The Origin of Rake Bottom, Butser Hill

by R. J. SMALL

In the light of the dry valley controversy, the origin of the remarkable valley known as Rake Bottom is discussed. The features of the valley suggest that is has been mainly eroded by the process of spring sapping, and that meltwater in the Pleistocene played at best a secondary role. The exceptional depth of incision of Rake Bottom is explained by reference to its history of capture and rejuvenation by a tributary of the West Sussex Rother. Superficial deposits, probably of recent age, in the floor of the valley are examined.

1. INTRODUCTION

DRY valleys which show clear signs of having once been occupied by running water are found in many types of rock and under many climates, but in England they are perhaps best developed and certainly most numerous in the Chalk. Indeed, except where local geological conditions dictate otherwise, the drainage of the higher Chalk lands is entirely underground. Under normal conditions, all rainfall quickly infiltrates into the thin rendzina soil and the residue, after evaporation and plant transpiration have taken their toll, descends numerous joints and fissures in the rock to a zone of saturation which may be several hundreds of feet below the surface. However, this descending water does eventually re-emerge by way of the many springs which issue at lower levels, where the zone of saturation, or water-table, comes to the surface. Fluctuations in the water-table, resulting from increased or decreased percolation, are naturally accompanied by variations in the level of spring-line. For example, after periods of excessive rainfall, the springs may attain uncommonly high positions, and valleys which are usually dry may again be occupied in their lower parts by the small ephemeral streams known in Hampshire as 'lavants' and in Wiltshire and Dorset as 'winterbournes'.

Under present climatic and hydrological conditions, however, the upper parts of virtually all Chalk dry valleys never experience appreciable surface run-off, and it is clear that, for their formation to have taken place, the valleys must at some time in the past have been subjected to conditions very much different from those encountered today. Surface run-off must then, for some reason, have been a common phenomenon even at high levels, for many of the now dry valleys are deeply incised and very striking features. Attempts by geographers and geologists to reconstruct in theory these past conditions have led to a good deal of controversy, from which two main schools of thought have emerged. The first ([1], [2]) envisages that run-off in sufficient quantities can have taken place on upper Chalk surfaces only during the actual glacial periods of the Pleistocene, when, owing to the proximity of the ice front and the allied severity of the climate, deep freezing may have rendered the Chalk impermeable and so favoured considerable, and occasionally violent, run-off from melting snow or spasmodic rainfall. The second school contends that the valleys are the expectable product of what have been termed normal erosive processes, in particular stream flow and spring action, and that most of them had been initiated long before the beginning of the Pleistocene period and its associated abnormal conditions. The fall in the water-table that left them in their state of arrested dissection is attributed to the lowering by erosion of the impermeable rocks surrounding the Chalk (notably the Gault Clay in front of the Chalk escarpments) while the latter remained upstanding[3], and to the incision of the main rivers within the bounds of the Chalk itself.[4] Undoubtedly the process may have been hastened too by a decrease in rainfall in the post-glacial period.[5]

