Alpine zones, which consist mainly of crystalline schists, are termed *central massifs*. Such intercalations of mechanically metamorphosed sediments with the crystalline schists are very frequently to be observed at the ends of the strike of the *central massifs*, and between the *central massifs*; they are not rare even in the interior of the *central massifs*. The crystalline schists and metamorphosed sediments not only present the same stratigraphical position, but also similar characters in other respects. The cleavage of the sedimentary rocks may be continued in the same direction into the crystalline schists; and similar contortions may traverse both: in the latter, as in the former, a marked linear extension in the same or but slightly deviating direction may be present: calcareous patches in the crystalline schists are crystalline and granular, and contain layers of mica-scales which have undergone extension, precisely as in the neighbouring Jurassic limestones, &c., &c. From these facts we see that in these crystalline schists we have not to deal with rocks of original constitution, but that both these rocks and the sediments have undergone similar mechanical metamorphism. The only difficulty in dealing with the schists is contained in the fact that we are never in a position to describe the original appearance of the rock before it underwent the mechanical metamorphism.

Now it is in the crystalline schists that the plications of the earth's crust are most potently developed. The isoclinal and fan-shaped folds, the wedging and "kneading together" at the contact with the sediments—in short, all these high forms of dislocation, which are the earliest to modify the inner structure of rocks, are to be found in the crystalline zones of the Alps. They are most highly developed in the northern series of the *central massifs* (Mont Blanc, Aiguille Range, Finsteraar-*massif*, Gotthard-*massif*, Silvretta-*massif*, &c.).

At first sight it appears as if the crystalline schists and the true sediments, in the Alps, were separated by a constant unconformity; but frequently even recent sediments are found folded in, parallel with the crystalline schists. Again the sediments often take the position of a *central massif*; indeed, it seems as if a great part of several of the *central massifs* consisted of Palæozoic sediments. On the other hand, in the southern *central massifs* of the Central Alps, we see the crystalline schists lying in all respects like the sediments.

Those who have worked in these parts of the Alps will have remarked how often the mechanical crushing undergone by the rocks obliterates the limits of stratigraphical and petrographical characters, and how many rocks have become confused thereby in their development (*Ausbildungsweise*). Such changes can sometimes be directly proved to be the result of local crushing; sometimes, however, they are regional, and then passages into the unaltered rock are difficult to trace. All degrees of change by earth-movements are to be found, from a slight alteration of the structure up to complete metamorphism. In hundreds of places one does not know whether one has to deal with the residual traces of original bedding or with a cleavage (*Transversalschieferung*, *Quetschungsschieferung*) that has completely obliterated the original structures. In many cases it is impossible to distinguish between a schistose structure (*Schieferung*), superinduced by earth-movements, and one that is original. Schistose structures which cross one another are by no means rare. Whether the more pronounced or the less definite one is then the original is often not to be decided. Even an exact microscopical examination will often not suffice to distinguish between structures resulting from crushing and lateral deformation; and the fluxion-structure of an eruptive rock. It is certain that a structural modification by earth-movements has everywhere taken place where linear extension abounds. The latter is never original. In such crystalline schists with linear-parallel structure there are often elongated, ragged mica-scales. The linear extension can go as far as the development of rod-like separation (*stenglige Absonderung*).

Are there any rocks left in the *central massifs* of the Alps which have undergone no change in structure during the orogenetic processes?

The metamorphism can penetrate still deeper.

Enormous zones, for instance, in the interior of the Finsteraar-*massif*, that were formerly held to be true crystalline schists, prove to be originally clastic rocks of the Carboniferous period that have been squeezed into schists, and pervaded by secondary mica. Conglomeratic rocks of the Verrucano group, and clay-slates, nipped into the *central massif*, have become crystalline, schistose, and even gneissose. They can scarcely be distinguished, in the field and in the hand-specimen, from crushed gneisses pervaded by sericite. Granites can be proved, locally and perhaps also regionally, to have been compressed into gneisses. Gneisses, having a different position relatively to the pressure, have locally become granitoid. Massive eruptive felsite-porphyries have become felsite-schists. Mica-schists have been dragged out; their quartz grains ground down; and the whole converted into a rock that one would be inclined to describe as a sandy clay-slate. Even Liassic slates with fossils have been converted into garnetiferous mica-schists, staurolite-schists, &c. The boundary between the old crystalline schists and real sediments in the Alps has, by such processes of dynamic metamorphism, been obliterated, and the proper character of the rock so altered as to render recognition impossible. When we see, in true sediments, new minerals developed by the progress of the mechanical metamorphism (magnetite in the crushed Oolitic ironstone of the Windgälle, garnet in the Belemnite-slates of Scopi), the question arises, for the crystalline schists of this and neighbouring regions—Which minerals are original, and which have been produced subsequently, by orogenetic processes?

