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[1] 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

[1] 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.

and its terminal moraines in the United States, and later in Ireland, Wales and England. The present article reviews his contributions to our knowledge of these drift formations and of the history of the Ice Age, bringing into comparison and correlation the glacial records of America and Europe. Comprehensive as were Professor Lewis' observations and studies in this field, he was planning yet more thorough and extensive exploration of the drift in Britain, Germany and Scandinavia, when he was taken from us. In his death the geologists of two continents mourn the loss of a most gifted and faithful fellow-worker, who indeed already had achieved a grand life-work in the few years allotted to him.

Professor Lewis first became specially interested in the glacial drift and the terminal moraine of the North American ice-sheet during the later part of the year 1880, when in company with Prof. G. F. Wright he studied the remarkable osars of Andover, Mass., the gravel of Trenton, N.J., containing palæolithic implements, the drift deposits of the vicinity of New Haven, Conn., under the guidance of Professor Dana, and finally the terminal moraine in Eastern Pennsylvania, between the Delaware and Lehigh rivers. The following year Professors Lewis and Wright traversed together the southern border of the drift through Pennsylvania, from Belvidere on the Delaware west-north-west more than 200 miles across the ridges of the Alleghanies to Little Valley, near Salamanca, N.Y., and thence south-westerly 130 miles to the line dividing Pennsylvania and Ohio, which it crosses about fifteen miles north of the Ohio river. The report of this survey of the terminal moraine was published in 1884, forming volume Z of the Reports of Progress of the Second Geological Survey of Pennsylvania. With the similar exploration of other portions of this great moraine done a few years earlier by Prof. Chamberlin in Wisconsin, Profs. Cook and Smock in New Jersey, and the present writer in Long Island, thence eastward to Nantucket and Cape Cod, and also in Minnesota, it completed the demonstration of the formation of the North American drift by the agency of land-ice.

The observations of the moraine in Pennsylvania detailed in this volume are summarized by Prof. Lewis as follows:—"The line separating the glaciated from the non-glaciated regions is defined by a remarkable accumulation of unstratified drift material and boulders, which, heaped up into irregular hills and hollows over a strip of ground nearly a mile in width, forms a continuous line of drift hills (more or less marked) extending completely across the State. These hills vary in height from a few feet up to 100 or 200 feet; and while in some places they are marked merely by an unusual collection of large transported boulders, at other places an immense accumulation forms a noteworthy feature of the landscape. When typically developed this accumulation is characterized by peculiar contours of its own,—a series of *hummocks*, or low conical hills, alternate short straight ridges, and inclosed shallow basin-shaped depressions, which like inverted *hummocks* in shape are known as *kettle holes*. Large boulders are scattered over the surface; and the unstratified *till*

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which composes the deposit is filled with glacier-scratched boulders and fragments of all sizes and shapes."

From its lowest point in Pennsylvania, where it crosses the Delaware 250 feet above the sea-level, this terminal moraine of the ice-sheet extends indiscriminately across hills, mountains and valleys, rising over 2000 feet above the sea in crossing the Alleghanies, and attaining the maximum of 2580 feet on the high table-land farther west, being there "finely shown at an elevation higher than anywhere else in the United States."

Preliminary outlines of Professor Lewis's work on the glacial drift of England, Wales and Ireland are given in his papers in the Reports of the British Association for 1886 and 1887; and the first of these also appeared in the American Naturalist for November, and the American Journal of Science for December, 1886, and in this MAGAZINE for January, 1887. Their most important new contribution to knowledge consists in the recognition of the terminal moraines formed by the British ice-sheets, which Lewis traced across Southern Ireland from Tralee on the west to the Wicklow Mountains and Bray Head, south-east of Dublin; through the western, southern and south-eastern portions of Wales; northward by Manchester and along the Pennine Chain to the south-east edge of Westmoreland; thence south-easterly to York and again northward nearly to the mouth of the Tees, and thence south-eastward along the high coast of the North Sea to Flamborough Head and the mouth of the Humber. It is a just cause for national pride that two geologists of the United States, Lewis in Great Britain in 1886, and Salisbury [1] the next year in Germany, have been the first to discover the terminal moraines of the ice-sheets of Europe. Like the great moraines of the interior of the United States, those of both England and Germany lie far north of the southern limit of the drift.

Another very important announcement by Professor Lewis relates to the marine shells, mostly in fragments and often worn and striated, found in morainic deposits and associated kames 1100 to 1350 feet above the sea on Three Rock Mountain near Dublin, on Moel Tryfan in Northern Wales, and near Macclesfield in Cheshire, which have been generally considered by British geologists as proof of marine submergence to the depth of at least 1350 feet. These shells and fragments of shells, as Lewis has shown, were transported to their present position by the currents of the confluent ice-sheet which flowed southward from Scotland and Northern Ireland, passing over the bottom of the Irish Sea, there ploughing up its marine deposits and shells, and carrying them upward as glacial drift to these elevations, so that they afford no testimony of the former subsidence of the land. The ample descriptions of the shelly drift of these and other localities of high level, and of the lowlands of Cheshire and Lancashire, recorded by English geologists,[2] agree

[1] American Journal of Science, III. vol. xxxv. pp. 401-407, May, 1888.

