indicated by the vascular grooves and impressions which mark the surface of both plates and spines, except their bases, which were evidently implanted in the thick skin.

The peculiar group of extinct reptiles named by the writer the *Stegosauria*, of which a typical example is represented in the present restoration, are now so well known, that a more accurate estimate of their relations to other Dinosaurs can be formed than has hitherto been possible. They are evidently a highly specialized sub-order of the great group which has the typical *Ornithopoda* as its most characteristic members, and all doubtless had a common ancestry. Another highly specialized branch of the same great order is seen in the gigantic *Ceratopsia*, of the Cretaceous, which the writer has recently investigated and made known. The skeleton of the latter group presents many interesting points of resemblance to that of the *Stegosauria*, which can hardly be the result of adaptation alone, but the wide difference in the skull and in some other parts indicates that their affinities are remote. A comparison of the present restoration with that of *Triceratops*, recently published by the writer,¹ will make the contrast between the two forms clearly evident.

All the typical members of the *Stegosauria* are from the Jurassic formation, and the type specimen used in the present restoration was found in Wyoming, in the *Atlantosaurus* beds of the Upper Jurassic. *Diracodon*, a genus nearly allied to *Stegosaurus*, occurs in the same horizon. *Omosaurus* of Owen, from the Jurassic of England, is the nearest European ally now known, but whether it possessed a crest of dermal plates like that of *Stegosaurus* is doubtful, although caudal spines were evidently present.

II.—THE SCANDINAVIAN GLACIER, AND SOME INFERENCES DERIVED FROM IT.

By T. F. JAMIESON, F.G.S.

IT is now fifty years since Charpentier² told us that the heaps of Northern boulders which stretch across the plains of Prussia and Saxony mark the ancient limits of the great glacier of Scandinavia, and that the smaller debris met with farther south represents the stuff carried on by the torrents that escaped from the margin of the ice. All this he explained to his incredulous contemporaries, and now after half a century of debate, in which every other conceivable mode of accounting for the phenomena has been tried, it seems to be agreed on all hands that he was right—right in every particular—but, strange to say, it appears to be now generally forgotten that he was the man to whom we owe the first sketch of this explanation.

Agassiz,³ in 1846, alluding to the previous observations of Charpentier, candidly said, "I was unable to believe in his conclusions when he first imparted them to me, and I made observations in order

¹ See GEOL. MAG. Dec. III. Vol. VII. 1890, Pl. I. pp. 1-5, and Vol. VIII. 1891, pp. 193-199, Pls. IV. and V., and pp. 241-250, Pl. VII.; and Amer. Journ. of Science, vol. xli. p. 339, April, 1891.

² Essai sur les Glaciers, note to p. 319.

³ Bull. Geol. Soc. France, 2 ser. iii. p. 420, 6 April, 1846.

to combat them, but I have been converted to his mode of view." Charpentier, however, tells us that it was his friend Venetz who was the first to perceive (as he tersely puts it) that "tout le phénomène du terrain erratique trouvait son explication dans l'existence ancienne d'immenses glaciers."

When the Scandinavian Glacier reached its maximum, it extended over most of Northern Europe and stretched eastward beyond Moscow. To the south-east it went as far as the 50th parallel of lat. on the banks of the Dnieper, and from that its southern border ran westward along the northern base of the Carpathian Mountains and the hills of Central Germany to the mouth of the Rhine. If the starting-point lay in the mountain-chain of Scandinavia, the ice must have travelled to the south-east, a distance of fully 1000 miles. Nitikin¹ tells us that the northern erratics extend over the whole Government of Tschernigow and the east part of that of Kiew, but the unstratified brown Boulder-clay which accompanies them does not go beyond the eastern border of the Tschernigow Government.

General Helmersen² says that heaps of northern boulders, generally of small size, but some of them four feet in length, occur as far as Moscow, while further south they rapidly diminish in size to mere pebbles. The large angular blocks mentioned as occurring in the Governments of Kursk and Woronesh are not erratics, but consist of sandstone the same as that of the district in which they are found. The size of the erratics diminishes gradually with the distance from their source. In Finland they are often as big as cottages, and in the Government of St. Petersburg blocks of large dimensions may also be seen. Most of them are of granite and gneiss, such as occur in Finland and Northern Norway.

