

Jubilee Contribution
University of Bristol Speleological Society

Geomorphology and Hydrology of the Central Mendips

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Only in the last few years has the Society carried out and published work on cave geomorphology and hydrology. This article attempts to relate this work to the geomorphological problems of the Mendip Hills. These will be reviewed first.

The first question which must be settled is the degree to which the relief of the Palæozoic rocks is an exhumed relief dating from Triassic times, revealed by the removal of Mesozoic rocks. Some authors, perhaps inspired by Lloyd Morgan (Morgan 1888 p. 250; Morgan & Reynolds 1909, p. 24), have thought Triassic erosion an important factor in determining details of present relief. While the broad relief of north Somerset certainly reflects that of the late Trias, when the Coal Measures vales between the Carboniferous Limestone uplands had already been eroded to their present level or lower, I question whether the relationship holds in any detail. Some of the marginal slopes of Mendip may be little more than old Carboniferous Limestone slopes exhumed by removal of Trias, but along the southern limit of the Mendips the characteristic steep, regular marginal slope is, in fact, largely cut in the Triassic Dolomitic Conglomerate which has an exceedingly irregular contact with the Carboniferous Limestone. Similarly, the summit plateau cuts indiscriminately across Carboniferous and Triassic. All the anticlinal cores were exposed by erosion in Triassic times, but except west of Rowberrow, where the Old Red Sandstone core of the Blackdown anticline was already eroded down to a low level in the Trias, I conclude, with Ford and Stanton (1969) that the Triassic landscape is unimportant in controlling present relief.

The summit plateau is conspicuous, especially from north of Cheddar (easting 450) to north of Wells (easting 565) in which area it is developed on Carboniferous Limestone between 800 ft. and 900 ft. above O.D.; mostly between 825 ft. and 860 ft. (Ford and Stanton, 1969). There appear to be extensions of this central Mendip surface to the east and west, possibly warped. Westwards from Cheddar the surface descends with a

steady gradient of about 1 in 90 to Crook Peak (628 ft.) and with only slightly less regularity to 400 ft. at the western end of Bleadon Hill. East of easting 565 the surface falls abruptly by about 50 ft. across the Biddle Fault and is then developed on Carboniferous Limestone between 700 ft. and 800 ft. as far as easting 690 where summits finally drop below 700 ft.

The Old Red Sandstone outcrops of the cores of the anticlines rise as hills of smooth outline from 100 ft. to 200 ft. above the plateau surface. They form limited gathering grounds for small streams which cross the outcrops of the Lower Limestone Shale and enter swallets at the base of the massive limestones (Black Rock Limestone). The greater altitude of the sandstone areas may indicate that lowering of the limestone plateau was largely by solution (Ford and Stanton, 1969, p. 408).

The plateau is pitted with hollows of two orders of size: eighteen "closed basins", from ten to 300 acres in area, described in detail by Ford and Stanton (1969), and more than 500 "closed depressions", up to about 30 yards in diameter (Colman and Balchin 1960; Donovan 1960).

The age of the summit plateau is not well-established. In the Castle of Comfort area the base of the Rhaetic Beds shows gentle folds which do not affect the limestone plateau; it is, therefore, later than this folding (Green 1958, p. 79). Former greater extent of Jurassic deposits is proved by relics in fissures (Green & Welch 1965, *Fig. 14*) but the present plateau does not seem to be a Jurassic erosion surface from which deposits have been removed, as some authors have thought, although it could incorporate parts of such surfaces. Green (in Green & Welch 1965, p. 125) thought the plateau to be late Tertiary. This is doubtless true with respect to its present form but late Tertiary erosion may merely have removed a sedimentary cover, resulting in super-imposition of drainage as suggested below. Thus Ford and Stanton (1969, p. 408) regard the plateau as late Pliocene incorporating large areas of a Rhaetic-Liassic erosion surface. I believe that this view is right in principle but that too little importance has been allowed to the mid-Cretaceous (pre-Gault) erosion. Elsewhere in south-west England this truncates structures in the Jurassic rocks, just as the Mendip plateau does.

Well-known marine benches of Wales and south-west England such as the early Pleistocene ones near 600 ft. and 400 ft. (cf. Brown 1960), and even the 100 ft. sea level of Great Interglacial (Mindel-Riss) time, appear to have left no trace on the steep marginal slopes of central and western Mendip, although Ford and Stanton (1969) have recognized several other levels. Probably they were cut in Mesozoic rocks which covered the Somerset levels and the Vale of Wrington which have since been removed. I conclude that the summit plateau is older than the marginal slopes, and is part of a once more extensive surface truncated by them. One is

reminded of the way that the upland surface(s) of Devon and Cornwall (whether they be considered as polycyclic in origin or not) are truncated by the steep coastal slopes and cliffs.

