

he was led to believe he must look to other causes besides the present meteoric abrasion. Since accumulations of sand occur at or in the vicinity of all the valleys of Yar-connaught that open towards the west; and as in each of them there is palpable evidence that glaciers once flowed down them towards the west, he cannot but be inclined to believe that these sands originally owed their origin to glaciers. That similar accumulations do not always exist at or near the mouths of the valleys in that country which open eastward—seems due to their glaciers being feeders of the glacier of the Lough Corrib valley, which itself was a branch of the glacier that flowed down the valley now occupied by the waters of Galway Bay; however, at the mouth of some of these valleys they do exist, and are described in the Memoirs of the Geological Survey of Ireland (sheets 95 and 105). Furthermore, his belief is strengthened when he considers that all the accumulations of this kind of sand in Ireland, with which he is intimately acquainted, both at or near the sea-board, and inland, have similar relations to valleys in which, if he has not observed the traces of glaciers, yet it is not only possible but also highly probable, that they once existed. Since the glacial period, on account of the loose and frail nature of the Æolian sand, they have been a prey to the caprice of the wind or other moving forces, and have been drifted hither and thither, and their real relations to the more recent deposits obliterated.¹

III.—ON THE PRE-GLACIAL GEOGRAPHY OF NORTHERN CHESHIRE.

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

BETWEEN the mountains of North Wales and the sea, occur two terraces, an upper composed of Boulder-clay sloping towards the sea, and a lower, consisting of peat and alluvium, but little removed above high-water mark, running far inland, where broad valleys like the Vale of Clwyd breach the coast, and where rocky headlands jut into the sea, as the Great and Little Ormes Heads. The two terraces are almost entirely denuded away, but often the lower one has alone suffered, as between Penmaen Bach and Penmaen Mawr, where a bay in the rocks, so to speak, is filled up with Upper Boulder-clay. It is quite evident that before denudation of the coast took place, the peat plain had a far greater extension than at present, which is proved by the fact of the occurrence of peat and a submarine forest at Rhyl, in borings in the Dee, and around the whole coasts of Cheshire, Lancashire, and southern Cumberland. It is also evident that considerable denudation of Glacial beds had taken place before the period of the old forests, and that the seaward prolongations of these beds, which themselves rested on an old sea-bottom, had been denuded away, and that a great plain, or series of plains, formed much of what is now the Irish Sea, before the forests came into existence; the lower terrace now fringing the coasts

¹ These supposed glacier-formed sands must not be confounded with the accumulations of *shell sand* that are found in many places on the Irish sea-board, and often contain from 70 to 90 per cent. of calcareous matters.

being the landward edge of this plain. It is nowhere better seen than in the Birket plain, forming the northern portion of the Hundred of Wirral, in North Cheshire. It is bounded to the south by an old pre-Glacial cliff, which abruptly terminates the northerly prolongation of all the numerous longitudinal valleys running with the strike of the Triassic rocks, of which this district is composed, each valley having a steep escarpment facing the west, as described by Professor Hull¹ and myself.² To the east the continuity of this plain with the Mersey and with that surrounding Lancashire further to the north, is broken by a comparatively high tract of Triassic sandstones, rising like an island between the Mersey and the plain; to the north this tract is bounded by the sea, which is forming cliffs, and to the south its continuity is broken by a transverse gorge running across the strike of the strata, at the bottom of which flows to the east the tributary of the Mersey called Wallasey Pool. The western margin of the tract is above the plain, consisting of a natural escarpment, a continuation of that forming the eastern slope of a valley south of the Pool. On the side of the Mersey the eastern face of the tract is concealed by a bed of Glacial Drift, nearly seventy feet in thickness, forming a cliff of about that height; these deposits also fill up the bottom of Wallasey Pool gorge, and cover to a great extent the undulating plains stretching away from Liverpool towards Ormskirk, on the opposite side of the Mersey. The banks of the latter, on the north side, are sometimes composed of about twenty feet of rock, capped by Boulder-clay, but more often the latter comes down to high-water mark, and occasionally even far below, proving that the deepest line of the pre-Glacial valley did not precisely correspond in position to the present channel of the river. This, taken in conjunction with the fact that the bottom of the Wallasey gorge, as well as the rock floor of the Birket plain, is excavated far below high-water mark, the space being filled in with Boulder-clay, leaves little doubt that in pre-Glacial times the land stood at least thirty feet higher than at present. The breadth of the actual stream of the Mersey is inconsiderable compared with the present extent of its estuary, which is produced by the bottom of the old valley being submerged beneath the tidal level, but not until the Boulder Drifts had been re-excavated out by post-Glacial denudation, which, in the case of the Mersey, was chiefly fluvialite, but in the Birket plain was marine, the sea wearing back the Boulder-clay up to the old pre-Glacial east and west cliff, and also slightly cliffing the base of the natural escarpment, forming the western margin of what may be called the "Wallasey island." This Wallasey escarpment exhibits fine sections of the unconformable junction of the Keuper with the upper mottled sandstone, and was once continuous with that of Flaybrick Hill. These two form the eastern slope of an old longitudinal valley before the formation of the gorge, the western slope of which has been removed by that denudation which produced the Birket plain, and also destroyed the seaward prolongations of all the existing north and south valleys further to