Judging from the accounts of Torell, De Geer, and other Swedish geologists, the stream of ice that came down the Baltic must have had a length equal to fifteen degrees of latitude, or more, and the whole tenor of the evidence leads me to think that I am not overstating, when I say that the Scandinavian glacier travelled in some directions at least 1000 miles. The reason why it went so far to the south-east no doubt was because there were neither hills nor opposing glaciers to obstruct its march, and the plains of Russia gave ample room for it to spread freely onwards. The Canadian ice seems to have travelled nearly as far in a south-westerly direction, and for similar reasons.

Now what would be the inclination or slope of the surface in a glacier of such dimensions? The nearest thing of the kind that we have any knowledge about is the ice-sheet of Greenland. What the average slope of its surface amounts to has not yet been properly determined, but from all we have hitherto learned it does not seem to be less than half a degree, or 46 feet per mile. In the glaciers of

¹ S. Nitikin, *Die grenze der Gletscher spuren in Russland und dem Ural Gebirge*, Peterm. Geog. Mit. 1886; also *Geol. Bau der Eisenbahn linie, Gomel Briansk, Russia*, 1887.

² G. V. Helmersen, *Studien über die Wanderblocke und die Diluvial Gebilde Russlands*, Mem. de l'Acad. Imp. des Sci. St. Petersburg, 1869.

the Swiss Alps the smallest mean inclination is 3° or six times greater.

Nordenskiöld's Expedition, in 1883, in lat. 68° , was alleged to have penetrated 160 miles into the interior of Greenland, at which distance an altitude of 6000 feet was said to have been attained. This would give an average rise of $37\frac{1}{2}$ feet per mile over the whole distance; but I suspect these figures cannot be relied upon, because we are told the last 115 miles were done by the Laplanders of the party, whose estimate of the distance seems to have depended on mere conjecture. Nordenskiöld himself attained a distance of only 62 miles from the outer edge, at which point he made the altitude to be 4500 feet or $72\frac{1}{2}$ feet per mile. The positions of his camp were determined by solar observations, the other distances by pedometers, while the heights seem to have been fixed by the barometer. How the Lapps estimated the height they reached I have been unable to ascertain.

Dr. Hayes, who believed that he penetrated 70 miles into the interior of Greenland, found that the surface of the ice had a slope at first of about 6° , and then diminished gradually to 2° at the end of the first 30 miles. At 70 miles from the coast he calculated that he had attained an altitude of 5000 feet, which would give about 71 feet per mile, and this is almost the same result as that obtained by Nordenskiöld himself. Dr. Nansen states that, in 1886, an American, R. E. Peary, travelled 100 miles from the edge of the iceblink, his highest elevation being 7525 feet. This was further north than Nordenskiöld's route in 1883, and gives 75 feet per mile.

Nansen and his party, in 1888, landed on the east coast of Greenland at lat. $61^\circ 30'$, and then travelled along the coast northward to Umiavik, lat. $64^\circ 30'$. From this, after penetrating ten miles into the interior, they reached a height of 3000 feet. In lat. $64^\circ 50'$, at 40 miles from the coast, they were at a height of about 7000 feet on the 27th of August. By the beginning of September they got to a flat extensive plateau, whose height was 8000 or 9000 feet, and which seemed to rise considerably higher to the north. Over this plateau they travelled for more than two weeks, reaching the west coast in lat. $64^\circ 12'$ on the 26th September. The breadth of Greenland where Nansen crossed it in lat. $64\frac{1}{2}^\circ$ does not seem to exceed 340 English miles, which would make the central point 170 miles from the coast, and taking the altitude at the centre to be 8500 feet, this would give an average slope of just 50 feet per mile. Nansen's results probably afford the best approximation we have yet got, as the fact of his crossing the whole breadth of the land in an ascertained latitude enables us to gauge the extreme distance he penetrated into the interior with some confidence, if our maps are at all correct. Further north the greatest width of Greenland seems to be about 700 miles, which would make the middle point 350 from the coast. A rise of 50 feet per mile on this distance would give 17,500 feet for the altitude of the surface at the centre.