The third group of surface features, cut into the summit plateau and marginal slopes, are the dry valleys, of which Cheddar and Ebbor Gorges and Burrington Combe are the most conspicuous. Their lower reaches, in particular, present strikingly youthful profiles. Green (in Green & Welch 1965, p. 124) thought that the gorges are younger than the higher, tributary valleys, and in fact at both Cheddar and Burrington gorges appear to have been cut into the floors of older, more mature valleys. Cheddar Gorge, has a complex long profile (Ford and Stanton, 1969), and the successive erosional stages are discussed later (p. 71).

The most curious dry valley is Rickford Combe, an isolated meandering fragment as deep as Burrington Combe, which cuts into Dolomitic Conglomerate of the northern slope of Mendip west of Blagdon and leaves, one mile further on, at Rickford. It is clearly a fragment unrelated to present drainage. Mr. G. A. Kellaway has suggested (personal communication) that it is an overflow channel cut when the Vale of Wrington, which is narrowest here (the upper end of the Combe lies where the dam for Blagdon Lake was built) was blocked. The Chew Valley must also have been blocked since the col between it and the Vale of Wrington is only just over 200 ft., while the upper end of Rickford Combe is above 250 ft. These blockages could have been by land ice and associated deposits, perhaps when the Severn Estuary was blocked by Irish Sea Ice during the Gipping Advance (West 1968, p. 240).

The dry valleys on the summit plateau pose another problem. Some of them, notably that extending from Lower Pitts Farm (534504) to Black Rock at the head of Cheddar Gorge, are cut into a surface with no gradient, so they cannot have originated on it. Either the valleys were excavated before the plateau was cut in Carboniferous Limestone, which seems unlikely, or the valleys were initiated on a sedimentary cover which lay unconformably on the limestone. In the latter case the most likely candidate for the cover is the Upper Cretaceous, which is strongly transgressive near the eastern end of Mendip. The underground drainage presumably began to develop when the sedimentary cover had been removed.

Catastrophic views of the origin of the valleys and gorges, such as that of Maton (1797, p. 124) who thought (of Cheddar) that the "mountain must have been here violently rent asunder", fell out of favour as knowledge of erosional processes improved, and were in fact rejected by Sutcliffe as early as 1822 (p. 20). Boyd Dawkins (1862) appears to have started the popular idea that Cheddar Gorge is an unroofed cave, inspired

by the ravine at Wookey Hole where this process has doubtless operated to some extent. The much greater size of the Cheddar and Burrington gorges and other features render this explanation improbable for them (Green *in* Green and Welch 1965, p. 124). Later authors agree that the gorges were cut by subaerial denudation and most of them (e.g. Morgan 1888, p. 25; Reynolds 1927, p. 189) think that this took place during glacial periods when runoff was seasonally greater than at present due to melting snowcaps and when underground channels were inactive due to permafrost. Such views seem convincing although one must remember that even today surface streams flow in the gorges after abnormally great precipitation, as in the floods of August 1930 and July 1968.

Gravel fans, now degraded, lie at the mouths of the dry valleys and of some of the wet valleys (Clayden and Findlay 1960). They are shown on the One-Inch geological map as Head and on the Soil Survey map as the Langford and Brinsea Soil Series. The gravels are attributed to periglacial conditions and are likely to date from the Last Glaciation; they are to be correlated with the fans at the foot of the Cotswold scarp (Tomlinson 1941).

The drainage of the limestone area is wholly underground. Most of the effluent water along the southern flank is concentrated at three major springs—Cheddar, Wookey Hole and St. Andrew's Well, Wells, although there are at least 17 risings between Axbridge and Wells. Although this appears to indicate considerable integration or maturity of the underground drainage it is likely that in central Mendip, as in the Stoke Lane area (Drew 1968), most of the water goes underground as infiltration water and only a little as swallet streams. This is supported by the work of Smith and Mead (see below). North of the surface watershed the limestone outcrop is much smaller in area than to the south and there are no large risings. Green (*in* Green and Welch 1965, p. 125) thought that the risings represent the rivers which formerly flowed down the gorges, because there would be greater permeability beneath the valleys due to solution by percolation water below their floors. This may well be the case at Cheddar, where the situation of the present and former risings on the southern or down-dip side of the Gorge could be explained by control of percolation by bedding planes. At Wookey Hole the relationship is less convincing: although Wookey Hole Cave opens near the mouth of the Ebbor Gorge valley, diving has shown that it turns to the east, away from Ebbor. On the northern flank of Mendip there is no spring at the mouth of Burrington Combe, but Rickford Rising lies 1,100 yards to the east at the mouth of Rickford Combe (see above), and Langford Rising 1,100 yards to the west. As there appears to have been a former rising at Burrington (Aveline's Hole; p. 67) it is conceivable that a lower level rising deve-

loped but was later blocked by deposits of the gravel fan, causing diversion to Rickford and Langford.

