A BRIEF REVIEW OF SOME ASPECTS OF GEOMORPHOLOGY IN ENGLAND AND WALES

by

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Introduction

Ever since the beginning of the present century, topographic relief in Britain and America has been largely explained on principles associated particularly with the name of the celebrated American geomorphologist W. M. Davis. The chief assumption made is that the character of the relief of a region depends primarily on the evolutionary stage reached in the course of a 'geographical cycle' (also called a 'cycle of erosion') initiated by a relatively rapid uplift, and that such cycles, in various stages of completion, may be repeated. The exponents of these ideas claim to find examples of their application in Britain in features which seem to me to be readily accounted for on more general and already well-established principles. The philosophical virtue of economy of hypothesis ('Ockham's razor') seems to be neglected. However, there are now signs that a new look is being taken at some of the aspects of geomorphology.

I have elsewhere (1974) tried to put very shortly something of the essentials of my own ideas, as opposed to those of Davis. From this (p. 464) I quote nearly verbatim as follows:-

'Geomorphology became, and has remained, so steeped in the Davisian ideas that it is very generally taken for granted that any feature that can possibly be explained in accordance with them is to be so explained. Thus such things as uplifted peneplains (entire or as remnant hill-tops) are claimed as being recognized, and certain irregularities in river profiles are made to give evidence of successive cycles induced by successive uplifts. There appears, however, to be an obvious and fundamental flaw in his premise. Uplift is assumed to be so rapid as to produce, all at once as it were, an elevated surface on which erosion begins and develops its work until, perhaps, another relatively sudden uplift superimposes another 'cycle'. But erosion would begin at the first emergence of the region from the sea and it would go on as the land more or less gradually rose. It is very unlikely that the land would ever approach, much less reach, the height to which the earth-movement would have carried it, and its form would at all stages be determined mainly by its geological structure, differential erosion of the less and more resistant rocks being the guiding principle. The land surface would be worn away and sculptured as it rose. At the same time, this subaerial erosion (of various kinds but normally chiefly fluvial) would everywhere tend to produce its characteristic curves and features, evolving in its own way according to particular circumstances. A river-system might well be initiated by an original up-warp or tilt.

Surely that is a more reasonable assumption as to the action and results of earth-processes than is the Davisian model? If so, observed land-forms conforming to what may be inferred as a deduction from it must, as a matter of logic and common sense, preferably be explained in that way.'

D.W. Johnson was one of Davis's students and disciples and in his well-known book (1919) he applied an evolutionary hypothesis to coastal geomorphology. In 1949 I published a paper in which I analysed an opposite view, a view analogous to the one I take regarding the entirely subaerial erosion and denudation of an inland area.

Throughout the geological history of any particular region there were, it seems, long periods during which the uplift of the land gained on the contemporaneous and continual down-cutting and removal processes of erosion and denudation. Between these periods were long intervals in which the lowering of the land gained, on the whole, on the effects of up-rising

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tendencies due to earth-movement. The higher the land, at any time, above base-level (sea-level) the greater the power of the combined erosion-denudation process, but all the time there would be a continual balance and adjustment between earth-movement on the one hand and erosion-denudation on the other.

A powerful impetus to view without prejudice the factors controlling relief was given in America by the publication in 1960 of a paper by T. Hack of the United States Geological Survey. In this he advocates a principle which he calls 'dynamic equilibrium'. If I understand him correctly this principle, which he applies in considerable detail, largely accords with the one I have outlined above. Hack's work has been further discussed in the course of Schumm and Lichty's paper (1965).

In the present article I propose to consider very briefly a few representative regions of England and Wales by way of illustrating my own ideas. We shall chiefly be concerned with the history of the 'hill-top surface', by which I mean an imaginary surface draping the hills and ridges of a region (more or less closely according to how it is envisaged). This surface may be imagined as extending from the higher onto the lower parts of a region.

Examples of the hill-top surface

North Cardiganshire

This is a region composed of Ordovician and Silurian rocks, chiefly the latter. The view that has for long been advocated is that the hill-top surface here comprises several 'platforms' representing plains formed originally either just above sea-level (subaerial peneplains) or just below sea-level (plains of marine denudation) which have been successively raised by earth-movement, the highest, forming a plateau, being the earliest. My own view, first detailed in 1930, is that there is one surface, continuously carved by subaerial erosion out of a region uplifted, perhaps, during Tertiary times.

