The Geomorphology of Longwood Swallet, Charterhouse-on-Mendip.

(O.S. 6 in. to 1 mile, ST 45 NE., N.G.R. ST 486557)

By
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INTRODUCTION

The Mendip Hills lie some 15 miles to the south of Bristol. Their steep south face rises from the flat peat moors of the Somerset levels to a maximum altitude of just over 1,000 ft. O.D. (300 m.). The greater part of the hills, however, consists of a dissected plateau on Carboniferous Limestone, with an elevation of 820–60 ft. O.D. (246–258 m.). Four whaleback hills rise 200 ft. (60 m.) above the plateau. The westernmost of these is Blackdown hill, which is composed of resistant Devonian quartzite, arched in the core of a pericline. The axis of this pericline is approximately east-west and on its south flank a succession of Carboniferous rocks is exposed (*Fig.* 45). The lowest member of the succession is the Lower Limestone Shale, a fine dark shale with occasional limestone bands. This passes upwards into the Black Rock Limestone, the lowest member of the limestone series. It is described by Ford (1964) as, "the purest of the Mendip limestones, dolomitization being minimal", and by Green (1958, in Ford, 1964) as, "dark grey and black, crinoidal, rather fine-grained". The Black Rock Limestone is 750–1,000 ft. (225–300 m.) thick and dips south at 25–34°.

The quartzites of Blackdown are covered by over 10 ft. (3 m.) of peat and solifluxion deposits, from which water rises in small springs (Tratman, 1963, p. 25). The largest of these springs occur close to the contact of the

Lower Limestone Shale, or a short distance onto the quartzite. Comparatively few rise at the position of the contact as it is marked on the 1 in. to the mile Geological Survey map of the area. Tratman (*ibid.*, p. 23–5) has shown that water rising on the north flank of Blackdown is derived from the superficial deposits and not from the quartzite. It would appear that this is the case on the south flank also.

The streams flow across the shales and sink shortly after reaching the Black Rock Limestone. The four principle sinks in the area are at Manor Farm Swallet, Longwood Swallet, Read's Grotto, and Tyning's Farm Swallet. The last of these discharges its water into G.B. Cave. The water from Manor Farm Swallet, Longwood Swallet, and G.B. Cave, has been traced to the springs at Cheddar, at the bottom of the south flank of the hills.

The plateau south of Blackdown is dissected by dry valleys. In the west the surface drainage is directed towards Longbottom valley, while in the east, a network of dry valleys drains into Velvet Bottom, a tributary of Cheddar Gorge. Manor Farm Swallet and Longwood Swallet are entered in the floor of two of these valleys. G.B. Cave and Read's Grotto are associated with a very shallow valley, the Long House Barn valley, which is a tributary of the Longwood valley. The latter is deep and well developed. At the entrance to Longwood Swallet (700 ft. O.D. (210 m.) its floor is 100 ft. (30 m.) below the level of the plateau. It heads in the Limestone Shales, where it is extensively developed along the strike. The gradient of its thalweg is consistently 120 ft. per mile (22 m. per Km.). Above 800 ft. O.D. the gradient of the Long House Barn thalweg is 170 ft. per mile (31 m. per Km.). A short distance above its confluence with the Longwood valley, however, the thalweg steepens to over 400 ft. per mile (75 m. per Km.). It is therefore discordant. Ford (1963, 1964) puts forward two explanations for this discordance. Firstly, Longwood Swallet may be later in origin than G.B. Cave, and thus during a period when the Longwood stream still ran overground, G.B. Cave may have captured the Long House Barn stream. Secondly, the extension of the Longwood valley westward along the strike of the shales may have captured part of the catchment of the Long House Barn stream.

The date of the origin of Longwood Swallet is discussed below. It is found that development probably began at some time during the Penultimate (Hoxnian) Interglacial. Ford (1963, 1964, p. 181–2) gives the date of the origin of G.B. Cave as during the Last (Ipswichian) Interglacial. The first of the two possibilities may, therefore, be eliminated. The present writer, like Ford, prefers the hypothesis of headward capture at the surface as the explanation.

Longwood Swallet itself is entered at 700 ft. O.D. (210 m.) in the floor of the Longwood valley. It extends to a depth of 465 ft. (139 m.) below the entrance, and has a total passage length of 4,800 ft. (1,440 m.) on the plan. The underground drainage is characterized by the way in which the stream has changed its course through the rock, leading to the formation of a large number of passages with a very complex plan view. The present catchment area of the cave is 0.70 sq. mls. (1.8 sq. Km.), giving a mean discharge of 0.97 cusecs (26 litres/second).* In wet years in the present climatic regime, this figure may be greatly increased. It should be appreciated, however, that the catchment has expanded to the west at the expense of the Long House Barn valley, and that a similar expansion has probably taken place to the east. The catchment area in the past was probably not as large as it is at present.

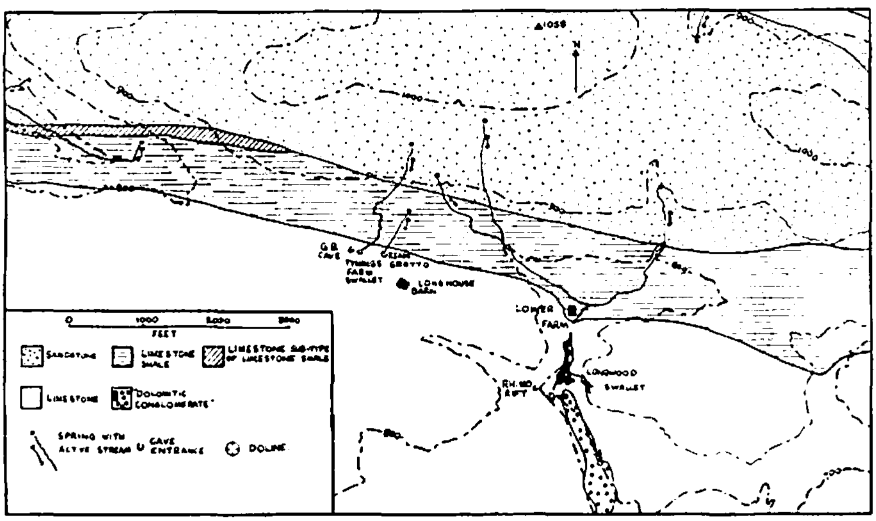

Fig. 45. The environs of Longwood Swallet. Based on O.S. and Geol. Survey maps. (Crown copyright reserved.)

Like Swildons Hole and Eastwater Cavern, two other large Mendip swallet caves, Longwood Swallet has few associated dolines. Stride and Stride (1946) describe the swallet at the present entrance as poorly developed and partly blocked by rock debris and vegetation. Rennie (1962) shows several dolines on his map of the environs of the cave. Most of these are poorly expressed on the ground and only two are worth mentioning here. 50 yards (45 m.) south of the Long House Barn confluence is a doline in the valley floor. A vestigial stream bed runs down to

* The mean discharge was not measured but calculated by comparing the Longwood catchment area with the G.B. catchment, which is immediately adjacent to the west. (Ford, 1964, footnote p. 154).

this from the present sinks. 10 yards (9 m.) down-valley of the entrance to Longwood Swallet is a well-developed depression with an excavated rocky shaft 15 ft. (4.5 m.) deep, leading down to a narrow rift plugged with stones. The stream sinks here in flood.

There is good evidence to suppose that several buried dolines may exist upstream of the present entrance to the cave. The Upstream Series (see below) consists of large stream passages which terminate in boulder chokes beneath the valley floor, close to the surface. Rennie's map of the environs of the cave shows two points upstream of the principle sink at the entrance, where water disappears into the stream bed. These points, too, are difficult to locate exactly on the ground. They may, however, represent buried dolines which were originally connected with the Upstream Series passages.

The underground drainage bears little relation to the valley floor. Inlet passages from the valley floor turn along the strike of a large fault, and the drainage is carried eastward under the plateau. On leaving the line of the fault, the passages run parallel to the valley, but in the Oxbows, near the end of the cave, drainage is once again to the east. *Plate* 28 is a survey based on Rennie's of 1962.

STRUCTURAL GEOLOGY OF THE CAVE

Longwood Swallet is developed in beds dipping in an overall southerly direction at 12–40°. Measurements of dip and strike are shown in *Plate* 29. The rocks are well jointed, and fractured in several places by faults. The most important of these is a complex of parallel fractures with a strike of around 125° (true) and crush zones up to 20 ft. (6 m.) wide. They have guided the solution of Great Chamber, Fault Chamber and Fault Grottoes, and have exerted a major influence on the course of the passages since their earliest development. These faults hade 25–50° to the south. Other faults have exerted control on the passage directions, though not to the same degree. The relation of the cave to faulting is shown in *Fig.* 46.

