altitude of about 400 m, with a central summit mass of shales, sandstones and thin limestones rising to 723 m (Figure 2.13). The summit rocks belong to the Yoredale facies of the Wensleydale Group, except for the Namurian grit cap. The Great Scar Limestone is a strong, fine-grained, massive carbonate with bedding planes mostly 0.5–5.0 m apart and commonly marked by thin shale horizons; it ranges in age from Arundian to Asbian, and is about 200 m thick. Most of the Ingleborough limestone dips 1–3° north, but the south-eastern sector has many shallow folds and local dip variations; it is well jointed and there are many small faults with mainly horizontal displacements. The base of the limestone is a marked unconformity over the folded and faulted, impermeable rocks of the Lower Palaeozoic; ridges and valleys on the buried pre-Carboniferous surface create over 30 m of local relief on the unconformity.

The drainage of Ingleborough is essentially radial. Streams off the shale outlier sink into the limestone all round the margin, and over 250 caves are recorded. Underground drainage from the larger sinks continues the radial pattern, except for deflections of the cave conduits in response to the immediate geology. There is some convergence of underground drainage, most of which feeds to ten major resurgences; most of these lie on or close to the basal unconformity, and the largest are marked on (Figure 2.13).

Though the caves of Ingleborough are important components of an important karst, the inhospitable nature of the deep, cold shafts has limited the extent of detailed scientific studies in them. Descriptions of nearly all of the known caves on Ingleborough are given in Brook *et al.* (1991), and are summarized in Waltham (1974a). The more comprehensive descriptions of individual caves and areas include those of White Scar Cave (Waltham, 1977b), the Meregill area (Brook and Crabtree, 1969b), Chapel Beck (Monico, 1995), Alum Pot (Milner, 1972), the Allotment potholes (Booth, 1905; Brodrick, 1905; Griffiths, 1927) and the Gaping Gill area (Brindle, 1949; Patchett, 1953; Glover, 1974; Ford, 1975; Beck, 1984). The geology and geomorphology of the Gaping Gill caves were considered in detail by Glover (1974), and the geomorphology of the Ingleborough karst was reviewed by Waltham and Tillotson (1989) and Waltham (1990). Particular features of the cave geology have been discussed by Halliwell (1979b), Halliwell *et* al. (1975) and Waltham (1970, 1971b, 1977a). The chronology of cave development, based on speleothem dates, and its relationship to landscape evolution has been discussed by Waltham and Harmon (1977), Atkinson *et al.* (1978), Gascoyne and Ford (1984), Gascoyne *et al.* (1983a, b) and Waltham, (1986, 1990). The underground drainage was determined by a programme of water tracing by Carter and Dwerryhouse (1904), and further aspects of the cave hydrology were discussed by Pitty (1974), Richardson (1974), Waltham (1977b) and Halliwell (1980).

Description

More than 55 km of cave passages are known within the Ingleborough limestone. The radial drainage pattern has caused these to form a series of discrete caves, and there is no integration into large dendritic systems comparable to those of Ease Gill and Kingsdale. Furthermore, the caves within the different sectors around the Ingleborough summit mass have

considerable contrasts between them, imposed by local variations in the geology and topography. The influent caves lie all round the perimeter of the shale outlier (Figure 2.18), and fall into groups which are largely defined by their shared resurgences. No long drainage routes have yet been followed from sink to rising, and most known caves reach only from a sink to a sump at the head of a phreatic conduit.

Caves of White Scars

The limestone bench between Chapel-le-Dale and Crina Bottom is named after its extensive, bare pavements and scars (Figure 2.13). Much of it is drained by White Scar Cave, which carries water from sinks in Crina Bottom to the resurgence exit in Chapel-le-Dale (Figure 2.19); it has 6500 m of mapped passages, and is operated as a show cave as far as the Battlefield Chamber. Except for a few high avens, all the known cave is developed in the lowest 30 m of the Great Scar Limestone; Ordovician slates form the floor of the passages to the resurgence and the show cave entrance, and also at a small cascade up the Far Streamway. The main stream emerges from the flooded tubes of the Phreatic Series, and drains over a knickpoint cascade into a fine streamway canyon which is continuous to the cave exit. Deep lakes are ponded behind sediment banks and collapse debris from avens, and there are numerous small inlets. The tube from the Phreatic Series continues as a roof tube over part of Far Streamway, creating a splendid keyhole cross-section; it then turns away to the west where the dry passage is heavily choked. Sleepwalker is an old phreatic tributary, now drained and carrying an underfit stream from choked sinks in Crina Bottom. Just downstream of the Sleepwalker junction, the old phreatic tunnel diverges from the line of the streamway; it continues on the west side for 150 m, beyond which it is choked with sediment. Further north, the Battlefield is a large old chamber whose collapsed floor has been partly undermined by the modern streamway; it is part of an isolated segment of abandoned trunk cave 20 m above stream level. All the abandoned passages contain thick deposits of sand and mud; straw stalactites, stalagmites and flowstone are spectacular in many parts and also in sections of the streamway (Figure 2.20). Stalagmites from the Battlefield and Sleepwalker passages have been dated to over 350 ka (Gascoyne and Ford, 1984), while flowstone from the roof of Far Streamway has an age of 225 ka (Atkinson *et al.,* 1978).

Floodwaters which overflow the Sleepwalker sinks in Crina Bottom go underground at Rantry Hole, and are joined by some drainage from Newby Moss before resurging at Skirwith Cave (Figure 2.18). They pass through old, choked tunnels beneath Crina Bottom and then into the kilometre of small streamway known in Skirwith Cave.

At the head of Crina Bottom, Quaking Pot has a series of narrow, immature, vadose canyons and shafts, aligned along a fault. This drains into a meandering streamway which reaches a depth of 143 m, where it has invaded an older, largely choked, chamber on a fault; the water is next seen in White Scar Cave. The next large sink to the north is Tatham Wife Hole, where a deep, meandering, vadose canyon intercepts the Tatham Wife Fault; the rest of the cave consists of tall, inclined rifts developed along the fault, and it drains to Granite Quarry Rising.

Caves around Meregill Hole

Meregill Hole takes the largest sinking stream on the Chapel-le-Dale flank of Ingleborough (Figure 2.13). Its entrance is a fault-guided rift 50 m long and 5 m wide, with vertical walls dropping 15 m to The Mere, a perched lake 25 m deep. The lake outlet is into a tall rift passage, which extends south-east under the shale margin and drops 120 m down a series of shafts developed along a fault (Figure 2.21). The stream canyon then drains north, down the dip of its bedding plane roof. At a level of 225 m, this drains into bedding controlled phreatic tubes which rejoin and continue through the lower, flooded passages of Roaring Hole. Black Shiver Pot has a long upper series of low bedding-plane passages, leading to joint-guided cascades and a massive vadose shaft dropping 90 m' down a fault. From the foot of the shaft, the streamway follows the bedding planes again, passes through a flooded section, and becomes a tributary to the lower streamway in Meregill Hole. Roaring Hole has a sequence of rifts and canyons descending steeply to join the flooded conduit from Meregill Hole.

Directly above the deep bedding plane caves of Meregill's lower level, a parallel series of caves drain downdip along the bedding planes and shale beds near the top of the limestone. These include Hallam Moss Cave, Sweetwater Hole and Sunset Hole (Figure 2.21). The Sunset stream canyon can be followed into a complex of chambers modified by collapse and fill beneath the large old doline of Braithwaite Wife Hole.