Smith and Mead (1962) made a study of the solution of limestone in Mendip based on analysis of 1,000 water samples. They concluded that, of three possible mechanisms, the dissolving power of Mendip ground water is due to the presence of carbon dioxide, and further that this is controlled by the CO_2 content of the soil. With the unexplained exception of Langford Rising they found that the CaCO_3 content of the water of the central Mendip risings is remarkably constant throughout the year. Most of the underground solution must occur during the winter months on account of the greater flow at this time. They also found that, in G. B. cave, the CaCO_3 content of percolation water varied little with the season while that of stream water varies inversely with the rate of flow. Taken with the constancy of carbonate content at the risings this supports the view that most of the rising water is infiltration water. Ford (1966) described a water sample programme in three swallet caves (G. B., St. Cuthbert's and Swildon's). In contrast to Smith and Mead's findings at the springs, concentrations of solute CaCO_3 varied considerably. It was suggested that many short-interval samples are required to clarify the picture.

The hydrology of the Burrington area has been studied by Tratman (1963). Water testing by Drew, Newson and Smith (in press) has shown that water from swallets at Read's Cavern, West Twin and East Twin valleys, and Ellick Farm, and percolation water from Burrington Ham, drains in every case to both Langford and Rickford Risings, so that streams must bifurcate underground. The authors thought that one rising might be in process of capturing the other. Alternatively the present state of affairs might have resulted from the blocking of a rising at Burrington, as suggested above.

The various small swallet caves near Burrington have been summarized by Tratman. The small passage sizes of these vadose caves are probably due to the small catchment areas as compared with those on the south of Black Down feeding G. B. Cave and Longwood Swallet. Aveline's Hole may have been a former water outlet (Tratman 1963, p. 38) truncated by the cutting of the Combe to its present level. It would have discharged at a minimum level of about 370 ft. above O.D.

The streams from G. B. Cave, Longwood Swallet and Manor Farm Swallet flow to Cheddar, while those from Eastwater Swallet, Swildon's Hole and St. Cuthbert's Swallet rise at Wookey Hole (Atkinson et al. 1967, *Fig. 4*). The Cheddar catchment could be regarded as the area surrounding the Cheddar Syncline, bounded on the north by the Blackdown pericline. The rising, however, is not on the axis of the syncline but on the northern limb, and much of the drainage must cross the axis. To the east

there must be a water parting between the catchments supplying Cheddar and the springs at Litton and Chewton Mendip, but its position is not apparent unless it is formed by the Mesozoic cover between Harptree and North Hill. Whether the main springs on the southern flank of Mendip are larger than those on the north merely because the limestone outcrop is wider on the southern side, or whether any process of underground river capture has operated to produce the Cheddar and Wookey Hole risings, is a problem for the future.

The catchment areas of the Cheddar and Wookey Hole springs, which must be of the same order of size, do not coincide with the dry valley systems. The Cheddar valley system is much larger, and the swallets feeding Wookey Hole lie in valleys leading to Cheddar. According to Ford and Stanton (1969, p. 406) the Cheddar stream beheaded and captured drainage lying to the east. According to me (p. 65) the Priddy-Cheddar valley is superimposed and so any captures must have taken place before the Mesozoic cover was wholly removed and probably long before present lines of underground drainage were established. This suggests that from the first underground catchment areas did not necessarily bear any resemblance to surface catchments, but developed independently.

Underground erosion of limestone has been classified into phreatic, when a cave is water-filled and solution can act on all the rock surface exposed, and vadose, when a cave is air-filled except for streams (Bretz 1942). In both cases the mode of attack, by solution, is the same, it is merely the localization of the attack which is different. It is likely that the earliest stages of any cave system are phreatic except in the event of its being started in a major fissure system of tectonic origin where free-flowing streams could exist from the beginning.

A theory of cave formation in Mendip has been advanced by Ford (1965, 1968). He supposes that initially a cave system consisted of many "phreatic loops", each having a descending bedding plane and an ascending joint-determined component. By these loops water pursued on average a nearly horizontal path through the steeply-dipping rock. With the lowering of the external base level (the Mesozoic rocks flanking the limestone) the loops became airfilled and some of them passable to cavers. Vadose erosion truncated the highest parts of some loops as they became air filled, and other loops were short-circuited by "subsequent" passages. When a system became air filled streams cut trenches in passage floors. Large chambers formed locally by collapse.

