The Hydrology of the Burrington Area, Somerset

(Somerset, O.S. 6 in. to 1 mile, ST 45 N.E.)

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SUMMARY

The area considered is the north side of the Blackdown pericline of the Mendip Hills in Somerset. The development of the drainage is described. It is considered that Burrington Combe consists of four parts, of which part of the top and all the bottom have been eroded along in-filled pre-Triassic valleys while the main part of the Combe has been developed along an entirely new line. The Combe was formed by a surface river downcutting during the Pleistocene. The caves connected with this development are considered in turn. All the caves are thought to have been mainly developed under phreatic conditions with relatively little development under vadose conditions. Two main risings or resurgences are considered and the discrepancy in volume between the known input and the output waters is noted. There is a brief account of the lowering of the water table in the superficial deposits in the last four to five decades.

THE PHYSICAL FEATURES, THE STREAMS, THE SWALLETS

The area dealt with is that north of the watershed of Blackdown, and its east and west extensions. The principal physical features are Blackdown itself, Burrington Combe, part of Dolebury Bottom and part of Rickford Combe (*Fig.* 5). The principal streams at higher levels are the springs at Middle Ellick Farm at the geographical, as distinct from the titular, head of Burrington Combe, the East (20) and West (19) Twin Brooks, the Bath Swallet stream and the Hunter's Brook (6) (Read's Cavern stream). The Ellick Farm springs go underground over a considerable area and there is no well-developed swallet. The East Twin Brook goes into a swallet dug out by U.B.S.S.* and which leads into the cave there.

The West Twin Brook ordinarily went down a swallet by a yew tree in the valley floor (ST 47585832) till this swallet was choked by the debris from the adit driven into the side of the valley further up. The water went into Goatchurch Cavern. Some of it still does so and some goes into parts of Sidcot Cave and some goes on down the valley where it used to go underground at a point which is now the site of Peter Bird's Dig; it is diverted from this, and will usually go down to the main road in flood times because the engineer's road up to the adit has blocked the older route down to a roadside hollow close to the upper side of the mouth of the valley, in a position exactly comparable to that of the East Twin (ST 47655836).

The small Bath Swallet† stream goes down amongst boulders in one part of a double depression. The Hunter's Brook goes underground at either the east or west swallet outside Read's Cavern, but a new route is beginning to develop upstream. Thus, though the streams will ordinarily go underground as soon as they reach the massive limestone after crossing the Lower Limestone Shales, they may continue on the surface of the limestone if the swallets become blocked.

All these streams are usually regarded as being overflow springs from the Old Red Sandstone core of the Blackdown pericline. That is to say that when this rock is full of water the surplus flows out at certain levels and the springs are replenished by rainwater penetrating the rock, which thus serves as a reservoir to maintain the flow. This view of the origin of the springs will not stand up to examination. First, all the larger springs originate high up on Blackdown, quite close to the top of the ridge, and the smallest one, the Bath Swallet stream, rises much lower down, the reverse of the expected. Secondly, the flow of all the streams is quickly affected by the rainfall, and the flow goes back very quickly and both Twin Brooks may dry up completely. The Bath Swallet stream, rising several hundred feet lower down the slope of Blackdown, is the first to be affected and is very soon reduced to a minor trickle and dries up completely as soon as there is a dry spell of a few weeks, whereas if it was an overflow spring it should be the last to dry up, having the lowest source.

On the assumption that the streams were overflow springs from the Old Red Sandstone it was a natural conclusion that if a boring was made into the hill a good water supply would be obtained. The Axbridge Rural District Council, acting on the advice of a geologist, tested this by driving in an adit horizontally in the West Twin Brook valley. The rock proved

* U.B.S.S. = University of Bristol Spelæological Society.

† So called because of the tank built there to serve as a bath.

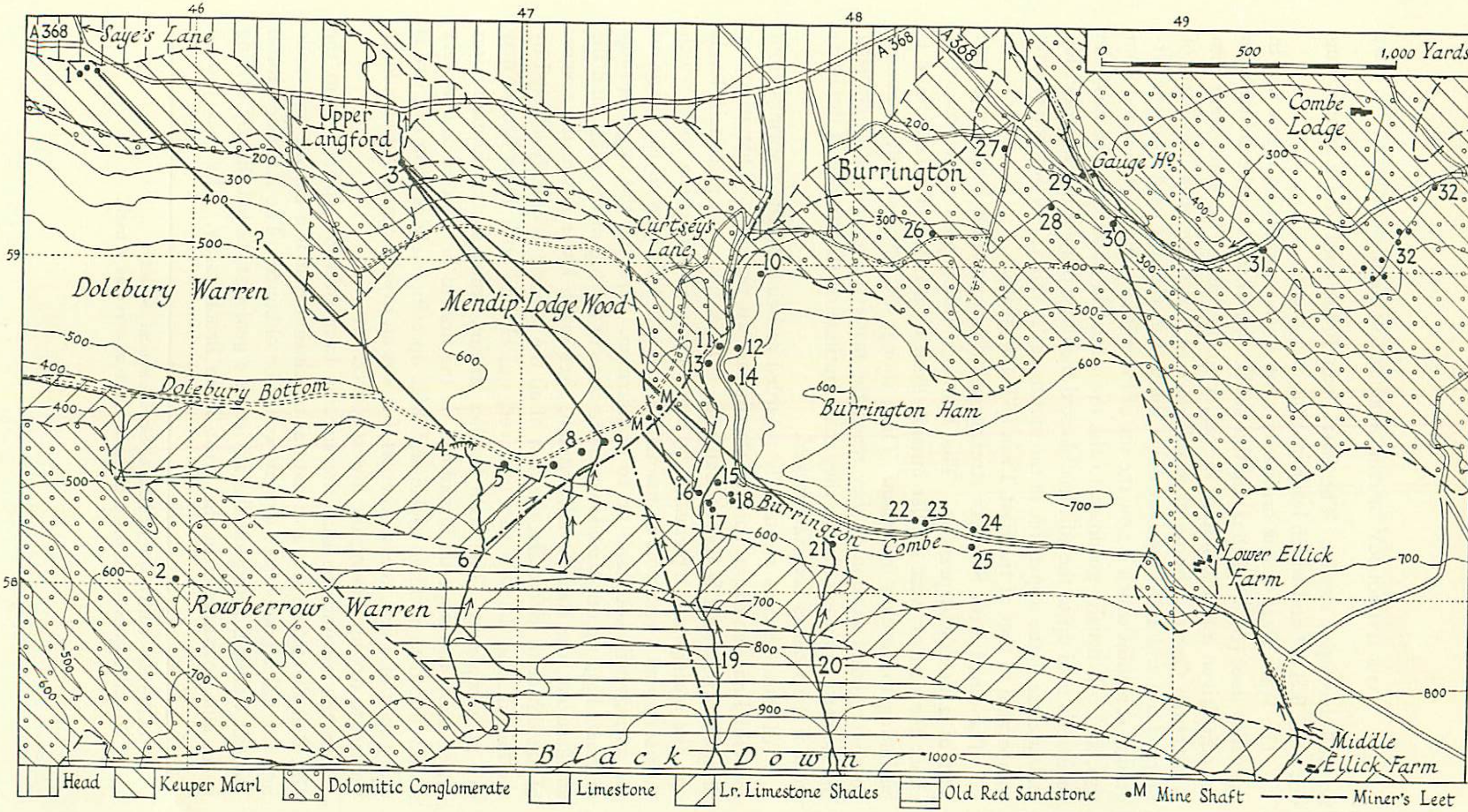

Fig. 5.—Map of Burrington Area. Map drawn by H. Freke. Based on Geological Survey, Crown copyright reserved.

Key to Fig. 5

1. Saye's Lane Risings
2. Rowberrow Cavern
3. Langford Rising
4. Read's Cavern and Fox Holes
5. Bos Swallet
6. Hunter's Brook
7. Drunkard's Hole
8. Rod's Pot
9. Bath Swallet
10. Milliar's Quarry Cave
11. Rock of Ages
12. Plumley's Den
13. Nameless Cave
14. Aveline's Hole
15. Peter Bird's Dig
16. Sidcot Cave
17. Goatchurch Cavern
18. Whitecombe's Hole and adjacent cave
19. West Twin Brook
20. East Twin Brook
21. East Twin Cave
22. Trat's Crack
23. Fox's Hole
24. Toad's Hole
25. Elephant's Hole
26. Porch's Pot
27. Rickford Farm Cave
28. Rickford Fox Hole
29. Gauge House Rising
30. Rickford Rising
31. The Squire's Well
32. Combe Lodge Risings

to be extremely hard, so much so, the engineer told me, that he had to put two compressors to work one drill instead of the other way round. Comparatively little water was obtained. The volume figures, kindly supplied by the Bristol Waterworks Company, from April 1958 to October 1962 show a yield with a maximum of 76,000 gallons per day down to a mere 11,000. The figures show that the variation is significantly seasonal and so derived from superficial sources. Finally, Dr. R. J. G. Savage (*in litt.*) has investigated the pH of the water of the streams and found them to be 4·2, whereas if the streams had been derived from the O.R.S. the pH should have been 7·0 or a little lower.

The sources of water for these streams are, then, only the superficial deposits, including the peat, lying over the O.R.S. These deposits are thick, but exactly how thick is not known. A trench cut along the south slope of Blackdown in the 1920's went down over 10 ft. without meeting rock. Recent test borings by the Department of Geography of this University showed that there were more than 10 ft. of deposit in the catchment area of the Bath Swallet stream. These superficial deposits appear to be solifluction products, later covered by peat.

Langford (3) and Rickford (30) are only two resurgences with substantial output in the area.

THE DEVELOPMENT OF BURRINGTON COMBE

Burrington Combe is one of the major dry valleys of the Mendips. It consists of four parts. Its head is on the watershed between its own catchment and that of Cheddar Gorge. The valley runs down from east to west. Its central axis follows the outcrop of the Lower Limestone Shales. It gradually steepens to just beyond the main buildings of Middle Ellick Farm. There a small stream emerges from the fill in the valley bottom. Close to this, and from the south, a substantial tributary stream runs down. It has been taken for a water supply. This valley is steep-sided and narrow. At this junction the Combe changes direction to continue north, and has a gentle gradient. It soon develops low cliffs in places along the steep east side as far as the road (ST 492579), where the valley becomes very shallow and, about 50 yd. beyond the road, it makes an abrupt turn back to a westerly direction with the buildings of Lower Ellick Farm across its floor. The valley gradually deepens and continues in this west direction down past the opening of the East Twin Brook valley and on to that of the West Twin, where it turns abruptly north to debouch past Aveline's Hole and the Rock of Ages (Toplady, *c.* 1762).