A series of influent caves lies further north along the shale margin (Figure 2.18). Knacker Trapper Hole has narrow stream canyons leading to a large fault-controlled rift which descends to the south-west, against the dip, to a perched sump at a depth of 98 m; some high-level chambers are well decorated with calcite stalactites. Another stream cave drains into the shaft of Hardrawkin Pot. Sinks at Middle Washfold Cave and Southerscales Pot feed long streamways which converge on the large collapsed pothole of Great Douk Cave, where the downstream route is lost in narrow fissures and collapse debris. Keld Bank Sink is one of a series of small, shallow caves which eventually drain to the perched risings at Eller Keld. Round the northern tip of Ingleborough, the caves are young and immature; Gauber Pot feeds Batty Wife Cave through passages too small to be followed.

Caves of Chapel Beck

Chapel Beck crosses the limestone at the head of Chapel-le-Dale and its course is normally dry between the main sink at Haws Gill Wheel and the resurgence at God's Bridge (Figure 2.18). An almost completely flooded cave system has over 4 km of active phreatic conduits, beneath a surface channel which carries only floodwater.

Weathercote Cave, Jingle Pot and Hurtle Pot are all shafts in or beside the river bed. In Weathercote Cave, the main flow drops from a high-level bedding cave, down a waterfall and into rifts and collapsed bedding caves descending to sump pools; the other two are normally dry windows into the phreas, whose water surface is at 225 m. The phreatic conduits downstream of Jingle Pot mainly follow the limestone bedding, which rises gently to the south; joints provide the alignment of some sections, cause enlargements on cross rifts, and guide some sections into phreatic loops which reach depths of 30 m.

The main Chapel-le-Dale conduit is known from Jingle Pot to Midge Hole, south of which it may continue under the west bank (Figure 2.22). A complex overflow route lies at shallow depth in the northern part of Joint Hole, where it joins a deeper route from the east carrying water from sinks high on the limestone bench. Chapman's Rising and Meregill Skit are flood outlets from the main submerged trunk routes, which continue to the perennial God's Bridge resurgence.

Caves around Alum Pot

Alum Pot is a massive open shaft, 30 m long, 10 m wide and 70 m deep, developed on a minor fault. From its foot a tall rift follows the fault north into a chamber, with a sump pool in its floor. The flooded passage has been followed for 385 m, along the fault and then north-east at depths of up to 25 m. The resurgence is through the floor of Turn Dub, a sediment-choked pool on the far side of the River Ribble (Figure 2.13). Footnaw's Hole is a pool in the alluviated valley floor west of the Ribble, and appears to be a flooded window into the conduit from Alum Pot to Turn Dub; it normally swallows minor local drainage, but it produces large outflows in flood conditions.

Except after heavy rain, little water enters the open shaft of Alum Pot. The main streams of the area drain into youthful vadose caves less than 10 m below the surface. Borrins Moor Cave is a shallow dendritic system fed by several sinks, which drains into the Upper and Lower Long Churn Caves, and then into Diccan Pot (Figure 2.23); the four caves are separated by short unroofed and collapsed sections of the stream course. The main passages are splendid vadose canyons with clean, scalloped walls and floors of pale limestone; these are cut beneath the wide roofs of initial, shallow elliptical openings etched out of thin shale beds (Figure 2.24). They drain downdip until they meet the Mum Pot fault; in Diccan Pot, the active streamway drops 100 m down a series of spectacular waterfall shafts into the lower chamber of Alum Pot.

Washfold Pot lies further north (Figure 2.18) and also drains beneath the river to Turn Dub. A stream sinking at the shale margin flows northeast, down the dip, for more than 300 m in a shallow vadose canyon, before descending a series of vadose shafts; these are developed obliquely down a major fracture, as far as a flooded shaft 10 m above resurgence level.

Potholes of the Allotment

On the eastern flank of Ingleborough, the Allotment contains a group of deep and spectacular potholes, largely developed on minor faults in the limestone close to the shale margin (Figure 2.18). They all descend steeply to sumps at or close to the level of Austwick Beck Head, their common resurgence on the base of the limestone in Crummack Dale. Flow to the resurgence is obliquely updip, largely along flooded bedding caves.

Nick Pot lies on the Sulber Nick Fault; it has a complex of short entrance rifts which descend 20 m, and then open onto a shaft 10 m in diameter and 100 m deep dropping to a sump. In the adjacent shakehole, Hangman's Hole has a series of rifts and shafts descending the same fault obliquely to the east. Juniper Gulf is a magnificent pothole with a long fissure entrance, deep rifts, massive shafts and fine underground waterfalls, all developed on a vertical fault. Slasher Hole is an adjacent system of narrower rifts on another fault.

Rift Pot has a sequence of deep shafts developed on a brecciated fault zone with slickensides visible on the rift walls. Long Kin East Cave has a long, meandering, vadose canyon with a shale bed roof just below ground level; this ends at a 60 m underground waterfall into the main chamber of Rift Pot. The outlet from the chamber is a series of bedding-plane passages extending east of the fault to a sump perched 14 m above the level of Austwick Beck Head. Also on the Rift Pot fault, Jockey Hole is a dry 75 m deep shaft from daylight, and Lizard Pot is a rift system reaching a depth of 90 m.

Marble Pot lies at the end of a spectacular blind valley cut in thick glacial till. The cave below consists of a series of partially choked rifts and shafts connected by bedding caves, but was blocked in 1980 by a massive collapse of the till slopes rising over the entrance. Marble Sink is entered from an adjacent shakehole, and its very narrow rifts and canyons lead to some tall chambers extensively choked with collapse debris and glaciofluvial fill; these are probably part of the old choked passages below Marble Pot.

Gaping Gill Cave System

Gaping Gill Hole is the best known pothole in Britain, and is the sink for Fell Beck, the largest stream on Ingleborough. Its water falls 110 m down the Main Shaft, forming Britain's highest waterfall. The shaft is about 10 m in diameter, until half way down where it breaks through the roof of the Gaping Gill Main Chamber; this is the largest known cave chamber in Britain, 140 m long and 30 m high and wide (Figure 2.25). Under normal flow conditions the water sinks into the floor of the chamber, and is not seen again in the northern part of the cave system, but a network of largely abandoned passages extend to the south and east.

The cave system of Gaping Gill has over 16 km of mapped passages, including inlets from five other entrances and a route through to the old and new resurgences at Ingleborough Cave and Clapham Beck Head (Figure 2.26). The main passages form a low-level distributary system spreading out from the Main Chamber; nearly all are abandoned phreatic tubes, developed into rifts along some of the faults in the limestone. Probably the oldest passage is the highest route, through the large muddy tunnels of East Passage, Mud Hall and part of Car Pot; a branch at a lower level continues through Whitsun Series, and may relate to the tubes of Far Waters. Another old route heads south and joins fault guided rifts and tubes including Sand Cavern; clastic sediment chokes many of the outlets, but they may once have continued through to Mountain Hall. Between these two old . trunk routes, Hensler's Passage starts as a remarkable bedding cave; it is over 300 m long, mostly 5 m wide and all less than 1 m high. This leads to a large entrenched vadose canyon, and an abandoned high-level which continues as the Far Country phreatic network.

