Charterhouse caves

[ST 471 564]–[ST 498 556]

Highlights

The Charterhouse caves encompass classic examples of vadose swallet caves in steeply dipping limestones. Their varied and complex morphologies, and extensive sediment and speleothem deposits, provide a valuable record of the Pleistocene development of the Mendip plateau and adjacent lowlands. These caves have been, and continue to be, the scene of intensive scientific research, often pioneering new techniques and methodologies. As a basis for so much karst research they are of international importance.

Introduction

Close to the centre of the Mendip limestone plateau, a group of ten caves lies along the southern flank of Black Down, 3 km north-east of Cheddar (Figure 5.1) and (Figure 5.8). Four of these are major influent cave systems, fed by allogenic streams draining south from the Old Red Sandstone outcrop of the Black Down pericline. The sinks are all close to the base of the Black Rock Limestone, and the known cave passages are in the lower beds of this unit, which dips to the south at 15–30°. The limestone is fractured by a number of faults, which may be associated with local steepening of the dip and have brecciated zones up to 6 m wide; it is also well jointed, with the dominant set having a roughly north-south trend. All the water from the caves resurges at Cheddar Rising, at the foot of the gorge.

The Charterhouse caves have been intensively studied, partly as a consequence of their proximity to the very active karst research unit in Bristol University. Detailed accounts of the main caves have been published by Goddard (1944), Stride, R.D. and Stride, A.H. (1946, 1949), Atkinson (1967), Atkinson *et al.* (1986), Ford (1964), Norton (1966), Smart and Stanton (1974) and Smart *et al.* (1984). Descriptions of the caves can be found in Barrington and Stanton (1977) and Irwin and Jarratt (1992). Further accounts of the geomorphology and development of the systems are given in Drew (1975b), Donovan (1969) and Ford (1965b, 1968). Aspects of the hydrology have been investigated by Atkinson (1968b), Atkinson *et al.* (1967), Drew (1975a), Stenner (1973), Smart and Hodge (1979, 1980), Smith and Mead (1962), Stanton and Smart (1981), Friederich (1981) and Friederich and Smart (1981, 1982). Effects above and below ground of the major floods in July 1968 were described by Hanwell and Newson (1969, 1970), Newson (1969) and Savage (1969). Uranium-series dates for some of the sites have been published by Atkinson *et al.* (1978, 1984); others remain unpublished, while dates derived from uranium-series decay and electron spin resonance, and studies of sediment remnant magnetism are recorded by Farrant (1995).

Description

The most westerly cave in the group is Tyning's Barrows Swallet (Figure 5.8). The cave consists of an initial series of narrow vadose passages descending steeply downdip and through several large rift chambers. These tributaries converge before entering a much larger vadose canyon, which is up to 5 m high and wide. The passage then swings round to the west, following a predominantly strike-orientated course, with many minor offsets on cross joints, as far as a sediment choke. The whole system shows very close joint control of its passages. There are extensive breakdown deposits but very few speleothems.

The swallet system of GB Cave lies at the foot of a short blind valley which ends on the limestone boundary (Figure 5.8). It contains almost 2000 m of passages (Figure 5.3) extending to a depth of 135 m. A number of small inlets near the entrance converge on the head of the main streamway. The passage from the Gorge to the Main Chamber is the largest in a Mendip cave, a vadose canyon in places more than 10 m high and wide. It contains massive banks and terraces of sediment and breakdown debris (Figure 5.4), and descends steeply to a sediment choke. Extensive inlet passages and several oxbows on its western side are smaller but mimic the overall morphology. Rhumba Alley and some of the inlet passages near the entrance show clear evidence of initial phreatic development, and a phreatic half-tube is visible in the roof in parts of the Gorge. From the south end of Main Chamber several much smaller distributary passages branch off. These have a much more gentle gradient and show clear morphological evidence of phreatic development below the water table. Above the downstream choke one of these abandoned distributary passages extends to further chokes and the Great Chamber, 50 m in diameter and extensively modified by roof collapse and upward stoping.

Many of the passages in GB Cave show close geological control, with the dip of 25° influencing the profile, and joints and faults dictating the plan relationship of the various passages. Throughout the cave, speleothems of various types are abundant, some of them formed of aragonite or inter-layered calcite and aragonite. In addition there are extensive clastic deposits interbedded with stalagmite layers and recording episodes of erosion and deposition. Major flooding in July 1968 modified parts of the system considerably, blocking at least one of the inlet passages, causing surface collapse into the northern end of the Gorge and causing extensive scouring and redeposition of some sediment sequences. Dating of stalagmite and sediment sequences (Atkinson *et al.,* 1978; Farrant, 1995) has revealed evidence of at least four phases of speleothem growth timed at about >330, 170–120, 63 and <13 ka.

Adjacent to GB Cave lies Charterhouse Cave (Figure 5.3). This resembles GB in having a series of small inlet phreatic tubes leading into a main streamway, the Citadel, which has been greatly enlarged by vadose erosion. The cave is essentially part of GB, but there is no passable connection between the two. It also contains thick clastic sediment deposits and is exceptionally well decorated with speleothems. Both GB and Charterhouse Caves lie below a shallow dry valley where successive stages of fill have choked old sinks and thereby generated multiple sink passages on diversionary routes which coalesce underground.

