## V.—The Gneissose Rocks of the Himalaya.

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It had not been my intention to publish anything on this subject at present, as I have in preparation a review of the present state of our knowledge of Himalayan geology; but as Col. McMahon has started the subject, and his paper is not exhaustive, I trust the following outline of that part which relates to the gneissose rocks may prove of interest.

The gneissose or granitoid rocks of the Himalayas may be divided into three groups:—

(1) The fundamental or "Central" gneiss of Dr. Stoliczka.
(2) The orthoclase, usually porphyritic and gneissose, granites.
(3) The oligoclase granite.

The last of these appears to be distinct from and of later date than the first two, and will not be further referred to here.

The fundamental, or, to use the term under which it was first described, the central, gneiss consists of a great thickness of crystalline rocks. In the little disturbed sections of the Upper Pábar Valley in Bissahir it is seen to unconformably underlie rocks which I have little doubt are the equivalents of Dr. Stoliczka's Babeh series of Silurian age. Both by lithological structure and mode of occurrence, these beds are shown to be of metamorphic, as opposed to intrusive origin; they contain beds varying from almost pure felspar to almost pure quartzite or mica-schist, but felspar is seldom altogether absent; some of the beds are *augen gneiss*, the eyes being lenticular in form, lying in accord with the planes of foliation, and, as regards their internal structure, consisting of a single twinned crystal of orthoclase.

On the section over the Babeh Pass, that first examined by Dr. Stoliczka, the beds are more disturbed and more metamorphosed. Highly foliated beds are rare, and the rock is for the most part a more or less fine-grained granitoid gneiss: some beds are *augen gneiss*, in which the eyes still maintain their lenticular form, though, as a rule, they have more or less acquired an outline in conformity with their crystalline structure; these crystals, however, still lie along the planes of foliation or very slightly oblique to them.

There can be little doubt that it is from the fusion of these beds that the gneissose granite was derived. Typically this rock consists of a somewhat fine-grained, slightly-foliated matrix, through which porphyritic crystals of orthoclase are scattered; the crystals exhibiting no definite orientation, but being scattered about with their axes pointing in every direction, as described by Col. McMahon. It occurs in large intrusive masses, or in veins of various thickness, usually intruded parallel to the bedding planes; the former usually show very slight signs of foliation, except near their boundaries, while the latter are almost, if not quite, invariably distinctly foliated. As the veins are traced away from their parent masses, the larger crystals of felspar appear to be left behind, and the rock gradually ceases to be porphyritic, and sometimes contains merely a small proportion of felspathic material. How complete is the assumption of a gneissose and loss of the granitic structure may be judged from the fact that specimens from one exposure, which can be shown to be intrusive, have been examined by Col. McMahon, and declared by him to be a true gneiss showing no signs of intrusive origin.[1]

Col. McMahon has shown that the microscopic structure of this rock, as well as the inclusions of mica-schist, prove its intrusive nature. I may add that the same is shown by its mode of occurrence, by the manner in which it cuts across the bedding of the rocks among which it occurs, and by the invariable occurrence of contact metamorphism in the neighbourhood of any large mass of it. The intrusion, in many cases, does not seem either to have caused or been accompanied by any considerable disturbance, but to have taken place by a fusion (or solution) and absorption of the rocks which it has replaced. These often continue with a perfectly steady, low dip right up to a large mass of the gneissose granite, and end abruptly there; yet the intrusive nature of the granite is shown by the presence of included masses of these very rocks. The same thing is indicated by a study of the intrusive sheets; they constantly thin out and thicken without any disturbance of the bordering beds, which simply run up to the edge of the gneissose granite, and stop there abruptly; the granite itself too becomes more micaceous or more quartzose (according to the prevailing type of rock it has passed through) and less felspathic the further it is traced from its source, indicating a gradual increase of impurity. But the most conclusive proof I know of is exhibited by the sections on the eastern side of the Chor Mountain. The southern sections show a considerable thickness of volcanic beds, altered to more or less schistose hornblende rock; while on the northern sections these hornblende rocks are absent, but the granite has become so highly hornblendic that the ground-mass is of a dark green colour, throwing up the porphyritic crystals of white orthoclase in a most conspicuous manner.

