at Airdrie in Scotland carried eastward from the bottom of the Clyde; and those in Caithness from Moray Firth, were among examples adduced in proof of this principle. The improbability of a great submergence not leaving corresponding deposits in other parts of England was dwelt upon.

It was also held that there was insufficient evidence of more than one advance in the ice-sheet, although halts occurred in its retreat. The idea of successive elevations and submergences with advances and retreats of the ice was disputed, and the author held that much of the supposed interglacial drift was due to subglacial water from the melting ice.

The last portion of the paper discussed the distribution of boulders, gravels, and clays south of the glacial area. Much the greater part of England was believed to have been uncovered by land-ice. The drift deposits in this area were shown to be the result in part of great freshwater streams issuing from the melting ice-sheet, and in part of marine currents bearing icebergs during a submergence of some 450 feet. The supposed glacial drift about Birmingham, and the concentration of boulders at Wolverhampton, were regarded as due to the former agent; while the deposits at Cromer and the distribution of Lincolnshire chalk across southern England was due to the latter. The supposed esker at Hunstanton was believed to be simply a sea-beach, and the London drift deposits to be of aqueous origin. Thus the rival theories of floating icebergs and of land glaciers were both true, the one for middle and southern England, the other for Scotland, Wales, and the north of England; and the line of demarcation was fixed by great terminal moraines. The paper closed with an acknowledgment of indebtedness to the many geologists of England and Ireland, who had uniformly rendered generous assistance during the above investigation.

VII.—Note on the Facetted Pebbles from the Olive Group of the Salt Range, Punjab, India.

By R. D. Oldham, A.R.S.M.,
of the Geological Survey of India.

At the last meeting of the British Association certain facetted pebbles derived from the Olive group of the Salt Range, and presumably of glacial origin, were exhibited and commented on.[1] Some doubt appears to have been expressed as to their being due to glacial action. The following notes on these pebbles and the bed they were derived from may prove of interest.

The boulder bed of the Olive group in the Salt Range consists of a fine-grained, thin-bedded, shaly matrix, usually of that shade of green from which the name of the group is derived; through this are scattered blocks of hard crystalline and metamorphic rock, of all sizes, from an inch or less to several feet in diameter. They are too abundant for their occurrence to be explained by the action of drift wood, nor is there any sign of cabonaceous matter in the bed; there is no indication of volcanic action, and, as many of the fragments must have travelled scores, if not hundreds of miles, we are compelled to allow that their occurrence in their present position is primarily due to the action of floating-ice. So much has long been allowed by all who know the bed.

[1] See Geol. Mag. 1886, Decade III. Vol. III. pp. 492, 494, 574.

Of these blocks of stone an appreciable proportion show a flattened striated surface, exactly like that produced by glacial action; but a peculiarity of this boulder bed is that a very large proportion of those blocks which show this feature are not striated on a single face only, but on several; and in some cases the original form of the pebble is so completely obliterated, and the facets meet on so clean-cut an edge, that the pebble assumes almost the appearance of a crystal. Something similar to this is known in the Boulder-clay of England; instances were quoted at the British Association, and I have myself seen a pebble from the Boulder-clay of the Midland Counties so striated on three faces; but these surfaces did not meet in a sharp edge, like those so commonly met with in the Salt Range specimens.

Having shown that the occurrence of these pebbles in their present position is due to the action of floating-ice, we have next to consider whether their peculiar form is also due to the action of ice, and if so whether as coast-ice or in the form of a glacier.

A suggestion was made at the British Association that the facetting might be due to the action of wind-blown sand; this, however, I cannot admit. Without egotism I may say that I have had opportunities of studying the erosive action of blown sand such as fall to the lot of few geologists. I have seen numbers of stones facetted by the sand blown against their different faces as they were overturned from time to time through one cause or another; but I have never seen anything which, to a practised eye, resembled these Salt Range pebbles any more than these latter do a crystal of felspar.

Where blown sand acts on a rock sufficiently hard or fine-grained, a polished surface, marked with numerous fairly parallel scratches in the direction of the prevailing wind, is produced. These scratches, however, could not be confounded with glacial striæ; for they are such as would result from particles of grit getting into an artificial polisher, and are very different from the clean and finely-cut scratches produced by glacial action. Where the rock is softer, it is often cut into grooves parallel with the direction of the prevailing wind; these, too, are not like the grooving produced by ice, but broad shallow channels separated by sharp-crested ridges, giving the rock an appearance as if it had been roughly dressed with a carpenter's gouge. In any case there is an entire absence of anything approaching to a sharp edge except in the direction of the wind, all angles oblique or transverse to that being rounded off. Now the facetted pebbles and boulders of the Salt Range show by the direction of the striæ on them that in almost every case the facets are due to some cause acting in a direction more or less transverse to the line along which they meet; consequently the facets cannot be due to the action of blown sand, which would have rounded off any angle so situated with reference to the direction in which the sand was drifted.

