SCIENCE

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THE NORIAN ROCKS OF CANADA.

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AN important advance has been made in American Archæan geology by the publication of a memoir, by Professor Frank D. Adams of McGill College, Montreal, on the Norian or Upper Laurentian rocks of Canada.[1] The memoir embraces the results of five seasons' field-work conducted for the Geological Survey of Canada, together with an exhaustive and masterly petrographical investigation in the laboratory of the rocks constituting the Norian terranes. A full bibliography of these interesting rocks accompanies the memoir; also a map showing their known distribution, and a table of twenty-four analyses compiled from various sources. Thoroughness of research and soundness of judgment characterize the work throughout, and all interested in Archæan geology or in general petrography will welcome it as one of the sure steps which make for scientific progress. The author introduces his subject by a general presentation of the geology of the Laurentian, in which he gives a brief history of the growth of our knowledge and theories of these rocks, and discusses their nomenclature, both geological and petrographical. In the latter connection he takes occasion to describe, in general terms, the rock of which the Norian is prevalently constituted, and makes good its claim to be regarded as a distinct petrographical type, the characteristic of which is the preponderance of plagioclase to the partial or entire exclusion of the ferro-magnesian silicates. For this type of rock he uses the term "anorthosite," in accordance with a usage which has long been in vogue among the Canadian geologists. The anorthosites are regarded as belonging to the gabbro family, constituting one extreme of a graded series, of which pyroxmites and other granular rocks, rich in ferro-magnesian minerals to the practical exclusion of feldspar, are the other extreme, while common gabbros, norites, etc., are the middle members.

The various regions occupied by these anorthosites are described, and the petrographical and geological relations are discussed in detail. Their occurrence appears to have a peculiar relation to the so-called Archæan nucleus of the continent. So far as explorations serve us, they are only known to occur on the periphery of this great "Canadian shield," along the line of the St. Lawrence drainage, from near its source to the Straits of Belle Isle, and again farther north on the Labrador coast. Professor Adams calls attention to the seeming analogy between this distribution and the modern distribution of volcanoes on the periphery of the continents. The more important anorthosite occurrences, both by reason of their great extent and for the greater study that has been given to them, are (1) the Morin region, north of Montreal, and (2) the Saguenay region, which is the largest known. The Morin mass has a diameter of 37 miles and an area of 990 square miles. It is surrounded by the gneisses, crystalline limestones, quartzites, etc., of the Grenville series (Laurentian), through which it is clearly eruptive. It holds included in it blocks of the surrounding gneiss, and the latter is traversed by apophyses from the main mass; and at places distinct evidence of an alteration contact-zone is observable. The deeply-worn surface of both the Laurentian and the invading anorthosite is overlaid by flat-lying, unaltered Cambrian strata. The age of the anorthosite is thus limited as Post-Laurentian and Pre-Cambrian. Petrographically, the anorthosites are characterized by a peculiar cataclastic structure, which is most pronounced where the rock mass evinces a schistose or foliated structure. This cataclastic structure is ascribed to pressure acting on the mass and deforming it while it was yet deep in the crust of the earth, and at a temperature probably near its fusion point. In addition to the dominant mineral plagioclase, many other rock-forming minerals occur, such as augite, hypasthene, ilmenite, hornblende, biotite, etc. Most of these play a very subordinate *rôle* as normal constituents, while others are rare accessories; and some are secondary or decomposition products. Certain layers of anorthosite occur intercalated with the gneiss and crystalline limestone of the surrounding Grenville series. These layers of apparently interbedded anorthosites vary in thickness from one yard to several hundred yards, and in length from half a mile to eight miles. The apparent interbedding is due to the intrusion of the anorthosite within the strata of the Grenville series.

The Saguenay region presents a mass of anorthosite of still more extensive proportions, occupying not less than 5,800 square miles. The anorthosite of this region is essentially similar to that of the Morin region, both petrographically and in its relations to the Laurentian and to the base of the Palæozoic. There are, however, some differences in petrographical detail; one of these being the common occurrence of olivine among the ferro-magnesian constituents. The Laurentian gneiss of the surrounding region corresponds rather to the Ottawa gneiss than to the Grenville series, and the contact phenomena on the periphery of the anorthosite mass are more confused than in the case of the Morin mass.

