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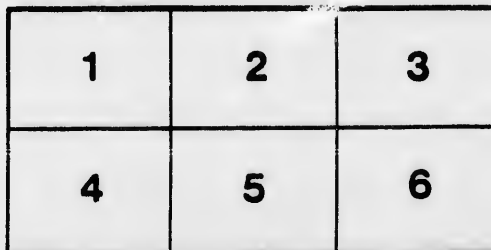
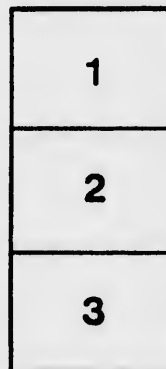
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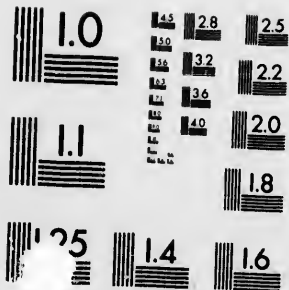
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PAPERS FROM THE DEPARTMENT  
OF  
GEOLOGY.

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NO. 3.—CANADIAN LAURENTIAN.

BY

F. D. ADAMS, A. E. BARLOW, AND R. W. ELLS.

[Reprinted from the American Journal of Science and Arts, pp. 173-180.]

MONTREAL, 1897.

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ART. XVII.—*On the Origin and Relations of the Grenville and Hastings Series in the Canadian Laurentian*; by FRANK D. ADAMS and ALFRED E. BARLOW, with remarks by R. W. ELLS.\*

AS the exploration of the more remote portions of the great Canadian protaxis of the North American continent progresses, accompanied by the detailed mapping of its more accessible parts, the true character, structure and origin of the Laurentian System is being gradually unfolded. The work of Logan during the early years of the Canadian Geological Survey, though excellent in the main, is being supplemented and, in certain directions, corrected; and as the work is now being pushed rapidly forward, it is believed that the time is not far distant when, difficult as the study is, we shall possess as complete a knowledge of these ancient rocks as we now do of many more recent formations. In a paper which appeared in 1893,† it was demonstrated that Logan's "Upper Laurentian" does not exist as an independent geological series, the amorthosites, which were considered as constituting its main feature, being in reality great intrusive or batholithic masses; while in a subsequent paper,‡ it was shown that in the remaining portion of the Laurentian, two distinct classes of rocks could be distinguished, the first being beyond all doubt igneous rocks, and the second consisting of highly altered rocks of aqueous origin. In addition to these two classes of rocks of which the origin could be recognized, there was yet a third class, concerning the genesis of which there remained some doubt.

Since the appearance of these papers, the present writers have been working together in mapping a large area (about 4800 square miles) of the Laurentian in central Ontario, comprising map-sheet No. 118, and a portion of 119, of the Ontario series of geological maps, the district lying to the north of Lake Ontario, along the margin of the Protaxis, and being especially well suited for purposes of study. Portions of three summers have already been spent in the district, and as two years more must probably elapse before the work can be completed, it is desired here to present a general outline of the results so far obtained, indicating certain conclusions which seem likely to be reached concerning the origin of the rocks in question.

The Fundamental Gneiss, as shown by the work of the Canadian Geological Survey, occupies by far the larger portion of the protaxis as a whole; while the Grenville Series has prob-

\* Published by permission of the Director of the Geological Survey of Canada.

† Adams, F. D.—Ueber das Norian oder Ober-Laurentian von Canada, Neues Jahrbuch für Mineralogie, Beilage Band viii, 1893.