From all we know of the Greenland ice it would seem that the

gradient of its surface increases always towards the outer edge, and that for the first hundred miles from the border we would not be justified in assuming an average slope of less than 60 feet per mile, and probably 70 would be nearer the truth. Then for the remainder of the distance suppose we put the slope as low as even 12 feet per mile, we still get the following result for a distance of 1000 miles,

100 miles at 60 feet per mile	6,000 feet.
900 „ 12 „ „	10,800 „
1000 miles.	16,800 feet.

which gives an average of nearly 17 feet per mile over the whole length, and I see no reason for thinking a less slope at all probable. Now the present culminating point of Scandinavia is 8544 feet, and only a very few of the mountain tops exceed 6000 feet; we have therefore a very strong presumption that the former height of that land must have been vastly greater than it is now, and the same conclusion will apply to the centres of glaciation in Canada and Scotland. Supposing that in Scandinavia we place the centre of radiation for the ice not in the Norwegian hills, but in the lower ground to the eastward, still it will not materially affect the result, for although we thereby shorten the length of the glacier, we lower the present altitude of the point from which it had to start. The probability, therefore, seems to be very great that at the commencement of the Glacial period the altitude of Scandinavia was higher—very much higher—than at present, and this conclusion is strongly supported by other considerations of scarcely less weight.

1. In the first place the whole sea-board of Norway is intersected by long deep fjords, which have all the appearance of being the sunken valleys of a submerged mountain-land that had been deeply cut by rivers at a time when the country stood at a far greater height above the sea. Christiania Fjord reaches a depth of 1380 feet, Hardanger 2624, and Sogne Fjord no less than 4080 feet. Their sides are often very precipitous, and Sexe¹ tells us that in the Hardanger Fjord, in fine calm weather, when the water is very transparent, the head turns quite giddy on looking over the side of a boat down these submarine cliffs. Probably few will believe that glaciers could have eroded the hard crystalline rocks of Norway to a depth of thousands of feet beneath the sea-level, or could have cut them into such precipitous forms, for the action of a glacier on its bed has a tendency to produce flowing or bowl-shaped outlines. Moreover, the heaviest current of ice seems to have been that which came down the Baltic, which is a shallow sea, the general depth being only 40 to 60 fathoms. The probability, therefore, seems to be that these fjords of Norway, like the cañon of Colorado, were cut by mountain-streams in pre-Glacial times when the land stood at a much greater height, for how otherwise can we suppose them to have been excavated? The same observation will apply to the sea-lochs which indent the west coast of Scotland and also to the fjord latitudes of America, as Dana long ago pointed out.

¹ S. A. Sexe, Mærker, efter en Iistid i omegnen af Hardangerfjorden. Christiania, 1866.

2. Again, Dr. Tyndall reminds us that what we most want in order to produce the glaciers of the Ice-time is improved condensers. Now there is no better condenser than a lofty mountain. Heave it high enough and you will get snow at the Equator, as we see on the Andes, and at Kilima-Njaro in Africa. Here then we have another good argument for a much greater height of the Scandinavian plateau, and the same observation will hold good for other glaciated regions. I therefore think that at the commencement of the Ice-time these countries had a far greater altitude than at present—an opinion which I expressed quite as distinctly thirty years ago.¹ It is difficult, indeed, to see how otherwise a sufficient permanent condensing power could have been sustained in these latitudes; for even in Greenland, at the present day, the line of perpetual snow is 2000 feet above the sea-level, and it is on the high mountain range of the interior that the ice is generated. Dr. Croll,² in his paper on the Antarctic ice, asserted that "the Greenland ice-sheet, like the Antarctic, must be thickest at the centre of dispersion and thinnest at the edge." If the ice lay upon a perfectly flat horizontal plane, no doubt it would require to be thickest at the centre, but if the ground supporting it is 10,000 or 15,000 feet higher at the centre than at the edge, as seems not unlikely, then the thickness at the centre of dispersion need not be so very great. If Croll had said that the surface of the ice-sheet must be *highest* at the centre and *lowest* at the edge, it would have been all very well; but the thickness of the ice at the centre of dispersion must depend much upon the altitude of the surface on which the ice rests.

