31. *THE SHELLY CLAYS and GRAVELS of ABERDEENSHIRE, considered in RELATION to the QUESTION of SUBMERGENCE.* By DUGALD BELL, Esq., F.G.S. (Read May 8th, 1895.)

THE high-level shelly gravels and clays of Aberdeenshire were described in some detail by Mr. T. F. Jamieson, of Ellon, in two valuable papers read to this Society in March 1882.¹ They have also been treated of at some length by the Geological Survey of Scotland, in their published memoir relating to the district.² As these deposits have been frequently, and quite recently, referred to as proving a submergence in Scotland during Glacial times, to the extent of 500 feet or upwards,³ I would ask leave briefly to review the facts, for the purpose of showing that they do not lead to or warrant such a conclusion.

1. There are, first, certain beds or undulating ridges of sand and gravel which, according to Mr. Jamieson, contain fragments of shells of Crag species. These extend along the sea-shore and for some distance inland, a few miles north of the river Ythan, and are found up to a height of 225 feet above the sea, but chiefly between 100 and 200 feet. They rest on the grey Boulder Clay of the district, which is formed of the débris of the gneiss, granite, and mica-schist rocks prevailing there; but they are different from it, containing many pieces of yellow limestone and calcareous shale belonging to some Secondary formation not found *in situ* in Aberdeenshire. 'The shelly material occurs generally in the form of fine pounded débris and small worn crumbs, with here and there a larger bit, generally a hinge.' The evidences, as a whole, indicate transport from the southward, and the inference is that, after the deposition of the grey Boulder Clay, there had been a change in the movement of the ice, bringing it more from the southward, and that some patch of Crag along the coast, or near the estuary of the Ythan, had been scoured out, and the débris carried northward and partly inland by the ice in its progress. In short, Mr. Jamieson considered that 'the gravel represents the scourings of the surface which the ice carried along with it and shed off along its border.'⁴ In this view it is a purely glacial deposit, and cannot be cited as evidence in favour of even a moderate submergence.

2. Overlying this shelly gravel is a well-marked bed of red clay which extends over a somewhat wider area, covering much of the low ground between Aberdeen and Peterhead. It ranges from the sea-level up to about 300 feet, 'although there are here and there some indications of it at a higher level.' These indications consist of numerous water-worn pebbles of quartz and flint, similar to

¹ Quart. Journ. Geol. Soc. vol. xxxviii. pp. 145, 160.

² Mem. Geol. Surv. Scotl. 1886, Expl. Sheet 87.

³ J. Geikie, 'Great Ice Age,' 3rd ed. pp. 139, 166.

⁴ Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 152 *et seqq.*

those in the clay, found up to 470, and a scattered few of the same kind up to 560 feet. On the assumption that the clay is a submarine deposit, these pebbles are taken to indicate the limit of the submergence, which is thus currently stated to have been about 560 feet. Nevertheless, we think it clearly appears, from Mr. Jamieson's minute and faithful description of this clay, that it is as truly a glacial deposit as the underlying gravels, to which reference has already been made.

Sketch-map showing the Movement of Ice along the N.E. coast of Scotland.

B=Boulder Clay containing sea-shells.
C=Clava. K=King Edward.

This clay, Mr. Jamieson remarked, 'is not such a deposit as would be derived from the rocks of the district in which it occurs'; it is quite unlike the grey Boulder Clay derived from the gneiss and

granite; but 'looks more like what we should expect to find in a district of Old Red Sandstone, being of a decided brick-red colour, exactly resembling the clay we find in the Red Sandstone district of Kincardine and Forfar.'¹ It also contains large round pebbles of grey quartz with a smooth reddish exterior, such as are met with in the Old Red conglomerate of Kincardineshire. Moreover, it contains many stones of a volcanic nature, unlike the rocks of Aberdeenshire or the North of Scotland, but resembling the masses of trap which occur in the Old Red district of Forfar and Kincardine.