[2] Quart. Journ. Geol. Soc. vol. xxx. 1874, pp. 27-42; xxxiv. 1878, pp. 383-397; xxxvi. 1880, pp. 351-5; xxxvii. 1881, pp. 351-69; and xliii. 1887, pp. 73-120; also, GEOL. MAG. Dec. II. Vol. I. 1874, pp. 193-197.

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perfectly with the explanation given by Lewis, which indeed had been before suggested, so long ago as in 1874, by Belt and Goodchild.[1] This removes one of the most perplexing questions which glacialists have encountered, for nowhere else in the British Isles is there proof of any such submergence during or since the Glacial period, the maximum known being 510 feet near Airdrie in Lanarkshire, Scotland.[2] At the same time the submergence on the southern coast of England was only from 10 to 60 feet,[3] while no traces of raised beaches or of Pleistocene marine formations above the present sea-level are found in the Shetland and Orkney Islands.[4] The work and writings of Professor Lewis emphasize the principle that glacially transported marine shells and fragments of shells, which occur in both the till and Boulder-clay and the modified drift in various parts of Great Britain, are not to be confounded with shells imbedded where they were living or in raised beaches, for only these prove the former presence of the sea.

The drift deposits of England south of the terminal moraines traced by Lewis were regarded by him as due to floating ice upon a great freshwater lake held on the north by the barrier of the ice-sheet which covered Scotland, Northern England and the area of the North Sea, and on the south-east by a land barrier where the Strait of Dover has been since eroded. Under this view he attributed the formation of the Chalky boulder-clay in East Anglia, and of the Purple and Hessle boulder-clays in Lincolnshire and much of Yorkshire, to lacustrine deposition. But shortly after the British Association meeting in 1887 his observations on Frankley Hill in Worcestershire and thence westward[5] led him to accept the conclusion, so thoroughly worked out by other glacialists both in America and Great Britain, that there were two principal epochs of glaciation. divided by an interglacial epoch when the ice-sheets were mostly melted away. There can be little doubt that the continuation of Lewis's study of the drift in England, if he had lived, would have soon convinced him of the correctness of the opinions of Searles V. Wood, jun., Mr. Skertchly, and James Geikie,[6] that land-ice during the earlier glacial epoch overspread all the area of the Chalky boulder-clay, extending south to the Thames. Small portions of Northern England, however, escaped glaciation both then and during the later cold epoch, when the terminal moraines mapped by Lewis were accumulated; and these tracts of the high moorlands in Eastern Yorkshire and of the eastern flank of the

[1] Nature, vol. x. pp. 25, 26, May 14, 1874; Geol. Mag. Dec. II. Vol. I. pp. 496–510. Nov. 1874. A similar opinion was held fifty years ago by Mr. James Smith (Researches in Newer Pliocene and Post-Tertiary Geology, pp. 11, 16), though he attributed the drift to debacles instead of glaciation.

[2] Quart. Journ. Geol. Soc. vol. vi. 1850, pp. 386–8; xxi. 1865, pp. 219-21.

[3] Quart. Journ. Geol. Soc. vol. xxxiv. 1878, pp. 454-7; xxxix. 1883, p. 54. Geol. Mag. Dec. II. Vol. II. 1875, p. 229; Dec. II. Vol. vi. 1879, pp. 166–72.

[4] Quart. Journ. Geol. Soc. vol. xxxv. 1879, p. 810; xxxvi. 1880, p. 663.

[5] Geol. Mag. Dec. III. Vol. IV. pp. 515-17, Nov. 1887; Vol. V. p. 430, Sept. 1888.

[6] Quart. Journ. Geol. Soc. vol. xxxvi. 1880, pp. 463-500; Great Ice Age, second ed. pp. 350–365.

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Pennine Chain[1] are similar to the driftless area of South-western Wisconsin.

Comparison of the drift in North America and Great Britain enabled Prof. Lewis to refer the British modified drift, both that often intercalated between deposits of till and that spread upon the surface in knolly and hilly kames and more evenly in plains and along valleys, to deposition from streams supplied by the glacial melting, the material being washed out of the ice-sheet. These beds are to be carefully distinguished from others, similar to them in condition and material, which are of interglacial and post-glacial age. In this connection it is also important to discriminate between subglacial till or ground moraine and englacial till that was contained in the ice-sheet. The differences marking these deposits in New England and generally through the northern United States[2] are the remarkable compactness and hardness of the subglacial till, due to compression under the ice-sheet, contrasted with the looseness of the englacial till; the abundance of glaciated stones and boulders in the former, and their comparative infrequency in the latter; and the usually greater proportion of large boulders in the englacial till. Weathering has changed the small ingredient of iron from the protoxide combinations which it still retains in the lower or subglacial till to hydrous sesquioxide in the upper or englacial till, giving to the latter a yellowish or reddish colour, in contrast with the dark grey or blue of the former.