It is suggested, by correlation of lithologies across the fault complex, that the Great Chamber-Fault Chamber faults are normal faults. The other fractures seen in the cave are on the whole reverse faults and low angle thrusts with movement from the south. All are local in their development, dying away within a few feet. In the Wet Way, a thrust plane which guides the roof of the passage, appears to be truncated by the Great Chamber fault. The actual point of truncation is not well exposed, but if this truncation is accepted, the normal faults may be regarded as later than the thrust style of fracturing.

Joints are unusually well opened, and in areas away from the fault

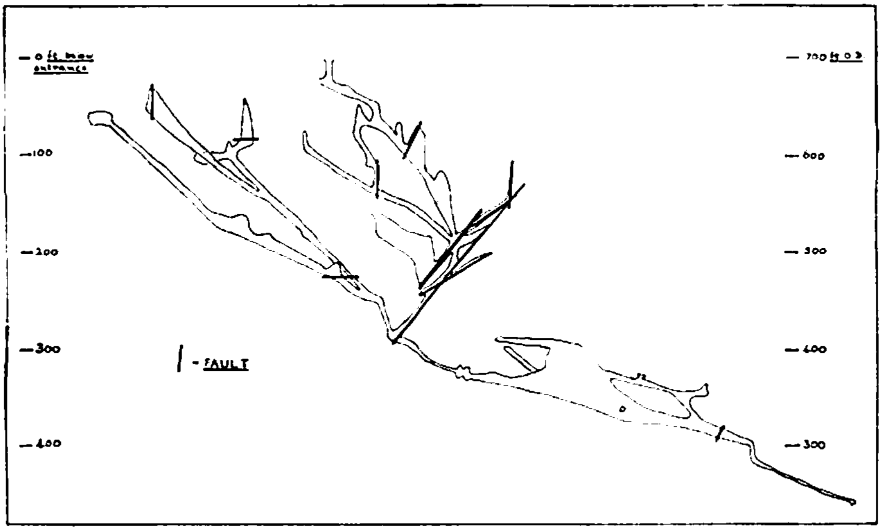

Fig. 46. Section of Longwood Swallet, projected onto 035° (true), to show relation between cave passages and faults.

complex there is rarely any calcite filling. Close to the complex there are numerous tension gashes with widespread calcite filling. The relation of the cave to jointing is shown in *Plate* 29. No pattern of jointing is clearly definable by inspection of *Plate* 29, but histograms reveal clear groups whose median directions are 017°, 077°, 117° and 166° north of the fault complex, and 042°, 072°, 132°, 167°, south of it. Unfortunately this data is of little significance, as when it is compared with the directions of joint-guided passages, no significant correlation is obtained. This is not the case in G.B. Cave (Ford 1964).

The relative importance of joints, faults, and bedding, in guiding passages was determined by analysing a sample of 2,840 ft. (850 m.), measured over 64 legs. 54.5 per cent of the total length was joint controlled, 37.6 per cent bedding controlled, and 7.9 per cent fault controlled. This sample excluded the Great Chamber, Fault Chamber, and Fault Grottoes, and passages in which breakdown has destroyed the evidence of the original form of control.

GEOMORPHIC HISTORY OF THE CAVE

For the purposes of describing and interpreting the morphology of the passages, the cave is arbitrarily divided into three areas. The upper Series consists of all those passages which lead from above into Fault Chamber and Great Chamber, these chambers themselves, the Wet Way, and Fault Grottoes. The Upstream Series comprises all the remaining passages upstream of the point T (*Plate* 28), while the Downstream Series includes all the remaining passages south of this point.

In view of the controversial nature of the concept of water tables in limestones of the Mendip area, the term "phreas" is used here to mean that part of a cave system which contains a complete water fill. No concept of a "phreatic zone" in which all the pore spaces and interstices of the country rocks are filled with water, and through which water can move freely, is applied in this study. Nevertheless, there is evidence which suggests that the upper limit of the phreas stood at stable levels within the cave at various times during its development. These levels are referred to as "rest levels of the phreas", or simply as "rest levels". Their existence does not necessarily imply the existence of a general piezometric surfaced in the surrounding area.

Development of passages in the phreas

The Upper Series may be divided into two areas, distinguished by passage types. These are the cavity formed by Fault Chamber, Fault Grottoes, and the Great Chamber, and the various watercourses which drain into it. A third area, the Wet Way, carried water out of the Great Chamber.

The south side of the Great Chamber, Fault Chamber, and Fault Grottoes, all lie in the plane of the faults of the Great Chamber-Fault Chamber complex, which strikes 125°, and hades 25–50° to the south. The cavity formed by these chambers measures 60–120 ft. (18–36 m.) along the dip of the fault planes, and has a known extent of 180 ft. (54 m.) along their strike. It is from 6 ft. (2 m.) to 20 ft. (6 m.) wide, perpendicular to the fault plane. While the upper part of the cavity is continuous from Great Chamber to Fault Grottoes, it is restricted in places by collapsed blocks, stream deposits, and stalagmite. The blockage by similar deposits in the lower portion of the Great Chamber is so great that its continuity with Fault Chamber cannot be established.

The floor of this cavity has almost everywhere been altered by vadose erosion. Elsewhere it is masked by deposits. The walls either consist of crush breccia, or are also masked. Large areas of the roof are collapsed or have been fretted by trickling vadose water. Sufficient areas of smoothly contoured, solutional, roof surfaces remain, however to suggest that the cavity is phreatic in origin. These surfaces are well exposed in Fault Grottoes, where solutional pockets provide corroborative evidence.

Draining into this cavity from its hanging wall side are no fewer than four separate inlets. These are the Icing Chamber, Waterfall Chamber, the series of passages from the entrance and Water Chamber, through the Great Rift, to the Great Chamber at the point A (*Plate* 28), and the passage BFG. They all show remnants of early phreatic elements.

Icing Chamber is formed along a fault. Pockets extend upwards from the roof, and the upper part of the passage walls shows smooth, solutional, surfaces.

The passage between Great Chamber and Waterfall Chamber has a high, narrow, cross section, in the upper part of which the walls have solutional, smoothly contoured, surfaces. The phreatic element of the passage is very narrow, rarely wider than 9 in. (22.5 cm.) (point C).

Close to the entrance, at D, the cave is developed along a bedding plane. The smooth surfaces of the roof and the presence of pockets indicate a phreatic origin. A similar phreatic remnant is seen in the roof at the north-west end of the Great Rift. No further recognizable phreatic features are seen in these passages until the point E is reached. Here the passage has a high rift form, rarely more than 2 ft. (0.6 m.) wide. The upper part shows phreatic features similar to those in Waterfall Chamber.

At B there is little sign of a phreatic passage in the roof, though no collapse has