Longwood Swallet lies in the floor of one of the main valleys which are tributary to Cheddar Gorge (Figure 5.8). It contains over 1600 m of cave passages, reaching to a depth of 175 m. A natural shaft in the valley floor leads to a complex series of passages with several large chambers developed on faults and enlarged by collapse (Figure 5.5). Evidence of an extended phase of early high-level phreatic development is seen in the presence of tubes, loops and avens with crests at the same height. Lower down the cave these passages converge on a steep fault-controlled rift descending to the main streamway. This extends for more than 500 m along mainly vadose canyon passage often only a metre or so wide but of considerable height and with phreatic remnants preserved in places. Upstream, separate tributary passages have been followed to chokes a short distance below the surface sinks. Downstream the known cave ends at a sump beyond a series of very narrow joint-guided rift passages. Although the system contains relatively few speleothems there are extensive clastic sediment deposits containing interbedded stalagmite layers.

Rhino Rift consists essentially of a single series of vadose shafts developed along a fault and adjacent joints and descending to a small, choked phreatic tube at a depth of 145 m. The entrance lies in a tributary valley below Longwood Swallet, some distance south of the boundary between the Black Rock Limestone and the underlying shales (Figure 5.8). The cave contains extensive collapse debris but relatively little finer clastic material or speleothems. Dating of flowstone indicates that the cave has been in existence for at least 75 000 years (Atkinson *et al.,* 1984).

Manor Farm Swallet lies at the next sink to the east (Figure 5.8), and has over 900 m of passage (Figure 5.6). A series of fairly small, steeply descending, vadose inlet passages include one choked by the debris from the Great Shaft, which collapsed in the 1968 flood. These all unite before entering NHASA Gallery, which is a section of old phreatic passage extensively modified by collapse; it is up to 10 m wide and 3 m high, with a dipping bedding plane roof and a floor of mud and breakdown blocks. Parts of the cave contain thick clastic sediments and false floors, locally overlying massive gour barriers and flowstone. There are many stalactite curtains and banks of active flowstone.

A large stream sinks in the Blackmoor Valley (Figure 5.8), but the associated cave system has yet to be discovered. Several smaller cave systems have been found, including Blackmoor Flood Swallet, Waterwheel Swallet (Stanton, 1987) and Grebe Swallet. The latter is important as it contains evidence for the origin and emplacement of the lead ores in the Mendip Hills (Stanton, 1991).

Charterhouse Warren Farm Swallet (Levitan *et al.,* 1989), lies to the south of the Velvet Bottom valley (Figure 5.8). It is entered via a narrow shaft which drops into a series of phreatic passages, much modified by collapse, speleothem deposition and the influx of clastic material. The site is an important archaeological site and its position is intermediate between the Charterhouse swallet caves and the Cheddar resurgence.

Interpretation

The caves developed on the southern flank of the Blackdown pericline include classic examples of vadose caves developed in dipping limestone. They show a wide range of morphologies from the massive canyon passage in GB Cave to the fault-guided rifts in Longwood Swallet. The smaller cave of Charterhouse Warren Farm Swallet is the only one known on the Mendip Hills which is intermediate between the predominantly vadose swallet caves and the largely phreatic caves at the resurgence.

All the major swallet streams were dye tested to the Cheddar Risings with travel times between 16 and 48 hours (Atkinson *et al.,* 1967; Drew, 1975a). Pulse wave tests at Longwood Swallet (Smart and Hodge, 1979) indicate that at low flow, only 9% of the Longwood-Cheddar conduit is vadose. Repeated dye tests at several sites on the Mendips included Longwood Swallet to demon- straw that the travel time is inversely proportional to resurgence output (Stanton and Smart, 1981). The presence of up to three fluorescein peaks for each trace suggests the possibility of several alternative conduits to the resurgence. The identification of a common resurgence at Cheddar has enabled the evolutionary history of the swallet caves to be compared and their response to base-level change at the resurgence examined.

Geomorphology

The Charterhouse caves display many of the features common to the typical Mendip cave. All the swallet caves exhibit complex passage networks developed predominantly downdip and extensively modified by vadose erosion, sedimentation and collapse. Many of the caves provide excellent evidence of structural control. Joint direction is the dominant control, and is clearly recognizable on cave plans (Figure 5.3), (Figure 5.6). Over 80% of the passages in Manor Farm Swallet are joint controlled (Smart and Stanton, 1974). Bedding plane control is shown by the downdip orientation of many of the passages while faulting is especially important in the formation of large chambers, notably in Longwood Swallet and vadose shafts such as Rhino Rift. All the swallet caves are developed at the base of the Black Rock Limestone.

The most westerly of the caves is Tyning's Barrow Cave. Although not a true stream sink, its morphology is similar to the swallet caves. Admirable structural control is shown in the lower streamway where downdip joint-controlled segments are linked by strike-orientated passages.

The most complex of the swallet caves and one of the most intensively studied is GB Cave, genetically related to the adjacent Charterhouse Cave. The geomorphology of GB Cave was first studied in detail by Ford (1964), who elevated it to his type example of a vadose drawdown swallet cave. He envisaged an initial period of phreatic erosion forming a complete passage network. This was followed by alternating phases of vadose drawdown, erosion, clastic sedimentation and speleothem deposition along the outline plan established during the initial phreatic phase. The water tables were initially controlled by the lack of cave development, but fell rapidly to a stable base level once a mature cave system had been established. Thus vadose cave development took place in a vertically extensive vadose zone, the sequence of captures and trenches being unrelated to base-level lowering.

