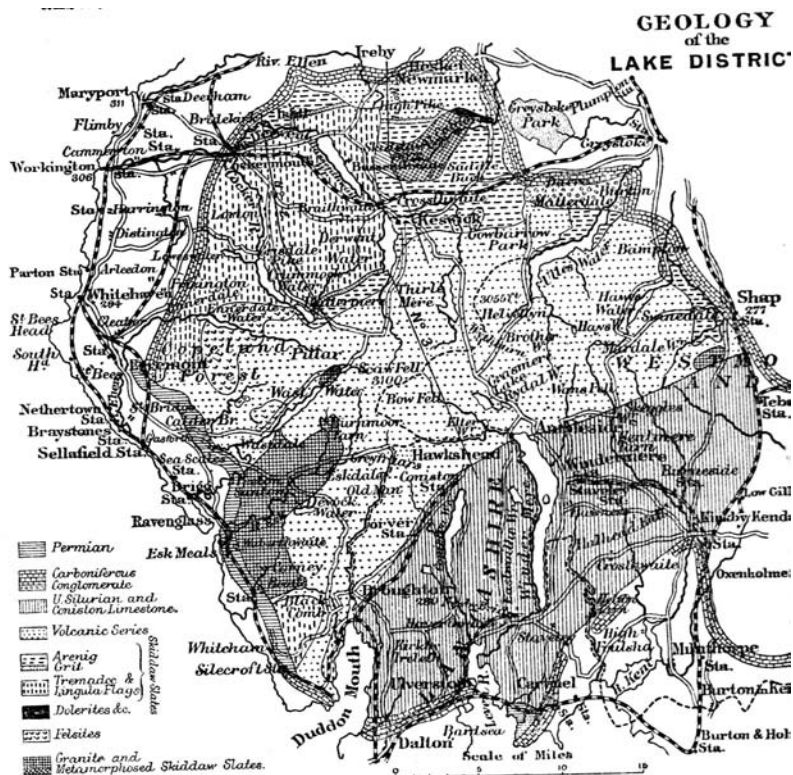


## II.—ON THE SUPERIMPOSED DRAINAGE OF THE ENGLISH LAKE DISTRICT.

By J. E. MARR, M.A., Sec. G.S.

“WHAT was the condition of our present mountain tract during the great Carboniferous period? Was it wholly submerged after the elevation and denudation to which we have already seen it subject, or was there always a nucleus of dry land—an embryo of Cumbria—around which the Carboniferous deposits were laid down? I do not think this is a question that can ever be decidedly answered.”<sup>1</sup>



It is a question which has frequently been asked, and the answer given are various. In the present communication I intend to look at it from a somewhat different point of view from that in which has usually been approached, though the view here adopted in many respects resembles that taken by the late Mr. Hopkins.<sup>2</sup> The ex-

<sup>1</sup> On the Physical History of the English Lake District, by the Rev. J. C. War GEOL. MAG. Dec. II. Vol. VI. p. 58.

<sup>2</sup> On the Elevation and Denudation of the District of the Lakes of Cumberland and Westmoreland, Q. J. G. S. vol. iv. p. 70.

influence which the faults have had in determining the trend of the major valleys is however of little importance to my present inquiry.

§ 1.—*Structure of the District.*

The well-known general structure of the district is seen in the sketch-map, which exhibits the Lower Palæozoic rocks nearly surrounded on every side by a girdle of Carboniferous Limestone, the strike of which is always approximately parallel to the line of demarcation between the older and newer rocks, the former rising up as an irregular dome within the latter. Whereas the main axis of the older rocks *within the district* runs through the Skiddaw group of hills, the present watershed is marked by an east and west line running through the Scawfell group across Kirkstone, and the passes at the heads of the Kentmere and Long Sleddale valleys to Shap Wells, whence it is continued in an easterly direction over ground occupied by Carboniferous rocks, separating the head-waters of the rivers Eden and Lune.