‡ Adams, F. D.—A Further Contribution to our Knowledge of the Laurentian, this Journal, July, 1895.

ably its principal development along the southeastern margin, although as the exploration of this vast area is continued, new and possibly more extensive areas of these rocks may yet be found. Strata belonging to this series are already known to occur on the upper Manicouagan River, the lower Hamilton River, on the Manonau Branch of the Peribonka and on the lower part of the Ungava River, in the Labrador peninsula; while similar rocks, which would seem to belong to this series, but which have not as yet been thoroughly examined, have been met with about southern Ballin's Land, and possibly about Baker Lake near the head of Chesterfield Inlet, as well as on the west coast of Hudson Bay and also at Cross Lake on the Nelson River.

The Fundamental Gneiss consists of various igneous rocks closely allied in petrographical character to granites, diorites and gabbros, and which almost invariably have a more or less distinct foliation. Where this foliation is scarcely perceptible it becomes very difficult to decide whether the rock is an intrusive granite or diorite, or a very massive form of the gneiss in question. The different varieties of gneissic rock alternate with or succeed one another across the strike, or sometimes cut one another off, suggesting a complicated intrusion of one mass through the other, but there is usually a general direction of strike to which, in any particular district, the foliation of all the varieties conform. The associated basic rocks are very dark or black in color and are usually foliated, but sometimes this foliation is absent and the rock occurs in masses of all sizes and shapes scattered through the acid gneisses, and in the great majority of cases so intimately associated with the latter that it is impossible to separate the two in mapping. The smaller of these masses can be distinctly seen to have been torn from the larger, which latter are often of enormous size. This process can be observed in all its stages. The granitic gneiss invades the great basic masses, sending off wedge-like arms into them, which tear them apart and anastomose through them in the most complicated manner. These smaller masses can then be observed to be separated into still smaller fragments, which either from the fact that they split most readily in the direction of their foliation or owing to subsequent movements, when the rock was in a more or less plastic condition, often assume long ribbon-like forms. That great movements have taken place in the whole series during or after this invasion is shown by the complicated twisting of these darker bands and masses into all manner of curious and intricate forms, as well as in the frequent rolling out of great blocks of the amphibolite, after having been penetrated in all directions by small pegmatite veins, resulting in masses of a dark basic gneissoid rock, filled with strings, bunches, separated fragments or grains of quartz or feldspar, giving to the mass a pseudo-conglomeratic appearance.



There can be but little doubt that the various gneissic rocks, constituting the more acid part of the series, are of truly igneous origin; and there is no evidence whatever of their having ever formed part of a sedimentary series.

The true character of the more basic members is more uncertain, but they are probably closely related to the pyroxene granulites of Saxony, and doubtless represent either differentiation-products of the original magma, or basic intrusions whose structural relations and characters have been largely masked by the great movements which have taken place in the whole series at a later date.

The Grenville Series differs from the Fundamental Gneiss in that it contains certain rocks whose composition marks them as highly altered sediments. These rocks are chiefly limestones, with which are associated certain peculiar gneisses, rich in sillimanite and garnet, having a composition approaching ordinary shale or slate, or else very rich in quartz and passing into quartzite, having thus the composition of sandstone. These rocks, as has been shown in one of the papers before referred to, usually occur in close association with one another, and are quite different in composition from any igneous rocks hitherto described. They are considered as constituting the essential part of the Grenville series. They usually, however, form but a very small proportion of the rocky complex in the areas in which they occur, and which, owing to their presence, is referred to the Grenville series. They are associated with and often enclosed by much greater volumes of gneissic rocks, identical in character with the Fundamental gneiss. The limestones are also almost invariably penetrated by masses of coarse pegmatite, and occasionally large masses of the limestone are found embedded in what would otherwise be supposed to be the Fundamental gneiss. The whole thus presents a series of sedimentary rocks, chiefly limestones, invaded by great masses of the so-called Fundamental Gneiss, and in which, possibly, some varieties of the gneissic rocks present may owe their origin to the partial commingling of the sedimentary material with the igneous rocks by actual fusion. There is, however, no reason to believe, from the evidence at present available, that any considerable proportion of the series has originated in the last mentioned manner.