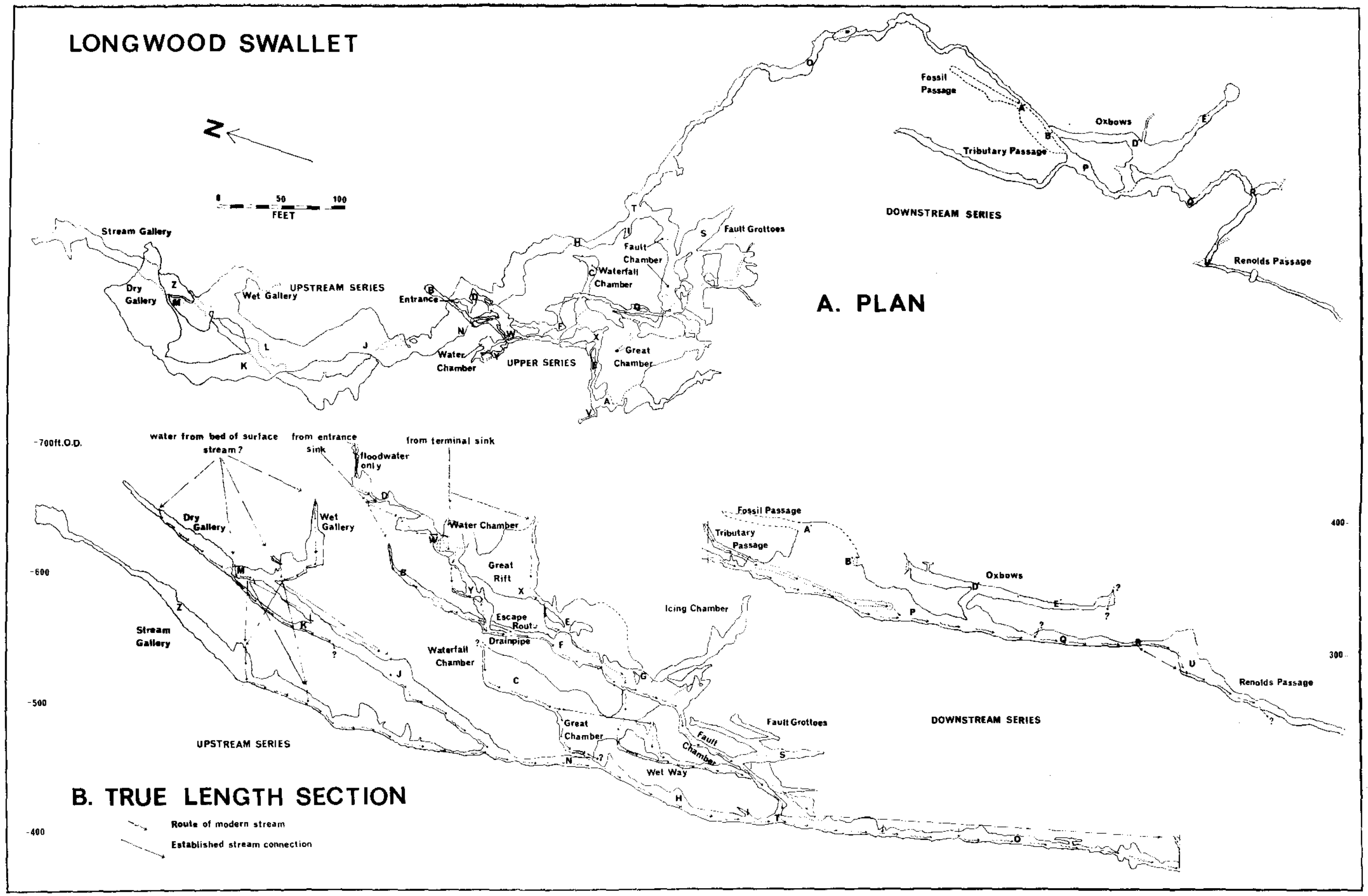

PLATE 28

Longwood Swallet showing localities referred to in the text and modern hydroglogy.
Based on survey by M. Rennie, 1962, and published with his permission.

occurred. At F, however, there is a well developed, arched, phreatic roof, controlled by a joint. A little way downstream a small phreatic passage may be seen above the roof of the main passage, with its floor intact. Water has leaked down the joint along which it runs, and cut the vadose trench below. Another isolated phreatic remnant is seen in the oxbow at G, and in the rift passage by which this passage reaches Fault Chamber.

The Wet Way has a T shaped cross section, the upper part of which is an elliptical phreatic passage. This is guided along the strike of a low-angle thrust plane, and maintains its altitude for some 60 ft. (18 m.). The cross sectional area of the phreatic element is 15 sq. ft. (1.4 sq. m.).

The Upstream Series consists of heavily collapsed passages, which are for the most part joint controlled. There are few phreatic remnants. At H pockets extend upwards along a fault plane in the roof. A little way downstream, at I, is a small passage formed in a fault. A well developed phreatic arch can be followed from it into a half tube leading upwards into Fault Chamber. At J a smooth surface, which may be solutional, is seen on the roof. Similar features are seen on bedding controlled roof surfaces at K and L There is a passage of elliptical cross section and phreatic appearance at M, but it is blocked by stream deposits. Its cross sectional area is about 15 sq. ft. (1.4 sq. m.).

The most important of the phreatic features in this part of the cave is a line of pockets extending up a fault plane at N. The north-east side of this passage is heavily collapsed, and any further phreatic features have been destroyed. The significance of these is explained below in the paragraph on past rest levels.

At the point T, the main stream passage has two separate phreatic elements. On the south west side is the phreatic tube mentioned above; a lowering of the roof separates it from an elliptical phreatic passage developed along the strike of a bedding plane to the north-east. The two parts are morphologically distinct, as *Fig.* 5 shows.

From T to O the passage has a phreatic element, developed along the strike of a bedding plane. The floor has been partly removed by vadose erosion, but sufficient remains to demonstrate its elliptical shape. The cross sectional area is 25–30 sq. ft. (2.25–2.7 sq. m.). At O the upper parts of the passage are filled with stream deposits, and this remnant is no longer visible.

Fossil Passage has a phreatic element of 30–40 sq. ft. (2.7–3.6 sq. m.) cross sectional area, which continues downstream as far as the Oxbows (B¹). It turns south-east into the Oxbows, whose phreatic element is also 30–40 sq. ft. (2.7–3.6 sq. m.) in area. From D, two high level passages lead east along the strike of the beds. Both are blocked by stream deposits and mud. The northerly of the two is entirely phreatic and filled with fine sand and silt. Its cross sectional area is estimated to be 20–25 sq. ft. (1.8–2.25 sq. m.). The other has an upper phreatic element, and a lower, filled, vadose trench. The cross section is 20–25 sq. ft. (1.8–2.25 sq. m.). From this information it is clear that there was once a well defined phreatic waterway from Fossil Passage to the Oxbows.

Tributary Passage has a sub-ovoid cross section, which has been considerably modified by collapse. Vadose erosion is unlikely to produce such a cross section on a gradient as steep as that of this passage. It is therefore suggested that Tributary Passage is phreatic in origin. The roof at P is collapsed, so that no phreatic elements can be seen. There is a phreatic tube of cross section 6–8 sq. ft. (0.58–0.72 sq. m.) in the roof of the lower stream passage from Q to R. Renolds Passage is manifestly phreatic with many pockets and bedding and joint controlled cross section. There is only minor vadose modification. It is suggested therefore, that a second phreatic waterway once existed, extending from an upstream limit at Tributary Passage, *via* P to the QR phreatic element, and thence down Renolds Passage to the end of the known cave, where it becomes too narrow to follow.

This second waterway eventually captured the water from the first. The lower entrance to the Oxbows is an entrenched phreatic passage, developed along a bedding plane. Half tubes in the roof demonstrate its phreatic origin. From this point, solution cavities along joints in the roof of the stream passage lead down to the point Q, where they join the QR tube. It is suggested that the Oxbows distributary passages leaked into the Tributary-Renolds Passage waterway. This probably took place under conditions of falling water fill, as is shown below. The capture itself produced a further drop in the level of the water fill.

Rest levels of the phreas

In assessing the position of past rest levels the following criteria are used:—

1. The existence of an up-and-down stepping phreatic passage, the tops of whose loops are at a similar altitude.
2. A phreatic passage of low gradient cutting the strata.
3. The correlation of heights at which passages trending upwards narrow markedly or end completely.
4. Phreatic passages following the strike of a structural plane (bedding plane or fault), and maintaining their altitude along it.

With the exception of 2, which has been used alone by other writers (*e.g.* Ford 1964), none of these criteria are valid, in the opinion of the present writer, when applied singly.

The passage trending south-east at S, the Wet Way, and the passage N, all follow the strike of controlling structural planes at 460–70 ft. O.D. (138–141 m.). They all show signs of phreatic origin (see above), though they have been modified by collapse or vadose erosion. Furthermore, phreatic remnants in the Upstream Series indicate the existence of a waterway from N to S (above). That this is not the same waterway as is seen in the roof between T and O is shown by the separate morphology of the two parts of the roof at T (*Fig.* 47). Criteria 1 and 4 are therefore

Fig.47:Diagrammatic cross section of passage at T. Not to scale.

Fig. 47.

satisfied, and a rest level at 460–70 ft. (138–141 m.) may be inferred.

The flat roof of the passage between A' and B' truncates the bedding at 400 ft. O.D. (120 m.). The altitude of Fossil Passage is also 400 ft. (120 m.), and is similar to that of the phreatic element at T (410 ft., 123 m.), which follows the strike of a bedding plane. Tributary Passage narrows to an impenetrable rift at 395 ft. (118.5 m.). A second rest level at or around 400 ft. (120 m.) may be inferred.

