REVIEW.*

It has been much the fashion of late to deplore that the Alps are becoming exhausted, and it is a mere truism to repeat that few, if any, new expeditions of the first class remain to be made. It is impossible to deny that some of the special interest attaching to excursions in the high Alps, which has presented so strong an attraction to mountaineers during the last twenty years, has now ceased to exist. It is in vain to urge that, apart from the mere gratification of vanity, the charms of the high-level route, or the grandeurs of the Matterhorn, remain unchanged. There is a difference, which is not to be argued away between the active pleasure of exploration and the passive satisfaction of following in the track of others. There are doubtless in the world other Alps to climb. But New Zealand and Japan have not yet been brought within the reach of the long vacation tourist, and even the Caucasus is practically as inaccessible to the majority of travellers.

It seems to us, however, that the old expeditions may yet, for some time to come, be invested with an interest and novelty analogous to that of which we are regretting the loss. There are questions and problems which will present themselves by the way of a higher interest than whether this or that couloir be the most practicable, and discoveries to be made, the attainment of which will even equal the satisfaction of a successful first ascent. The author of the work before us is one of those mountaineers who do not enjoy their excursions the less because they pursue them with a scientific object, and who would derive less gratification from being the first to attain a given summit than from being the first to observe any important fact or phenomenon which might there present itself.

M. Favre's geological researches have extended over nearly thirty years—a period in which the science has made much progress, and undergone some remarkable transformations. The results of his observations are given in great detail in the present work. The first volume, and nearly all the second, are occupied with the description of the plain country around the Lake of Geneva, and the secondary mountain masses between this and the valleys of Chamonix and the Isère. The conclusion of the second volume, and the first half of the third, describes the mass of Mont-Blanc, part of the Tarentaise and Maurienne, and the secondary chain which extends from the Little to the Great St. Bernard on its southern side, which may be regarded as geologically one, though intersected by the valley of the Dora between Courmayeur and Pré St. Didier. The remainder of the third volume is devoted to an examination, in the order of succession, of all the geological formations which are found in the districts already described. In this *résumé* the author is necessarily led to the exposition of his theoretical ideas. The reader will hardly consider the apology which

* *Recherches géologiques dans les parties de la Savoie, du Piémont et de la Suisse voisines du Mont Blanc.* Par Alphonse Favre.

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he makes for so doing to have been needed, but will appreciate the justice of the following remarks:—'Experience has shown me that observations last longer in science than theories, and that we ought not to attach so much importance to these last. This relative position of these two sorts of labours is natural: an observation establishes an unchangeable fact, but the interpretation of that fact may be modified according to the extent to which new light is thrown on the obscure parts of science; and as we only approach the truth by little and little, the fluctuations of theory are far from being terminated.'

M. Favre commences the theoretical portion of his work with an inquiry regarding the nature and origin of granite. It has often been the subject of question whether true granite was to be found in the Alps. Perhaps in this, as in many other disputed questions, the dispute has rather been of words than of facts. The centre of the chain of Mont Blanc consists of Protogine,* a crystalline rock, so named by Professor Jurine of Geneva, who believed it to be primæval (protogonos). Our author states that this designation has remained in science, in spite of the resistance of Aubuisson, Von Buch, and Raumer, the two latter having maintained, with reason, in 1817, that this rock was of a recent period. If not primæval, however, M. Favre holds that the granites and protogines are the oldest rocks which are now to be found on the surface of the earth. These, and nearly all the others with which we are acquainted, are not igneous, but sedimentary. The only true igneous rocks are the lavas and other volcanic formations, and the only true primitive rocks were the igneous rocks of a similar nature, which formed the crust of the earth before the condensation of the water, and of a great part of the gaseous elements which now enter largely into the composition of the materials of the earth's surface.

That the granitic rocks were of igneous origin, and that they were elevated into the nuclei of mountain chains in a pasty or semifluid state, was a doctrine that scarcely any geologists would have ventured a few years ago to call in question. But a change has come over the spirit of our dream. The Neptunists are again in the ascendant, and the Plutonists are nowhere. According to M. Favre (and we may add many other lights of geological science), it is not only probable that granite has originated in the 'moist way,' but almost impossible that it can ever have been subjected to a temperature near that of fusion. M. Delesse says, 'The existence of organic volatile matters in the granitic rocks would alone suffice to demonstrate that they have not been subjected to a high temperature, and that they have not an igneous origin.' We have already hinted at the difficulty which the same fact throws in the way of other theories. What it suggests is *metamorphism*, but metamorphism is in M. Favre's view even more heretical than igneous origination.

* True granite is, however, found also in the Alps, and even on Mont-Blanc itself. The most important granite known in this district is that of Beaufort, which is, however, porphyritic in structure. It is found also in the valley of Poncellamont, near Beaufort, and in veins at Valorsine, in the route of the Tête Noire.