The discovery of the neighbouring Charterhouse Cave enabled Smart *et al.* (1984) to test Ford's hypothesis. They concluded that rather than an initial period of phreatic development, followed by rapid base-level lowering and vadose drawdown, base-level probably fell slowly and intermittently, thus deepening the vadose zone slowly through time. During this period, passage morphologies reflect the transition from phreatic, through paraphreatic to entirely vadose conditions, which ultimately led to the abandonment of the strike-orientated pressure-fed phreatic conduits in favour of free-draining vadose dip tubes and joint-guided rifts. Initially the only mature phreatic conduits were along the Double Passage–Chiaroscuro Passage–Citadel route and the Rhumba Alley–Berties Pot–Ladder Dig route. The sequence of trenches in Charterhouse can be related to the declining water table level. Both Ford (1964) and Smart *et al.* (1984) recognized two major phreatic rest levels in the GB–Charterhouse system; in Double Passage at 238 m and a second just above Ladder Dig at 137 m. The multiplicity of inlet passages reflects the large number of sinks the stream has utilized through time, caused by the infilling of former sinks by clastic material and the opening of new ones when the loess cover was eroded.

The hydrology of GB Cave has been studied in some detail. D.C. Ford (1966) found that the calcium hardness of dripwaters varied by up to 50 ppm. Stenner (1973) showed that the increase in solute load in the GB Cave stream was not due to direct solution of calcite by the stream water, but was the result of admixtures of waters with higher calcium contents. Friederich and Smart (1981, 1982) studied the water in the vadose zone and based their classification of autogenic percolation waters on samples taken from GB Cave.

Longwood Swallet was studied in detail by Atkinson (1967). He suggested that initial phreatic erosion was followed by a fall in the water table by 56 m, thus initiating vadose erosion. He identified three further aggradation and two renewed vadose incision stages corresponding to further drops in base level, compared to the two identified by Ford (1964) in GB Cave. On this evidence, he concluded that Longwood was older than GB. Atkinson identified three phreatic rest levels in Longwood Swallet, at 138–141 m, 120–123 m and 90–93 m. There is slender evidence for a fourth at 70 m. The modern phase of vadose erosion is graded to a water table at 40 m. It is clear from their contrasting morphologies that the Longwood stream is capturing water from GB Cave. In GB, the large size of the gorge in comparison to the stream suggests that the cave once had a much larger catchment than at present, whereas the opposite is true in Longwood Swallet where a large stream flows through some small and immature passages. The incision of the deep Longwood valley has enabled headward erosion along the strike of the Lower Limestone Shales, beheading the GB catchment area.

In Manor Farm Swallet, Smart and Stanton (1974) identified an initial phreatic dip-tube network, which was later entrenched under vadose conditions as the phreas fell to a stable level at 120 m OD, shown by the excellent vadose trench graded to the floor of the NHASA Gallery phreatic tube. Two phases of vadose erosion followed by clastic sedimentation and speleothem deposition occurred, as the phreas dropped to 92 m and below 81 m. They concluded from the smaller size and relative simplicity of the cave that it was younger than GB Cave and Longwood Swallet.

The two non-swallet caves show markedly differing morphologies. Rhino Rift is a classic vadose invasion cave (Ford, 1965b), comprising of five vadose shafts descending to a small phreatic passage at the 75 m level. Stanton (1972) argued that Rhino Rift was an earlier sink for the GB stream and thus predated GB Cave. Atkinson *et al.* (1984) refuted this hypothesis, and suggested that the cave was formed by local run-off from snow-patches sinking along the line of a prominent fault. Similar modern examples can be seen in alpine karst areas, and it is commonly found that vadose shafts can develop to large dimensions with a comparatively small stream (Pohl, 1955). In contrast, Charterhouse Warren Farm Swallet (Levitan *et al.,* 1989) is dominantly phreatic and represents an important link between the Charterhouse swallet caves and the resurgence in Cheddar. It consists of a remnant of phreatic passage which functioned as a major strike integrator when the regional base level was at or above 227 m. Three types of sediment fill in the cave include a siliceous allochthonous gravel derived from the Blackdown pericline, several calcareous allochthonous fills, and limestone breakdown. The calcareous fills are especially important as they contain profuse archaeological remains (Levitan *et* al., 1989).

Geochronology

Dating of the cave sediments, using uranium-series, electron spin resonance (ESR) and palaeomagnetic techniques (Atkinson *et al.,* 1978, 1986; Atkinson and Smart, 1982; Levitan *et al.,* 1989; Farrant, 1995; Smart *et al.,* unpublished data), has revealed much about the evolution of the Charterhouse caves; the data have enabled comparisons to be made between the swallet caves, and to the sequence of caves at the resurgence in Cheddar, and thus to changes in external base level. Early work with uranium-series dates showed that GB Cave was older than 350 ka. The chronology was extended using ESR and palaeomagnetic methods back as far as 900 ka (Farrant, 1995). These dates demonstrate that the early phreatic conduit in GB and Charterhouse, along the Double Passage–Chiaroscuro Passage–Citadel route, was probably established before about 900 ka and certainly prior to 780 ka.