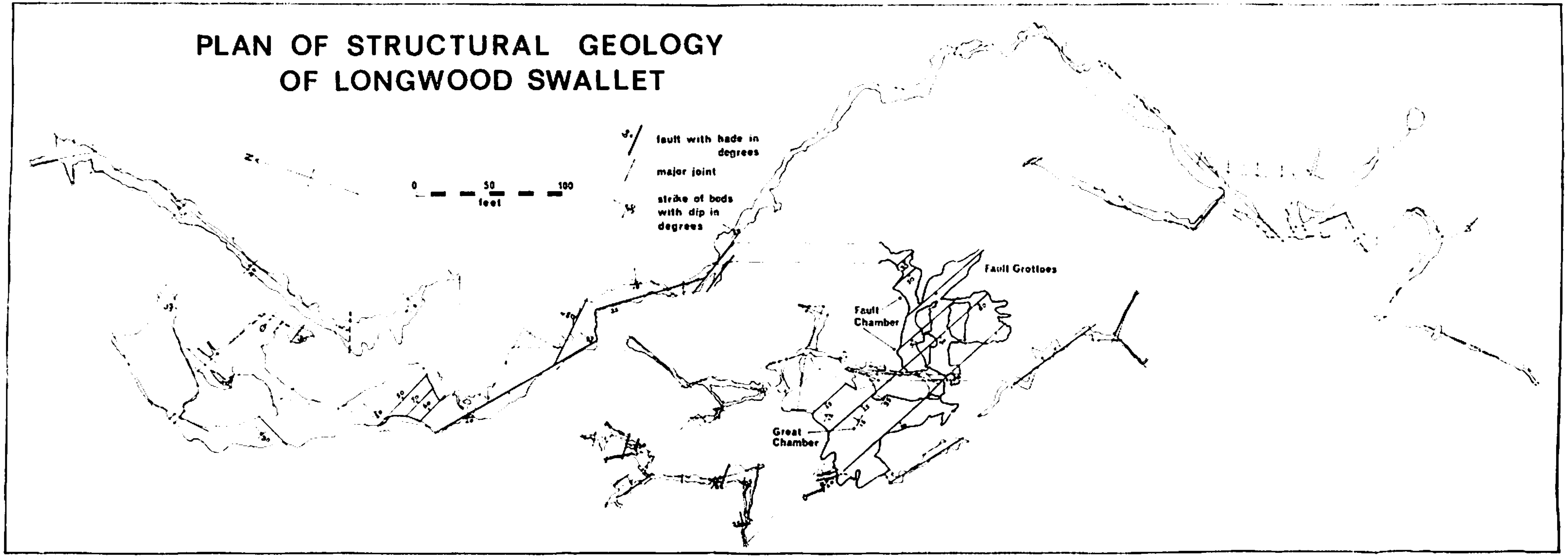
PLAN OF STRUCTURAL GEOLOGY
OF LONGWOOD SWALLET
fault with hade in degrees
major joint
strike of beds with dip in degrees
0 50 100
feet
Fault Grottoes
Fault Chamber
Great Chamber

PLATE 29

The passage RU has phreatic features in its roof and truncates the strata in its upstream limb, but follows the strike in its downstream limb. This is judged to be sufficient criterion for inferring a rest level at 300–10 ft. O.D. (90–93 m.).

Conditions of falling water fill

As Table 1 shows, the cross sectional area of inlet passages in the Upper Series increases with depth below the entrance.

Table 1

THE INCREASE IN CROSS SECTION OF PHREATIC ELEMENTS IN THE UPPER SERIES

Passage	Altitude	Cross Sectional Area of Phreatic Element
Entrance	700 ft. O.D. (210 m.)	
Passage at D	655 ft. O.D. (197 m.)	7 sq. ft. (0.63 sq. m.)
Great Rift	630 ft. O.D. (189 m.)	c. 10 sq. ft. (0.9 sq. m.)
Passage at E	570 ft. O.D. (171 m.)	c. 15 sq. ft. (1.4 sq. m.)
Waterfall Chamber	515 ft. O.D. (155 m.)	c. 20 sq. ft. (1.8 sq. m.)

This increase in phreatic erosion with depth might suggest that the lower passages remained in the phreas for longer than the higher. The passages above the 460–70 ft. rest level may, therefore, have developed under conditions of falling water fill.

The 460–70 ft. (138-41 m.) rest level lies about half way up the Fault-Great Chamber cavity, whose height range is 400–520 ft. O. D.(120–156 m.). Any estimate of the cross section of this cavity is approximate, as its dimensions have been extensively modified since it ceased to lie in the phreas, but a conservative estimate of the cross section due to phreatic erosion in the plane 035° (true) is 60 sq. ft. (5.4 sq. m.). This is very much larger than the size of the inlet passages draining into the cavity. This fact, the position of the 460–70 ft. (138–41 m.) rest level in relation to the cavity, and its location in a highly brecciated fault zone in which ground water could presumably move easily, suggest that this cavity was in existence prior to the development of the main cave. The latter has used it as a path for channelled ground water, and shows a relation to it which is significant in this context. The inlet passages of the cave all drain into the fault cavity from its up-dip, hanging, wall, while the outlet passages—the Wet Way, Fossil Passage, and the Downstream Series—leave it some distance to the south-east and on its footwall.

During the period of the first, 460–70 ft. (138–41 m.) rest level, water from the inlets to Great Chamber must have discharged through the Wet Way, at least in part. The latter has a cross section of only 15 sq. ft (1.4 sq. m.), and it seems unlikely that this could have accommodated the combined flow of these inlets. As shown below, the inlet passages do not appear all to have carried streams at the same time. Nevertheless, it is possible that excess water flowed downwards through what is today the boulder floor of the Great Chamber, and into further cavities in the plane of the Great Chamber fault.

The stream in the Wet Way has been tested with fluorescein, and shown to reappear in Tributary Passage. The ends of these two passages are very constricted, and how such a small cavity could have accommodated the flow from the Wet Way remains problematical. It is suggested that unexplored passages beneath the floor of the Great Chamber may have carried part of the water.

The water from the passage BFG flowed into Fault Chamber *via* a rift above the latter, while that from the Upstream Series discharged upwards *via* phreatic remnants at T, into Fault Chamber. This water appears to have left Fault Chamber to the south-east, at S, during the period of the 460–70 ft. (138–41 m.) rest level. The relation between the sequences of trenching and infilling in Fossil Passage and at S suggest that water may have flowed from S to Fossil Passage at some time in the past. This is discussed in more detail below. If this conclusion is tentatively accepted, it appears that during the period of the 460–70 ft. (138–41 m.) rest level, water left the known cave at the Oxbows (from Fault Chamber) and Renolds Passage (from the Wet Way).

As *Fig.* 47 shows, the phreatic element in TO, associated with the 400 ft. (120 m.) rest level, bears no genetic relation to the half tube remnants leading upward into Fault Chamber. It appears that the lowering of the phreas from 460 ft. (138 m.) to 400 ft. (120 m.) was accompanied by the erosion of the passage TO. This captured the water previously channelled in the passage S, which became fossil. The genetic relations between the passage TO and the 400 ft. (120 m.) rest level are close. TO came into existence because streams graded to a base below 460 ft. (138 m.) could no longer flow past S to Fossil Passage. At the same time, the drop in rest level appears itself to have been in part due to the opening of the passage TO. Why the rest level should have occurred at 400 ft. (120 m.) and not at another altitude is not apparent from evidence within the cave.

During the period of the 400 ft. (120 m.) rest level there was little change in the relations of passages in the phreas. The Oxbows and Renolds Passage took separate streams from T and the Wet Way. At this stage they were still separate passages.

The lowering of the phreas to the 300 ft. (90 m.) rest level involved a complex sequence of events which cannot be established on the evidence of phreatic features alone. Since by this stage the majority of the active waterways of the cave were operating under vadose conditions, a full discussion of this sequence is given below. The phreatic features of the 300 ft. (90 m.) rest level are constricted compared with those of higher levels. The phreatic element of QR has a cross section of only 6–10 sq. ft. (0.54–0.90 sq. m.). This might suggest a reduction in the amount of water flowing in the cave during this period.

Vadose features—stream-cut trenches, fill material, stalagmite

The unravelling of the formation of the stream-cut trenches of the Upper Series presents greater problems than any other part of the cave. Streams have migrated from one inlet passage to another in a complex fashion, rendering the establishment of an erosional history very difficult. Hard and fast criteria do not exist by which the sequence in time of the capture of one stream passage by another can be established. One criterion which can be used is the position of the upstream ends of the inlet passages in relation to the valley floor. It is assumed that those lying down-valley are older, those up-valley, younger. Its application is liable to error, however, since only one of the inlets can be followed to the surface of the ground and because swallets may be initiated down valley of an older swallet, which has been blocked by debris.

The inlet lying farthest downstream in the Upper Series is the Icing Chamber. It contains a vadose trench, the top 6 ft. (2 m.) of which is exposed. The walls of the trench are rough, and grooved, in contrast to the smoothly undulose phreatic surfaces. The floor is masked by deposits of compacted gravel with larger quartzite and limestone cobbles, of varying angularity. These are in turn covered by thick stalagmite of ancient, crystalline appearance. Individual crystals are clearly visible with the naked eye. The fill material has been partly eroded since the deposition of the stalagmite, which is cracked and broken. Beneath the entrance to the Icing Chamber is a vertical drop of 10 ft. (3 m.) to the floor of Great Chamber, which slopes steeply away to the north.