§ 2.—*Condition of the area at the commencement of Carboniferous times.*

Mr. Hopkins pointed out that the dip of the Carboniferous rocks was everywhere sufficient to carry them far above the present surface of the older rocks in the central part of the district, and he gives cogent reasons for supposing that they actually did so extend. As it is of the utmost importance that this point should be definitely settled, I propose here to give further arguments in favour of the submergence of the whole of the Lower Palæozoic area during Carboniferous times, and to show that the present drainage was certainly not impressed upon the district in pre-Carboniferous days.

The very uniform plain of denudation upon which the Carboniferous rocks were laid down in the Ingleborough region is well known, but those who maintain the existence of a pre-Carboniferous ridge over the area of the present Lake District require the cessation of this plain towards the west. But M.M. de Koninck and Lohest<sup>1</sup> show that the Lower Carboniferous beds of Belgium are represented by the conglomerate of the Ingleborough district, and it is probable that beds quite as low occur in the immediate proximity of the Lake District, though this point will be definitely settled when Mr. E. J. Garwood, B.A., who is now engaged in a detailed examination of the Carboniferous zones of the region has published his researches. If the Lake District area had stood out as an elevation at this period, the equivalents of the lowest strata of Ingleborough should be absent here. Not only does the Mountain Limestone form a nearly complete ring round the lakes, but at one point where the ring is broken by the complex group of faults uniting the Craven and Pennine fractures, great masses of the limestone are let down into the dome, as at Grey Rigg and Kendal, indicating that the limestone at any rate extended thus far.

Again, the folding of the Lower Palæozoic rocks would not give

<sup>1</sup> Notice sur le Parallélisme entre le calcaire Carbonifère du nord-ouest de l'Angleterre et celui de la Belgique, *Bulletins de l'Académie royale de Belgique*, 3<sup>me</sup> série, t. xi. no. 6.

rise to a ridge along the present line of watershed of the Lake District, but along the centre of the anticline, though there may have been higher ridges of older rock existing to the north of the Skiddaw axis, which determined the trend of the pre-Carboniferous valleys, and that this was the case is indicated by an examination of the mode of occurrence of the irregular patches of the basal Carboniferous conglomerate, and a study of their included pebbles. These conglomerates, from their extremely local distribution, are generally and probably rightly supposed to have been deposited in the troughs of inequalities, though there is some doubt as to the region from which the material was brought. Mr. Clifton Ward, in the paper cited, comments upon the close similarity between the pebbles of the Mell Fell conglomerate to the rocks forming the Ludlow beds of the Kendal district, and the great rarity of local rocks in the conglomerate. I have recently detected a pebble in the same conglomerate at Roman Fell near Appleby, containing a fossil which appears to be *Rhynchonella nucula*, a characteristic Ludlow form. But, that these pebbles came from the south is unlikely for the reason to be noted immediately, and similar rocks occur in the southern uplands of Scotland on the south side of what probably constituted a pre-Carboniferous mountain axis, so that the drainage may well have come from this direction. Prof. Hughes has detected in the same conglomerates in the Lune Valley, pebbles of the well-known Keisley limestone of Appleby, a peculiar and easily recognizable rock, which is developed in this form in no other part of the district, and which, for reasons which cannot be here given, is unlikely to occur elsewhere. This discovery indicates a drainage on the pre-Carboniferous slopes in a southerly direction, and suggests a northern source for the pebbles of the conglomerate. Now Keisley is separated from the Lune Valley by a continuation of the main watershed of the Lake District, so that at the time of the formation of the conglomerate, if the pebbles of the Lune Valley have actually come from Keisley, *the present watershed did not exist*, and indeed the way in which the Carboniferous rocks rise from Tebay to Shap Wells, and then sink to the Eden Valley, proves that this elevation was post-Carboniferous.

Recent discoveries, it will be seen, fully confirm Mr. Hopkins's conclusion that the Carboniferous rocks were laid down over the area of the present Lake District upon an even horizontal surface.

