THE
GEOLOGICAL MAGAZINE.

No. CX.—AUGUST, 1873.

ORIGINAL ARTICLES.

I.—ON THE SURFACE-GEOLOGY OF THE NEIGHBOURHOOD OF CROSS
FELL, IN CUMBERLAND.¹

By C. E. DE RANCE, F.G.S.

THE eastern margin of the Vale of Eden, in the neighbourhood of Blencairn, Ousby, and Melmerby, is abruptly terminated by a steep and lofty escarpment, which rises to an eminence of 2892 feet at Cross Fell, 2331 feet at Melmerby Fell, and 2082 feet at Fiends Fell, the elevations between these points being nearly as great. Eastwards, from the top of the escarpment, a large expanse of elevated moorlands slope gradually towards the North Sea.

The upper portion of the escarpment consists of successive scars of limestone and grit resting conformably on "Old Red" Sandstone and Conglomerate, lying in denuded hollows of Lower Silurian rocks, which form the base of the range, and abut against the Permian Sandstone, brought in by the Pennine fault.

In general aspect the Cross Fell escarpment may be compared to that of the North Downs near Folkestone, the Limestone scars corresponding in a scenic point of view to the Chalk (weathering in very similar curves), the Old Red and Lower Silurian to the Gault, and the Permian and Boulder-clay plain to that of the Lower Greensand.

Near Folkestone lines of springs occur at the base of the Chalk, the overflow of a wedge of water partially held back by the sea, after flowing down the dip of the strata. Springs occur on the face of the Cross Fell escarpment, above impermeable beds of shale, with a similar inwards dip, the overflow probably being caused by the outlets of the water, the lower outcrop of the water-bearing stratum not being sufficiently large for the volume of water flowing out into the streams.

The continuity of the lower escarpment of Cross Fell is broken by several valleys cut back into the breast of the hill, as Ardale, between Muska Hill and High Cap. This valley runs a mile into the hill to a height of 1750 feet, after which the stream flows over a sloping plain and through an escarpment "Black Doo," through which it has cut a V-shaped hollow.

North of this, nearer Melmerby, is an extremely wild valley,

¹ The notes on the Cross Fell district were chiefly made during a holiday expedition into that country in July, 1872, and partly when in the adjacent country with Prof. Hull, F.R.S., in April of the same year.

Ousby Dale, excavated almost entirely in Silurian rocks, overhung, on the west, by Cuns Fell, 1760 feet high, the top of which was found by Prof. Hull and myself to be composed of Minette. This valley, the level of which is above 1250 feet, splits into several branches, or rather the stream (rising in the peat-covered plain above) divides into several runnels, which flow rapidly down the escarpment without forming a valley. Great numbers of these streams do not appear to originate in springs, but to draw their supplies from a sheet of water at the base of the peat,¹ which on the slopes is extremely wet, but becomes drier nearer the watershed, which is an extremely flat arch in section, with the water flowing below the surface as a sheet, and never differentiating into a stream, the first intimation of which appears to be at the foot of the curved slope, where the water breaks out and appears at, and on the surface, and then eroding the peat into channels, forms the first beginning of a stream.

On the south side of the Cross Fell escarpment is the Great Dale, through which flows Crowdundle Brook, which separates Cumberland from Westmoreland. At the foot of the escarpment it meanders across a narrow alluvial plain, bounded on either side by cliffs of Permian Red Sandstone and Boulder-clay.

Between the Pennine fault and the escarpment there is a terrace of Lower Silurian rocks rolling in a series of W.S.W. anticlinal and synclinal folds under the Old Red Sandstone conglomerate, which forms the conformable bed of the Limestone series. Of these beds, especially of the Skiddaw Slate, magnificent sections² are exposed, where Crowdundle beck has worked across its alluvial plain, and eaten back the bluff margining the terrace into cliffs, more or less covered with Boulder-beds; and at still higher elevations on Grumphy Fell may be noticed many large boulders of felsitic ash and breccia, and also of Permian Sandstone, at 1300 feet above the sea by the aneroid.

Within the escarpment the Great Dale is extremely wild, the bottom scattered with irregular heaps of rounded and angular masses of rock and stones, through which the brook forces its way in two and sometimes into three changing and shifting channels. These stones are partly derived from cliffs, which are very fine, especially those on the north or Cross Fell side, which rise 500 feet in a horizontal distance of 370 yards (from 1508 to 2000 feet above the level of the sea) at Willie Bed, from which the ground slopes gradually up to the last small escarpment forming the top of Cross Fell.

