fragment of *Nucula Cobboldia*, to which some doubt is attached, all the rest of the Wexford shells being living species of ordinary depths, and of not distant shores. If *Nucula Cobboldia*, however, be really present in them (not of course as a derivative, as it is in the Aberdeenshire gravel), it would suggest a greater antiquity for those sands than any Glacial bed of the North-west of England or of Scotland seems to possess.

If any of the readers of this MAGAZINE have the opportunity of collecting from the Wexford beds, I should esteem it a favour if they would send anything they can find by post (duly secured against injury) to me at the subjoined address, when they would be carefully examined by my father and myself, and promptly returned to the sender.

In conclusion, I should add that the possibility of the shells from the East Anglian Mid-glacial being derivative has been duly weighed; and for several reasons, intrinsic and extrinsic, which I have not space to set out, that possibility has been rejected as inadmissible.

BRENTWOOD, ESSEX.

VI.—ON THE GLACIATION OF THE NORTH-WEST OF ENGLAND.

By C. E. DE RANCE, F.G.S.,
of the Geological Survey of England and Wales.

IN bringing the last of a long series of papers on the Surface Drifts of the Lake District of Cumberland and Westmoreland to a close, Mr. Mackintosh sums up the general results at which he has arrived. All will agree with the first of his conclusions, "that land-ice *may* have planed, smoothed, polished, and striated rock surfaces, and pushed loose débris forward. . . ." But I cannot see his reason for adding, "to the nearest *protected* situations," for one would expect to find a terminal moraine at the *open* entrance of a valley, on a plain, or even on what can be proved to have been a true sea-bottom.

Thus, Mr. Lamont, F.G.S., described in 1861 a glacier in Deeva Bay that was separated from its terminal moraine by two miles of water, mostly covered with "fast ice;" the moraine being three and a half miles long, 200 to 400 yards broad, and twenty to thirty feet in height. As Mr. Lamont observed in this bay bones of the whale, of apparently no great age, at an elevation of forty feet above the sea, the whole of this moraine would appear to have been formed under the sea, being pushed along the sea-bottom by the backward weight of the glacier, which formerly extended further than at present, and filled up what is now the space between the "island moraine" and the land. And, in another instance, he observed a glacier extending *into the sea*, and actually in the process of pushing before it "a huge moraine of mud and débris, the base of which is washed by the sea, . . ." which becomes muddy "for several miles around."

All scratched and polished surfaces of rock *in situ*, now covered by deposits, which, from stratification, the presence of marine shells or of rounded boulders, can be proved to be *marine*, I consider to

have been formed beneath *low-water* mark, either by the grounding of icebergs, or by the seaward prolongation of glaciers, which, on retreating, left a vacant space, afterwards filled up by Boulder-clay, with or without subsidence of the sea-bottom. Mr. Mackintosh states¹ that "one of the fundamental principles of geology" is, "that the sea preserves the most delicate marks on rocks in *areas of deposition*," and accuses me of overlooking it, in affirming that the Grange *rôche moutonnée* has not been touched by the sea since its formation.² It appears to me, if we assume these rocks to have been rounded under the sea, and the associated mounds to be of marine origin, that as they are now *above* the sea (and, in fact, above Derwentwater), their movement betwixt land and water must have been in an *upward* direction, and that Mr. Mackintosh must, therefore, prove another fundamental principle (?) in geology, "that the sea preserves delicate marks on rocks in *areas of elevation*." If the *striæ* were made under the sea, as they are now above it, they necessarily, in process of elevation, must have been exposed to the action of the waves on the tidal or littoral zone, and when so exposed must have suffered denudation.

Mr. Godwin-Austen, F.R.S., has shown,³ "that the tidal zone" is capable of division into two belts, an upper, composed of clean shingle, and a lower, seldom broken up, and covered with sand and mud, with various species of plants and animals growing on the isolated stones. He has also shown that the greatest movements of pebbles on a beach take place on the upper zone, especially at its upper edge. I have generally found the lower sub-belt to commence a *little below* neap-tide high-water mark, ending at the lowest water margin, the upper sub-belt terminating at the highest limit of breaker action. It is along this edge, or upper margin, that the sea exerts its denuding agency; for in the lower portion it merely causes a movement of pebbles, in the direction of the "flow-tide," but in the seaward sub-belt, stones of only two or three pounds weight will remain, when the coast slopes at a low angle, for weeks and even months, in the same position: delicate *Conserveæ*, and numerous, but slightly prehensile marine organisms, remain unscathed, and the fine *striæ* of glaciated stones and boulders retain the sharpness of their sculpturing. It follows, (1) that should a rock-surface be glaciated above the sea-level, and be afterwards submerged beneath the waves, it will necessarily suffer denudation on passing the upper edge of the tidal or marginal zone; (2) should a surface of rock be glaciated in the lower belt of the tidal zone, say by land-ice, and then submerged, and never again elevated to a higher level, than it had when first glaciated, it will retain its striations and smooth surface; and (3), similarly, rock-surfaces

¹ GEOL. MAG., Vol. VIII., p. 305.