The geological map (1962 edition) shows a south–north deposit of Dolomitic Conglomerate running up almost into the mouth of that head part of the Combe which follows this direction. The deposit must once have extended considerably further and have been removed by erosion. There is evidence for this in the presence of blocks of this rock in the field walls along the lower track to Middle Ellick Farm, well beyond the present limit of the Conglomerate. The present valley line, as in the lower part of the Combe, is a little to the east of that of the older valley. Another similar deposit fills part, but only part, of the lowest section of the Combe, where it runs south–north. In this part the Conglomerate clothes the west side of the Combe, extending down the side to about a third of the depth from the lip. The Conglomerate now extends along the side to a point just inside the mouth of the West Twin Brook valley and must have once extended further. It also covers a considerable area of the plateau above the lip of the Combe in the area west of the Rock of Ages and considerable parts of Curtsey's Lane valley. Nowhere in the Combe does the Conglomerate extend downwards to the floor, though of course it clothes the whole of the flank of Mendip beyond the mouth of the Combe. The summit of the Rock of Ages is at 400 ft. O.D. and is fairly flat. There is a corresponding notch at the same level cut into the cliff above Aveline's Hole, but the notch is not very wide. The profile of the rock, when viewed from the south, shows a slope extending west upwards from the limestone of the top of the rock. Then comes an abrupt break in the slope, which suddenly steepens. Near the north side of the mouth of the West Twin Brook is a limestone bluff, and its top is about the same level as the top of the limestone of the Rock of Ages. Again there is a change of slope of the Combe side above this bluff, and there is Conglomerate to be seen part way up the steeper part. This suggests that the pre-Triassic valley was not cut deeper than this break in slope level, which is approximately 420 ft. O.D. The Combe has been cut deeper than this and its line is a little to the east of that of the older valley.

The pre-Triassic drainage, then, seems to have consisted of two separate valleys running down from south to north, namely the Middle Ellick valley and the West Twin–Rock of Ages part. The present Burrington Combe is thus not an exhumed pre-Triassic feature but a much later drainage line which has used the old valleys in part at its head and foot. The head of the Combe and the part from Lower Ellick to the West Twin are cut along the strike of the limestone and it only leaves that line when it encounters the older drainage channels.

If the foregoing is a correct interpretation of the facts then it poses another question. Briefly, why did the stream cutting into the pre-Triassic valley in the Ellick Farm area not continue to follow this line instead of turning west? The floor of the Combe at the turning point is about 100 yd. from and about 30 ft. below the steep descent of the north flank of the Mendips. It would have taken so little for the stream to continue along the pre-Triassic valley and over the edge. The most likely explanation is headward cutting by the Combe river.

The form of Burrington Combe has all the characters of a valley which has been formed by a surface river downcutting its bed to base level, and has none of the features of a collapsed cave system. There are typical meanders and knick points and, where the Combe runs along the strike, the typical steep slope is on the down-dip side and the gentler slope on the up-dip side. In the south–north parts the slopes of the two sides are more alike. Of course a vadose stream running in a cave should also produce knick points under suitable conditions, but they have not yet been demonstrated and certainly cave passages do meander when they have been developed mainly under vadose conditions, but this is not evidence that Burrington Combe is an unroofed cave system.

This idea of a surface river downcutting on Carboniferous Limestone is not a new one. It was noted for Burrington Combe and Cheddar Gorge as long ago as 1927 by Reynolds, who also dealt with the climatic conditions under which this would be possible. He only considered the question of glaciation and the permafrost zone. There are three main possibilities. First, the water table was too high and, though caves might be developed under the river or in the immediately adjacent rock, the main flow would be on the surface and the rate of downcutting might keep pace with the rate of fall of the water table. Secondly, that the cave systems might not have developed sufficiently to take more than a small proportion of the water, and thirdly that the ground might have been, for some reason, impermeable. All three could have been, and probably were, interlinked.

At the beginning of the Pleistocene the sea-level relative to the land was over 400 ft. higher than it now is, and, if the Villafranchian and Calabrian are included in the Pleistocene (Oakley, 1948), as much as 600 ft. O.D. in the Mediterranean. But there is considerable difficulty in extrapolating these Mediterranean levels to countries as far north as England. The eustatic sea-levels are affected by such things as the isostatic depression of the strata by the weight of the ice and the converse uplift that will occur when the ice melts, so that, though correlations have been made, notably by Zeuner (1959), they are not universally accepted. However, Wooldridge (1961) has demonstrated an erosion level at 600 ft. O.D. and his *Fig.* 1 demonstrates the Pliocene/Pleistocene shore line at that level, and it will be noted how little of the limestone of the Mendips protrudes above this level in the area under discussion.

In the Pleistocene the general sequence, with considerable fluctuations, was a gradual lowering of the sea-level, culminating, in the Bristol Channel area, in a sea-level about -150 ft. O.D. The length of the Pleistocene has been variously estimated. One such estimate is 1,000,000 years, and this has come to be widely accepted. The climatic characteristic of the Pleistocene was a succession of ice ages separated by interglacial periods, when the climate sometimes became warmer than it is at present.

It is usually claimed that the Mendips were never glaciated. But the ice-sheets which produced the Newer Drift on the Welsh side came down to the coast in places, such as the Gower, and the Older Drift extended still further. Zeuner (1959, p. 293) and Mitchell (1960, p. 318) and others agree that during at least one glaciation ice from Ireland and the Irish Sea reached the north coast of Devon, and Mitchell claims that ice abutted on the south coast of the Bristol Channel from Gloucester to North Devon and may even have crossed Cornwall. What is in dispute is which glaciation produced this ice. Whether it was the last (Mitchell) or the Penultimate or one still earlier (Zeuner) has not yet been decided. Zeuner's view seems to be the more likely one. Such advances of the ice must have hindered the drainage of the Mendips and even with the lesser extent of the Newer Drift, which can be correlated with the Last Glaciation, the Mendips would have been within the zone of permafrost and would have had a snow cap for several months of the year. The spring thaws would provide, seasonally, abundant temporary water supplies to do the physical work of downcutting to form such valleys as Burrington Combe and Dolebury Bottom. The water could not go underground because the ground was frozen. If then there were surface streams downcutting there ought to be fluviatile deposits outside the valley mouths and Clayden and Findlay (1960) have found and mapped these fans of detritus in relation to each of the three principal valleys of western Mendip, Burrington Combe, Dolebury Bottom and Cheddar Gorge. According to them "the gravel material was produced by intense frost-shattering of the Mendip rocks under periglacial conditions in Pleistocene times and was moved out of the vales by periodic torrents of water flowing along the gorges". They conclude that "the gravels were formed in a cold phase during the Last Interglacial". This conclusion would seem to imply that the underground drainage systems, that is the caves, were either not developed sufficiently or were choked. Contrarily it is suggested that the formation of the gravels is more likely to have taken place during the Last Glaciation or even be a mixed deposit derived from more than one episode.

The sea-level during a glaciation would be relatively low and high during an interglacial. But it was not until the Last Glaciation that the sea-level fell substantially below that of the present day. The rivers cut themselves deep channels, which are now silted up. At Gloucester (Wills, 1938, p. 229) the bottom of the buried channel of the Severn is at least −15 ft. O.D. and at the Severn Tunnel −35 to −44 ft. The Bristol Avon near the Suspension Bridge has its old bottom at least 32 ft. below its present bed (Codrington, 1898, p. 261) but Donovan (1960) makes it 39 ft. at the Bristol Waterworks Tunnel. Richardson (1927) records an erosion level of the old coastal plain south of the Mendips at Rooksbridge at −120 ft. O.D. and this level was covered by marine sands and above these fluviatile deposits. Hawkins (1962) has discussed the matter more fully, and his paper includes a series of references to other papers. He found the buried channel to be at least −65 ft. O.D. at Avonmouth. Jones (1942) considers that the base of the ancient valley of the Tawe at Swansea was at −180 ft. O.D. He suggests (p. 170) that the sea-level might well have been more than −200 ft. O.D. but less than −240 ft. McFarlane (1955) recording evidence for rivers on the north and south of Devon considered that the old valleys corresponded to a former sea-level of −150 ft. O.D. This may be taken as a middle figure.

However, the mouths of Burrington Combe and Dolebury Bottom now lie at about 250 ft. O.D., but how far down their rock floors are is not known. Once the sea-level had fallen below 250 ft. O.D. erosion could have been a continuous process, though it might have been interrupted during an interglacial when the ground would not be frozen and the water could go underground. The consideration of the step form of valley profile that should result, at least in the lower ends of the valleys, from a combination of these processes is outside the scope of this paper.

The entrances to the highest known caves in the area are between 550 ft. and 600 ft. O.D.* The limestone now extends but little higher. From the foregoing the inference must be that the known cave systems in the area here considered did not begin to form before the beginning of the Pleistocene, and that the principal mode of formation must have been by solution under the water table, that is under phreatic conditions, with comparatively little vadose stream action in parts of the caves as they came to lie at the water table. In no case has any infilling, other than stream-borne

* Heights are taken from the O.S. 6 in. to 1 mile map and estimated from the contours. There is thus bound to be a small margin of error.

detritus, of Trias age been found in any of the caves.* Vadose action is bound to have been slight because caves would be successively drained by erosion outside (cf. Ek, 1962) during glacial episodes.

It is necessary to define the term "phreatic". It is here meant to state the conditions when caves are formed by solution under the local water table. There is no through drainage as the caves have not developed far enough and the circulation or exchange of water is very slow. In due course through drainage is established though the resurgence may be only a few feet lower than the inlet(s). There is still no air space above the water except at the very top of the system, which is behaving as any other large volume of water, such as a lake. The total water exchange is large but no current will be observable except near the input and output ends. The rate of solution of the limestone is very considerably increased because of the high rate of water exchange. Near the resurgences some degree of turbulence results, such as can be observed, for example, at those of Cheddar and Rickford. Scallops may develop and will, in suitable places, be asymmetrical with their higher side upstream and they will be an indicator of the direction of water flow. The scallops will tend to be large as are the more usual phreatic symmetrical ones, which are usually 1 ft. or more across. These sets of conditions are different from those defined by Bretz as constituting the phreatic stage of cave development, so the term "para-phreatic" (Tratman, 1957) is suggested for them and though, obviously, there are subdivisions, the main distinguishing feature is the rapid exchange of water in contra-distinction to the very slow exchange visualized by Bretz.

