Karst and Caves of Great Britain

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Chapter 6

Karst in Wales

INTRODUCTION

Carboniferous limestones have outcrops in various parts of both North and South Wales, but most of the significant karst and cave development is located in the narrow outcrop of limestone, known as the North Crop, which fringes the northern side of the South Wales coalfield. This outcrop is over 100 km long, though seldom more than 2 km wide (Figure 6.1). Within its sinuous belt and under the adjacent grit cover, a number of limestone caves include the deepest and many of the longest systems in Britain. Though the area is not distinguished by dramatic limestone landscapes and spectacular karst landforms, it does contain a turlough and an extensive interstratal karst with some large doline fields, both features which are not well represented elsewhere in Britain.

Stratigraphically the limestones of the North Crop range through much of the Dinantian, within the Lower Carboniferous, but erosional and non-depositional breaks mean that the full sequence is not found in any one section. The full thickness of the exposed carbonates varies from 120 m to 150 m along the outcrop (Ramsbottom, 1973; George *et al.*, 1976; Wright, 1986a; Barclay *et al.*, 1988; Barclay, 1989; Lowe, 1989b). All are of shelf facies, consisting of micrites, sparites, bioclastic limestones and oolites, and some horizons are extensively dolomitized. Most are well bedded, and they contain many thin shale, mudstone, sandstone and palaeosol horizons, the latter overlying shallow zones of palaeokarstic features (Wright, 1982, 1986b).

The North Crop limestones are underlain by the Lower Dinantian Lower Limestone Shale; this rests, with only slight unconformity, on the sandstones and shales of the Devonian, which rise northwards to form the escarpments of the Brecon Beacons and Black Mountain. In some places the limestone is capped by a thin Upper Dinantian shale. Elsewhere this is cut out, and the strong, coarse-grained Basal Grit, of Namurian age, rests directly on the limestone. The permeability of this caprock has been responsible for the extensive interstratal karst which distinguishes much of the North Crop with its doline fields formed in the grit.

Along the North Crop, the limestone dips gently

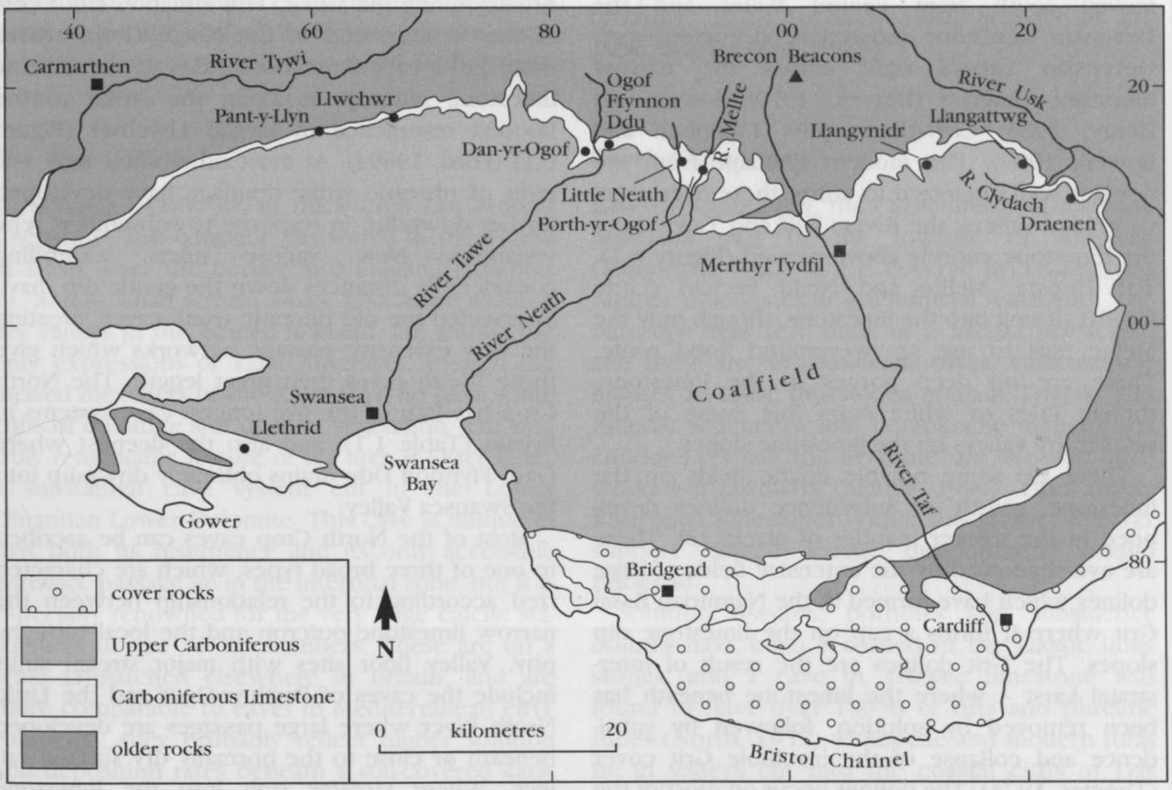

Figure 6.1 Outline map of the karst areas around the perimeter of the South Wales coalfield, with locations referred to in the text. The cover rocks in the south are Triassic and Jurassic mudstones and thin limestones.

south into the coalfield syncline. Dips are generally less than 15°. Numerous north–south faults cross the outcrop, and there are local zones of more severe disturbance, orientated SW–NE, with major faults and steep folding (Lowe, 1989b).

The karst of the North Crop

Surface karst features are not conspicuous components of the limestone landscapes of South Wales, and there is none of the spectacular landmarks which distinguish the Carboniferous limestones in much of England. This is partly because the limestone is surrounded by topographically prominent sandstones which lie stratigraphically both above and below. Much of the limestone outcrop is little more than a line of scars backed by a narrow dip slope and overlooked by the scarp face of the strong Namurian Basal Grit.

The limestone outcrops were subjected to glaciation during the Devensian, but limestone pavements are developed on only a few of the interfluves where the dip is low; much of the karst is now veneered with till, and limestone pavements are not extensive (Thomas, 1970). Ice moved south from central Wales and the Devonian sandstone mountains, deepening pre-Devensian valleys right across the narrow limestone outcrop (Bowen, 1970: Bowen and Henry, 1984; Crowther, 1989; Campbell and Bowen, 1989). The modern drainage from the north is well organized to utilize these deep, gently graded valleys; the Rivers Taff and Tawe cross the limestone entirely above ground (Figure 6.1). The Hepste, Mellte and Nedd Fechan (Little Neath) all sink into the limestone, though only the Mellte fails to use an overground flood route. There are no deep gorges in the limestone, though lines of white scars line some of the smaller dry valleys on the limestone slopes.

There are some notable doline fields on the limestone, mostly of subsidence dolines developed in the thicker mantles of glacial till. These are overshadowed by the extensive fields of large dolines which have formed in the Namurian Basal Grit where it forms a cap on the limestone dip slopes. The Grit dolines are the result of interstratal karst – where the limestone beneath has been removed by solution, followed by subsidence and collapse of the insoluble Grit cover (Thomas, 1974). The dolines occur on most of the Grit plateaus immediately south of the limestone outcrop of the North Crop, with the finest on Mynydd Llangynidr; they are unmatched anywhere else in Britain.

The caves of the North Crop

The most important feature of the North Crop drainage is the southward flow off the higher slopes of Devonian Old Red Sandstone in the north. Though the limestone outcrop is only narrow, its position across the regional trend of slope and surface drainage allows it to capture very large supplies of allogenic water. Where a valley outlet exists in the same bed, the favourable hydraulic gradients through the limestone have created conditions ideal for cave development. Compared with the Yorkshire Dales karst, the caves of South Wales are few in number, but those that do exist are notably long and deep (Ford, 1989a).

A characteristic of many North Crop caves is that allogenic water sinks into them at or near the stratigraphic base of the limestone. The immediate underground drainage is then downdip, until the contemporary water table is reached close to the level of the adjacent valley breaching the limestone outcrop. Phreatic flow then develops broadly along the strike. This situation still exists at the western end of the North Crop, where drainage, locally from both sides of the narrow limestone outcrop, is along the strike to the flooded resurgence of Llygad Llwchwr (Figure 6.1) (Ford, 1989a). At most other sites, new systems of phreatic strike drainage have developed further downdip, in response to subsequent rejuvenations. New vadose inlets, extending considerable distances down the gentle dip, have intersected the old phreatic trunk caves, creating the very extensive passage networks which give these Welsh caves their great length. The North Crop has four of the five longest cave systems in Britain (Table 1.1), and also the deepest where Ogof Ffynnon Ddu drains obliquely downdip into the Swansea Valley.

Most of the North Crop caves can be ascribed to one of three broad types, which are characterized according to the relationship between the narrow limestone outcrop and the local topography. Valley floor sites with major stream sinks include the caves of Porth-yr-Ogof and the Little Neath River where large passages are developed beneath or close to the normally dry surface valleys. Where streams sink into the limestone outcrops high on the major interfluves, caves develop down the hydraulic gradient and obliquely to the adjacent valley floor; the caves of the Swansea Valley are of this type, and the contrasting patterns of Ogof Ffynnon Ddu and Dan-yr-Ogof reflect a relationship between geological structure and valley orientation. The third cave type underlies the gently sloping Grit plateaus, and carries drainage from sinks in the marginal limestone outcrop on the higher, updip side through to risings in the lower side; the caves of Llangattwg have this pattern, where the lower edge of the gentle dipslope has been trimmed by recession of the Clydach Gorge.

The sheer size of the North Crop caves give them a special place in any review of Britain's karst. They also have an exceptional diversity of passage morphology and depositional detail, and their long Pleistocene histories are recorded in their complex passage networks.

The karst and caves in outlying areas of Wales

Apart from the North Crop, the Carboniferous Limestone forms outcrops scattered across North and South Wales. They all have their own distinctive limestone sequences, structure and karst features, but the surface landforms and the caves are more limited in scale than those of the North Crop.

The Wye Valley

Carbonates nearly 300 m thick crop out around Chepstow, and continue eastwards to the Forest of Dean, over the border into England (Chapter 7). A few small stream sinks, and some shallow dry valleys in the farmed lowland, are almost the only expressions of karst processes, though the incised meanders of the River Wye do have some cliffs of dolomite shrouded in vegetation. The one truly remarkable feature of the area is Otter Hole, a substantial cave system cut in the Lower Dinantian Lower Dolomite. This cave is unique in that both its resurgence and its only accessible entrance passage lie in the intertidal zone, but it is especially renowned for the very large calcite stalagmites in one of its chambers. These are on a scale unmatched elsewhere in Britain, and are more comparable to caves in Mediterranean environments; they probably reflect higher solution and deposition rates beneath a soil-covered karst further south and at lower altitude than other major caves in Britain's Carboniferous Limestone.

The Gower Peninsula

The limestones along the southern margin of the main South Wales coalfield syncline have been broken into two fragments by the coastal incursion of Swansea Bay. The western fragment forms the Gower Peninsula, and contains the only notable karst features. The Dinantian limestones thicken to the south and west in South Wales (Lowe, 1989b), and Gower has a sequence of pure limestone more than 400 m thick. Hercynian compression increased along the syncline towards the west; the limestone was steeply folded, and now forms a series of narrow outcrops between belts of sandstone.

Dry valleys cross the limestone outcrop where drainage is underground. The known caves are mainly small, but there are some larger old chambers; these could be remnants of more extensive pre-Devensian cave development which is also responsible for some recent collapse features in the Bishopton Valley (Ede and Bull, 1989). A number of caves open in the coastal cliffs of Gower; Bacon Hole and Minchin Hole, both on the southeast coast, are very old solution cave fragments, now most notable for their extensive sequences of Pleistocene sediments and archaeological material (Stringer, 1977; Sutcliffe, 1981; Stringer *et al.*, 1986; Bowen *et al.*, 1989).

South Glamorgan

East of Swansea Bay, the Carboniferous Limestone underlies part of the lowland of southern Glamorgan. Much of it is covered by Triassic and Jurassic mudstones or glaciofluvial sediments. The outcrops bear few signs of a karstic landscape, and there are no significant caves. Palaeokarstic fissures in these limestones contain Triassic and Jurassic sediments, and comparable, larger karst conduits contain the hematite ore deposits once worked at Llanharry (Simms, 1990). Thin, nearly horizontal limestones within the Mesozoic cover support limited karstic development around Bridgend.

Solution fissures, potholes and subsidence dolines have been recorded in the Liassic limestones, and a cave in Triassic limestone was found to have over 100 m of rifts and phreatic tubes (North, 1952). Holocene and modern tufas lie in valleys cut into the coastal cliffs of Lias limestones south of Bridgend (Campbell and Bowen, 1989).

South Dyfed

The Carboniferous Limestone thickens to over 1000 m in the south-western corner of Wales, but much of the succession is thin bedded with high proportions of intercalated shale. The limestones are tightly folded in the Hercynian compression zone, and form only narrow outcrops. Inland, the glaciated platform has little sign of karst, except for a few small caves largely choked with sediment (Davies, 1989). The high cliffs of the south coast contain numerous caves; many of these have karstic origins, and have been breached or modified by marine action. Some caves in the wave-battered cliffs contain evidence of human occupation, which must have occurred when the sea was far from its present position during the Devensian (Davies, 1989).

The Clwydian Hills

Carboniferous Limestone forms high ground on both sides of the Vale of Clwyd, at its most conspicuous on the great escarpment of Eglwyseg Mountain, just north of Llangollen (Figure 6.2). The Asbian Loggerheads Limestone is the dominant unit, only 100 m thick at Eglwyseg, but over 500 m thick further north.

East of Clwyd, Halkyn Mountain is part of a limestone belt with poorly developed surface karst, whose natural underground drainage all flowed to St Winifride's Well at Holywell. The limestone is laced with mine workings, developed to extract the rich ores of lead and zinc (Richardson, 1937; Warwick, 1968; Appleton, 1989); the main production was from about 1800 until 1958. The mines intercepted many stream caves and large phreatic chambers extending above and below sea level; Powell's Lode Cavern is 70 m long and over 30 m high and wide. Drainage adits, mined through the impermeable Namurian cover towards the east, lowered the water tables throughout the limestone. This action permanently dried up the natural resurgence at St Winifride's Well, a vauclusian rising in a faulted anticline of Brigantian black limestones and chert beds at the top of the main carbonate succession (the rising is an important religious site and its flow has been reinstated by a concealed diversion of water from another nearby drainage tunnel). The adits also drained extensive phreatic cave systems beneath the Alyn Gorge, where the middle course of the River Alyn is normally dry in summer. Halkyn Mountain has a

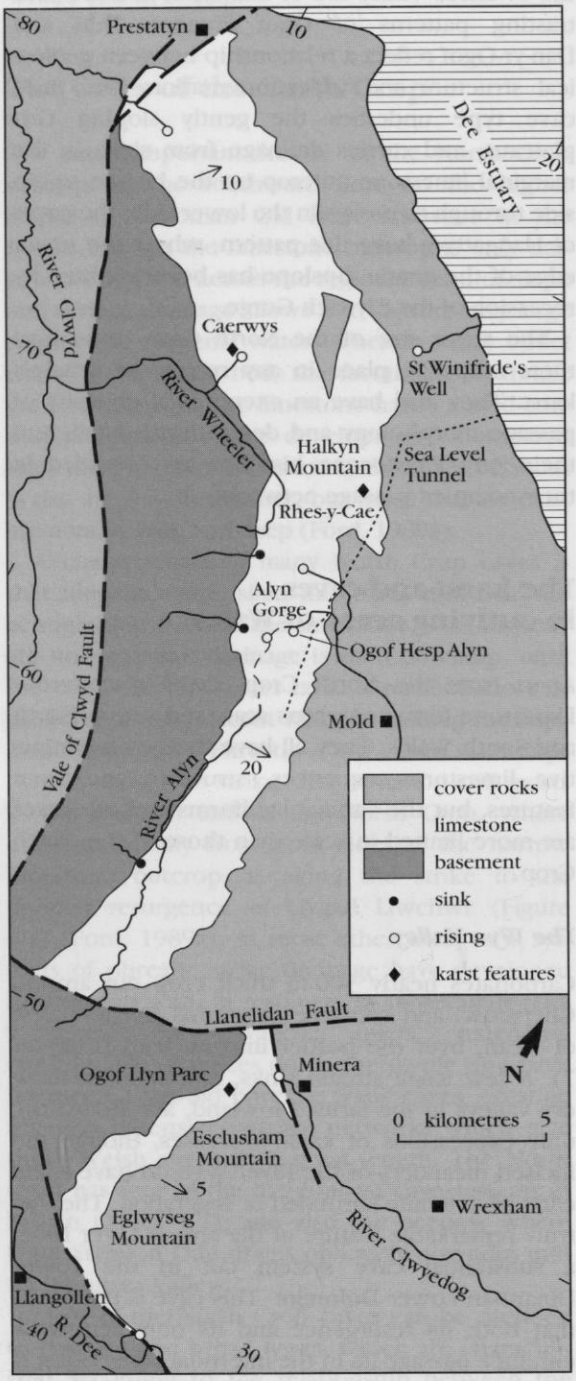

Figure 6.2 Outline map of karst features in the Carboniferous Limestone of eastern Clwyd, North Wales, with locations referred to in the text. The main rivers and risings are shown as they were before disturbance by the mine drainage. The basement is Ordovician shale; the cover rocks are Upper Carboniferous and Triassic clastics. Many of the steps on the boundaries are due to minor faults.

number of pocket deposits where subsided Tertiary sediments are preserved in solution depressions; the Rhes-y-Cae pit is the best documented (Walsh and Brown, 1971). Postglacial tufa deposits at Caerwys are the most extensive in Britain; they have been heavily quarried, but this has revealed the structure of the barrage, pool and cave deposits (Pedley, 1987).

South of the Llanelidan Fault, the splendid Minera cave system lies beneath the northern slopes of Esclusham Mountain; it also has its lower phreatic passages partially drained by the mining activity. To the south, Eglwyseg Mountain has towering limestone cliffs and some of the finest limestone pavements in Wales. The outcrop is a topographic high, so no allogenic drainage reaches it, and there are no influent caves; its autogenic waters collect in a karstic drainage system feeding sediment-choked risings in the Dee Valley.

West of Clwyd, the limestone outcrops are smaller, and the karst is poorly developed. The River Elwy crosses the limestone in a gently graded, alluviated valley. In its northern slope, Pontnewydd Cave is a truncated fragment of large cave passage which was almost full of sediments; excavation of these has revealed a record of Pleistocene environments and human occupation extending back 240 ka (Green, 1984) – it is the most northerly site in Europe with human remains of this age. The limestone continues through broken outcrops to the Great Orme, at Llandudno, where the karst drainage is so poorly integrated that adits were driven to permit mining down to sea level.

Anglesey

The upper Dinantian limestones form two outcrops in southern Anglesey, but the lowland aspect and the thick cover of glacial and glaciofluvial debris preclude significant karst development. The island's limestones are most notable for the spectacular palaeokarst exposed in the wave-cut platform and low cliffs of the east coast (Baughen and Walsh, 1980; Walkden and Davies, 1983). Cylindrical sandstone pipes, about 1 m in diameter, penetrate the limestone for up to 3 m. The sandstone fills are Dinantian; they lie in hollows which appear to be solutional features excavated in a temporarily uplifted coastal platform, though some may be moulins developed by wave action.

DAN-YR-OGOF

Highlights

Dan-yr-Ogof is an outstanding example of a cave system with contrasting geological controls on its configuration; it has fault-guided inlet passages draining to a trunk route which is predominantly bedding-controlled close to the axis of a minor syncline. The cave contains classic examples of phreatic and vadose passage morphology, some of which are now superbly decorated with calcite speleothems.

Introduction

The Dan-yr-Ogof cave system includes the truncated fragment known as Tunnel Cave and is located on the western side of the Tawe, or Swansea, Valley, north-east of Ystradgynlais (Figure 6.1). Parts of both Dan-yr-Ogof and Tunnel Cave are operated as show caves, the latter under the name of Cathedral Cave; above the two entrances, Ogof yr Esgyrn is a cave fragment which has yielded many Bronze Age and later artefacts (Mason, 1968). The caves are developed almost entirely in the Carboniferous Dowlais Limestone, of Holkerian age, which locally reaches a thickness of about 100 m; some passages extend into the Asbian limestone above. Old Red Sandstone crops out to the north, and part of the cave lies beneath the cap of Namurian Basal Grit which overlies the limestone to the south. The gentle southerly dip of the Palaeozoic succession is interrupted by the Cribarth Disturbance (Owen, 1954; Lowe, 1989b), a belt of tight folds and faulting. Immediately north of this, the cave lies within a shallow, asymmetric syncline in the limestone (Figure 6.3). Several minor faults extend north or NNE from the Cribarth Disturbance, parallel to the major joint set, and a minor joint set is orientated WNW–ESE.

Allogenic water reaches the caves mainly from the Old Red Sandstone slopes to the north, though it appears that much of the flow which formerly entered the system has been captured by the River Haffes to the north. Percolation water from the limestone outcrop contributes significantly to the underground flow, and there are numerous dolines and small stream sinks on the hillsides above the cave.

The Dan-yr-Ogof cave system has been described by Coase and Judson (1977) and Coase

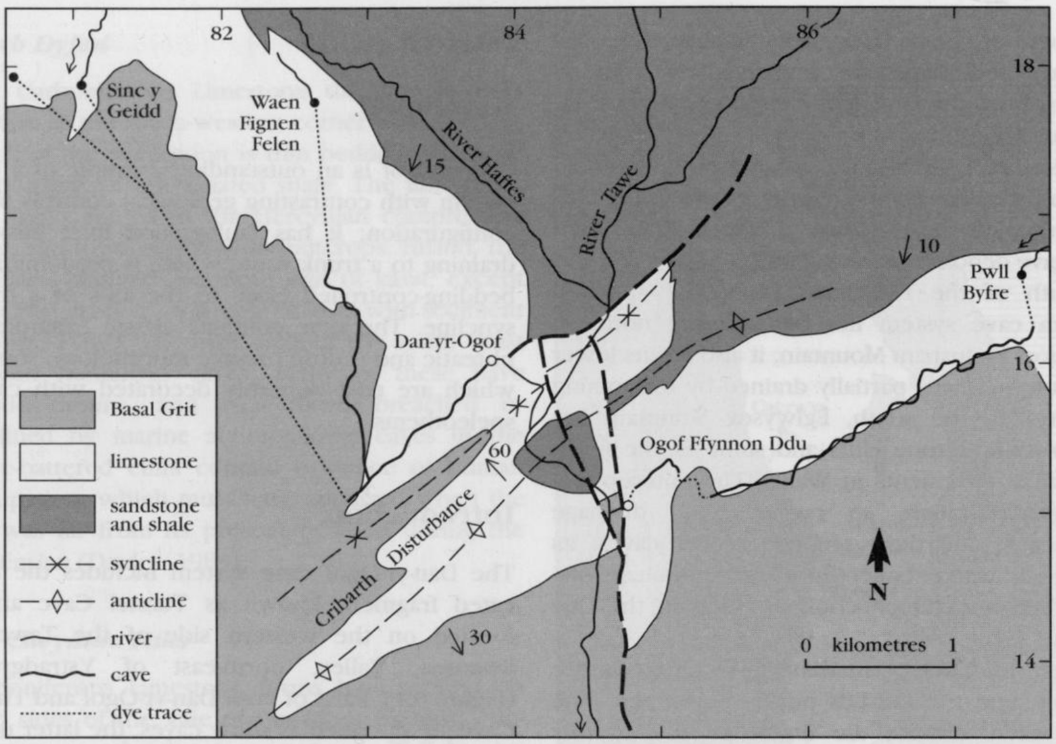

Figure 6.3 Geological map of the North Crop of the Carboniferous Limestone where it is crossed by the River Tawe in the Swansea Valley. Many small faults are omitted to improve clarity. The sandstones and shales below the limestone are mainly Devonian but include the Lower Limestone Shale from the Carboniferous. The only caves marked are the main stream passages in Dan-yr-Ogof and Ogof Ffynnon Ddu.