The inlet passages at the entrance show a complex sequence of captures from one trench to another in the area around W and D. Below W and at E, there are two trenches, one incised in the floor of the other. The separate indentity of the two is established at points where the lower is narrower than the upper, and ledges remain on either side of the passages to represent the previous floor. In this area, the upper trench is 10–15 ft. (3–4.5 m.) deep, the lower 8–15 ft. (2.4–4.5 m.). There is abundant evidence of infilling after the erosion of the lower trench. In many places it is filled with gravel, sand, broken stalagmite, and quartzite and limestone blocks and cobbles. A 9 in. (22.9 cm.) thick stalagmite layer is often present. This is being eroded by an intermittent waterfall at X, and in many other places it is cracked or has been removed altogether. The fill, also, has been partly removed in places, suggesting a short episode of active stream clearance after the deposition of the stalagmite layer.

This fill does not extend upward into the upper trench in the Great Rift. High on the walls of the passage, however, are thick stalamite deposits with small cobbles cemented into them, testifying to a previous episode of infilling and stalagmite deposition. While this earlier fill is poorly exposed, it does seem likely that it was deposited between the two trenching episodes.

At V a narrow rift passage hangs 4 ft. (1.2 m.) above the floor of the main passage, with its floor 10 ft. (3 m.) below the top of the lower trench. The inlet is therefore assigned to the later of the trenching episodes. Discharge from it must have been greatly reduced to produce the discordance.

At W the north wall is collapsed, and fallen blocks rest upon deposits of the later fill. The passage from W to the Water Chamber also contains two trenches, similar to those already described.

The sequence of trench cutting in the entrance area is illustrated in *Fig.* 48. The passage at a is phreatic in form and runs aslant dip and

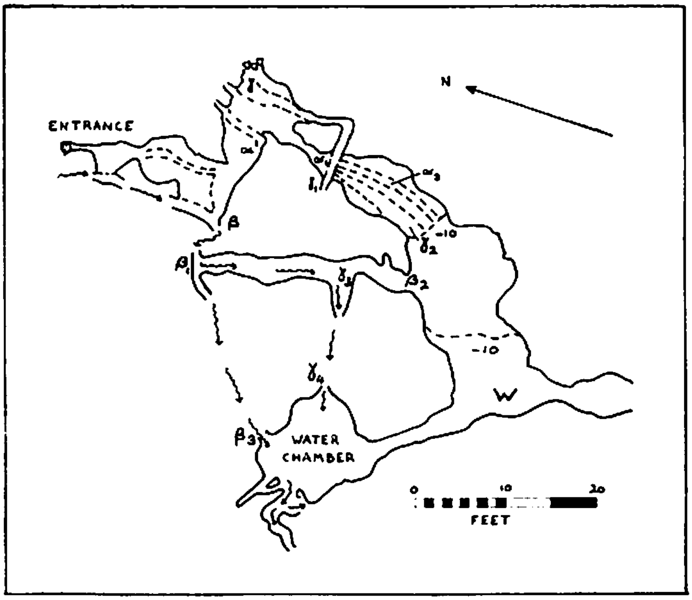

Fig. 48. Plan view of entrance area to show sequence of erosion. Curly arrows show paths of modern stream under normal conditions. Other symbols conform to Cave Research Group or are explained in the text.

strike. At the earliest stage of vadose erosion, water from the present entrance spilled over its eastern end and cut the shallow trench $\alpha\alpha_1$ α_2, which is up to 18 in. (0.45 m.) deep. Leakage of water via β soon followed, however, and the vadose passage β_1 β_2 was formed, leaving a discordance of 10 ft. at α_2. Further leakage to the Water Chamber occurred, and the upper trench from there to W was cut as a result. The floor of trench α is covered by stalagmite in which small pebbles are cemented. The infilling of the upper trench at W has already been demonstrated, and it may be inferred that the α and β trenches are contemporaneous with the upper trench in the Great Rift, and were infilled some time after their formation.

The trench $\gamma\gamma_2$ cuts across α_1 α_2 and is incised into solid rock to a depth of 2 ft. below it (0.6 m.). It must have been incised through a fill in α_1 α_2. There is a prominent opened joint in the floor of $\gamma\gamma_2$ and water passed down it to γ_3, γ_4, and Water Chamber. From the latter it flowed into the Great Rift, where it eroded the lower trench. There are inlet passages in the south wall and roof of Water Chamber. The former contains an 18 in. (0.45 m.) thick stalagmite layer, beneath which the modern stream enters the chamber in flood. It seems likely that it was these inlets, rather than the restricted passages at β_2 and γ_4 that supplied the majority of the water for the erosion of the trenches in the Great Rift. It may be inferred that the swallets which supplied these inlets are later than the swallet at the present entrance.

Waterfall Chamber also shows two periods of stream entrenchment. The upper trench here is 6–8 ft. (2–2.6 m.) deep, and at its base there has been considerable penetration along a bedding plane in a southerly direction. The bedding passage is 18 in. (0.45 m.) high, and contains loose, waterborne, debris. Incised into the floor of the upper trench is a lower one, as much as 5 ft. (1.5 m.) deep. It is filled at most points by boulders and gravel. In Waterfall Chamber itself are eroded fill deposits containing limestone, quartzite, and broken stalagmite pebbles. The phreatic part of this passage, and possibly part of the upper trench also, forms a high slot in the roof of the Great Chamber. The lower trench is graded to the top of a 35 ft. (10.5 m.) waterfall, which drops to the floor of the Great Chamber.

The Great Chamber reached its present dimensions by the large-scale collapse of its northern half. The walls and roof show all the features of block collapse (Davies, 1951), and the floor is formed of the fallen blocks. The arrangement of the two trenches in Waterfall Chamber suggests that this collapse occurred between the two trenching episodes there. The fallen blocks are covered by 15 ft. (4.5 m.) of stream deposits with further blocks in places. This is covered by thick stalagmite, now broken, and finely laminated mud, especially in the south and east. The fill material in the middle of the Chamber has been removed, and the basal boulders are exposed.

The Wet Way has two shallow trenches, 3–6 ft. (1–2 m.) and 1–3 ft. (0.3–1.0 m.) deep respectively. The original entrance to the passage is blocked by a bank of collapsed blocks and fill material, and the modern stream enters from an opened joint from Waterfall Chamber, and by a low tunnel beneath the floor of Great Chamber. The modern stream is an underfit and is cutting slots in the lips of two potholes, whose plunge pools are now inactive.

An estimated volume of 13,000 cu. ft. (351 cu. m.) of fill material has been removed from the floor of the Great Chamber since the infilling. Free access from the space left by this removal to the Wet Way is prevented. The fill must have been removed by some other passage, possibly one extending beneath the present floor, down the plane of the Great Chamber Fault.

The inlet passage BFG also has two trenches. At G the upper is 10 ft. (3 m.) deep, and a pothole in its floor has been incised by the lower, which is 8 ft. (2.4 m.) deep. From F to G there is abundant evidence of infilling of the lower trench. The top of the fill is marked by stalagmite bridges which span the passage at two points. Scattered remains of a earlier fill are seen on the walls of the upper trench. At B there are also two trenches, the upper 6 ft. (2 m.) deep, while the lower is almost entirely infilled. A stalagmite layer over the fill material is being eroded by a small modern stream, and in places the fill may be seen through it. The north entrance of the Escape Route, a tight oxbow passage, is about 3 ft. (1 m.) above the floor of the upper trench, and the stream now finds its way down the Drainpipe, where further evidence of infilling may be seen.

Clearly, the BFG inlet shows two cycles of erosion, aggradation, and deposition of stalagmite. However, the floor of Water Chamber lies at a lower level than the floor of the lower trench at W. The modern stream enters Water Chamber from the roof and south wall and flows down through collapsed blocks and into the passage Y, where traces of fill and stalagmite may be seen on the walls of a trench 10 ft. (3 m.) deep. From here the stream flows down a 30 ft. chimney, formed along the intersection of a joint and minor fault, and thus reaches the head of the Drainpipe. Clearly, this section of passage is later in origin than the lower trench in the Great Rift. By implication, the upper trench in BFG is contemporaneous with the lower trench in the Great Rift, and drew its water from the passage B, while the lower trench in BFG is later than that in the Great Rift. Thus there is evidence of at least three cycles of erosion, aggradation, and deposition of stalagmite, and a modern episode of partial re-excavation of passages.

The Icing Chamber inlet may be assigned with some confidence to the first of the three cycles, with some excavation at the start of the second.

The Wet Way lies at the position of the 460–70 ft. (138–41 m.) rest level, and the two trenches in it must postdate this level. Vadose trenching presumably begins as soon as a passage becomes airfilled. The conclusion is therefore drawn that the first trenching episode is associated with the initial lowering of the phreas from a position above 655 ft. O.D. (197 m.) to its first stable position at 460–70 ft. (138–41 m.). The two trenches in the Wet Way are assigned to the second and third cycles.

The Waterfall Chamber trenches are more difficult to place in this relative chronology. Such a large volume of material has been removed from the Great Chamber since the last infill there that it does not seem likely that the modern stream could have accomplished the work required. The last infill in Great Chamber may be tentatively assigned to the second fill and its removal to the third trench.