It will be readily seen that an exact delimitation of areas of the Grenville series is thus sometimes a matter of great difficulty, as they often appear to shade away into the Fundamental gneiss, and it has hitherto been difficult in the case of the Grenville series to account for the existence of such a comparatively small proportion of sedimentary strata, intimately associated with such great volumes of igneous gneisses.

The relations of the two series, as determined by the investigations of the last two seasons, throws new light upon the subject, and indicates the probable explanation of the difficulty.

The northwestern half of the more restricted area at present under consideration is underlain by Fundamental Gneiss, presenting the characters described above. A smaller area of the same gneiss occurs at the southwestern corner of the area, in the townships of Lutterworth, Snowdon and Glamorgan, while in the southern and southeastern portions of the area there are other occurrences, which, however, present a more normally granitic character.

The southeastern portion of the area is underlain by rocks of the so-called Hastings Series, consisting chiefly of thinly-bedded limestones, dolomites, etc., cut through by great intrusions of gabbro-diorite and granite. These limestones and dolomites are usually fine-grained and bluish or greyish in color, with thin interstratified layers, holding sheaf-like bundles of hornblende crystals. As compared with the limestones of the Grenville series they are comparatively unaltered. They form beyond all doubt a true sedimentary series, and in the southeastern corner of the area are associated with conglomerates or breccias of undoubtedly elastic origin. Between the great area of Fundamental Gneiss in the northwest, and the Hastings series in the southeast of the sheet, there lies an irregular-shaped belt of rocks, presenting the characters of the typical Grenville series as above described, the limestones having in all cases the form of coarsely crystalline, white or pinkish marbles, although more or less impure. The strike of the foliation of the Grenville series follows in a general way the boundaries of the Fundamental Gneiss, and is seen in an especially distinct manner to wrap itself around the long and narrow development of the gneiss exposed in the southwest corner of the area. Isolated masses of the limestone and gneiss characteristic of the Grenville series are also found in the form of outlying patches about its margin, as for instance in the townships of Lutterworth and Stanhope. The relations of the Grenville series to the Fundamental gneiss are such as to suggest that in the former we have a sedimentary series later in date than the Fundamental Gneiss, which has sunk down into and been invaded by intrusions of the latter series when this was in a semi-molten or plastic condition. The limestones, while themselves rendered more or less plastic by the same heat which softened the lower gneisses, do not show any distinct evidence of absorption or solution by the invading rocks, unless some of the highly garnetiferous gneisses usually associated with the limestones are formed by a commingling of the two rocks. Masses of the highly crystalline limestone or marble in some cases lie quite isolated in what are, to all appearances, the lower gneisses, as if they had been separated from the parent mass, and had passed outward or downward into the gneissic magma.

The contact of the Fundamental Gneiss and the Grenville series would appear therefore to be a contact of intrusion, in very many cases at least.

The question of the relations of the Grenville series to the Hastings series then presents itself. Although repeated traverses have been made from one series into the other, no sharp line of division has been found. Towards the southeast the limestones of the Grenville series in many places, though still highly crystalline, seem to be less highly altered, and finally, as the Hastings series is approached, present in places the bluish color of the limestones of the latter series; so that it is often impossible to determine to which series they should be referred. The limestones of both series also have the numerous small interstratified gneissic inclusions or bands so frequently referred to in the descriptions of the limestones of the Grenville series, making the resemblance still more complete. In fact, although the true relations of the two series are obscured by the presence of numerous great intrusions of granitic and basic pyroxenic rocks, and can only be determined with absolute certainty by the completion of the mapping, the investigations so far indicate that in the region in question the Hastings series would seem to represent the Grenville series in a less altered form. In other words, the Hastings series, when invaded, disintegrated, fretted away and intensely metamorphosed by and mixed up with the underlying magma of the Fundamental Gneiss, constitutes what has elsewhere been termed the Grenville series. The Grenville series may, however, represent only a portion of the Hastings series, and the work so far done in this district has not been sufficient to determine the stratigraphical position of this portion.