(1967, 1975, 1989), and the hydrology is reviewed by Gascoine (1989). Short descriptions of the cave passages are given by Stratford (1995), though there are significant more recent discoveries (Kealy, 1992; Murlis, 1992).

Description

Dan-yr-Ogof contains more than 16 km of cave passages (Figure 6.4). The south-eastern arm of the system, largely known as Dan-yr-Ogof 1 and part of Dan-yr-Ogof 2 (DYO1 and DYO2), is the trunk route of the cave, with passages at several levels draining to the north-east. The linear passages of Dan-yr-Ogof 3 (DYO3) form the western arm of the system and are inlet passages draining south, largely along a series of north–south faults.

The downstream end of DYO1 has an artificial tunnel into the show cave just above the resurgence. This intercepts a long high-level passage, which connects with the lower, active passage at various points. The main river cascades through a series of lakes, ponded by sediment banks and rock bars within the old, horizontal, phreatic tubes. Downstream it flows through the sumps of the Battle of Britain Series (Murlis, 1992); upstream it emerges from more totally flooded passages, and is only seen again in the Syphon Series of DYO1, in the magnificent phreatic borehole of Bakerloo Straight in DYO2, and in the complex series of partly flooded phreatic tubes of Mazeways. Above the lower, active level, there is an extensive, and complex, series of meandering high-level passages, locally well decorated with calcite speleothems and containing thick, clastic, sediment sequences. The show cave high level has undercut vadose passages with remnants of a phreatic tube preserved in the roof (Figure 6.5). Further west, this level is dominated by old phreatic passages, modified considerably by vadose entrenchment. Extensive collapse and choking with sediment have broken these passages into a series of isolated fragments; the chokes have been bypassed via much smaller high-level phreatic passages – including the series of small rifts which provide the route into DYO2.

A massive choke immediately north-east of Gerrard Platten Hall lies directly below the Crater, a large collapse doline on the surface. The high

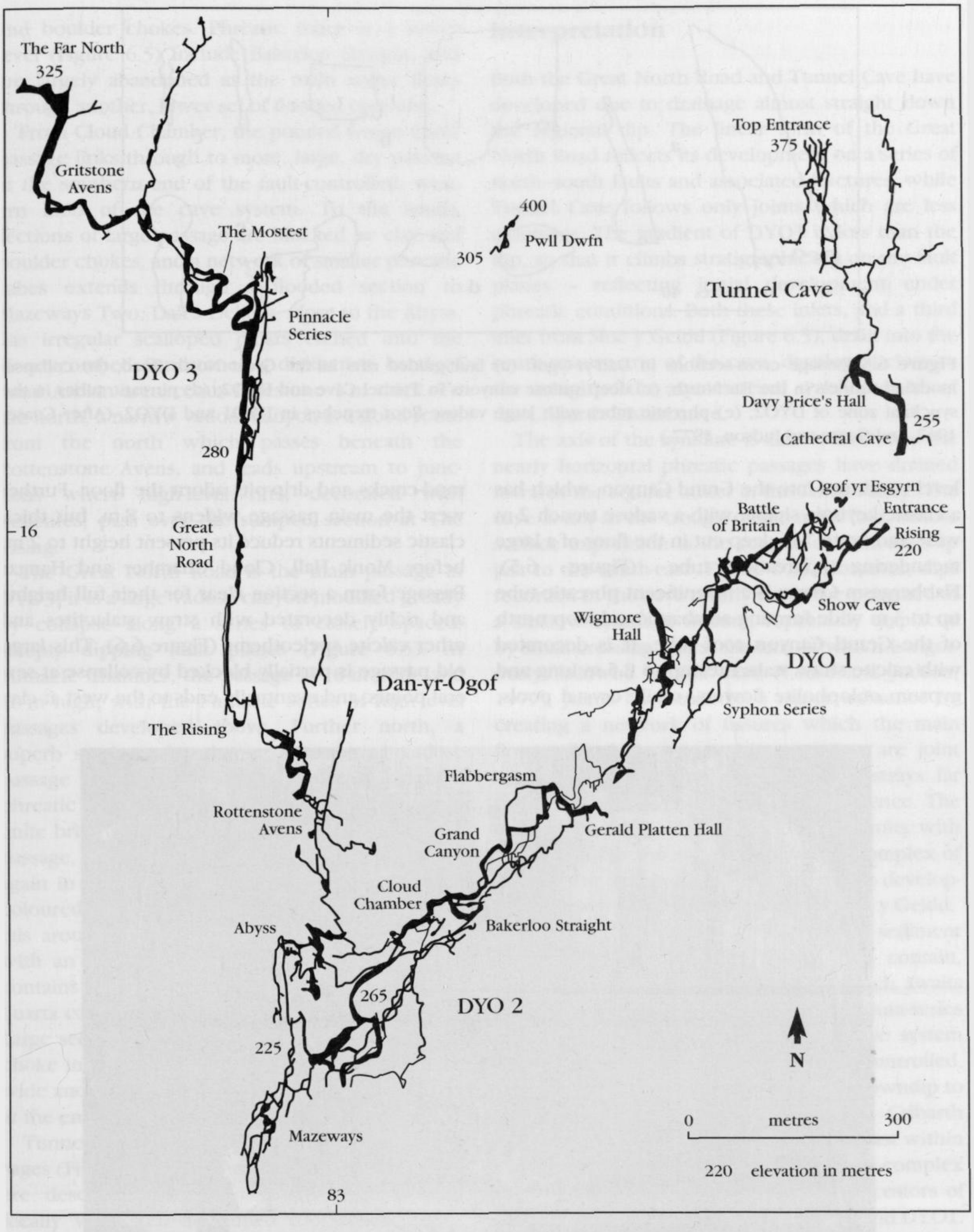

Figure 6.4 Outline map of Dan-yr-Ogof and Cathedral Cave (from survey by South Wales Caving Club).

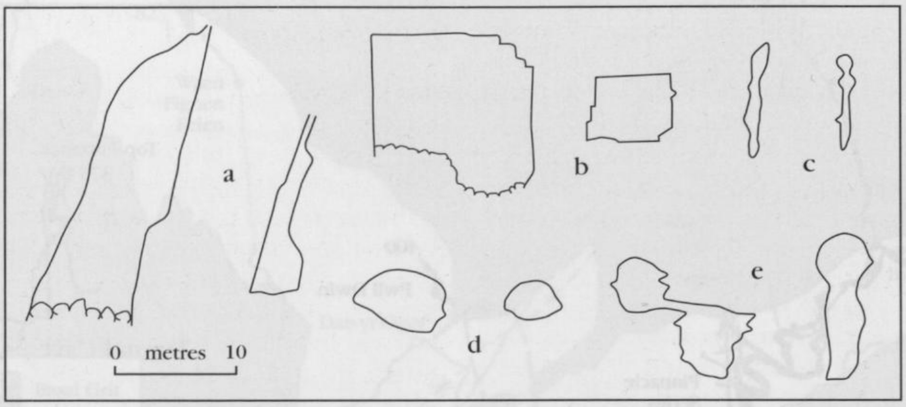

Figure 6.5 Passage cross-sections in Dan-yr-Ogof: (a) fault-guided rifts in the Great North Road; (b) collapse-modified tunnels in the Far North; (c) deep vadose canyons in Tunnel Cave and DYO2; (d) phreatic tubes in the synclinal zone of DYO2; (e) phreatic tubes with large vadose floor trenches in DYO1 and DYO2. (After Coase, 1967, and Coase and Judson, 1977.)

level continues into the Grand Canyon, which has a classic keyhole shape, with a vadose trench 2 m wide and up to 7 m deep cut in the floor of a large meandering phreatic tube (Figure 6.5). Flabbergasm Chasm is a magnificent phreatic tube up to 3 m wide forming an abandoned loop north of the Grand Canyon roof tube. It is decorated with calcite straw stalactites up to 2.5 m long and gypsum oulopholite flowers, while crystal pools, mud-cracks and drip-pits adorn the floor. Further west the main passage widens to 8 m, but thick clastic sediments reduce its present height to 2 m, before Monk Hall, Cloud Chamber and Hangar Passage form a section clear for their full heights and richly decorated with straw stalactites and other calcite speleothems (Figure 6.6). This large old passage is partially blocked by collapse at several points, and eventually ends to the west at clay

Figure 6.6 Calcite straw stalactites hang from the arched phreatic roof of Cloud Camber in Dan-yr-Ogof. (Photo: J.R. Wooldridge.)

and boulder chokes. Phreatic tubes at a lower level (Figure 6.5) include Bakerloo Straight, and are largely abandoned as the main water flows through another, lower set of flooded conduits.

From Cloud Chamber, the ponded Green Canal passage links through to more, large, dry passage at the southern end of the fault-controlled, western limb of the cave system. To the south, sections of large passage are blocked by clay and boulder chokes, and a network of smaller phreatic tubes extends through a flooded section to Mazeways Two. Dali's Delight, close to the Abyss, has irregular scalloped pillars etched into the Honeycombed Sandstone, a distinctive band of basal Asbian arenaceous limestone 1 m thick. To the north, a narrow vadose canyon is a flood route from the north which passes beneath the Rottenstone Avens, and leads upstream to junctions where high-level rifts, decorated with helictites, pass over the sumped section at The Rising.

The Great North Road is the main passage in DYO3; it is a large vadose canyon modified greatly by collapse along a series of closely spaced, steeply dipping fault planes (Figure 6.5). At Pinnacle Chamber, the passage is 10 m wide and 20 m high, with the Pinnacle Series of high-level passages developed above. Further north, a superb section of undercut, meandering vadose passage swings round from the west below a phreatic tube, 6 m high and 15 m wide. The two unite briefly upstream in a classic keyhole-shaped passage, before the phreatic tube turns north again in The Mostest, beautifully decorated with coloured flowstone, gour pools and calcite crystals around a dried-out pool. Beyond a junction with an inlet from the north, the main passage contains numerous large boulders of grit and quartz conglomerate beneath the Gritstone Avens. Large sediment banks precede a massive terminal choke in The Far North, a passage 13 m high and wide and modified by block collapse (Figure 6.5), at the end of the explored cave.

Tunnel Cave contains more than 2100 m of passages (Figure 6.4). The northern inlets of the cave are descending series of narrow vadose rifts, locally with well developed roof tubes (Figure 6.5). These unite downdip, to the south, into a vadose canyon which leads into the large passage of Davy Price's Hall, extensively modified by collapse and containing thick banks of sand, silt and mud. This chamber is now open as a show cave, under the name of Cathedral Cave, with an artificial entrance close to its tiny active outlet.

Interpretation

Both the Great North Road and Tunnel Cave have developed due to drainage almost straight down the regional dip. The linear form of the Great North Road reflects its development on a series of north–south faults and associated fractures, while Tunnel Cave follows only joints which are less extensive. The gradient of DYO3 is less than the dip, so that it climbs stratigraphically on the fault planes – reflecting initial development under phreatic conditions. Both these inlets, and a third inlet from Sinc y Geidd (Figure 6.3), drain into the south-eastern arm of the cave, developed close to the trough of the asymmetrical syncline north of the Cribarth Disturbance.

The axis of the syncline is almost level, and the nearly horizontal phreatic passages have drained towards the aquifer outlet in the Tawe Valley. The cave is not in the trough of the main fold, whose surface expression is the tongue of Grit outcrop just to the south-east (Figure 6.3). However, dips recorded in the cave clearly show the presence of a shallow synclinal flexure, repeatedly displaced by small crossing faults, the axis of which is rigorously followed by the cave (Coase and Judson, 1977). Joints have exerted a minor influence by creating a network of fissures which the main flow utilized; many passage segments are joint aligned, but the main cave nowhere strays far from the direct line to the valley resurgence. The confluence of the Great North Road faults with the syncline is the site of a sprawling complex of passages in Mazeways, which extends as development along the strike by water from Sinc y Geidd.

The series of passage levels, and the sediment and speleothem deposits which they contain, record a long and complex history which awaits an absolute chronology based on uranium-series dating of speleothems. Initially the cave system consisted of a series of small, fracture-controlled, phreatic rifts and tubes which drained downdip to the south, into the syncline of the Cribarth Disturbance. Slower flows to the north-east within the syncline trough enlarged the more complex network of fissures which were the ancestors of the many passages now forming DYO2 and DYO1. Remnant from this phase may be the small, high-level, phreatic tubes which survive as bypasses around the massive chokes in the southern part of the system. The large high-level trunk passages, mostly on DYO2, represent the main phase of cave development, since fragmented by collapse and sediment infill. The large size of the trunk passages probably indicates a much higher flow than that of the present active streamway.

Subsequent drawdown has resulted in extensive vadose modification of many of these old phreatic passages, notably on the shallow phreatic loops caused by the interplay of joint control and dip within the syncline. Downcutting of the Tawe Valley, and erosion through some of the phreatic loops within the cave, has favoured enlargement of new drainage routes at lower levels through the same fissure networks. This process has been repeated a number of times in different parts of the system, but the majority of the development has been phreatic in the synclinal trough; the active drainage route is still largely flooded. Vadose entrenchment of the phreatic tubes has been deepest close to the resurgence, in direct response to the surface lowering, and in the steeper passage gradient of Tunnel Cave.

The abrasiveness of sand sediment washed into the cave may account for the largest section of passage being that closest to the former sinks feeding into the Far North. These large passages date probably from a period prior to the capture of much of the surface drainage by the River Haffes (Figure 6.3). The choke in Gerrard Platten Hall lies 40 m below a large collapse doline, and the feature represents an early stage of the dissection and eventual destruction of the cave. Tunnel Cave appears to have been an inlet to Dan-yr-Ogof before the side of the Tawe Valley retreated far enough to remove the junction; its truncation is another aspect of cave destruction.

The stages in the development of the caves, with their consecutive sequences of passages and repeated rejuvenations, must relate to the series of ice advances and the glacial and fluvial valley deepening during the Pleistocene. Much of the original allogenic drainage has been lost to the River Haffes, in an unusual example of underground drainage being captured by a surface stream. The resurgence is now perched above the valley floor, as the water emerges from a truncated phreatic tube very close to the base of the cavernous limestone. A preliminary interpretation of events ascribes different drainage routes and cave passages to the interglacial stages of the Pleistocene (Coase, 1989), but it remains conjectural without absolute dates from the cave sediments. Environmental and chronological data have yet to be elucidated from the thick clastic and speleothem sequences in the various cave levels, to obtain a clearer picture of the evolution of both the cave system and its surrounding landscape.

Conclusion

Dan-yr-Ogof is a major cave system with large, fault-guided passages uniting in a drained phreatic trunk route along the axis of a syncline. It shows very clearly the effect of various geological controls on cave development, and it contrasts with the adjacent Ogof Ffynnon Ddu, a cave system with a conspicuously different morphology in the same limestone in a different structural situation on the other side of the Cribarth Disturbance (Figure 6.3). Rejuvenation in response to valley incision has left an extensive series of partly abandoned, high-level passages, many of which are classic examples of their type, superbly decorated with calcite speleothems.

OGOF FFYNNON DDU

Highlights

Ogof Ffynnon Ddu is the deepest cave system in Britain, and is also one of the most extensive. The complex network of large high-level passages, the exceptionally long vadose streamway, and the many inlets perched high above it, provide an unparalleled record of drainage evolution in the limestone.

Introduction

Ogof Ffynnon Ddu lies beneath the eastern slopes of the Tawe Valley (or Swansea Valley) at Penwyllt, upstream of Ystradgynlais (Figure 6.1). It is the second longest cave system in Britain, with around 50 km of explored passages, and is Britain's deepest cave with a vertical range of 308 m.

The cave is developed entirely within the Holkerian Dowlais Limestone, which is locally just under 100 m thick. This limestone has a broadly uniform dip of about 10° to the south, as it lies clear of the Cribarth Disturbance (Figure 6.3), and it forms an outcrop less than 1 km wide across the upland interfluve between the Neath and Tawe valleys. It is broken by numerous faults, mostly orientated north–south with displacements of up to 35 m, and the major joint sets trend roughly north–south and east–west. A series of gentle fold flexures have their axes aligned close to the regional dip. Allogenic water flows south from the Old Red Sandstone slopes, and the only large surface stream feeds the main sink at Pwll Byfre. Underground flow is westwards through Ogof Ffynnon Ddu to the resurgence of Ffynnon Ddu, close to the floor of the Tawe Valley. Most of the upland slopes have a thin veneer of till which obscures truncated passages known from inside the cave system.

The progressive exploration and understanding of Ogof Ffynnon Ddu has been documented primarily by Railton (1953), O'Reilly *et al.* (1969) and Smart and Christopher (1989), and the main cave passages are described by Stratford (1995). The relationship of the cave to the geology has been discussed by Glennie (1950) and Charity and Christopher (1977), while aspects of the hydrology have been investigated by O'Reilly and Bray (1974) and Bray and O'Reilly (1974).

Description

A main stream passage extends through the length of the Ogof Ffynnon Ddu cave system, but most of the 50 km of known passages constitute complex, three-dimensional networks of active and abandoned caves (Figure 6.7).

The main streamway is 5 km long, covering most of the distance between sink and rising. The upper end is in the large chamber of Smith's Armoury, where the water from the Pwll Byfre sink emerges through a choke of sandstone boulders. Most of the streamway is a magnificent, clean washed, vadose canyon, 2–5 m wide and 5–30 m high. The Marble Showers area is notably spectacular where the canyon walls, cut in dark limestone streaked by white calcite veins on small faults, are washed by inlets from the roof. The water cascades and swirls through numerous moulins and deep pools, and over ledges where dolomitic horizons have resisted solution more than the adjacent limestone. There are few waterfalls along the main streamway, for it descends 300 m largely by following the bedding obliquely downdip. At floor level, the stream follows a contorted course where meanders have enlarged as they have been entrenched. The higher levels of the canyon are commonly aligned on joints, so that they appear as straight rifts; the Traverses (Figure 6.8) are high in a spectacular straight canyon over 40 m high, now abandoned where the stream passes through a short flooded loop between the canyons of OFD3 and OFD2. From just below the Piccadilly junction, the stream route is again through a flooded loop beneath the Rawl Series, until it emerges in

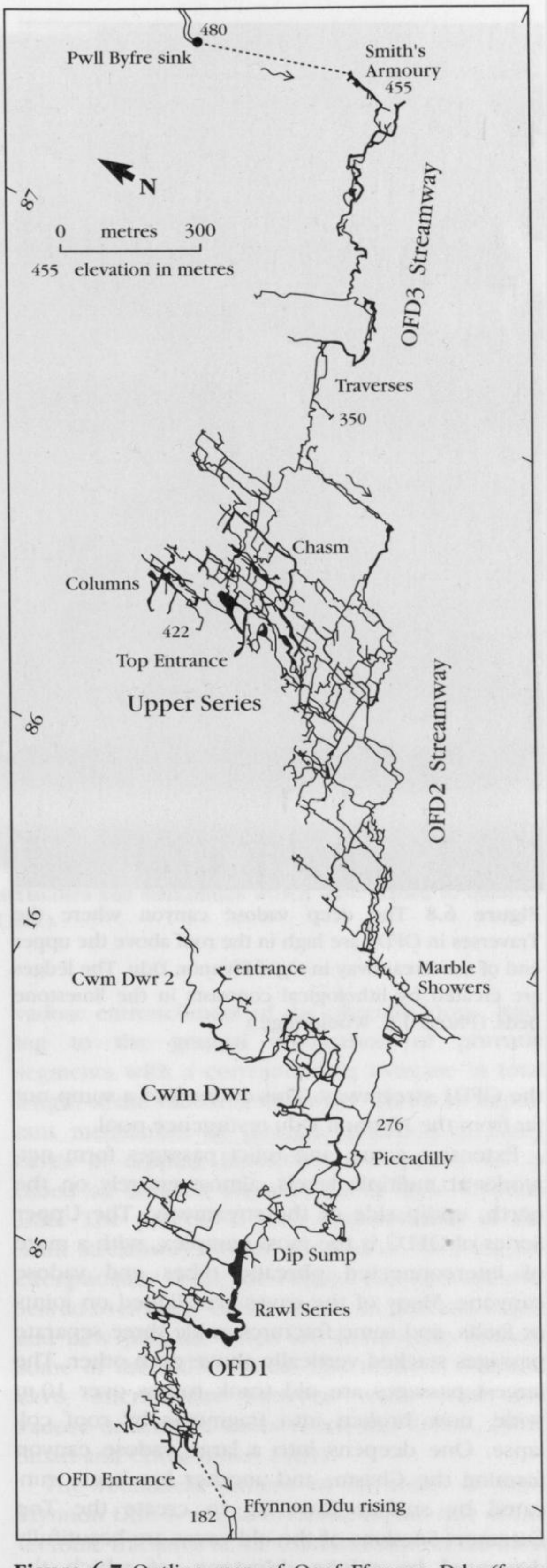

Figure 6.7 Outline map of Ogof Ffynnon Ddu (from survey by South Wales Caving Club).

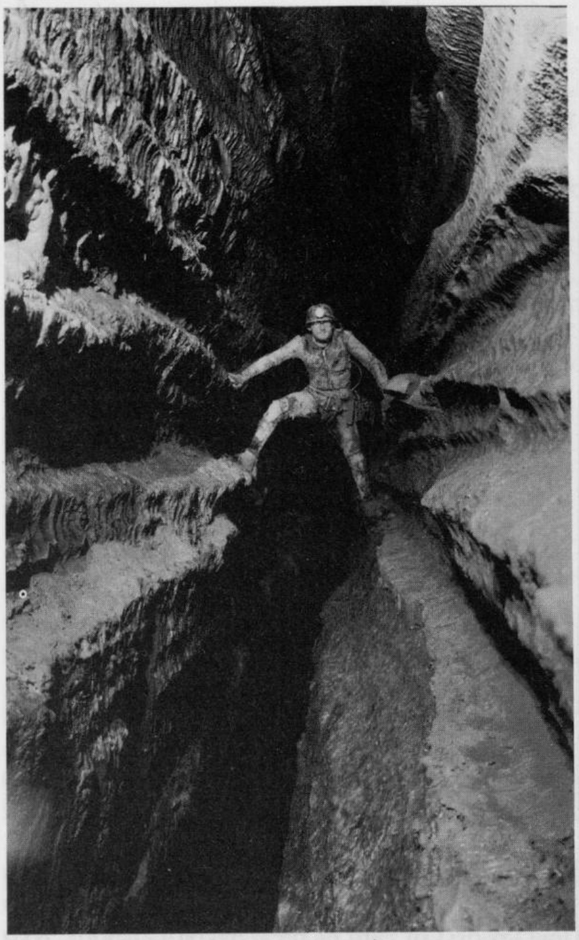

Figure 6.8 The deep vadose canyon where the Traverses in OFD3 are high in the roof above the upper end of the streamway in Ogof Ffynnon Ddu. The ledges are created by lithological contrasts in the limestone beds. (Photo: J.R. Wooldridge.)

the OFD1 streamway. This drains into a sump not far from the Ffynnon Ddu resurgence pool.