The levels of the phreatic still-stands (at about 238, 138, 120, 90 and 70 m) show a good correlation between all four of the major swallet caves (Smart and Stanton, 1974; Farrant, 1995). The timing of these major phreatic still-stands has been estimated; the highest at 238 m is about 900 ka, with the lower levels at about 480, 350–380, 200–225 and 95–100 ka, respectively. Similar distinct levels have been found in Gough's Cave at the resurgence, inviting correlation with the swallet caves (Figure 5.10). Ford (1964) and Atkinson *et al.* (1978) correlated the Ladder Dig water table level at 138 m to that of Great Oone's Hole in Cheddar on stratigraphic and geomorphic grounds. This was challenged by Farrant (1995) who suggested that the 120 m level drained to Great Oone's Hole based on evidence from uranium-series dates (Figure 5.10).

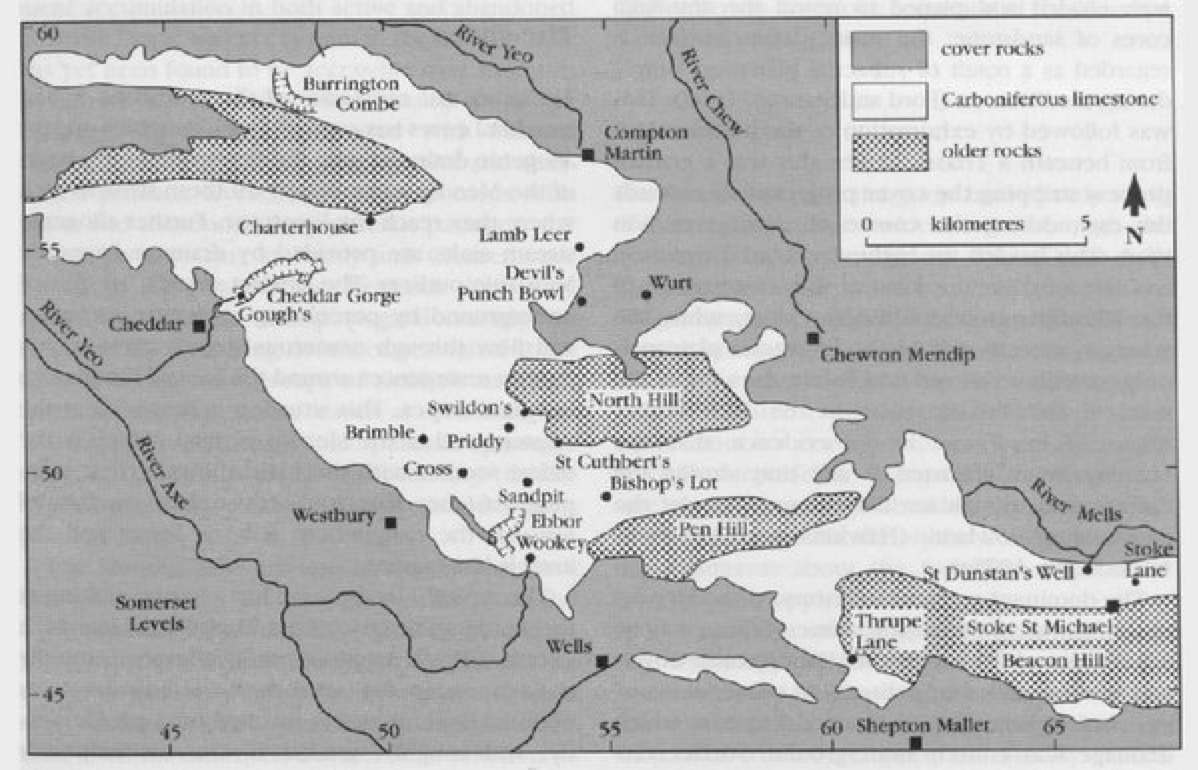
The good correlation of water table levels between the major swallet caves at Charterhouse suggests they underwent a uniform response to changes at the resurgence. This response is driven by progressive base-level changes at the resurgence which propagate up the conduit. The rate of propagation is controlled by the abandonment and capture of phreatic links at the resurgence (Smart *et al.,* 1984). This correlation is not so clear in the Priddy caves, where the swallet caves have markedly contrasting morphologies. This is probably because the Priddy-Wookey system responds slower to base-level lowering; it has yet to fully respond to the last phase of base-level lowering, as active vadose incision of the earlier phreatic loop crests is still progressing.

Thick, coarse, angular, sandstone and limestone gravel fills occur in all the swallet caves. At many places, stream erosion has undercut these cemented gravels leaving perched false floors. The gravels were emplaced under periglacial conditions by the transport of frost-shattered surface material into the cave by solifuction and debris flow events. The associated speleothem was deposited in the intervening warmer periods when increased biogenic soil activity raised the carbon dioxide levels in the soil, causing saturation of the percolation groundwater and stalagmite deposition. In GB Cave, several generations of fills are recognized, interbedded or capped with calcite flowstones which have been dated. At least eight major gravel fills have been identified in a complex sequence of gravel emplacement and speleothem deposition (Figure 5.7). Within the limits of the available dating, the phases of gravel emplacement appear to correspond with the cold stages of the Pleistocene. Stratigraphical relationships show that similar, complex sequences occur in Charterhouse Cave, Longwood Swallet and Manor Farm Swallet, but have yet to be dated. However, the dangers of trying to elucidate the developmental history of the cave from the clastic sequences alone were highlighted by the profound changes wrought by the 1968 flood (Hanwell and Newson, 1970).