The other localities where occurrences of anorthosite rocks are described are: In Labrador, in Newfoundland, on the north side of the St. Lawrence River and Gulf, in the State of New York, and on the east coast of Lake Huron. To this list of localities the present writer may be permitted to add northern New Jersey and the northwest coast of Lake Superior, where he has met with anorthosite rocks in the field.

Among the more important results of Professor Adams's work may be mentioned: —

1. The clear recognition, as plutonic eruptive formations, of rock masses, which, being petrographically and geologically units, have each an enormous extent. The Morin mass occupies nearly 1,000 square miles, and the Saguenay mass is at least about six times that area. For such irruptive plutonic masses Suess has proposed the designation "batholite," and it will facilitate discussion to use that term. The recognition and description of the laccolitic type of mountain structure by Gilbert has been prolific of very fruitful results. The fact that there are such structures was so ably presented by their discoverer that it was warmly and generally received, and it has become an important element in discussions of orogeny. The fact that there *are* batholites has not had so vigorous a presentation, and the important *rôle* which they play in the structure of the earth's crust has not received the recognition which its importance merits. The able account which Professor Adams gives us of these great batholites of anorthosite is, therefore, a welcome addition to our knowledge of such structures. The present writer has elsewhere endeavored to call attention to the existence of granitic batholites in the Rainy Lake region, which are comparable in size to the anorthosite areas of Quebec; and it seems to him that a more general appreciation of the importance of these great igneous masses would simplify and advance our discussion of certain problems of tectonic geology, metamorphism, and geognosy. If it be a fact, as Professor Adams and the writer have shown for two distinct regions, that immense masses of igneous matter, ranging from 25 to 100 miles or more in diameter, have invaded the crust from below, dis-

[1] Ueber das Norian oder Ober-Laurentian von Canada. Stuttgart, 1893.

placing or absorbing it, is it not likely that such an event has occurred frequently and in many different parts of the earth's crust? Geological records are, indeed, full of suggestions that such is the case. Yet in all our current discussions of orogeny, epeirogeny, and regional metamorphism, how little is this factor in the problem considered? What part has the development of the Nova Scotia batholite played in the folding of the Cambrian strata of that province, in their metamorphism and in their becoming charged with gold? What part has the development of the great batholite of the Sierra Nevada played in the folding and metamorphism of the earlier Mesozoic rocks of California and in their becoming charged with gold? What part has the development of the great British Columbian batholite played in the folding and metamorphism of the earlier Mesozoic strata of the west coast of that province? Was the British Columbian batholite synchronous in its development with the Sierra Nevada batholite? Are they separate and distinct affairs, or are they simply geographically separate manifestations of one stupendous process of crust development? In either case has not the exposure by denudation of these great batholites and their intrusive relations to the surrounding terranes practically reproduced the conditions which we find in the Archæan terranes of the Canadian plateau? These are a few of the questions which can only be profitably discussed when the batholite is recognized as a much larger element in tectonic geology than the dyke, the neck, the boss, the sill, or the laccolite. Batholites abound. Why should they not be recognized?

2. A second important result is the immense simplification which is effected in Archæan geology in the Canadian territory, where most questions of that ilk must find their final solution. Hitherto the Norian rocks have been classed as part of a supposed system of metamorphic sedimentary strata known as the Laurentian. This system was divided by Logan into an upper and a lower division, the latter being sub-divided into two parts, viz.: the Grenville series and the Ottawa gneiss, so that his scheme stood thus:—

Norian series = Upper Laurentian
Grenville series = Upper division } of Lower Laurention.
Ottawa gneiss = Lower division }