Extensive active and relict passages form networks at multiple levels, almost entirely on the north, updip side of the streamway. The Upper Series of OFD2 is the most complex, with a maze of interconnected phreatic tubes and vadose canyons. Many of the caves are aligned on joints or faults, and some fractures guide three separate passages stacked vertically above each other. The largest passages are old trunk routes over 10 m wide, now broken into fragments by roof collapse. One deepens into a large vadose canyon forming the Chasm, and another has been truncated by surface lowering to create the Top Entrance. Sections of the old caves are beautifully decorated by calcite dripstone, of which the Columns are the most distinctive (Figure 6.9); a stalagmite floor over an eroded clastic fill in the Upper Series has been dated to 267 ka by uranium-series analysis (Smart and Christopher, 1989). Younger vadose canyons have been cut by invading streams right through the mazes of old passages; they drain down the dip to the main streamway. Even though these are deeply entrenched, their incision rates have not matched that of the main stream, and most are perched as roof inlets.

Downstream in OFD2, another series of large, abandoned, phreatic passages forms a high level, reaching towards a truncation at the Cwm Dwr Entrance. Cwm Dwr 2 is an isolated fragment of tributary streamway (Herbert and Langford, 1991).The relict passages from Cwm Dwr to Piccadilly also extend downstream to form a passable link over the flooded section of streamway into OFD1. These continue through the spacious passages of the Rawl Series, which are the only extensive old passages on the downdip side of the present stream route. They continue into another very complex maze which can be followed above the modern stream canyons, to emerge from the original OFD Entrance where the abandoned passage is truncated by the side of the Tawe Valley.

Pant Mawr Pot lies 1500 m east of Pwll Byfre (Alexander and Jones, 1959; Moore, 1989). In the floor of a large shakehole, a shaft drops into a single passage up to 8 m wide and 5 m high, with extensive clastic sediment fills. Though this largely abandoned passage may once have related to Ogof Ffynnon Ddu, its underfit stream now drains into the Neath Valley further east.

Interpretation

The evolution history of Ogof Ffynnon Ddu is long and complex. The narrow outcrop of dipping limestone, from the interfluve ridge to the valley floor, has dictated the overall pattern of karst drainage – obliquely down the dip to the contemporary valley floor resurgence. This pattern has survived through successive deepening of the Tawe Valley, creating consecutive series of passages superimposed into each other. The overall drainage oblique to the dip has been developed by utilization alternately of downdip and strike fractures. Passage development further down the dip has been inhibited where longer loops would have passed beneath the Grit cover into limestone less favoured by authigenic solutional enlargement of its fissure network. New downdip

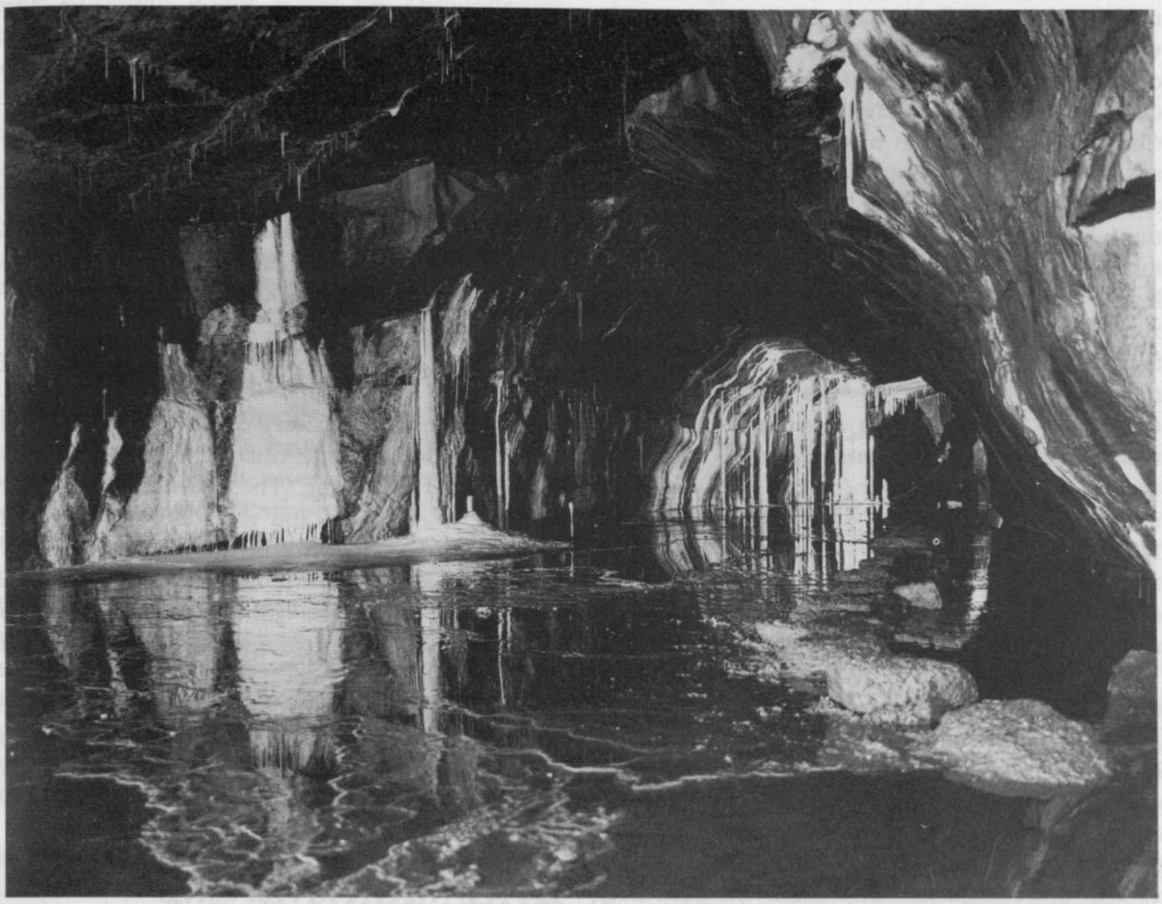

Figure 6.9 The Columns in Ogof Ffynnon Ddu – calcite stalactites and stalagmites which have grown to connection in a fossil phreatic tube. (Photo: South Wales Caving Club.)

drainage paths have therefore developed largely in response to the surface lowering and downdip shift of the outcrop, with simultaneous lowering of the valley floor. The valley deepening also permitted the development of new, lower resurgence sites, while the downstream ends of the older, higher phreatic passages, which had also discharged to the west, were progressively destroyed by surface erosion.

Solutional fissure enlargement in the well bedded and well fractured limestone of Ogof Ffynnon Ddu has led to an uncommonly large number of drainage captures in both the phreatic and vadose parts of the aquifer. This has led to the development of a complex multi-level network cave quite distinct from predominantly two-dimensional maze caves, such as Mossdale Caverns (Figure 2.48), in which passage capture has played only a minor role. The local relief on cave drainage routes created sections of steep downstream gradients; these became the sites of rapid updip vadose entrenchment of the phreatic loops, leading to the gradual elimination of phreatic segments with a corresponding increase in total length of the vadose streamways. This is an important mechanism of passage evolution in many caves in dipping limestone, and Figure 1.7 is based on detailed observations in Ogof Ffynnon Ddu. The process is well demonstrated in the main streamway, where the vadose canyons are exceptionally deep; the original passages are preserved over many crests of the old phreatic loops, and new phreatic loops are developing beneath some of the old canyons. The result is a hybrid cave, intermediate between water table and vadose drawdown caves (Ford and Ewers, 1978; Smart and Christopher, 1989).

The rectilinear pattern of so much of Ogof Ffynnon Ddu is ample evidence of the role of the tectonic fractures in the establishment of the karst drainage and the cave passages. There are further expressions of geological control in the caves. The major networks of high-level passages coincide with gentle anticlinal structures which plunge down the regional dip, while the intervening synclines house far fewer cave passages (Charity and Christopher, 1977); this may be due to either the tensional opening of fissures over the fold crests, or the earlier exposure of the limestone on the structural highs. Bedding of the limestone has also influenced passage morphology, where projecting ledges are formed by more resistant dolomite horizons, and where passages with square sections and flat roofs have been modified by collapse. In the upper part of the Dowlais Limestone, the *Composita ficoides* bed is more sparsely jointed than most; roof collapse and upward stoping frequently stop at this horizon, which forms the roof in many parts of OFD2 Upper Series. The Pwll Byfre sink is close to the base of the limestone, but the cave system climbs stratigraphically in numerous phreatic lifts, so that the past and present resurgences lie at the top of the Dowlais Limestone.

Although evidence of only the last two glaciations has been recognized in this area it is probable that the development of the cave system has been influenced by earlier ones, surface evidence of which has been entirely removed by later glaciations. The effects of these glaciations include truncation of near-surface passages, vadose entrenchment consequent on base-level lowering, and subsequent infilling of passages with glaciofluvial sediments. Solutional enlargement of the cave passages takes place more rapidly in warm interglacial environments, and some of the cave levels may correspond to resurgences at interglacial valley floor levels, though no detailed correlations have yet been made. The one dated flowstone from the OFD2 Upper Series shows that these passages were drained by the Hoxnian stage (267 ka), but these passages are among the oldest in the cave and were probably dry long before this flowstone was deposited. Vadose entrenchment in the Traverses of OFD3 totals about 75 m, and a mean entrenchment rate of 100 mm ka^{-1} may be interpreted from comparable dated sites elsewhere in Britain (Gascoyne *et al.*, 1983a). This suggests an age of about 750 000 years for the OFD3 streamway, and a history for the whole cave is likely to span more than a million years (Smart and Christopher, 1989).

The sequential cross-cutting relationship of many passages and the extensive sediment and speleothem deposits which Ogof Ffynnon Ddu contains gives this system enormous potential for elucidating the Pleistocene history of the upland area, evidence for the early part of which has been entirely removed from the surface landscape. Pant Mawr Pot may represent a fragment of large passage which was once related to the older components of the high levels in Ogof Ffynnon Ddu. This would imply that the Tawe Valley was deeply entrenched before the Neath Valley was excavated, but further speculation is inappropriate until more is known of the interfluve caves so heavily choked with sediment.

Conclusion

Ogof Ffynon Ddu is a very extensive cave system developed by drainage obliquely through a dipping bed of limestone. The prevailing southerly dip, the minor folds and the joint sets have all exerted a strong control on the configuration of the cave passages. Continued incision through a large depth range has allowed the passages to evolve within these geological constraints over a very long timespan. The morphology of the passage network provides a striking contrast with the nearby cave system of Dan-yr-Ogof, and provides many features of detail which are among the finest in Britain.

LITTLE NEATH RIVER CAVE

Highlights

The caves of the Afon Nedd Fechan provide an excellent example of the progressive underground capture of a surface river in a limestone karst. They contain passages in all stages of development, including immature vadose inlets, a large main streamway, an active phreas, partly and completely abandoned high levels, and truncated fragments beneath the active part of the surface river bed.

Introduction

The caves adjacent to the Afon Nedd Fechan, west of Ystradfellte, include the Little Neath River Cave, Bridge Cave, Pwll y Rhyd, White Lady Cave and Town Drain (Figures 6.1, 6.10). The underground drainage is developed largely in the Holkerian Dowlais Limestone, which dips south at less than 10°, and is broken by a number of dip faults. Draining south from the Old Red Sandstone slopes of the Fforest Fawr mountains, the headwaters of the Afon Nedd Fechan (Little Neath River) sink at various points across the Carboniferous Limestone outcrop. All the water from the sinks in the river bed rises from deep fissures at Pwll Du, where the top of the limestone dips beneath the sandstone of the Namurian Basal Grit.

The morphology of the Little Neath River Cave is well documented by Norton *et al.* (1967), Standing *et al.* (1971) and Mullen (1987, 1988, 1990), and all the caves are briefly described by Moore (1989) and Stratford (1995).

Description

In dry weather the entire flow of the Nedd Fechan sinks within 200 m of leaving the sandstone outcrop into impenetrable riverbed fissures. The first open sink is the Flood Entrance of Little Neath River Cave. The main sink of the river is also choked, but drains into Bridge Cave, which has a dry entrance in through a doline. The water then flows through a short sump, and east along a wide bedding plane canal into the Main Stream Passage of Little Neath River Cave (Figure 6.10). This is the trunk route through the cave system, which has nearly 9 km of mapped passages, including the small joint-controlled tributaries from the Flood Entrance.

Much of the gently graded Main Stream Passage is 10 m high and wide, but it is broken by a series of shallow phreatic loops, each up to 200 m long, which are permanently flooded. The faulted and fractured limestone walls break away in numerous large collapse blocks, and there are some extensive banks of clastic fill. Abandoned oxbows and high-level passages leave and join the streamway at various points, and some of these carry invading tributary streams. The Old World and the New World Series are both complexes of old passages, at an elevation of about 260 m, close to the cave river level at the upstream end but 40 m above at the south end of New World; they include tall avens and collapse chambers containing extensive calcite speleothems. The present limit of exploration is 600 m from the resurgence, at a point 27 m deep in Sump 8, whose water surface level is the same as that of the resurgence. This flooded passage appears to pass through a downfaulted block, 400 m wide, in which the top of the limestone is below resurgence level. The faulting is more complex than the surface outcrops shown

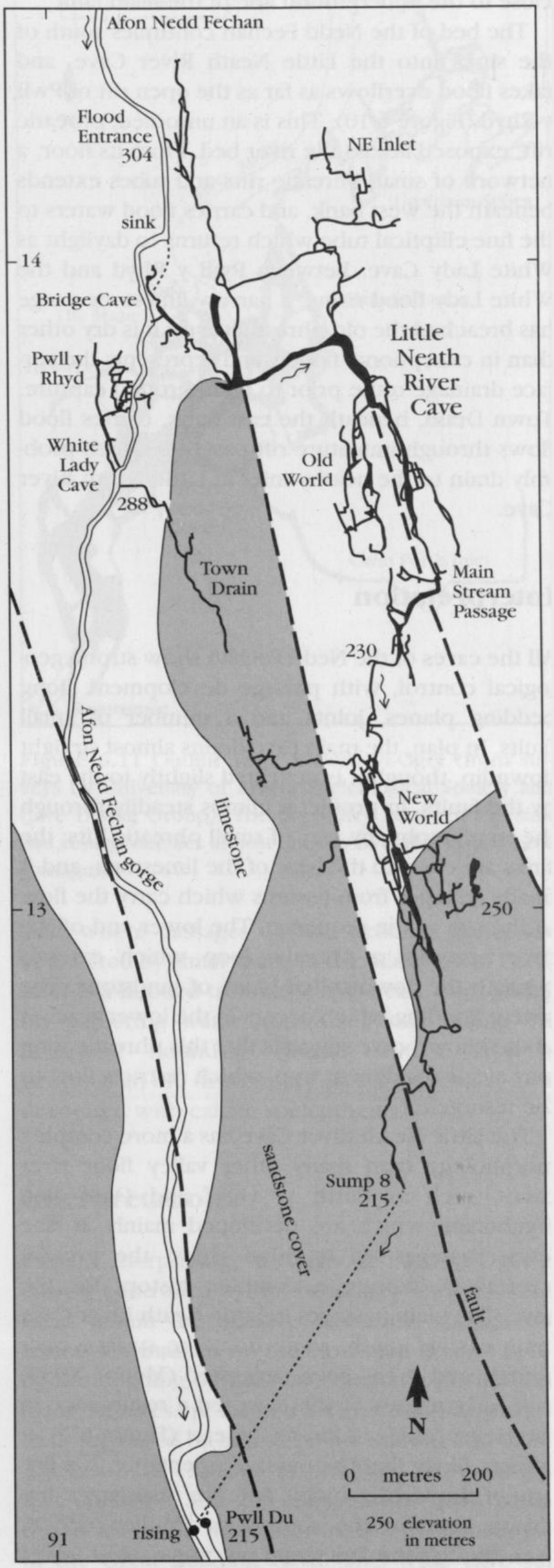

Figure 6.10 Outline map of the Little Neath River Cave, its surface geology and the adjacent caves of Pwll y Rhyd (from survey by University of Bristol Speleological Society).

on Figure 6.10, and Sump 8 may lie on or very close to the underground line of the main fault.

The bed of the Nedd Fechan continues south of the sinks into the Little Neath River Cave, and takes flood overflows as far as the open rift of Pwll y Rhyd (Figure 6.10). This is an unroofed, phreatic rift, exposed across the river bed. From its floor, a network of small phreatic rifts and tubes extends beneath the west bank, and carries flood waters to the fine elliptical tube which returns to daylight as White Lady Cave. Between Pwll y Rhyd and the White Lady flood rising, a narrow limestone gorge has breached the old phreatic caves; it is dry other than in exceptional floods, and represents the surface drainage route prior to underground capture. Town Drain, beneath the east bank, carries flood flows through immature rift passages which probably drain to the nearby inlet in Little Neath River Cave.

Interpretation

All the caves of the Nedd Fechan show strong geological control, with passage development along bedding planes, joints and a number of small faults. In plan, the main cave drains almost straight downdip, though it is deflected slightly to the east by the faults. In profile, it climbs steadily through the stratigraphy, by way of small phreatic lifts; the sinks are close to the base of the limestone, and it finally resurges from fissures which carry the flow to the top of the sequence. The lower end of the cave occupies a phreatic loop which extends beneath the downfaulted block of sandstone. The severe flooding which occurs in the lower reaches of the known cave suggests that this phreatic loop may act as a sediment trap, which restricts flow to the resurgence.

The Little Neath River Cave has a more complex morphology than many other valley floor river caves, such as Porth yr Ogof and Ogof Hen Ffynhonau, which are developed mainly at one level. Passages up to 30 m above the present streamway indicate a complex history for the cave. The main passages in Little Neath River Cave drain east of south, away from the surface river course, and it has been suggested (Moore, 1989) that early phases of the cave fed a resurgence in the Mellte Valley, 2 km to the east (Figure 6.1). It is more likely that the passage orientation is a feature of the local geology, and the resurgence has always been to the south-west (Mullen, 1990), even though the limestone outcrops are at lower level in the eastern valley. The New World Series represents the earliest underground drainage route, active until it was captured by the present streamway. These large old passages were subsequently filled by extensive sediment deposits, which have only been partly removed by the present streams.

Cave development has also been influenced by changes in the surface topography and drainage imposed by the Pleistocene glaciations. The Nedd Fechan, Mellte and Hepste originally flowed south-east as headwaters of the Cynon catchment, until they were captured by Pleistocene excavation of the Vale of Neath (North, 1962). The rejuvenated rivers entrenched into their present steep gorges, exposing the limestone at lower levels and rapidly draining previously phreatic sections of the karst aquifer. The Nedd Fechan gorge, entrenched along a fault zone west of the caves, is a youthful feature which may postdate the main downcutting of the Mellte and Hepste valleys. Its course across the limestone was probably excavated by high meltwater flows in cold stages of the late Pleistocene, creating the site of a new outlet for the cave water in subsequent warm stages. Any diversion of the cave drainage, from an earlier route to the Mellte, has not yet been dated, but the Nedd Fechan gorge is pre-Devensian as its lower reaches contain glacial till. This relatively late incision also accounts for the breaching of the caves at Pwll y Rhyd.

Conclusion

The caves of the Afon Nedd Fechan constitute an excellent example of karstic development beneath a large river valley crossing a narrow limestone outcrop. Their multiple phases of vadose and phreatic passages represent an early capture of the surface drainage, flow patterns dictated by geological constraints, and a diversion of the outlet path in response to surface rejuvenation.

PORTH-YR-OGOF

Highlights

Porth-yr-Ogof is a spectacular river cave, with the main conduit accessible from sink to resurgence. It is a fine example of underground capture of surface drainage and of the initial stages of development of a river gorge through cavern collapse.

Introduction

Porth-yr-Ogof lies in the floor of the Mellte Valley, south of Ystradfellte (Figure 6.1). Several streams drain south from the Old Red Sandstone slopes to converge near Ystradfellte, before crossing onto the lowest beds of the Carboniferous Limestone dipping south at about 4°. In dry weather, the water all flows underground into massive limestone at the impenetrable Church Sink. In flood conditions, a surface stream continues south for a further 600 m to enter the Main Entrance of Porth-yr-Ogof at the end of a short limestone gorge. The entire cave is developed near the top of the Holkerian Dowlais Limestone. After 300 m underground, the river resurges through a deep pool, 700 m upstream of a fault which crosses the valley at the end of the limestone outcrop. A shallow rocky ravine lies almost directly above the cave; it is permanently dry and its floor is breached by a collapse into the main cave passage.

The cave and its geomorphology have been described and discussed by Standing and Lloyd (1970), Lloyd (1980) and Waltham and Everett (1989), and the Mellte hydrochemistry was discussed by Groom and Williams (1965).

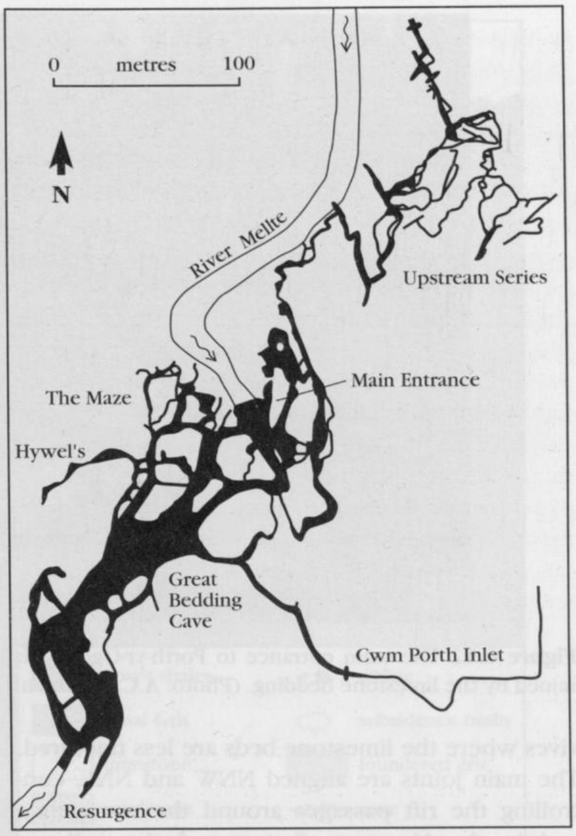

Figure 6.11 Outline map of Porth-yr-Ogof (from surveys by University of Bristol Speleological Society and Cave Diving Group). The dry valley between the sink and resurgence lies almost directly over the largest cave passages.

Description

Porth-yr-Ogof has nearly 2500 m of passages within a very small area and reached by fifteen entrances (Figure 6.11). These include the main river entrance and exit, a number of incidental joint fissures and three roof collapses towards the resurgence. The Main Entrance is 15 m wide with a shallow arched roof into a wide bedding plane chamber, with the river in a trench between wide rock shelves (Figure 6.12); it lies at the lower end of a short gorge between vertical limestone walls. Inside the cave, the Mellte flows in a wide passage with numerous oxbow loops at water level. The Great Bedding Cave is up to 30 m wide, with shallow pools and shingle banks spanned by an unbroken limestone slab beneath a gently dipping bedding plane. Downstream the passage narrows into the joint-guided resurgence rift. The baseflow of the Mellte enters Church Sink and drains into the flooded tubes and rifts which are the active part of the Upstream Series. The whole cave is distinguished by the braided form of its passages, with numerous loops extending in the bedding planes on both sides of the main drainage path. These are particularly complex on the western side, where passages on two bedding planes are connected by small shafts in the Maze. Cwm Porth Inlet is a flooded tributary on the east side, probably gathering water from small sinks along the limestone boundary (Burke, 1967). Hywel's Grotto is an old distributary on the west side, now decorated with calcite speleothems.