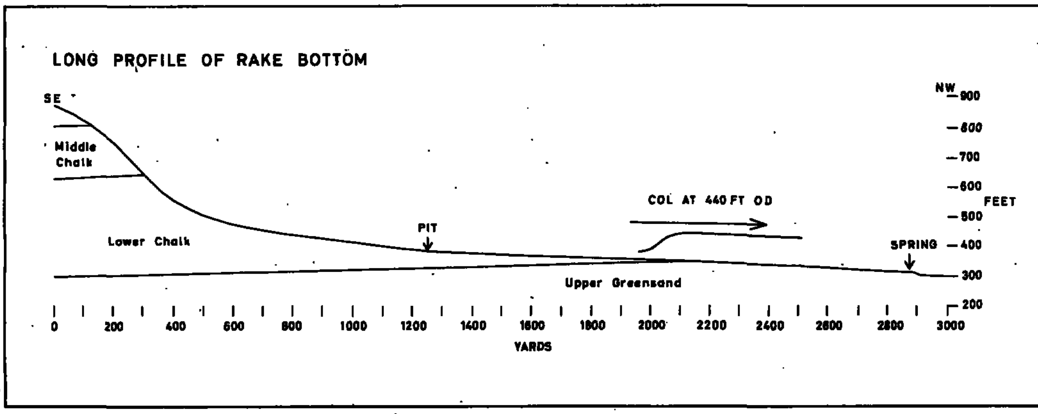
Perhaps the most unfortunate outcome of this controversy is the impression it has left in the minds of many geographers, that an arbitrary distinction can be drawn between those features of the earth's surface which result from abnormal erosion and those due to normal erosion. In reality, the terms ' normal ' and ' abnormal ', though convenient to use when making a general comparison of the present with certain periods in the past, have no precise meaning in the geomorphological sense; and, as will be illustrated in this paper, a further difficulty is encountered because so-called abnormal conditions may merely lead to an accentuation of normal processes already operative, so that the landform-types resulting from the two are simply not distinguishable from each other.

In the light of this controversy, a general investigation into the Chalk dry valleys of Central Southern England led the writer to examine the valleys cut into the Chalk mass of Butser Hill, on the Hampshire-Sussex border. One of these valleys, known locally as Rake Bottom, is such an exceptional feature, in terms of depth of incision, length, and steepness of valley side, that it seemed to merit special attention. It was accordingly surveyed in some detail, and its floor subjected to limited excavation.

2. THE FEATURES AND ORIGIN OF RAKE BOTTOM

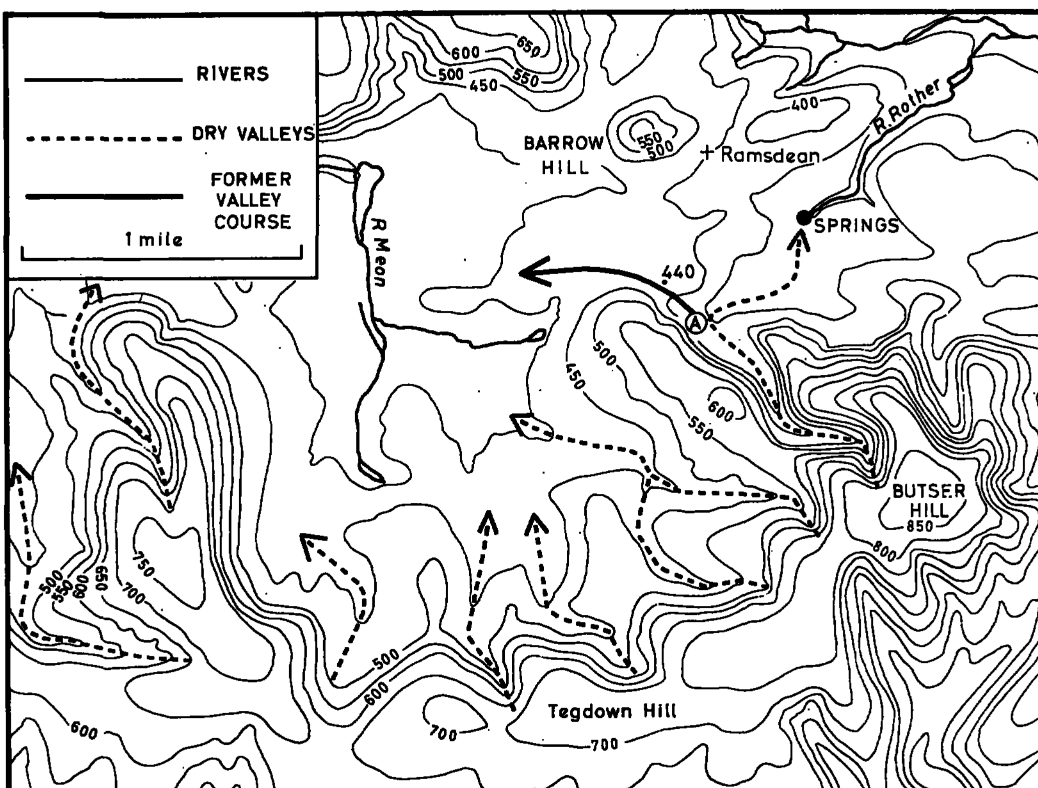
The main features of the long-profile of Rake Bottom may be seen from Figure 1. The lower part of the valley rises gently from the springs which issue 100 yards to the north of the minor road passing Twentyways (706218) and Harroway (713216) Farms. Where the valley is floored by Upper Greensand the gradient is approximately 1 : 60, and where floored by Lower Chalk is slightly greater, 1 : 40. In the upper part of the valley, however, a significant change occurs: towards the upper part of the Lower Chalk outcrop the valley profile steepens rapidly, and on the lower part of the Middle Chalk outcrop attains a maximum gradient of approximately 1 : 4.