The recognition of the irruptive character and post-Grenville age of the Norian rocks is a great gain, and reduces the Laurentian system to two members. The simplification thus effected suggests to the present writer still other possibilities in the same direction. It seems probable that the Grenville is a profoundly metamorphosed series of sedimentary strata. Its bedded character and the fact of its being composed of strata of limestone, quartzite, iron ore, graphite, etc., in addition to the gneisses, favor this view. The Ottawa gneiss, on the other hand, has a very different character. There are no beds of limestone, or quartzite, or iron ore, or graphite. The mass of the formation is eminently granite, with gneissic foliation, which in some cases is well defined, and in others vague or almost absent. What is the relation of the Ottawa gneiss to the Grenville series? The former would be recognized by any petrographer as a granite — a plutonic igneous rock. Professor Adams recognizes the geological identity of the Ottawa gneiss with the Laurentian gneiss and granite which the writer has described as invading the upper division of the Archæan complex (Ontarian system) in the region northwest of Lake Superior. There the igneous irruptive and batholitic character of the granites and gneisses (= Ottawa gneiss) and its invasion of the Upper Archæan rocks is unequivocally demonstrated by evidence which has been abundantly adduced elsewhere. Does the Ottawa gneiss of the Ottawa valley bear a similar batholitic and intrusive relation to the Grenville series? From what the writer knows of the region, it seems to him eminently probable that such will be found to be the case. This hypothesis is favored somewhat by certain harmonious analogies which it would establish between the Archæan complex in the Lake Superior region and the region of the Lower Ottawa. Generally, the Archæan complex throughout Canada, omitting the Norian, is composed of two great divisions. The lower division seems generally to have the petrographical characters of the Ottawa gneiss. The upper division is usually recognizable as an assemblage of metamorphic, sedimentary, or mixed sedimentary and volcanic strata. Part of this upper division has usually been referred to as Huronian, but, according to several authorities, this term was originally applied to a post-Archæan series on the north shore of Lake Huron; and there is some confusion attending its use. Even when applied to Archæan rocks, the term has embraced only a portion of the upper division of the complex. In western Ontario, this upper division includes at least one other group besides that which has usually been called Huronian. The writer has elsewhere proposed the term "Ontarian system," as a comprehensive designation to embrace the whole of the upper division of the Archæan in western Ontario. Now it seems to the writer that the Grenville series in Quebec occupies the same stratigraphical position in the Archæan complex as does the Ontarian system (embracing Contchiching and Keewatin [Huronian?]) in western Ontario. Admitting, for the sake of clearly stating the hypothesis, that the Grenville series is the equivalent of Ontarian system, or any part of it, we would have the following parallelism:—

	Western Ontario and Minnesota.	*Eastern Ontario.*	*Quebec.*
In order of superposition.	Ontarian system	Hastings series	Grenville series
	Laurentian system	Ottawa gneiss	Ottawa gneiss
	[1] Carltonian { Anorthosites of Minnesota		Norian
In order of chronological sequence; an irruptive rock being of later age than the formations which it invades.	[1] Carltonian { Anorthosites of Minnesota		Norian
	Laurentian System { Batholitic Granites and Gneisses	Ottawa gneiss	Ottawa gneiss
	Ontarian System	Hastings series	Grenville series

[1] See Bulletin, No. 8, Geolog. and Nat. Hist. Surv. of Minnesota.

If this hypothetical correlation should ever be established, it would then seem that different names and different stratigraphical positions had been given to groups of strata geologically equivalent because of their petrographical dissimilarity. The Grenville series is characterized by limestones and quartzites, with little or no volcanic admixture. In the Ontarian system of western Ontario sedimentary rocks, in a more or less metamorphic state, are common enough; but there is a scarcity of crystalline limestones and quartzites, and altered forms of volcanic rocks abound. This petrographical dissimilarity, however, in no way militates against their geological correlation. It is interesting to note in this connection that the Hastings series, which is geographically between the Quebec region and the Lake Superior region, is intermediate in petrographical character between its suggested equivalents on either side. By some authors it has been correlated with the Grenville series, and by others with the Huronian (Archæan).

GEOLOGY OF TUCUMCARI, NEW MEXICO.

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IN 1852, Professor Jules Marcou, as United States geologist, made a trip across the country with the engineers who were sent out to survey a railroad route from Fort Smith, Ark., to the Pacific Ocean, near the thirty-second parallel. On that trip he passed through the Tucumcari region, and published a description and section of Pyramid Mountain, one of the representativ