Interpretation

Passage morphology throughout Porth-yr-Ogof is closely controlled by the bedding planes and fractures within the massive limestone, though the effects are masked on the cave map (Figure 6.11) by the braiding on the major bedding planes. The main passages are formed on four bedding planes, each separated by limestone beds about 1 m thick. These are all exposed in the Main Entrance and first chamber, and are most conspicuous where the second from the top forms the wide roof span of the Great Bedding Cave. This wide cave sur-

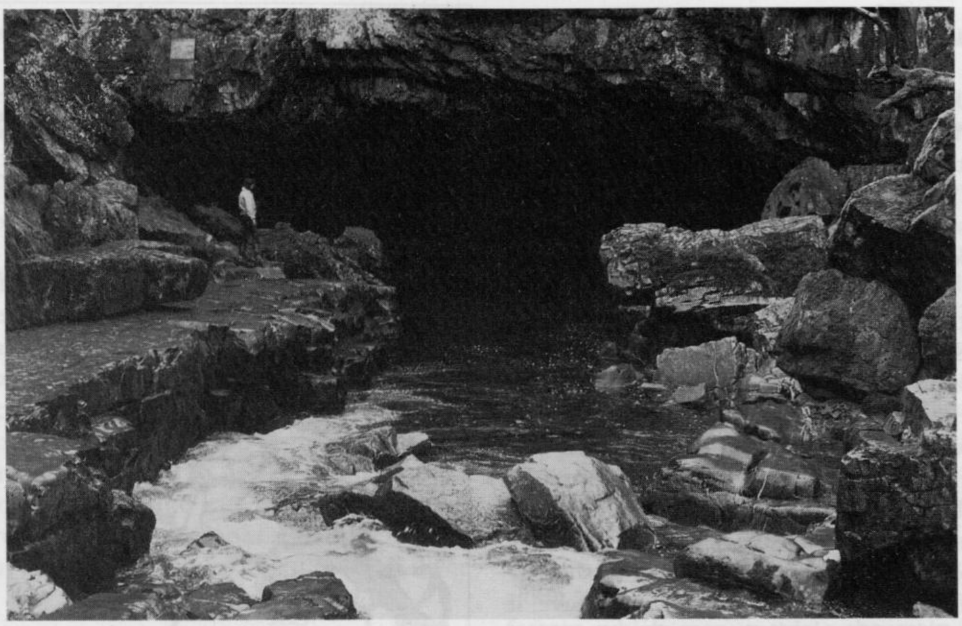

Figure 6.12 The main entrance to Porth-yr-Ogof with the River Mellte flowing in between rock terraces determined by the limestone bedding. (Photo: A.C. Waltham.)

vives where the limestone beds are less fractured. The main joints are aligned NNW and NNE, controlling the rift passages around the resurgence and in the Upstream Series, and the collapse entrances at the lower end of the Great Bedding Cave. Where they are more densely packed, they have allowed more roof collapse to form the gorge upstream of the Main Entrance.

Initial development of the cave was by phreatic solution opening up fracture routes through the limestone beneath the river bed. Aided by the steep gradient of the rejuvenated Mellte (North, 1962) and the hydraulic continuity within the four dipping bedding planes, the karstic conduits were soon large enough to take the entire flow underground. A short phreatic lift at the resurgence was removed due to incision by its overflow, and the whole cave was then further enlarged in a vadose environment. Evolution has now reached a stage where the upstream end of the cave is being progressively unroofed to create the upstream gorge. Adjacent to this, the cycle is restarting where renewed underground capture is developing in the Upstream Series, which is still largely within the phreas and cannot yet take flood flows.

The gorge upstream of the Main Entrance represents the finest example in Britain of gorge incision by progressive roof collapse downstream from an influent cave entrance; unroofing of the cave is also progressing on a small scale where the old dry ravine is collapsing into the river cave beneath.

Conclusion

Porth-yr-Ogof is Britain's finest example of a completely vadose river cave in a valley floor environment. It may be compared with valley floor caves in Nidderdale, Chapel le Dale and the Alyn Valley, but its morphology is far more diverse. It shows every stage of underground capture, from early phreatic fissure enlargement through to collapse and transformation into a subaerial gorge. Within the cave, the wide roof spans in single limestone beds are particularly spectacular and are unmatched elsewhere in Britain.

MYNYDD LLANGYNIDR

Highlights

Mynydd Llangynidr contains the finest array of collapse dolines and subsidence basins seen anywhere in Britain, and clearly demonstrates the surface geomorphic effects of interstratal karst.

Introduction

Mynydd Llangynidr is located on the summit of an escarpment overlooking the Usk Valley on the northern edge of the South Wales coalfield syncline. The escarpment is formed by the Carboniferous Limestone, but is capped by

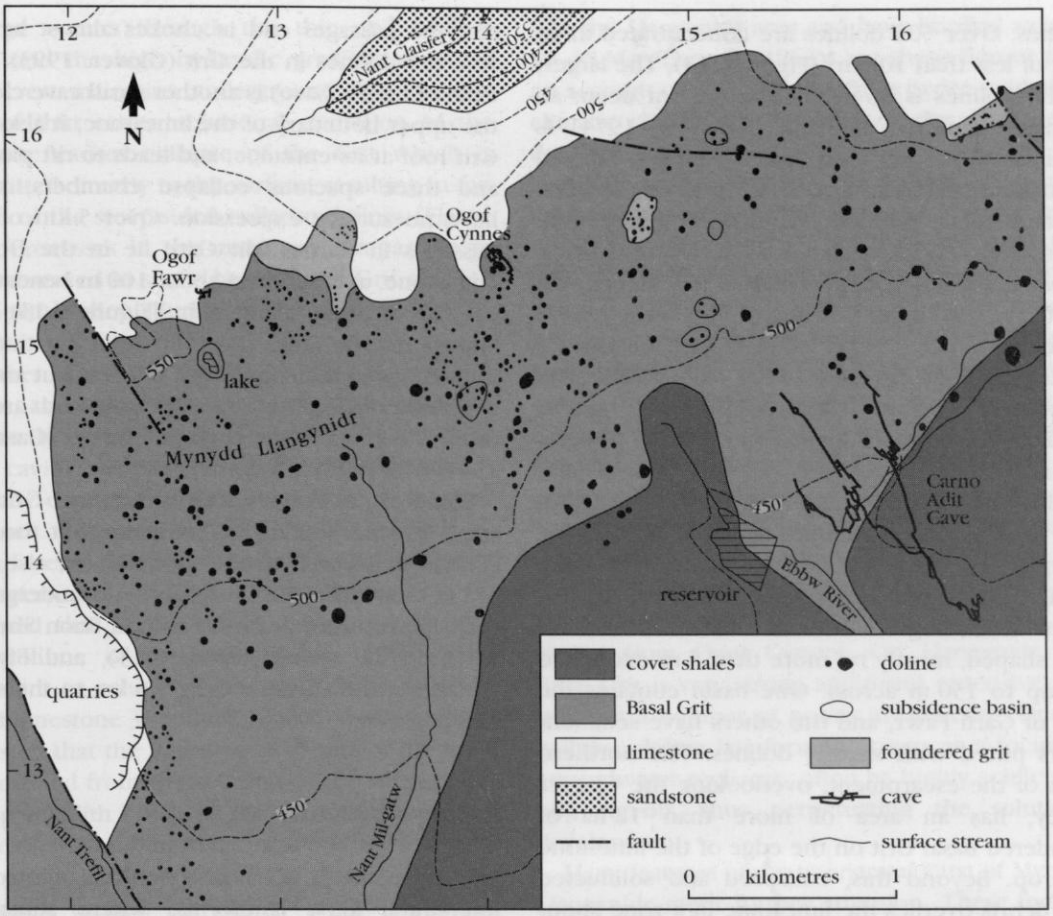

Figure 6.13 Geological map of the doline field on Mynydd Llangynidr (partly after Thomas, 1974: Ogof Carno from survey by Brynmawr Caving Club). The cover rocks are Namurian shales above the Basal Grit and Coal Measures. The sandstone beneath the limestone is Devonian. Much of the limestone outcrop is covered by soliflucted Grit blocks.

Namurian Basal Grit, and the moorland of the dip slope is pocked by a spectacular suite of collapse dolines and subsidence basins. These form a packed doline field 2 km wide near the crest of the escarpment, which is fringed by foundered masses of the Grit lying on the limestone of the scarp face (Figure 6.13). The site clearly demonstrates how subsurface, interstratal karst solution can induce collapse and therefore produce dolines and subsidence basins in the non-carbonate outcrop.

Thomas was the first to describe the geomorphic effects of the interstratal karst on the limestone and sandstone outcrops all along the northern rim of the South Wales coalfield (Thomas, 1954, 1963, 1973, 1974). The link between surface collapses and underlying cave systems was examined by Bull (1977) in the adjacent Mynydd Llangattwg, while Battiau-Queney (1980, 1986) recognized a buried palaeokarst exposed in quarries 4 km west of Llangynidr, and Smart and Christopher (1989) attribute some examples of large masses of foundered Millstone Grit to faulting.

Description

Mynydd Llangynidr is a bleak moorland rising to 550 m. To the north it is bounded by a steep scarp face overlooking the Usk Valley, and to the south an extensive dip slope extends towards Tredegar and the South Wales coalfield. Dinantian limestones, about 120 m thick and dipping 2–5° SSE, form the main escarpment. The dip slope is capped by the Basal Grit, a strong, coarse-grained sandstone forming the lowest unit of the Namurian Millstone Grit Series; the thickness of the Grit cover progressively increases from the escarpment edge to about 30 m where it gains a cover of Namurian shales.

The dip slope has a spectacular assemblage of dolines. Over 500 dolines are concentrated in an area of less than 10 km^2 (Figure 6.13). The largest of the dolines is 55 m wide and 17 m deep; an average diameter of 29 m (Thomas, 1974) is significantly greater than that of typical solutional dolines formed in limestone. Most have a roughly symmetrical, inverted conical cross-section. Thomas (1954) investigated 437 collapse dolines, across the whole of the South Wales interstratal karst belt, and found that nearly 75% of them have a depth:diameter ratio of 1:3. The remainder include both steep-sided, rocky dolines, and also broad and shallow depressions with saucer profiles. The doline sides have an average slope of about 30° on a veneer of Grit blocks and solifluction deposits; exposed rock walls form only part of the perimeters of about 30% of the dolines. The steeper funnel-like dolines dominate the Llangynidr interstratal karst, but there are also seven much larger subsidence basins. These are oval shaped, mostly no more than 5 m deep, and are up to 150 m across. One basin contains the lake of Garn Fawr, and the others have sediment floors pitted with smaller dolines. The northern edge of the escarpment, overlooking the Claisfer Valley, has an area of more than 12 ha of foundered Basal Grit on the edge of the limestone outcrop. Beyond this, collapsed and soliflucted Grit debris overlies the limestone in a zone about 200 m wide which is almost continuous along the edge of the solid outcrop of the limestone.

There are two small caves on Mynydd Llangynidr (Figure 6.13). Ogof Cynnes is a cave with 900 m of rift passages formed in the top beds of the limestone beneath the Grit cover. The entrance passage has a roof of Basal Grit, and the complex of narrow rifts are plastered with mud and blocked by Grit boulder chokes; there are no large collapse chambers in the cave. The cave passes beneath the floor of the entrance doline, and the passages end in chokes almost beneath adjacent dolines in the Grit (Glover, 1993). Ogof Fawr (Chartist Cave) is another small cave close to the upper boundary of the limestone; it also has a Grit roof at its entrance, and leads to rift passages and three spacious collapse chambers, which have no surface expression. Over 5 km of cave passages in Carno Adit Cave lie in the Dowlais Limestone, at a depth of about 100 m beneath the eastern edge of Llangynidr (Figure 6.13); they appear to be the downdip continuations of influent caves including Ogof Cynnes, but are only accessible from the drainage adit and are not directly related to the surface features (Gascoine, 1991; Bailey, 1992; Rogers, 1992).

Some of the dolines within the Basal Grit have small streams sinking within them, but the main surface drainage is to the south. Water also sinks at the Grit/limestone boundary, and underground drainage resurges at both Ffynnon Shon Sheffrey, in the Trefil valley (Figure 6.13), and Ffynnon Gisfaen in the Clydach Gorge, 6 km to the south-east (Gascoine, 1989).

Interpretation

The doline fields seen on Mynydd Llangynidr are interstratal karst landforms, where subsurface solution has induced deformation and collapse of the overlying cover rocks (Thomas, 1974). Interstratal karst occurs along much of the adjacent Lower Carboniferous outcrop, but is particularly well developed on Mynydd Llangynidr, where the dip slope gradient is very close to the regional dip, so that the cover of Basal Grit remains thin across a broad belt.

Where the Basal Grit is thinnest, along the northern margin of the interstratal karst belt, solutional erosion is at a maximum; groundwater

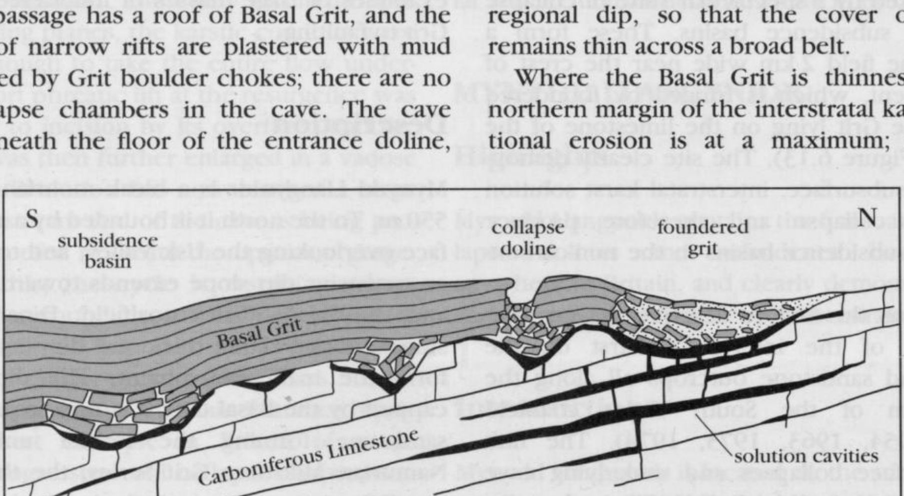

Figure 6.14 Diagrammatic cross-section through the three types of surface depression formed in the Basal Grit due to solution of the limestone beneath (after Thomas, 1974).

recharge occurs through the thin and broken cover, and the high hydraulic gradient near the scarp crest maintains underground flow. In this zone of thin cover, solutional cavitation of the limestone causes collapse of the Grit which is transmitted directly to the surface, resulting in formation of the steep-sided collapse dolines (Figure 6.14). Processes in this zone are comparable to those observed in shafts beneath the Grit close to the Mellte Valley (Burke and Bird, 1966; Burke, 1967).

Further down the dip slope, the Grit cover is thicker, and lower fracture permeability at depth reduces the solutional activity. Collapses into solutional cavities within the limestone of this zone is generally confined to the lower beds in the Grit sequence. Repeated collapse expresses itself on the surface as a shallow basin caused by sagging of the uppermost beds (Figure 6.14). Thomas (1954) estimated that in one block covering 6 ha, the total volume of the dolines was 180 000 m^3, equivalent to solutional removal of a continuous bed of limestone 3 m thick. Battiau-Queney (1980) suggested that the widespread rotting of the Basal Grit resulted from the solution of the silica under a deep regolith cover in the warmer climates of the Tertiary, and limestone solution only followed when uplift allowed circulation through the rotted zones; though the history of the solutional activity may remain open to debate, the dolines are clearly the result of cavity development within the limestone. The maze of rift passages in the top limestone beds in Ogof Cynnes, and the collapse chambers in Ogof Fawr, indicate the style of cavity development which ultimately will cause undermining and collapse of the Grit cover. Neither of these has developed to the point where collapse of the cover rocks can be seen underground as clearly as in Siambre Ddu (see below).

Along the northern edge of the escarpment, the limestone has undergone solutional erosion, and the Grit forms only a minor escarpment. There have been several phases of subsidence and collapse of the overlying Grit, which in places is so distorted that little of the original structure remains; these areas have been mapped as 'foundered Basal Grit' (Figure 6.14). However, some of these grit outliers, outside the Llangynidr karst, may be due to faulting, rather than solutional subsidence (Christopher and Smart, 1989). The age of the initial karstification may be estimated from measured solution rates and the extent of solutional lowering of the foundered Grit masses; maximum lowering has occurred outside the Llangynidr area and have implied ages of 10–15 Ma (Thomas, 1963), but these figures take no account of acidic waters from pyrite oxidation, climatic change and focusing of the drainage as the depressions evolve.

On Mynydd Llangynidr, the pattern of collapse dolines may reflect the form of the irregular unconformable interface between the Basal Grit and the underlying limestone (Thomas, 1974). Solutional activity may have been concentrated to produce major caverns along the bases of depression within the plane of unconformity; many caves, including Ogof Cynnes, are developed at the unconformity. There is no clear relationship between the collapse dolines of Llangynidr and collapse features directly underground in the few known cave systems. On the adjacent Llangattwg plateau, direct links can be traced between the surface collapses and boulder chokes in Ogof Agen Allwedd (Bull, 1977), but similar links are absent from Ogof Cynnes. On Llangynidr, the Basal Grit is very strong and forms extensive roof spans at a number of points in this cave. Once a collapse doline has formed, it acts as a focus for groundwater recharge, often by highly acidic peat bog run-off, thus perpetuating the solutional development.

Many features of the interstratal karst of Mynydd Llangynidr merit further attention. These include the effect of river rejuvenation and lowering water tables (Crowther, 1989), and examination of the nature, extent and age of some of the subsidence features, especially the foundered Grit masses north of the main outcrop.

Conclusions

Mynydd Llangynidr is Britain's finest example of interstratal karst. Doline fields within the grit outcrops are a special feature of the karst on the gently dipping escarpments of South Wales, and Llangynidr has the densest, largest and most spectacular assemblage of dolines. Collapse dolines, broad shallow subsidence basins and large masses of foundered grit all occur within a small area.

MYNYDD LLANGATTWG CAVES

Highlights

The caves beneath Mynydd Llangattwg form one of the two most extensive integrated systems in

Britain, containing exceptionally large karst conduits containing important sediment sequences. The network of ancient and active passages records a very long history of karst drainage modification in response to surface downcutting.

Introduction

The Llangattwg cave systems include Agen Allwedd, Daren Cilau and Craig a Ffynnon, all lying beneath a moorland escarpment at the eastern end of the North Crop (Figure 6.1). Mynydd Llangattwg is a peat-covered upland formed by the Basal Grit dip slope overlying the Carboniferous Limestone; it is almost a plateau, as the dip is only 2–3°. The Grit dips south beneath a cover of Namurian shales and sandstones followed by the Lower Coal Measures. Scarp faces to the north and east have steep screes and quarried crags in the limestone, overlooking the Old Red Sandstone floor of the Usk Valley. Along the southern margin of the plateau the River Clydach flows east through a steep gorge tributary to the River Usk. Input drainage to the caves is through numerous small sinks and percolation into the outcrops of both the limestone and the fractured and permeable Basal Grit. Pwll y Cwm is the largest of the multiple resurgences along the floor of the Clydach Gorge.

All the main cave passages are developed in the 50 m of Chadian oolitic limestones and dolomites within the Abercriban Oolite Group: the most cavernous unit is the Blaen Onneu Oolite (Wright, 1986a). These are overlain by the thin impermeable mudstones of the Arundian Llanelly Formation, and the Holkerian Dowlais Limestone which contains very little explored cave under Llangattwg. Palaeokarstic horizons, with associated mudstones or palaeosols, are developed at several levels in the oolites, and also at the junction of the Dowlais Limestone with the overlying Basal Grit. The limestone dips 2–3° to the south-west, with minor flexures producing local dips up to 15°. The area is traversed by a number of faults, mostly trending ENE or NNW, and there are well developed joint sets trending NNW and NNE.

A wealth of publications refer to Agen Allwedd, but the main passages of Daren Cilau have only been explored since 1984 and therefore largely await the scientific study that they warrant. The cave geomorphology has been comprehensively assessed by Smart and Gardener (1989), and the passage details and hydrology were described by Stratford (1995), Stevens (1992) and Gascoine (1989). Detailed accounts cover the succession of major new discoveries in Ogof Agen Allwedd (Leitch, 1960, 1973; Jenkins, 1963; Gardener, 1983; Tomalin, 1987; Abbot and Murgatroyd, 1988; Price, 1988), Ogof Daren Cilau (Gardener, 1984, 1985, 1986; Gardener and Westlake, 1985; Farr, 1985, 1986, 1993) and Ogof Craig a Ffynnon (Parker, 1978; Gascoine, 1979). Agen Allwedd has also been a prime site for research on the environments and paleomagnetism of clastic cave sediments (Bull, 1975, 1976a, 1978, 1981; Noel *et al.*, 1979, 1981; Noel, 1983, 1986, 1988).

Description

More than 65 km of cave passage have been explored under Mynydd Llangattwg, in three major cave systems, Ogof Agen Allwedd, Ogof Daren Cilau and Ogof Craig a Ffynnon, together with several smaller caves and isolated sections of larger systems (Figure 6.14). Morphologically these constitute a single cave system, but links have not yet been explored between the three main caves. Each has its own single dry entrance, though Daren Cilau can also be entered through the flooded passages at the resurgence.

Ogof Agen Allwedd

This is the most westerly of the three major caves, was the first to be explored, and now has more than 34 km of mapped passages (Figure 6.15). Its main stream drains from the Remembrance Series under the northern tip of Mynydd Llangattwg, along Turkey Streamway and the lower part of the Main Streamway, into Maytime Series where active phreatic loops link sections of vadose streamway. The water then flows into the lower reaches of Daren Cilau. The streamway steadily increases in size downstream; many sections are 5–10 m high and wide, and the downstream passage is a massive phreatic tunnel now partially drained. Vadose trenches are discontinuous as they are mainly incised through the crests of low phreatic loops.