Under the conditions of a falling water table there must come a time when the roofs of the caves in their upper portions will be above the water table and air filled. In isolated cavities the conditions are still essentially phreatic, water exchange rate being very slow, but where the cave is part of a system entered by a stream vadose action commences and progresses steadily deeper down the cave as the water table continues to fall. Temporary halts, or even a return to para-phreatic conditions, will be likely to occur with a rise in sea-level and it may be difficult to disentangle the evidence at the critical levels in the caves. Thus, greatest vadose action should be expected in the highest levels in the caves, provided they were not drained completely at an early stage.

THE CAVES

The ones to be dealt with first are those in Burrington Combe and its associated valleys. They will be considered from the top downwards, and rights and lefts are used in their geographical sense of the observer looking downstream.

* There are, of course, pre-Triassic caves but none is known in the area here considered.

First on the right is Toad's Hole (24) (620 ft. O.D. ST 4840820). It is a rectangular mine shaft about 20 ft. deep and ending in boulders embedded in fine silt. The beginnings of several small phreatic channels can be seen at the bottom. Nearly opposite is Elephant's Hole (25), which is a horizontal miners' adit running in 12 ft. to where it enters a natural steeply descending rift along the dip slope. Entry can also be gained through this rift (580 ft. O.D.). From the end of the adit it is possible to get down into a small chamber running back under the adit towards the road on the continuation of the slope of the rift. At the bottom is a blockage of stones and mud. U.B.S.S. did some clearing here in 1919–21 but did not reach the tiny chamber, shown as completely blocked on an old survey. The rift can be followed on the surface for some way towards the head of the Combe, and also down the Combe almost as far as the East Twin Swallet. The rift is a widely opened bedding joint descending with the dip slope and is an obvious line of weakness. Wherever it has been attacked by enthusiastic cavers a choke is met with at a shallow depth consisting of stones and boulders embedded in silt.

Next on the right is Fox's Hole (23) (600 ft. O.D. ST 48455814), as it is now known, though its original name was Plumley's Den.* Boyd Dawkins had the second lower entrance cut for his convenience. He found some Pleistocene remains in the first chamber, which has suffered further alteration by its use as a wartime emergency ammunition dump. The lower chamber contains a massive accumulation of reddish yellow silt with boulders in it and partially, perhaps originally totally, covered over by flowstone. There is no evidence of vadose solution in the cave.

Just round the bluff from this cave, and a few feet lower, is Trat's Crack (22) (ST 48205821). This has been dug to its present state entirely by U.B.S.S. Underneath the angular scree at the mouth was fine gravelly silt, reddish yellow in colour and horizontally laminated. The passage is narrow and descends at the angle of dip. Towards the floor of the passage the gravelly silt surrounds weathered limestones which do seem to have been subjected to attack by running water, and the side walls also show some evidence of action by a vadose stream. Thus there have been at least three phases in the development of this tiny passage. First, a phreatic one, when most of the passage was formed, then a short vadose one period, and subsequently a period of repeated flooding when the fine gravelly silt was laid down via the mouth of the cave. Though the fine silt could have been brought up from below by rising flood waters, such waters could not have brought up the gravel element and the manner in which the silt and gravel are combined indicates derivation from one source and not two. Finally the angular scree was formed by surface weathering, and filled the mouth.

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* *See* Donovan (1954, p. 34) about this change of name.

Since it was dug out, water, collected from the surface round the entrance, is very slowly washing away the finest elements of the silt and leaving the gravel behind.

Next comes the East Twin Swallet (21) on the right side of that branch valley (500 ft. O.D., ST 47955814). It was dug out originally by U.B.S.S. (Pearce, 1944; Ineson, 1958). The swallet, when first attempted in 1935, was almost completely choked. The water used to run on down the valley to soak away in a stone-filled hollow close to the road (ST 47995819). Human effort has allowed the water to re-enter the choked swallet. The cave was entered by following along the actual streamway to a small chamber, the present way in, the East Passage, being found and opened the same day. Extensive changes have occurred inside the cave since then, so much so that its present form differs greatly indeed from its original one (Pearce, 1944). These changes are still going on. Many tons of the finer elements of an original stream-deposited fill have been carried down to lower levels. The main development of the cave passable today is along the bedding jointing and not along the strike. No fine laminated silt has been found yet in this cave but only stream-borne gravel. Some of the components of this gravel are so large that they could not have been transported by a stream of the present size except under high flood conditions. The present stream has undermined the choke, which had originally been introduced through a higher entrance not yet located. So it is not known whether there are any extensive higher-level galleries, which may or may not be open.

In the Combe the next openings worthy of note are two on the left side, high up in the bluff, shutting off the mouth of the West Twin valley from the Combe. Both have been formed under phreatic conditions and subsequently exposed by downcutting of the Combe. The larger one is known as Whitcombe's Hole (18) (600 ft. O.D., ST 47655827). In it Boyd Dawkins and Sanford found some pottery and iron objects attributable to the Early Iron Age (Dawkins, 1865). It is not known where the finds are.

In the West Twin Brook valley, starting from the head, the first cave encountered is Goatchurch Cavern (17) (530 ft. O.D., ST 47575825) on the right, with its entrance about 40 ft. above the valley floor. It was originally opened up as a show cave. The survey (*Fig.* 6) is based on that made by the Mendip Caving Group. The cave consists of a series of galleries developed mainly along the strike with some effect from dip. These are connected by other passages descending steeply with the dip. All the passages have been originally formed within a thin series of beds so that the passages lie obliquely below each other (*Plate* 1). The whole is a classic example of Bretz's concept of a phreatic system formed in steeply dipping limestone.

Baker (1924) gives the first account of excavations in this cave by U.B.S.S., and he was the first to draw attention, under the influence of

M. A. C. Hinton, to the possible relationships between the passages, their contained deposits and the oscillations of the sea-level in Pleistocene times. He drew attention (p. 61) to the intercalation of stalagmite "between successive deposits of earth or gravel". Also he mentions "remains of stalagmite floors projecting from the walls, evidently untouched by earlier excavators, indicate that deposits have been washed out after remaining undisturbed for long periods". I have not been able to verify this last observation by re-examinations of the cave in 1962 and 1963.

The U.B.S.S. also dug and blasted a way into an upper gallery, in 1922, above and to the right of the Entrance Gallery. There are some deposits there, but they have not been investigated.

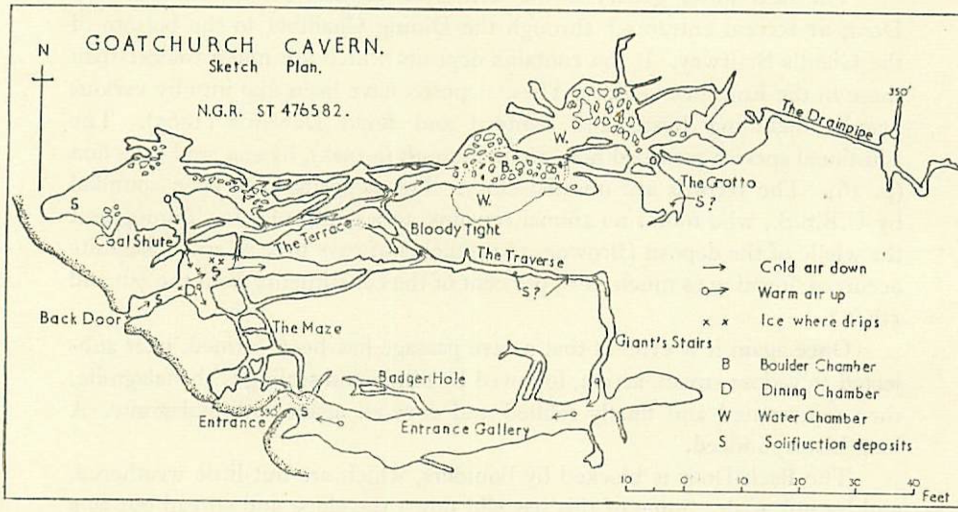

Fig. 6.—Based on survey by Mendip Caving Group and published with their permission.

In the Entrance Gallery (the First Gallery of Browne (1925)), some excavations were made in the Vestibule, that is just inside the entrance, at 60 ft. from the entrance and in the Swirl. The fauna* comprised cave bear, brown bear, wild cat, pig, horse, badger and some rodents which were, unfortunately, never reported upon. The main mass of the deposit is in the vestibule.

The material seems to be largely, if not entirely, a solifluction deposit introduced through the entrance. It thins out inwards. On the left the bone-bearing layer passes under several very massive fallen blocks, themselves practically unweathered. Frost action would seem to be the cause of this shattering of the rock at the entrance. The fauna is Late Pleistocene,

* All material and MS. records destroyed in war.

though the presence of cave bear taken in conjunction with the covering of boulders suggests a date prior to the last maximum of the last glaciation. Perhaps it belongs to the Solutrean amelioration.

The Entrance Gallery itself shows many features of phreatic origin particularly in the roof and on the upper parts of the walls. There does not seem to have been much modification by vadose waters. The deposits on the floor are not very thick but do comprise a soft upper stalagmite and hard lower layers of the same material overlying, in the lower parts of the gallery, a thin layer of cave earth resting on bed rock. Some of this deposit, according to Baker, was broken up and removed by natural means, that is by a vadose stream. This has not been verified by recent re-examinations (1962/1963).

The next lower gallery is the Traverse. It runs down from the Back Door, or second entrance,* through the Dining Chamber to the bottom of the Giant's Stairway. It too contains deposits which are much thicker than those in the Entrance Gallery. These deposits have been dug into by various people, including Beard and Sanford and Boyd Dawkins (1865). The additional species recorded here are mammoth (a tusk), hyæna, and cave lion (p. 16). The records are unsatisfactory. The deposits have been sounded by U.B.S.S., who found no animal remains, to a depth of 5 ft. Throughout the whole of the deposit (Browne, 1925) pieces of cave breccia and stalagmite occurred, forming as much as 19 per cent of the constituents from the 4th and 5th ft.†

Once again it is evident that a cave passage has been formed, later subjected to vadose stream action, followed by filling and sealing with stalagmite, then rejuvenated and finally refilled and covered again with stalagmite. A long history indeed.