Concerning the age of the Hastings series but little is known as yet. To the southeast of the area under consideration, however, its elastic character is well marked, breccias and conglomerates, often greatly deformed by pressure, being present as well as certain fine-grained and comparatively unaltered limestones, in which a very careful search may yet be rewarded by the discovery of fossils. Both lithologically and stratigraphically the rocks bear a striking resemblance to rocks mapped as Huronian in the region to the north and northeast of Lake Huron, and it seems very likely that the identity of the two series may eventually be established. The two areas, however, are rather widely separated geographically, so that the greatest care will have to be exercised in attempting such a correlation.

Like the Grenville series, the rocks of the Hastings series are unconformably overlain by and disappear beneath the flat-lying Cambro-Silurian rocks of the plains, which limit the pro-taxis on the south and are separated from it in time by an immense erosion interval. Further investigation in this area, as well as in that adjoining to the east, now being mapped by Dr. R. W. Ells, will, however, it is hoped, before long throw additional light on the age of this very interesting and important series of rocks. If further investigation proves that the relations of the several series have been correctly diagnosed,

and that the explanation of these relations as given above is correct, the Laurentian system of Logan will resolve itself into an enormous area of the Fundamental Gneiss, which is essentially of igneous origin and which there is every reason to believe forms part of the downward extension of the original crust of our planet, perhaps many times remelted and certainly in many places penetrated by enormous intrusions of later date; into which Fundamental Gneiss, when in a softened condition, there have sunk portions of an overlying series, consisting chiefly of limestones.

Farther east, in that portion of the province of Quebec where the Grenville series was first studied by Logan, the rocks of the Hastings series proper have not been recognized. The Lower Paleozoic strata rest directly upon the Grenville series and would cover up the Hastings series to the south should it extend as far east as this. The limestones of the Grenville series, moreover, here extend much farther back from the edge of the protaxis in bands and streaks conforming to the strike of the underlying gneissic rocks, so that the origin of the series and its relations to the Fundamental Gneiss is not so clearly indicated. When, however, its relations here are interpreted in the light of the Ontario occurrences, there seems to be no reason why the same explanation might not be offered to account for its origin also. The bands of limestone, which often vary in thickness from place to place, and are frequently interrupted in their course or abruptly cut off, might be considered as having taken their form from long folds in the series from which they were derived as it settled down into the magna beneath, or as having been separated by great lateral intrusions of the gneissic magna. Their original shape and character has, however, without doubt been greatly altered by the enormous movements to which both series of rocks have been subsequently subjected.

If again this proves to be the true explanation of the relations of these series, the Grenville series will cease to be an anomaly among our Archaean formations and will, so far as its mode of occurrence is concerned, bear the same relation to the Fundamental Gneiss as the Huronian does farther west in the Lake Superior and Huron district, as shown by Lawson and Barlow; the similarity in position, however, not implying identity in age.

The recognition of the Grenville series as consisting of a series of sedimentary rocks, largely limestones, invaded by igneous material which now makes up by far the greater portion of the series and consists largely of extravasations of the Fundamental Gneiss, is now pretty certainly established by the field evidence. Its recognition as a portion of the Hastings series which has been intensely metamorphosed, will probably be more clearly established as the field work progresses. Since subordinate areas of the Grenville series also occur to the

south of the St. Lawrence in the Adirondaek region, and are now being mapped, it will be of great interest to ascertain whether the same relations do not also exist in that area, and whether a continuation of the Hastings series to the south cannot be recognized in the "Huronian Schist" of St. Lawrence and Jefferson counties, shown upon the Geological Map of the State of New York, which has just been issued by the Geological Survey of this State.

It is perhaps unnecessary to draw attention to the fact that the recent investigations of Messrs. Wolff, Brooks, Nason, Kemp, Westgate and others on the crystalline limestones of New Jersey have a certain bearing on this subject.

