ROCKS OF BRITISH COLUMBIA & CHILE.

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MESOZOIC VOLCANIC ROCKS OF BRITISH COLUMBIA AND CHILE.

RELATION OF VOLCANIC AND METAMORPHIC ROCKS.

By GEORGE M. DAWSON, F.G.S.,

of the Geological Survey of Canada.

IN Chile and adjacent regions of South America, Mr. Darwin, in his "Geological Observations," has described a great series of Mesozoic rocks, which he calls the "porphyritic formation," and which shows an interesting resemblance to certain rocks in British Columbia. These I had provisionally designated in my report in connexion with the Geological Survey of Canada for 1876, as the Porphyrite series, without at the time remembering Mr. Darwin's name for the Chilian rocks. Many of Mr. Darwin's descriptions of the rocks of Chile would apply word for word to those of British Columbia, where the formation would also appear to bear a somewhat similar relation to the Cascade or Coast Range, which that of Chile does to the Cordilleras. By its fossils, the porphyritic formation of Chile is proved to occupy a position intermediate between the Jurassic and Cretaceous, which is much that which the Porphyrites of British Columbia must hold. Beds overlying the Porphyrites on Tattayoco Lake by some thousands of feet—probably conformably—hold fossils characteristic of the Shasta Group or lowest of the Cretaceous in California, which is believed to represent the English Series from the Gault downwards. Fossils collected last summer in the porphyrite and felsite—altered ash rocks—of the Ilitasyoos, a branch of the Salmon River in latitude 52° 50', present a more distinctly Jurassic facies, though their palæontological value will be more certainly known when Mr. Whiteaves shall have finished his examination of them.

Of the South American Series Mr. Darwin writes:[1]—"The alternating strata of porphyries and porphyritic conglomerates, and with the occasionally included beds of felspathic slate, together make a grand formation; in several places within the Cordillera I estimated its thickness at from 6000 to 7000 feet. It extends for many hundred miles, forming the western flank of the Chilian Cordillera, and even in Iquique in Peru, 850 miles north of the southernmost point examined by me in Chile, the Coast escarpment which rises to a height of between 2000 and 3000 feet is thus composed."

The area over which the Porphyrite formation occurs in British

[1] *Loc. cit.*, p. 176.

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[1] *Loc. cit.* p. 476.

Columbia is very great, but is as yet imperfectly defined. I have roughly estimated its thickness in one locality at not less than 10,000 feet. It is built up of porphyrites, tending occasionally towards quartz porphyries, felsites, and fine-grained dolerites, diabases, and probably also diorites, with other rocks transitional between these and the first named, and great masses of volcanic breccia or agglomerate. Many of these rocks are of sedimentary origin, as shown by their holding fossils, and by their bedding, but the material has been supplied ready made as volcanic ashes and sand, and in the region near the eastern flanks of the Coast Range no intercalated siliceous sandstones, or water-leached clays forming true argillites, are found.

It may seem hazardous even to compare rocks so widely separated in space, but it is very generally found that in directions parallel to the main axis of disturbance on the West Coast, the formations are remarkably constant in character, and it is just in such cases that lithological resemblances may to some extent safely supplement other facts. I am not aware that contemporaneous volcanic products have been recognized as forming a part of the Cretaceous or Jurassic formations of California,—which of the intermediate region is the most carefully studied portion,—but in reading Professor Whitney's report, one is much tempted to believe that a portion of the very puzzling appearance of metamorphism in certain groups of beds intercalated with others almost unchanged, may really be due to their original composition as volcanic materials easily hardened and crystallized. The "red rock" or "imperfect serpentine" of the Cretaceous of the vicinity of San Francisco certainly resembles nothing so much as a partly altered volcanic product.[1]

It is evident that by the folding together and complete metamorphism of such masses of volcanic material as those described in Chile and British Columbia, they would form, without addition or much chemical change, a great series of granites, gneisses, diorites, and crystalline schists, like those characterizing many of the older formations in portions of their extent. Besides the mere chemical identity rendering this change possible, it may, I think, be stated that the equivalency of volcanic products with rocks of this class has actually been demonstrated in the field. I would refer especially in this connexion to the work of Prof. Judd in West Scotland, and to that of Mr. J. Clifton Ward in Cumberland. In Vancouver Island, we have, in fact, also a great series of rocks of Palæozoic age, almost certainly referable to the Carboniferous period, which while composed of diorites, felsites, schistose and gneissic rocks which Mr. Selwyn has compared in their lithological character to those of the Huronian or Altered Quebec group of Eastern Canada, yet retain ample evidence of their origin as volcanic sediments and igneous flows, and hold some beds of crystalline limestone, and of argillite,

[1] It should be mentioned that Prof. J. J. Stephenson, in reporting on a portion of Colorado, speaks of "large fragments of volcanic rocks and volcanic ash in the lower portion of the Cretaceous everywhere." U.S. Geol. Surv. West of the 100th Merid., 1875, vol. iii. p. 500.