The Back Door is blocked by boulders, which are but little weathered, and by hill wash. Some of this has slid down the slope and spread out as a fan in the Dining Chamber and at least part way down the gentler slope of the Traverse. Original levels before excavation can still be traced. Some of the excavated material from the Dining Chamber has been thrown down the passage leading directly to the Terrace.

The spoil from the U.B.S.S. soundings in the Traverse near its lower end was stacked partly in that passage and partly at the bottom of the Giant's Stairway. This spoil has been looked at again and it seems to be solifluction in origin rather than fluviatile, but it is hard to be certain. Some of the deeper

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* When this entrance was made *c.* 1924 it was named thus. Since then, for some unknown reason, it has come to be called by the cumbersome name of the Tradesmen's Entrance. In this account the original name is used.

† It is not clear from the account whether the soundings were made in an area undisturbed by previous excavators, but Browne's figures (p. 130) suggest that this part had not been disturbed.

material, to judge from Browne's description, might be fluviatile in origin. If so, then the valley floor must have been at least 30 ft. higher than it now is for the stream to enter this passage.

How much vadose enlargement of the Traverse itself took place cannot be decided, but probably a considerable amount. That some vadose solution took place is evident from the presence of a small area of typical small, turbulent water scalloping on the slope down from the Back Door just before the Dining Chamber. It is to be found on the right on the roof of an undercut. This is the only example that I know as existing in this particular cave.

It will be clear that the developmental history of these two galleries has been much the same, but this development cannot have been entirely contemporary as the entrances are about 20 ft. apart vertically. The problem is complicated by the existence of a network of interconnecting passages, largely choked with what seems to be solifluction deposits in their upper parts towards the surface. These passages are known collectively as the Maze and the Badger Hole Series. One at least of the former opens to the surface between the Main Entrance and the Back Door.

The bottom of the Coal Shute opens into a small chamber. Just beyond and to the left is a steeply ascending passage with a mass of debris, presumably of solifluction origin, in it. This mass soon reaches the roof. But undoubtedly there is a third way to the surface, which is here about 10 ft. away. To the right of the bottom of the Coal Shute are many boulders, irregular and unweathered, with a minimum of fine deposit about them. Through them lie alternative routes to the Boulder Chamber.

It is obvious from this brief summary that there are still questions to be answered about these deposits and their relative chronology and the physical conditions necessary for their formation. The possibility that the Traverse deposits may be in part the Entrance Gallery ones re-sorted should not be overlooked. In the passage below the Traverse there are no deposits corresponding to those in the upper galleries, with two exceptions. The first is that just mentioned near the foot of the Coal Shute. The second is a talus cone, partly covered with stalagmite, in the small chamber known as the Grotto. It opens off to the right from the usual way down from the Boulder Chamber to the Water Chamber. From its position, in relation to the bottom of the Giant's Stairway and the Traverse, this cone is probably the base of the deposit in the last-named passage. One might speculate for a long time on the reasons for this absence of large quantities of material in the lower chambers, but only judiciously sited excavations are likely to provide the evidence for a reasoned answer to the problems involved.

So far it has been assumed that the break-up of the old stalagmite floors has been due to rejuvenation by vadose streams. That this happens is self evident in some Mendip caves but not in all. In Goatchurch it seems possible that frost action may have played a part. Under permafrost conditions, freezing could quite easily have taken place to the depth of the bottom of the cave if not beyond. Muller (1947) records the maximum depth of freezing as 1,300 ft., tailing off as the distance from the ice increases. The bottom of Goatchurch is far less than this maximum below the surface. But simple freezing is not enough, and for substantial results to be produced in deposits or rocks it is necessary for them to lie within the "active zone" of the permafrost (e.g., Muller, 1947, *Fig.* 12). The levels below the Entrance Gallery of Goatchurch would ordinarily be below the "active zone". This cave, though, is a special case, for there are two entrances and both were almost certainly open at the same time. Under conditions of an external temperature below freezing point, cold air will flow like a river down the slope from the Back Door, which, when it was opened, was covered by much less than 6 ft. of deposit, and on down the Traverse. If frost is at all severe for a day or so and there are drips, these will form icicles and ice stalagmites as far down as the lower side of the Dining Chamber. The cold air flows past the Coal Shute, where it is crossed by a warm air current coming up this passage and going across the Dining Chamber into the Maze. The cold air rolls down the Traverse, being gradually warmed. Some of it flows down left by the direct route to the Terrace and more along the base of the passage, marked in chalk on the wall of the Traverse as "Bloody Tight". Warm air sometimes comes up the higher levels of this passage. The warmed air continues up the Giant's Stairway and the current may be so strong near the roof as nearly to blow out a candle flame.

The cold air thus reaches the Terrace by two routes, but the main route is the direct one from the Traverse to the Terrace. A portion of the cold air reaching the Terrace is diverted, left, towards the bottom of the Coal Shute, but promptly turns off to go down to the right amongst the boulders and to re-appear in the Boulder Chamber, from which (Jan. 1963) it flows down to the Water Chamber and its boulders. Here, then, is a second way in which frost could penetrate into this cave sufficiently to cool the rocks and deposits. Frost heaving would take place, floors would be broken up and limestone blocks loosened from the walls and roofs, and if, as was probable, the third entrance was open, cold air would have had an even readier access. It is probably frost action by this method which has produced the unweathered and often massive limestone blocks of the Coal Shute–Boulder Chamber–Water Chamber series.

These air currents were investigated on Jan. 13th, 1963, during the long cold spell. There was no wind outside the cave on this occasion. The direction in which a candle flame was blown was used to determine in which way an air current was flowing. On this day it was noted that the rock surface on the route from the Traverse to the Terrace was appreciably colder to the touch than rock elsewhere. The Entrance Gallery was still pouring out warm air and it was like passing into a humid hothouse to go from an external temperature of about $-5°$ C. into the cave. Small birds take advantage of this warm air and will go to the limit of the Entrance Gallery, which is also the limit of the twilight zone. But how long the air coming up the Entrance Gallery would remain above freezing point under the prolonged cold conditions of a glaciation is not known.

In the lowest part of the cave, beyond the Tunnel, there is a deposit of fluviatile gravel. It was probably brought in through the now blocked swallet under a yew tree in the valley floor. Fluorescein tests have shown that the stream beyond the Tunnel is the one first seen in the Water Chamber, and this in turn comes from the Yew Tree Swallet. How little work this vadose stream has done can be seen by examining its inlet end. It is now removing the gravel fill. However, though the distance from the swallet to the Water Chamber is of the order of only 200 ft., the volume of the stream in the cave is not always the same as that on the surface, and the cave stream will continue to run in small volume long after the outside stream is dry. So somewhere a tributary of unknown origin comes in (cf. Zed Alley stream in Read's Cavern, p. 45).

The next cave is Sidcot Cave (16) (450 ft. O.D., ST 47565832), found by members of the Sidcot School Caving Club (Stride, 1945). This has been formed in the same set of beds as Goatchurch. Its entrance is a few feet above the valley floor on the left. Part of the cave is under the valley floor and one branch comes very close to the Yew Tree Swallet. It descends steeply and should be regarded as a deeper part of Goatchurch.

A little farther down the valley on the right is the excavation known as Peter Bird's Dig (15). The principal importance of this is the demonstration it gives of a valley floor fill going down to 20 ft. It has not yet yielded any explorable cave system but it may yet do so. It may be noted that the passages at a corresponding depth in Goatchurch and Sidcot Swallet are all rather restricted, suggesting that the phreatic and vadose solution phases were of short duration and then the whole was drained by the lowering of the water table.

In the Combe below the mouth of the West Twin Brook valley are several minor openings which do not call for comment, so that the next important cave is Aveline's Hole on the right side (14) (360 ft. O.D., ST 47645867). The rock lip of the floor at the entrance is several feet below the road, but the upward slope of the floor has been proved by excavation to continue fairly evenly for 10 ft. beyond the entrance, thus rising towards the road level. On the far side of the road there used to be a hollow, which has been partly levelled with material dug out of the cave. The floor of this hollow was below the level of the cave mouth and the hollow itself was certainly not on bed rock, but how far above it is not known. Thus in the final stages of downcutting the cave entrance must have been perched above the valley floor.

The cave itself consists of two chambers separated by a constriction, which is in fact a typical bridge of the type left by phreatic solution. The presence of fine silt below it and to the left, continuous it must be supposed with that in the Inner Chamber, proves this. The cave slopes fairly steeply downwards. The deposits originally in it consisted of a stalagmite floor, not quite continuous in the Outer Chamber, over a layer of cave earth, which contained a late Pleistocene fauna associated with a Late Upper Palaeolithic flint and bone industry and human remains of the same period.* In the Outer Chamber there was about 3 ft. of cave earth which brought the floor level up to that of the Inner Chamber where there was a thin covering of cave earth under the stalagmite. Beneath the cave earth was fine laminated silt, barren of remains except in the topmost parts. Boyd Dawkins sank his shaft at the back of the Inner Chamber to a depth of 38 ft. and claimed to have found remains of sheep and the sternal bone of a wolf. U.B.S.S. excavations quite clearly demonstrated that either his dig was "salted" or he failed to notice that he was excavating a disturbed deposit. In the Inner Chamber the silt is laminated horizontally. In the Outer Chamber it was found to cover and surround boulders and to extend right up to the entrance where it was bottomed and found to lie directly on the bed rock.

At the bottom of the entrance slope, that is at the back of the Outer Chamber, the original explorers described a deep pit covered by rock slabs. The U.B.S.S., in the course of excavating the cave, proved this to be a mass of jammed boulders, which collapsed and left a nearly sheer shaft, 16 ft. or more deep.† The space had been created by a secondary trickle of water removing some of the fine silt from around the boulders. This process is still continuing.

The general form of the cave, and especially the walls and parts of the roof, show that it was formed under phreatic conditions. The signs are obvious. Nowhere is there any evidence of vadose action, save of the most trivial nature where there are small roof openings.