This abrupt steepening, which may be noted in many escarpment valleys and in some dip-slope valleys (for example, those cut into the south slope of Butser Hill itself), is difficult to explain in terms of erosion by a stream, normal or composed of meltwater, running from near the summit of Butser Hill. It is a principle of geomorphology that such a stream would cut a more gentle, more unified curve of erosion than that depicted in Figure 1. It seems more likely, in fact, that the steep slope at the head of Rake Bottom is the product of a process involving some form of undermining lower down in the valley, and that the uppermost part may never, or at best rarely, have been occupied by running water. As Sparks and Lewis[5] have pointed out in connexion with escarpment valleys elsewhere, the undermining process may have been that of spring sapping. Fortunately for the argument, the lower part of Rake Bottom still contains a group of small springs, probably the direct descendants of the springs which were responsible for the excavation of the upper valley. These springs, though now diminished in volume, still illustrate particularly well some of the individual processes implied by the term ' spring sapping '.



LONG PROFILE OF RAKE BOTTOM
SE
NW
Middle Chalk
Lower Chalk
Upper Greensand
PIT
COL AT 440 FT OD
SPRING
FEET
900
800
700
600
500
400
300
200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
YARDS

FIG. 1.



RIVERS
DRY VALLEYS
FORMER VALLEY COURSE
1 mile
BARROW HILL
Ramsdean
R. Rother
SPRINGS
R Meon
440
A
BUTSER HILL
850
Tegdown Hill

FIG. 2.

Three springs constitute the group, which rises at the head of a small but impressive trench cut through the Upper Greensand cuesta east of Ramsdean. Above the point at which each issues there is a steep slope, a few feet high, which is largely devoid of vegetation and, just above the spring itself, often extremely moist. It is common for lumps of soil to slip into the brook beneath, to be quickly borne away. This process is naturally most effective near the spring, so that the slope is being constantly undermined and, as it is pushed back, its steepness maintained. Above the central spring another process may be readily observed. In the valley floor there is a distinct hole, nearly a yard in diameter, which is clearly the product of collapse. It seems likely that water is moving quite rapidly underground towards the spring along a fissure in the Greensand, and that the fissure is being transformed by actual corrasion into an elongated cavern or series of small caves. The collapse observed shows that the roof is becoming increasingly unstable, and with further collapse the trench will be extended several yards up-valley and the spring will migrate headwards accordingly. Doubtless this process would have been important in the Chalk, where corrasion would be supplemented by solution by weak carbonic acid solutions.

The cross-profile of Rake Bottom, as might be expected, offers neither support for nor grounds for attack against the spring sapping theory. Near the steep head of the valley, especially above the pit indicated in Figure 1, the sides are unusually steep, reaching an angle of approximately 30 degrees at some points. The slope profiles comprise two distinct sections, the lower rectilinear in form and the upper, generally less significant, convex. The steepness on the rectilinear section has promoted a good deal of rapid soil creep, as evidenced by the numerous ' sheep-runs ' and the large patches on the right-hand wall where soil and vegetation are absent and weathered Chalk rubble occupies the surface. In the lower part of the valley where the Upper Greensand forms terrain which is considerably lower than that of the Chalk, the slopes are less steep, the distinctive rectilinear slope section disappears, and soil creep is correspondingly less rapid. Only below the springs, in the Greensand trench, do the features characterising the upper valley reappear, though on a much reduced scale.