A complex of shafts and chokes in the Far Country drops to a series of active phreatic tubes carrying the water from the Main Chamber. These drain into the Inauguration Series of Ingleborough Cave, then into partially flooded bedding caves and totally flooded rifts through to the gently descending streamway in Beck Head Stream Cave, and out to the Clapham Beck Head resurgence. One abandoned distributary leads to daylight through the old phreatic tubes of Ingleborough Cave, now accessible as a show cave, and another emerges at Foxholes.

There are few passages above or below the main network which forms a series of levels stepping down only 70 m in total from the Main Chamber to the resurgence. Stream Passage and Disappointment Pots have fine streamways and shafts from active stream sinks. Car, Bar and Flood Entrance Pots are largely abandoned inlet systems. Various shafts reach below the main cave level, but are flooded windows into the phreas that hides the main conduit at an unknown depth for

most of its route from the Main Chamber.

Some of the larger chambers and fault rifts have been modified by collapse and are choked with breakdown debris. Many of the old, abandoned, phreatic tubes contain thick clastic deposits, and some sections are well decorated with calcite flowstone and dripstone. Stalagmites from East Passage have been dated to periods of deposition at about 230–>350 ka, 37–50 ka and 10–15 ka, and material from Far Country dates from 114–135 ka (Gascoyne *et al.,* 1983a, b; Gascoyne and Ford, 1984). Stalagmite on top of the varved sediments in Sand Cavern is only 800 years old.

Grange Rigg Pot has a small, descending streamway unconnected to Gaping Gill but also draining to Clapham Beck Head. Above it, the blind valley of P5 feeds a shaft system into Grange Rigg, and also a separate small streamway into a complex of abandoned phreatic tunnels (Figure 2.26). Hurnell Moss Pot has a vadose shaft dropping 65 m into a section of very large, ancient, phreatic tunnel along a fault (Figure 2.18).

Potholes of Newby Moss

The south-west corner of Ingleborough contains over 20 caves characterized by deep vertical shafts developed on faults, with almost no horizontal passages (Figure 2.18). Long Kin West is the deepest, and the foot of its second great shaft is choked by breakdown at a depth of 168 m. Grey Wife Hole and Newby Moss Pot contain short lengths of canyon passage, but neither reaches a depth of 100 m. Lying further east on Hurnell Moss, the short passage fragment of Newby Moss Cave contains flowstone dated to over 350 ka (Gascoyne *et al.,* 1983a, b; Gascoyne and Ford 1984). Most water sinking on Newby Moss resurges from Moses Well, but flood flows emerge from Cat Hole (Figure 2.18), and some appears in Ingleborough Cave; sinks west of Long Kin West drain into White Scar Cave.

Interpretation

The cave systems of Ingleborough are many and varied, and between them provide fine examples of almost every feature of underground morphology. Most notable are the many cave features that demonstrate the clear influences of geological guidance.

Stratigraphic control of cave inception and development is evident in both the vadose and phreatic passages in many of the caves. Many bedding planes within the limestone succession contain thin partings of shale, and the downdip vadose streamways guided by these are major elements in many cave systems. Meregill Hole provides the finest example, in the parallel formation of vadose canyons close to the surface and more than 100 m down in the main drain. The Long Churn streamways into Alum Pot provide some of the best and most easily accessible examples of shallow vadose canyon passages in Britain. The only long vadose streamway out to a resurgence is in White Scar Cave, because the limestone basement is exposed in a dale side downdip of the sinks, and there is no high basement ridge to create ponding within the aquifer. The active phreatic tubes below Chapel Beck largely follow bedding horizons updip, and the old drained phreatic tubes in White Scar Cave can be seen to follow the bedding, but also step up joints to change horizons.

Some bedding planes contain no shale, and purely lithological contrasts within the carbonate sequence can provide horizons of cave inception. The most conspicuous of these is the Porcellanous Band, formed by less than 1 m of very fine-grained micritic limestone. Many of the old trunk passages in Gaping Gill lie just above this band, and Hensler's Passage lies directly on top of it, forming the longest and most spectacular bedding cave in Britain.

The buried topography of impermeable rocks, expressed in the local relief on the unconformable base of the Great Scar Limestone, has influenced groundwater flow and cave development in the lowest beds of the karst aquifer. Most of the current main resurgences lie at or close to the basal unconformity, and the flooded caves behind God's Bridge are a feature of both the updip drainage direction and the ponding behind a ridge in the basement rocks (Waltham, 1990). The resurgence from White Scar Cave is on the unconformity, but the cave passages inside are nearly all perched on shales and bedding planes in the limestone above the basement (Waltham, 1977a, b); phreatic inception of nearly all the caves minimizes the gravitational flow of groundwater to the limestone floor except where the aquifer is fully drained close to the valley resurgence site. Where underground drainage has to pass over impermeable basement ridges, horizons which just clear these become the favoured inception lines; a basement ridge beneath Clapham Bottoms probably accounts for the

perching of the Clapham Beck Head and Ingleborough Cave passages (Glover, 1974).

The limestone of Ingleborough is broken by numerous minor faults, some of which contain breccia zones up to 1 m thick; there are also many major joints with no recognizable displacement. Both types of fracture influence the morphology of the caves. Vertical shafts are conspicuous on the fractures; they include those of Alum, Nick and Rift Pots, Long Kin West and the Main Shaft of Gaping Gill. A steeply dipping fault also appears to guide the sloping roof of the Gaping Gill Main Chamber where it cuts away south from the Main Shaft. Other caves are developed obliquely down the faults along sequences of rifts and shafts; Juniper Gulf and Meregill Hole are the best examples of this type. Many horizontal passages are formed along fracture/bedding intersections; the lower reaches of Tatham Wife Hole are a clear example, and many of the old conduits in Gaping Gill are guided in this style.

An understanding of the chronology of cave development under Ingleborough is complicated by the contemporaneous development of many discrete conduits; these drained to disparate resurgence sites, each subject to its own cycles of surface lowering and karstic rejuvenation. The Pleistocene climatic cycles and glaciations provided common links, but the geomorphic histories of many caves are independent of their neighbours. A number of older caves may be recognized by their sink entrances away from the retreating shale margin. These include Alum Pot and Great Douk Cave, both 500 m from the shale cover. Newby Moss Cave contains stalagmite dated to >350 ka (Gascoyne and Ford, 1984); it lies almost at the modern shale margin, and is unlikely to have formed beneath the shale cover. These sites therefore indicate greater erosion and slope retreat on the north side of Ingleborough, exposed to the Pleistocene ice flows from the north; the lack of old cave passages in the limestone around Ribblehead may be a consequence of a complete shale cover until removal by glaciers in the late Pleistocene (Waltham, 1990). The clean vadose canyons are the youngest caves, but many of them appear to have origins which predate the last glaciation, as modern rates of passage entrenchment (Gascoyne *et al.,* 1983a) are too low for their development entirely within the last 13 000 years.