All the swallet caves show features due to vadose erosion but these are developed to differing degrees. G. B. Cave is dominantly vadose, while at the other extreme St. Cuthbert's Swallet has mainly phreatic-

type passages. Ford (1968, pp. 21–22) interprets this as meaning that St. Cuthbert's is older.

Penetrable swallet caves are known only near the base of the limestone, and it is likely that only here has water been sufficiently concentrated for man-sized passages to develop extensively. They are spaced along the shale/limestone contact at intervals of the order of half a mile, and to judge from the distribution of known swallets and caves, not many more remain to be discovered in the Cheddar and Wookey Hole catchments.

The passages connecting the lowest points of the swallet caves with the risings have not been penetrated except at Swildon's Hole, where about 600 yards of air-filled stream passages with occasional "sumps" where the roof falls to water level have been explored, and at Wookey Hole where a similar situation prevails. Atkinson, Drew and High (1967, p.14) thought that the remaining part of the connection between Swildon's Hole and Wookey Hole is largely water filled, with comparatively unobstructed flow, on the evidence of the behaviour of lycopodium spores released at Swildon's and recovered at Wookey Hole. For the passages between St. Cuthbert's Swallet and Wookey Hole they thought that short travel time and high recovery of spores indicated an open passage with a free-flowing stream. Average gradients for the most direct routes from lowest known points of swallet caves to Cheddar and Wookey Hole risings range from 3° to 4° . Comparison of travel times observed for the first arrivals at risings of material put in swallets led Drew and his co-workers to presume that the paths of streams from the lowest known points of swallets to risings are separate for most of their lengths.

Outlet caves at Cheddar and Wookey Hole (Ford 1965, p. 123) show striking phreatic features such as near-circular passage sections and blind roof chimneys (well seen in Gough's Cave, Cheddar). Ford has inferred a former water level from the upper ends of these chimneys which lie in the range 200–225 ft. above O.D., representing the upper limit of hydrostatic lift. Evidently outlet caves in the past were usually water-filled, as they are today at Cheddar.

Most known caves are swallets or outlets but a few do not fall comfortably into either class. Lamb's Lair Cavern, lying well away from the shale/limestone boundary, has a large dome-shaped chamber with small passages leading off. It has not been studied geologically. South and south-east of Lamb's Lair the existence of similar large chambers in the Carboniferous Limestone is indicated by collapse pits, of which the largest are Wurt Pit and the Devil's Punch Bowl, in the thin overlying Mesozoic rocks. Nothing is known about the mode of formation of caves in this part of Mendip.

Water tracing to establish underground connections between points of inflow and risings has been a recent activity of the Society and has reached a high peak of sophistication. Lycopodium spores have been used in our area for the first time in the United Kingdom. Their advantages include the fact that batches of spores can be dyed and spores released at several swallets simultaneously can be distinguished at risings. A few results are referred to here, but work is still in progress.

One result of water tracing has been to suggest that many discrete water channels exist within the limestone, and this tends to oppose any concept of a water table such as exists in many porous rocks. The Carboniferous Limestone is not porous, passage of water being through channels, and hence a water table can only develop if a network of interconnecting fissures is opened up. This has probably not happened in Mendip, although the matter is controversial and the idea of a water table has been favoured more, for example, by Ford than by Drew (1968).

Four Mendip swallet caves have been studied geomorphologically: G. B. Cave, St. Cuthbert's Swallet and Swildon's Hole by Ford (1963, 1964, 1965) and Longwood Swallet by Atkinson (1967). The publication of full accounts of G.B. Cave and Longwood Swallet in these *Proceedings* forms a landmark in Mendip geomorphology. Both caves show repetition of a cycle comprising vadose erosion followed by clastic deposition and then by stalagmite. In G.B. two complete cycles have been detected, followed by the modern erosional phase, while at Longwood three complete cycles are claimed. At least one episode of clastic fill is known at Rod's Pot, Burrington (Donovan 1949). The two cycles at G.B. have been correlated with the last two at Longwood (Atkinson 1967, p.184) on the assumption, presumably, that there is no gap in the sequence in either cave. Sure correlation must await some method of distinguishing or dating the cycles.

The lowest point of G. B. Cave is about 165 ft. higher than that of Longwood, but before attaching any significance to this one must remember that the lowest passage of G. B. is in boulders: in other words, the main cave is still large but has been blocked by boulder falls (Gilbert, 1963; Norton, 1966; E. K. Tratman, personal communication). The real bottom of the system is therefore unknown.