The cave has many of the characters of a rising. The tendency to split up into smaller passages at the back is one such character and can be seen in Aveline's Hole in Boyd Dawkins' shaft. A rising floor is another common feature. It is seen, for example, at Gough's Cave, Cheddar, which still

* For the principal papers on this cave see references under Davies, Fawcett, Hinton, Keith, Kennard and Newton. Most of the material and all the MS. records were destroyed in the war.

† In order to make the cave safe again the entrance side of this shaft was blown down, at the request of the commoners of Burrington Commons, to make the steep slope seen today.

serves as an intermittent rising. The main active risings at Cheddar both come up from steeply ascending passages. Other active risings explored by cave divers show this too. Finally an upward direction of flow is demonstrated by the scalloping (*Plate* 3) seen in the roof just below the Roof Niche in the Outer Chamber, for the steep and higher slopes of the paraphreatic type scallops are towards the interior of the cave. So it is concluded that Aveline's Hole was developed under phreatic conditions as a resurgence, and it has been exposed and truncated by surface downcutting during the final stages of the development of the Combe, and its mouth was, in the end, left hanging above the valley floor.

The deposit of laminated silt has been formed by repeated floodings by water welling up from the back, probably during the final stage of downcutting when the cave was beginning to be abandoned as a resurgence route. Each flood would leave its film of silt behind and if the flood was big enough it would leave silt right up to the entrance. A similar layer of silt is left behind every time Gough's Cave at Cheddar is flooded, and here silt was also noted round the basal boulders and on the bed rock itself when this was exposed in the recent cuttings made to lower the entrance to the cave. The silt extended right up to the rock lip.

On the other hand, at Gough's Cave, from a little way inside the rock lip, Donovan (1955) has described basal layers of conglomerate and, beneath, laminated sand and coarse sand. The conglomerate has not been found in Aveline's Hole, but Boyd Dawkins does record bands of sand in the lower parts of his shaft. So perhaps if this is dug still deeper, coarse sand may be found.

If Aveline's Hole was a rising in the past, where does the water now rise? There is no lower level rising nearby, as at Cheddar and Rodney Stoke, and so perhaps the water gets away through the outwash fan and does not appear as a definite rising. Certainly there is plenty of water in this material, as the number of wells dug into it show, and even when shallow septic tanks are dug in the area they are very apt to be flooded out. A more likely probability is that the water has developed newer routes to such active resurgences as Rickford, 190 ft. O.D., or Langford, 135 ft. O.D.

The last two stages of Aveline's Hole were when it was used as a habitation and burial site in late glacial times, followed by the cave mouth becoming closed and the deposition of stalagmite commencing. It is possible that the closure owed something to artifice following upon the last burials in the cave. It may be noted in passing that in cold weather the cold air flows down the slope into the cave, and, after a couple of days of continuous frost, ice will form at the bottom of the entrance slope, so that Aveline's could never have been a very comfortable residence in the cold of the last glacial retreat.

A few minor sites must now be considered. On the left side of the Combe, opposite Aveline's Hole and about two-thirds up the side, is a small unnamed opening (13) in conglomerate. It has a double entrance and a considerable thickness of deposit in the floor. Much of this is probably of post-glacial origin. The upstream, or south face of the Rock of Ages, has on it two smooth surfaces separated by a mass of weathered rock. The smooth surfaces seem to be the remnants of an old cave wall, the rest of the cave having been destroyed when the Combe was cut. The smooth surface cannot be the result of wind action because they are separated by rough rock.

Immediately beyond the mouth of the Combe on the right is an old quarry. In the north-east corner of it is the site of Plumley's Den (12). This is a nearly vertical shaft, now permanently closed, which was broken into during quarrying. It is stated to be 150 ft. deep and to have a stream in the bottom (Tratman, 1953). Such a depth is not an impossibility, and the stream, if it were truly present, could be the remnant of the water from Aveline's Hole, as the bottom would be 50 ft., perhaps more, below the bottom of Boyd Dawkins' shaft. If the two caves are connected, and they almost certainly are, as the sound of hammering on the rock in Plumley's Den at a depth of 40 ft. could be heard plainly in Aveline's Hole, then, when Aveline's was functioning as a resurgence, water would have stood in Plumley's Den to the very top, as it is described in the old accounts, and if there was a subsidiary opening, not noted in those accounts, Plumley's Den could also have been a resurgence.

The Rock of Ages and the Aveline's Hole cliff together form the jaws of the Combe. Beyond, it opens out rapidly. On the left, west, thick deposits of Dolomitic Conglomerate can be seen to lie against the limestone and to reach down to the valley floor. On the right, east, the original form cannot be determined because of extensive quarrying.

To the east of the Combe is Milliar's Quarry, called after the person who used to work it; in it is a nearly vertical shaft going down to a choke at 40 ft. (10). The choke is of stones loosened by blasting or which have been thrown down. It was first explored by U.B.S.S. who had to enlarge the top opening to get in. It has been formed under phreatic conditions, but since the water table has gone down, trickling films of water have made changes, chiefly in the form of erosion furrows running down one wall. The same is true of Porch's Pot* (Robertson, 1956 (26)) and its associated fissures in the Dolomitic Conglomerate (380 ft. O.D., ST 48155903). The cave has been permanently sealed. At Rickford Farm (210 ft. O.D., ST 48475938) another joint determined cave was found (27) in 1959, during rock cutting for a new shed. The rift was covered by about 18 in. of rock. It is about 20 ft. deep

* Named after the owner of the property.

and 100 ft. long (Chapman, 1959). It once had a boulder-choked entrance, which is now sealed under the concrete of the farmyard. The cave can be entered through a manhole in the shed with the permission of the farmer, at present Mr. Wyatt. This and several other minor rifts in the Dolomitic Conglomerate were presumably developed under the water table by phreatic solution when the sea-level was much higher. Near Rickford Rising itself is the small simple tunnel passage known as the Rickford Fox Hole (28). It is about 20 ft. long.

To the west of Burrington Combe along the flank of the Mendips there are no known caves to well beyond Langford Rising (3).

From the western lip of the Combe, opposite Aveline's Hole, a plateau extends south-west for about 1,200 yd. It rises gently in this direction to a very poorly defined watershed, about 250 yd. from the Hunter's Brook (6). To the south it is flanked by the slope of Blackdown. Close to the north-west side of this plateau, and forming a line roughly parallel to the edge of Mendip Lodge Wood, is a series of hollows. Some are obviously old mine shafts and some seem to be natural, but how many of the apparently natural hollows and others of a more doubtful nature are due to mining is not certain. There has been considerable mining in the area because the miners constructed two leets, both stone lined, to bring water to their ore washing site at ST 474586. The tailings dumps are very obvious when the bracken and other undergrowth are burnt off. The arrangement of these hollows is shown in *Fig.* 7.

The tiny stream at the Bath Swallet goes down amongst boulders and then into a narrow passage in solid rock (9). The total distance is a matter of a few feet only. The hollow is a double one. The next in sequence, going south-west, is Rod's Pot (8) (Pearce, 1946). This is a steeply descending cave (547 ft. O.D., ST 47245845) formed mainly under phreatic conditions and subsequently choked by stream-borne debris. Still later, part of this choke was washed out by a stream (Donovan, 1949). The hollow has a short steep stream valley, now dry, with steep sides running down into it. The form of this valley shows that it was formed in post-glacial times, probably when the Bath Swallet stream went down here.

Next come several hollows probably entirely due to mining, as they have not even rudimentary stream valleys running into them, and the next one with an intermittent stream is Drunkard's Hole (7), discovered by U.B.S.S. *c.* 1924 (ST 47115838). The cave is phreatic in its main development and a later fill is being washed out by the small intermittent stream. A short way beyond is Bos Swallet (5), dug out by the Sidcot School Caving Club. The few feet of cave descend steeply and the cave is now closed. When digging for the cave some ox bones were found, hence the name, and fragments of Early Bronze Age pottery (Beaker) and flint implements as well. Subsequently the site was dug by U.B.S.S. as an archæological dig. The Beaker age horizons, for there were two, were found at a most unusual depth of over 8 ft., but these turned out to be miner's spoil heaps, from an unknown nearby site, thrown into a hollow already mined to a depth of 30 ft. It is

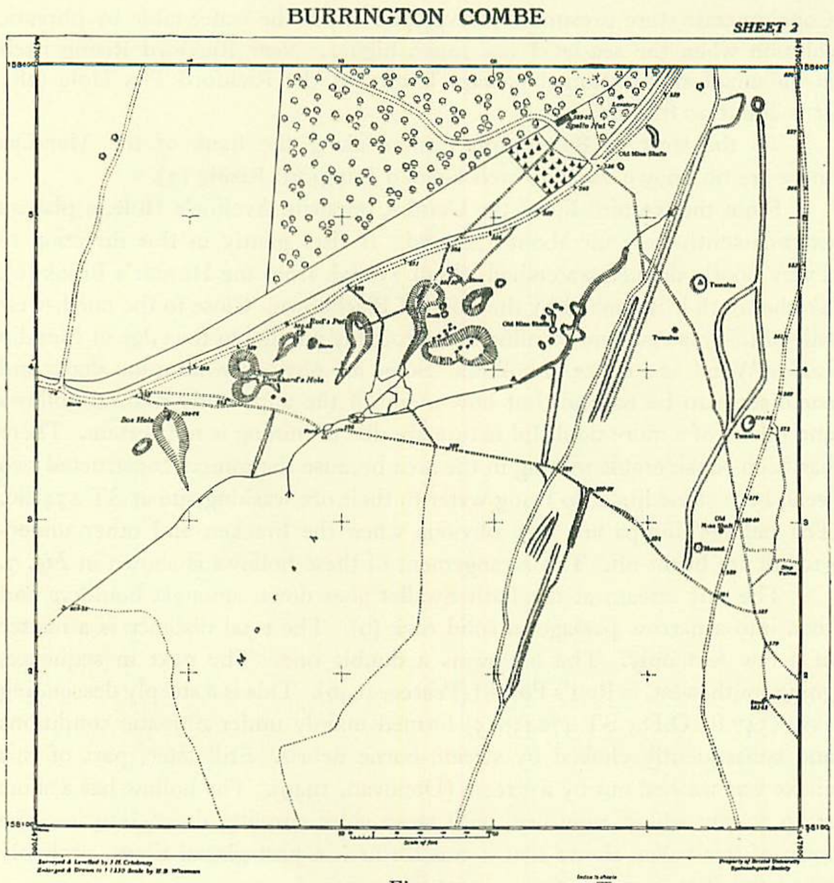

Fig. 7.

this discovery which makes one suspicious that other hollows are not entirely natural and may be entirely due to mining.