The number of stones showing one or more striated surfaces prevents us from ascribing their origin to a movement of the soil-cap, while the steadiness of direction of the striæ on each face shows that the fragment must have been firmly held, and, in the case of the smaller ones, it is difficult to see how they could have been so held except by being imbedded in some material which, like ice, would adapt itself completely to the shape of the pebble.

The striated faces bear no resemblance to slickensides, and as the fragments seldom touch each other in the bed, but are separated by a greater or less thickness of the fine-grained matrix, any attempt to explain their origin by friction of the pebbles against each other subsequent to deposition is inadmissible; moreover, there is no exceptional disturbance of the beds, and the striated fragments are as common where they lie nearly horizontal as where they are tilted.

The only other agency by which the facets could have been produced is that which is at first sight suggested by the appearance of the pebbles, viz. *ice*, and it only remains to see whether this was in the form of coast-ice or glaciers. Here we must leave the domain of certainty, and enter on that of probability.

Prof. J. Milne has shown [1] that, as far as the live rock is concerned, many of the appearances usually considered characteristic of glacier action may be produced by coast-ice; but in the present case we are not concerned with what happens to the rock *in situ*, but with the effect produced on the loose pebbles and boulders caught up in the ice and ground on the solid rock. At first sight the number of striated faces on many of these pebbles would seem to point to the action of coast-ice, for, after every melting of the ice, the pebble would probably be fixed each winter in a fresh position, and offer a different face for abrasion; but it is doubtful whether the facets do not indicate a greater pressure and a greater constancy of direction of motion than could be given by coast-ice, and it is still more doubtful whether they could be produced during a single winter, which on this supposition is all that can be allowed for each facet.

A much stronger objection is the entire absence of any sign of the action of water on some of the pebbles. Had the facets been due to the action of coast-ice forming in winter and melting again in summer, the pebbles would every year have been exposed for a longer or shorter time to the action of waves, and the sharp, clean-cut junction of the facets which we find would have been more or less abraded; so that, if the shape of these pebbles is due to the action of coast-ice, it must have been perennial. I need but point out that coast-ice lasting through winter and summer implies a much severer climate than is needed to account for glaciers descending to the sea; *a priori* then the latter is the more probable hypothesis as requiring the least climatic change, besides being more in consonance with the evidence derived from the appearance and mode of occurrence of the boulders and pebbles showing signs of glacial action.

I have now shown that these boulder beds owe their origin primarily to the action of floating-ice, that the shape of the facetted fragments must be due to glacial action, that some at least of them can never have been exposed to the action of waves on a sea-beach, and that consequently they must have been shaped either by perennial coast-ice rising and falling with the tides, or by a glacier which descended to the sea and there gave off icebergs. In either case they imply a change of climate which, if we bear in mind that the fragments have all come from the southwards, and in many cases from long distances, is of a degree and kind difficult if not impossible to explain in accordance with accepted theories.

[1] Geol. Mag. Dec. II. Vol. IV. p. 293 (1877).

VIII.—The Lower Palæozoic Rocks near Settle.

By J. E. Marr, M.A., F.G.S.

The rocks of this area have been previously described by Professor Hughes (Geol. Mag. Vol. IV.), and some notes upon the same were subsequently submitted by myself to the British Association at York in 1881, and published in the Proceedings of the Yorkshire Geological and Polytechnic Society (Proc. Y. G. & P. S. n.s. vol. vii.).

Further work was carried on this year, in company with a party of Cambridge geologists, under the guidance of Prof. Hughes, and I have to thank him and them for much information, and for the opportunity of examining many specimens.

Firstly, I would correct one or two errors in my previous paper.

In the section in Austwick Beck, a considerable thickness of black shales is indicated between the conglomerate and the calcareous band with *Phacops elegans*. These black shales are really below the conglomerate, which latter appears in each limb of the anticlinal represented in the section, though *much attenuated*, and the black shales have yielded Bala fossils, including *Orthis testudinaria*, Dalm.

The only deposit between the conglomerate and the bed with *Phacops elegans* consists of two or three inches of leaden-grey shales, in which no fossils have been yet found.

The beds marked 5 in the section already referred to, and described as pale green shales, are really a portion of the same series as 6, and contain identical fossils with it, and the difference of colour is simply due to weathering.

We must therefore strike the beds 3 and 5 out of the list of those which I correlated with the Stockdale shales (Valentian), and admit that these are represented at Austwick only by the conglomerate, the leaden-grey shales, and the zone of *Phacops elegans*. That these thin beds represent the whole of the Valentian of other areas is doubtful, and it is possible that the representatives of the Coniston mudstones are here absent, and that the pale slates only are represented. That this may be the case is further indicated by the fact that *Phacops elegans* does occur in the higher Valentian beds, as in the Tarannon shales of Onny River, for I have recognized this species in the Jermyn Street Museum from that locality.

I may now proceed to a more detailed description of the different deposits in ascending order, as seen in the small valley near Austwick, through which Crummack Beck runs, and in the main Ribble Valley to the north of Settle.

As I do not wish to introduce new names, I shall speak of the beds