Other evidence exists, in the transport of local rocks, to show that there has been a movement of the ice from the south; and the striae on some points along the coast, showing first an older set from the W.S.W., or interior of the country, and then a newer set nearly from the S., or parallel to the line of coast, together with the 'hard and tough' appearance of the clay itself in some parts, convinced Mr. Jamieson that the agent was land-ice, which came from the southward 'along the coast, grazing the surface of the rocks at the projecting headlands, and bringing with it the red clay and débris of the Sandstone formation.'²

The reason of this northward movement of the ice along the coast was, as Mr. Jamieson also points out, the ice-blocked condition of the North Sea, as demonstrated by Dr. Croll some five-and-twenty years ago,³ 'so that the Scottish ice would be unable to move out to the eastward, and be compelled to turn along the coast in the direction it seems to have actually taken.'

The conclusions of the Geological Survey on these points agree generally with those of Mr. Jamieson, though in one or two rather important respects they differ. They agree in regard to the general succession being (1) the grey or lower Boulder Clay, (2) the intermediate sands and gravels, and (3) the upper or Red Boulder Clay. They agree also in supposing a first or local glaciation for the grey or lower Boulder Clay, and a later movement of the ice-sheet from the south when the upper Red Clay was deposited. With regard to the latter the Surveyors say that it 'can be traced along the coast as far south as Stonehaven, and there is little doubt that the materials of which it is composed were brought from that quarter.' Again, they refer to 'the ice-sheet that passed to the north and left behind it the upper Boulder Clay.'⁴ But they differ in that the Surveyors pronounce the intermediate sands and gravels to be interglacial, and to have been accompanied by a submergence of 360 or probably of 500 feet. The grounds on which this pronouncement rests are not very apparent. We are told that while these sands and gravels 'strongly resemble moraine-stuff,' they have been 'washed and rolled,' and contain 'marine shell-frag-

¹ Quart. Journ. Geol. Soc. vol. xxxviii. (1882) pp. 160, 162.

² *Ibid.* pp. 165-66.

³ Geol. Mag. 1870; also 'Climate and Time,' 1875.

⁴ Mem. Geol. Surv. Scotl. 1886, Expl. Sheet 87, pp. 23, 24.

ments mixed through' them.¹ This seems a very insufficient reason for having recourse to the expedient of a submergence. And to adduce the upper limit of these gravels, even where no shells have been found in them, as proving submergence to that extent, is exactly the mode in which a submergence of 2000 feet was at one time thought to be made out by certain high-level unfossiliferous gravels in Wales which are now admitted not to be marine at all. The writer of the Survey memoir says, 'It may be presumed that the interglacial beds here described were accumulated during the same submergence that introduced the shells into the interglacial clays of King Edward and Clava. At the latter place a submergence of 520 feet above present high-water mark is necessary to account for the present position of the shells.'² This is surely a somewhat hastily drawn conclusion. Every case must be judged upon its own evidence, and must be clearly proved before it can be made a means of proving others. King Edward and Clava have enough to do to answer for themselves.³ Considered as evidences of submergence they may both be said to be in a 'parlous state.' To take them as proved and admitted marine deposits in order to strengthen the case for submergence elsewhere is hardly admissible.

Further, the Survey officers differ from Mr. Jamieson in considering the Red Clay simply as an 'upper Boulder Clay' due to the later glaciation. They say nothing about submergence in connexion with it, nor do they take any notice of the marine remains in it, thereby quashing the evidence for submergence on which Mr. Jamieson chiefly relied. The question occurs, why should fragments of shells in the intermediate, 'morainic,' 'false-bedded' sands and gravels be taken as proving submergence, and those in the Red Clay be quietly passed over?

Briefly, Mr. Jamieson took the intermediate sands and gravels as purely glacial, saying nothing about submergence in connexion with them, but thought that the Red Clay did indicate submergence. The Survey officers reverse the finding in these respects; they interpret the sands and gravels as evidences of an interglacial submergence, and consider the Red Clay as purely glacial.

By this diversity of opinion I feel emboldened to state, with all deference, my own view, which is that both the deposits in question are due to the same cause,—the one to an earlier and the other to a later stage of the same glacial conditions, and that submergence is not indicated, far less proved, by either of them.

We have already seen how weak is the case for submergence as inferred from the intermediate sands and gravels. Let us now turn to that which has been made out from the Red Clay.

Having clearly shown, by the facts which we have summarized, the glacial origin of this clay,—that it was due to a great sheet of land-ice moving northward along the coast,—and also stated the

¹ *Op. cit.* p. 22.

² *Ibid.* p. 23.