We arrive at this conclusion:—*The constitution of the crystalline schists in the Alps has been much changed by the orogenetic process* (dynamic metamorphism). *Original material and material mechanically produced at a later period, are often not to be separated from one another.*

Besides these, the Alps present other difficulties that stand in the way of the recognition of a stratigraphical grouping of the crystalline schists. The field-relations are frequently so intricate, that often it is very difficult to decide what originally lay under and what above; and whether the enormous thickness, for instance, of many gneiss-complexes, is real, or merely produced by repetitions of the folding, the folds being concealed by cleavage.

It follows that, if, on the basis of petrographical relations, a general stratigraphy of the crystalline schists is to be attempted, *this must never take place as the result of observations made in plicated regions of the earth's crust: districts must rather be chosen which are not influenced by disturbances of the Alpine character.* In the question of the stratigraphy of true crystalline schists, the Alpine geologist is not in the position to furnish material of essential value; he must rather wait for the results of the workers in other regions, in order to be able to apply them to his own district. The dislocations of fractured regions have, in the main, left unaltered the constitution of the rocks. There, then, the crystalline schists can be studied in their unaltered condition. There also they lie in flatter and more regular bedding; and a stratigraphical sequence is sooner to be found than in the Alps.

ON THE ORIGIN OF THE PRIMITIVE CRYSTALLINE ROCKS.[1]

IN this paper the author briefly summarizes the ideas prevailing on the origin of the crystalline schists, and throws a doubt on the current opinion that the primitive rocks have been formed by the *direct* crystallization of their constituents. He divides his treatise into two parts: (1) stratigraphical considerations; (2) the mode of association of the component minerals.

(1) *Stratigraphical Considerations.*—The primitive crystalline rocks form the fundamental floor upon which lie the earlier detrital deposits, their schistosity being often parallel to the stratification of the latter.

Although composed mainly of acid gneisses, the primitive rocks present countless variations in chemical and mineralogical composition; they include very basic representatives, such as the amphibolites, pyroxenites, peridotites, cipolines, and dolomites, &c. These intercalations are always parallel to the schistosity: they form elongated lenticular patches, of which the greater axis is in the direction of the general banding.

At the same time, their relative homogeneity in composition is shown by comparison of sequences established, not only in Europe, but also in the United States and the rest of the world. Acid gneisses predominate at the base; then come frequent intercalations of mica-schists and leptynites, with which are

[1] "Sur l'Origine des Terrains Cristallins Primitifs," by M. A. Michel-Lévy, Bull. Soc. Géol. France. 3e série, t. xvi. p. 102, 1888. Published by the International Geological Congress in London, 1888. (Abstracted from the French by Dr. F. H. Hatch.)

associated amphibolites and cipolines. Above this first division chloritic and sericitic mica-schists are developed, alternating occasionally with amphibolitic layers. This second stage is succeeded by a series which also comprises hornblendic and augitic (*cornes vertes*) schists, but includes, further, the first detrital deposits. At every horizon there is a gradual passage from the one stage to the other. The first detrital deposits alternate with sericitic and chloritic schists; and even as far up as in the Cambrian, large bands of felspathic schists, which can scarcely be distinguished from the more ancient gneisses, are developed in connection with the intrusion of granite.

The primitive rocks are, as first pointed out by the author, injected and penetrated by ancient eruptive rocks. This phenomenon is al o to be observed in the earlier detrital schists.

Rolled pebbles and fragments of gneiss, mica-schist, &c., have been repeatedly found in the granitic and granulitic gneisses of various localities. The author's own observations lead him to compare these phenomena with those in which rounded balls have been inclosed in a truly eruptive granite. In numerous cases, in which fragments of gneisses have been enclosed in other gneisses, he has always been able to prove that the enclosing rock is much more felspathic than the inclosed fragments.

These facts cannot, therefore, be advanced in support of the detrital origin of true gneisses.

(2) *Mode of Association of the Component Minerals.*—The mineralogical composition of the gneisses and of the schistose basic rocks associated with them, is nearly identical with that of the granular eruptive rocks; and all the types of the older eruptive rocks have their representatives in the schistose series.

A great analogy therefore exists between the natural forces instrumental in the production of the two series.

Speaking generally, the older eruptive rocks are rigorously homogeneous over vast areas: fragments of these rocks are everywhere comparable to one another. This homogeneity is reproduced in the schistose series; but it is, so to speak, periodic, and one must first know the orientation before comparing fragments taken from a distance.

The structure of the gneisses presents a series of successive crystallizations, accompanied by mechanical phenomena and a cementing of the dislocated components. The author, while seeing in these phenomena the traces of a series of metamorphic actions, followed by the injection of foreign material, does not wish to deny the additional intervention of secondary mechanical actions. But, whatever theoretic explanation be adopted, the facts are well established, and irreconcilable with the assumption of a preliminary mixing of the magma of the schistose rocks, and therefore with the hypothesis of a primordial origin.