¹ Explanation of Hor. Sec., Sheet 68.

² Quar. Journ. Geol. Soc., Feb. 1871.

the westward towards the Dee, now abruptly cut short by the cliff forming the southern margin of the Birket plain and Wallasey Gorge. Before the formation of the former plain, and before the north and south valleys were deepened to their present extent, it is clear that the Mersey flowed westward over a plain, the level of which coincided with, or was but little above, that of the various escarpments occurring between the valleys. For when it first commenced to flow they were not in existence, and the streams which afterwards flowed in them could only deepen them in regard to the gradually decreasing level of the transverse gorge, which regulated the height of the outfall. Therefore, it is not improbable that when the river flowed over this old plain, that it extended far to the westward, until it abutted against the mountains of Wales, and that the hard and soft beds composing it were alike level—longitudinal valleys not being yet scooped out of the latter. For in all districts where these phenomena are observable the slope of the soft beds composing a longitudinal valley is towards the brook or stream, which runs at right angles to an escarpment, forming the landward side of it, and which, in cutting through escarpments lower down, forms transverse gorges, the upper termination of the slope corresponding to the level of the base of the escarpment. It is therefore clear that before the latter was formed these longitudinal slopes could have had no existence, and that their angle increased exactly in proportion to the height gained by the escarpment, or in other words to the descent of the level of the base. Therefore, there is reason to believe, that the various valleys south of the old high-level course of the Mersey did not extend indefinitely northwards, but fell into that river at points, opposite which entered similar streams, flowing from the north. The continuity of the old plain westwards was broken by the River Dee, which must have formed a broad valley, receiving the waters of the Mersey as a tributary, at a point opposite Mostyn; from thence, flowing northwards, far out into what is now the Irish Sea, and receiving the waters of the Clwyd. As the Mersey deepened its course, longitudinal valleys began to be formed by the wash of rain on the soft sandstone, and after a time the hard beds began to be left as escarpments, through which the river always cut a channel *before the soft beds behind* were removed by lateral wash, which could never work lower than the level of the outfall, the key to which was the transverse stream. Subsidence taking place, marine denudation went on, and the sea gradually approached the district, the valleys and hills to the west were shaved across, and the Birket low-level plain came into existence, at a level but slightly below that to which the longitudinal valleys had worn themselves; the Mersey flowed at the bottom of the Wallasey Pool gorge, and fell directly into the sea.

In historic times the Wallasey Pool was a main outlet of the Mersey, but at present it enters the sea by a broad valley between Liverpool and Egremont; but it would appear probable, as this is a longitudinal valley, with a fault at the bottom, lying north of the Wallasey Gorge, that in pre-Glacial times the stream that occupied it flowed south into the Mersey, and that on the deepening of the

valleys, and the subsidence of the land, its seaward margin was exposed to marine denudation at the period of the formation of the Birket plain.