³ The shelly clay at King Edward is only about 150 feet above the sea, and so, in any case, cannot help us much in a question of 520 feet.

reason why the ice moved in that direction, Mr. Jamieson unexpectedly proceeds to consider the 'progress of the submergence.'¹ What submergence? The facts which have just been mentioned—the ice-blocked condition of the North Sea, and a great glacier from the mountainous region to the south creeping up along the coast—seem far from justifying any such hypothesis.

I am rather inclined to think that a submergence of 500 feet or more being at the time he wrote generally accepted, Mr. Jamieson—to whom I would invariably refer with the greatest respect—simply admitted it among his facts, not deducing it from them. Having observed that 'the fine red mud implies deep, or at least quiet water,' he adopted the submergence as furnishing what was required. The first fact, however, which he mentions in connexion with it presents a difficulty. 'There is no evidence at the bottom of the clay of littoral mollusca, such as would indicate shore-conditions at the commencement of the submergence. . . . As a rule, it [the fine red mud] lies immediately on the top of the grey Boulder Clay without the intervention of any beach-gravel or sand between them, as if still water of some depth had at once taken the place of the glacier.' To explain this, Mr. Jamieson supposes that the glacier did not break up till a considerable amount of submergence had occurred. 'In this way deep water would take the place of the ice as soon as it floated off the bottom, and the red mud would then settle down on the exposed surface of the grey Boulder Clay.' Then, as the submergence proceeded, the glacier gradually retired, sending out red mud all along its margin. And this process, Mr. Jamieson conceives, would begin at the N.E. corner of the country, where the ice was 'less heavily developed' than elsewhere; the thinnest ice would yield soonest, and the sea-water would thus first establish itself, say, 'in the neighbourhood of Peterhead and Fraserburgh, and thence creep south and west along the coast as the ice gradually broke up.'²

Now, there seem to be several difficulties in the way of Mr. Jamieson's theory. The chief and most obvious is this:—It was the ice-blocked condition of the North Sea which compelled the land-ice from Kincardine and Forfar to turn northward along the coast, as it clearly appears to have done. As soon as that condition began to give way, and in proportion as it approached an end, the ice would undoubtedly cease to take that direction and would proceed out eastward to the more or less open sea. The compelling cause of its turning northward being removed, and a more direct exit at the same time set before it, of course it would turn northward no longer. The ice in the North Sea being thus the dominating factor in the case, the question arises, where would it most likely give way first? Be it remembered that it was land-ice, chiefly from Scandinavia, occupying as a solid mass the bed of the North Sea. Can we imagine that in the north, at Peterhead and beyond, that ice had melted away, while in the south, at Stone-

¹ Quart. Journ. Geol. Soc. vol. xxxviii. (1882) p. 168.

² *Ibid.* p. 168.

haven, it still invested the sea-bed and blocked the passage? Would it not be thinnest and 'less heavily developed' to the south, and therefore first give way there? Thus it would keep receding gradually northward, the sea becoming more and more open to the south as it withdrew. Accordingly, before—probably long before—it was deep open sea at Peterhead and Fraserburgh, it would be deep open sea in the neighbourhood of Stonehaven, and the ice ceasing, as we have said, to go north, there would be no fine red mud carried thither for deposition in the deep still water when that came. The two conditions thus seem incompatible—the northward-moving ice-sheet excludes the deep water, and the deep water excludes, or precludes, the northward-moving ice-sheet.

Besides, could sea-water afford the tranquillity which seems to have been required for the deposition of this fine mud? Would not waves, and tides, and currents play their part, especially so near the coast, and prevent anything like so fine and, in parts, so 'delicately laminated' a deposit?

Again, why is this deposit, if marine, so 'remarkably devoid of remains of animal and vegetable life?' It is rare to find shells in it, and when they do occur they are very scanty and usually in broken fragments. 'For a marine deposit,' Mr. Jamieson continues, 'the scantiness of fossils is surprising; for the greater part of it seems absolutely barren.' The only explanation he can give is that this extreme sparseness of organic remains 'seems to point to a sea in which marine life was far from abundant.'