The author then proceeds to demonstrate at some length that the intimate structure of the gneisses is identical with that of sedimentary schists modified by contact metamorphism, and finally injected by eruptive rocks.

Microscopic studies have disclosed the minute liquid inclusions contained by the quartz of the gneisses. Zirkel and Kalkowsky have made the interesting observation that the streams of inclusions are restricted to the central portions of the quartz-grains and are not prolonged to the periphery; and De Lapparent adduces this fact as a proof that the grains have not been derived from a pre-existing rock. But this argument is overthrown by the fact that the quartz-grains in the Cambrian micaceous schists, which are of indisputably detrital origin, present exactly the same phenomenon. It admits, moreover, of a very simple explanation. These quartz-grains, of clastic origin, have undergone subsequent enlargement by the assimilation of secondary quartz, which tends also to give them an exterior crystalline form. This secondary quartz is poor in liquid inclusions, and encloses scales of black mica and other minerals.

General Considerations and Hypotheses on the Origin of the Primitive Rocks.—Among the hypotheses advanced to explain the origin of gneiss, the author discusses the two that have found the most general acceptance. The first, which is now somewhat abandoned but has the merit of perfect clearness, makes the gneisses the result of a kind of conflict between water and the primary molten magma of the earth. The other explanation, which is more vague, accords to the gneisses a sedimentary origin. They are the deposits of a kind of supersaturated sea, which precipitated on to its floor the successive crystalline bands which characterize the gneisses. Note that this hypothesis presupposes a floor—an unknown substratum.

(1) Geologists originally supposed that the first substratum was formed by the granites which are found cropping out over such vast areas. Detailed studies have shown, however, that the granites are younger than the gneisses which they traverse, inject, and displace. Even the most ancient among them are at least younger than the first detrital schists.

It is therefore to the gneisses, distinctly banded and alternating in their lower beds with mica-schists, that this mixed origin—this *rôle d'écumes primordiales*—must be attributed.

Has this substratum of the terrestrial crust ever been seen in the most disturbed regions?

Cordier supposed that terrestrial refrigeration was constantly increasing, in the downward direction, the thickness of the first solid crust. If we could descend through the earth's crust, we should pass successively through rocks of increasing basicity until we should find, enveloping the still incandescent nucleus of impure iron, a rock analogous to lherzolite.

A serious objection to this is the fact that a descending order of basicity is not borne out by the stratigraphical relations of the gneisses. Lherzolite is found erupted through the primitive rocks; and the basic peridotites are intercalated moderately high up in the gneissic series.

From the purely speculative point of view it is improbable that the first products of consolidation did not receive a thorough mixing, rendering the rock homogeneous, and preventing the formation of those numerous micaceous membranes so characteristic of the primitive rocks. If these first products were acid, as there is reason to suppose, the first substratum must have constituted a massive and homogeneous granite. It is on a floor of this kind that the precipitation of the atmospheric waters must have prepared the elements of the first detrital rocks—the first arkoses.

(2) The second explanation—the successive crystallization of bands of gneiss from the waters of a universal sea—encounters similar difficulties. It appears to the author irreconcilable with the structure of the gneissic rocks. The continuous membranes of mica, and the almost vein-like appearance of the quartz and felspar, do not accord with the notion of concretionary deposits that this hypothesis requires, supposing the supersaturated liquid to have been in a state of perfect tranquillity. If, on the other hand, we suppose that there existed local agitations due to the unequal distribution of high temperatures, the remarkable periodic homogeneity of the gneisses becomes inexplicable.

From a consideration of these facts and hypotheses, the author arrives at the conclusion that the veritable and primary substratum of the terrestrial crust is not visible; that this substratum has undergone much alteration; finally, that the so-called primitive rocks are a complex of eruptive rocks, later than the gneisses, and of rocks which are really detrital, but which have undergone excessive metamorphism.

The eruptive rocks, by which the primitive rocks have been injected, are later than the beginning of the Cambrian. They were produced in extraordinary abundance in the later portion of this period: granites, diabases, diorites, norites, and lherzolites.

In discussing the primary causes of the eruption of these rocks, the author mentions that Lehmann and others of the German school, are inclined to seek them in the partial transmutation into heat of the mechanical work performed during the intense periods of contortion undergone by the earth's crust. The author himself refers them to manifestations of the internal heat of the globe, the great earth-movements having simply effected the ascension and injection of the eruptive magmas.

NOTES.

By the death of Mr. Jameson on the Upper Congo, science has lost a most promising young naturalist. The collections made by him some years ago in Borneo were never described, but we believe that in that island Mr. Jameson met with many species of birds since obtained by other travellers. His expedition to Mashoona Land resulted in the discovery of some interesting new species of birds, and an elaborate paper was written on his collection by Captain Shelley in the *Ibis* for 1882. A small number of birds has also been sent by him from the Aruwimi River to his friend Mr. Bowdler Sharpe, who has been waiting for further collections before writing an account of