² *Idem*, "On the Two Glaciations, etc."

³ Quart. Journ. Geol. Soc., and "On the Valley of the English Channel," vol. vi., 1850, p. 69.

⁴ The "littoral zone" of Forbes and Audouin, and the "marginal zone" of Godwin-Austen.

striated under the sea by projecting glaciers, or by icebergs, and afterwards covered with marine drift, will retain their striations on elevation above the sea, and the glaciated surface be preserved on passing the tidal zone, provided they are elevated above it, at a greater rate than the waves can denude, the precise thickness of overlying and protecting Boulder-drifts; but this marine drift will have been deposited during either subsidence or entire cessation of movement of the sea-bottom. In Lancashire, it is often a great thickness. I have had a recent instance, north of Wigan, of its attaining a depth of 180 feet in a flat country.

I, therefore, for these reasons, cannot admit Mr. Mackintosh's dictum, "that it is a fundamental principle in geology, that striæ are preserved in areas of depression," nor its converse, "in areas of elevation;" and, further, I believe that it is the former alone, almost without exception, that are areas of *deposition* of true sedimentary rocks. Mr. Darwin, F.R.S., states on this point, "I am convinced that nearly all our ancient formations, which are throughout the greater part of their thickness *rich in fossils*, have thus been formed during subsidence. Since publishing my views on this subject in 1845, I have watched the progress of Geology, and have been surprised to note how author after author, in treating of this or that great formation, has come to the conclusion that it was accumulated during subsidence."¹ And he further shows that, though vast quantities of sediment may enter a sea, from muddy rivers and eroded coasts, around a rising continent, and littoral and sub-littoral deposits may be formed, these must be infallibly gradually worn and denuded away, as they are successively brought up to the action of the waves by the slow and gradual rise of the land.

If the sands and shingle occurring between the two marine Boulder-clays have been deposited as sand-banks, similar to those now found in the estuaries of rivers, and on coasts with small soundings,—as I have endeavoured to show in my paper on the "Glacial Phenomena of Western Lancashire and Cheshire,"² and which Mr. Mackintosh does not appear to question,—it appears to me to be impossible that they could have been thrown down, as he states, "during elevation," for each sandbank as it rose would be exposed to the action of the breakers, and, at the least, be denuded and re-deposited as a flat surface; while everywhere, from Carnarvonshire to Cumberland, I have observed the surface of these sands to have a curved, flowing outline, the hollows of which have since been filled in with Upper Boulder-clay.

The observations of Mr. Lamont, F.G.S., in the seas of Spitzbergen, on the changes of direction in the currents of the sea at different times of the year, have an important bearing on many of the phenomena of the Glacial drift. Thus, he shows that the Gulf Stream has little or no influence to the north and east of Black Point (Spitzbergen) and the Thousand Isles, as the ice is always travelling south-west, but immediately it is driven past that promontory, so as

¹ "Origin of Species," 5th ed., pp. 358-9.

² Quart. Journ. Geol. Soc., vol. xxvii.

"to come within the influence of the Gulf Stream, it is rapidly dissolved, that is, during June, July, August." After this month the arctic current bears back the remnant of the Gulf Stream, and the "polar ice, aided by the increasing cold, comes down in such quantities as to defy the efforts of the now vanquished Gulf Stream to dissolve it." It sweeps round the coast, meets another polar current from the other side, and wraps the island during the winter in an impenetrable barrier of ice. Regarding the warm episode in the Glacial epoch, during which the Middle Sand was formed, as an extended summer, it is easy to explain the fact, that though both of the Boulder-clays contain northern erratics, yet in the Middle Sand fossils and pebbles from the south often occur. Thus in 1861 I found in the sands of Leamington, in Warwickshire, Corals from the Lias of Cheltenham, Pectens and other fossils from the Red Crag, and a Nautilus from the London Clay. And in the neighbourhood of Crewe Mr. Taylor, F.G.S., has recorded the presence of a great number of chalk flints, though possibly these, like those from Blackpool, may come from Antrim.

In Lancashire the Middle Sands are invariably current-bedded to the south-east; and as I believe that they were thrown down during the *flow-tide*, it follows that it moved from the north-west, but in the south it may possibly have moved in the opposite direction, the meeting of the tides being then in Warwickshire, instead of in Morecambe Bay, as now. In the Upper Boulder-clay the north-west currents no doubt moved nearly as far south as the Thames.