The major active tributaries are two vadose streamways which drain in from the north. The first is a stream from the entrance in the northern escarpment, which collects other inlets and forms the upper part of the Main Streamway, above the junction with the larger Turkey Streamway. The second is the long narrow canyon of Southern

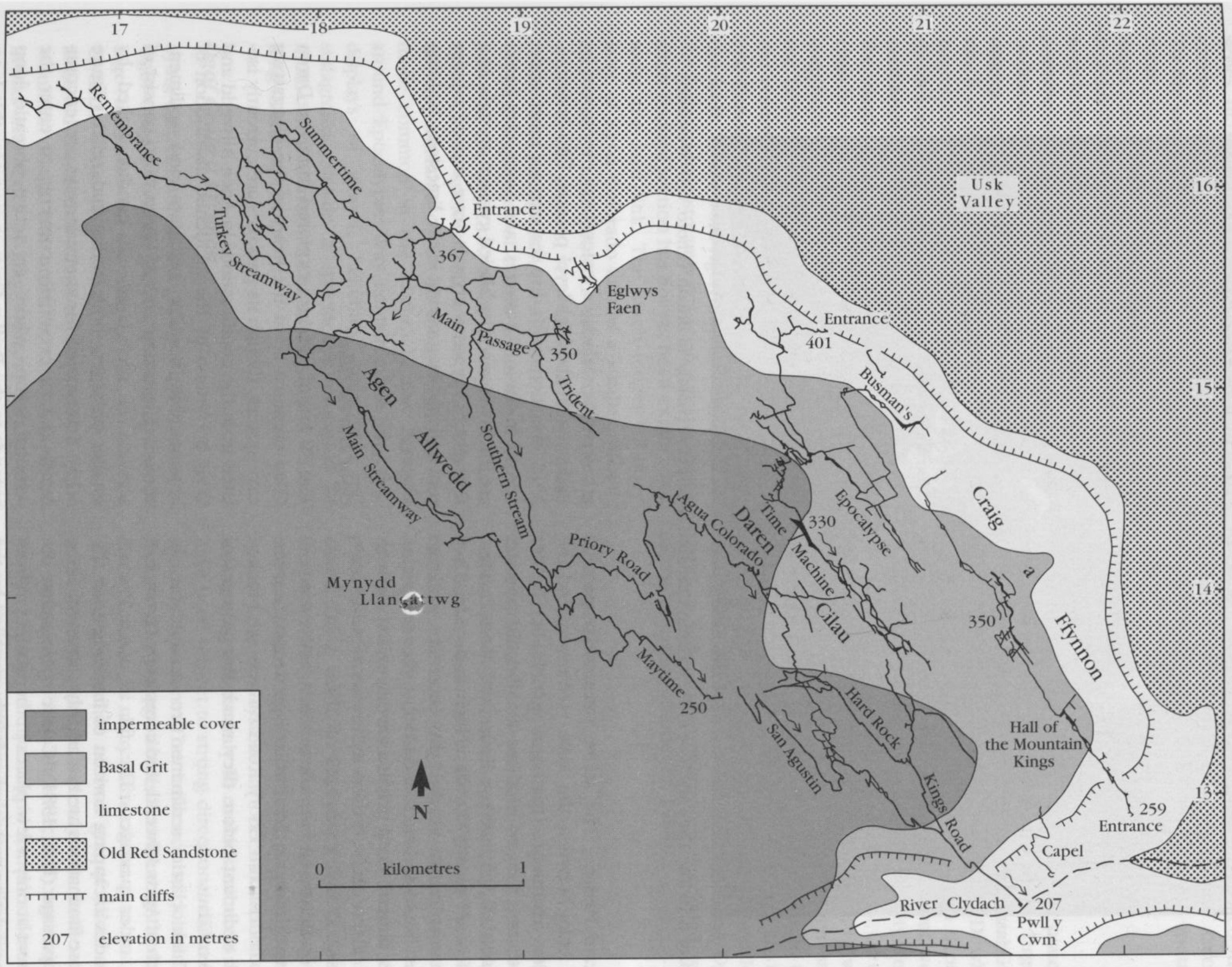

Figure 6.15 Outline map of the caves under Mynydd Llangattwg (from surveys by Chelsea Speleological Society, British Speleological Association, Cwmbran Caving Club, Cave Diving Group and others).

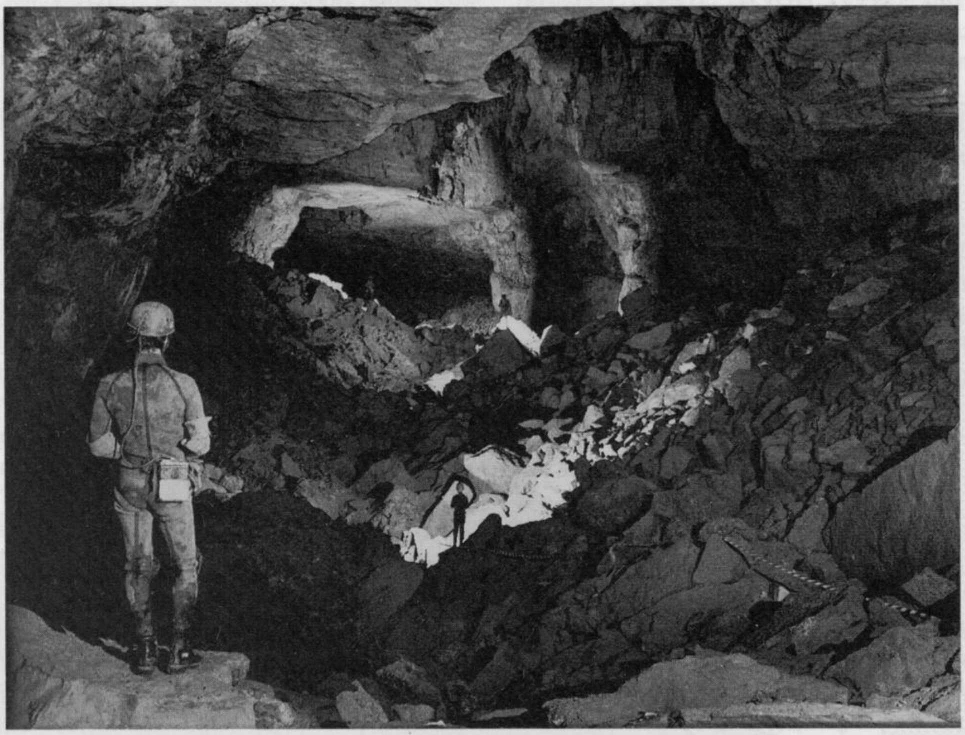

Figure 6.16 The Time Machine in Ogof Daren Cilau, the largest cave passage in Britain. (Photo: C.D. Westlake.)

Stream Passage. The active streamways provide the links between the Main Streamway and the major abandoned passages which lie further north-east. Largest of these are the old phreatic tunnels of Summertime Series and Main Passage, which are mostly 10–20 m high and wide. They are now partly blocked by enormous collapse piles, boulder chokes, and thick sequences of clastic sediment; deep profiles have been cut through the fills, notably at the south-eastern end of Main Passage. Smaller passages off these trunk routes are numerous and at various levels, and some connect with fragments of other large trunk passages; the Trident and Priory Road tunnels are blocked with sediment before they reach the passages of Daren Cilau.

Thick clastic sediments are conspicuous in much of Agen Allwedd, and completely fill some of the older passages. The fill in Main Passage includes a capping horizon of fine lacustrine silt, whose laminations are remarkably consistent along the passage (Bull, 1981). Calcite speleothems are present at only a few places in the cave, as inflows of percolation water are severely curtailed by the impermeable cover rocks over these deeper zones of the escarpment (Figure 6.15). However, there are very fine stalactites, extensively overgrown by helictites, in the high-level passage into Maytime. Mud formations with drip features are more widespread in the old passages, and some clay banks are thickly covered by bladed gypsum crystals. In a few places, gypsum crystals have caused tabular roof collapse by growing in the limestone bedding planes.

Ogof Daren Cilau

The 30 km of passages explored from the Daren Cilau entrance lie at the heart of the Llangattwg cave system, though its passages are currently isolated from the continuations in Agen Allwedd and Craig a Ffynnon by the incidental distribution of impenetrable boulder collapses and sediment chokes. The main caves of Daren Cilau consist of sections of very large old conduit linked by smaller passages, both active and relict (Figure 6.15). Sections of three streamways are encountered, and all eventually converge to enter the terminal sump, where an active phreatic loop extends to the Pwll y Cwm resurgence; this loop reaches a depth of 217 m below the highest point in the cave.

The Entrance Series has a small vadose passage into a rift and a short section of large, old passage blocked at both ends by collapse. Beyond this, a series of rifts and muddy, abandoned passages extends to a large chamber and a major junction. To the east, Epocalypse Way is a major old trunk route, up to 8 m wide, with smaller vadose passages leading off into Antler Passage and Busman's Holiday. To the west, a complex series of rifts and high-levels leads to the Time Machine. This is a massive tunnel so heavily modified by vadose undercutting and block collapse that its phreatic origins are barely recognizable (Figure 6.16); much of it is 30 m high and wide, making it the largest cave passage in Britain. The Time Machine divides at its southern end, but the main route continues into the high-level Kings Road, beyond the Hard Rock series of small rifts and larger chambers entering from the west. Kings Road continues to the lower streamway which feeds to the Terminal Sump into the flooded connection to the resurgence. From this open streamway, several flooded sections guard the major inlets from the west. Water from Agen Allwedd drains down the large vadose streamway of San Agustin, but a short flooded section has not yet been explored to make the final link. The much longer tributary inlet of Agua Colorado carries a smaller stream, and near its head provides access to high-levels which reach chokes very close to the similar Priory Road passage in Agen Allwedd.

Thick sequences of clastic sediments occur in many of the large old trunk passages of Daren Cilau. Calcite speleothems are restricted beneath the impermeable cover on the plateau, but are more common in the eastern sector. Passages around Epocalypse Way contain some very fine displays of straws, helictites, stalactites and stalagmites, beside a spectacular profusion of multi-coloured aragonite anthodites up to 40 mm long (Kendall, 1988).

Ogof Craig a Ffynnon

Lying east of Daren Cilau, nearly 9 km of caves in Ogof Craig a Ffynnon are reached through a passage truncated in the side of the entrenched Clydach Gorge (Figure 6.15). A first section of large old abandoned tunnel ends at the Hall of the Mountain Kings, but much of the continuation breaks into series of long, straight, parallel rifts, some of which link down to short sections of active streamway. The cave is broken by five areas of massive collapse; some of these contain large blocks of sandstone and lie directly below collapse dolines on the moor over 100 m above. Craig a Ffynnon now lies well clear of the impermeable cover on the limestone, and percolation drainage has deposited many excellent calcite speleothems; the older passages also contain extensive clastic sediments.

Minor caves

There are few open stream sinks on the plateau moorland. Llangattwg Swallet takes the largest flow into a collapse doline in the cap of Basal Grit. Other dolines reach down into the Dowlais Limestone, but none can be followed to depths greater than 40 m. Sediments in Pwll Gwynt were deposited with reversed magnetic polarity, indicating an age greater than 780 000 years. Of the smaller caves around the escarpment rim, Eglwys Faen is the longest with passages which start large, only to terminate in major collapses. In the Clydach Gorge, the most important caves are the Pwll y Cwm resurgence and its flood overflow through the narrow rifts of Elm Hole, and Ogof Capel, a vadose streamway well decorated with calcite dripstone (Gardener, 1988).

Interpretation

The overall drainage trend in the Llangattwg limestone is to the south-east, to resurgence positions determined by the surface topography. This direction is almost across the low SSW dip. There has, therefore, been a long history of vadose inlet drainage roughly downdip to join phreatic trunk conduits along the strike; the latter have shifted progressively downdip in response to valley downcutting and lowering of resurgence levels, leaving parallel abandoned caves north-east of the active drains. Both vadose and phreatic components of the cave system have been constrained to a zone of limestone only 50 m thick, wherein they have been subject to strong directional control by tectonic fractures. The influence of joints and faults on the passage details is evident in the rectilinear patterns in many parts of the cave system. The strong influence of two sets of joints on a strike phreatic passage is clearly seen in the modern stream route into Maytime; the cave's zigzag pattern through the joint grid includes downdip loops which are still flooded between updip segments which are now drained.

Palaeokarst and palaeosol horizons have

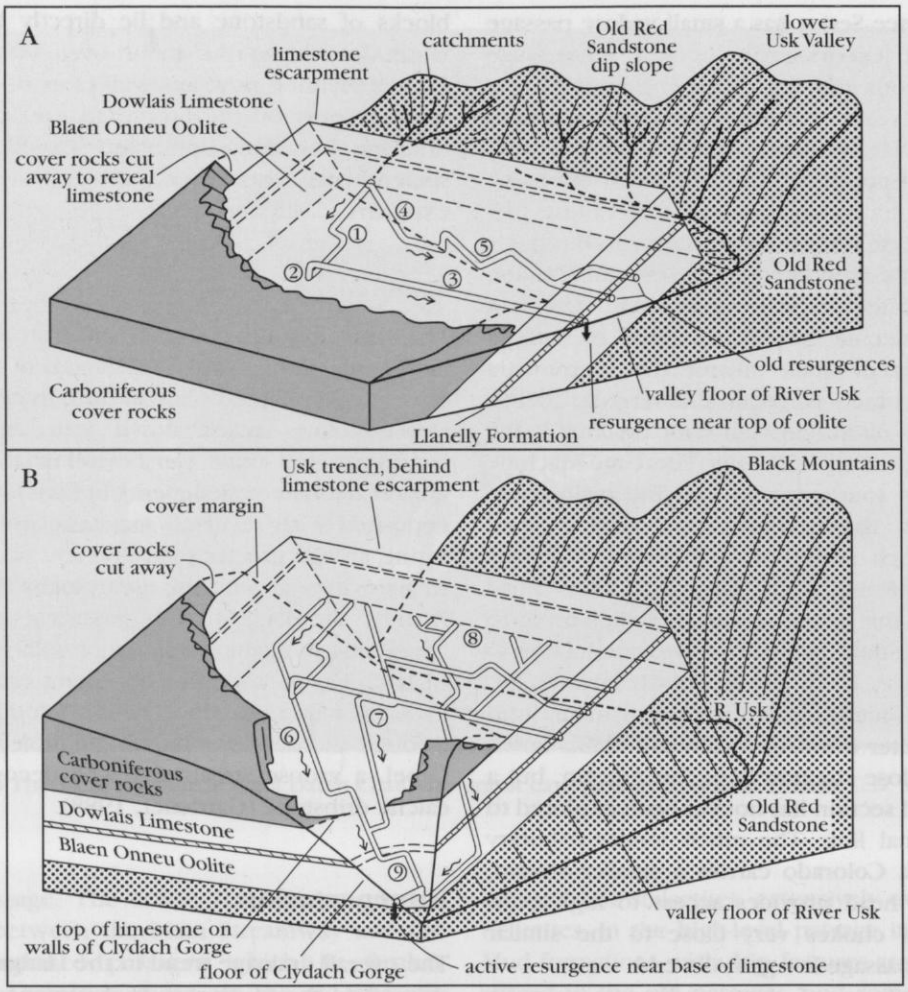

Figure 6.17 Block diagrams showing stages in the evolution of the Llangattwg caves. (A) In the early stage, the Usk headwaters drain into the cave: 1 = vadose flow downdip; 2 = phreatic lift taking water from the base to near the top of the oolites; 3 = phreatic strike flow; 4 = vadose flow on joints; 5 = phreatic conduit looping along joints. (B) In the later stage, the limestone escarpment is perched above the Usk trench: 6 = main drainage on joints with greater downdip component; 7 = older passages invaded by vadose streams; 8 = vadose inlets from limestone outcrop and from glacier melt during Pleistocene; 9 = limited phreatic development behind resurgence. (After Smart and Gardener, 1989.)

influenced the stratigraphic positions of passage development, acting as aquicludes or inception horizons and also limiting the extent of upward collapse stoping; hence many passages are roofed by these beds. Stratigraphy has also exercised broader controls. Inlets to the overlying Dowlais Limestone drain along the shales and calcite mudstones of the Llanelly Formation for considerable distances before finding routes through fractures into the cavernous limestones below. The impermeable cover, of Namurian and younger clastics, has largely excluded percolation water from the caves, and there are few calcite and aragonite speleothems, except in the uncapped passages of Craig a Ffynnon. Some very delicate speleothems appear to have been formed by evaporation of water which was intergranular seepage through the Grit. The Namurian shales are pyritiferous, and may have been the source of the sulphate which has formed so much gypsum in parts of Agen Allwedd.

Smart and Gardener (1989) interpreted the isolated sections of very large trunk passage as parts of ancient systems of essentially strike-orientated phreatic conduits. Major streams flowing off the Old Red Sandstone dip slope entered sinks into vadose passages which drained downdip, or obliquely along the joints, to feed the trunk cave drainage; this was orientated ESE towards presently unknown resurgence sites along the eastern outcrop of the limestone (Figure 6.17). The main sinking drainage was then captured by the River Usk whose valley was deepened, fluvially and glacially, along the outcrop of the softer rocks around the Devonian/Carboniferous boundary. The beheaded trunk passages were largely choked by collapse and sediment infill, while new, smaller vadose caves developed obliquely downdip under joint control, and in many places cut across the older, strike-orientated, phreatic trunks. New trunk drains at lower positions, down the dip, were originally phreatic, but resurgence lowering left them in the vadose environment except for the lower phreatic loops. They have since undergone extensive vadose modification, with considerable entrenchment at the crests of phreatic loops. The vadose passages developed in the lower beds of the limestone, and some have subsequently entrenched into the underlying shales, while the phreatic caves had lifting segments which took them and the early resurgences to the top of the oolitic limestones just beneath the Llanelly Formation (Figure 6.17).

The complexity of the Llangattwg cave systems, with the variation in size and morphology of their passages, reflects a long and complex history extending well back into the Pleistocene. The very large sizes of the old trunk caves is incompatible with the modern drainage to the limestone. The oldest passages were fed by headwaters of the River Usk, but this river was then entrenched below the plateau sinks. Glaciers breached the Old Red Sandstone escarpment to flow down the Usk Valley: they could have supplied large flows of sediment-charged, aggressively acidic meltwater to the high-level marginal sinks in the limestone. Some of the Llangattwg caves may therefore be unusual in having been active largely during the glacial stages of the Pleistocene. During the interglacials, water charged with biogenic carbon dioxide had less effect because of the very small flows reaching the elevated limestone outcrops. This concept is supported by the glacial ancestry of much of the cave sediment (Smart and Christopher, 1989; Bull, 1976a, 1980), but the sediment sequences in the main caves have not yet yielded a framework of absolute dates.

While the upper end of the cave system was being modified in response to entrenchment of the Usk, the lower end was rejuvenated as the Clydach Gorge retreated into the limestone escarpment. The ages of the earliest trunk passages are not yet known, but they appear to predate much of the glacial excavation of the Usk Valley, and probably date from the early Pleistocene. Early resurgences could have been close to the mouth of a proto-Clydach valley. The chronology of entrenchment of the Clydach Gorge is debatable. South of the Clydach, Ogof Draenen contains some old abandoned cave passages which were formed by northward drainage into the Clydach Gorge, thus indicating its considerable age (see Figure 6.18). Draenen has no passages large enough to represent the downstream continuations of the old Llangattwg trunk conduits, truncated by a younger Gorge, but these could lie downdip of the known cave system. The age of the Clydach Gorge therefore remains uncertain, but current evidence suggests that it is older than most of the caves.

Unlike other systems of comparable size and complexity, such as the Ease Gill caves and Ogof Ffynnon Ddu, the Llangattwg cave system appears to have experienced a major change in drainage pattern at some point in its development. Establishing the nature and cause of this change is fundamental to understanding the geomorphological history of this area.

Conclusion

The caves of Llangattwg form one of the most extensive systems in Britain, which developed largely beneath an impermeable cover. They record the evolution of a massive karst drainage system over a very considerable timespan, during which the surface drainage underwent major changes and captured much of the early sinking water. Subsequently these caves were modified by smaller percolation flows and possibly by episodic invasion by glacier marginal drainage. The much greater underground flows of the past formed trunk drains, one of which is now the largest single cave passage in Britain. The old caves contain exceptional clastic sediment sequences of great stratigraphic value, and some unusual speleothems of calcite, aragonite and gypsum.

OGOF DRAENEN

This is a proposed GCR site, of which only Siambre Ddu is currently a designated SSSI

Highlights

Ogof Draenen is a major cave system developed in Carboniferous Limestone almost entirely beneath its own allogenic catchment on the overlying Coal Measures. Large passages record an unusually clear example of flow diversion related to differential rates of incision in two adjacent valleys. Abandoned phreatic conduits contain the finest examples in Britain of solutional wall notches associated with sediment deposition or ponding. The adjacent cave of Siambre Ddu is Britain's finest example of a chamber which is an element of interstratal karst, formed by solution directly beneath a cover of Millstone Grit.

Introduction

Ogof Draenen is developed beneath the escarpment and moorland extending south-east of the Clydach Gorge (Fig 6.1). The outcrop of the limestone is confined to a narrow sinuous strip along the steep, north-facing scarp face of the escarpment and an elongate window in the Afon Lwyd valley south of Blaenavon. Most of the cave lies beneath the outcrop of the cover rocks; less than 10 m of Namurian Basal Grit is overlain by thin shales and sandstones, also of the Namurian, and a much greater thickness of Westphalian Coal Measures. The cave passages of Draenen are developed at numerous levels throughout almost the entire thickness of the Abercriban Oolite Group. These Lower Dinantian limestones are 50 m thick on Gilwern Hill, but thin to 30 m on the Blorenge, due to progressive eastward overstep of the unconformable Basal Grit cover. Other than the massive, bioclastic Gilwern Oolite at the top of the sequence, much of the carbonate is extensively dolomitized and some is thinly bedded. The dip is 4° south-west, and the dominant joint set is NNW–SSE, nearly parallel to several small faults.

There are no major sinks feeding the cave, but many of the streams draining across the escarpment have at least part of their flow captured as they cross the limestone outcrop. The largest risings proven to take flows from Ogof Draenen are at Snatchwood and Pontnewynydd, both 7 km south of Blaenavon down the Lwyd Valley and just north of the Trevithin Fault. Some cave water drains to small risings in both Cwm Llanwenarth and Cwm Dyar.

Ogof Draenen was discovered late in 1994, and the only published descriptions are those by the explorers (Bolt *et al.*, 1994, 1995) and one brief discussion of the geomorphology (Simms *et al.*, 1996). The hydrology is discussed by Gascoine (1994), and Siambre Ddu is briefly referred to in Stratford (1995), Thomas (1974) and Gascoine (1982).

Description

The entrance to Ogof Draenen is a small phreatic tube developed high in the Gilwern Oolite and truncated by the hillside above Cwm Llanwenarth. It is the only access to more than 48 km of mapped cave passages (Fig 6.18). The entrance series descends to Tea Junction, where it meets the long passages aligned almost on the strike on the western side of the system. To the south, Beyond a Choke is a major active streamway; the large phreatic passage is increasingly entrenched to the south, with a narrow, locally joint-guided, vadose canyon more than 30 m deep beneath an almost horizontal phreatic tube. Towards its southern end the phreatic tube descends to stream level in a series of loops. Strewn with boulders in the northern section, it has a fine sediment floor and deep pools towards the south. North of Tea Junction, Gilwern Passage is a major abandoned conduit with several tributary passages from complex areas of rifts and collapse; its underfit stream now drains to a rising in Cwm Dyar. The Gilwern Passage series contains some fine speleothems, including calcite rafts; thick sediment sequences contain false floors, clastics with epsilon cross-bedding, numerous coal clasts, and well preserved current ripples which indicate northward flow.