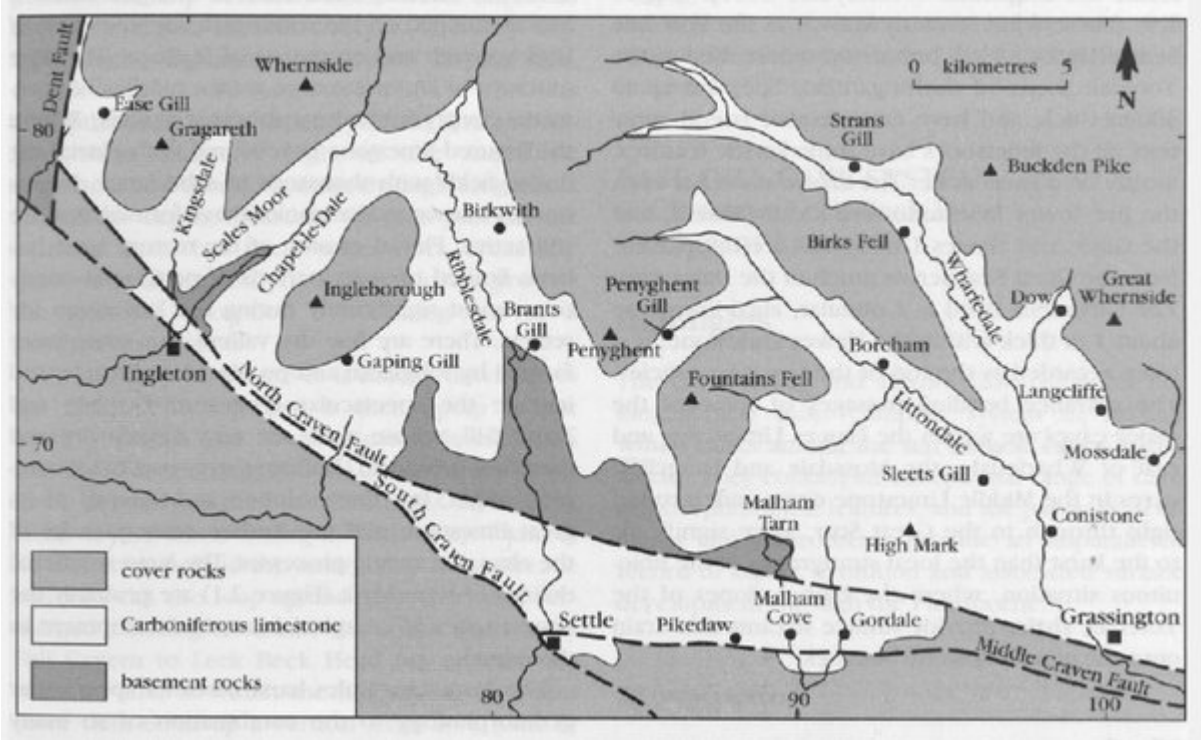
The Battlefield passages in White Scar Cave may be remnants of an ancient trunk cave beneath an ancestral Chapel-le-Dale at higher level, perhaps analogous to the modern Chapel Beck caves, and resurging against the North Craven Fault. Stalagmites, dated to over 350 ka, were formed after the phreatic route was largely drained and abandoned. Flowstone from the roof of the main streamway has an age of 225 ka, and must have been above the contemporary resurgence level in Chapel-le-Dale. The levels of the old passages in White Scar Cave indicate a maximum of 0.35 m/ka of valley floor lowering in Chapel-le-Dale, since the caves were drained (Waltham, 1986).

The very old abandoned phreatic passages of the Gaping Gill Cave System, with their thick sediment sequences and stalagmite layers, may prove to contain the most complete record of Pleistocene climatic change and landscape modification in the Yorkshire Dales. However, the evolution of this complex network of abandoned passages has only been assessed in outline (Glover, 1974), and stalagmite dating has only shown that some passages are older than 350 ka (Gascoyne *et al.,* 1983a, b; Gascoyne and Ford 1984), when they are probably much older. Interpretation of the Gaping Gill geomorphology is made more difficult by the strong geological controls, by faults and a thin band of stratigraphical levels, so that past resurgence levels are not easily recognized in a complex profile of deep phreatic loops. Old outlets from the Gaping Gill caves may include Bar Pot (as a vauclusian rising), the roof passage over Mountain Hall (Figure 2.26), a depression in the Foxholes valley (Figure 2.15) and the floors of Clapham Bottoms and Trow Gill, but all are obscured by debris and collapse. Gaping Gill appears to be one of the older caves in the Yorkshire Dales karst, but its history remains largely unknown.

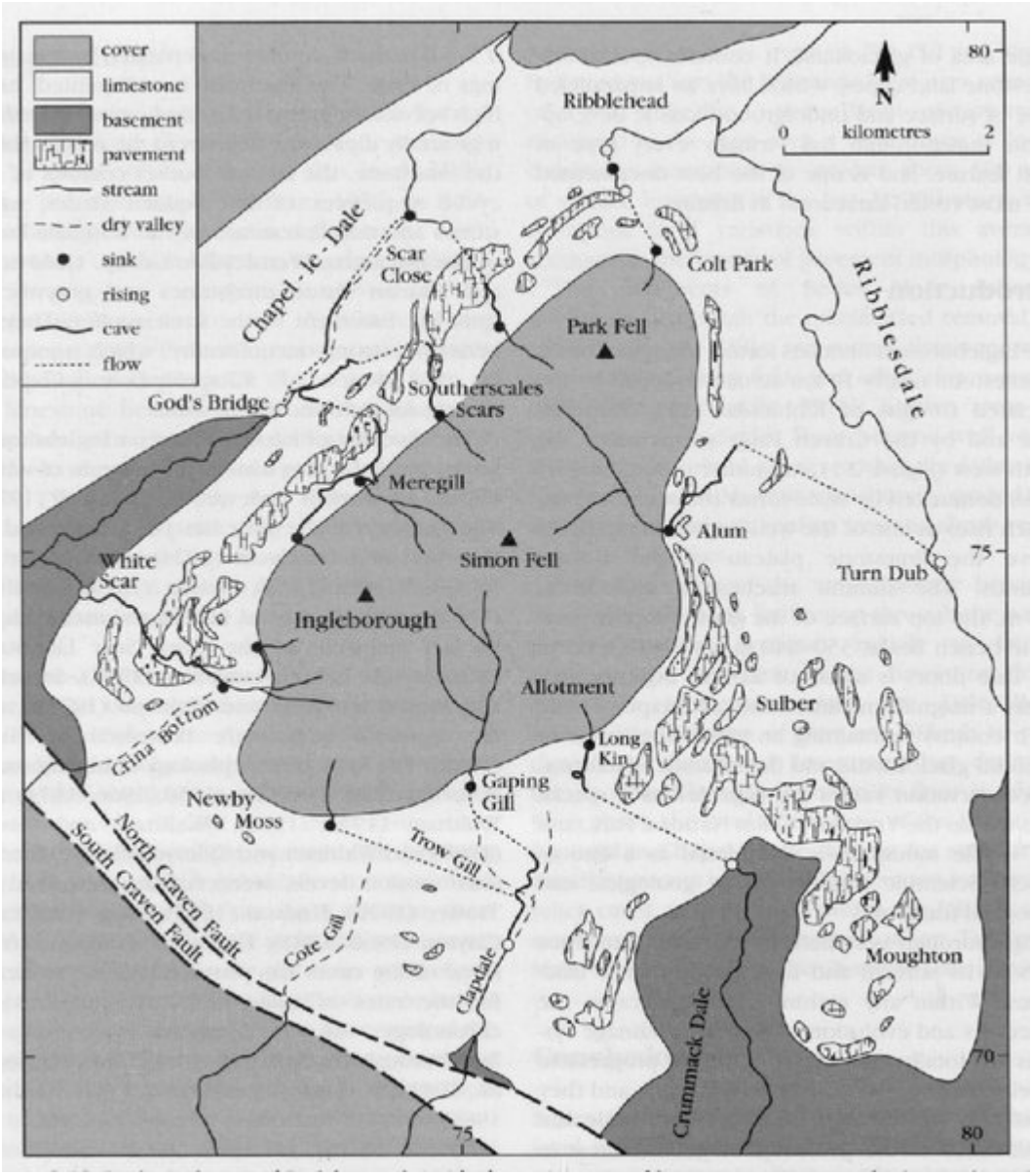
Conclusion

Ingleborough provides Britain's finest example of cavernous karst, as it has not only a spectacular suite of surface landforms but also an excellent range of associated caves. As a teaching site it is without parallel, and many of the individual features are classics of their type. The cave morphology is strongly influenced by many geological factors, and the many deep shafts are the clearest expression of fracture control of cave development. Gaping Gill is among the best known karst landforms in Britain, and its cave system may span a time range longer than any other in the Yorkshire Dales karst.