Ascending the beck after leaving hard felsite, which apparently rests conformably on the Skiddaw Slates at 1149 feet, not much is seen until the Old Red Sandstone is reached, dipping into the hill

¹ Every peat-covered plateau, in fact, acts precisely as an ordinary sponge filled with water; never giving off any considerable streams, save after rains, when the spongy mass is surcharged with moisture and pours into the Dales those peat-stained moorland waters which painters love so dearly to depict.—EDRT. GEOL. MAG.

² From one of these sections Prof. Nicholson obtained *Agnostus Morei*, Salt., and other rare fossils.

from 1250 feet to about 1400 feet above the sea, the thickness being not less than 400 feet; the pebbles are chiefly derived from the Volcanic rocks of the Lake-district.

From the forms discovered by Dr. Nicholson in the beds of this age, it would appear to have been deposited in very shallow water, and at the base it often rests on old valleys, which in some cases appear to coincide with the modern one in this direction, as Little Dale, west of Grumphy Fell, in the bottom of which occurs an outlier of Old Red Conglomerate, 100 feet below the base of the main mass. This formation cuts off the upward extension of the joints, fissures, and vertical dykes of siliceous red hæmatite so common in the Volcanic series under Cross Fell; but whether the iron in them, and in similar dykes in the Lake-district described by the late Mr. John Bolton, was derived by percolation from the red beds of the Old Red Sandstone above, is a doubtful point, though it is very possible that what may be called the primary or upper valleys of the Lake-district were Old Red lake-basins, from which all Red Beds have since been removed by later denudations, except in the district flanking the Lake-district, as at Butterswick, and near Ulleswater, etc., where Prof. Phillips, F.R.S., has described them.

Following Crowdundle beck to the watershed,¹ the alluvial flats disappear, the sides approach, and the valley becomes a V-shaped gorge, with cliffs gradually steeper and steeper, various limestones and sandstones dipping into the hill at about 15°, until weathered basaltic columns of the Great Whin Sill are seen standing, each separate, like a row of gigantic figures against the skyline. This magnificent sheet of basalt, measured by the aneroid, appeared to be 100 feet in thickness. Its upper surface, where cut into a little notch by the beck, was about 1840 feet above the sea. A little above occurs the Tyne-bottom Limestone, which reappears on the dip, on the other side of the Fell, many miles to the east, forming the bottom of the South Tyne. At about 2000 feet the gorge rather widens, and a small waterfall occurs over a shale bed, which is gradually being worn back under sandstone; but it again contracts, near a mine level, and becomes smaller and smaller, until it is lost in a mere runnel, in the thick peat forming the col, 400 yards on the eastern side of which the Tees takes its source in a similar runnel, at 2502 feet above the sea.

From the col, which has an elevation of 2540 feet, down to the River Tyne, the country consists of long dreary moors sloping gradually eastwards, through which the Tees has formed an ex-

¹ In addition to the great watershed running along the Cross Fell range in a general N.N.W. direction, separating the waters that flow into the North and Irish Seas, another originates in the terraced scars of that mountain, running a little north of east, separating the valleys of the Tees and the South Tyne, passing near the source of the latter river to Bel Beaver, on which is some evidence of an old camp, from whence it turns northward to Burnhope Seat (2452), and runs along that range of hills (the boundary between Durham and Cumberland, and afterwards, further north, between the former and Northumberland), parting the waters of Weardale from those of the rivers East and West Allen.

tremely shallow valley, with a peat-covered alluvial plain, bounded by low cliffs, which increase in height to some sixty feet at Providence Vein, opposite the sources of the Tyne. The slope of the country is that of the beds; but the latter dip at a rather stronger angle, the lowest of the Cross Fell beds being, however, the Great Whin Sill.

The whole of this Upper Tees Valley would appear to be pre-glacial, for Boulder-clay occurs on the cliff tops well within the very head of the valley under the col. The gradual denudation of valleys by river-action is well seen in the higher course of the South Tyne, and of the Tees. Between Alston and Garrigill, strong stone walls, locally called Warrens, built in the last century to keep the river from eating away the land, are now in the centre of alluvial meadows, some distance from the river, and several feet above its level. In some places there are at least three terraces, but generally they have been swept away by the river, which constructs a fourth with a portion of their *débris*, and new spoils from above. From Garrigill, which is built on the lowest alluvial terrace, to Tynehead Smelt Mill, the river flows on the Tyne-bottom Limestone; a little north of this point the "Great Sulphur Vein" brings the Great Whin Sill to the surface, which forms a great boss, more or less glaciated, and covered on the west side of the river with dark-grey Boulder-clay, with many rounded and sub-angular stones, most of which are scratched, at an elevation of 1560 feet above the sea. The river has cut a narrow notch through the basalt, but not completely, for there is a small waterfall—"Tynehead Force." In the deep tributary valley of Shield Waters there is a much finer waterfall, Cashburn Force, also on the basalt; fine cliffs of columnar basalt were also found by Prof. Hull and myself near Smittergill Mine.