One feature of the cross-profile is, however, deserving of special attention, namely the flat bottom which becomes increasingly evident as the valley is descended, and gives it almost a trench-like character. This feature has been noted by other writers[5, 6] as occurring in Chalk valleys elsewhere; and in giving them the appearance of having been cut by large bodies of rapidly flowing water—an appearance in many ways similar to that of the pro-glacial overflow channels of northern England—has been largely responsible for the theory of their formation by meltwater torrents. However, Sparks and Lewis[5] have demonstrated that in escarpment valleys near Pegsdon, Hertfordshire, this flattening of the floor is solely the result of accumulation of material derived from the valley sides by rapid soil creep, such as has been described above. Excavation in Rake Bottom has shown this to be true here, and the one piece of evidence seeming to support the meltwater hypothesis loses its validity.

The most striking feature of Rake Bottom in plan is its angular, zig-zag course (Figure 2). The upper part of the valley runs slightly west of north (Bearing 350 degrees) for 200 yards, then turns sharply to run almost due west (275 degrees) for another 400 yards, before again turning sharply to run north-north-west (330 degrees). In the lower valley, there is a further change of direction which, though in overall effect more important than the upper changes, is slightly more gentle in character and, as will be shown below, is probably genetically different too.

In order to account for the sharp angularity of the upper valley, it is reasonable to infer that erosion has sought out and closely followed significant lines of weakness in the Chalk, though what these weaknesses are cannot be readily determined. It is certainly difficult to see why meltwater torrents, or even normal streams, should erode such an unusual course, or indeed pay attention at all to what must be subtle, since unidentifiable, weaknesses in the Chalk. On the other hand, such an agency as a spring could, particularly if the line of weakness happened to be an important joint along which movement of underground water to the spring would be facilitated and underground corrasion localised. Sparks and Lewis[5] have suggested that such joints may help to explain the angular pattern of some of the valleys at Pegsdon. In the writer's opinion, jointing in the Chalk, though vitally important in its effects upon internal features such as permeability, is generally of little significance in its direct effects upon the evolution of surface scenery. In contrast to Rake Bottom, most Chalk escarpment valleys in Central Southern England show no clear features of angularity. The winding nature of nearly all dip-slope valleys, the gently undulating, rounded landscape (the sum of many broad convexities) so characteristic of Chalk, and the uncomplicated form of Chalk cliffs such as those of the Sussex coast between Brighton and Eastbourne, all point to a similar conclusion. Nevertheless, it is possible that locally, and under certain conditions, the joint pattern may be so strongly developed that it has an important effect through the agency of spring action; and this may account for the features at Pegsdon and Butser Hill. It will be seen from Figure 2 that several valleys to the west of Butser Hill, particularly those cut into the north face of the Chalk ridge running through Tegdown Hill, also show some signs of angularity, together with the steep heads indicative of undermining and headward extension by springs. It is possible that in this area the structural flexuring which led to the formation of the Meon pericline in Oligocene-Miocene times may have affected the pattern of jointing in the Chalk. A further feature may support the major joint theory. The writer has noticed that several escarpment valleys elsewhere which follow curvilinear courses and which do not therefore seem to be influenced by major joints commonly have walls which are broken by numerous amphitheatre-like hollows; these may be seen, for example, in the dry valleys above Bratton and Tinhead in Wiltshire, in Coneycroft Bottom near Selborne, Sussex, and in the valley at Barton-in-the-Clay, Bedfordshire. They presumably mark points at which subsidiary springs or seepages, controlled by minor fissures in the Chalk, once issued. However, the hollows are absent from Rake Bottom, and this may indicate, though proof is not of course forthcoming, the overriding control over underground water movement exercised here by a few master joints.