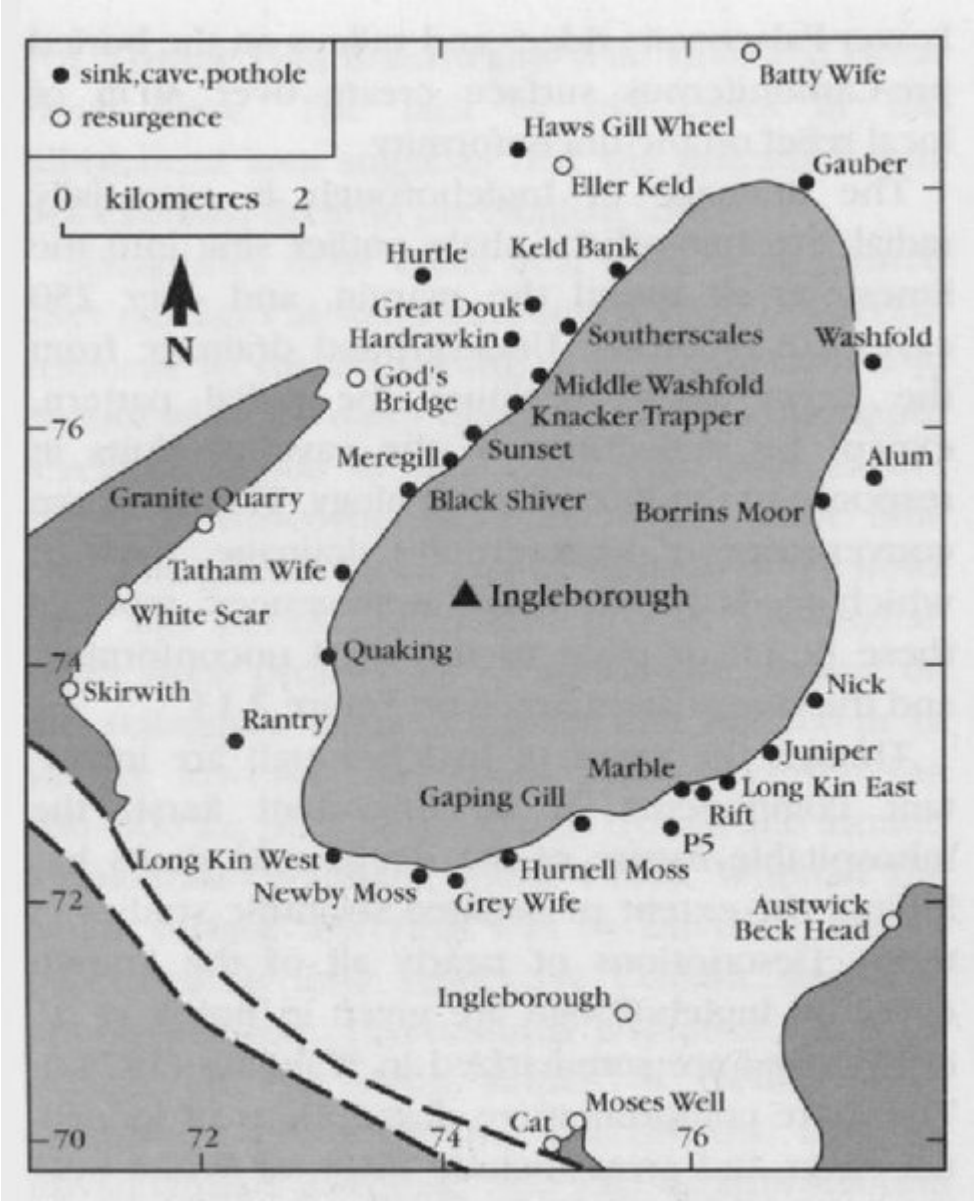
References



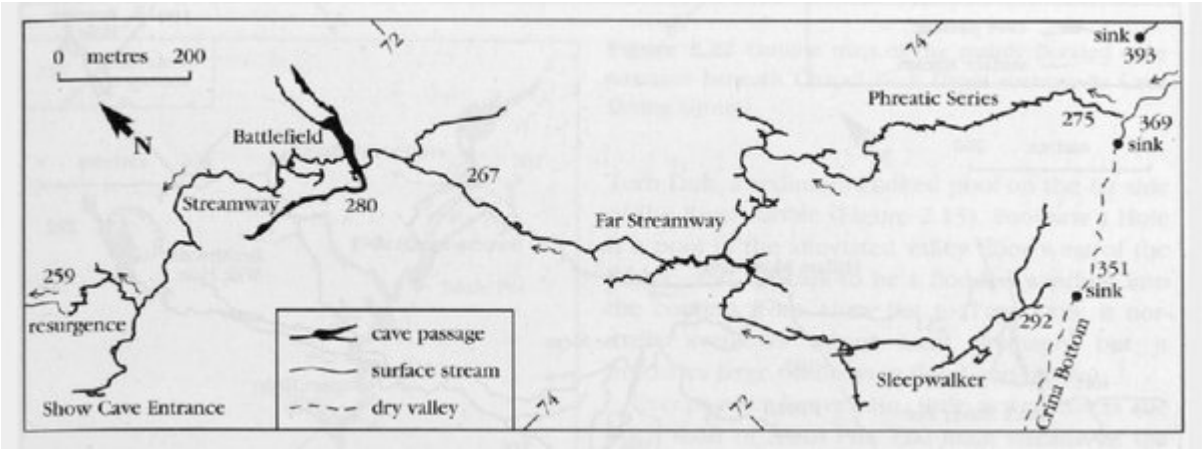
(Figure 2.1) Outline map of the Yorkshire Dales karst, with locations referred to in the text. The Carboniferous limestone shown includes all the Great Scar Limestone (Kilnsey, Cove and Gordale Formations) and also the lower Yoredale limestones (of the Wensleydale Group) where they are hydrologically linked to the Great Scar and are therefore part of the same karst unit. Higher limestones within the Yoredale Series are not marked. Basement rocks are Palaeozoic slates and greywackes. Cover rocks are the Yoredale facies of the middle and late Brigantian Wensleydale Formation and various Upper Carboniferous and Permian clastic formations.



(Figure 2.13) Geological map of Ingleborough, with the main areas of limestone pavement, the larger dry valleys and some of the main underground drainage routes. The limestone is the Great Scar Limestone, including the Hawes Limestone. Cover rocks are various clastic units and thin limestones in the Wensleydale Group and the Namurian Millstone Grit Group, and Upper Carboniferous clastics south of the Craven Faults. Basement rocks are Palaeozoic slates and greywackes. The only pavements marked are those of good or excellent quality (as defined by Waltham and Tillotson, 1989).