If we take the extensive 'high plateau' of the region, how is it that erosion, which has admittedly deeply dissected the plateau, has proceeded just so far as to leave intact the tops of the hills? The hills must surely have been lowered while the valleys were being carved out. The surface on which this morphological development was initiated would have been hundreds, if not thousands, of feet above the present plateau; that is, taking the action of the earth-movement by itself and ignoring the effect of erosion while the uplift was going on. I would explain the existence of the plateau as being the natural result of erosion working on rocks which, over the greater part of the area, are of much the same resistance. The mountain of Plynlimon, being composed of the harder Ordovician rocks in the core of a structural dome, stands out above the plateau on the principle of differential erosion.

The consideration of the production of this surface in Cardiganshire and the neighbouring country begins with A. C. Ramsay's paper 'On the denudation of South Wales' in 1846. He views the whole surface of Central Wales, hills and valleys alike, as an uplifted surface which had been not only planed off, but deeply hollowed out, by marine erosion. In 1866, with his attention on northern and north-central Wales, Ramsay put forward the same general idea of an uplifted planed surface but he now (1866) accepts the fact that the valleys have since been carved out by subaerial erosion. He recognizes plateau-surfaces, each at a different height, over several areas respectively of different rock-resistance, but he does not attempt to reconcile this correspondence with his hypothesis which, indeed, it seems clearly to contradict. He places the age of the uplift as far back as pre-Triassic (Hercynian) times. These views were repeated unchanged in 1881 and they were re-stated, with special reference to Cardiganshire, in his book on Great Britain (e. g., the last edition, 1894).

Ramsay's hypothesis, with variations, persisted, becoming more and more firmly fixed in geological literature. For instance, we find W. G. Fearnsides remarking that the Central Uplands of Wales are 'indeed an ancient peneplain deeply dissected ... probably an early

Tertiary surface of subaerial denudation' (1910). O. T. Jones's more detailed and precise rendering of essentially the same story, in 1911 and 1924, served to fix it still further.

In addition to the postulated uplifted plain forming the high plateau of northern Cardiganshire, several other 'platforms' have been forced on the relief, against all the evidence, including that adduced by the advocates themselves. Among the more recent publications in which this has continued to be done are those of E. H. Brown (1950, 1952, 1956, 1957, 1960) and O. T. Jones (1952, 1957, 1961). J. C. Rodda (1970) while claiming that his analysis supports a three-fold planation suggested by Brown (which it does not seem to do) nevertheless admits that 'it also indicates that Challinor's single surface is almost as appropriate'. I have reviewed this whole subject at some length (1951), reprinted with an additional paragraph (1969).

Snowdonia

The diversity of ideas about the origin and evolution of the present mountains of Snowdonia (formed out of Ordovician, with some Cambrian, rocks) was well shown at a meeting of the Geological Society of London on 3 November 1937, when a paper by Edward Greenly was read on 'The age of the mountains of Snowdonia' (published in 1938) and discussed by some of the most eminent geologists of the day.

When we view the Snowdon mountain-group from any point outside, for instance from Anglesey, we can imagine a line connecting the higher summits, and we see that this line is a fairly even one. Combining several such views we find that the summits reach a gently convex hill-top surface. This is also evident from a map showing the relief and the heights of the hills.

It may at first sight be tempting to suggest that this imaginary hill-top surface coincides with a once-real surface of a dome-shaped mass out of which the mountains have been carved by erosion.

Whatever the history of the height and relief of North Wales during Upper Palaeozoic and Mesozoic times may have been, it seems to be generally assumed (e.g. George, 1961, p. 77) that by early Tertiary times, at the latest, that region had become worn down to a low-lying, more or less level, surface. This surface may have been beneath the sea in late Cretaceous times (but there are no deposits of Cretaceous age) or a plain not far above sea-level. Again it seems to be generally assumed (e.g. George, 1961 p. 78) that this surface was later raised by stresses in the earth's crust, perhaps as a distant effect of the Alpine (Tertiary) orogenic movements. The supposed dome-shaped mass whose surface is envisaged as coinciding with the present hill-top surface might thus, as was suggested by Greenly (1938 pp. 119-120), have been formed by this uplift. There are, however, what appear to be fatal objections to this idea.

The same considerations apply here as in Cardiganshire and are even more obvious. I have called attention to them recently in writing about Snowdonia (1973). It seems particularly impossible here that the present hill-top surface could be, or could represent in any way, an original low-lying surface which had been uplifted into a gentle dome; any such surface would be completely lost, because while the valleys were being carved out, the whole surface could hardly escape being greatly lowered by the general erosion and denudation going on everywhere at the same time.