At this point it will be convenient to summarize the conclusions reached so far. There are good reasons, in the form of the valley long-profile, in its angular course, and in its relationship to eroding springs at lower levels, for believing that Rake Bottom has at least been greatly modified by the process of spring sapping. There are no such reasons for assuming that the valley is the product of a meltwater torrent; indeed, it is difficult to imagine the restricted summit area of Butser Hill supporting a snowcap sufficiently large to supply the water needed to erode such an impressive feature. Nonetheless, it is very likely that under periglacial conditions in the Pleistocene some surface run-off occurred. This would account for the slightly V-shaped nature of the valley cross-profile above the maximum height attained by springs, but not the main features of the valley.

Two further questions now remain. Firstly, to what extent did Rake Bottom, fundamentally the product of a normal process, depend for its origin on that normal process being accelerated in the Pleistocene by periods of exceptionally high rainfall and percolation, by deep frost weathering, and by rapid solifluxion? Secondly, why does Rake Bottom stand alone in this area in terms of size?

The first question is so difficult and has such wide implications that it cannot receive more than passing attention here. The down-valley migration of the springs which has led to the drying up of Rake Bottom may be the result of a secular lowering of the Chalk water-table through the incision of the Rother and its tributaries to the north, or it may be due to a recent decrease in overall percolation, or it may be due to both. What may be said is that a relatively small increase in rainfall and percolation would be enough to cause the springs to re-occupy their former site below the steep head of the valley, for the gradient of the lower valley (average 1 : 50) can hardly be much less than that of the water-table itself. At present, the main springs are at approximately 300 feet O.D., but even after moderately wet periods a temporary spring issues in a small coppice 1500 yards up-valley, at 382 feet O.D., giving rise to a tiny lavant which is just sufficiently powerful to breach the turf where ploughing has not taken place.

The second question is more easily answered. The important change of course in the lower valley (A in Figure 2) has been described above, and suggested to be genetically different from those apparently due to master joint control in the upper part of the valley. It will be seen that, if the modifications imposed by these angles are ignored, Rake Bottom follows a general north-north-west course above point A, and in doing so resembles several left-bank tributary valleys of the Meon to the west. If this course is extrapolated beyond point A, it crosses a significant pass at 440 feet O.D. on the Meon-Rother watershed in the vicinity of Lythe House (700215). In addition, the wooded left-hand wall of the valley continues in the same direction for a quarter of a mile, and actually forms the south-western slope overlooking the pass. That the Meon itself was once a much larger stream is evidenced by the important wind-gaps to the north and south of the Middle Chalk outlier of Barrow Hill. However, it has suffered from the disadvantage common to all streams which rise in and flow over Chalk, namely the continual depletion of run-off as the water-table is lowered, and its catchment area has gradually been reduced by the extension of the Rother, taking advantage of its course over weak sandy clays of the Sandgate Beds and Gault Clay to the east. As a result, the watershed between the Meon and the Rother has been pushed westwards and has become markedly asymmetrical. In the process, the Meon has been effectively separated from some of its tributary valleys, which have been diverted into the Rother system. The features described above suggest that Rake Bottom itself was the valley most recently diverted, and the change in direction at A (Figure 2) almost certainly marks the point at which it was captured by a pirate tributary of the Rother.

If this hypothesis is correct, it follows that Rake Bottom has been eroded in two distinct stages, the first as tributary to the Meon, and the second as tributary to the Rother. During the first stage, a valley similar in form and depth to those west and south of Butser Hill was formed. During the second, the valley was rejuvenated and deepened by a further phase of spring sapping at a lower level; and this last fact undoubtedly accounts for the present remarkable depth of incision of Rake Bottom in comparison with its neighbours.