Not far beyond Bos Swallet is the Hunter's Brook valley, which terminates in the large depression where are the entrances to the Fox Holes (*Plate* 2) and the entrance to Read's Cavern (4) discovered by U.B.S.S. in September, 1919 (510 ft. O.D., ST 46855843).

Four of this series of hollows have or have had small streams running into them in post-glacial times. The twin hollows of the Bath Swallet are by far the largest, but the post-glacial valley has been incised very shallowly into only one. There have been two natural collapses in this hollow in the past 40 years. Rod's Pot has the best defined post-glacial valley and it is probably no coincidence that it also has the largest passable cave. Each of these four hollows has a small cave opening off the bottom. The stream-borne fill in each case is being washed out by the present streams.

These four caves, as far as they can be followed, descend very steeply and, in the case of Rod's Pot, at the angle of dip for most of the way (Donovan, 1949, p. 72). In the initial stages of phreatic development the local water-table surface must have been at about 450 ft. O.D., and it was probable that this was the general level of the water table too. At this stage of development the caves would be kept full of water and the surplus would drain off as surface streams either down Dolebury Bottom (Read's Cavern and Bos Swallet) or down Curtsey's Lane valley (Drunkard's Hole, Rod's Pot, Bath Swallet). At a considerably later stage the caves would drain out through their bases and their upper parts would be subject to vadose stream action from the limited supplies available from the catchment area, and none would go down the two valleys from this particular area. At the same time the catchment area would have been reduced by the lateral development from the sides of the West Twin Brook and Hunter's Brook. Some obstruction, deeper in the systems, eventually led to them being filled with detritus. Finally there has been some post-glacial rejuvenation, possibly assisted by mining operations.

This series of hollows and swallets presents another problem. The usual place for swallets to develop is at the junction of the massive limestone with the Lower Limestone Shales. But it is only at Read's Cavern that this is approximately true. The rest of the line of hollows north-eastward from there diverges further and further north away from this junction line (Donovan, 1949, p. 72). Phreatic systems can develop anywhere and be entirely unrelated to surface streams, ancient or modern. The evidence of the mining activities indicates heavy mineralization, at least to shallow depths, along this line, so perhaps the mineral-filled joints offered easy routes for the water to percolate. The plateau and the north slope of Blackdown are known to be covered by solifluction deposits of unknown depth, and it would seem that for some reason these are impervious and the water falling on them does not go down through them into the rock till it reaches this line of hollows. Does, perhaps, the reason lie in a bed of almost boulder-clay-like material laid down over the area during a glacial maximum? Deep borings might supply the answer.

At the Fox Holes/Read's Cavern a short length of steep sided narrow valley has been incised into the floor of a much older valley, which comes down off Blackdown and turns west at the cave. The shoulders of this newer valley are level with the western lip of the hollow outside the cave, so that the new valley and depression are contemporary features and both belong to recent developments in post-glacial times. The openings in the cliff face, the original Fox Holes, are obviously phreatic in origin (*Plate* 2).

The Main Chamber (*Fig.* 8) is surprisingly large and is parallel to the cliff face. There is very little evidence in this chamber of any solutional activity at all. This has to be looked for in the deeper levels amongst the boulders of the floor. Yet the cave must have been formed under mainly phreatic conditions. The reason for this lack of evidence is structural.

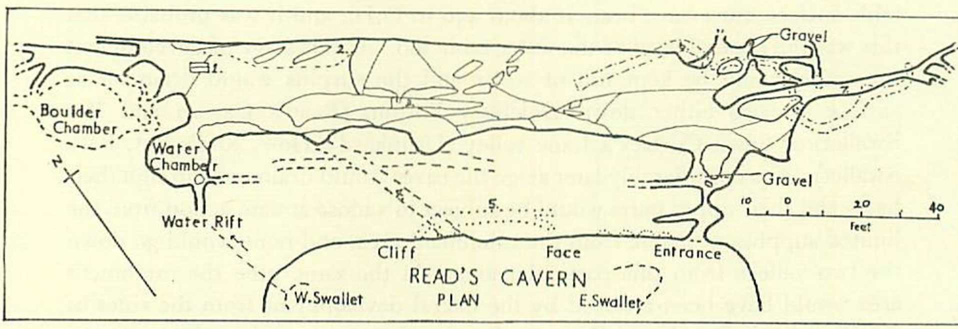

Fig. 8.

1. Right Angled Rock. 2. Crook's Passage. 3. The Bridge. 4. Prehistoric entrance route. 5. The Fox Holes. 6. Zed Alley. 7. The Grotto.

The northern wall of the Main Chamber is formed almost entirely by a single bed of limestone lying at the angle of dip, about 60°, inwards over the cave (*Plate* 4). But in the apex of the roof there is a sharp folding over of the beds through a right angle along the line of the cave. There is a further contortion, more easily seen in the cliff face outside the cave than in the cave, consisting of a slight undulation from west to east, and at the east end of the cliff there is a sharp upward folding followed by another in the opposite direction bringing the beds back to the horizontal but at a higher level.

These foldings have produced a weakened structure with joints easily penetrable by water. Massive rock falls have later taken place so that the Main Chamber and some of the offshoots are now formed by the space left by these rock falls, which fill the original phreatic cave below. One such mass weighing thousands of tons forms the platform at the higher west end of the Main Chamber. It has dropped down as one main, but shattered, mass leaving the triangular-sectioned Crook's Passage between it and the north wall (*Plate* 5).

Passages in solid rock, as distinct from between boulders, can be found notably in the bottom part of Zed Alley and the Water Rift and in a passage opening off the top of the latter and running parallel to the Main Chamber. It is in these bottom passages that there is evidence of vadose stream action.

A characteristic of these parts, especially where the main solution has been by trickling films of water, is the manner in which the matrix of the limestone has been dissolved leaving the more resistant fossils standing out in jagged, clothes-tearing profusion.

If the surface stream is made to run into the west swallet its water appears pouring down through boulders into the top of the Water Rift and can be followed down to the bottom. If the water goes down the east swallet it is not seen again, though one can get very close to it by devious routes. In Zed Alley the stream coming down from the roof, about two-thirds of the way down, is not the surface stream, as it continues to run long after the surface one has dried up.

There is, however, evidence of a short period of action by a vadose stream in the form of gravel deposits. One such deposit can be found on the ledge of the north face of the entrance way, just above the final drop into the Main Chamber. The nearly vertical rock face above this ledge shows faint scalloping of vadose type for a few feet. More of this gravel can be found at two places, more or less vertically above one another, on the way down to Zed Alley. But a stream coming down the present entrance way would have to cross the floor of the cave, where it would undoubtedly be dispersed to form a delta of gravel, and such a delta does not exist, as a trial trench, dug many years ago, proved. So when this vadose stream was active the condition of this part of the cave must have been quite different, and there must have been some form of continuous passage down the entrance and across the cave to allow the water to carry its load of gravel to the lower positions. This passage must have been destroyed in the main collapse.

This vadose stream could not function till the water table locally had dropped sufficiently and a through route had been developed. The massive rock falls are likely to have been responsible for the beginning of the development of the hollow outside the cave. This, by reason of the stream valley running into it, can be placed as being formed in post-glacial times, so it is suggested that this also is the time of the main collapse, which brought to an end the rejuvenation process, marked by the partial removal of the gravels. If so, then the main collapse in this case does not seem to have been by frost action but by earth movement, and additional support is lent to this by the presence of areas of slickensiding in the cave, notably near the Water Rift and about one-third of the way down the entrance passage. Earlier frost action may well have contributed to the effectiveness of earth movement. Further, very extensive rock falls terminated the use of the cave (by Early Iron Age people) as a dwelling site (Tratman, 1931).* These falls sealed the

* For accounts of this cave and its use as a habitation site see references under Langford, Palmer and Tratman. Some of the material survived the war and is in the U.B.S.S. museum.

cave, and this and later very minor falls buried the entrance then in use to a depth of 15 ft. There are also distorted stalagmites which have been fractured and rejoined, and curtains which are horizontal to the floor to confirm the other evidence of major earth movements about 50 B.C.–A.D.50. The sealing of the cave altered the climate inside and then, and then only, did the extensive stalagmite flows come to cover large areas of the floor.

The last cave to be considered is Rowberrow Cavern (2) (570 ft. O.D., ST 45965802). This is a small cave in Dolomitic Conglomerate in Rowberrow Warren (now part of the Mendip State Forest). It lies in the tongue of land between the double head of the valley below and east of Warren House. It has been extensively excavated by U.B.S.S.* It is now a dry cave. Its floor is only 100 ft. above the small permanent springs in the valley floor to the north.

The cave exhibits phreatic features, including roof pockets. Its greatly shattered rock floor slopes very steeply up to reach the surface about 30 ft. from the present entrance and level with the roof of the cave at the entrance (Taylor, 1926, *Plate* 14), though, of course, sub-aerial denudation has reduced its level. From its high level and other features the cave ought to be a very old high-level rising, yet the infilling has accumulated rapidly, for the Early Iron Age hearth (Taylor's "Black Band") was 4–5 ft. below the surface at the entrance and was closely overlain by a Romano-British layer. Lower down were Pleistocene deposits, which, from their position, must belong to a very late stage in that period.

There is no trace of a valley leading from the cave as there ought to be if it had functioned as a substantial rising before it was drained by the valleys being cut down on either side of it. To the south of the cave and about ½ mile away are two tiny swallets taking local accumulations of water. They are, presumably, the original swallets for the rising and are now being rejuvenated. They lie at the junction of the O.R.S. with the Dolomitic Conglomerate.

It is suggested that the cave is an Upper Pleistocene development but was fed by such small quantities of water that its overflow was insufficient to carve a valley of any appreciable depth or width for itself. The U.B.S.S. barrow run cutting would certainly have shown evidence of such a valley if it had been present. The cave was finally drained late in the Pleistocene when the shattering of the floor under permafrost conditions took place. The cutting of the side valleys and of their lower common part could have started earlier as they would not affect this rather special cave system for some time. The valleys might owe their development to the Last Glaciation.

* For accounts of this cave see references under H. Taylor. None of the material survived the war.