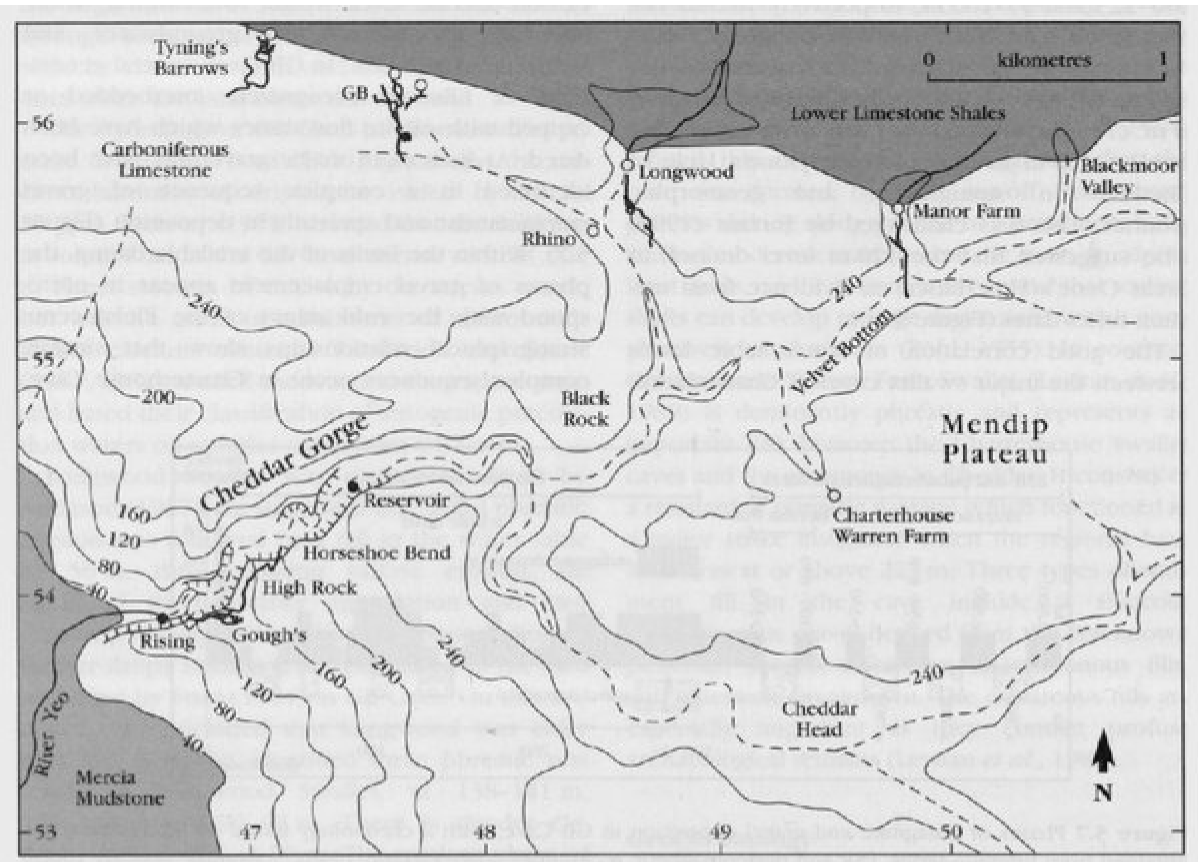
Conclusions

The Charterhouse caves provide some of the finest examples of cave development in dipping limestones. The cave morphology, clastic sediments and speleothems are the most intensively studied in Britain, and have far-reaching implications for the study of cave development, karst hydrology and Pleistocene chronology. The wealth of dated sediment and speleothem has enabled the construction of a remarkably long chronology and an elucidation of the geomorphic history of the Mendip Hills. The correlation of water table levels in the swallet caves with those at the Cheddar caves demonstrates the role of base-level control at the resurgence on the whole conduit system. Although the designation of some of the caves as type sites has been challenged, the pioneering nature of the underground work renders the Charterhouse caves of international importance.