### § 3.—*Post-Carboniferous Changes. Formation of the Dome, and Determination of the Drainage.*

The examination of the area has shown, what would be *a priori* expected, that the pre-Carboniferous drainage was not determined by the more modern Lower Palæozoic rocks of the district, and these could be converted into the highest ground of the region by no other means than a further upthrust, which took place in post-Carboniferous times. Even then, the drainage would not radiate from an area of Lower Palæozoic rocks, unless these rose above the surrounding high ground caused by the accumulation of the up-

heaved newer sediments, and the thickness of the latter in the immediate proximity to the centre of the district forbids the supposition that a high mountain tract over which Carboniferous rocks were never deposited arose in that centre. If we prolong the Carboniferous rocks over the present area in accordance with their various dips at the margins, we shall find that *the centre of the dome composed of these rocks would coincide with the small tract from which the principal valleys radiate*, viz. the region of Scawfell and Gable. The appearance of the eight principal valleys extending from this point, like the spokes of a wheel, is beautifully described by Wordsworth.<sup>1</sup> They are Windermere, Coniston, Duddon, Eskdale, Wastdale, Ennerdale, the Vale of the Cocker, and Borrowdale. Further to the east the symmetry of the dome is destroyed by its prolongation in an easterly direction as an anticlinal (though even here the Carboniferous beds dip eastward on the summit of the anticlinal axis, showing that the district does not merely comprise the end of an anticline), and by the proximity of the great faults of the Lune Valley. Here, also, the radial character of the valleys is noticeable. To the north of the axis are the vales of Thirlmere, Ulleswater, and Haweswater, and to the south, those of Kentmere, Long Sleddale, Crookdale, Bannisdale, and Wastdale. This radial arrangement is well exhibited in the case of the valleys containing the larger lakes, on examining the small map. The valleys do not in all cases coincide with the observed or theoretical faults shown by Mr. Hopkins upon his map, though the general direction is the same.

The radiating disposition of the vales could not have been determined except by a somewhat regular dome-shaped upheaval of the country, and the trend of the Lower Palæozoic rocks shows no tendency towards the formation of a dome in them before the deposition of the Carboniferous rocks, whereas, as has been above noted, the dips of the Carboniferous rocks do point to the production of a post-Carboniferous dome, whose centre coincides with the point from which the valleys diverge. The drainage system is, in fact, strikingly similar to that represented by Mr. Gilbert in the case of the Ellsworth Arch,<sup>2</sup> even to the slight irregularity which occurs at the north end of the latter, owing to the proximity of Mounts Holmes and Hillers, and at the east end of the Lake District owing to the anticline separating the Lune and Eden Valleys, and the faults of the Lune Valley.

It is hard to resist the conclusion that in the Lake District, as in the Henry Mountains, we have a case of *superimposed drainage*, the valleys having had their direction determined by the slopes caused by the upheaval of the Carboniferous and possibly of newer rocks, though they now run in the centre of the district entirely through Lower Palæozoic rocks, the newer rocks which were the cause of their present trends having been completely removed by denudation.

This seems to me the strongest argument in favour of the former

<sup>1</sup> A Complete Guide to the Lakes, third edition, page 111.

<sup>2</sup> Geology of the Henry Mountains, p. 139, fig. 71.

extension of the Carboniferous rocks over the district, and the study of the valley-systems of other areas will probably enable us in many cases to argue concerning the former extension of beds over regions from which they have long since disappeared.

The duration of the movement which caused the elevation of the dome is hard to determine. There is no doubt that elevation had taken place before the deposition of the New Red Sandstone deposits of Edenside and the Cumbrian coast, for the latter rest unconformably upon the Lower Palæozoic rocks in places, and the former contain fragments of Mountain Limestone, whilst the sandstones were probably derived in great part from the denudation of the Carboniferous sandstones. In connexion with this point the rarity or absence of Lower Palæozoic pebbles in the New Red breccias of Edenside is noticeable, and has been commented upon by Mr. Goodchild.<sup>1</sup> It furnishes another argument in favour of the extension of the Carboniferous rocks over the central part of the district. But that the elevation was entirely carried on during the time that elapsed between Carboniferous and New Red Sandstone times is negated by the dip of the New Red itself, which, as observed by Mr. Hopkins and Mr. Goodchild, is sufficient to carry these deposits also over the central dome. Now, the north-east portion of the Lake District dome coincides with the western margin of the New Red basin of Edenside, and was therefore partly determined simultaneously with the latter.