The factors governing the cycles need to be explained. A controlling factor must have been the amount of clastic debris available. This would be at a minimum under interglacial/interstadial climate, with good soil cover, and at a maximum under glacial climate with tundra at the surface and much loose debris. Ford (1964, pp. 177, 181) supposed that during the clastic fill phases the volume of underground water was reduced. It seems to me that strong flow would have been needed at least occasionally to transport Old Red Sandstone debris (up to "small boulder" size) into the



PLATE 7

Cheddar Gorge, looking east-north-east. The picture shows the summit plateau of Mendip, with valleys tributary to the Gorge, and the marginal slope. Long Wood lies on the plateau on the left-hand side, and Charterhouse-on-Mendip at top centre.

(Photo: Aerofilms Ltd.)



PLATE 8A

Burrington Combe, looking north. West Twin Valley in the foreground

(Photo: Dr. J. K. St. Joseph)



PLATE 8B

Summit plateau west of Charterhouse-on-Mendip. The western branch of Long Wood is seen in foreground, with Long House Barn beyond. Tynings Farm at top centre. The slight hollow due to the Lower Limestone Shales is well seen. *(Photo: Dr. J. K. St. Joseph)*

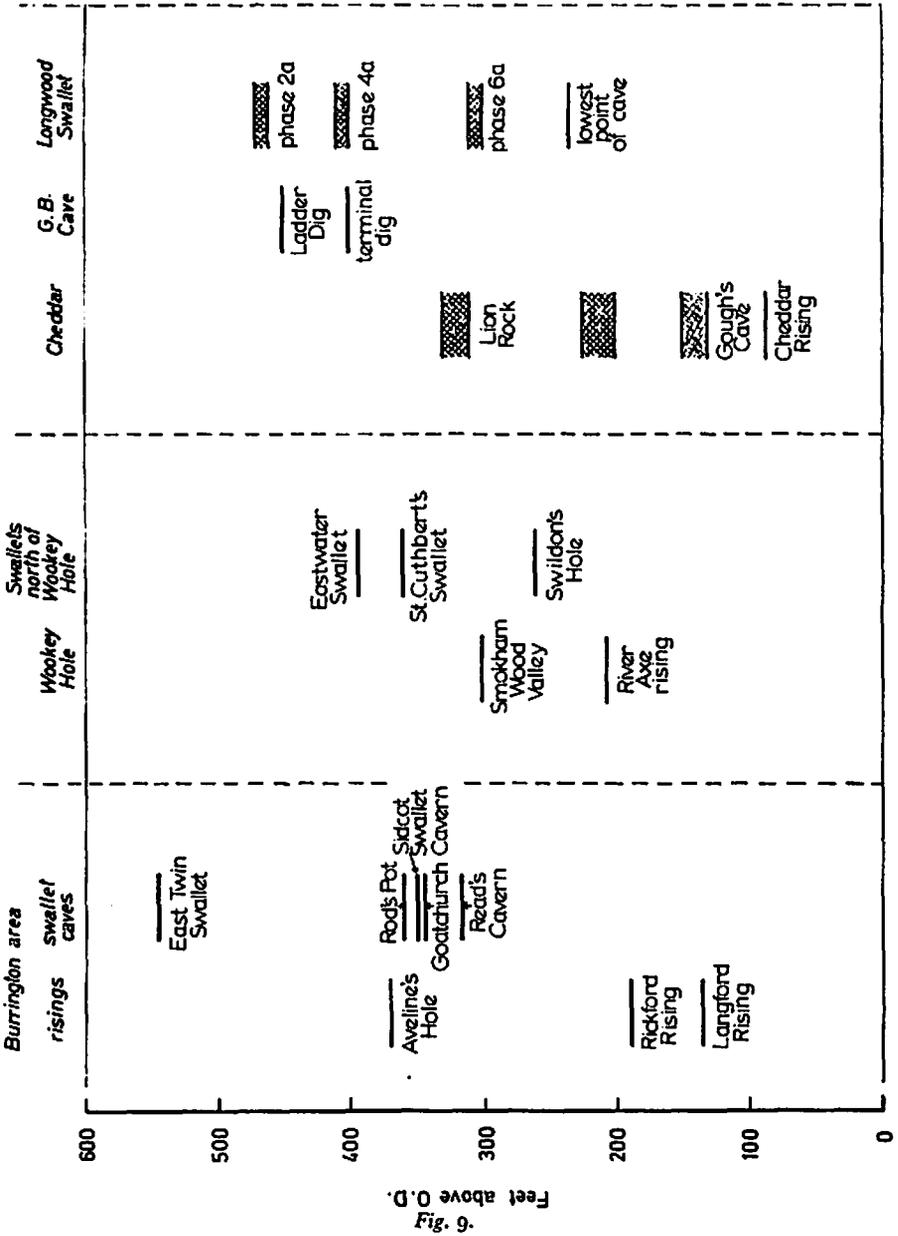
caves, and would have been supplied by spring meltwater. This idea is reinforced by the effects of the great storm of July 10, 1968, reported by Savage elsewhere in this number. The resulting water flow caused great changes in the distribution of loose debris in G. B. Cave. It may be that the clastic fills need to be reconsidered in the light of experience of the effects of the storm. The stalagmite phases are more difficult to explain. Ford supposed (1964, p.174) that seepage was active but that there was no stream of any size, but did not explain in his paper how this might have come about. He has suggested to me (*in litt*) that it was due to permafrost, which blocked swallet entrances but allowed seepage water to pass. This is known to be the case in Alaska where the seepage water has a very high CaCO_3 content. If this was so, the clastic fill would mark the early stages of a cold phase, before permafrost had been established, and stalagmite the most intense cold. The absence of a second clastic phase during amelioration of climate could be explained by time-lag in thawing of the permafrost.