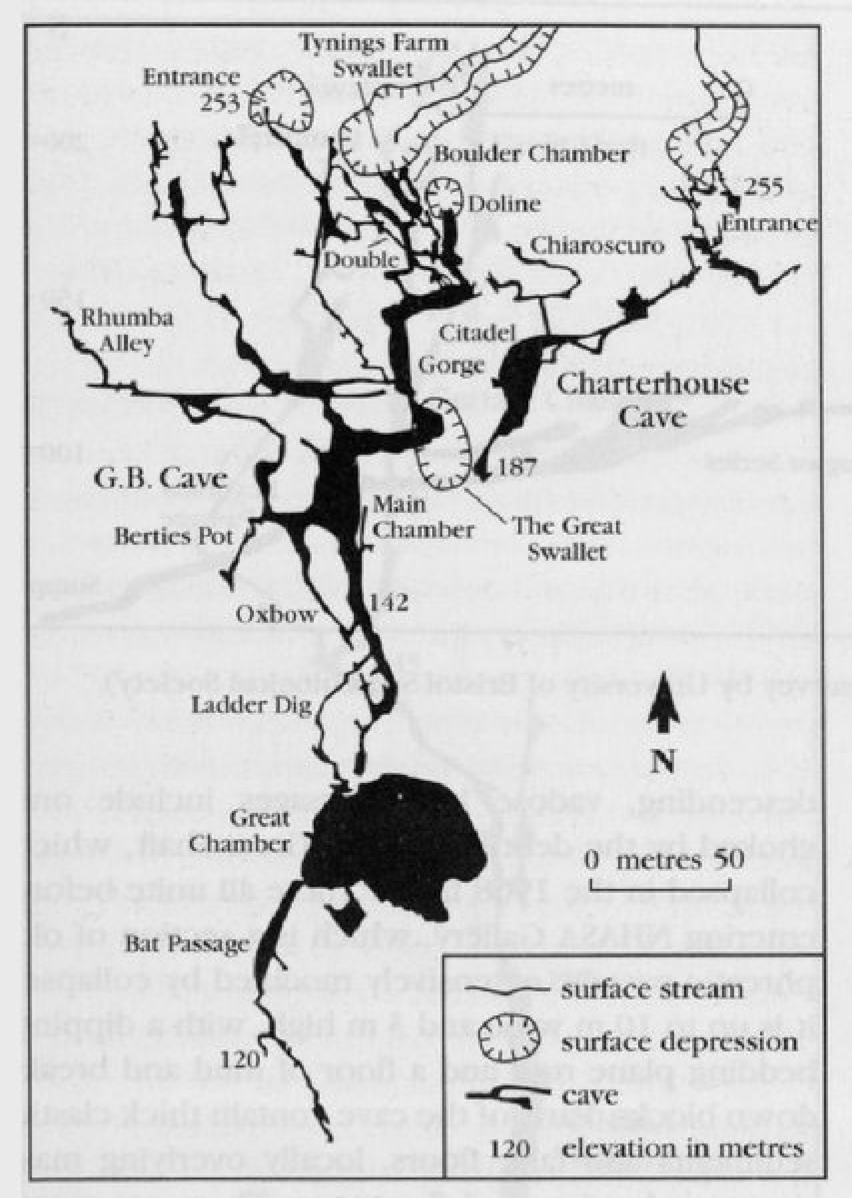
References



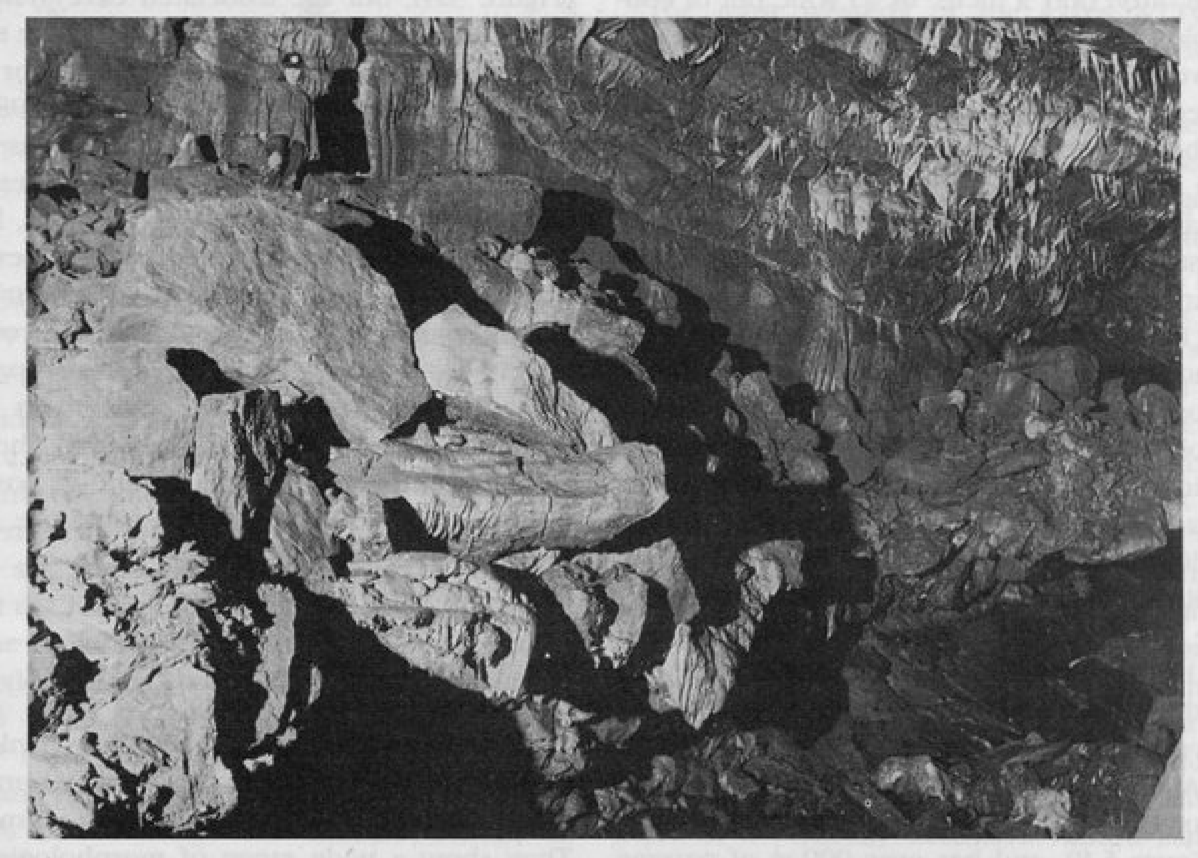
(Figure 5.1) Outline map of the Mendip Hills karst, with locations referred to in the text. Cover rocks are mostly the Triassic and Jurassic mudstones and limestones; Upper Carboniferous rocks form the thrusted outlier on the east side of Ebbor Gorge. The Triassic Dolomitic Conglomerate is included with the Carboniferous limestone where it is composed of blocks of the limestone and is an integral part of the karst. Older rocks are the Devonian Old Red Sandstone and the Dinantian Lower Limestone Shale.