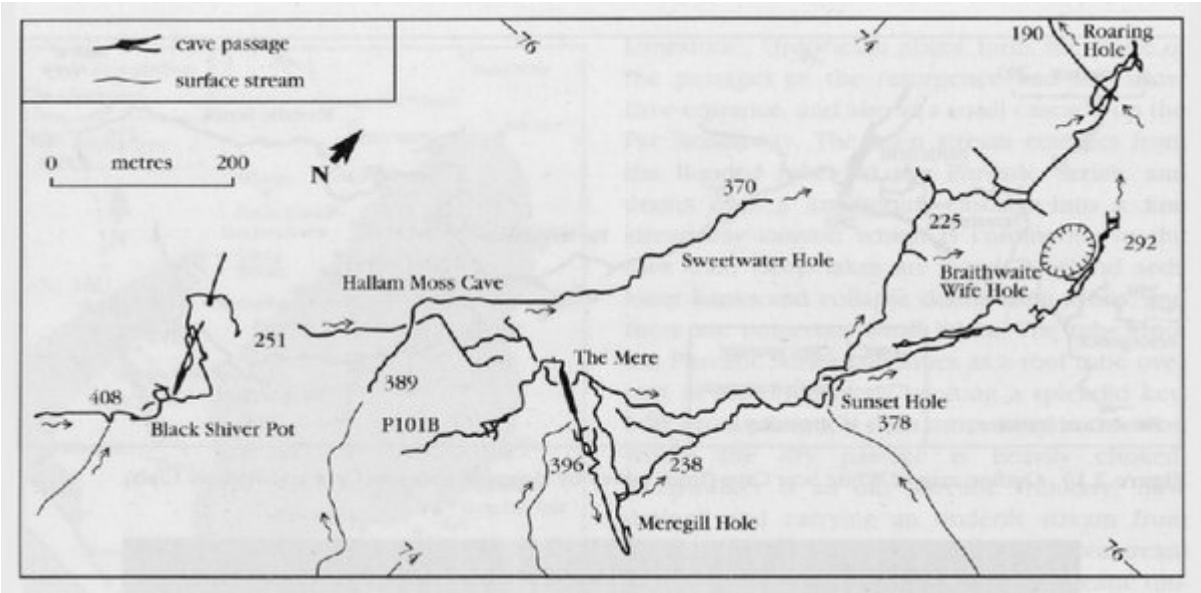


(Figure 2.18) Outline map of Ingleborough, with locations of the main caves referred to in the text. Geology as in Figure 2.13.

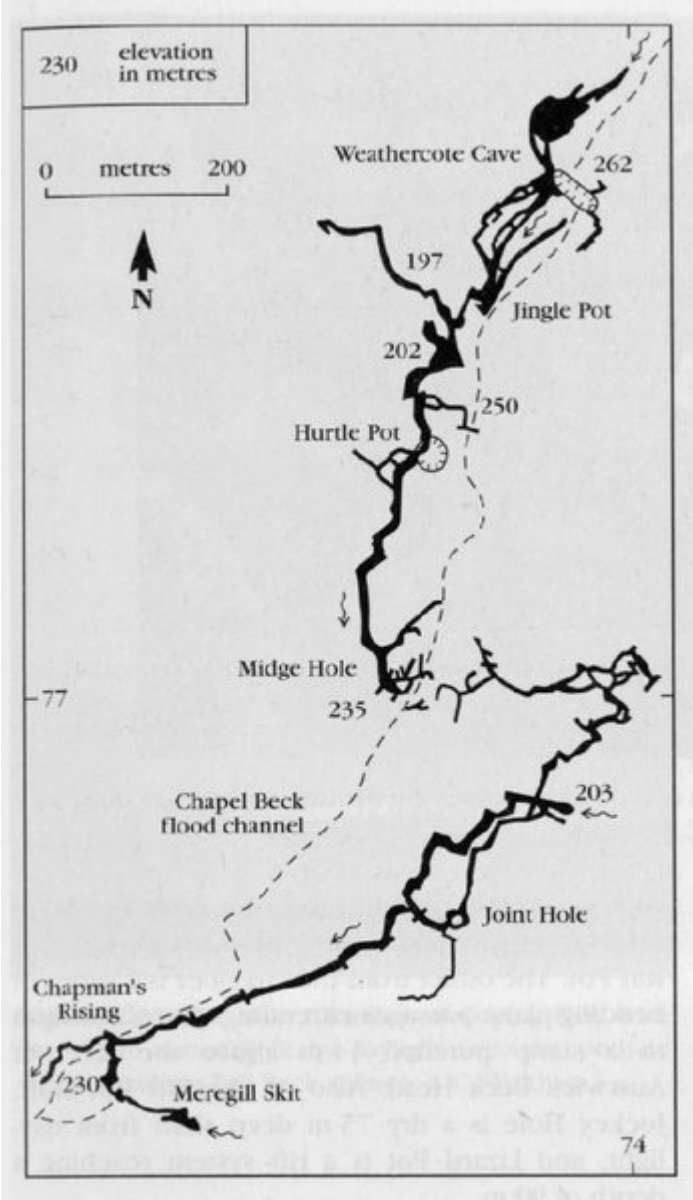


(Figure 2.19) Outline map of White Scar Cave (from survey by Happy Wanderers Cave and Pothole Club).

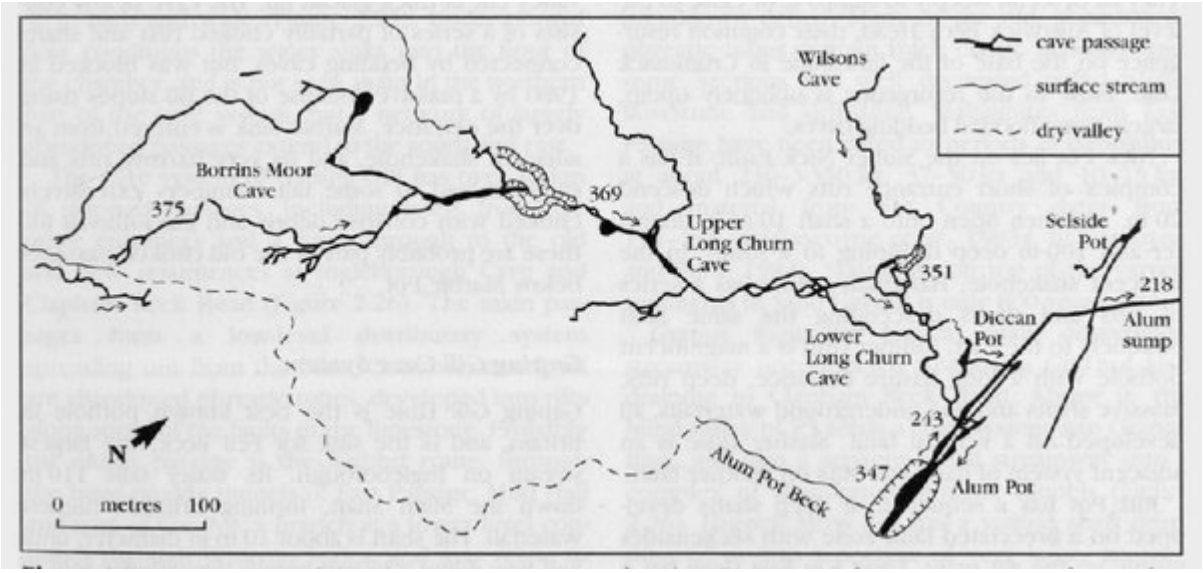
(Figure 2.20) Long calcite straw stalactites in the Far Streamway of White Scar Cave. (Photo: A.C. Waltham.)