A complex series of mainly abandoned passages lies east of Beyond a Choke (Fig 6.18). Upstream Passage contains thick deposits of laminated sands and clays similar to those in Main Passage of Agen Allwedd; they drain south, but the current bedding indicates flow to the north, and the sediment fill may be from temporary glacial inputs at passage breaches, which were remote from the sinks at the head of the stream caves. A minor inlet extends north to give access to more than 2 km of abandoned high-level passages in Waterfall Series. South of the entrance series, Lamb and Fox Chamber is a large collapse feature extending into the upper part of the Abercriban Oolite; its walls are undercut by an exceptionally wide solutional notch, and have sands and gravels preserved on remnant ledges. Two vadose canyon passages drain towards the south; the eastern passage has a small phreatic tube in its roof and extends to a further junction. The Canyon is a large paragenetic canyon passage with a vadose trench incised

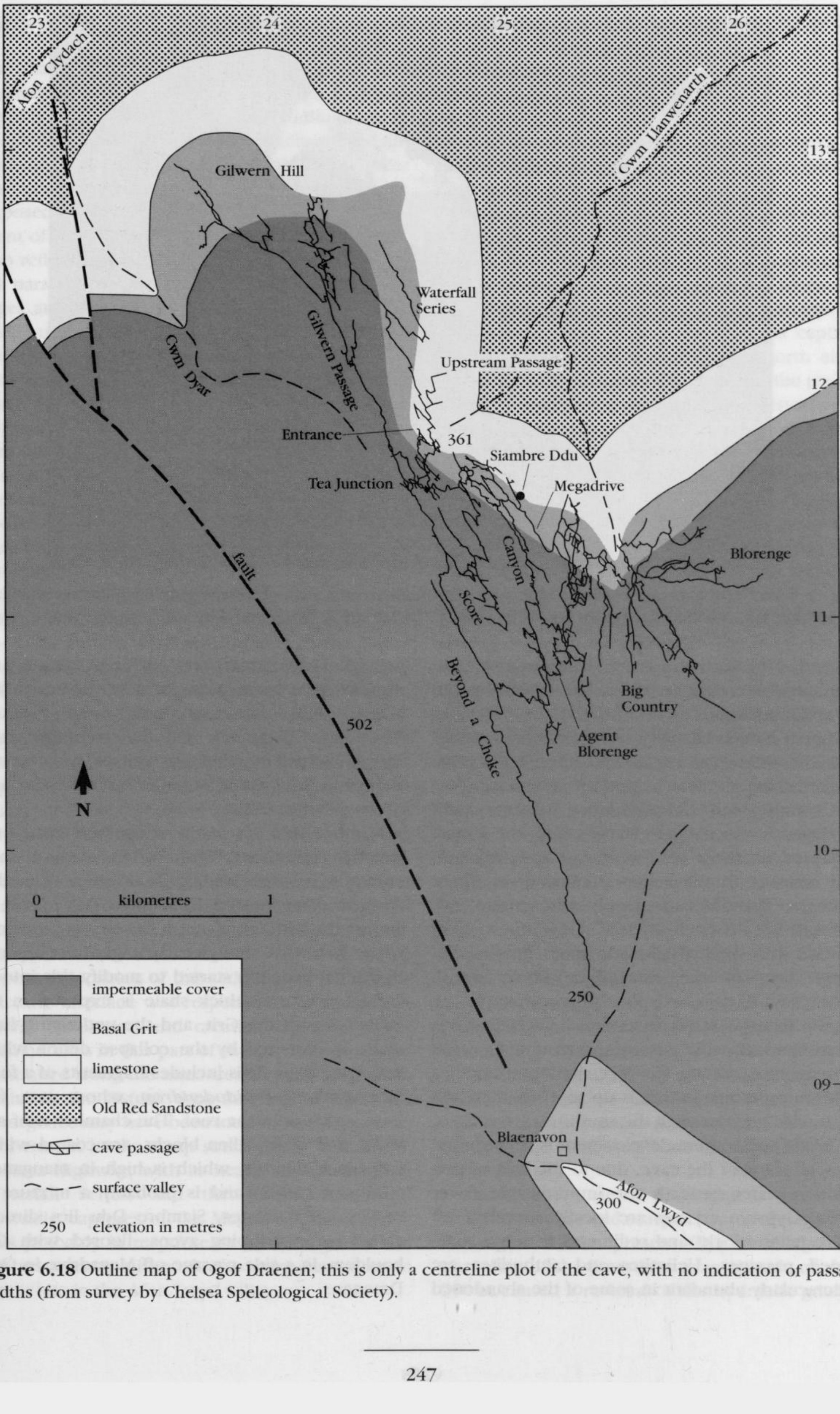

Figure 6.18 Outline map of Ogof Draenen; this is only a centreline plot of the cave, with no indication of passage widths (from survey by Chelsea Speleological Society).

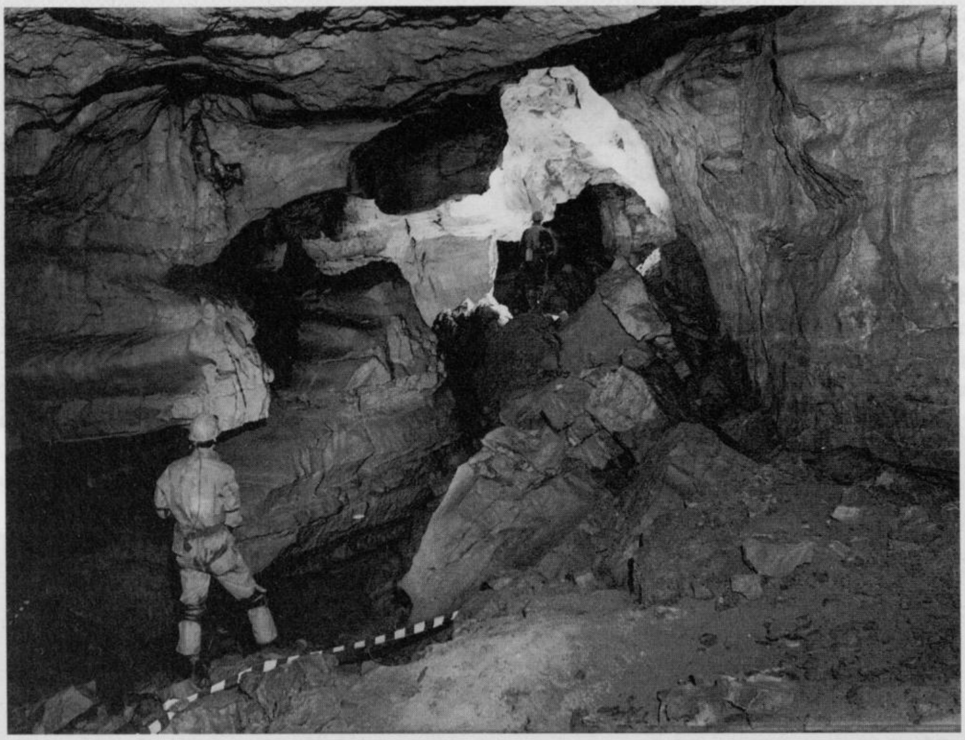

Figure 6.19 The abandoned conduit of Megadrive in Ogof Draenen, with preserved solutional notches along the wall on the left. (Photo: C.D. Westlake.)

beneath. Megadrive is a major abandoned phreatic conduit with a meandering vadose trench incised several metres into its floor; it contains extensive sediment banks, has very fine solutional notches along its walls (Figure 6.19) and extends to a large choked chamber close behind the scarp face.

A complex series of abandoned passages south of Megadrive includes St David's Hall, the largest collapsed chamber yet found in Ogof Draenen, and connect to the active streamway of Agent Blorenge. This descends steeply via a series of cascades into a trench incised more than 30 m beneath the original phreatic tube; it joins the lower part of the Beyond a Choke trunk streamway. Abandoned phreatic conduits in the Elliptic Passage Series extend east of Megadrive; these connect with passages extending beneath Blorenge to the Big Country, where tributaries unite in a passage which is up to 10 m high and 20 m wide and drains to the south.

Calcite speleothem development is very limited through most of the cave, due to the lack of percolation water beneath the impermeable cover rocks. Gypsum crystals are locally abundant on walls, fallen blocks and sediments in some abandoned passages. Helictites and anthodites are spectacularly abundant in some of the abandoned passages. Accumulations of bat guano are significant in some passages near the scarp face where old entrances are now blocked. Bradyodont fish teeth and fin spines are commonly etched in relief on passage walls in the richly bioclastic Craig-y-Caer Coral Bed at the base of the Gilwern Oolite.

Siambre Ddu lies in the scarp face east of the Draenen entrance (Figure 6.18), with a short entrance passage leading to a single chamber 25 m in diameter and 10 m high. The roof is an almost flat bedding plane in the strong sandstone of the Basal Grit, though early stages of collapse of individual beds has started to modify this into an arched profile. A thick shale is exposed in the walls beneath the Grit, and the underlying limestone is obscured by the collapse debris which litters the floor. This includes fragments of a fossil tree trunk of *Lepidodendron*, whose cast, 6 m long, survives in the roof. The chamber roof and walls, and many fallen blocks, are coated with a soft black deposit, which is high in manganese (Gascoine, 1982) and is probably a mixture of oxides and humates. Siambre Ddu lies directly above some dripping avens, floored with Grit boulders, in a side passage off Megadrive in Ogof Draenen.

Interpretation

The main passages of Ogof Draenen are largely aligned close to the strike in a thin unit of gently dipping limestone. Successive conduits have developed due to progressive downdip shift of the drainage in response to the availability of lower resurgence sites in new outcrops of the limestone exposed by surface lowering. The uniform alignment of the Gilwern and Beyond a Choke Passages also reflects the orientation of the dominant joint set parallel to a strike-slip fault. Most of the passages are developed along joints adjacent to the fault, suggesting that the latter is relatively impermeable. A minor fault is crossed in one chamber which is modified by collapse, but the lack of collapse throughout such a great length of passage adjacent to a fault is remarkable. Lithological factors have influenced the cave passage shapes. Passages in the Gilwern Oolite and other massive units have largely retained their original solutional profile, while those in more thinly bedded carbonates lower in the succession have been greatly modified by collapse.

Passages in Ogof Draenen are developed at multiple levels within the limestone, and show a complex pattern of flow. Passages in the lower part of the Abercriban Oolite were formed by flow either to north or south, or in some cases to both. In the Gilwern Oolite almost all passages, including Megadrive, which is the highest and oldest trunk conduit in the system, have scallops indicating flow to the south. The fossil passages in Waterfall Series appear to represent an upstream extension of Megadrive, but the intervening section has been removed by retreat of the escarpment face. An abundance of coarse, angular sediment derived from the Millstone Grit suggests that the main sinks lay only a short distance to the north, but have since been destroyed by scarp retreat. Deposition of this sediment at the vadose-phreatic interface was responsible for promoting lateral dissolution and creating the spectacular wall notches in this part of the cave. If Megadrive continued along the same trend as the other main drains in the system, then the original high-level resurgence may have been located in Cwn y Nant, a re-entrant in the scarp south-east of Blaenavon. Indiana Highway, with its headward extension in Waterfall Series, and the Canyon represent downdip captures of the Megadrive flow, which was probably in response to a westward shift of the resurgence, either due to scarp retreat or to lower site in the Afon Lwyd valley.

Subsequently, White Arch Passage developed as a separate drain, lower in the limestone, extending north into Gilwern Passage, where scallops and sediment bedforms indicate consistent flow to the north. It was also fed by inlets draining north along the Score, perhaps derived from sinks on Blorenge. The underfit stream in Gilwern Passage now drains to a resurgence in Cwn Dyar.

The modern main streamway of Beyond a Choke is the lowest passage in the cave and drains south from Tea Junction down a very gentle gradient. A Choke marks the capture point where the earlier northward flow was re-routed towards the south. During the initial stages of this capture, water may have continued to flow north along Gilwern Passage as well as south along the precursor of Beyond a Choke. The preservation of current ripples which are unmodified or draped by mud suggests that the final abandonment of Gilwern Passage was comparatively sudden. Water continued to drain north along the Score after the capture, and supplied small capture passages westwards towards Beyond a Choke. The main capture was relatively recent, but sufficient time has elapsed for the remaining misfit streams in the Gilwern Passage series to entrench to the level of the main trunk passage. The deep and narrow vadose canyon in Beyond a Choke, and the comparable entrenchment in Agent Blorenge, suggests rapid incision since the abandonment of the northward flow route. Much of the Beyond a Choke streamway appears to be graded to current base level; it has a very low gradient with stretches of sediment floor and local ponding, but incision continues in the steeper, boulder-strewn descent of its upper reaches.

The flow re-routing from south to north then south again allows a sequence of scarp retreat and valley incision to be constructed for the cave catchment, though no dates for the cave sediments are yet available. In the earliest stage of cave development, water sinking along the eastern outcrop of the limestone, at altitudes of more than 380 m, drained southwards almost along the strike, until it could drain down the dip to limestone outcrops at altitudes around 310 m, exposed by differential scarp retreat. This stage predated the incision of both the Afons Lwyd and Clydach.

The second stage of development was associated with more rapid scarp retreat to the north, in the region of the present Clydach Gorge. The unroofing of the limestone at an altitude of about 250 m caused a reversal of the hydraulic gradient towards a new resurgence in the proto-Clydach valley. The new cave drainage to the north, via Gilwern Passage, was offset to the west of its southbound predecessor, as it shifted both downdip and into lower parts of the Abercriban Oolite. This stage of development in Ogof Draenen may be correlated tentatively with the development of Ogof Craig a Fflynnon, which still drains to a resurgence at a similar altitude on the opposite side of the Clydach Valley. The abundance of coal debris in the Gilwern Passage sediment suggests rapid stripping of overlying Coal Measures, perhaps associated with a poorly vegetated, periglacial environment. Remnants of cross-bedded sands in Upstream Passage are also the produce of a cold environment.

In the final stage of cave development, the main flow was captured southwards along Beyond a Choke, in response to incision of the Afon Lwyd towards the 120 m level of the present main risings; these were far below rising sites in the Clydach Gorge.

The present resurgence of drainage from the Llangattwg caves may lie at Pwll y Cwm only due to the breaching of a deep phreatic conduit by the incision of the Afon Clydach (Smart and Gardner, 1989). Prior to this breach, water may have continued southwards to an unidentified lower than any passages yet discovered in Ogof Draenen. The consistent northward flow in Gilwern Passage indicates that Ogof Draenen was not formed by water draining from a former eastward extension of the Llangattwg caves prior to incision of the Clydach Valley. The resurgences from Gilwern Passage and from Ogof Craig a Ffynnon lie at close to the same altitude, and may indicate comparable ages for the two caves. The older, high-level passages in Ogof Daren Cilau and Agen Allwedd may also have drained towards this resurgence unless they developed in response to the incision of the Agon Lwyd, providing a low-level outlet more than 10 km to the south. The Megadrive trunk conduit predates the main Llangattwg caves, but the second and third phases of development on Ogof Draenen may have been contemporary with the evolution of the Llangattwg drainage system, when the Afon Clydach became a major control on the regional cave development.

Dating of the caves is not yet possible. Early Pleistocene origins are indicated by the altitude of the large fossil phreatic conduits high above the modern base level and their truncation by the modern hillside. Deep vadose entrenchment of the Beyond a Choke main streamway and its Agent Blorenge tributary suggests that the presently active passages are also of considerable age. Dating of the cave sediments will establish a chronology for the flow diversions already recognized within Ogof Draenen; this will provide evidence for the relative ages of the Clydach Gorge and the Afon Lwyd valley, and also relative rates of scarp retreat in this region of South Wales.

The abundance of coal clasts in sediments throughout Ogof Draenen suggests that allogenic recharge to the narrow limestone outcrop has been from the west, draining directly from the Coal Measures which overlie much of the cave; there is no positive evidence for input from a former Old Red Sandstone catchment to the east, comparable to that on Llangattwg. Downdip drainage into the limestone beneath the Namurian clastics has produced the interstratal karst of which Ogof Draenen is a component.

Siambre Ddu is also a feature of the interstratal karst, where a cave chamber is undergoing progressive collapse and upward stoping. It lies only 15 m below the modern surface, and will ultimately form a collapse doline in the overlying Millstone Grit. Collapse of the cap rock into the solutional chamber in the limestone has blocked and obscured the shafts into the underlying cave passage, but comparison may be made with the shafts of the Mellte Valley formed by dripwater immediately beneath the Grit (Burke and Bird, 1966; Burke, 1967). Continuing stages in the evolution of Siambre Ddu may be compared to the massive Grit chokes in Craig a Ffynnon, under Llangattwg, and the doline fields of Llangynidr. Iron and manganese deposits are well developed in the Siambre Ddu chamber, and may be comparable with the complex iron minerals formed by oxidation of pyrite and deposited with peat in shafts in the Mellte Valley (Burke, 1970).

Conclusion

Ogof Draenen is a major cave system with a downdip sequence of abandoned and active, strike-aligned conduits. These have evolved through an environment of changing hydrology where flow from the central part of the cave was first to the south, then to the north, and finally to the south again, in response to the early incision of the proto-Clydach and the later incision of the Afon Lwyd. The scale of the flow reversals is unmatched elsewhere in Britain, and their ease and rapidity were largely due to the very low gradients in major cave conduits which were developed almost along the strike. Both Ogof Draenen and Siambre Ddu are components of a system of interstratal karst, and the latter represents an early stage in the progressive development of a collapse doline in the overlying Basal Grit.

OTTER HOLE

Highlights

Otter Hole contains a profusion of calcite stalactites and massive stalagmites on a scale unmatched by any other cave in Britain, and is the only major cave in the country located entirely within dolomites.

Introduction

Otter Hole lies in the west bank of the River Wye, just north of Chepstow (Figure 1.11). It has more than 3200 m of mapped passages developed entirely in the Lower Dolomite, a 100 m thick sequence of well-bedded dolomites and dolomitic limestones in the Courceyan stage of the Carboniferous Limestone. The main cave roughly follows the strike of the carbonates towards the east; dips are less than 10° to the south, and they swing around shallow flexures which plunge down the dip. The Vicarage Fault and the major joints are orientated NNW, parallel to the plunging flexures. Allogenic water drains into sinks along the boundary of the dolomite with the underlying Lower Limestone Shales, which separate it from the Old Red Sandstone to the north and west. Drainage through the cave flows to a resurgence between high and low water levels on the west bank of the River Wye about 100 m downstream of the entrance. The cave is intertidal at its lowest point, and rises to elevations of about 40 m.

The cave has been described by Elliott *et al.* (1979) and Westlake *et al.* (1989), and its diverse troglobitic fauna is recorded by Chapman (1979).

Description

An abandoned bedding plane passage, opening in the west bank of the River Wye a few metres above high-tide level, is the only entrance to Otter Hole. This joins the active streamway at the lowest part of the system, where backflooding at each high tide creates the unique tidal sump. At low tides, this can be passed to reach the active streamway which extends upstream along a fault-guided rift, and west to where the water emerges from low bedding plane passages with several flooded sections.

Above the active streamway, a series of old high-level passages extends to the west and north-east (Figure 6.20). Crystal Ball Passage is 200 m long to a choke and its rifts are up to 10 m high; there are many gour banks and spectacularly coloured curtains, and the crystal balls are roughly spherical calcite growths developed round the ends of straw stalactites where they dip below the

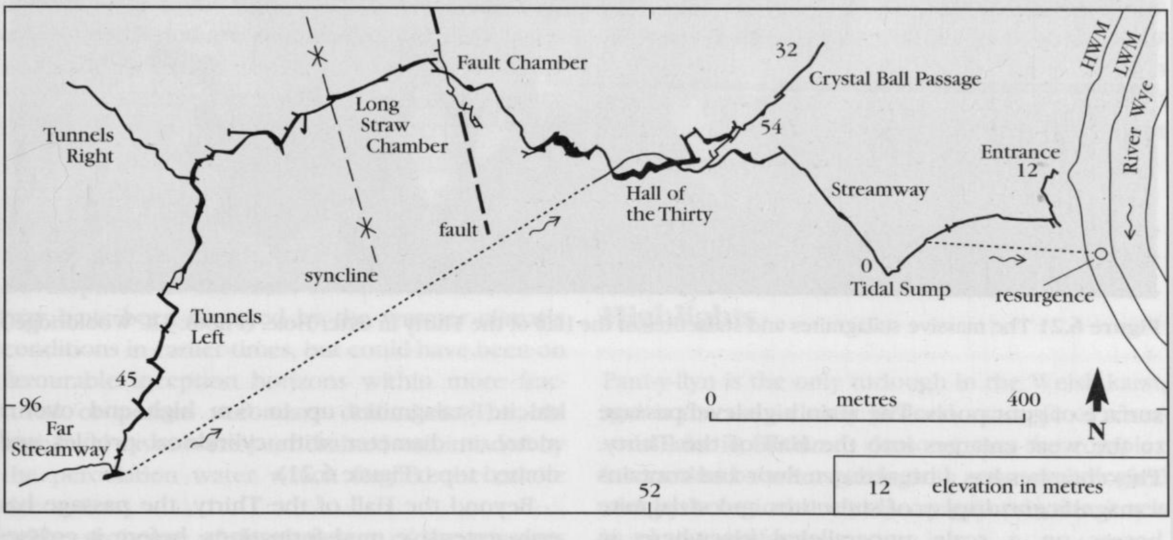

Figure 6.20 Outline map of Otter Hole (from survey by Birmingham University Speleological Society).

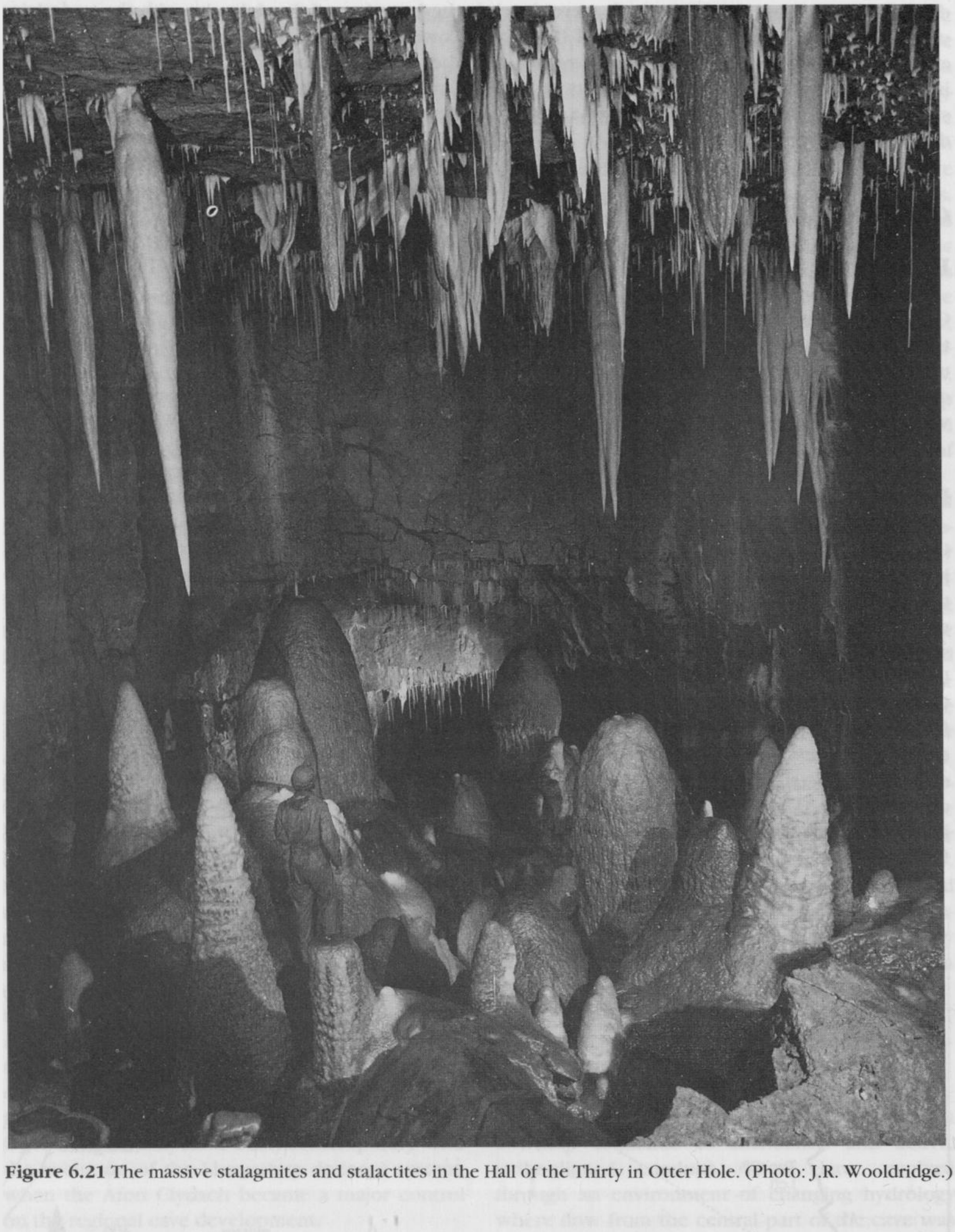

Figure 6.21 The massive stalagmites and stalactites in the Hall of the Thirty in Otter Hole. (Photo: J.R. Wooldridge.)

surface of gour pools. The main high-level passage to the west enlarges into the Hall of the Thirty. This chamber has a breakdown floor and contains a magnificent display of stalactites and stalagmite bosses on a scale unparalleled elsewhere in Britain. The most notable features are the many calcite stalagmites up to 6 m high and over a metre in diameter with cylindrical profiles and domed tops (Figure 6.21).