The evidence in Fault Chamber is scanty, as vadose trenches are not developed on its wide floor. There are, however, abundant exposures of fill material, and the chamber was at one time completely infilled, as cobbles and thick stalagmite at its top show. At S there are similar deposits. Collapsed blocks at the base are followed by fine muds and gravel with cobbles, and 9 in. (22.5 cm.) of stalagmite. The latter has been broken and recemented. These deposits clearly postdate the first rest level, and are tentatively assigned to the second fill, and their partial re-excavation to the start of the third erosion.

The relative chronology of the Upper Series is summarized in Table 2. This chronology will be used below as a type in the study of the other parts of the cave.

Table 2

THE RELATIVE CHRONOLOGY OF THE UPPER SERIES

Phase	Events	Location of Evidence
1*a*	Phreatic erosion	Great, Fault Chambers
b	Phreas falling from above 655 ft. O.D. (197 m.) to 460–470 ft. (138–41 m.)	All passages
2*a*	Major vadose erosion	Icing Chamber, Entrance, Great Rift
3*a*	Aggradation	Icing Chamber, Entrance, Great Rift
b	Deposition of stalagmite	
4*a*	Minor vadose erosion	Icing Chamber
b	Major vadose erosion	As for 2*a*, and BFG, Wet Way, Waterfall Chamber
c	Collapse	Great Chamber
5*a*	Aggradation	All passages
b	Deposition of stalagmite	
6*a*	Excavation of fill	All passages
b	Major vadose erosion	BFG, Y, Wet Way, Waterfall Chamber
c	Collapse	Great Chamber, W
7*a*	Aggradation	BFG, Waterfall Chamber, Fault Chamber
b	Deposition of stalagmite	
8	Modern: Excavation and minor vadose erosion	All passages.

The Upstream Series has two branches, Dry and Stream Galleries, which meet at N, at the 460–70 ft. (138–41 m.) rest level. Whilst Dry Gallery has the phreatic elements described above, Stream Gallery does not, though the extensive collapse in both passages may conceal more extensive remnants.

Dry Gallery has a rectangular cross section, with a collapsed roof. The projecting, sagging, ends of fallen beds in the upper walls indicate the breakdown to have been of the slab type (Davies 1951). No well defined trenches have been incised, and it is not possible to determine how many episodes of trenching have occurred. At L, the junction between Wet and Dry Galleries, the gradient of the former is very steep, about 45°. The gradient of Dry Gallery, at this point and below it, is only about 30°. This suggests a discordant relationship between the two, as the upper parts of Wet Gallery are almost horizontal. Between L and M there is evidence of at least one vadose trench, which has been infilled and is at present being re-excavated. Stalagmite deposits are not seen. Although only one cycle of erosion can be detected, there has been heavy slab collapse since the last infilling, and further evidence may have been buried.

The passages of Dry Gallery north of K also show only one vadose trench. Here, too, collapse has been extensive, and for 100 ft. (30 m.) the passage is filled almost to the roof with limestone blocks. At one point there is a broken stalagmite layer, 9 in. (22.5 cm.) thick, with traces of stream fill beneath it. A small quantity of waterworn debris rests on the layer. The large chamber at the top of Dry Gallery also contains a large quantity of fill material. Little stalagmite is seen in this chamber, but in some places the unsorted fill is covered by a layer up to 2 ft. (0.6 m.) of coarse sand with a few pebbles.

There are similar deposits at J, where they are covered by stalagmite. All the fill deposits described have been partly re-excavated, and are often buried beneath piles of fallen rock.

It is tentatively suggested that the Wet Gallery may have been the area in which the stream entered the Upstream Series during phases 2 and 3a. The route it took is represented today by Wet Gallery L, J, and N, where the cave entered the phreas. The water may have entered via its present inlets, which are constricted, or by the blocked passage at M. On the same hypothesis, the Dry Gallery, north of K, may be taken to represent the second trench, phase 4b. The fill in Dry Gallery may be assigned to 5a, and that in Wet Gallery to 3a. The discordance between the two is therefore supposed to have developed in 4b. These conclusions are extremely tentative, however.

Between N and H are exposures of fill up to 15 ft. (4.5 m.) thick, and capped by 6 in. (15 cm.) to 1 ft. (30 cm.) of stalagmite. The lower walls of the passages are vadose in appearance, though the etching of fossils in places may indicate backing up of flood waters. The floor is everywhere masked by stream deposits. Since these passages lie between 460 ft. (138 m.) and 400 ft. O.D. (120 m.) the fill in them cannot be assigned to 3a.

For most of its length, Stream Gallery has a rectangular cross section, heavily collapsed by both slab and block breakdown. In the northerly sections of the passage, the walls are collapsed on a large scale, but sufficient remains of the original passage to indicate that only one major episode of trenching has occurred. At Z, this trench is 25 ft. (7.5 m.)deep, and the remains of a fill, plastered onto the walls, are 12 ft. (3.6 m.) thick.

In the roof of Stream Gallery there is an impersistent, narrow rift, with rough, vadose walls. In some places etching by trickles obscures the original nature of the wall surface. The rifts are up to 12 ft. (3.6 m.) high, and appear to represent a watercourse older and smaller than the passage below. At two points water enters from Wet Gallery (see below) through the roof of the rifts. As there are no signs of fill in the rifts, it is impossible to date them. However, since Wet and Dry Galleries appear to represent erosion in 2a and 4b, it may be that Stream Gallery was eroded in 6b. The fill seen between N and H can then be assigned to 5a or 7a, of which the latter seems more likely in view of the amount of material preserved.

Layered muds and silts on fallen slabs at N and Z are evidence of ponding. It is difficult to envisage ponding occurring except under conditions of infill. The collapsed boulders at Z and N can, therefore, be inferred to have fallen during or shortly after 7a, before the fill had been removed by the modern stream. The stalagmite of 7b is not widely represented in the Upstream Series, except between N and H.

It should be emphasized that the Upstream Series is so heavily collapsed that very little evidence of past events remains for inspection. The relative chronology deduced above is possible, and in the opinion of the writer the simplest and most likely. There are other possible interpretations, however, which will explain the limited data equally well.

The sequence of vadose erosion in the Downstream Series is dominated by the fall of the phreas from the 400 ft. (120 m.) position to 300–310 ft. O.D. (90–93 m.).

At T there are two trenches, an upper represented by ledges on the walls, and a lower in which the modern stream flows. If the ledges are followed downstream they remain almost horizontal, while the passage roof descends slightly. The ledges merge downstream into the higher ledge representing the floor of the original phreatic passage. The upper trench was therefore graded to a base level at 400 ft. O.D. (120 m.).

Downstream, the lower trench deepens rapidly. At O it is 10 ft. (3 m.) deep, and downstream of this point becomes blocked by calcite-cemented fill, beneath which the explorer must crawl. At C' there are two inactive potholes, beyond which the stream passage is 20 ft. (6 m.) high.

At A' the roof soars to a height of 50 ft. (15 m.) above the floor. There are two trenches, the upper 25 ft. (7.5 m.) deep, the lower 15–20 ft. (4.5–6 m.). In places there is a 3 ft. (1 m.) deep trench cut by the modern stream. Fossil Passage has a single trench 15 ft. (4.5 m.) deep, partly filled and floored with a 1 ft. (30 cm.) stalagmite layer. The latter has been broken, overlaid by a thin, discontinuous layer of gravel, and re-cemented. The layer of stalagmite in Fossil Passage may be followed round the walls to a stalagmite bridge over the stream passage between A' and B'. In the Oxbows, there is a 12 ft. (3.6 m.) deep trench from B' to D', and the top of a trench can be seen at E', where excavations have revealed stream deposits banked against fallen boulders. Throughout the Oxbows, all deposits are overlaid by a layer of fine sand and mud.

Between B' and P, there is no evidence of phreatic development, but vadose stream deposits have been plastered onto the walls at several points. The vadose trench at B' is 30 ft. (9 m.) deep. Its upper 12 ft. (3.6 m.) is continuous with the Oxbows trench, while the lower 18 ft. (5.4 m.) leads to P where it is 15 ft. (4.5 m.) deep, and thence to Q, where the depth is only 2 ft. (0.6 m.). The 3 ft. (1 m.) modern trench at P increases to 6 ft. (2 m.) at Q, where the floor is masked by stream deposits. At the lower entrance to the Oxbows is a bank of fill, covered by 6 in. (15 cm.) of stalagmite, 15 ft. (4.5 m.) above the floor of the stream passage.

Tributary Passage has a single 4 ft. (1.2 m.) trench. The potholes in its floor are being undercut by the modern stream. There is little sign of past infilling.