The New Red Sandstones were apparently deposited in a fjord-like indentation produced during the deposition of these rocks (a point which is well worth working out in detail by any one who has carefully studied the characters and distribution of these rocks). But there appears to be no important physical break between the New Red deposits of Edenside and the lowest Jurassic beds of Carlisle. The position of the latter indicates that they also were deposited during the continuance of the formation of the basin, and there is no reason why these and newer Mesozoic rocks should not have once extended over the gradually rising dome of the Lake District. If this be so, the valleys of the district need not date back to any very remote period, and may even have been commenced in Tertiary times.

#### § 4.—*Origin of the Dome.*

It has been observed, that although the Lake District dome is a continuation westward of an anticlinal axis, it is, nevertheless, in a certain sense distinct from this axis. Not only is this the case, but it will be noticed, on examining a geological map of England, that the dome causes a marked asymmetry in the arrangement of the Carboniferous rocks.

The north and south Pennine axis, and the east and west axis separating the coal-field of Yorkshire, Derbyshire, and Nottinghamshire from that of Newcastle, and that of South Lancashire and North Staffordshire from that of Cumberland, give rise to a cruciform

<sup>1</sup> Trans. Cumb. and West. Assoc. 1885, p. 37.



arrangement of the coal-fields, but the north-west part of the cross is interfered with by the Lake District dome, and hence the Cambrian coal-field is of small dimensions as compared with that of Newcastle. Whilst the widespread movements which caused this cruciform arrangement were proceeding, a local movement has produced the asymmetry of the north-west portion. To what is this local movement due? Can the comparison with the laccolitic structure be carried further, and may we suppose that a lenticle of igneous rock lies at some depth below the Lower Palæozoic rocks of the Lake District? The evidence on this point is wanting. Most of the igneous rocks which penetrate the Lake District slates appear to have been intruded before the formation of the Carboniferous deposits, and the latter are remarkably free from igneous intrusions. Those which do occur are of a basic character.

The existence of the Whin Till indicates the occurrence of large masses of basic rock at a lower level, and it might be compared with one of the outlying sheets of the Henry Mountain laccolites. But the position of the igneous masses with which it is connected are not easy to fix, and the rocks of the Lake District and the surrounding area do not exhibit the abundance of basic dykes which one would expect in the vicinity of a laccolitic mass. There are a few dykes in the Carboniferous rocks of the Whitehaven district and near Ulleswater, and another dyke pointing to the Lake District is mapped by the geological surveyors in the Carboniferous rocks of Caton Green near Lancaster. Near the centre of the dome are several radial and tangential basic dykes, as seen in the geological map of the country around Wastwater, and these dykes are newer than the numerous acid dykes which cut through the same rocks, for they displace them. We may be allowed, then, to suggest the possibility of a mass of basic rock underlying and connected with the formation of the Lake District dome, without in any way insisting upon its probability.

Be this as it may, the superimposed drainage of the Lake District appears to be an actual fact, and the occurrence of this is an interesting point in the fascinating study of the physical history of this beautiful and remarkable area.

### III.—THE WORK OF PROF. HENRY CARVILL LEWIS IN GLACIAL GEOLOGY.

By WARREN UPHAM, of the United States Geological Survey.

THE recent notice<sup>1</sup> of the life and work of Prof. Henry Carvill Lewis, whose lamented death occurred in Manchester, July 21st, 1888, in his thirty-fifth year, well indicates the wide range of his scientific labours. He published valuable results of investigations in astronomy, mineralogy and petrology, and especially in glacial geology, the last being based on his exploration of the drift

<sup>1</sup> This MAGAZINE, III. Vol. V. pp. 428–430, September, 1888. A similar but more extended notice, with portrait, appeared in the *American Geologist* for December, 1888.