3. THE VALLEY INFILL OF RAKE BOTTOM

In order to confirm that the flattening of the valley floor is indeed the result of accumulation of weathered material, and not an erosional feature attributable to torrent action, a preliminary investigation was recently made, with the aid of students from the Department of Geography, Southampton University. By kind permission of Mr. Sylvester of Lythe House, Ramsdean, a large hole was dug in the lower part of the valley at the point shown in

0–9 INCHES	DARK BROWN SOIL LAYER. VERY FEW PELLETS OF WHITE CHALK.
9–12 INCHES	A CHANGE TO LIGHTER BROWN LAYER. SMALL PELLETS AND FRAGMENTS OF WHITE CHALK BECOMING COMMON.
21–36 INCHES	A CHANGE TO WHITE LAYER COMPOSED OF SLIGHTLY ROUNDED WHITE CHALK FRAGMENTS. (1/2 to 2 Inches DIAMETER) IN A MATRIX OF WHITE CHALKY PASTE
36–42 INCHES	A "RUBBLE" LAYER. LARGE FRAGMENTS OF WHITE CHALK (3 inches DIAMETER) IN SOFT WHITE MATRIX. A LITTLE FLINT.
42–52 INCHES	A "FLINT" LAYER. LARGE FLINTS (3 to 6 Inches DIAMETER) WITH CHALK RUBBLE. SEVERAL FRAGMENTS OF MARCASITE.
52–84 INCHES	A SHARP CHANGE TO GREY CHALKY MARL. SMALL PELLETS OF GREY CHALK NEAR TOP. LARGER FRAGMENTS OF GREY CHALK, SHOWING LITTLE SIGN OF ROUNDING, APPEAR WITH INCREASING DEPTH NEAR BASE, FRAGMENTS 2 to 3 inches DIAMETER. AT BASE, PASSAGE TO HARD LAYER OF GREY CHALK (SURFACE OF LOWER CHALK OUTCROP?).

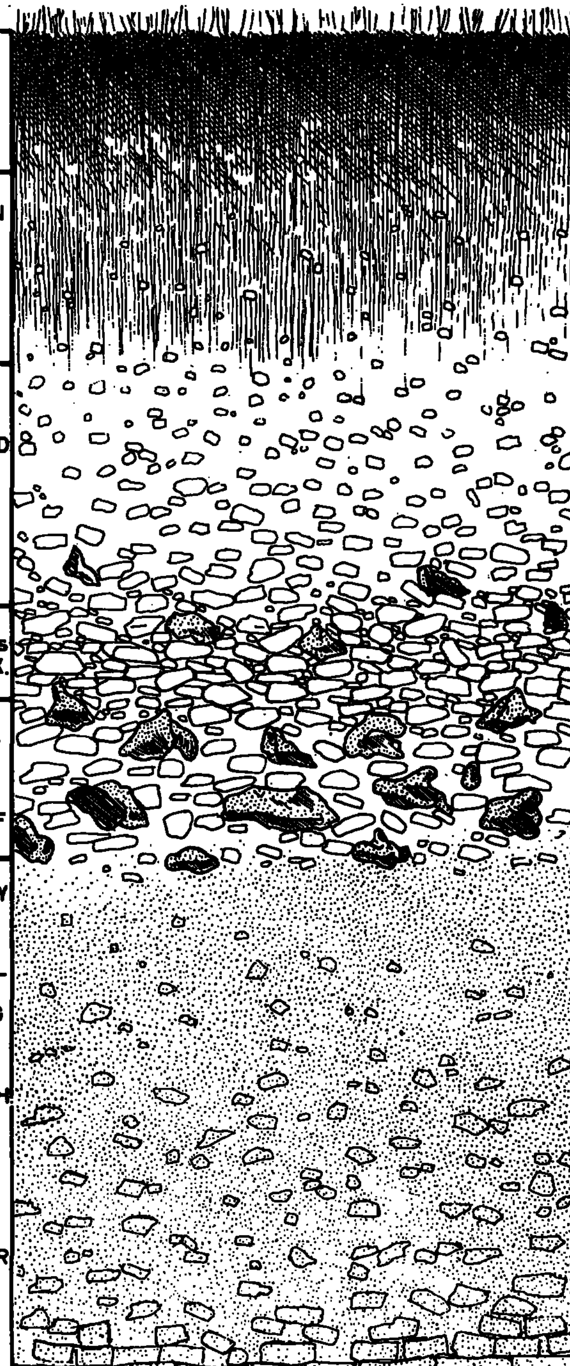


FIG. 3.