Their life cycle as valleys carrying surface streams must have been quite short, for they have produced only a very minor eddy indentation* in the south flank of Dolebury Warren compared with that produced by the river issuing from Rowberrow Bottom to the west.

THE RISINGS OR RESURGENCES

There are two, Langford and Rickford. The former (3) (135 ft. O.D., ST 46635932) bubbles up through gravel retained behind a dam so that its real form cannot be seen. It is located at the upper edge of the impervious Keuper Marls, which may have determined its height above sea-level. The trench which its stream has cut in the old pre-Triassic valley is not very deep and is short. This old valley, like the others, runs down from south to north. The present stream-cut valley is therefore a fairly recent one and perhaps could be late glacial in origin. The output is variable and responds quickly to rainfall and can run dark-brown in colour after very heavy rain. Discoloration may appear within 24 hours of heavy rain though the flow is affected sooner. Smith and Mead (1962) have studied the flow, which can vary from 14 million gallons a day down nearly to nothing. The smallness of the tongue of Head extending towards this rising suggests that this has contributed but little to the formation of the deposit.

Rickford Rising (30) is much more complex than Langford. The stream from it has cut itself a somewhat longer and deeper valley into the floor of a pre-Triassic valley. The rising can be considered in four parts. The lowest opening discharges into the main stream just above the Gauge House (29). It is marked by an old pump alongside the road (ST 48685931). It has not been known to run dry, but its individual output is not known, nor is it possible to examine the rising. Its flow does not seem to vary much, so that the passages feeding it are likely to be very small and quite impassable to man. It may be an independent rising not connected with the others.

The next higher rising is the one generally known as Rickford Rising (190 ft. O.D., ST 48795917). It comes up through the Dolomitic Conglomerate just south of the road. The entrance is partly artificial. The entrance has been examined under very low water conditions by E. K. Tratman in 1921 and D. G. Mead in 1961. Both reported that the water issues from a narrow slot about 8 in. wide by 2–3 ft. long just inside the entrance on the left going in. The Cave Diving Group investigated it under fairly high water conditions (Lloyd, 1955) and reported water as rising on the right. They seem to have mistaken the swirl from the real rising for this. In both 1921 and 1961 no water was seen on the right, but

* The form of this has been modified by a detritus fan produced by local collections of water off Dolebury Warren running down into it from the north. The fan is clearly a product of later date than the eddy indentation and must be post-glacial in origin.

only a sand bank. The main rising has never been known to run dry. On the two occasions when it has been known that Rickford pond was empty, outside the rising, some water was still being taken from the rising by the pipe installed there, in the low dam at the mouth. Smith and Mead (1962) have studied the flow. Its maximum recorded output is about 20 million gallons per day and its minimum about 200,000. Its flow is quickly affected by rain but discoloration does not usually appear in under 24 hours. The usual discoloration is a sort of milky opacity, but dark muddy brown water can issue under high flood conditions. As rain increases the flow, a stage is reached when the water is seen to be boiling up in a turbulent manner and is obviously coming out under a very considerable head. There is no air space then under the artificial lintel.

If there is still more rain, the next higher rising, known as the Squire's Well (31) (280 ft. O.D., ST 49275908), begins to function. Water comes out from amongst boulders immediately south of the road. Ordinarily the water is clear, but if there is further heavy rain after it has started to flow the water becomes muddy, but this occurs about a day later than at the main rising and it clears about a day later also. The maximum flow never fills more than about two-thirds of a 21-in. diameter pipe and so it is very unlikely that behind it there are passages large enough to be passed by man. The site of the rising is the floor of the pre-Triassic valley which runs up to the head of Burrington Combe in the Lower Ellick–Middle Ellick Farms area (p. 26).

More rain still will cause springs to flow in the field opposite Combe Lodge gates (32). The water comes from a whole series of small springs scattered towards the south and higher side of the field. The highest ones are at 300 ft. O.D., though under extreme conditions it may rise at 310 ft. O.D. at ST 49425896. The total output from all of the springs is not large, and even when the water has been running for as long as 2 weeks no muddiness has ever been noted.

The manner in which the three upper risings behave suggest that they are interconnected. Confirmation for this view is to be found in the identical $CaCO_3$ content of the water of all three under all conditions (Smith and Mead, *in litt.*). For the two uppermost it seems as if the junction between the limestone and the Dolomitic Conglomerate is being exploited by the water which eventually comes up through numerous small channels. It is unlikely in the extreme that access to any passable caves can be gained through these openings. The lowest rising is probably not connected with the others. The difference in level between the highest rising and the Main rising is of the order of 120 ft. (150 ft. if the lowest one is considered). This is a very considerable variation in level to occur in the local water table. It also implies that at the input end water will temporarily stand at least this amount higher.

The Rickford stream, with its intermittent tributaries, has cut quite a substantial valley into the Dolomitic Conglomerate and has contributed appreciably to the deposit of Head. The contribution is well defined.

THE UNDERGROUND DRAINAGE PATTERN

The obvious sources for the water at the risings are the streams on Blackdown. The Bristol Waterworks Company gave permission for tests to be carried out, using fluorescein as the tracer dye. The first positive was dramatic. The fluorescein was put into the East Twin Swallet when the water flow was very low and all flow ceased a few hours after the last of the fluorescein had dissolved. There was no rain for several days. Then there was heavy rain for 2 days. Another 2 days later Langford rising was running bright green. Rickford was negative. This was a great surprise. A subsequent check of the records of the Company showed that they had made tests in 1910. The Twin Brooks drained to Langford and the Ellick Farm springs to Rickford. The Hunter's Brook was marked with "?" to Langford indicating a negative result.

Subsequently, further tests were made on the Twin Brooks. Both drained to Langford. Later the Bath Swallet stream was tested and, as to be expected, it too rose at Langford. The time taken for the fluorescein to traverse the route depended upon the flow. The minimum time was 48 hours and the maximum 5 days. When there was a good flow, fluorescein was detectable by a careful observer over a period of several days at the actual rising, but in this and later tests care was taken to make certain that no colour would be seen by the casual observer. Direct vision was used to detect the fluorescein supplemented by sampling and examination under ultra-violet light. As a final check the dye was adsorbed on cocoa nut charcoal and this was subsequently elutriated with alcoholic potassium hydroxide. All three methods gave the same negative or positive results.

It may be deduced that Rod's Pot also drains to Langford, though Drunkard's Hole and Bos Swallet may follow the Hunter's Brook drainage.

The last named was tested on three occasions and each time no fluorescein appeared at Langford. Just in case there was something very unusual in the underground drainage, Rickford was checked as well, but it, too, was negative. No colour was reported elsewhere, so though the Hunter's Brook does not run to Langford it is not known where it does go. The only likely spot for its reappearance is the intermittent rising opposite the south end of Saye's Lane (1) (ST 45665960). Here, in the roadside part of two fields, after heavy and prolonged rain, water wells up in the same way as it does in the field opposite Combe Lodge gates (p. 48). This area of the fields remains waterlogged long after rain has ceased. Nearby fields are not so affected. These intermittent springs come up just within the boundary of the Keuper Marl, which must be quite thin here, and so the water has been able to force a way to the surface through it.

The Ellick Farm springs were not tested as it was obvious that the Waterworks Company's tests could be relied upon.

This drainage pattern is an unexpected one, particularly as the West Twin Brook in Goatchurch Cavern is running along the strike heading almost directly away from the proved line of drainage. It must turn back to this line not so very far beyond the end point at which it is seen in the cave. The Ellick Farm stream would seem to be re-excavating, but below ground in the limestone, along the line of the pre-Triassic valley.

The output of the two risings has been recorded by the Bristol Waterworks Company over many years. Some of the records have now been published by Smith and Mead (1962). The flow of Langford rising can be as much as 14 million gallons and that of Rickford over 18 million per day, but, to anyone who has observed the flow of the known suppliers and compared this with the recorded volumes at the risings, it is very obvious that the known input forms not more than 10 per cent and perhaps as little as 5 per cent of the output. This is not peculiar to these two risings. It is a well-known phenomenon of all the major risings round Mendip. Obviously the water is derived from all over the catchment area, but this is outside the scope of this paper to be considered in detail.

All the local water undertakings are now merged in the Bristol Waterworks Company. This Company takes water from the high-level springs and from the low-level risings. This take off at the top must affect the output at the bottom, and so it is indeed fortunate that the high-level springs make such a small contribution to the bottom output, otherwise the Company would be, so to speak, robbing Peter to pay Paul.

THE FALLING WATER TABLE OF THE SUPERFICIAL DEPOSITS OF BLACKDOWN

This is a problem that has some bearing on the future supplies to be drawn from the high-level springs and the risings. All those who know the area intimately and have studied it over a long period are well aware that there has been a progressive lowering of the water table in the past 40 years. No precise figures can be given, but it is known that pools near the summit of Blackdown used never or very rarely to go dry. Nowadays they do so regularly and one of them scarcely holds water even in winter these days. The flow of the Twin Brooks goes down more quickly than it used to do. The small stream to the Bath Swallet, which stream did not go quite dry even in the drought of 1921, now dries up very much more quickly, and in an ordinary summer may not be flowing for weeks on end. The

Hunter's Brook was never known to go dry but it certainly does so now, as those dependent upon it for their water supply are only too well aware.

The rainfall records do not show any significant change over the same period so it would seem that there is some other reason, but what that is remains to be decided. It may be that the records do not go back far enough and that in the past century or so there has been a diminution and that at last it is beginning to show itself in the falling water table. If so, in the long run it is bound to affect the output at the risings. These are, after all, only the outlets for the water contents of the limestone and Dolomitic Conglomerate at or above their level. They are overflow springs. They do not drain the lower levels which are known* or can be postulated to exist and which must drain into the subsoil of the valley floors. It is here, and perhaps within the next 50 years, that the big supplies of water that will be needed will have to be looked for. The use of such sources might make it unnecessary to drown any more good agricultural land under shallow and expensive reservoirs.

CONCLUSIONS

In these an attempt is made to provide correlations with the accepted Pleistocene chronology. Many of these correlations must be regarded as tentative. They may be upset or confirmed by later work, but at least they provide a basis for argument and are applicable not only to the Burrington area but also to Mendip as a whole. It is hoped that they will provide a stimulus for investigations by others. Some conclusions have already been stated in the various sections.