It is, however, highly improbable that any uplifted original unmodified surface ever existed. Erosion, both subaerial and marine, would start its work as soon as the plain began to rise. It would never reach the height or assume the form that would have been produced by the earth-movement alone.

The Lake District of Cumbria

The main features of the structural and morphological history of the Lake District appear to admit of little doubt, forming indeed a well-known 'model'.

The core of the region - that is, the Lake District proper - is, like Snowdonia, composed of Lower Palaeozoic rocks. Here, the highest mountains (the Scafells, Helvellyn, Skiddaw) all reach a little over 3000 ft so that there may be said to be a nearly horizontal hill-top surface at this level. Taking this mountainous core by itself there seems no reason why it should not have been suggested, as it was in the case of Snowdonia, that this imaginary hill-top surface, restored to reality, was a plain that had been uplifted to its present position. So far as I know, this suggestion has never been made; and with good reason, for it would have been difficult to maintain when the structure of the whole region was taken into account. As is very well known, the Lower Palaeozoic core is surrounded by Carboniferous rocks which presumably covered the whole area and which were uplifted in the form of a dome, subsequently being removed by erosion from the central part. This erosion has continued, cutting deeply into the resistant core which has remained all the time (particularly the part of it composed of the hard Ordovician rocks) to stand higher than its surroundings of later rocks. The radial drainage of rivers and lakes is assumed to have originated on this uplifted surface.

The geological history of the district is given diagrammatically in, for instance, Eastwood *et al.* (1971, p. 5); the uplift there being shown as renewed in post-Triassic times. Moseley (1972) places this second gentle doming as part of the Alpine (Tertiary) movements. We do not know the relative rates of uplift and contemporaneous erosion; a question which, in general, seems to be of the utmost importance in geomorphology.

S.E. Hollingworth, however, in two papers (1937, 1938), has claimed to recognize remnants of platforms at several levels corresponding approximately to nearly level surfaces formed originally just above or just below sea-level. He admits that these are 'deeply dissected and preserved in comparatively small residuals... However, owing to dissection, the varying resistance to erosion of the constituent rocks, and the masking effects of glacial erosion and deposition, the presence of platforms is not at first sight apparent. Nor are the residuals sufficiently continuous to indicate an obvious linking up on the basis of altitude' (1938, p. 56).

I have never myself seen anything in the landscape of the Lake District that would suggest the presence of any such 'platforms'. My contention throughout this review is to suggest that the logical procedure as regards interpretation is to show, first of all, that features such as so-called 'uplifted platforms' and 'rejuvenation effects' on river-profiles would not be produced by the normal action of erosion working on a stable land.

The Weald

A detailed review of the history of the development of the rivers and relief of the Weald of south-east England has recently (1973) been made by B.C. Worssam of the Institute of Geological Sciences (Geological Survey). To quote from parts of the preliminary matter of this paper:

'In 1895 W.M. Davis, in a paper dealing with a large part of eastern England, described the development of the rivers of the Weald in terms of his theory of the cycle of erosion. With this authoritative paper as their example most subsequent writers on the geomorphology of the Weald, up to and including Linton (1969), have tended to describe the Weald as providing straightforward illustrations of the working of the cycle of erosion theory. Wooldridge and Linton's *Surface and Drainage of South-East England*, published in 1939 and reissued with amendments in 1955, and which since its first publication has been regarded as the standard work on its subject (see Clayton, 1969), is certainly written from a Davisian standpoint' (p.1).

'The concept of dynamic equilibrium, put forward by J.T. Hack in 1960, provides a simpler explanation of the present topography of the Weald than does the cycle of erosion theory of W.M. Davis. Doubt is cast on the existence in the Weald of a '200-ft Platform'

and of a '400-ft Platform'. The evidence for a '600-ft' or 'Pliocene Platform' is reviewed; remnants of a Pliocene plane of unconformity on the Chalk of the North Downs form a topographical platform at about 600 ft above O.D., but S.W. Wooldridge and D.L. Linton's ideas on the denudation history of the Weald, based as they are on the assumption that this topographical platform represents the offshore equivalent of a Davisian peneplane, appear to be structurally unsound' (Summary on p.v.).

Worssam, however, if I have understood him rightly, seems to have some difficulty in establishing any very clear fundamental difference between the 'offshore equivalent of a Davisian peneplane' and a 'plane of unconformity', and (what is the most important similarity between the two) in either case the plane is supposed to have been raised to form a present platform (hill-top surface) at about 600 ft. The difficulty is the presence of several patches of Pliocene deposits, of various ages, at places on the Chalk at or near this level.