Before passing on, it will be well to explain how these two distinct rocks came to be confused with each other. In the Sutlej Valley, between Simla and the Wangtu-bridge, there are extensive exposures of gneissose rocks; these are almost all the gneissose granite, but owing to similarity of lithological appearance and absolute continuity of outcrop, they were (erroneously) confounded by Dr. Stoliczka with the granitoid gneiss which is exposed almost to the exclusion of intrusive granite on the ascent from the Wangtu bridge to the Bábeh pass. In 1877 Col. McMahon published a paper on the "Central gneiss" of the Simla Himalayas, in which he (correctly) identified the rock of the Chor and the gneissose granite intrusions south of the Sutlej with the rock of the Sutlej Valley. In 1883 he showed that while the rock of the Dhaoladhar, which he had identified with that of the Chor, could not in a single case be

[1] Rec. Geol. Surv. India, vol. xvii. p. 60; vol. xix. p. 86.



shown to be a true gneiss, it presented all the characters of an igneous rock. In this paper he dropped the term granitoid gneiss in favour of gneissose granite, and added that "it is for consideration whether the term 'central gneiss,' introduced by the late lamented Dr. Stoliczka, and since used to denote the 'granitoid gneiss' of the North-West Himalayas, should not be discontinued in future." Consideration is entirely in favour of this proposition, but against the total abandonment of the term "central gneiss," which may still be conveniently used for the fundamental gneiss, the oldest rock, in the Himalayas.

The separation of these two rocks in the field will often be a matter of difficulty, and not always possible, except where the gneissose or the intrusive characters are well developed; the microscope will not aid in this, for, as I have remarked above, in one case it has declared what can be shown to be an intrusive rock to be a metamorphic gneiss, while some of the more granitoid forms of the central gneiss show so little foliation and are so granitoid as seen in a hand specimen, that I doubt whether even microscopic examination would give a decided answer as to whether they are granite or gneiss. The general result then is the satisfactory one (for it is always more satisfactory to confirm than to refute a previous observer) that Dr. Stoliczka was correct in describing the oldest rock he observed as a *gneiss*, while Col. McMahon is equally correct in maintaining that the rocks of the Sutlej Valley and the Dhaoladhar are *granite*. I may now pass on to consider the cause of the foliation of this granite.

In considering this question, it is necessary to distinguish between the large, slightly foliated masses and the distinctly foliated sheets. In the former case the obscure foliation is probably in the main a form of fluxion structure, but the well-developed foliation of the thin sheets, which are occasionally sufficiently fissile to be used as flags or roofing slates, cannot be solely due to this cause.

When we find intrusive sheets of a few feet, or even a few tens of feet, in thickness, extending for miles without more than mere local variations of thickness, it must be evident that their fluidity cannot have been in any great degree due to excess of temperature; in the case of the thinner sheets I do not think that it can have been in any degree due to this cause, but rather to a difference of composition which enabled the granite to maintain some degree of fluidity, while the rocks into which it was intruded remained solid. Whatever this temperature may have been, it was sufficient to metamorphose the sedimentary beds which have always been converted into more or less perfect schists, that do not exhibit any marked increase of metamorphism near the sheets of gneissose granite intruded into them.[1]

[1] Contact metamorphism is only conspicuous in the case of large intrusive masses. The statement in the text may seem inconsistent with that of Col. McMahon regarding the slightly metamorphosed condition of the slates in contact with the outer band of gneissose granite in the Dalhousie region; but the particular slates referred to are everywhere characterized by a much greater power of resisting metamorphism than those above and below them. I have more than once observed the total absence of metamorphism, or the mere development of a micaceous glaze on the bedding-planes, where associated beds were converted into distinct schists.

The exact causes productive of foliation are not thoroughly understood, but it appears to be in some way related to the parallel structure due to stratification or cleavage, as the case may be. In the case of an intrusive sheet of granite, there would be neither stratification nor cleavage; but friction against the sides of the channel it flowed in would be sufficient to produce a slight parallel structure in a viscid mass; while it is not inconceivable that the very fact of the minerals, in the rock on either side, arranging themselves in a laminated structure, would induce similar rearrangement of the minerals in the gradually cooling granite. In short, I believe that the very slight foliation of the larger masses is principally a fluxion structure, while the more developed structure of the thinner bands, and near the margins of the larger masses, was produced in the solid but still heated granite by the same causes—whatever they be—that led to the foliation of the adjacent sedimentary beds.[1]