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But other facts connected with the granitic rocks seem to lead to a similar conclusion. Sir Humphrey Davy had observed the presence in quartz crystals of minute cavities containing a gas or liquid, and it is difficult to understand the formation at a very high temperature of crystals containing such matters. De Saussure, moreover, remarked crystals of quartz which had formed upon and after fibres of amianthus. In a similar manner quartz is often found to envelope minerals that are easily fused, such as the molybdate of lead, gold, copper, sulphuret of antimony, and others, upon which it could not have been crystallised by igneous fusion. In the granites we often see quartz moulded upon felspar, which is much more easily fused, and M. Favre has made the same observations on the crystalline schists. We may lay down as a general rule that the order of formation of the minerals in the crystalline rocks is not that of their solidification, supposing them to have been fused. Quartz crystals are, moreover, found in clay geodes in the sedimentary rocks, which have unquestionably not been exposed to a high temperature. Why should not quartz veins in gneiss have equally an aqueous origin? It is almost overwhelming when M. Favre produces this last piece of evidence against quartz considered as any proof of primæval existence or igneous origin:—'Lastly, I have picked up at St. Acheul near Amiens, a geode of quartz several centimetres in diameter, composed of crystals very slightly agglutinated together. I found it in the white siliceous sand above the beds of gravel which contain the celebrated flint axes, and I am persuaded that it has been formed in this position, at the expense of the sand, and since the axes have been made and deposited.'

We have already dwelt almost too long upon this point. M. Favre gives reasons to believe also that felspar, mica, and talc must equally have had an aqueous origin. How then have the granitic rocks originated? Their origin, he supposes, goes back to the remotest period of the history of the earth, to the epoch when the water of the globe, in a state of vapour, formed with certain gases an atmosphere of extreme density, and began to condense. Following the authority of MM. Daubrée and Delesse, he estimates the pressure of such atmosphere at 710 atmospheres, under which water would boil at about 480° C. or 900 Fah. Of course, this would diminish as the aqueous vapour became precipitated and seas were formed, but an immense lapse of time would be required for its reduction to a degree at which animal life could exist. 'During this epoch the waters flowed in torrents on the surface of the ground, produced mechanical and chemical decompositions, swept away the materials, and necessarily deposited sediments which must have been very different from those formed in the epoch of organised beings. May we not then believe that granite, protogine, and gneiss, the elements of which have all been formed under the influence of water, are aqueous deposits, produced during the first times when the water reacted on the earth?'

The reader will find in this work much interesting matter on the elevation of mountain chains, the origin of valleys, and of the remarkable depressions now occupied by lakes, and other vexed questions of Alpine geology, as well as upon the now generally admitted ancient

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extension of the glaciers and transportation of the drift. We regret that our space will not permit us to do justice to the author's views on any of these points, and we can only attempt to touch upon one or two features of interest regarding them. M. Favre regards the elevation of the Alps, and nearly all dislocations on the earth's surface as consequences of the different rate of cooling of the crust and the interior; the former having since a remote period nearly attained a condition of equilibrium, while the latter continued to lose its heat, and consequently to contract in volume. Hence arise the doubling and convolutions of strata which are so remarkable in mountain regions, and which have caused so much difficulty in the identification of the several formations. Hence also the 'fan structure' and apparent reversal of the beds on the flanks of the principal mountain chains, and the fact that the most elevated rocks are also the oldest, and geologically the lowest.

Closely connected with the structure of the mountains is the form and position of the valleys. It is scarcely possible to resist the conclusion that these were, in many cases, compared at least with the mountains, deeper when first formed than at present, and that, so far from their having been entirely excavated by aqueous or glacial erosion, these powerful influences have not only lowered the mountains, but partly filled up, while they have widened, the valleys. 'It appears to me evident,' says M. Favre, 'that the valleys of Savoy and the Valais are connected with the structure of the mountains. They present a remarkable regularity, and are nearly all perpendicular or parallel to the general direction of the Alps.' This fact alone is almost decisive in refutation of the theory attributed to Professor Tyndall, that before the glacial epoch this chain of mountain presented an enormous boss, with a surface more or less united, in which the valleys and the lakes have been excavated by the glaciers.

The question of the origin of the lake depressions is one that has been warmly discussed. MM. Tyndall and Ramsay on the one hand, have attributed them entirely to glacial erosion. Sir Charles Lyell, MM. Studer, Desor, Ball, Omboni, and our author, have strongly opposed this theory. M. Mostellet, while allowing the previous existence of these cavities, has supposed that they had been filled up by the ancient alluvium before the glacial period, but re-excavated by the action of the ice. The phenomenon which has given rise to these discussions is the existence of extensive beds of pre-glacial alluvium beyond and below the lakes, and the difficulty of accounting for its existence in these localities, supposing the lake basins to have existed, as at present, at the time of their deposit. The answer of M. Favre appears simple and satisfactory. The lake basins at the period when these beds were deposited were filled up, but with ice, not with gravel or solid rock. The materials of the alluvium were carried across them in and upon the ice. Similar deposits of rolled pebbles are found arranged and levelled by the torrents below the termination of most existing glaciers, and this supposition is powerfully confirmed by the fact that in the lower portion of the alluvium, near Geneva, are found many stones which are not water-worn but angular, like those of

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glacier moraines. There is, moreover, reason to question whether there is any ground to credit the glaciers with such an erosive power as has been supposed. It was long ago remarked by Charpentier, 'that in 1818 the glacier du Tour, in the valley of Chamounix, had advanced, without excavating, about eighty feet over ground which was gravelly, and uncovered by soil, but at the end of this space it came upon meadows, the soil of which being somewhat marshy was lifted up and overturned.' In the same manner the Glacier des Bossons had advanced, in 1818, nearly across the valley without effecting any excavation of the soil, which is nevertheless easily shifted.