The difficulty would be removed - there would be no need to have any platform at all raised from below sea-level to 600 ft - if it could be shown that these Pliocene deposits were not *in situ*. In a paper by E.R. Shephard-Thorn (1975), another senior officer of the Geological Survey, the suggestion is made that these high-level deposits on the Chalk 'have been glacially transported to their present locations from the southern bight of the North Sea' (p. 538). He says: 'Traditionally, south-east England has always been regarded as lying beyond the maximum southerly extent of the Pleistocene ice-sheets in Britain. If, however, the recent proposals of former glaciations of the English Channel and adjacent areas, by ice-sheets originating on the western margin of the European continental shelf (Kellaway and Others, 1975; Destombes *et al.*, 1975), gain acceptance, many aspects of the development of the Wealden landscape call for fresh consideration. For example, could Wooldridge's Pliocene surface be in reality an old glacial terrain of the earliest Pleistocene, with the clay-with-flints its relict till and the high-level deposits of the Chalk downs glacially rafted equivalents of the East Anglian Crags?' (p. 544).

It therefore seems reasonable to suppose that both accordances (including the so-called 'bevels') and variations in height along the Chalk escarpments, and along the Lower Greensand escarpments, and the high central area of the Weald, are all due to erosion working on the principle of dynamic equilibrium; with any oscillations of sea-level during the Glacial Period being taken in its stride.

The two papers here discussed go deeply into their subject matter and are fully documented. Of the works they refer to, I here list only those mentioned in the extracts I have quoted above, with one exception, a paper by D.K.C. Jones (1974) which contains a detailed discussion and criticism of Linton's ideas.

Southern Pennines

The present state of ideas concerning certain aspects of the geomorphology of this region is shown in the publication by Walsh *et al.*, (1972), to which may be added the lively excursion report by Ford (1972). This paper, which is copiously documented with historical references, is concerned primarily with the Neogene Brassington Formation. In the first place it describes these highly interesting deposits, one of which contains fossil plants considered to be of Lower Pliocene age, and discusses the manner of their present occurrence in 'pockets' in the Carboniferous Limestone, having evidently foundered therein through a process of solution subsidence. Secondly, there is consideration of the bearing of these observations and inferences 'on the evolution of Upland Britain'. Throughout the paper these two strands are interwoven. Whereas the first is everywhere strictly factual and logical, the second is almost entirely speculation. The authors admit the speculative element, but they are clearly ready to accept without argument the presumption of uplifted planes of erosion. The critical, and linked, questions here are: at what geographical level (relative to sea level) was the Brassington Formation of sands, gravels, and clays deposited and how did it come to be at a considerable height, a height well above even its present position in the pockets of the limestone upland? The authors state that they are 'of the opinion that there can be little doubt that the Brassington Formation... accumulated in a terrestrial environment on what is now,

through uplift, a high-level planation surface above the Pennines' (p. 523). The other possibilities - though not seriously considered in the paper - are (1) that the deposits were formed *in situ* at the high level from which they seem to have foundered into the pockets or (2) that they had been transported, presumably by glacial action, to that high elevation from elsewhere.

There is no more fundamental and well-known fact-and-inference in geology than this - that it is a regular thing for deposits to be laid down in the sea and subsequently to be raised to form land (perhaps at a great height), the strata becoming more or less bent, broken, and deformed in the process. The Carboniferous rocks of the Pennines are an eloquent example of this; the uplift occurring at the end of Carboniferous times, as proved by the unconformable Permo-Trias. In contrast to this certainty is the extremely dubious evidence about the subsequent history of what is now the southern Pennines. For instance, what effect, if any, did the Alpine (Tertiary) movements have? As to the recognition, in the present relief, of uplifted planes of erosion; the criticisms that I have already made as regards the other regions considered (though so briefly) in the present article apply here as indeed throughout Britain and further afield. It is my native land on the western edge of the Peak District - the Namurian and Millstone Grit country of the Roaches, Morridge, Gun Hill, Shuttlingslowe - that I see so clearly in my mind as I write. It certainly appears to me that it would be very difficult to find any 'platforms' of uplifted erosion surfaces here, where there is such a beautiful expression of the intimate relationship between land-form and geological structure.

I leave it to the Mercian geologists to ponder, to reason, and to discuss.

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