Figure 1. According to the Geological Survey, the rock outcropping here, and on the lower parts of the valley sides above the pit, is Lower Chalk; R. M. Brydone is more specific, mapping the outcrop as the *Holaster subglobosus* Zone of the Lower Chalk.[7]

The valley floor here is approximately 80 feet wide, but although situated only 15 feet from the base of the left-hand valley wall, the pit revealed seven feet of weathered Chalk infill; therefore, in the centre the true valley floor probably lies over fifteen feet below the present surface. The details of the section obtained are shown in Figure 3. From this it will be seen that the infill may be conveniently divided into two distinct parts. The lower 2½ feet, composed of strongly weathered light grey marly Chalk, is, to judge from its colour, texture, and the total absence of flints, almost certainly derived from the Lower Chalk (*Holaster subglobosus* Zone), and may even be material which has been weathered *in situ.* The upper 4½ feet is composed of weathered whiter Chalk, with a large number of slightly rounded fragments set in a pasty matrix. Near the base of this upper deposit, there is a good deal of flint, very much broken, together with several spherical and cylindrical nodules of marcasite. Flints are exceedingly rare in the Lower Chalk, but are found, in relatively small numbers, in the *Rhynchonella cuvieri* Zone near the base of the Middle Chalk. If the flints are derived from this horizon or, as is more likely, from an even higher level in the Chalk, it is clear that the deposit in which they now rest has been at least partly derived from soil creep on the valley sides above the pit, or from a form of sludging down the valley floor. Certainly the absence of any clear stratification and the limited rounding of the Chalk fragments suggest that the part played by running water in transporting the material from up-valley has been very limited. In further support of this view is the fact that the marcasite found with the flint is probably derived from the Lower Chalk, for it is noted by White[8] as being common in the *Holaster subglobosus* Zone a little way to the north. This admixture of material from different horizons is an expectable result of soil creep and sludging.

Failing a detailed palaeontological examination of the valley infill, it is possible merely to speculate as to its age. The absence of a fossil soil between the upper and lower deposits, or indeed at the base of the lower, would seem *prima facie* to indicate the possibility of both having formed or collected at a time when vegetation, and therefore humus, was non-existent in Rake Bottom i.e. during periods of severe climate in the Pleistocene. The broad resemblance of the deposit to Coombe Rock supports this view. This would mean that the valley cannot have supported, above the pit, a powerfully eroding spring or stream since the last glacial period, otherwise the deposit would have been rapidly flushed out.

On the other hand, Sparks and Lewis[5] have recently shown that deposits in the Pegsdon valleys which are almost identical in appearance to those at Rake Bottom contain warm fauna and are clearly post-glacial in age. As these authors point out, the general absence of humus from all but the highest layer of the infill poses a difficult question which cannot yet be answered.

4. CONCLUSION

In showing evidence of having been mainly formed by spring erosion, and in possessing the not uncommon history of capture and rejuvenation, Rake Bottom might with justice be referred to as an essentially normal feature of the physical landscape of East Hampshire. However, it is not at present possible to judge to what extent this process and these events were speeded up during the Pleistocene period. The form of the valley offers no clues, and study of the valley infill is no more helpful, since this is almost certainly recent and marks only the very latest stage in the evolution of the valley. Paradoxically, therefore, study of Rake Bottom throws comparatively little new light on the dry valley controversy, yet at the same time serves a useful purpose in underlining the point made in the introduction to this paper: that the controversy has perhaps been based on too extremist views, and that the difference between 'normal' and 'abnormal' erosion is sometimes more imaginary than real.

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