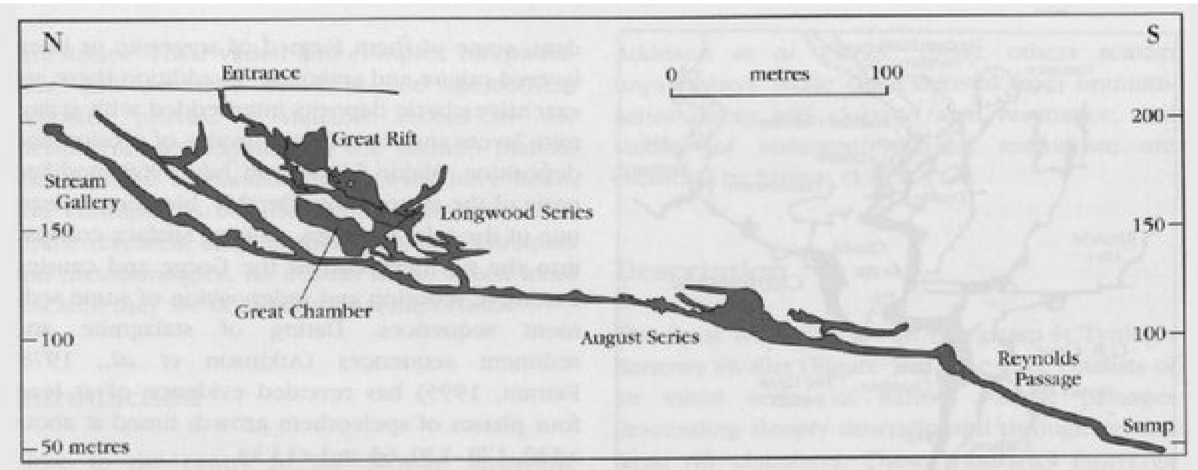
(Figure 5.8) Map of Cheddar Gorge and the lower part of its dry valley system reaching across the karst to the edge of the Mendip Plateau.



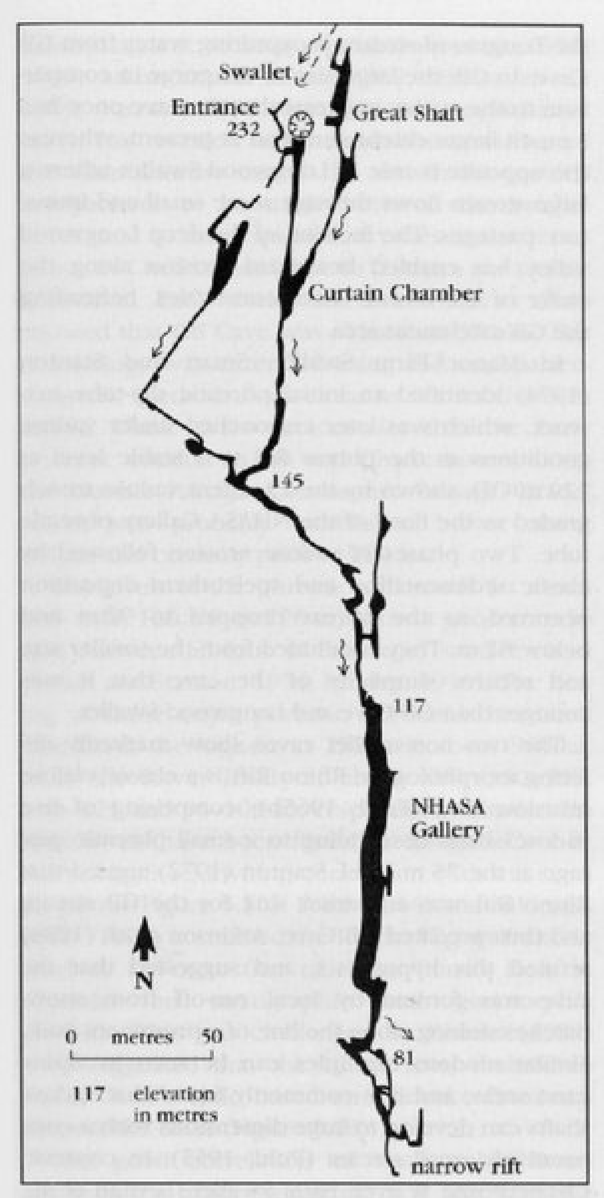
(Figure 5.3) Outline map of GB Cave, Charterhouse Cave and the main surface features above them (from survey by University of Bristol Speleological Society).