It therefore appears probable that in pre-Glacial times a plain of marine denudation composed of hard and soft beds of New Red Sandstone existed from the borders of Wales to south-western Lancashire,¹ unbroken by valleys, over which flowed the Dee to the north, receiving as a tributary from the east the Mersey, which gradually cut for itself a transverse gorge across the strike of the rocks; at the same time, longitudinal valleys to the north and to the south, gradually came into existence. Those to the north were afterwards entirely destroyed by Marine denudation, which formed a lower plain. The subsidence continuing and the climate becoming glacial, the district was submerged beneath the waters of the Glacial Sea, and the Gorge, or transverse valley, as well as the longitudinal valleys, were filled up with Glacial deposits. Afterwards, on the re-elevation of the country, these were excavated out, partly by running water, and partly perhaps by small glaciers which, as I have attempted to show elsewhere, undoubtedly held their ground, at the close of the Glacial epoch, in the valleys of the Lake-district. The entire valley of the Mersey, including its termination through the Wallasey Gorge, would be equally filled up with Drift; over this surface of Drift the river must have flowed, widening and deepening its channel as it ran, here making great cliffs of overhanging Boulder-clay, and there cutting through the Drift, down to the bare rock, and in some instances cutting its bed wider and deeper in the rock than it was before the Glacial submergence.

In the cliffs on the south side of the Mersey, near Eastham, the base of the Glacial Drift, resting on the rock, is more than twenty feet above the present base of the cliff, which is slightly below high-water mark. The river is now wearing this cliff back and back into the gradual slope of the old pre-Glacial valley, which appears to have had its deepest hollow near the opposite bank on the Lancashire side of the river; near the Otter's Pool the base of the Drift is rather below high-water mark, the rock only forming the strand between tide-marks. The rock-surface is also below high-water mark on the west coast of the peninsula, where the banks of the Dee are formed of Boulder-clay, more or less from Hoylake to Parkgate and Neston. Near Hoylake a submarine ridge of rocks occur, Bunter pebble-beds thrown up by a fault, culminating in Hilbre Island. Between the ridge and the Cheshire coast there is a channel, and from the ridge to the opposite coast of Wales the rock surface descends to a great depth, and the Glacial beds are much denuded, and are covered up by an immense thickness of alluvial silt resting on peat, the silt reaching, I believe, a thickness of 60 or 70 feet. It has been penetrated in boring for coal, which has been found to lie under the western side of the estuary of the Dee.

The bed of the Mersey from Runcorn Gap to the sea is excavated

¹ And of course much further, but in the above notes the country around the mouth of the Mersey is alone considered.

partly by tidal action, in the bottom of one of the old north and south longitudinal valleys, mentioned as occurring so frequently in Cheshire; on the emergence of the country it was re-excavated by the Mersey, which cut for itself a fresh channel in the Drift, in addition to excavating out the Wallasey Gorge, and cutting its present course between Egremont and Liverpool, which is daily becoming wider and wider, under the horizontal denuding power of tidal waters.

NOTICES OF MEMOIRS.

ON THE NATURE OF THE EARTH'S INTERIOR.¹

By DAVID FORBES, F.R.S., etc.

IN a previous discourse on Volcanos, GEOLOGICAL MAGAZINE, 1870, Vol. VII., p. 314, attention was directed to the phenomena of volcanic action, specially considered in relation to the part which such igneous or internal forces have played in determining the grand features of the external configuration of the sphere upon which we live.

If, now, we follow up this subject still further, it will naturally lead to an inquiry into the nature of the internal substance of the globe itself, within which the foci of such agencies must be situated; but quite independent of this, there can be little doubt but that most intelligent persons have at some time or other already asked themselves the question as to what the central mass of the earth beneath them consisted of.

The answer which in the first instance would be most likely to suggest itself to the mind would be, that it consisted of solid stony matter, such as is seen forming the body of its mountains, the foundation of its continents, and the rock basins which contain its seas. The belief in such an hypothesis would, however, be rudely shaken by the first personal experience of the shock of an earthquake, the sight of a volcano in eruption, or the consideration of the immense faults which, in many places have disturbed and dislocated the solid land; whilst, so far from disposing us to regard the ground under us as entitled to the appellation of *terra firma* commonly employed by the ancients, the study of such phenomena could not but suggest grave doubts in our minds as to whether the earth, after all, could be anything like so solid and stable as at first sight we might have felt inclined to suppose it.

But very little inquiry into this subject is necessary, however, to convince any one of the great difficulties in the way of obtaining a satisfactory answer to this question, and to prove that in the present state of science we have not at our command sufficient data or evidence to enable us to arrive at any thoroughly conclusive solution of this most interesting problem.

As the rapid advances made by the natural sciences in all directions are, however, daily adding to our information bearing upon this subject, and thereby enabling previous deductions to be

¹ A lecture delivered in St. George's Hall, January 29, 1871.