Beyond the Hall of the Thirty, the passage has only extensive mud formations, before it crosses the Vicarage Fault in Fault Chamber. To the west, it is again profusely decorated with gour and crystal pools, flowstone and immense numbers of straw stalactites up to 4 m long. The finest of these are in Long Straw Chamber, where the cave crosses the trough of a shallow plunging syncline. From Tunnels Junction, the larger upstream passage is Tunnels Left, a phreatic tube 4 m in diameter with many high cross-rifts; at its farthest explored limit, this is intersected by a short section of modern streamway, choked in both directions.

Interpretation

Otter Hole is developed within a thick, uniform sequence of dolomites and dolomitic limestones, lithologies which elsewhere in Britain have very limited cave development. Passage location within the carbonates is closely controlled by bedding, with the cave curving round the shallow plunging syncline while maintaining an almost constant elevation. Joints and faults guided the initial flow paths, and greatly influence the passage morphology.

The cave lies at a lower altitude than any other major system in Britain, and its intertidal entrance series provides a unique restriction on access to the passages beyond the tidally fluctuating sump. This low altitude environment, and the sheltered west coast location, may account for the scale of speleothem development in Otter Hole. The massive cylindrical stalagmites are typical of those formed by high inflows of saturated dripwater which continue to deposit calcite as they flow down the stalagmite sides. They are unlike any others in Britain, and are comparable only to those in southern European caves formed in warmer, Mediterranean climates with thick soil and vegetation cover on the carbonate outcrops. Their presence suggests a local climatic regime during parts of the Pleistocene which was significantly warmer than climates in Britain's other karst areas, mostly further north and at higher altitude. Development of the main caves in the dolomites may have been favoured by the warmer climatic conditions in earlier times, but could have been on favourable inception horizons within more fractured or porous secondary dolomites. The old high-level caves were later drained and invaded by the percolation water which formed the calcite decorations.

The sequence of development of the passages in Otter Hole correlates closely with the history of the River Wye, where four levels of terraces at altitudes of 3–60 m lie above a buried channel at least 15 m deep beneath the estuarine alluvium at Chepstow. In the earliest stage of Otter Hole, the main phreatic drainage flowed from Tunnels Left, along the main high-level cave, and out to a contemporary resurgence beyond the end of Crystal Ball Passage. The downstream end of this passage lies at about 30 m OD, just below the level of the second terrace. Further incision of the Wye, in response to the low sea level of a Pleistocene glacial stage, drained the old phreatic trunk caves into a lower route; this now forms the phreatic elements in the upper part of the active streamway, and the old phreatic passages of the entrance series, which correlate with an old resurgence at the level of the 3 m terrace. Lowering of base level during the Devensian caused vadose entrenchment in the streamway, and abandonment of the old resurgence in favour of the present one. The intertidal position today reflects a subsequent sea-level rise in the Holocene. The higher Wye terraces and the earlier stages of the cave development are not yet dated; analogy with other sites suggests a Hoxnian age for the old trunk cave and an Ipswichian timing for the main stalagmite deposition.

Conclusion

Otter Hole contains the largest stalagmites in Britain, which are comparable with speleothems in caves of the Mediterranean regions, and appear to reflect the southerly site at low altitude. The passage levels correlate with terraces on the River Wye. They are unusual in their extension down into the intertidal zone, and their development within a dolomitic sequence – both features not seen in other large caves in Britain.

PANT-Y-LLYN

Highlights

Pant-y-llyn is the only turlough in the Welsh karst, and is the only clearly defined example of a seasonal lake in Britain. It demonstrates the complex interaction between geological, geomorphological and hydrological controls on groundwater levels in a karst aquifer.

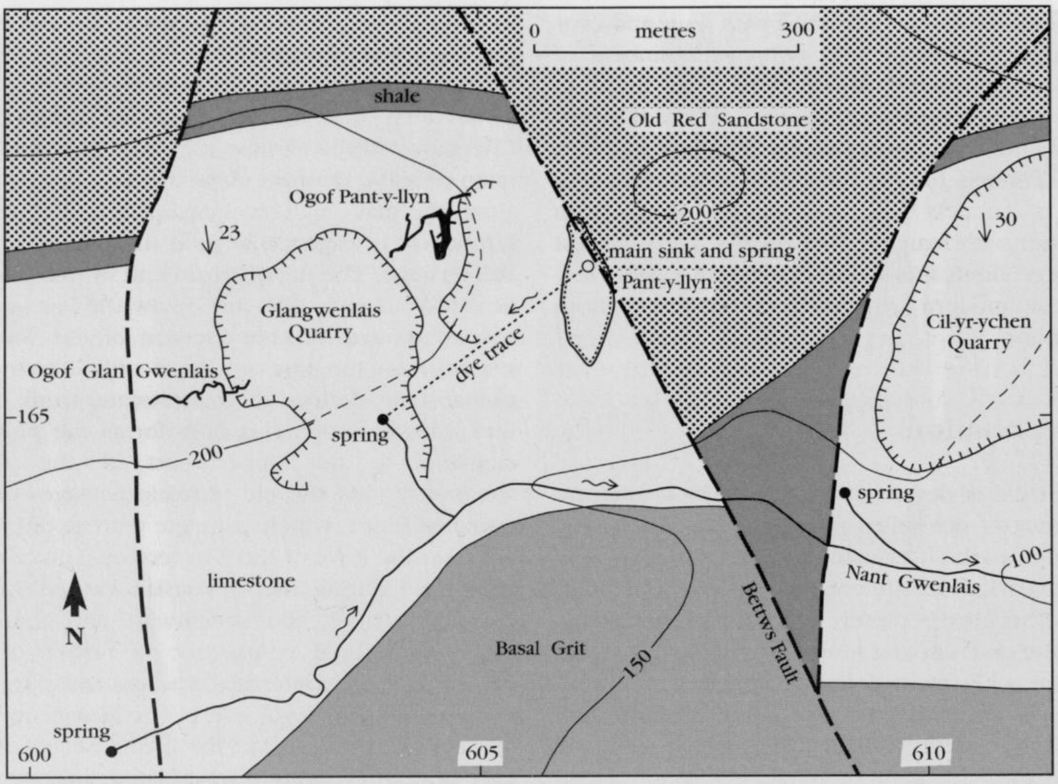

Figure 6.22 Geological map of the area around Pant-y-llyn.

Introduction

Turloughs are seasonal lakes that occur in lowland karst terranes and are best developed on the Carboniferous Limestone of western Ireland (Coxon, 1986, 1987a, b; Drew and Daly, 1993). Their water levels and intermittent appearance are related to the fluctuations of the regional water table, and they have no surface drainage, influent or effluent except for direct rainfall in the very small basin. The seasonal lake of Pant-y-llyn lies on the narrow Carboniferous Limestone outcrop near Llandybie (Figure 6.1). It slowly fills every autumn, and remains full until it drains in spring; the cyclicity is clearly related to the seasonal water table variations and is barely influenced by individual storm events. Pant-y-llyn appears to be the only turlough in Britain, as the ephemeral lakes in the chalk karst of East Anglia are in partially plugged dolines and do not have simple patterns of annual flooding.

The turlough is briefly described by Davies and Stringer (1991), Campbell *et al.* (1992) and Hardwick and Gunn (1995). The important biology of the site is described by Rundle (1993) and Blackstock *et al.* (1993), and the nearby caves are recorded by Adams and Jones (1984), Jones *et al.* (1984) and Jones (1991).

Description

The turlough is located in a closed depression within a saddle which is cut north to south through the narrow, broken limestone escarpment; it is 1500 m west of a deeper valley which carries the Afon Marlas through the limestone ridge. Quarries have removed much of the limestone both east and west of Pant-y-llyn. At its maximum extent in winter, the lake is 160 m long and up to 60 m wide, with a surface level of 160 m and a maximum depth of 3 m (Figure 6.22). The bed of the turlough is covered by a thin layer of organic debris, underlain by deposits of yellow-brown, silty clay. The lake level usually falls slowly through April, May and June, by draining through fissures in the bed; in summer the site is dry. Standing water first appears in autumn in a small pool at the northern end of the depression, where the main springs and sinks lie. It remains full over the winter; when it ices over, a small patch remains unfrozen over the spring site where warm groundwater emerges.

Pant-y-llyn lies on the northern margin of the South Wales coalfield syncline (Figure 6.1). The rocks in the area dip south at 20–40°, and include the Devonian Old Red Sandstone, the Dinantian Lower Limestone Shale, followed by about 200 m of limestone, and the Namurian Basal Grit. The turlough is underlain by the Bettws Fault, with an apparent downthrow to the west of about 200 m. This has brought the Dinantian Limestones into contact with the Devonian Sandstones; the eastern bank of the depression is cut into the sandstone, while the rest of the turlough lies on the limestone (Figure 6.22). The topography of the area consists of a low fragmented escarpment of Carboniferous Limestone, with a series of strike valleys running NE–SW, such as the Nant Gwenlais valley. The Bettws Fault zone appears to have offered a zone of weakness through the escarpment; during the Pleistocene, this was exploited either by ice moving south or by glacial meltwater (Bowen, 1965). More than 6 m of glacial till lies both north and south of the turlough, but is absent under the turlough site.

The regional drainage on the surface and in the limestone is eastwards to the lower outcrop in the Marlas valley. The Bettws Fault breaks this trend, as the limestones are not in contact across it; groundwater in the Pant-y-llyn block is therefore impounded, and its water table fluctuates between levels of 155 m in summer and 160 m in winter. Sinks and springs at higher levels drain the limestone west of a minor fault west of Ogof Glan Gwenlais (Figure 6.22). About 50 m above the level of the turlough, Ogof Pant-y-llyn has 350 m of phreatic rifts and bedding cave passages. Ogof Glan Gwenlais has 200 m of old phreatic passage aligned on the strike at an elevation of about 165 m (Figure 6.22).

Interpretation

Pant-y-llyn conforms to the three main criteria for distinguishing turloughs from other seasonal lakes (Coxon, 1986): it exhibits seasonal flooding to a depth of over 0.5 m for part of the year and a dry floor for part of the year, it is recharged via ephemeral springs or estavelles, and it empties via swallets or estavelles with no surface outlet. Dye tracing by Hardwick and Gunn (1995) indicated that the turlough was probably not fed by discrete well defined conduits, but instead receives and loses its water to the local groundwater body in its western flank. Recharge is mainly from the west, where the unbroken aquifer continues along the strike of the limestones, and outflow is to the west, as sandstone lies to the east. Tracing studies, limited by the lack of access to land around the quarries, have shown that water from the turlough reappears in fissure risings in the floor of the temporarily inactive Glangwenlais Quarry (Figure 6.22), and then flows into the Nant Gwenlais; it may also feed into the Nant Gwenlais from other unknown springs or seepages. The lower spring in the Gwenlais valley east of the Bettws Fault is fed only from the limestone around the Cil-yr-ychen Quarry.

Seasonal recharge and discharge of the turlough reflect seasonal variations in the groundwater surface. The local water table level is partly dictated by spring levels, which are where the valleys intercept cave conduits on inception horizons at various stratigraphic levels in the dipping limestone; there appears to be none in the youngest beds which have the lowest outcrop just west of the Bettws Fault. Groundwater storage is in fracture and bedding plane fissures opened by solution, but flow is probably impeded by both the immaturity of the karst and large amounts of inwashed clastic sediment. Perched water tables may lie behind rising phreatic loops and sediment chokes. A combination of these factors accounts for the turlough water table being perched 5–10 m above the Gwenlais valley. The water table fluctuation is caused by the limited capacity of conduits draining the groundwater to the risings. Excess recharge in autumn and winter raises the piezometric surface, causing the turlough to fill from fissures in the limestone; as recharge declines in late spring and early summer, the piezometric surface lowers and the turlough drains out via the same fissures in its bed. Direct drainage eastwards is impeded by the impermeable Devonian strata on the eastern side of the Bettws Fault. The flow pattern is not known in detail, but the known caves do demonstrate the importance of flow along the strike. The relationships between rainfall and turlough recharge, and the lag times involved, are still not known in detail, nor is the exact catchment area of the turlough.

Conclusions

Pant-y-llyn is a small turlough which reaches its maximum size in winter, when it measures 160 m long and 3 m deep. In late spring and early summer the lake drains through its floor. The lake appears to be the surface expression of the local water table. Dye tracing shows that the turlough drains to the Glangwenlais Quarry to the west and to the Nant Gwenlais via an unknown route. Pant-y-llyn is the only known turlough in Britain.

LLETHRID VALLEY

Highlights

The Llethrid valley system is a fine example of a complete dry valley system extending across the limestone outcrop, between a stream sink and a resurgence, each close to the limestone boundaries. Two caves include parts of the flood route of the underground drainage, and another has yielded an important Pleistocene fauna.

Introduction

The Llethrid valley is cut through the complete sequence of the Carboniferous limestones where the outcrop lies across the core of the Gower Peninsula (Figure 6.1). From the sink which swallows the water draining off the Namurian and Upper Limestone Shales, the valley is dry for 1500 m southwards to the resurgence, where older, impure limestones reach the surface. The underground route of the base flow is inaccessible, but Llethrid Swallet and Tooth Cave have passages which act as a flood overflow route.

The evolution of the valley system has been discussed by Groom (1971; and in Atkinson and Smart, 1977), though there is controversy over the local effects and extent of the Devensian glaciation (Bowen and Henry, 1984; Bowen *et al.*, 1989, Campbell and Bowen, 1989). The karst landforms of the Gower are summarized in Ede and Bull (1989), the caves are documented in Price (1984),

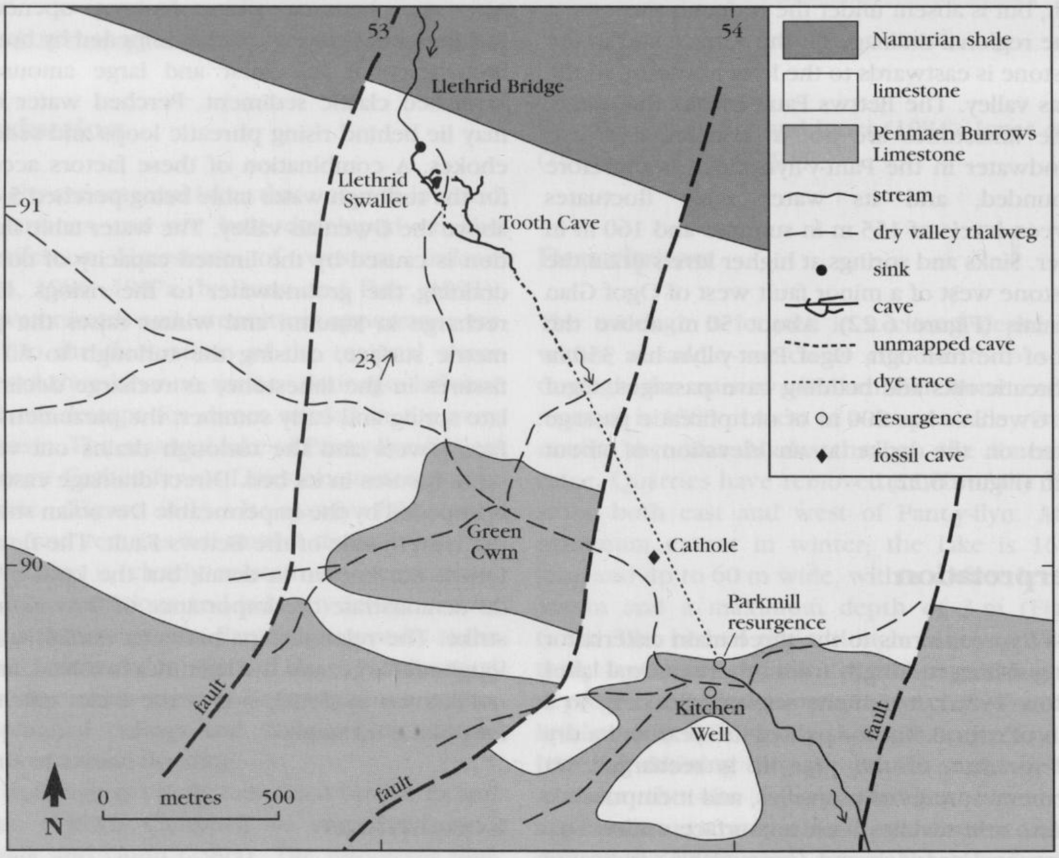

Figure 6.23 Geological map of the dry valleys and caves of Llethrid. The position of the downstream section in Tooth Cave is only approximate, as it is normally flooded and has not been mapped in detail.

Stratford (1995) and Oldham (1982), and the karst hydrology is considered in Ede (1973). Cathole is the most important of the inland caves in the Gower with respect to its Pleistocene fossils and Bronze Age human remains (Campbell, 1977; Campbell and Bowen, 1989).

Description

The valley drains against the northerly dip of the Carboniferous limestones, which is mostly at about 20° except where it steepens near Llethrid Swallet. A thin band of Oystermouth Beds, the local equivalent of the Upper Limestone Shales, separates the limestone from the Namurian shales which form the headwater catchment on Pengwern Common. Over 400 m of massive, pure limestones are exposed down the valley (Figure 6.23), before the less permeable Penmaen Burrows Limestone is reached; these are dolomitic and shale-rich, and continue south of the resurgence to a faulted contact with Devonian sandstones.

Upstream of Llethrid Bridge, a permanent stream flows on the shales. Where it passes onto the highest limestones, the water flows underground via a number of choked sinks. Downstream, the valley is dry and meanders south, as a trench cut 30 m into the limestone plateau. Its sides are steep, with crags and lengths of bare cliffs, and several dry tributary valleys drain into the main valley. Most of the dry valley has a broad grassy floor; this is widest at the Green Cwm where the main valley confluence is cut in the weaker Penmaen Burrows Limestone. A relict stream channel is present only along a short section just above the confluence.

The main sink, only active at high stage, is the entrance to Llethrid Swallet; this has over 300 m of small stream passage, which forms a flood route almost inactive at low stage, with a large sloping chamber heavily modified by bedding collapse above it (Figure 6.23). In the left bank, shortly below the sink, Tooth Cave has 300 m of low muddy passage leading into another section of the flood route about a kilometre long; this is normally dry down to an almost permanent sump, through which the downstream end is rarely accessible, and the whole passage fills in flood. Cathole has a wide entrance in a cliff 17 m above the valley floor; it is a cave remnant with two dry chambers, in which sediments have yielded a cold Devensian fauna and Creswellian artefacts (Campbell, 1977; Campbell and Bowen, 1989).

The Parkmill, or Wellhead, resurgence lies in the eastern side of the valley, at an elevation of about 15 m, nearly 30 m below the sink; it is impenetrable and now lies under a pool impounded to facilitate pumped abstraction. Llethrid Swallet provides about 20% of the water at the resurgence, with a flow-through time of 20 hours; the rest comes from percolation input and other smaller sinks. On the opposite side of the valley, Kitchen Well is a smaller spring, fed entirely by percolation water. It has a mean calcium hardness of 197 ppm in winter, and 206 ppm in summer; both these values are higher than those for the Parkmill resurgence, which is fed partly by swallet water and is frequently diluted by flood flows with low solute loads (Ede, 1973). Below the resurgences, the stream flows on the surface over the impure limestones to reach the sea at Oxwich Bay.

Interpretation

The Llethrid valley is incised into the 60 m coastal platform surface of Gower, which was probably developed in the early Pleistocene (Ede and Bull, 1989). Valley entrenchment was therefore later than this, and underground drainage was initiated to form phreatic caves, as the limestone plateau was exposed. The main chamber in Llethrid Swallet may be a remnant from this early phase. The dry valley system was almost certainly incised during periglacial periods when the underlying cave systems were choked with till or ice, allowing surface flow. Groom (1971) suggested that the main dry valleys on the Gower were incised during the penultimate interglacial, although this is unlikely unless underground drainage had not become fully integrated by this time. The northern part of the valley was probably glaciated during the Devensian (Bowen *et al.*, 1986), and meltwater from this and earlier glaciations almost certainly flowed down the valley. The meandering nature of the valley indicates its fluvial origin, while extensive infill by solifluction during periglacial episodes accounts for the smooth valley profile.

The known caves all lie in the younger part of the limestone sequence, where groundwater flow appears to have been captured on some particularly favourable cave-inception horizons (Lowe, 1989b). Beyond the explored limits of the caves, the flow route descends through the stratigraphic sequence, but rises to the surface above the dolomitic Penmaen Burrows Limestone. All the accessible passages in Llethrid Swallet and Tooth Cave pre-date the modern phase of cave formation and are only active under flood conditions. The modern drainage route is immature and unable to cope with flood discharges; it may be developing in smaller cave passages within the stratigraphically lower limestones. Dating of stalagmites in the Llethrid Valley caves has the potential to provide estimates for the timing of valley incision, which would define a minimum age for the formation of the 60 m planation surface.

Conclusions

Llethrid Valley contains some of the best karst features on the Gower. It is an excellent example of a karst dry valley with a complete spectrum of allogenic and autogenic underground drainage, and active and abandoned caves.

MINERA CAVES

Highlights

The caves of Minera form the most extensive integrated cave system yet explored in North Wales, with a major trunk conduit draining from active and inactive tributaries to a series of progressively more recent, and lower, resurgence passages.

Introduction

The Minera cave systems lie beneath the northern slopes of Esclusham Mountain, west of Minera and south of the Clywedog Valley (Figure 6.2). Ogof Llyn Parc, Ogof Dydd Byraf and Ogof Llyn Du are fragments of an integrated karst drainage system; they are now separated only by short sections of passage choked with sediment (Figure 6.24). The Carboniferous Limestone dips at 5–15° just south of east, and is truncated to the north by the Llanelidan Fault which downthrows the overlying Cefn y Fedw Sandstone of the Millstone Grit. The limestone unconformably overlies cleaved Ordovician shales which crop out to the west. Cave development within the site extends down through the Brigantian and Asbian succession of the Cefn Mawr, Loggerheads and Leete Limestones.

Water draining from the moorland in the west collects into the Aber Sychnant. This flows north across thick till and through a short limestone gorge, before turning east to become the River Clywedog, where the remains of another limestone gorge survive in the floor of the older, abandoned Minera quarries. The main allogenic input to the caves is through sinks west of and along the Aber Sychnant where it crosses the limestone west of Ogof Llyn Parc. Other sinks lie further south, near the outcrop of the Cefn y Gist Vein.