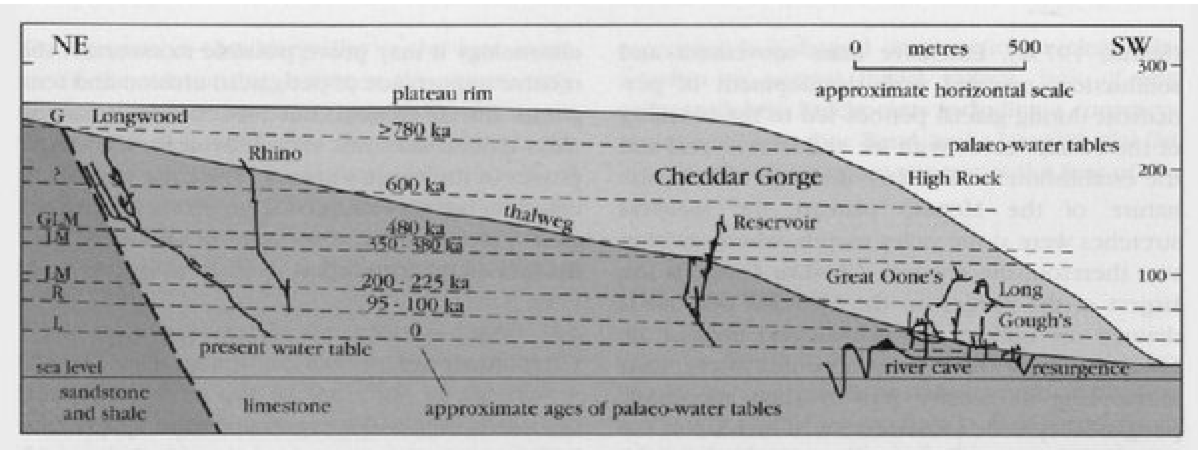
(Figure 5.4) Massive banks, terraces and false floors of coarse breakdown, clastics and stalagmite flowstone in the Gorge of GB Cave. (Photo; A.C. Waltham.)



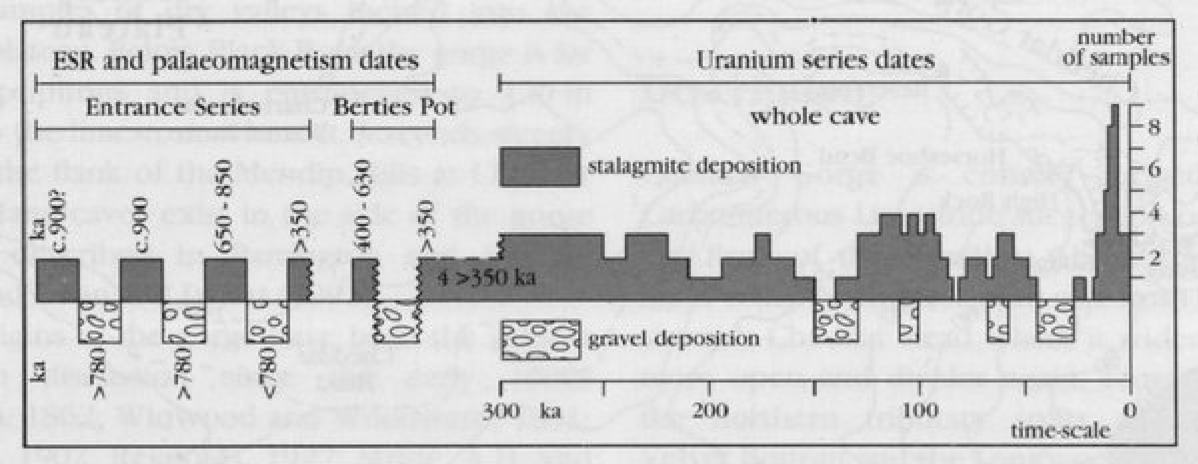
(Figure 5.5) Extended profile of Longwood Swallet (from survey by University of Bristol Speleological Society).



(Figure 5.6) Outline map of Manor Farm Swallet (from survey by University of Bristol Speleological Society).



(Figure 5.10) Long profile of Cheddar Gorge up into the Longwood Valley, with the caves beneath. Each palaeo-water table is recognized from cave and surface morphology, and is dated from the sediments in associated cave passages at both the swallet and resurgence ends of the system. The water tables steepen greatly in the sandstone and shale, but are marked beyond the limestone only to label the caves in which each is recorded (G = GB Cave; L = Longwood Swallet; M = Manor Farm Swallet; R = Rhino Rift). The horizontal scale is distorted by the projection, and the vertical scale is exaggerated three times (largely after Stanton, 1985; Farrant, 1995).



(Figure 5.7) Phases of stalagmite and gravel deposition in GB Cave, with a chronology based on stalagmite dates obtained from uranium-series, ESR and palaeomagnetic techniques (after Farrant, 1995). Stalagmite ages are represented covering the error bars on the dated samples; actual time spans of the deposition phases may be smaller, but data from stalagmites as yet undated may increase the lengths of the deposition phases.