Successive stages of development of the underground drainage of the Cheddar catchment, related to successively lower levels of the water table, have thus been recognized at both the swallets and the outlets. These are summarized in the following diagram (*Fig. 9*).

At Cheddar, Ford (1963, pp. 268-9; 1965, p. 123) recognized three former levels of outlet of underground water, the highest (310-330 ft.) discharging through Great Oone's Hole into a surface valley passing north of Lion Rock, the next (200-225 ft.) perhaps corresponding with a valley floor represented by the top of the spur north-east of Gough's Cave (my interpretation), and the third (130-150 ft.) marked by the utilization of the entrance passage to Gough's Cave as the main rising. He correlated the first major vadose phase at G. B., supposed to grade to the level of the Ladder Dig, with the 130-150 ft. water table at Cheddar, on the grounds that both lie at a similar height about present water level. This reasoning would be invalidated if the present bottom level of G.B. does not mark saturation level (see above).

At Swildon's Hole there are three abandoned water levels (Ford 1965, p. 117) at vertical intervals comparable with those at Cheddar. Ford and Stanton (1969) suppose that earlier outlets of the Wookey Hole system lay on the site of Ebbor Gorge, but a chronology has not been published in detail.

At Wookey Hole, Balch (1914, p. 20) recognized four former outlets. His work needs to be re-examined in the light of modern knowledge, but the highest level at about 260 ft. has been confirmed by Ford (1965, p.125). The cutting of the present ravine at Wookey Hole, which is unique in Mendip in ending upstream in a rocky precipice at whose foot



the stream issues at 200 ft. above O.D., has left a small valley (Smokham Wood) hanging at about 300 ft.

In considering the chronology of underground drainage development

EXPLANATION OF FIGURE 9

Diagram showing the levels of some of the chief risings and swallet caves in central Mendip. Levels for swallet caves are those of the lowest known points unless marked otherwise. Shading indicates a range of levels. Levels at Cheddar from Ford (1963, unpublished).

EXPLANATION OF PLATE 9

Pl. 9A. Relief of central Mendip. Contour interval 50 ft.

- 1 = Read's Cavern
- 2 = Bath Swallet
- 3 = West Twin Swallet
- 4 = East Twin Swallet
- 5 = Rickford rising
- 6 = Burrington Combe
- 7 = Rickford Combe

Based on the Ordnance Survey map by permission of the Director General.
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Pl. 9B. Geology of central Mendip. The map covers the same area as Pl. 9A. On both maps many small risings on the south-western flank have been omitted.