This data may be interpreted as representing the following sequence of events. During phase 2a water discharged from Fossil Passage to the Oxbows, and flowed along the two passages leading east. At the end of this phase, the rest level dropped to 400 ft. O.D. (120 m.), and the passage TA' took the stream. This is substantiated by the fact that the upper trench at T is graded to 400 ft. (120 m.) and can only be assigned to 4b. Fossil Passage became disused as a waterway during 4a and 4b, but discharge was directed to the Oxbows, as in 2a. At the start of 6, the rest level dropped again. Because the passages above 400 ft. (120 m.) were blocked by stream deposits, discharge must have been via Fossil Passage in 6a and part of 6b. Deposits in Fault Chamber suggest a complete fill, up to an altitude of 460 ft. (138 m.) (see above). As the phreas fell, the trench in Fossil Passage and the upper trench between A' and B' were incised. When excavation of the deposits of phase 5 had proceeded far enough, the passage TA' resumed its importance as a waterway, and trenching began there also. At the same time the phreas in Tributary Passage was falling, and the trench there being eroded.

It appears that at this stage the capture of the Oxbows water by the Tributary Passage/Renolds Passage waterway occurred. The trenches which had already been eroded in the Oxbows were deepened as a result, but their further erosion was forestalled by the development of a shorter link from B' to P and Q. This link was rapidly trenched, leaving the Oxbows hanging nearly 20 ft. (6 m.) at B'. This trench is that down which the stream now flows, and was described in detail above. It is graded to the 300 ft. (90 m.) rest level at Q. It is presumably contemporaneous with the third trench in the Upper Series, phase 6b. The 6 ft. trench (2 m.) in QU is younger, apparently eroded by the modern stream (phase 8).

The 6b trench was infilled during phase 7. At OA' this was complete, and water must have been forced to flow for a time through Fossil Passage, which also became infilled and stalagmited. At the end of a period of stalagmiting (7b), streams began to flow again, and re-excavation began. The stalagmite in Fossil Passage must have been broken at some time before OA' was reopened. Further stalagmiting has since recemented it. The rest level of the phreas fell to its present position during or after the stalagmite phase (7b), so that the modern trench was incised in QRU once excavation was complete.

The Wet Way is known to connect with Tributary Passage (see below and *Fig.* 49B), and the two trenches in the former belong to 4b and 6b respectively. Tributary Passage has only one trench and is used above as a criterion for the position of the 400 ft. (120 m.) rest level. This trench must, therefore, be assigned to 6b, like the other trenches in the Downstream Series.

From a comparison of the spacial relations of Fossil Passage and the passage at S, it seems likely that there is a connection, now blocked, between the two. Furthermore, the passage at S has been filled twice, in 5a and 7a, and a fill belonging to one or other of these two stages can be seen there today. Fossil Passage has only one fill, that of 7a. The two passages have similar sized phreatic elements, and the postulated connection fits neatly into the general scheme of development of the cave, which has been determined on independent evidence. The implication of this is important, since Fossil Passage has been shown to have discharged to the Oxbows during phase 2. If this link does exist, therefore, the Oxbows must represent the earliest point of discharge from the known parts of the cave. Excavation in the boulder choke at E' may reveal further passages which could contain evidence which will cast light on the validity of the interpretation of the cave's history given here.

The geomorphic history of Longwood Swallet is summarized in Table 3.

Table 3

THE SEQUENCE OF DEVELOPMENT OF LONGWOOD SWALLET

PHASE	EVENTS	
1*a*	Phreatic erosion.	Formation of cavity in Great-Fault Chamber complex.
b	Phreatic erosion.	Phreas falling from above 655 ft. (197 m.) to 460–470 ft. O.D. (138–141 m.).

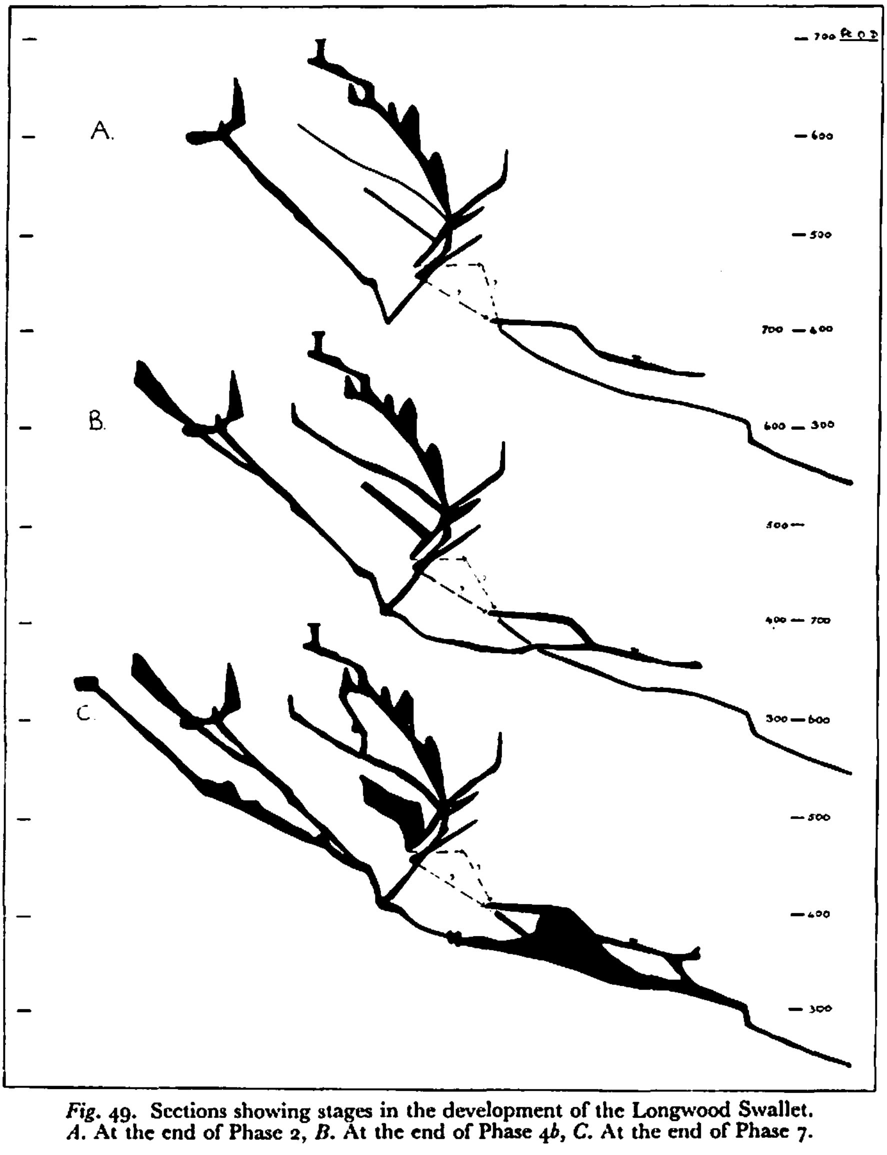

Fig. 49. Sections showing stages in the development of the Longwood Swallet. *A*. At the end of Phase 2, *B*. At the end of Phase 4*b*, *C*. At the end of Phase 7.

2a Major vadose erosion

3a Aggradation
b Deposition of calcite

Phreas falling to 400–10 ft. O.D. (120–23 m.)

4a Excavation and minor vadose erosion
b Major vadose erosion
c Collapse

5a Aggradation
b Deposition of stalagmite

Phreas falling to 300–10 ft. O.D. (90–93 m.)

6a Excavation
b Major vadose erosion
c Collapse

7a Aggradation
b Deposition of stalagmite
c Collapse (Upstream Series)

Phreas falling to present level, below 235 ft. O.D. (70 m.)

8 Modern. Excavation and minor vadose erosion.

Other vadose features

Dome pits are vertical cavities formed by large or small waterfalls. Three examples were noted in Longwood Swallet.

At B the passage ends in a pebble choke at floor level, and the vadose trench in the floor continues upwards into the choke. In the roof there is a 20 ft. (6 m.) shaft which ends in small tubes from which a trickle of water falls. The walls contain sinuous slots and on the floor are fallen blocks whose sides are similar to the inside walls of the slots. Another block has been cut out by the slots and is ready to fall.

In Water Chamber are sinuous vertical slots reaching to the roof in the north east wall. They are up to 2 ft. (0.6 m.) deep. A stream enters through the roof but there is no sign of back cutting. The height of the chamber in contrast with the surrounding passages is marked.

Showerbath Aven, at X, has sinuous vertical slots in its lower walls, which overhang to give a triangular cross section. Near the apex of the triangle, the walls become vertical, and a powerful light will reveal a slot cut in the roof, at one end of which a waterfall enters in wet weather.

The dome pits at B and in the Water Chamber conform to Bretz's (1942) definition of core block dome pits. Showerbath Aven appears to be a core block dome pit whose form has been modified by the appearance of a larger waterfall which has cut the slot in the roof.

