of what might be called a secondary boulder clay. He had been confirmed in this opinion by a careful examination of what seemed to be the old or primary boulder clay in Arran, in the valley between Lamlash and Slaodridh. When searching there for glacial shells, in that section specially described by Dr. Bryce in his excellent work on Arran, he had found two or three specimens of *Astarte borealis*, and a few fragments of others, in circumstances which rendered it improbable, he might say impossible, that they could have lived there. The texture and appearance of the clay led him to infer that it must have been formed during the glacial period, probably near its termination, but certainly long after the true or primary boulder clay had taken its place. He respectfully submitted these facts, in the hope that light might be thrown by other observers on points which were as yet confessedly difficult and obscure.

XV.—*On the VALLEY of LOCH LOMOND.* By G. H. KINAHAN, M.R.I.A., &c., of the Geological Survey of the United Kingdom.

(Read 22nd February, 1872.)

VARIOUS theories have been advanced to account for the present features of the earth's surface. Formerly it seems to have been a very general belief that these features were all more or less due to movements in the crust of the earth, combined with marine denudation. Hutton seems to have been the first to broach the theory that the present surface was principally sculptured by meteoric abrasion. The senior geologists of the present day appear still to lay most stress upon former movements of the earth's crust; but, as a rule, the younger geologists may be divided into "Marinists" and "Subaerialists;" the latter class being, perhaps, at present the more numerous.

No one can deny that meteoric abrasion is capable of executing a vast amount of work, especially in tropical climates. In the temperate zones a third part, at least, of the earth's surface is enveloped by peat, timber, grass, or the like; consequently the work performed under these circumstances by meteoric abrasion is more limited, as no denudation can take place except on the

bottoms or sides of ravines, river beds, and such places; while in Arctic and Alpine regions the effect of atmospheric denudation seems to be even less. It appears to me, therefore, that those who would account for the main features of the present surface, by such denudation, ascribe to it far greater results than it can fairly be held to have accomplished.

I still believe, for example, that many of the valleys in the south-west of Ireland, which the late Professor Jukes considered to be solely due to meteoric abrasion, were in a great measure caused by breaks in the rocks, combined with marine action. In the promontories jutting out into the Atlantic, similar valleys are now being excavated by the sea along lines of breaks and faults. In the mining districts of the promontory of Crookhaven, all the valleys and surface fissures have been proved, by the underground workings, to occur along lines of breaks or faults ("slides" or "heaves" and "cross courses"), and I find the same facts in other places. All the valleys in the groups of hills called Slieve-Aughta and Slieve-Bernard (Clare and Galway) are connected with lines of faults. In the Kilkenny and Queen's County coalfield, the colliers have proved that most, if not all, the valleys in that upland are connected with breaks in the underlying rocks; while in West Galway, or Iar-Connaught (a country specially adapted for the study of its internal structure, as the surface-covering over large tracts is a thin coat of peat), I and my colleagues found that every valley, ravine, lake basin, or other feature, is more or less connected with faults and breaks in the rocks.

Scotland is intersected by systems of breaks, which, however, are more intricate, and not as regular as those in Ireland; apparently on account of their being so numerous, and of so many different ages, the newer deflecting and displacing the older.* In the Highlands of Scotland, as far as I have visited them (where the rocks are similar to those in West Galway), I did not meet with a valley, ravine, or lake basin unconnected with a break. And I believe, had time permitted, I could have proved systems of breaks both as old and as new as those in Iar-Connaught.†

Professor Ramsay, as is well known, has suggested that rock-

* One most conspicuous system in the South of Scotland extends into the north-east part of Ireland.

† Even in the coalfields in the neighbourhood of Edinburgh, I think it will be found that some of the faults displacing the coals are of corresponding age to some of those in the Irish coalfields, namely, post-glacial.

basins containing lakes are due to the rocks having been eroded or scooped out by ice, seeing they are most numerous in those countries where signs of ice-action abound, whilst beyond the glaciated region they almost wholly cease. Sir Charles Lyell and others have urged several objections to this theory, and pointed out that it will not account for the formation of all lake rock-basins.

But if it be admitted that such basins are partly due to ice-action and partly to the contraction and displacement of the rocks, these objections would be removed; the hollows being at first formed by the crossing or junction of breaks, while subsequent ice-action would lift up and carry away all loose blocks and fragments to plane, scratch, polish, and etch the rocks *in situ*; and the longer the ice-stream lasted, so much less detritus would it contain to be deposited when it finally disappeared. This topic, however, would occupy too much time if now entered upon. Let us proceed to the special subject of this paper, namely, the formation of the valley of Loch Lomond.