'Consequently,' continues our author, 'glaciers are unable to hollow out their bed in gravelly and moveable soils. I do not think that any actual glacier ploughs up the ground over which it passes in such a manner as to construct before it a moraine drawn from the soil over which it advances. In the hypothesis of the excavation of the Lake of Geneva by a glacier, it would be very extraordinary also that the greatest depth (265 metres, near Meillerie, and 300 metres, a little more to the west) should be at the spot where the bottom is probably of hard limestone, while more to the west, where the soil is of soft mollasse, the depth is only 30 to 40 metres. This difference is easily explained in connecting the origin of the lake with that of the mountains. In effect, near Meillerie the beds, being much contorted, and often vertical, it is natural that the greatest depth should be in their neighbourhood, while nearer Geneva, where the beds of molasse descend from the two shores with a slight inclination, there is no reason that the lake should be deep.'

We have said that the former extension of the glaciers, which once excited a lively controversy, may now be said to be generally allowed. There remains, however, a question as to the causes of this extension, and before concluding, we must add a few words on this subject. A similar extension has obtained, at some former period—and that a geologically recent one—not only in most parts of the northern hemisphere, but also in New Zealand in the southern. There is no sufficient evidence, however, of the simultaneousness of these extensions, especially as between the two hemispheres. It may, however, be accepted as probable—though even this has been questioned—that the glacial extension in the Alps and in northern Europe generally, was contemporaneous. This extension has been accounted for by the hypothesis of a general climatal refrigeration; by the supposition of a former greater elevation of the mountains; and lastly, by the somewhat paradoxical theory advanced by Professor Tyndall of increased moisture and precipitation, arising from greater heat in the localities in which the evaporation, which supplied this moisture, took place. M. Favre appears disposed to allow a certain weight to all these suppositions, though he discusses, with something like contempt, theories which would attempt to account for the lower temperature by such a supposition as that of the non-existence at the glacial period of the Isthmus of Panama, and consequently of the Gulf Stream. Such a hypothesis may perhaps savour of presumption; but when we bear in mind that, at the present

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day, enormous icebergs are found floating in the southern ocean, at a latitude corresponding to that of the Alps, it is not unimportant to observe that slight variations in the configuration of land and sea in the northern hemisphere might effect a climatal change more than sufficient to account for the phenomena in question. M. Ch. Martens has shown that a depression of 4° C. (about 7° Fahr.) in the mean temperature at Geneva would bring back the glaciers of Chamounix to the neighbourhood of this town, and M. Dangler, of Zurich, considers that a depression of 5° C. (9° Fahr.) would be sufficient to cause an extension of the Oberland glaciers as far as Soleure.

The theory of M. Escher von der Linth, that the recent elevation of the Desert of Sahara above the sea has exercised an important influence on the climate of the Alps, is one of the same nature. It is well known that the hot south wind called the Föhn, which is believed to take its rise in that region, is at present a most active agent in the repression of the glaciers; but, as M. Favre observes, it is necessary not to lose sight of the fact that their extension at a certain epoch was not confined to the Alps.

That the mountains were higher, independently of any elevation or depression arising from causes acting in the interior of the earth, at the commencement of the glacial epoch than at the present time is sufficiently evident from the mass of matter which has since been removed, and transported to the plains or to the sea, and this fact may be allowed its due weight. But it is not unimportant to remark that in the northern parts of Europe, when the glacial extension appears to have been proportionately as great, there is reason to believe that at its period the land was much lower than it now is.

We approach with some diffidence the theory of Professor Tyndall, advanced as it is by such an authority, and the more so as M. Favre appears disposed to allow it considerable weight. The effect of increased moisture upon the extent of the glaciers involves a complex meteorological problem. If, in consequence, the sky were so constantly clouded as to intercept the greater portion of the sun's rays, it would be not unreasonable to expect a lower temperature to prevail. But one point appears somewhat strangely to have been overlooked. The conversion of a given amount of aqueous vapour into snow or ice, necessarily sets free an amount of heat sufficient to convert a still larger quantity of ice into water—we believe about six times the quantity; but Professor Tyndall could doubtless supply us with more exact data. A greater supply of vapour might therefore increase the rivers, but would probably diminish the glaciers. It has been remarked that the moist years of 1816 and 1817 produced an extension of the glaciers; but it would seem more reasonable to conclude that the greater condensation of these years was caused by the coldness of the season rather than the coldness by the greater condensation. Moreover, the supposition of a colder climate during the glacial epoch is supported by the evidence of the remains of the animals and birds then existing, as has been demonstrated by the researches of M. Lartet and Prof. Milne Edwards, while the hypothesis of greater precipitation is purely arbitrary.

R. C. N.

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