Before leaving this subject, there is one point that may be referred to with advantage. In Mr. Lydekker's memoir on the geology of Cashmir it is stated, both on the map and in the text, that part of the gneiss of that region consists of metamorphosed Silurian strata; this statement will not, I fear, be borne out by a more detailed examination of the ground. I have had a tolerably extensive, if fragmentary experience of the Himalayas, during which I have never seen a case of beds, which occur elsewhere as slates, having been converted into gneiss; but I have seen sections, similar to those described by Mr. Lydekker, where there appears to be a gradual passage from slate to gneiss. It appears not to be uncommon that near the boundary of a crystalline area there should be sections showing a considerable thickness of gneissic rocks, with small intercalations of non-gneissic beds, which can occasionally be recognized as belonging to some definite horizon in the slaty series. The sections, at first sight, seem to indicate an extreme metamorphism of the beds, a few of which have so far escaped metamorphism as still to be recognizable. Apart, however, from the fact that the gneiss exhibits those features especially characteristic of the gneissose granite, where I have been able to trace the horizontal extension of the rocks into unaltered slates, the change has not been by a gradual diminution in the metamorphism of the rocks as a whole, but by a gradual diminution of the gneissose beds, those which remain being as distinctly crystalline as before, till, where they have diminished in thickness and the schistose beds prevail, they can be distinctly recognized as intrusive gneissose granite. The sections indicate, not an extreme degree of metamorphism of the slaty rocks, but their more or less complete obliteration by gneissose granite.

In Western Garhwál there is a considerable development of arkose beds which have become foliated, but are still recognizable as foliated arkose. It is quite conceivable that similar beds might be so metamorphosed as to be undistinguishable from gneiss, but with this exception (which could not be called a true metamorphic gneiss as the felspar was provided ready made), I do not think that any beds belonging to the slaty series of the Himalaya have been converted into gneiss; whether they could be is a matter to be decided by chemical analysis.

[1] In 1884 Colonel McMahon seems to have held an opinion somewhat similar to this (see Records Geol. Surv. India, vol. xvii. p. 72), but so far as I can understand his paper in the May Number of this Magazine, he has now abandoned it.



## NOTICES OF MEMOIRS.

### I.—British Association for the Advancement of Science. Fifty-seventh Meeting, Manchester, 1887.

### Section C.—Geology.

*President*: Henry Woodward, LL.D., F.R.S., F.G.S.

Titles of Papers Read September 1st to 7th, 1887.

1. Address by the President.
2. *Prof. W. Boyd Dawkins.*—On the Geography of the British Isles in the Carboniferous Period.
3. *Prof. W. Boyd Dawkins.*—On the Structure of the Millstone Grit of the Pennine Chain.
4. *Mark Stirrup.*—Foreign Boulders from Coal Seams.
5. *Dr. G. J. Hinde.*—On the Organic Origin of the Chert in the Carboniferous Limestone Series of Ireland, and its similarity to that in the corresponding strata of North Wales and Yorkshire.
6. *Robert Law and James Horsfall.*—On the Discovery of Carboniferous Fossils in a Conglomerate at Moughton Fell, near Settle, Yorkshire.
7. *Dr. H. Crosskey.*—Report on the Erratic Blocks of England, Wales, and Ireland.
8. *Prof. E. Hull.*—Note on a few of the many remarkable Boulder Stones to be found along the Eastern Margin of the Wicklow Mountains.
9. *Prof. H. Carvill Lewis.*—The Terminal Moraines of the great Glaciers of England.
10. *Prof. H. C. Lewis.*—On some important Extra-Morainic Lakes in England, North America, and elsewhere, during the period of Maximum Glaciation; and on the Origin of Extra-Morainic Boulder Clay.
11. *Hugh Miller.*—A comparative study of the Boulder Clay in the Glaciated Districts of Europe—Britain, Norway, Switzerland, Low Germany, and the Pyrenees.
12. *Dr. H. Hicks.*—Report on the Cae Gwyn Cave, North Wales.
13. *J. W. Davis.*—On an Ancient Sea-Beach near Bridlington, containing Mammalian Remains.
14. *Dr. H. Woodward.*—On the Discovery of a Larval Cockroach, *Etoblattina Peachii* (H. Woodw.), from the Coal-Measures of Kilmaurs, Ayrshire.
15. *Dr. H. Woodward.*—On a new form of *Eurypterus* from the Lower Carboniferous Shales, Glencartholme, Eskdale, Scotland.