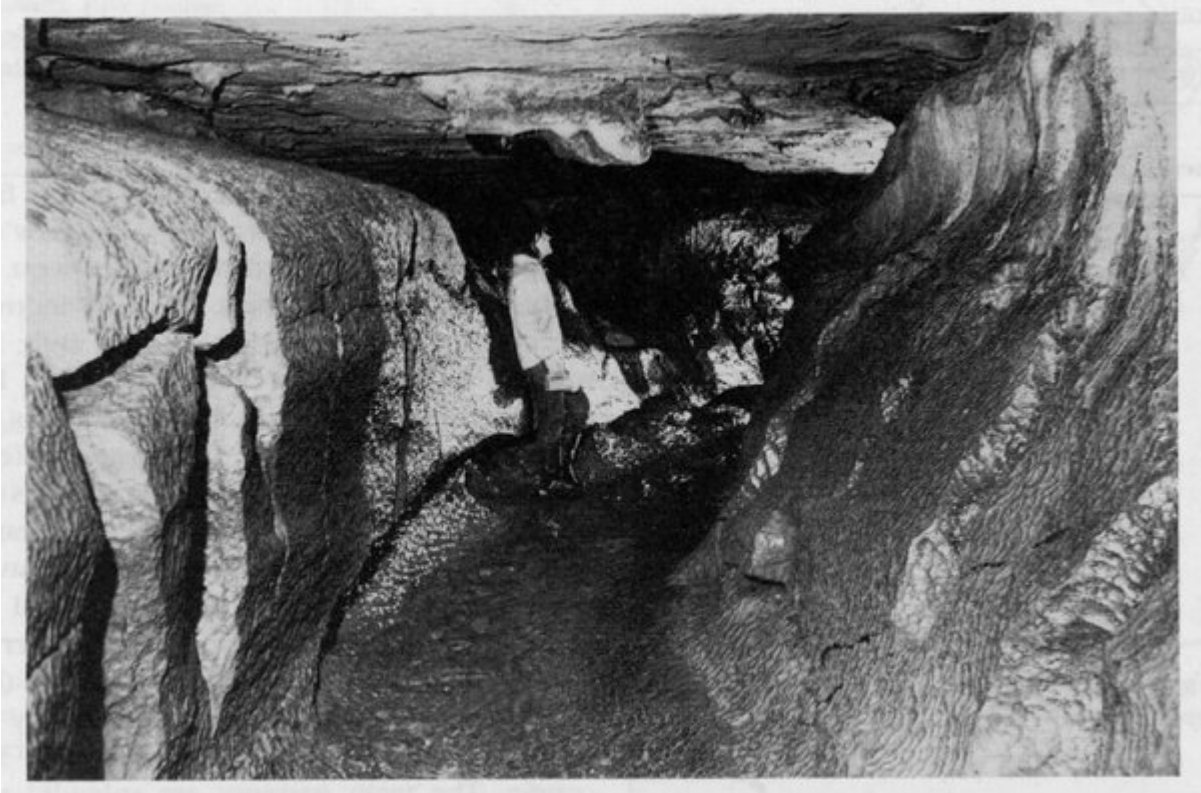
(Figure 2.21) Outline map of the cave systems of Meregill Hole; the flooded passage downstream of Roaring Hole is known to continue for another 300 m. Numbers given refer to elevation in metres (from surveys by University of Leeds Speleological Association).



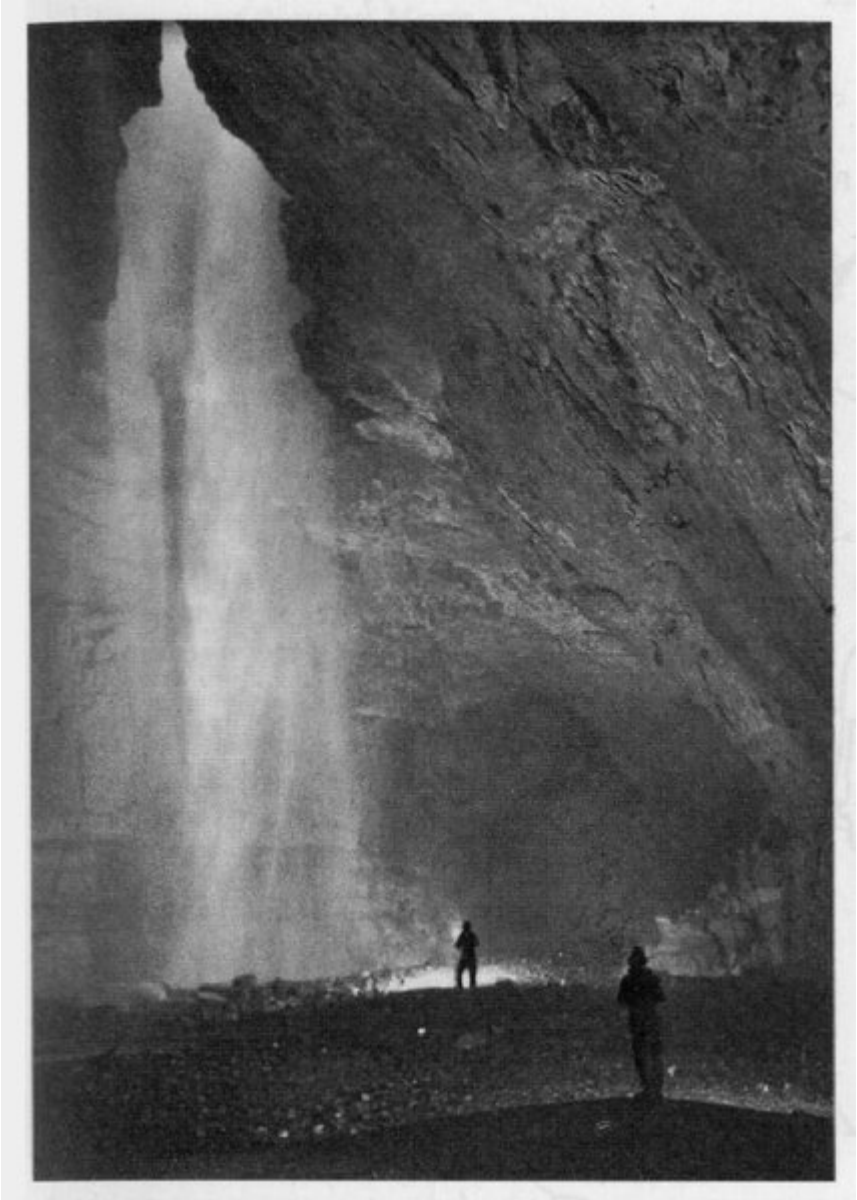
(Figure 2.22) Outline map of the mainly flooded cave passages beneath Chapel Beck (from surveys by Cave Diving Group).