The earliest time at which the erosion of Burrington Combe and the development of its caves could start would be the Pleistocene. If the Villafranchian and the Calabrian are accepted as forming part of the Pleistocene, the sea-level of 600 ft. O.D. or thereabouts would be too high for any erosion to have taken place along the present lines of Burrington Combe and its associated valleys, even allowing for a higher relief than that which now exists. The sea-level gradually dropped, and by the beginning of the Early Glaciation (Zeuner), the equivalent of the Alpine Gunz, the sea probably stood at about 400 ft. O.D. and this might have been responsible for the erosion level of 400–450 ft. described by Trueman (1938). It may have been during this phase that the waters from the slopes of Blackdown did the first stage of the re-excavation of Curtsey's Lane valley and of Dolebury Bottom together with the topmost parts of Burrington Combe.

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* E.g., at Gough's Cave, Cheddar, where the Cave Diving Group have proved that the water in the "Skeleton Pit" wells up through an opening in the limestone only a few feet above sea-level, whereas the level of the ordinary rising is about 85 ft. O.D.

As a glaciation develops, during it, and for the first part of the succeeding interglacial permafrost, conditions affect the drainage in the areas beyond the edge of the ice and abundant spring melt waters are kept above ground. In the Burrington area with the sea-level at or below 400 ft. O.D. the highly seasonal melt waters from the higher snowfields could now commence the erosion of Burrington Combe, though water, not captured by the as yet elementary valleys of The West Twin and Hunter's Brooks, would still continue down Curtsey's Lane valley. The initial purely phreatic stages of development of the highest level caves could have started now. That is Fox's Hole, Trat's Crack, Toad's Hole and Elephant's Hole in the Combe and possibly Read's Cavern as well. In Pleistocene chronology this is just prior to the Early Glaciation of Zeuner (Alpine Gunz). It is not to be assumed that the present mouths of the caves were exposed to the surface, and there is no necessity to postulate the existence of through drainage to a rising.

During the Early Glaciation, only surface erosion took place and with the lower sea-level the amount of erosion would have been considerable. In the subsequent interglacial the sea-level rose, but this time to only about 200 ft. O.D. The floor of the Combe would still be much higher than now. The high-level caves would still be phreatic and indeed their commencement is more likely to date from this time than the earlier period. The sea would be lapping the foot of the Mendips. Perhaps the slight change in gradient, which occurs in the Combe at *c.* 600 ft. O.D. (ST 48585814), represents all that is left of the knick point of this glaciation.

With the onset of the Ante-Penultimate Glaciation (Alpine Mindel) the sea-level went down and surface erosion began again. It is suggested that this is recorded by the rather poorly defined knick point in Burrington Combe. Its present top is just upstream from the S bend below Fox's Hole (ST 483582), *c.* 550 ft. O.D. Curtsey's Lane valley would still carry an active stream.

The following interglacial, the Great Interglacial, was a very long one and the sea-level rose to nearly 140 ft. O.D., with fluctuations, the equivalent of the "Tyrrhenian". Caves could go on forming and it could have been now that Aveline's Hole became fully functional as a rising providing a through route for the cave waters and draining the higher level caves and the Combe itself. The topmost parts of the caves were undergoing vadose development by streams at the water table and paraphreatic conditions had ensued below the water table. Flowstone could start to form in any of the caves or parts of the caves abandoned by the water. Some of the basal stalagmite in the Entrance Gallery of Goatchurch could have been formed now.

The sequence is repeated for the next or Penultimate Glaciation (Alpine Riss). This time the sea-level falls to near or perhaps below that of the present day. This very considerable drop in the sea-level and the consequent retreat of the shore line from the foot of the Mendips would permit substantial downcutting to take place in Burrington Combe and Dolebury Bottom. Curtsey's Lane valley would again be stream bed. Permafrost would begin to affect the water circulation through the caves. The silting up of Fox's Hole and Trat's Crack might be due to this, particularly if their outlets were frozen though their mouths were freely exposed. A suggested correlation for this stage is the knick point in Burrington Combe, just upstream from the mouth of the East Twin Brook valley (*c.* 450 ft. O.D.). Outwash fans would develop and would extend some way from the mouths of the Combe and Dolebury Bottom. There ought also to be a fan outside Curtsey's Lane valley, but it would be a much smaller one. The valleys on either side of Rowberrow Cavern probably began their development now.

With the last interglacial the sea-level rose again. The mouths of the rivers were drowned but the maximum transgression only brought the sea back to about 55 ft. O.D. (Monasterian). The waters could go underground again and the surface valleys would be generally dry. Curtsey's Lane valley would get no water, partly because its catchment had been reduced by encroachment laterally of the West Twin and Hunter's Brook valleys, and partly because the streams rising from the solifluction deposits covering the catchment area began to develop the series of small caves, Bos Swallet–Bath Swallet. Underground drainage continues and through-routes are being better developed, including, towards the end of the interglacial, those of Read's Cavern and Bos Swallet–Bath Swallet. Aveline's Hole was probably still in action as a rising, though newer routes to lower levels were developing extensively and it was well on the way to becoming fossilized.

The Last Glaciation (Alpine Würm) produced the lowest sea-level of the whole of the Pleistocene. This is the period of the "buried channels", which were cut down to −120 ft. O.D. near the Mendips. Erosion proceeded apace and valley gradients were steepened. Cave mouths, such as Goatchurch, were exposed through denudation of the valley sides and some solifluction material began to enter, but the entrances were soon largely obstructed by frost-induced rock falls. During the glacial maxima Curtsey's Lane valley reached its final stage of downcutting to 380 ft. O.D. and this presumptively coincided with the blockage of the small cave systems nearby, Bos Swallet–Bath Swallet, and the filling of their hollows. The East Twin Swallet was probably blocked now and the gravels carried into Read's Cavern and the bottom of Goatchurch. This is a period of vadose action to a considerable depth, but the cause of the silting up, which seems to be fairly general throughout Mendip Caves, is uncertain. During the interstadials the deepest underground drainage developed and Rickford and Langford risings started to function. Aveline's Hole, on the other hand, was gradually abandoned as a rising and it was finally left with its mouth hanging above the bottom of the Combe. The deepest underground drainage channels probably lay too deep to be affected by permafrost, but it is possible that frozen ground round the risings may have sufficiently impeded through-flow to cause backing up and silting further back in the cave systems.

The final cold phase of the Last Glaciation was probably responsible for the frost shattering observed in Goatchurch Cavern and Aveline's Hole. More rock falls helped to seal the other entrances to Goatchurch. What happened at Read's Cavern is obscured by later developments. It is suggested that the lowest knick point in Burrington Combe, just upstream from the West Twin valley (*c.* 380 ft. O.D., ST 47665835), was produced by the Last Glaciation. There is a similar knick point in Dolebury Bottom at the same level (ST 45805867) and it should be noted that the hanging Curtsey's Lane valley has its floor at its lower end at about the same level.

Rowberrow Cavern was formed during the later part of the last interglacial and was completed during the interstadials of the Last Glaciation (p. 46).

In the closing stages of the third maximum of the Last Glaciation the two upper galleries of Goatchurch Cavern were used as lairs by animals, perhaps in succession, as there is just a hint that the fauna of the Entrance Gallery is older than that of the Traverse and could be as old as the last interstadial. The remains from the Traverse include two predators, cave lion and hyæna, and these two beasts were responsible for the remains of such animals as mammoth. The Traverse fauna is likely to be contemporary with that from other caves such as the deeper levels of Soldier's Hole (Parry, 1931) and to belong to the Solutrean amelioration, *c.* 12,000 B.C. Aveline's Hole was occupied still later, but this time by man who not only lived in it but buried his dead there too. The fauna is late Pleistocene and the industry is similar to the Cheddarian (Bohmers and Wouters, 1956, p. 24). The cave was finally abandoned about 8000 B.C., either because rock falls finally sealed the entrance or because it was deliberately closed after the last burials, which were succeeded by a change of climate inside the cave. It was then, and then only, that stalagmite began to cover the floor.

In post-glacial times Bos Swallet–Bath Swallet series have all undergone some rejuvenation by tiny streams washing out part of the old fill, but exactly how much was done at Bos Swallet is problematical because mining has disturbed the site. Rejuvenation started at the bottom of Goatchurch and is continuing. In Read's Cavern the arrangement of the remnants of the streamborne gravels on the way down Zed Alley shows that some of them had been removed. This of necessity (p. 45) implies that the major collapse already described took place in post-glacial times, and this is in agreement with the form of the stream valley and hollow outside the cave.

In this paper, except for the Last Glaciation, no reference has been made to the matter of each of the earlier glaciations having more than one maximum nor to each interglacial being subdivided by minor advances and retreats of the ice. In both cases these will have had an effect on the erosional history of the caves and valleys. This omission has been due to there being no recognizable features in the area which can be correlated with these subdivisions. Again at the end of the Last Glaciation the sea rose, but its shore would be too far away to cause aggradation to occur in the valleys considered. Such aggradation that has occurred is due to the water going completely underground and so there has been nothing to remove the last masses of solifluction material and the normal but considerable accumulation of weathering products in post-glacial times.

Finally an attempt has been made to interpret the events of the Pleistocene in terms of the surface valleys and caves of the Burrington area. It is obvious that there are many gaps in our knowledge. Some of these can probably be filled by a still closer study of cave passage forms, arrangement and deposits in the caves such as stalagmite flows and floors. The laminated silts might turn out not to be the simple insoluble residue of the limestone that they are generally assumed to be but to be loess which has been retransported by underground streams. Erosion levels round the Mendips have yet to be studied in detail and also hillside deposits. When the results of such studies are known it should be possible to write a more positive account than this one. In this later account the "probables or possibles" of this present one will become "it is".

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PLATE 1

(*Photograph: E. K. Tratman*)

Goatchurch Cavern. Entrances at two levels in the same limestone beds.

PLATE 2

(*Photograph: E. K. Tratman*)

Read's Cavern. Part of base of cliff showing phreatic solution cavities, the Fox Holes. The entrance to the cave is below and to the right.

(*Photograph: D. Patmore*)

PLATE 3

Aveline's Hole. Current scalloping in roof of outer chamber. Photograph taken looking down the cave and lighted from the same direction and against the direction of water flow.

(*Photograph: D. Savage*)

PLATE 4

Read's Cavern. Main Chamber looking east. Inward slope of north wall and 90° fold along axis of roof are seen.