Beds of modified drift, that is, of gravel, sand and clay, brought by streams from the melting ice-sheet, may occur (1) enclosed within subglacial till, (2) intercalated between the subglacial and englacial till, or (3) overlying all other drift formations. In the first and second cases they were deposited beneath the ice-sheet, or sometimes in the second case were laid down in front of the ice-border and afterward became covered with englacial till by an advance of the ice. Prof. C. H. Hitchcock describes abundantly fossiliferous marine modified drift which he believes to have been thus overlaid by englacial till at Portland, Maine.[3] To the third case, where the modified drift is superficial, belong osars and kames, formed in ice-walled channels, and the more extensive plains and valley drift spread along the course of the floods that descended from the ice-border to the sea. In districts to which the ice-sheet transported fragments of marine shells, these are liable to be found not only in both divisions of the till but also in any portion of the modified drift.

The geologists of Sweden record a similar order of drift formations in that country, there being generally recognizable subglacial and englacial till, with associated beds of stratified gravel, sand and clay.[4]

[1] A. Geikie's Text-Book of Geology, p. 903; Quart. Journ. Geol. Soc. vol. xxxii. 1876. pp. 184-190.

[2] Geol. Mag. Dec. II. Vol. VI. 1879, p. 283; Third Annual Report of the U.S Geological Survey, p. 297.

[3] Geology of New Hampshire, vol. iii. pp. 279-282; Geol. Mag. Dec. II. Vol. VI. 1879, pp. 248–250.

[4] American Journal of Science, III. vol. xiii. 1877, pp. 76-79; Great Ice Age, second ed. p. 405.

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In north-eastern England it seems worthy of inquiry whether th Purple and Hessle boulder-clays may not be in like manner the sul glacial and englacial till of a single ice-sheet, its modified drift bein the Hessle gravel and sand. If this view be admissible, the Hessl beds containing *Cyrena fluminalis* and mammalian remains, wher they are overlain by the Hessle boulder-clay, mark an extensive re cession and subsequent advance of the ice.[1] Again, in north-wester England the Lower and Upper boulder-clays and Middle beds o gravel and sand have the same relationship. These groups of drif deposits, bounded wholly or in part by the terminal moraines trace by Lewis, probably belong, like the conspicuous terminal moraine of the United States, to the second or last glacial epoch; while th Chalky boulder-clay, like the southern portion of the glacial drift i the Mississippi basin, extends beyond these to the limits of an earlie glaciation.

IV.—On Soda-Microcline from Kilimandscharo.[2]

By J. S. Hyland, Ph.D., M.A.,
Of the Geological Survey of Ireland.

The material, in which this felspar occurs, was collected by Dr Hans Meyer during his visit in 1887 to the East-African "snow-mountain," the Kilimandscharo, and kindly entrusted to me for description by Prof. F. Zirkel of Leipzig, to whom I desire to express my indebtedness for assistance and advice supplied me whilst working in his laboratory.

The rocks which possess this mineral as felspathic constituent are Nepheline- and Leucite-basanites,[3] and were found *in sitû* on the south and south-east flanks of the Kibo peak. As rock-constituent this felspar is presumably confined to the outflows from the higher peak—the Kibo[4]—as no trace of it is to be found in the large series of rock-specimens, which represent the materials of which the other and lower peak—the Kimawenzi—is formed.

It is remarkable that Gustav Rose,[5] who described the collection of specimens brought back from the same locality by Baron von der Decken in 1861 and 1862, mentions the occurrence in a rock he terms "trachyte" of a curious porphyritic felspar "whose crystals are rhombic prisms, so that a transverse section parallel to the best cleavage face appears as a rhomb." From his description I hold this felspar to be identical with that which Dr. Meyer collected.

[1] Quart. Journ. Geol. Soc. vol. xvii. 1861, pp. 446–456, and 473–5; Great Ice Age. second ed. pp. 372–380.

[2] The orthography used by R. Andree and A. Scobel in their Map of Africa (Leipzig, 1884) is here employed.

[3] Under "Basanite" Rosenbusch (Mikrosk. Phys. ii. p. 753) includes all Tertiary massive rocks, which possess as essential constituents plagioclase (usually a basic lime-soda-felspar), nepheline or leucite, augite. olivine and magnetite. The name was first employed by Alex. Brongniart (Classification et caractères minéralogiques des roches homogènes et hétérogènes, Paris et Strasbourg, 1827, pp. 102–105). This is the *first* occurrence of Leucite in Africa. For further particulars, see Hyland, "Ueber die Gesteine des Kilimandscharo und dessen Umgebung," Tschermak's Mitt. 1888, X. 203–267.

[4] 6090 metres high.

[5] Zeitschrift für allgemeine Erdkunde, Berlin, 1863, vol. xiv. p. 246.

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