The general bearing of the valley of Loch Lomond is north and south, corresponding with the lie of other important breaks in this part of Scotland. Extending from this valley eastward and westward are transverse features—some forming valleys, while others are marked by greater or less depressions in the hills. That all these valleys and depressions are connected with dislocations in the underlying strata is manifest by the strike of the rocks being deflected, or the beds of rock rising to the upthrow of the faults, or by the shifting of conspicuous beds of rock.

Loch Lomond, at no very remote period, must have been a fiord connected with the valley of the Clyde. This is proved by the raised beaches of the latter valley being on a similar horizon with the terraces in the Loch Lomond valley, and the gravel-bar across the latter, a little to the north of the lake. The lake-basin, therefore, at that time, was a submerged valley, which, prior to its submergence, if the theory of the Subaerialists be correct, was excavated by "rain and rivers" or ice.

The lake is divided into two portions by the chain of islands stretching westward from Balmaha. From the chart we learn that south of these islands it is shallow, rarely exceeding twelve fathoms in depth; however, in a few places it is thirteen, and in one spot, east of Inchmurrin, a hole fourteen fathoms deep is recorded. North of the islands the lake gradually deepens to

Ross Point; it then shallows for a short distance, being only four or six fathoms deep on Hunter's Bank, which lies a little north-east of the inver of Douglas Water, but on the north of this bank it immediately deepens to over twenty-five fathoms, and northward it gradually gets deeper and deeper till it attains the maximum depth of 105 fathoms due west of the hamlet called Culness. North of this place a deep portion (over 100 fathoms) extends for nearly a mile, after which the basin gradually shallows to Whitepoint, between which and the end of the lake there is another deep portion, about 34 fathoms.

If we examine the country in the neighbourhood of the south part of the lake, we shall find there are features connected with breaks running about N. 30 E., the deeps in the adjoining portion of the lake basin having similar bearings. Immediately north of the islands the direction of the deeps is not so regular, being a combination of the N. 30 E., and a nearly N. and S. bearing, but in the rest of the lake they extend nearly north and south. Moreover, it may be observed that although the general bearing of the lake is N. and S., yet the deep portions in the north part have not an exactly similar lie, as in places they incline more or less to either side, from being deflected at the junctions of the transverse with the main valley. Furthermore, all the deepest spots coincide with one or other of these junctions.

The shallows may in part be due to accumulations when the lake was a fiord. It seems, however, that since it became fresh water they have considerably augmented by debris carried into them by the rivers and streams, especially the bank in the vicinity of the Douglas Water, which has all the character of a delta, shelving suddenly at its margin, especially northward. .

The irregular deep, east of Ben Dhubh, occurs at the junction or crossing of different breaks. The sudden deepening north of Hunter's Bank seems, in part, due to a fault, a downthrow to the north, coming into the main valley from the east. The shallow to the south of the deepest spot is evidently on the N.W. side of the fault-line which is associated with the Tarbet valley. This appears to be a very recent fault, and has considerably shifted the main fault of the valley. The Inversnaid and Inverglass faults also slightly shift the main fault, while the deepest spot in the basin (105 fathoms) seems to be at the junction of the Main and Culness Valley faults. Having now stated the facts in connection with

this lake-basin, we may consider suggestions as to its mode of formation.

If this valley were solely due to "rain and rivers," it would necessarily deepen gradually from its upper to its lower or south end. This, however, is not the case. If due to the erosion of ice, the deeps and shallows ought to graduate one into the other, and have a trend conformable with the lie of the valley, and consequently with the course of the glacier. This, however, is also contrary to facts. Again, marine action could not possibly have excavated this valley. On the contrary, it would tend to fill it up. Moreover, the extreme shallowness of the lower or south portion seems not to be due to such a cause, as the soundings record a rock bottom in many places.* Thus, "rain and rivers," ice, or marine action seems incapable, separately, of forming this basin, and we must look for causes elsewhere.

It has been shown that the valleys and depressions at the surface are connected with breaks in the strata, while the bearings of all the deeps in the lake-basin are similar to those of the features in the adjoining country, or they have a relation to the several junctions of the transverse valleys with the valley of Loch Lomond; consequently we have a right to assume that the form of the lake-basin is more or less connected with the breaks in the underlying strata. Let us suppose a great north and south break to have been first formed, with transverse breaks and their accompanying fissures branching from it. Meteoric abrasion, or marine action (if under the influence of the sea) would widen and deepen these; or if they were occupied by glaciers, all loose blocks and fragments of rock would be caught up and carried away, while the ice acting under the loosened blocks in the breaks, would lift them up and bring them under the transporting power of the glacier, especially in places where two or more breaks met or crossed, where it would excavate the rock to a great extent, thus forming deeps. Subsequently-formed breaks or dislocations would shift the work previously accomplished, and more or less modify it. By such a process, all the phenomena of this lake-basin may be accounted for—even the formation of the deep spot due west of the village of Culness.