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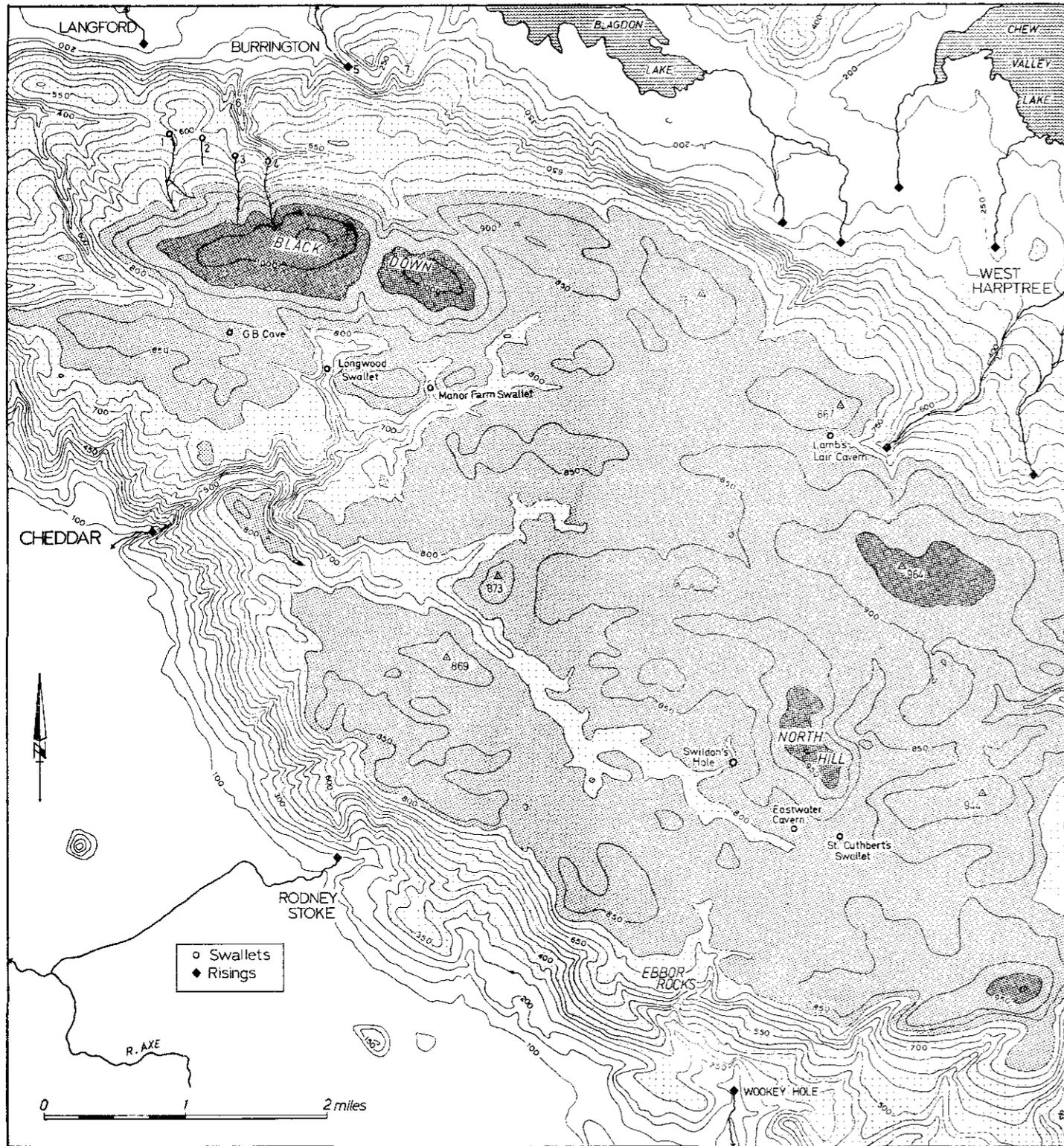