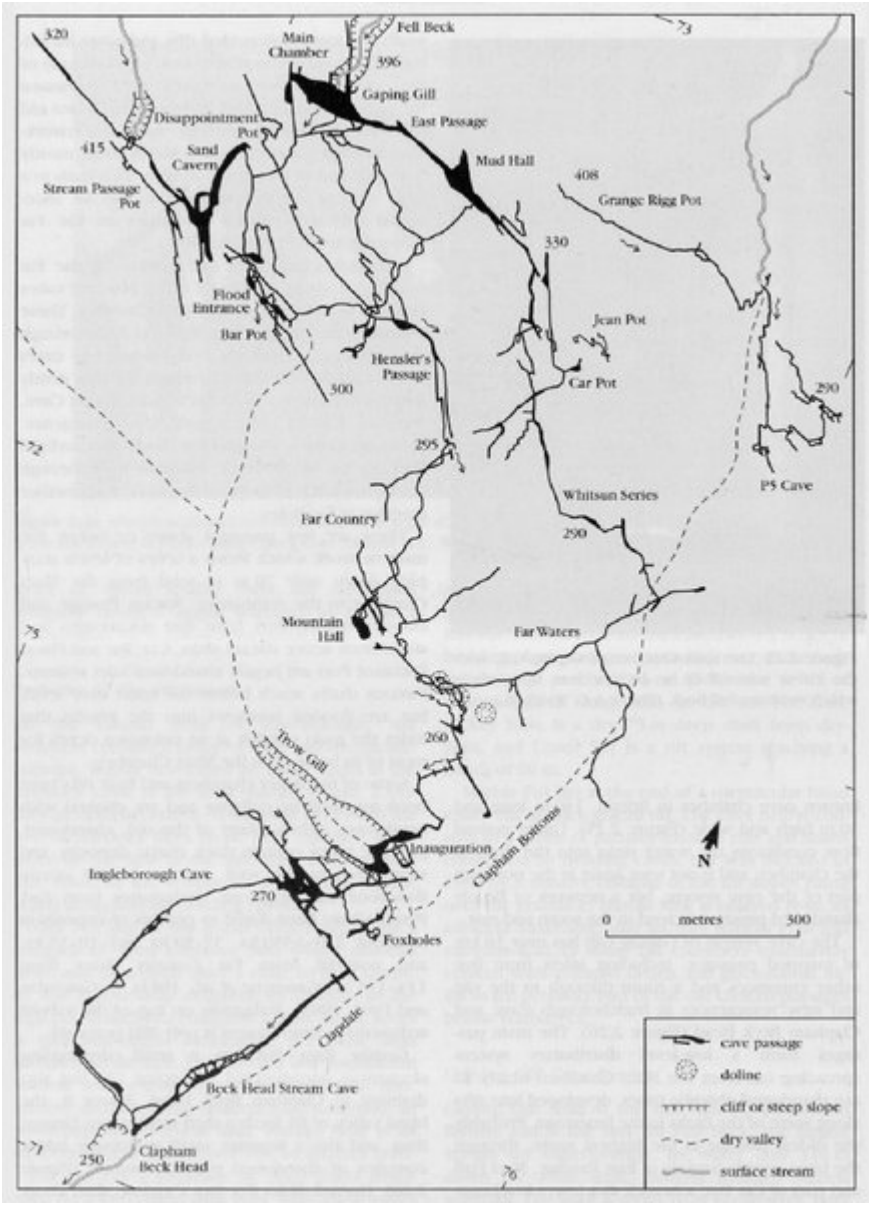
(Figure 2.23) Outline map of the Alum Pot cave system; the Alum Pot sump is known to continue for another 220 m beyond the margin of this map (from survey by University of Leeds Speleological Association).



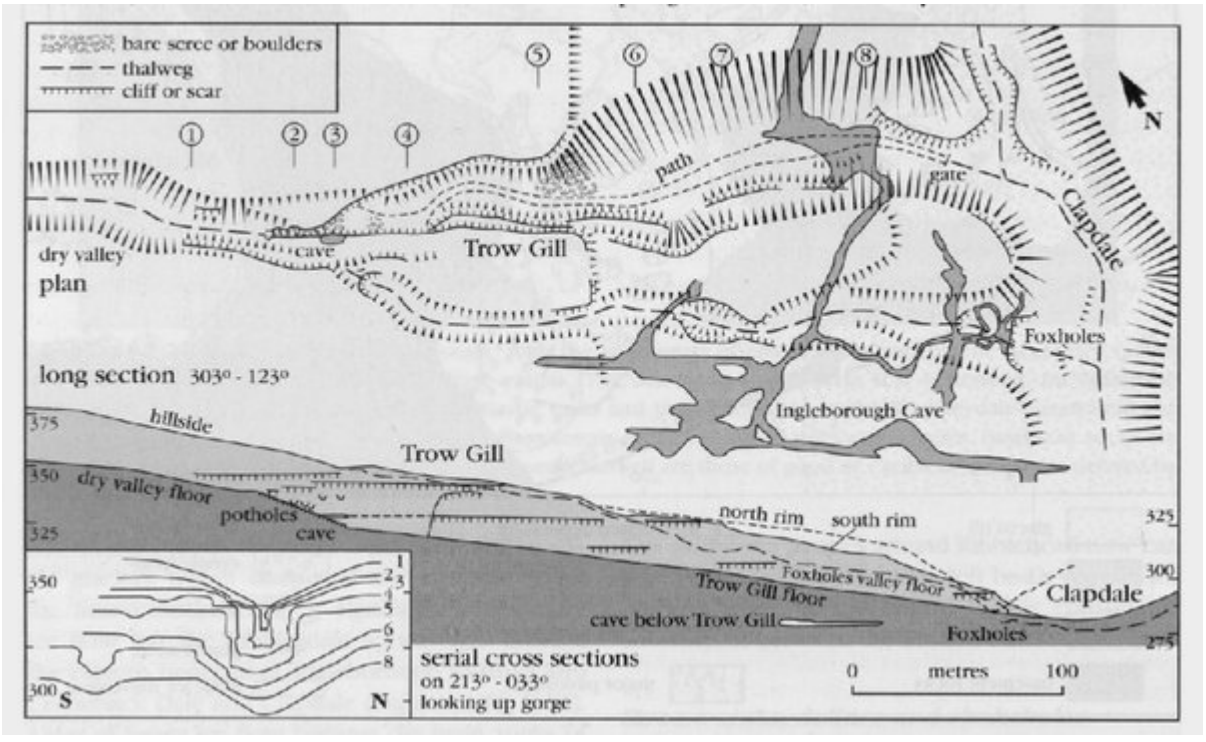
(Figure 2.24) Sharply scalloped limestone forms the walls of the vadose canyon cut beneath the bedding plane roof in the streamway of Upper Long Churn Cave. (Photo: A.C. Waltham.)



(Figure 2.25) The Main Chamber of Gaping Gill, with the 110 m waterfall lit by daylight from the pothole which swallows Fell Beck. (Photo: A.C. Waltham.)



(Figure 2.26) Outline map of the Gaping Gill Cave System, including the passages of Ingleborough Cave and Car Pot. Figures given represent elevation in metres. (From surveys by Bradford Pothole Club and many others.)



(Figure 2.15) Topographic map and projected long profiles of Trow Gill and the underlying caves. Some cave passages have been omitted to improve clarity, and all the caves lie below the level reached on the serial cross-sections; the thalweg down Trow Gill lies along the centreline of the path (from Waltham, 1990).