For the excavating of this Culness deep, two theories may be suggested. Suppose the land to be 600 feet higher than at present,

* It should be pointed out that the principal deep is similarly situated to deeps in fords, the charts of which have been examined.

and "rain and rivers" to be the workers. This being at the junction of the Main and the Culness valley breaks, it is therefore possible that in this place there might have been a subterranean outlet, which was capable of draining the water out of the greater portion of the basin of Loch Lomond; and such subterranean outlets at the junction of two or more breaks are not uncommon among similar rocks in the hills of Iar-Connaught, Ireland, where the "fault-rock" is of an incoherent nature or open structure; or when an internal fissure has not been filled with minerals. Such a theory as this would necessitate that all the rock debris taken out of the valley—which may have been more or less in accordance with the size of the original fissures due to the shrinkage of the rocks—was carried away through the subterranean passage; and as I have previously shown when describing the subterranean drainage in the neighbourhood of Gort, County Galway,* a considerable amount of detritus, and even blocks of stones, may be carried away through such passages. This theory, however, I own, does not appear to be satisfactory. I would therefore suggest, that after the main line of the valley was laid out by a break in the underlying strata, marine action, meteoric abrasion and ice, separately and combined, performed their respective parts in modifying, widening, and deepening the valley. During this process, other dislocations occurred, which also helped to modify the original form of the valley; and subsequently, among the later movements of the surface, the lower portions of the lake may have been lifted higher than the northern part, or the upper portion may have been depressed beneath its former level. That some of the dislocations in connection with this valley are post-glacial I am strongly inclined to believe. My examination, however, was too brief and restricted to justify me in making a positive assertion on this point; but the features of the country about the north part of Loch Lomond, and also in the neighbourhood of Loch Katrine, seemed to indicate very recent movements and breaks in the underlying rocks.†

* Memoir, Geol. Sur., Ireland, Extract Sheets 115 and 116.

† Loughs Corrib, Mask, and Derg, in Ireland, resemble Loch Lomond in several of the aspects that have been described. The latter especially is most interesting; its main feature being a break with a bearing of about N. 30 E. This has been shifted four times eastward, by nearly E. and W. faults (N. 80 E.), all downthrows to the south, whilst each of these faults are connected with valleys or conspicuous features in the mountain group called Slieve-Aughta, which occupies the country to the west of the lake.

It may naturally be asked why the basin of Loch Lomond was not more silted up during the period of its being a fiord; as the tidal action ought, as at the present day, to have spread the materials carried down by the streams more evenly over its bottom, filling up or modifying the deeps. In reply, I would suggest that at that time there was an arctic climate, as is proved by the fossils found in the raised beaches of the Clyde valley; and consequently the fiord was yearly covered with ice, or had an "ice-foot," on which was caught most of the debris brought down from the hills to be floated out to sea—little or none of it remaining to be deposited in the lake basin.

XVI.—*Notes on CARBONIFEROUS FOSSILS.* By JAMES
THOMSON, F.G.S., *Vice-President.*

I. *On the PLAGIOSTOMOUS FISHES of the COAL MEASURES, particularly ORTHACANTHUS DECHENII (Goldfuss).*

(Read 19th October, 1871.)

PROFESSOR AGASSIZ, in his *Poissons Fossiles*, published in 1837, described the genus *Diplodus* (sp. *gibbosus* and *minutus*) from specimens, chiefly of dissociated teeth, found in the English coal-fields. Subsequently, a well-preserved fish was discovered in Bohemia, and described in 1847 by Goldfuss, who named it *Orthacanthus Dechenii*. In 1848, Professor Beyrich, of Berlin, described the same fish, and named it *Xenacanthus Dechenii*, founding on the fact that the spine had a greater similarity to *Pleuracanthus* than to *Orthacanthus*.

At the meeting of the British Association in Glasgow, in 1855, Sir Philip Egerton, from discoveries that had been made in the interval, pointed out that the spines of *Pleuracanthus* and the teeth of *Diplodus* belonged, in fact, to the same fish. The specimens from which Sir Philip proved this to the Association were obtained from Carlisle and Edinburgh.

In 1867 Professor Kner went carefully over the remains of such fishes in the museums of Dresden, Berlin, Breslau, and Vienna. Although none of the specimens found in these museums were complete, yet in some of them he found the teeth of *Diplodus*