Sir Charles Lyell has stated that he once thought 'the absence of signs of organic life in the Scotch drift might be connected with the severity of the cold, and also in some places with the depth of the sea during the period of extreme submergence; but,' he adds, 'my faith in such an hypothesis has been shaken by modern investigations, an exuberance of life having been observed both in Arctic and Antarctic seas of great depth, and where floating ice abounds.'¹ So that the supposition of a sea in which marine life only sparingly existed does not seem very satisfactory.

These being some of the difficulties, one is disposed to ask whether it is necessary to assume that this Red Clay was laid down in the sea at all. It contains marine remains, truly, 'very scantily and in fragments';—is there not every reason to believe that these have been brought along with the Red Clay and the fragments of rocks from a distance, by the ice which moved northward along the coast? And if 'still water' were required for the deposition of the clay (which, by the way, occurs most abundantly, as might be expected, in the hollows and depressions and little valleys of the district), would not that condition most likely be furnished by the ice which passed northward along the coast, blocking the drainage of the adjacent country, and causing 'extra-glacial lakes' here and there along its margin? It seems inevitable that such effects would

¹ 'Student's Elements of Geology,' 1871, p. 154.

be produced at many points where the inland ice did not meet and coalesce with the northward-moving sheet along the coast. Into these bodies of still, tideless water, the fine red mud, fragments of shells, stones from a distance, etc., with which the ice was charged, would be shed and gradually accumulate.

Similar effects were produced elsewhere. Mr. Lamplugh has shown that as far south as Flamborough Head the ice had a thickness of at least 500 feet, overriding the cliffs in many parts and extending to some distance inland, across the mouths of the eastern valleys. 'The drainage-channels of the streams flowing eastward,' he says, 'were dammed by the ice, and lakes were formed wherein deposits of gravel and other material rapidly accumulated.'¹ And the observations of the present writer have led him to believe that similar conditions existed also at Clava.

It seems almost like an anticipation and confirmation of this suggestion that the late Dr. John Fleming, of Edinburgh,—a shrewd and sagacious naturalist, whom Mr. Jamieson quotes as having known the Red Clay well,—'thought it must have been accumulated in the water of some immense lake into which the sea had made only a temporary irruption.' This strikes us as being a remarkable surmise of fifty years ago, when the distinguished author had no idea, apparently, of how such a lake could be formed.

The writer is pleased to add that Mr. Jamieson has courteously acknowledged the probability of the conditions herein suggested.

DISCUSSION.

Mr. CLEMENT REID said that, although unacquainted with the particular district dealt with by the Author, he was inclined to agree with his explanation of the origin of the shelly deposits. The tumultuous character and the mixed fauna of the Clava sands and Boulder Clay agreed closely with what he had observed in other glaciated districts at heights of over 150 feet.

Prof. G. A. J. COLE remarked that the publication of the paper would be looked forward to with great interest in Ireland, where the extent of shell-bearing gravels and clays made the question of recent submergence of especial importance. The shells were now generally admitted by field-observers, including Mr. Maxwell Close himself, to have been removed from their original habitat. The speaker claimed that the submergence occurred in late Pliocene times, and may have been merely the continuation of that which deposited the Lenham Beds in England. Thus many of the so-called 'recent' species in Glacial beds might easily be derived from Astian or even earlier strata, on which the great mixing influences of the Glacial Period had been exerted.

Dr. HICKS mentioned the deposits containing shells at heights of from 400 to 600 feet in the Vale of Clwyd, North Wales, which are covered by a Boulder Clay with northern erratics.

¹ Quart. Journ. Geol. Soc. vol. xlvii. (1891) p. 428.

Mr. G. H. MORTON referred to the Glacial drift-deposits of the country bordering the Mersey and Dee, and he considered that they were deposited in the sea between the coast of Wales and the North of Lancashire where glacial conditions prevailed. Beds of inter-stratified sand, often ripple-marked, and sometimes containing rolled balls of clay, divided the Boulder Clay into beds, and frequently gave it a stratified appearance. The shells found in the Boulder Clay had been described as very fragmentary, but the numerous species in his own collection were remarkably perfect. They were all species now living in the Irish Sea, the most abundant being those common on the sea-shore at the present time. All the observations that he had made tended to show that the Boulder Clay and associated sands were deposited in a sea with floating ice, and were not the result of glacier-ice moving over that part of the country.

Mr. MARR also spoke.