Above the Smelt Mill the deep glen gradually contracts the cliffs on either side, until, at the source of the Tyne, two long sweeping peat-covered slopes range upwards to the top of Bel Beaver Rigg to the east, and Noonstones to the west; the top of the former hill is said once to have been a Roman camp.

From the top of the col, above the source of the Tyne, the ground on the other side slopes gradually down to the nearest point of the River Tees, which flows past in direction nearly at right angles to the course of the Tyne. Thick deposits of dark grey Boulder-clay form the banks of Crookburn, above the Tyne-bottom Limestone, which is glaciated near its junction with the Tees. I found Boulder-clay as high as 1770 feet towards the source of the river, but none on the col between Tees and Tyne, or the still higher col between the Tees and Crowdundle beck, which runs into the Eamont, in the vale of Eden, resting on the Permian sandstone of that vale. Between Penrith and the foot of Cross Fell are sheets of Upper Boulder-clay, with an underlying sandy gravel, which in Melmerby, Ousby, Blencarn, and Skirwith, contains erratic rounded pebbles of the Lake-district, much resembling in character, as well as in that of the matrix, the Boulder-clay of Lancashire. Erratic

pebbles and blocks abound on the Silurian hills at the bottom, forming the lower slopes of the Cross Fell range, and even on the lower portions of its magnificent limestone escarpments, the lowest of which, the Melmerby Scar Limestone, is 131 feet in thickness. The escarpment runs along the strike of the beds, but here and there they have been cut back, and deep openings and narrow valleys break the uniformity, and well show the inward dip, even at a distance. This was particularly the case when I first saw this range, at the end of April, when the escarpments were picked out with snow, which lingered on in crevices until nearly June.

II.—NOTES ON THE EXTENSION OF THE BOULDER-CLAY OVER THE GREAT AND LITTLE ORME, AND THE CEMENTING TOGETHER BY LIME OF SOME LARGE BOULDERS IN THE CLAY NEAR THE LITTLE ORME.

By W. C. LUCY, F.G.S.

HAVING seen an account, in Notes of the Geology of the District round Llandudno, by the Rev. W. S. Symonds, that shells had been found by Mr. R. D. Darbishire, F.G.S., in some clay near the New Baths at the Great Orme, it occurred to me that the clay was Boulder-clay, and would probably not be limited to so small a patch, but that it most likely extended far over the hills. And I now propose to give, very briefly, the result of some observations on the subject made during a short stay at Llandudno.

The Orme is composed of several squatted, rounded masses of Carboniferous Limestone, resembling huge farmhouse loaves, which give form to small valleys or gullies. Now I noticed that in these valleys or gullies there was vegetation; some corn crops were growing, and on examination the soil was found to be the remains of the Boulder-clay. Near the Copper Works is a large boulder of several hundredweight, resting on the clay, which is traceable over the hill, but in places only a very thin covering is left. The highest rounded portions are bare, which may be owing to there having been no place for it to rest at the time the clay swept over the hill.

In the cuttings made in forming the roads, good sections of drift occur several feet thick, containing boulders of large size.

On the shore at the Little Orme is a fine exposition of the Boulder-clay, with imbedded drift, as shown in the accompanying sketch. It varies very much, but at the point marked + the following is an accurate section:—On the surface is about a foot of soil, resting upon four feet of Boulder-clay, followed by eight to ten feet of angular drift, some blocks of great bulk and cemented together by lime, and reposing upon ten to twelve feet of drift of smaller size only partly cemented.

Several masses of the cemented drift were lying upon the beach, and the largest two are represented by the following drawings:—Fig. 1 shows a big block of smooth limestone with a face of about 5 ft. 6 in. long, 4 ft. 6 in. wide, and 5 ft. thick, to which was attached a huge mass of the drift 7 ft. long by 4½ ft. thick, containing large