As the ice accumulated upon these lofty regions they appear to have gradually undergone a movement of depression, and the opinion seems to be gaining ground that this depression may have been caused by the weight of ice which was laid upon them.³ It is at any rate quite clear that after the period of maximum glaciation Scandinavia underwent a partial submergence, during which the great glacier seems to have broken up and disappeared from much of the ground it once covered, and this same order of events seems to have occurred in the other great centres of glaciation in Britain and North America.

Dr. Penck's⁴ theory that the submergence was caused by attraction of the ice drawing the sea up on to the land, has not been sustained by an appeal to mathematical investigation; for Woodward in America, Drygalski, and Hergesell in Germany, and Faye in France, who have in elaborate papers discussed the subject from a mathematical point of view, seem all to agree that the cause in question would be quite insufficient to account for the facts, even on the most liberal estimate of the possible volume of ice. Indeed, it would

¹ Quart. Journ. Geol. Soc. vol. xviii. p. 180-1, Feb. 1862.

² Quart. Journ. of Science, Jan. 1879.

³ G. de Geer, Om Skandinaviens Nivåförändringar under Quartärperioden. Stockholm, 1890. Warren Upham, Review of the Quaternary Era, Amer. Journ. of Science, Jan. 1891.

⁴ Schwankungen des Meeresspiegels, Jahrb. der Geog. Ges. zu München, bd. vii. 1882.

appear that, owing to the abstraction of water required to form the ice, the surface of the sea would on the whole be lowered, and this effect would surpass the other, however great the thickness of ice, so that the combined effect of the European and North American glaciations, if simultaneous, would be to cause a general sinking of the sea-level during the period of maximum ice. The general result, however, would depend much upon the relative extent of the Arctic and Antarctic glaciers at the time, a subject regarding which we know little or nothing. Penck seems to have been under the impression that the attraction would have caused the sea to rise towards the border of the ice in a comparatively rapid swell, but such would not have been the case. Any rise in the level of the sea induced by such a cause would be nearly parallel to the present surface, and would extend much further horizontally outwards than Penck seems to have contemplated, while its vertical extent would be far less than he supposed.

If at the commencement of the Glacial period, Scandinavia (or at least a large part of it) stood several thousand feet higher than it does now, then it follows that the subsequent depression must have been very considerable indeed, and the subsidence of such a large area to the extent required would no doubt occasion much squeezing, disturbance, and probably some upheaval in neighbouring regions. I am inclined to think that the ice was gathering on the mountains of Norway at a much earlier period than is generally believed, and that the coming on of the glaciation took place in early Pliocene times, or even sooner. Many of the disturbances that have taken place in the strata near the Straits of Dover and elsewhere may have been occasioned by strains induced by the load of ice, and the bursting out of volcanoes in Germany, Auvergne, and other places may have arisen from pressure on the subterranean lava due to the same cause.

III.—TRANSVERSE VALLEYS IN THE EASTERN CAUCASUS.

By Professor HJALMAR SJÖGREN,

Professor of Mineralogy and Geology in the University of Upsala, Sweden.

1. *The Sulak gorge below Gimri in Daghestan.*

AMONG the many valleys of Daghestan that are interesting to the geologist there are none more remarkable than the channel by which the river Sulak passes through the chain of Cretaceous and Jurassic mountains which borders Inner Daghestan. Just above the entrance of this defile the four rivers Koissu unite in one stream, which in a series of cataracts tears through a stupendous chasm some fifteen miles in length, cutting the huge ridge almost at right angles to its axis.

The gorge traverses the main chalk ridge in the direction N. 40° E., then changes its line to N.W., which it still follows at the widening of the valley below Tjirkei, and finally comes back to due N. as it passes through the Tertiary hills below Subut. The mean height of the ridge thus cut asunder is some 2000 mètres or more