PLATE 9A

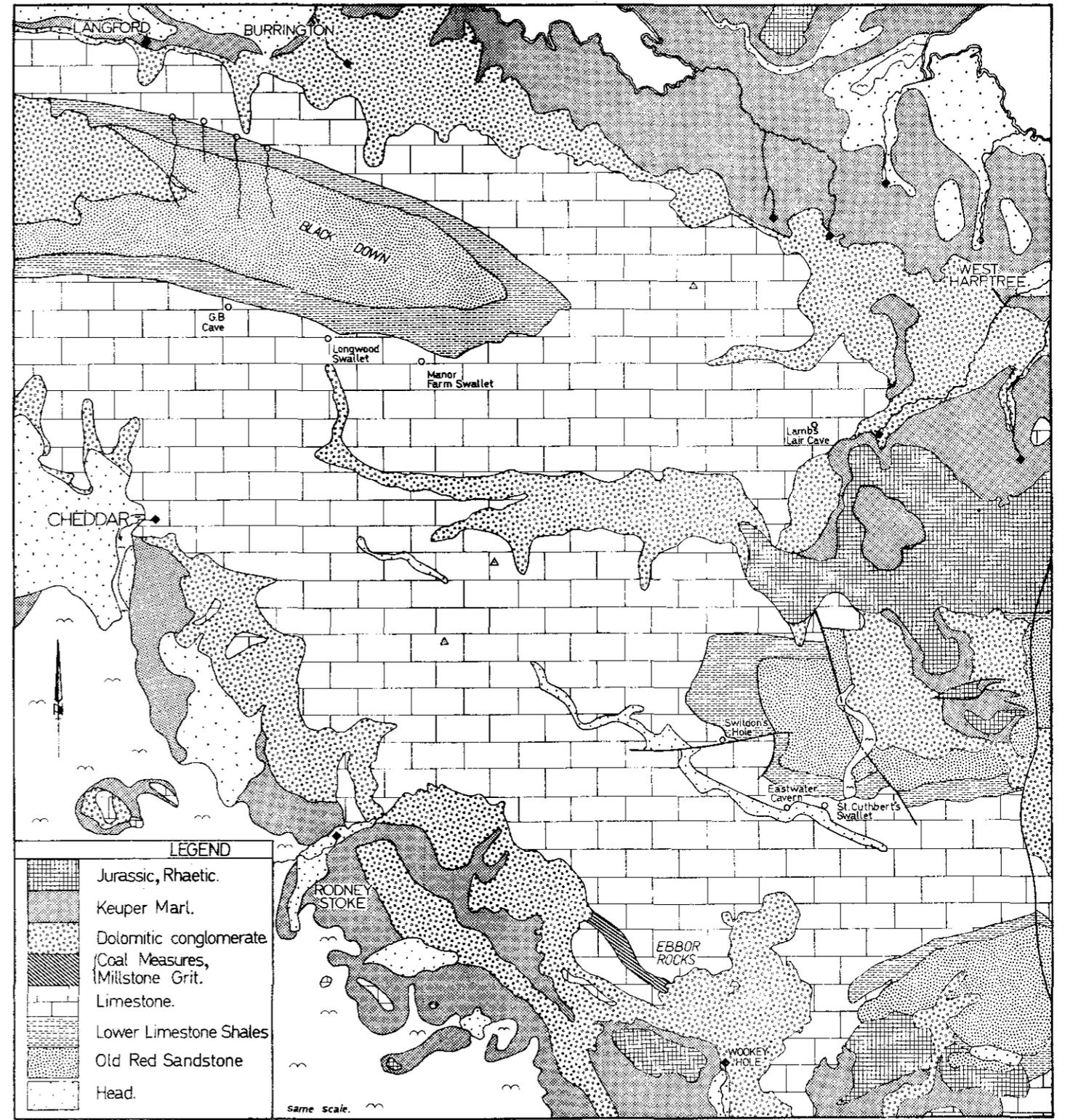


PLATE 9B

it is obvious that the levels in each underground drainage area must be considered separately, since outlet levels were controlled by the removal of impervious Mesozoic rocks and there was no equivalence of levels between areas (*Fig. 9*). Within a single drainage area it may be reasonable to correlate former water levels in swallet caves with those at the risings, on the basis of similar vertical intervals, but even this should for the present be approached with caution. It assumes that average gradients between swallet caves and outlets have remained constant, which seems a big assumption. Correlation of similar sequences between drainage areas is a further step which requires more caution.

I have suggested above that Mesozoic rocks were not removed from the flanks of Mendip until after the Mindel-Riss Interglacial and this would place an earlier limit to the lowering of the water and draining of phreatic caves. If the cycles in G.B. Cave and Longwood Swallet represent alternations of warmer and colder climate, the common-sense view is to correlate the several known cycles with phases of the Würm Glaciation. This takes the earliest, phreatic stages of these swallets back to early Würm or perhaps Riss-Würm Interglacial (Ford 1964, p. 182). It would appear reasonable to correlate the earliest outlet cave with the earliest passages in the swallets, but alternatively it could be that outlet caves which were well-developed due to the localization of water flow correspond to small, undetected swallet passages.

The highest known abandoned outlets at Cheddar and Wookey Hole lie near 300 ft. above O.D. Erosion of the now dry valleys down to this level *may* have been unaccompanied by development of underground drainage, due to incomplete removal of the sedimentary cover of the summit plateau. Below the 300 ft. level, at least, valley cutting and cave development went on either simultaneously or alternately. Since lowering of the water outlets must have been controlled by the removal of Mesozoic rocks, any attempt to date the successive levels by correlation with their presumed sea levels seems, at present, very dangerous.

Enough work has been done to show that the caves can be made to yield detailed evidence as to their history. A beginning can be made in tying in cave development with surface erosional history, but many more cave systems will have to be critically studied before a full account can be given of Mendip geomorphology.

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Note. The only detailed geomorphological study of the area covered by this review (Ford and Stanton 1969) was published in January 1969. By courtesy of the authors I was able to read a typescript of their article when my own was in a late stage of preparation, but I have not been able to do full justice to their work.

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