The only published accounts of the explored caves within this system are those of Appleton (1986, 1987, 1989), with a brief account of the divers' extension to Ogof Llyn Du by Whybro (1987).

Description

Swallow holes along the course of the Aber Sychnant are immature fissures largely choked with limestone blocks, gravel and peat.

Ogof Llyn Parc is entered through mined shafts and levels on the Pool Park Vein. These intercept the main cave at a depth of 130 m, from where natural cave passages extend for over 4000 m, with a vertical range of 115 m (Figure 6.24). The main streamway emerges from the Quarry, a passage up to 12 m wide and 8 m high, modified by roof collapse of the thinly bedded Leete Limestone south of the Pool Park Vein. Downstream, the Miners' River Passage is a phreatic tube 3 m high and 7 m wide following the strike of the beds. It enlarges as it is joined by three other tributaries flowing downdip from the west. The Northwest Inlet flows for almost half of its length over a floor of Ordovician shales, and forms a 3 m cascade over a minor fault with a 3 m throw. Fault Inlet follows a poorly mineralized fault with the Ordovician shales exposed on its north side. The water now sinks into impenetrable bedding planes towards the lower end of the Miners' River Passage. Prior to draining when the miners cut adits below the natural resurgence, the main stream flowed along the Northeast Passage. Both this and a high-level passage along the strike further updip lead into the Master Passage, up to 6 m wide and 11 m high, developed along the north side of a small fault. This was the main trunk drain for the whole mountain, and a number of large, ancient, phreatic passages converge onto it. These abandoned passages contain abundant calcite speleothems and clastic sediments, some in sequences of stalagmite layers interbedded with

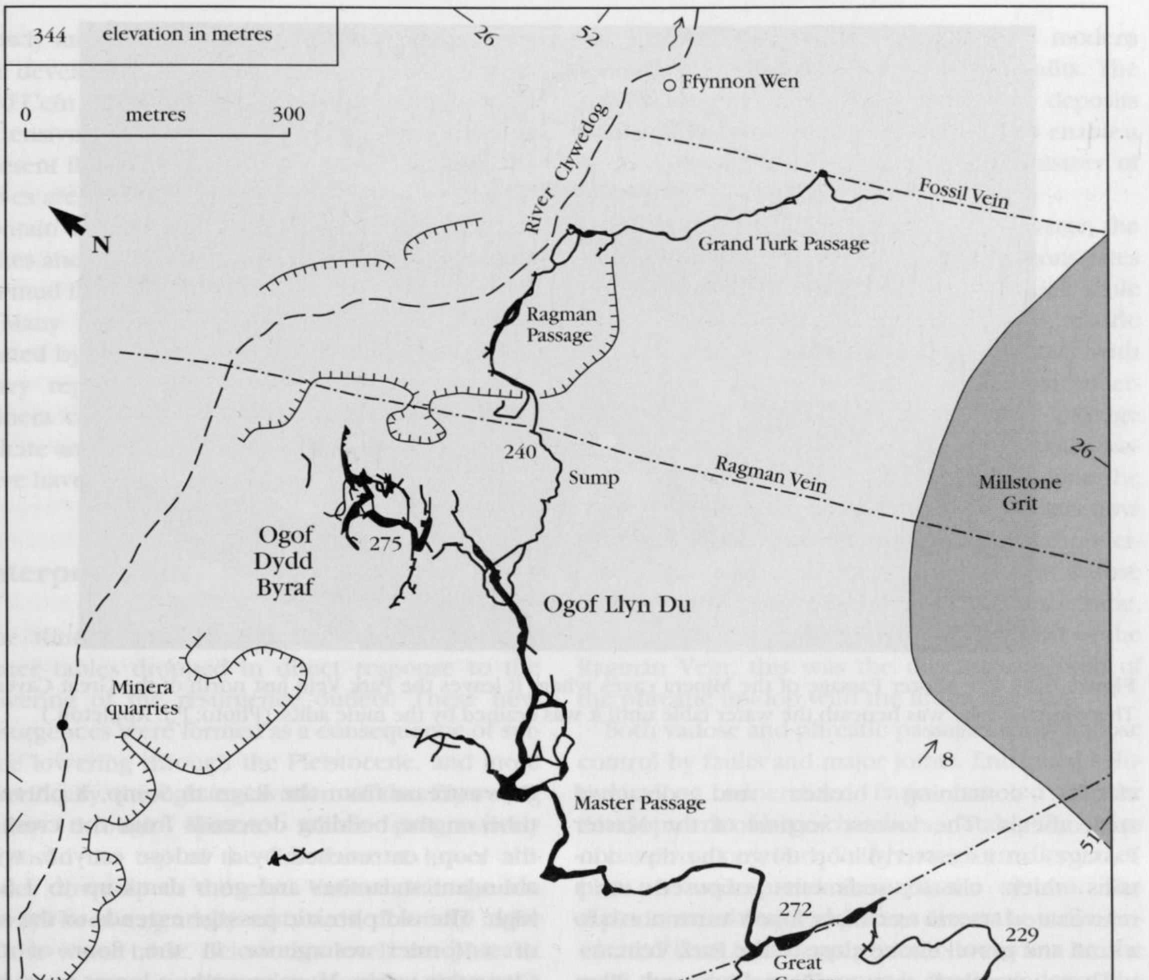

Figure 6.24 Outline map of the caves of Minera (from surveys by North Wales Caving Club). The Ffynnon Wen resurgence is no longer active as its water has been captured by the deep mine adits.

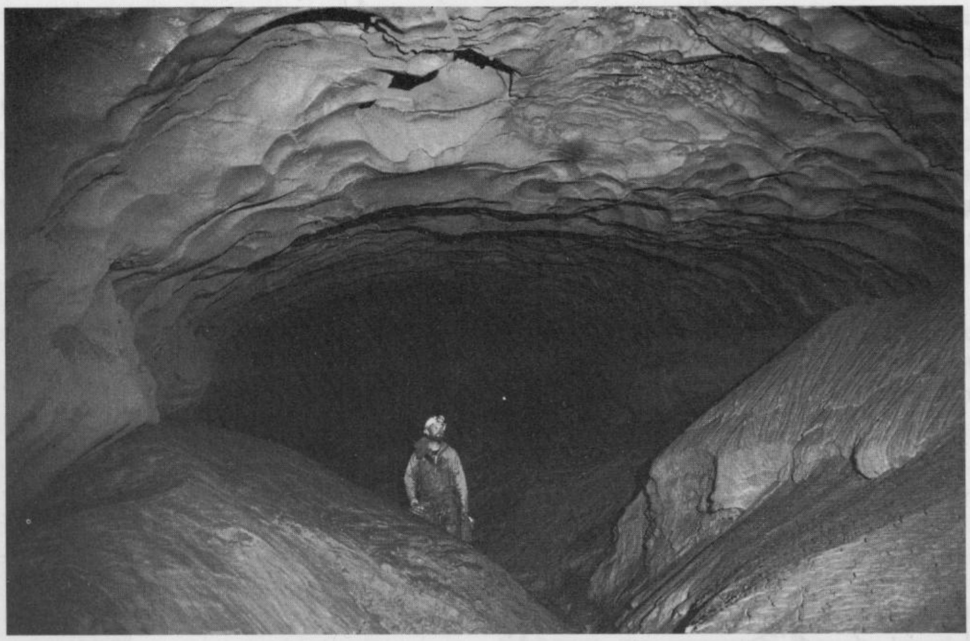

Figure 6.25 The Master Passage of the Minera caves where it leaves the Park Vein just north of the Great Cavern. This phreatic tube was beneath the water table until it was drained by the mine adits. (Photo: P.J. Appleton.)

clastics containing broken and detached speleothems. The lowest section of the Master Passage, on its easterly loop down the dip, contains thick clastic sediments exposed in a rejuvenated stream trench, before it turns north to a sand and gravel choke close to the Park Vein.

Three chambers, up to 70 m high and 20 m wide, are developed along the Park Vein, and are accessible via a separate 90 m deep mined shaft (Figure 6.24). The Great Cavern lies downstream of the sand choke at the end of Ogof Llyn Parc, and the downstream continuation is a phreatic tube 6 m in diameter choked with gravel in a downward loop (Figure 6.25).

The Master Passage of the Minera caves continues through Llyn Du Cavern (Figure 6.24). A large elliptical phreatic tube contains some flooded sections before turning north-east along the strike with a number of loops and tributaries; a large talus cone which contains sandstone blocks indicates a connection with the surface some 60 m above. The larger passage continues at a high level, to a choke close to Ogof Dydd Byraf, with a smaller inlet choked only a few metres from the northern cave system. A smaller phreatic tube lies directly beneath parts of the high level, and is linked to it by various younger vadose inlets. This then turns downdip into a phreatic loop which ends at a lift on the Ragman Vein; the whole loop, 26 m deep and 270 m long, is still flooded. Downstream from the Ragman Sump, a phreatic tube on the bedding descends from the crest of the loop, entrenched by a vadose canyon, with abundant stalactites and gour dams up to 1.5 m high. The old phreatic passage extends to the site of a former resurgence in the floor of the Clywedog valley. More recently, a lower route has taken the main drainage of the area to the Ffynnon Wen rising, prior to its capture by the miners' drainage adits. The Grand Turk Passage carried water against the dip, to the same old resurgence. It is a low phreatic tube on one bedding plane in the lower part of the Loggerheads Limestone, and the source of this water is unknown.

Access to Ogof Dydd Byraf is gained via mined passages which have intercepted a natural rift. Most of the cave is a relict phreatic system on two main levels. A lower main passage, developed in the middle of the massive Loggerheads Limestone, extends north through a series of decorated chambers, where elliptical tubes 4 m wide have been modified by roof collapse. High solution cavities lie on cross-joints, and one section opens into a three-dimensional network of passages developed on three bedding planes linked by steep joint fissures. These passages contain some very fine calcite deposits, with gours, crystal pools, cave pearls, curtains and white and green stalactites; there are also many mud formations and sequences of fine silts and muds deposited in slowly moving water. The upper level of passages are developed at the base of the more thinly bedded Cefn Mawr Limestone and have suffered more extensive collapse. They lie about 35 m above the present floor of the Clywedog Gorge. Some of the caves are choked with clastic sediment, and some contain a profusion of deep-red stalactites, stalagmites and helictites, with stalagmite crusts formed on mud flakes.

Many fragments of cave passage were intersected by the faces of the disused Minera Quarry. They represent remnants of old inlets to the Minera caves, and most have been choked with calcite and clastic sediments; stalagmites from one cave have been dated to about 56 ka.

Interpretation

The Minera caves developed in several phases as water tables dropped in direct response to the lowering of the resurgence outlets. These new resurgences were formed as a consequence of surface lowering through the Pleistocene, and more specifically through excavation of the Clywedog valley through Minera, which progressively exposed the top of the limestone at lower altitudes downdip to the east. Vadose drainage has always been essentially eastwards, downdip as far as the water table. Below this level, the phreatic drainage was northwards, roughly along the strike, to the contemporary outlet, at or near the lowest limestone outcrop. Successive routes were displaced downdip to the south-east, with greater lowering and displacement closer to the shifting resurgences at the downstream end of the system. Consequently, the old phreatic trunk routes diverge from a common source in the Miners' River Passage in Ogof Llyn Parc. Inlet passages have stayed in the same positions while their upper ends have been progressively removed by scarp retreat in their direction.

The shifting patterns of karst drainage can therefore be reconstructed and correlated with the geomorphological history of the area. The high-level passages in Llyn Parc, Llyn Du and Dydd Byraf are remnants of the same trunk route which was one of the earliest established through the limestone. Other fragments of ancient high-level routes, now almost entirely choked with sediment, were cut by the working faces of the Minera quarries. Later downdip captures include the Northeast Passage in Llyn Parc and the lower tube and Ragman Passage in Llyn Du. Youngest of all are the still immature and not yet accessible modern drainage routes into the low-level mine adits. The extensive sediment and speleothem deposits within the various parts of the system may enable a detailed chronology of the Pleistocene history of the area to be reconstructed.

Within the broad pattern of strike drainage, the morphology of the cave passages demonstrates strong control by geological features. Thick shale beds, palaeokarst horizons, the basal clastic sequence of the limestone, and the contact with the Ordovician shales are all well exposed underground, and clearly influence the passage positions and morphology. Major phreatic passages are developed on bedding planes along the strike, while at least two of the vadose inlets flow for part of their length downdip along the underlying Ordovician shales. In Ogof Llyn Du, vadose incision has occurred in the drained phreatic tube, downdip on the bedding, immediately east of the Ragman Vein; this was the downstream limb of the phreatic uploop with the lift on the vein.

Both vadose and phreatic passages show a close control by faults and major joints. Enhanced solution along mineralized faults has led to the development of large chambers, notably the series of caverns along Park Vein, though smaller examples are widespread through the system. The dip-orientated faults and veins divert the strike-orientated flow into deep phreatic loops out to the east; the most conspicuous is the loop down the Master Passage in Llyn Parc and back up through the Great Cavern on the Park Vein. Phreatic lifts also occur where the bedding planes feed drainage to the mineral veins; the 26 m deep Ragman Sump in Ogof Llyn Du is the deepest accessible lift, while the downstream end of Ogof Llyn Parc is another, now largely choked with sediment in its second downloop. The Llyn Parc lift is now active only when a sufficient hydrostatic head has been raised on the upstream side to breach the sediment plug by lifting sediment the full height of the lift. Fluidization of the sand under these flood conditions has polished the limestone walls over the lift crest.

Conclusion

The Minera caves represent one of the finest examples of completely integrated karst drainage in Britain. The system contains active and abandoned vadose inlets feeding to a sequence of phreatic strike passages which developed successively downdip in response to surface lowering and karstic rejuvenation. This pattern is repeated elsewhere in the dipping limestones of Britain; in their geometry, Yorkshire's Kingsdale and the Priddy caves drainage on Mendip differ only with respect to the magnitude of the local dips. All these cave systems have their oldest elements drained and abandoned, but only Minera has its recent phreatic passages accessible due to drainage by mined adits. Minera also has cave passages on mineral veins and along the base of the limestone, and the calcite speleothems in Ogof Dydd Byraf exhibit mineral colouring on a scale which is rare in Britain.

ALYN GORGE CAVES

Highlights

The caves of the Alyn Gorge provide excellent examples of both shallow and deep phreatic drainage systems which now lie within the vadose zone as a result of mine drainage.

Introduction

Ogof Hesp Alyn and Ogof Hen Fynhonau lie beneath the southern flank of the Alyn Gorge, upstream of Mold (Figure 6.2). These two caves represent components of the former underground feeders of the Alyn River, subsequently drained by mining activities. The Carboniferous Limestone rests uncomformably on Silurian mudstones and dips at about 15° east; the caves are formed in the Asbian Loggerheads Limestone. This is broken by two sets of faults; an east–west trending set are mostly mineralized, and a north–south trending set are generally barren but some have notably wide breccia zones. The caves are developed adjacent to the Alyn River where it flows through the Alyn Gorge on its route across the limestone outcrop.

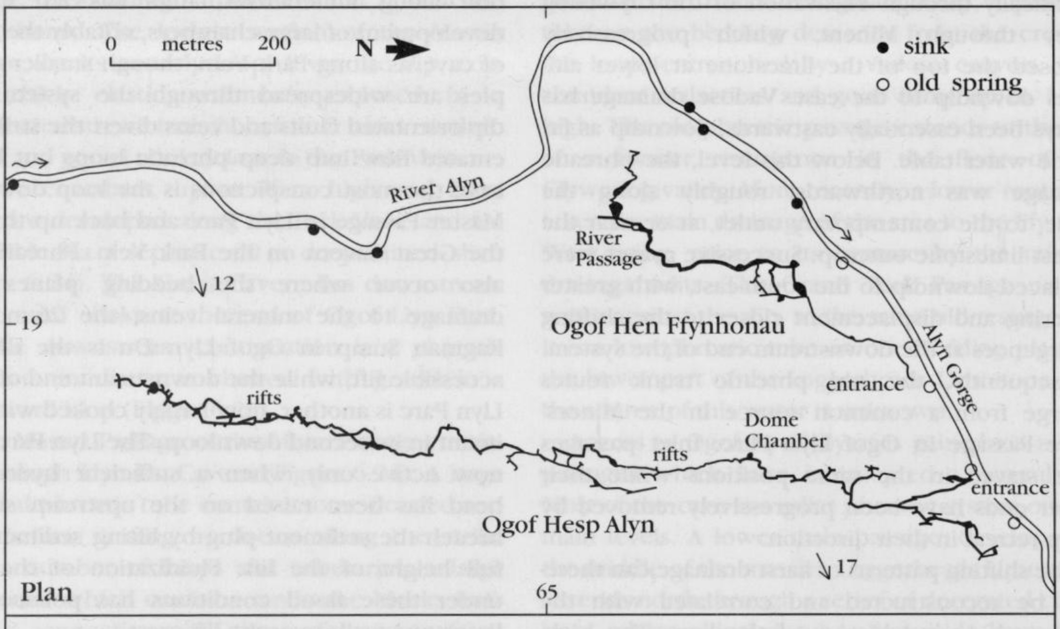

Figure 6.26 Plan and profile of the caves beneath the River Alyn (from surveys by North Wales Caving Club). The surface river loses water at the various sinkholes along its course on the limestone. Only Ogof Hesp Alyn is shown on the profile; it was almost completely flooded until deep mine adits captured its water.

The only published accounts of these caves and their hydrology are by Appleton (1974, 1984, 1989).

Description

The entrance of Ogof Hesp Alyn lies on the south bank of the Alyn Gorge. Over 2000 m of passages have been mapped in the cave, most of them along the phreatic trunk route which has a series of loops over a vertical range of 90 m (Figure 6.26). Most of the cave was beneath the water table, until it was drained in about 1901. Lead and zinc ores were mined from zones beneath the natural water table, and this required massive pumping until deep drainage adits were driven to drain the limestone almost to sea level. The new adits drained most of the cave by capturing the flow which it originally fed to risings at its northern end. The Hesp Alyn passages are a mixture of rounded phreatic boreholes, tall rifts on the main faults, and elliptical tubes on bedding planes. Slow phreatic flow has etched networks of fissures out of some fracture zones. Some of the downloops are partly choked with collapse debris and clastic sediment, or contain perched sumps, and small modern inlets have invaded some sections. The upstream end of the cave lies on a mineral vein breached by a short length of active streamway.

Ogof Hen Ffynhonau lies close to the west of Hesp Alyn, with its entrance in a mineralized fault adjacent to the main group of pre-mining springs in the Alyn Gorge. Over 800 m of passages have been mapped in the cave, and most are on bedding planes along the strike, with rifts where the main faults are crossed. They carry part of the River Alyn flow, and reach over half way to the sinkhole sources in the river bed (Figure 6.26). Large calcite decorations have been deposited in some of the passages, which were mostly above the water table prior to the mine drainage.

Interpretation

The two caves in the Alyn Gorge present a unique combination of two contrasting resurgence systems, one shallow and one deep, both now made accessible through artificial drainage of the phreas.

Ogof Hen Ffynhonau represents a relatively shallow drainage system which lay close to the local water table prior to mining; calcite dripstone accumulated in some dry parts. Sections of both phreatic and vadose passage typify the morphology of a cave close to the valley floor, which determined the levels of the local water table at the crests of its undulating profile. Much of the flow was derived locally, from sinks further south on the Alyn River, though some additional flow may perhaps have come from a deeper source. A natural rift choked with large rounded boulders lies 10 m above river level near the entrance and may represent a former resurgence.

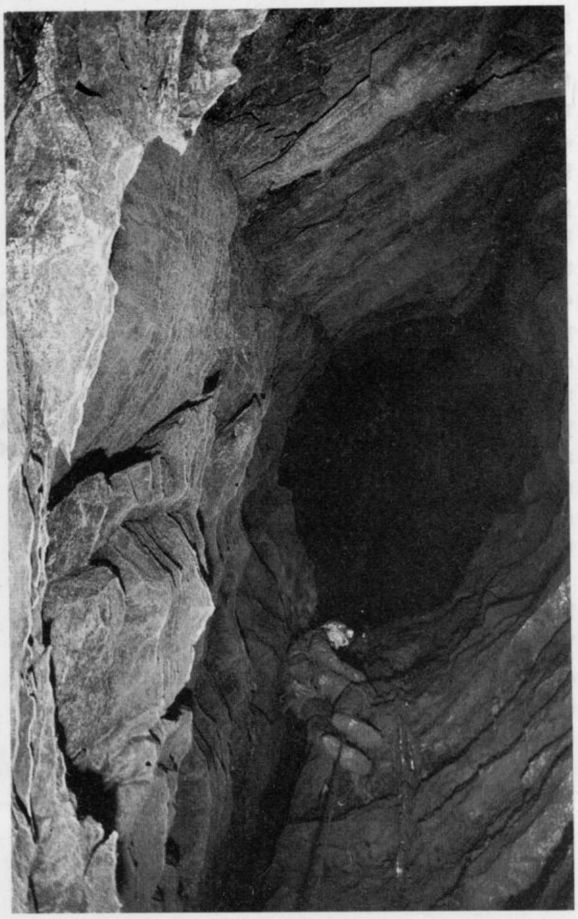

Figure 6.27 Looking up the 15 m shaft in Ogof Hesp Alyn. This phreatic lift on a major joint was active and completely submerged until mine drainage lowered the water table in 1901. (Photo: P.J.Appleton.)

Ogof Hesp Alyn has a quite different morphology, reflecting its deeper phreatic origin away from the valley. Water flowing northwards, almost along the strike following the intersections of fractures and bedding planes. This orientation took the flow to increasing depths until vertical phreatic lifts developed on veins or cross-faults (Figure 6.27); these took the water to higher bedding planes before finally escaping through springs at river level. The conduit may have drained a large area of limestone to the south; there is a dearth of known sinks nearby. Short sections of vadose trench were cut through the crests of two loops close to the pre-mining water level, but the rest of the cave developed entirely under phreatic conditions. Its drainage by mining activities has been so recent that there has not been any significant vadose modification. The cave shows clearly the effect of geological structure on phreatic development, in particular the influence of major jointing, and also shows many phreatic solution features, notably solution pockets, phreatic tubes and large phreatic lifts. The linear arrangement of passages in the northern half of the system is partly due to a coincidence of strong north–south jointing with the northwards hydraulic gradient.

Formerly the Alyn River flowed northwards beyond Cilcain and through what is now the Wheeler Valley (Figure 6.2). At some point it was diverted across the limestone outcrop, thereby excavating the Alyn Gorge (Embleton, 1964), and it is clear that the caves must largely, if not entirely, postdate this event. The river is cutting down through glacial till along parts of its route through the gorge, suggesting that its diversion was pre-Devensian. Ogof Hen Ffynhonau appears initially to have resurged some 10 m above the present river level, suggesting that the caves too pre-date the last glaciation. The sediments and stalagmite sequences in Ogof Hen Ffynhonau are a consequence of these later events, but a chronology has not yet been established.

Conclusion

The Alyn Gorge site provides a unique example of cave development in almost purely phreatic conditions from just above the water table to a depth of 80 m below resurgence level. Lowering of the water table by deep mine drainage has revealed some long phreatic caves, which have their morphology uniquely well preserved. There is almost no vadose modification or sediment infilling. The caves offer a unique insight to the anatomy of a flooded karst aquifer.