—the *latter showing comparatively little sign of alteration.* It is not, however, intended at this time to enter into detail with regard to these rocks, or of the yet more ancient-looking diorites and granites of the Cascade Range, which are very possibly of the same age and origin.

Passing from rocks such as these, however, of which the source is yet clearly demonstrable, to some of those of the Eastern border of the Continent, one is led to think that sufficient prominence has not been given, in endeavouring to account for their origin, to the possible inclusion at different periods of great masses of little weathered volcanic products; and that while in Britain the importance of such material has been fully recognized, and it has been found to occur at many stages in the geological scale,—forming in Cumberland from 12,000 to 15,000 feet of "green slates and porphyries," in Wales a great thickness of similar hard and more or less crystalline rocks in the Lower Silurian alone,—it has scarcely been allowed a foothold in Eastern America except in instances so patent that to deny its origin would be absurd. In discussing the possibility of the production of "metamorphic" rocks from ordinary aqueous sediments not chemically their equivalents, by pseudomorphism and replacement, and the *chemical* formation of sediments by processes not active at the present day, much ingenuity has been employed, while the place of volcanos in supplying ready-made the material of crystalline rocks has virtually in too many cases been ignored. This action, according to strictly uniformitarian principles, must be supposed to have been at least as important at former periods as at present, and very lately the *Challenger* soundings have added largely to our idea of its influence, Mr. Murray having shown in connexion with them that in point of fact all deposits in the depths of the Pacific not organic are volcanic.

The rocks of the Huronian are, where I have studied them on the Lake of the Woods, I have no hesitation in affirming, in great part of volcanic origin; these beds, described originally by Dr. Bigsby as "Greenstone Conglomerates," being undoubtedly of this character and connected with others not so evidently volcanic by transitional materials, the whole associated with some rocks which must have approached ordinary argillites in composition and with quartzites.[1] If correct in this instance, as I believe them to be, similar conclusions will apply to a great portion of the rocks of other localities supposed to be of Huronian age, as a perusal of their description in the "Geology of Canada" will render evident. In the felspathic and gabbro-like rocks of the Upper Laurentian, we have a series so completely the same in composition with certain abundant modern volcanic rocks, that the attempt to account for its composition by pseudomorphism, or by the theory of chemical precipitates unlike those of the present day, seems almost as unnecessary as it would be to invoke a similar remote origin for the formation of an ordinary sandstone. In suggesting volcanic agency as an important factor in the history of the Lower Laurentian, more hesitation may be felt,

[1] Geology and Resources, 49th Parallel, 1875, p. 52.

as the mere area covered by its rocks is so much greater than we would expect to result from any system or linear series of volcanos as at present known. It is still a fact that the greater part of the rocks of that formation are just such as would be produced from the complete metamorphism of volcanic products among which those of the acidic class preponderated. Its limestones and iron ores do not oppose the theory, as these, with the quartzites and graphites may have been formed during periods of repose; and it is also apparent that if considerable areas of recently ejected volcanic matter were from time to time exposed to sub-aerial influences, their decay would furnish lime and iron readily and in great abundance to the surrounding waters, there to be fixed by organic or other agency.

Judging from lithological characters alone, and without presuming to enter into questions of age, it would appear probable, or almost certain, that volcanic sediments or other more or less immediate volcanic products have assisted materially in the production of the crystalline rocks of the Green and White Mountains, and their probable southward continuations; the rocks of the Metamorphic Quebec group, and those of the supposed Huronian of Eastern Massachusetts and Maine. The concise description of these last given in Dr. Hunt's "Chemical and Geological Essays,"[1] might be applied with scarcely a word of alteration to portions of the Mesozoic volcanic series of British Columbia.

If we may be allowed thus to explain the building up of a great thickness of the older rocks by volcanic action, we may economize greatly in the call for geological time, which at present seems desirable. The crystalline character of any series of rocks may reasonably be supposed to depend more closely on their original composition than on subsequent alteration, and in volcanic products —which may be as finely stratified as any—we have the materials of many of the rocks of the older crystalline formations. If, however, the action of volcanos in supplying materials for rock-building on a large scale be admitted as possible at any era in geological time —and there is surely no reason why it should not be admitted—the correlation of separated areas of crystalline rocks on lithological characters alone, from the difficulty of completely eliminating volcanic action, and the precise similarity of the volcanic rocks of all periods, when they have sustained an equal degree of alteration, becomes at least extremely hazardous. On the other hand, as already stated, these rocks, due to the same period, may be found at a similar stage of metamorphism and showing precisely similar characters for great distances in certain lines of volcanic activity and disturbance, and may also be accompanied by parallel belts of contemporaneous materials of ordinary aqueous origin.

[1] p. 187, § 5.

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[1] p. 187, § 6.