MODERN HYDROLOGY

The courses of streams underground are shown in *Plate* 28B. Drainage is directed to the main stream passage in the Downstream Series, where almost all the water entering the cave comes together in a single stream. In the Upstream and Upper Series, the drainage is complex. Streams do not consistently follow the waterways of earlier phases in the cave's development, but instead are engaged in the erosion of new passages. To take an example, streams enter at two points in Wet Gallery. Instead of flowing along the open passage into Dry Gallery, they sink almost at once at separate points in the floor, and reappear from three different points in the roof of Stream and Dry Galleries. Similar behaviour is displayed by streams in the Upper Series, notably at Waterfall Chamber. Here a stream leaves open passage at the top of a 35 ft. (10.5 m.) vertical drop, and flows through a narrow crack to the Wet Way, where it reappears.

It would seem that this is the type of underground stream piracy which has occurred at several times in the past. Joints and bedding planes in the cave walls are on the whole narrow and tight, however, and cavities along them rarely extend inwards for more than a few inches. Water will presumably prefer to flow down open passages rather than to follow tight cracks in the passage walls and floor. It is suggested, therefore, that the opening of such joints as those by which piracy has been effected took place under conditions of infill. Under these conditions, water would not be free to flow down the choked passages, and such trickles as those which deposited stalagmite layers could have opened alternative routes down joints and bedding planes.

It appears from direct exploration that the passages between the points at which the surface stream disappears underground, and the points at which streams enter the known cave, are constricted. However, it is possible to infer a little about the pattern of waterways in them. Experiments by Lloyd and Morrison (Cheramodytes, 1957) and observations by others (Wessex Cave Club Jnl.) indicate that water flows from a point somewhere above Water Chamber to Showerbath Aven (X on *Plate* 28), and in flood from W to an aven at B. These connections are shown in *Plate* 28B.

Water tracing experiments were carried out in the summer of 1966, to establish the unknown paths of the various streams underground. Fluorescein and activated charcoal was used, the detectors being left in place for several days; the results are shown in *Plate* 28B. The two points at which water sinks into the bed of the surface stream shown on Rennies (1962) map of the environs of Longwood Swallet are difficult to locate precisely on the ground. Because of this, it was not possible to establish the relations of the various inlets in Wet and Dry Galleries to points of engulfment on the surface. These passages are located almost directly beneath the surface stream, however, and it seems likely that their water is derived from there.

DISCUSSION

As yet, no material suitable for dating has been found in any of the deposits in Longwood Swallet. The chronology given above is a relative one. It shows a rhythmic fluctuation of erosion and aggradation, similar to that found in other Mendip caves (Ford, 1963, 1964). Ford suggests that this rhythm is due to climatic fluctuations during the Pleistocene, phases of erosion occurring under interglacial and interstadial conditions and aggradation occurring during cold periods, possibly with the development of permafrost conditions (1964, p. 181).

The entrance to Longwood Swallet is located in a valley incised into the surface of the 820–860 ft. (246–58 m.) plateau. This and the fact that the cave penetrates to 235 ft. O.D. (70 m.) suggests that the origin of the greater part of Longwood Swallet took place after the levelling of the plateau in late Tertiary times. However, the date of origin of the cavity formed in the Fault Chamber-Great Chamber complex cannot be placed with certainty, since it appears to predate the active cave.

Ford (1963) gives a general account of a method for obtaining a time standard for erosional histories of the type deduced above for Longwood Swallet. It is of interest to examine this method further. Firstly, dates are obtained for the various events at the risings at Cheddar. This is done by comparing the altitudes of bore passages to those of Pleistocene marine benches. The latter, while they may be detected at several points on the south flank of the Mendips, are not always present at the cave entrances. However, a good correlation is obtained. The stratigraphy of the deposits in the main bore of Gough's Cave is then considered. The basal layer here is a deposit of water-laid sand, which is thought to mark the period when active streams were abandoning the main bore, in favour of the present risings. This is an adjustment from discharge at a base level at 120–30 ft. O.D. (36–39 m.) (Hoxnian, or Penultimate, Interglacial), to one at 70 ft. (21 m.) (Ipswichian, or Last Interglacial). The sand deposits are stratigraphically close to a Cresswellian ("Younger Dryas" of Ford) habitation layer (Donovan, 1955). This gives the date of adjustment to the modern springs as being sometime during the Last Glaciation (Weichselian).

The intervals in altitude of past rest levels in Swildon's Hole correlate with those between bore passages at Cheddar. The conclusion is drawn by Ford that Swildon's Hole discharged to Cheddar during the Pleistocene. When the sequence of erosion in G.B. Cave is compared with that of Swildon's Hole, and volumes of erosion in the two caves compared with time available, it appears that G.B. originated in the Last Interglacial. There are remains of two rhythms of erosion and aggradation in G.B. The older of the erosion phases (phase 2 (Ford, 1964)) is assigned to the latter part of the Last Interglacial, the younger (phase 4) to the Chelford Interstadial. The first fill (phase 3) is assigned to the early cold period of the Last Glaciation, and the second fill (phase 5) to the main cold period.

In Longwood Swallet, there are three full rhythms of erosion and aggradation. By comparison with G.B. the chronology given on the left hand side of Table 4 may be tentatively advanced.

Table 4

CHRONOLOGY OF LONGWOOD SWALLET AND G.B. CAVE

LONGWOOD	PLEISTOCENE TIME	G.B.
Phase 1*a*	Unknown	—
1*b*	Penultimate Interglacial	—
Phase 2 (Phreas at 460–70 ft. (138–41 m.))	Penultimate Interglacial	—
Phase 3	Penultimate Glaciation	—
Phase 4 (Phreas at 400–10 ft. (120–23 m.))	Last Interglacial	Phases 1 and 2 (Phreas at 450 ft. (135 m.)
Phase 5	Early Last Glaciation	Phase 3
Phase 6 (Phreas at 300–10 ft. (90–93 m.))	Chelford Interstadial	Phase 4 (Phreas at 400 ft. (120 m.)
Phase 7	Main Last Glaciation	Phase 5
Phase 8	Late-and Post-Glacial	Phase 6

The weaknesses inherent in this dating method should be recognized. Since it was first advanced in 1963 (Ford), water tracing has shown that Swildon's Hole discharges to Wookey Hole. Although the experiment was performed under high water conditions, no trace of the Swildon's water was detected at Cheddar (Atkinson, Drew, and High, in prep.). In view of this, discharge from Swildon's to Cheddar during the Pleistocene seems unlikely. Furthermore, the sequence of events in the development of the risings at Cheddar, proposed by Ford (1963) does not fully explain the roles of Cooper's Hole and Sayes Hole. The discovery in 1966 of 200 ft. (60 m.) of submerged cave passage, with a fast flowing stream, beneath the lake in Sayes Hole, further complicates the picture, and suggests that the full story at Cheddar may be more complex than that already described by Ford. Furthermore, the method involves the correlation of a period of occupation by a Palaeolithic culture (Cresswellian) with a floral zone (Younger Dryas). As the whole scheme of dating appears to rest upon this one correlation, any date obtained by it must be viewed with suspicion.

If the dates for Longwood and G.B. are provisionally accepted, however, comparison of the history of the two throws some light on conventional theories of karst water table. In Longwood each trench is graded to a particular rest level. This appears to be the case in G.B. also (Ford, 1964, p. 168). A brief inspection of Table 4 shows that during the Last Interglacial the G.B. rest level stood at least 50 ft. (15 m.) higher than the one in Longwood. Moreover, the G.B. level was established relatively late in the Last Interglacial (*ibid.*, p. 182), while the Longwood level was probably established rather earlier in the period. In both caves, joints are unusually well opened, compared with, say, Swildon's Hole, and only rarely do they have a calcite fill. On the basis of classical karst water table theory, therefore, the rocks between the two might be expected to contain a well defined piezometric surface. During the Last Interglacial, the minimum gradient such a surface could have had is 1:66. However, at the start of the development of G.B. Cave, the local rest level within the cave was at or above 760 ft. O.D. (288 m.) (*ibid.*, p. 164). At times, therefore, this gradient may have been as steep as 1:10.5, which is too steep a gradient to be compatible with the idea of a piezometric surface. The former figure, while more feasibly compatible with the demands of a water table theory, would suggest that some movement of water from G.B. to Longwood would have occurred. There is no evidence of such movements ever having taken place. Furthermore, during the Chelford Interstadial, the difference between rest levels was 100 ft. (30 m.), so that had a true water table existed between G.B. and Longwood, flow from one to the other would have been even more likely. The inference is drawn, therefore, that there was no general water table in the area, at least after the start of cave development. This conclusion agrees with that drawn by Drew (1966) for a separate area, on East Mendip, from evidence of a totally different, and more reliable, kind.

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