It is clear from the descriptions of Drs. Brown, Sutherland, Kane, Rink, and Lamont, and other arctic travellers, that land-ice can make its way for a considerable distance into the sea, scratching and striating the rock-surface, and forming true moraine mounds, not only in the sea, but rising above it, forming islands, the sea-margins of which being exposed to the waves will be slightly denuded, and re-deposited at lower levels; in fact, the moraine mound may be *faced*, so to speak, with a marine deposit, composed of re-assorted land-ice débris. And, further, that these marine beds fill up and render seas shallow in the neighbourhood of the embouchure of large glaciers, forming Boulder-clay similar to that of the north-west of England, lying upon and graduating into moraine matter, and resting upon glaciated rock-surfaces, such as we find in the Lake District; and it is clear that, on the retreat of the glacier and the subsidence of the sea-bottom, the sea-belt occupying the space between the moraine island and the land would also become gradually filled up with marine deposits.

In the Upper and Lower Boulder-clays, as I have endeavoured to show,¹ the included stones and clayey matrix are almost invariably from different sources, formations, and localities. In the Middle Sand, on the contrary, the pebbles are composed of fragments of the neighbouring and surrounding rocks, and where it rests on the Lower Boulder-clay, of such erratic pebbles as may occur in that deposit at the particular locality.

¹ Quart. Journ. Geol. Soc., vol. xxvii., "On the Glacial Phenomena, etc."

In the Till, or land-ice Lower Boulder-clay, the matrix and included fragments have often the same origin, and the pebbles and boulders are invariably angular or sub-angular, glaciated, and scratched, and comparatively local.¹ In North Wales I have described it as being eroded, denuded, and overlain by the ordinary marine Lower Boulder-clay, but in Lancashire the latter is absent at high levels, and the former does not generally occur at low levels, though in going north its level gradually descends.

Mr. Mackintosh mentions a "blue clay" under the Lower Boulder-clay, and states that it may be inferred from the facts given in his eight papers that it was formed in a "shallow sea and denuded (if not upheaved and again depressed) before it was overlaid by the Pinel"; and, further, in his "Drift-Deposits of the West Riding of Yorkshire," describes the sea as acting at a level principally between 300 and 600 feet above the present sea, during a period of subsidence. If this clay be really marine, as he states, and deposited when the land stood at 650 feet lower than at present, then it follows that the true Lower Boulder-clay, which in Lancashire, Cheshire, Cumberland, and Carnarvonshire, often occurs *below* the present sea-level, must have been formed in water of 650 feet depth, and when the Lake District and Lancashire were submerged under the sea to that amount. Unless it can be proved that an *elevation* of at least 600 feet took place between the depositions of the two clays, of which he gives no proof,—and as it is clear that the parent rocks from which all erratics found in the Lower Boulder-clay must have been, with the rarest exceptions, *above* the sea-level,—no Boulders should be found in it that occur *in situ* at an elevation of less than 600 feet; but an examination of the stones and boulders of the Lower Boulder-clay of Lancashire has convinced me, that at least eight to ten per cent. are derived from portions of hills to the north, *under* 300 feet in height.

I, therefore, see no reason to change the opinion, stated in my paper on the "Glacial Phenomena of Western Lancashire, etc.,"² that the Lower Boulder-clay was deposited when the land forming the sea-bottom was not more than 100 feet *lower* than at present, and that the movement of subsidence continued during the Middle Sand period, so that the shells found near Macclesfield at 1200 feet, and on Moel Tryfaen, are newer than those of Blackpool at 50 feet above the sea, by the period of time which the land took to subside that amount.

If, as Mr. Mackintosh states, these sands were formed during an elevation, it follows that the Moel Tryfaen and Macclesfield are older than those of Blackpool, and that the country was submerged twelve or thirteen hundred feet before the deposition of the Lower Boulder-clay ceased, and that of the sands in the high districts commenced; and it therefrom follows that before the sands of Western Lancashire

¹ For my descriptions of this clay in North Wales, see *Nature*, vol. ii., p. 391; in Lancashire, *Quart. Journ. Geol. Soc.*, vol. xxvii.; *GEOL. MAG.*, Vol. VIII., pp. 108, 116, and 310.

² *Quart. Journ. Geol. Soc.*, vol. xxvii., part i., p. 652.

were deposited, the land must have been elevated to a level only 50 feet lower than at present. But, unfortunately for that argument, the sands at Blackpool, and all over the North-west of England, are overlaid by *marine* Upper Boulder-clay, at all levels up to 800 or 1,000 feet above the sea.¹ If, therefore, his theory be true, the country must have subsided a second time more than a 1,000 feet for the Upper Boulder-clay to be deposited, which I at present see no grounds for supposing.