Remarks by R. W. Ellis:

In connection with the statements advanced in the preceding paper by Dr. Adams and Mr. Barlow, it is but right that the conclusions arrived at from the study of the similar rocks in their eastern and northern extension should be stated. The investigations in this quarter have now been carried on for six years, and have extended over a very large area to the north of the Ottawa, in which is included the typical Grenville series of Sir W. E. Logan, and extending far up the Gatineau River; while to the westward, the work has been carried on till the vicinity of the area, described in the accompanying paper, has been reached. It may be said therefore that the detailed examination of the rocks which make up the Grenville and Hastings series has extended over an area about 250 miles in length by 75 miles in breadth.

In the early days of the study of these rocks much difficulty was experienced. Firstly there was a great and almost inaccessible wilderness, the only available means of travel over the greater portion being by canoes; and in the second place there was an almost entire lack of trained observers to carry on the work. Add to this the entire absence of microscopical determinations, and one can readily comprehend the difficulty experienced in the attempt to solve this most difficult of the problems in Canadian geology.

Foliation and stratification were considered conclusive evidence of sedimentation, and as most of the rocks of the great Laurentian complex gave evidence of these forms of structure, the inference naturally followed that the greater portion of the gneissic, granitic and anorthositic rocks were of sedimentary origin. So far was this sedimentary theory carried out that, in the earlier reports of the Geological Survey, even the masses of binary granite and many of the pyroxenic rocks were included in the same category. This was at the time a very natural conclusion, since many of these masses have a regular bedded structure and conform, over very considerable areas, to the regular stratification of the rocks, either gneiss or crystalline limestone. As the country became more accessible the

field investigations showed very clearly the intrusive nature and later age of many of these masses, while the aid of the microscope fully established the non-elastic and igneous character of the great bulk of the gneisses. The more recent and probably sedimentary origin of the limestones and associated gneisses of the Grenville series, as distinct from the great mass of the underlying Laurentian Fundamental Gneiss, was pointed out some years ago in a paper by the author, read before the Geological Society of America. The subsequent investigations on these rocks, to the west and southwest, showed that the conclusions then presented were correct, but that as the work extended westward to the south side of the Ottawa the character of the various groups of rocks gradually changed. The areas of limestone became much more extensive, and there was a large development of hornblende and other dark-colored rocks, rarely seen to the north of the Ottawa. The limestones also were very often highly dolomitic, and in certain areas were blue and slaty, with but little of the aspect of the Grenville limestones, except where they were in close contact with masses of intrusive granite or diorite. There is also in the rocks of this group to the south of the Ottawa, where they have been styled the Hastings series, from the fact that they were first studied in the county of Hastings, a very considerable proportion of schists, micaceous, chloritic and hornblendic, with certain regularly slaty beds, and others of true conglomerate containing quartz pebbles. In certain portions the lithological resemblances between the Grenville and Hastings rocks are very close, and they may, for all practical purposes, be regarded as one and the same series. From a number of sections made in the counties of Renfrew on the south of the Ottawa, and in Pontiac, to the north of that river, it would appear that the original Grenville limestones and associated grey and rusty gneiss form the lower part of the series, since it is only on their development westward towards the typical Hastings locality that the characteristic Hastings schists and associated strata are met with.

In character and general aspect these rocks of the Hastings series are almost identical with many of those which in the Eastern Townships and in New Brunswick have been regarded as probably Huronian for many years; and so marked is the resemblance that the author, in presenting his summary report for 1894, referred the rocks seen near the Bristol iron mines to that division. It now appears very conclusively established that both in the eastern and western areas we have a well developed series of rocks, including limestones, gneiss and schists, which are of undoubted sedimentary origin, but which have been enormously acted upon by great intrusive masses as well as by other dynamic agencies, so that in many parts their original characters have almost entirely disappeared.

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