XII. *On the power of Icebergs to make rectilinear, uniformly-directed Grooves across a Submarine Undulatory Surface.* By C. Darwin, *Esq., Vice-Pres. R.S., F.G.S.**

HAVING been induced to believe, with many geologists, that certain continuously scored and polished surfaces of rock were due to icebergs, and not to glaciers, I have nevertheless always felt much difficulty in understanding how long, rectilinear scratches, running in one given direction across an *undulatory* surface, could have been thus formed. Others have felt this same difficulty, and it has been advanced as an insuperable difficulty by the opponents of iceberg action. The following considerations, though possessing little or no novelty, have in my own case removed the difficulty. But first, to give one instance of such scratches, I may quote a passage from Agassiz†, who, in describing the state of the surface near Lake Superior, says, "nothing is more striking in this respect than the valleys or depressions of the soil running E. and W., where we see the scratches crossing such undulations at right angles, descending along the southern gentle slope of a hill, traversing the flat bottom below, and rising up the next hill south in unbroken continuity." He proceeds to state that the scratches run up even steep northern slopes, though the southern faces of the hills are generally rugged. A glacier driven straight forwards over its unequal bed would perfectly account for these facts; but not so, at first appearance, floating ice, whether that of coast-ice or of icebergs. For such masses being borne along on the level ocean, would, when driven on shore or against a submarine hill, be deflected, as it might be thought, from their course, and mark the rocks horizontally or nearly so,—some allowance being made for the rise and fall of the tide. And although during either the submergence or emergence of the land, the whole surface of a mountain might become thus marked, yet the successive scores at each level would all be nearly horizontal. No doubt short inclined grooves might be formed by masses of ice being driven by gales up the beach; but as sea-shores run in every possible direction, it is obvious that such grooves could follow no uniform course, nor could they be of any considerable length; hence grooves thus made would not be comparable with those now under discussion.

The plasticity of glaciers, as shown by the manner in which they immediately expand after passing through gorges, and in which they mould themselves to every sinuosity and prominence in their beds, is now, thanks to the labours of a few eminent men, familiarly known to every geologist. It is asserted by

* Communicated by the Author.

† Lake Superior, its Physical Character, &c., by L. Agassiz, p. 406.

some authors that glacier ice is most plastic when most charged with water, and the lower part of an iceberg must be water-logged. Again, a glacier, for instance of 1000 feet in thickness, must press on its bed with the whole immense weight of the superincumbent ice; but in an iceberg 1000 feet thick, as the whole floats, there will of course be no pressure on a surface exactly level with its bottom, and if driven over a prominence standing up at the bottom of the sea some 50 or 100 feet above the basal line of the berg, only the weight of as much ice as is forced up above the natural level of the floating mass, will press on the prominence. It may therefore, I think, be concluded that an iceberg could be driven over great inequalities of surface easier than could a glacier. That the weight of a comparatively thin sheet of ice is sufficient to groove rocks, we may infer from the case described by Sir C. Lyell of the scores made by the packed *shore-ice* on the coast of the United States. That icebergs do not break up when grounded, as *à priori* might have seemed probable, is obvious from the simple fact of their having been often observed in this condition in open turbulent seas. Let anyone who has witnessed the crash of even so small an object as a ship, when run into by another having only a barely perceptible movement, reflect on the terrific momentum of an iceberg, some mile or two square, and from 1000 to 2000 feet in thickness, when, borne onwards by a current of only half a mile per hour, it runs on a submarine bank: may we not feel almost certain, that, moulding itself like a glacier (of which it originally was a portion), but owing to its water-logged state and little downward pressure moulding itself more perfectly than a glacier, it would slide straight onwards over considerable inequalities, scratching and grooving the undulatory surface in long, straight lines? In short, if in our mind's eye we look at an iceberg, not as a rigid body (as has hitherto been always my case) which would be deflected or broken up when driven against any submarine obstacle, but as a huge semi-viscid, or at least flexible mass floating on the water, I believe much of the difficulty will be removed which some have experienced in understanding how rectilinear grooves could be formed continuously running, as if regardless of the outline of the surface, up and down moderately steep inequalities, now existing as hills on the land. It should be borne in mind that the course of deeply-floating icebergs is determined by the currents of the sea, and not, as remarked by Scoresby, by the shifting winds; and as the currents of the sea are well known to be definite in their course, so will be the grooves formed by current-borne icebergs. It is indeed difficult to imagine any difference between the effect on the underlying surface, of a glacier propelled by its gravity, and that of a mountainous island of ice

driven onwards by an oceanic current, except that the iceberg would perhaps have the power, from the causes above specified, of even more closely moulding itself, and, as it were, of *flowing* straight over submarine obstacles, than has a glacier on the dry land.

One other point is perhaps worth considering. I have elsewhere* endeavoured to show that the action of coast-ice and of icebergs must be considerably different in transporting boulders; the worn stones on the beach being imbedded in coast-ice, and fragments of rock which had originally fallen on the parent-glacier being carried by icebergs as on rafts. But when we reflect that icebergs are driven onwards year after year in certain definite directions by the currents of the sea,—that they float so deeply as to have been seen aground at the depth of 1500 feet,—that when stranded they must (as I conceive) mould themselves to the inequalities of the bottom and slide some distance over it,—it can hardly be doubted that they also must, like glaciers on the land, push in certain determinate directions moraines before them. Although a fragment of rock or an irregularly formed moraine may by any one iceberg be propelled for only a very short distance, yet in the course of years the transportal can hardly fail to become far extended, the boulders being rolled over large inequalities of surface, and even up heights by the action of successively smaller bergs: an abyss, however, deeper than the deepest-floating iceberg would, of course, absolutely stop this rolling or pushing action. Finally, in the case of every mass of erratic boulders, we have now to determine, and I believe hereafter it will be so determined, whether they were transported by glaciers or by floating ice, and in this latter case whether imbedded in coast-ice, strewed on the surface of icebergs, or pushed onwards as a subaqueous moraine.

XIII. *On Electric Conduction.*

By Professor Faraday, *D.C.L., F.R.S.*†

SINCE the time when the law of definite electrolytic action was first laid down (Exp. Res. 783–966), it has become a question whether those bodies which form the class of electrolytes conduct only whilst they are undergoing their proper change under the action of the electric current; or whether they can conduct also as metals, dry wood, spermaceti, &c., do in different

* Transactions of the Geological Society, vol. vi. (2nd series) 1841. p. 430.

† From the Proceedings of the Royal Institution of Great Britain, for Friday, May 25, 1855.