Mr. Mackintosh takes exception to the statement in my paper,¹ on the "Surface Geology of the Lake District," that 1st, those lakes deliver as well as receive their waters, and 2nd, "that considering the immense depths of the lakes, the deep chasms in which they lie, it is impossible to say that *immense* quantities of detritus do not lie concealed beneath their placid waters," in opposition to those that hold that the limited excavating power of the Lake-district rivers "is proved by the small quantity of detritus they have yet been able to deposit." He states that he "ascertained from various persons, who were thoroughly acquainted with all the *ins and outs* of the Lake, that none of the detritus, or *sediment* brought in by the Brathay river, can find its way through the lake to the sea." But I am still perfectly unconvinced of any error in my statements; for (1) were the "various persons" competent judges, and (2) admitting that they were, the question to be decided is not "the ins and outs of the lake," but of the quantity of matter held in chemical solution and mechanical suspension, and pushed along at the bottom of the stream at the *point of outlet*; (3) that sediment is brought into the lake, not only by the Brathay, but by other streams, and by a portion of every rain-shower that falls upon the surrounding hills; that (4) granting that a deep current moving to the north is generated by the S.W. wind, this would aid the movement of sediment in all the lakes north of the great watershed, including all the chief lakes of the district, with the exception of Windermere and Coniston mere; and that (5) though in my paper in 1869,² I took especial care to point out the enormous lacustrine deposits, which no doubt exist at the bottom of these lakes, I cannot admit, with him, that even in "*Lake Districts*," that "*Lacustrine deposits, which have all resulted from the action of fresh-water, afford the only true measure of sub-aërial denudation since the Glacial period.*"

In the first portion of his last paper Mr. Mackintosh states, in regard to Wastdale Screes, that the "idea at first suggested itself that a great stream of land-ice may once have tumbled over the Screes escarpment, and smoothed the above rocks (between Greendale and Wastwater) in its passage across the dale. Mr. De Rance has expressed a similar idea, but I do not think it can be reconciled with attentive consideration of the physical geography of the district." But unfortunately he omits to give the result of his own considerations on the subject. In his section, however (Fig. 3), through the *roches moutonnées*, west of the lake, he clearly shows

¹ Quart. Journ. Geol. Soc. vol. xxvii., part i.

² GEOL. MAG., Vol. VI.

that the glacial agent came from the east, *i.e.* the high ground of Sca Fell and neighbourhood, and thus supports my position by the evidence of a tract of country which I have not had the opportunity of visiting; for it is clear that the ice-cascade, after falling over the Screes and digging out the deep eastern side of the Lake Wast-water (which, however, is not shown in his section), gradually made its way westward to the sea, over the various hills on the other side.

In regard to the Boulders in Peel Park, Salford, of which Mr. Mackintosh gives an analysis, it would be interesting to know, 1st, on what principle they were selected from the clay-pits, etc.; and, 2nd, in what manner the 100 specimens were chosen from this selection? For instance, if another 100 specimens had been taken, would it also have included one per cent. of Criffell granite?

In Mr. Mackintosh's list I notice a much higher number of granites and igneous rocks than in the per-centages of the Boulders of the Manchester Dift given by Mr. Binney, F.R.S., and Prof. Hull, F.R.S., as shown in the following table:

MR. MACKINTOSH.		MR. BINNEY. (Trans. Mem. Lit. Phil. Soc., vol. x., p. 133.)		PROF. RAMSAY. (given by Prof. Hull. Mem on Oldham.)	
Felspathic Trap and Porphyry	50	70	Igneous Rocks...	...	39
Eskdale Fell Granite.....	19			21	...
Criffell Granite	1			...	6
Silurian Grit and Local Sand- stones	30			31	...
			Carboniferous ...	55.33	17
			New Red	2.66	—

Mr. Mackintosh likens the conditions prevailing during the British Glacial epoch to those now holding in Labrador, but from what I have read in the works of my friend Prof. Youle Hind, M.A., of Montreal, the first white man to penetrate its central savage wilds, and from what he told me in the beginning of last year, I consider that those conditions do not at present nearly reach that degree of glacial severity which formerly existed in England; conditions now only met with in Greenland, Spitzbergen, and within the Antarctic circle.

I cannot here refrain from mentioning the observations of Mr. W. Bradford, of New York, the artist and companion of Dr. Haynes, who in his recent lecture at the Royal Institution, described the Sermitsialik Glacier in Greenland, which debouches into the sea at the head of a fiord three miles and a half in width, the ice extending from side to side, rising 275 feet above the surface of the sea, and extending 510 feet below it, resting on the rock bottom; the glacier steadily rising inland, and joining the Mer de Glace, *overtopping* the hills on either side of it. The heat of the rock melts the base of the ice, which flows out in a stream, producing a current running five miles an hour, which makes the sea coloured and muddy for a distance of many miles.