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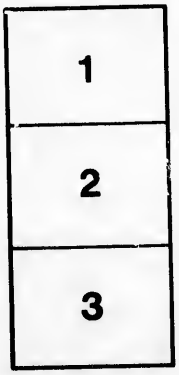

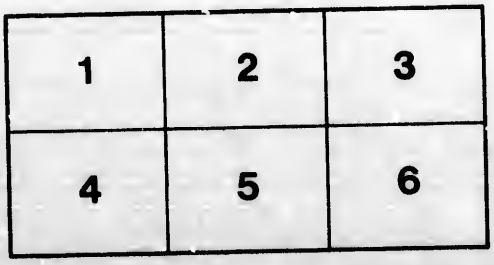

[From The American Geologist, March, 1891.]

PETROGRAPHICAL DIFFERENTIATION OF CERTAIN DYKES OF THE RAINY LAKE REGION.

By Andrew C. Lawson, with analyses by F. T. Shutt, M. A., F. C. I.

Communication No. 2.

At the Toronto meeting of the A. A. A. S. the writers submitted a paper in abstract bearing the above title. The material for the full paper was not at the time of the meeting complete,

and various vicissitudes have since then interfered with the work. However, as some of the facts observed are of interest it is proposed to give them here without attempting to elaborate them so fully as was originally contemplated.

The dykes of the Rainy Lake region show in a marked degree that variation from a fine texture at the dyke walls to a coarse texture in the middle of the dyke, which is more or less characteristic of dykes the world over. In the abstract referred to it was stated that "On examination of the dykes in question, it became apparent that this variation in the physical appearance of the dykes is not simply one of *texture* or degree of coarseness of the constituent minerals, but it is rather the incidental concomitant of important *structural*, *mineralogical* and *chemical* variations which appear very constantly in the same way in different dykes." It will be the object of the present paper to establish this general statement by giving some account of the facts upon which it is based.

A dyke about 150 feet wide which traverses Stop island on the south side of Rainy lake, in which the variations alluded to are strongly accentuated, will be first described somewhat in detail. From this dyke a series of four specimens was taken, viz.:

I at the contact with the dyke wall.

II at four feet from the contact.

III at fifteen feet from the contact.

IV at seventy-five feet from the contact (middle of dyke).

Textural variation.—To the unaided eye there is apparent a very distinct gradation in texture from that of an aphanitic rock at the contact to that of a coarse gabbro or diorite in the middle of the dyke. The gradation is rapid in the first four feet, less so from four feet to fifteen, and scarcely perceptible from fifteen feet to the middle of the dyke; the rock on which the observations were made in the field presenting a continuous, clean, fresh, glaciated surface. In order to arrive at some definite information regarding the gradation in texture, careful measurements were made of the constituent minerals in thin sections of the different specimens. The following are the results of these measurements:

I Ground mass.
Pyroxene—Largest grains..... .0315 mm
Ave. diameter..... .030 mm
Feldspar in slender needles.
Ave. size..... .004 × .052 mm

	Magnetite, ave. diameter	.0147	mm
	Porphyritic crystals.		
	Pyroxene, largest polysomatic grain	1.120	mm
	Feldspar, largest lath-shaped crystal	.056 × .560	mm
II	Pyroxene, approx. ave. diameter	.840	mm
	Feldspar, " " size	.560 × .056	mm
	Magnetite, " " diameter	.126	mm
III	Pyroxene in polysomatic masses, ave. diameter	2.000	mm
	Feldspar, lath-shaped crystals, largest	.350 × .100	mm
	Magnetite, few scattered grains, ave. diam	.700	mm
	Quartz, ave. diameter	.056	mm
IV	Pyroxene, much altered to hornblende, larger gr	1.000	mm
	Feldspar, ave. size of larger grains	2.000	mm
	Magnetite, few large grains, diam	.700	mm
	Quartz, larger grains	.840	mm

Structural variation.—The specimen taken at the contact with the dyke walls (I) appears in section as a porphyrite. The ground mass is a fine ophitic felt work of plagioclase and greenish yellow pyroxene, with viridite thickly studded with granules of magnetite, all of the latter belonging probably to the final consolidation of the magma. The porphyritic constituents are in the order of their generation (1) Plagioclase in lath-shaped crystals,

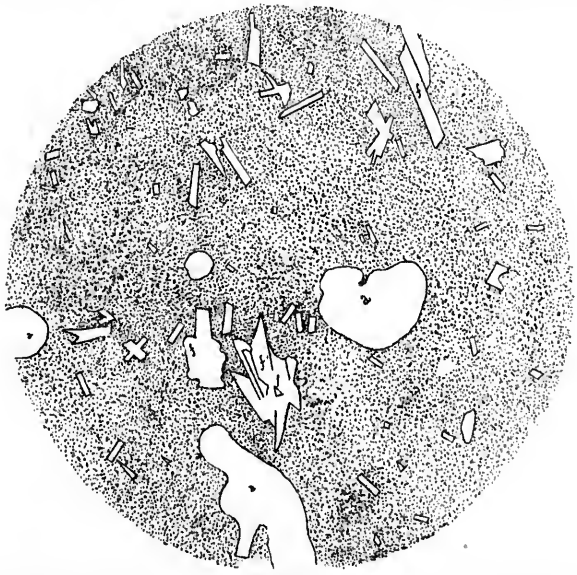

FIG. 1.

Stop Island dyke.—Section of dyke-rock at contact with dyke wall. ×38. a. polysomatic augite; f. plagioclase. Illustrating porphyrite structure.

either in distinctly isolated individuals or aggregated together in irregularly radiating clusters; (2) Augite, in rounded or bleb-like, colorless polysomatic masses. The plagioclase is occasionally included in the augite. The microscopic aspect of this portion of the dyke is shown in fig. 1.

In the specimen taken only four feet from the last, *i. e.*, four feet from the dyke wall, the structure of the rock presents a marked contrast to that just described. There is no ground mass, and the section presents the character of a typical ophitic diabase as shown in fig. 2.

FIG. 2.

Stop Island dyke.—Section of dyke-rock four feet from dyke wall. ×38. a. Augite; f. plagioclase; h. hornblende; m. magnetite. Illustrating ophitic or diabase structure.

In this portion of the dyke the dominant minerals are polysomatic augite and green hornblende. The latter mineral is in part derived from the augite, while part of it presents no evidence of such derivation and may be original. These two minerals occur in large interlocking masses in which are embedded beautifully sharp idiomorphic crystals of plagioclase and irregular grains of magnetite. It seems probable from a careful inspection of the

relative attitude of the constituents that a portion of the augite is of earlier generation than the rest, and earlier than such portion of the hornblende as may be original. The rounded contours of the fresher masses of polysomatic augite suggest analogy with the rounded porphyritic masses shown in fig. 1. In addition to the idiomorphic plagioclase there is a subordinate proportion of plagioclase which shows no crystallographic boundaries. Occasionally a small grain of quartz may be detected. At fifteen feet from the dyke walls the structure is still ophitic. Augite is the dominant mineral and appears to be of two generations, (1) large, irregularly bounded polysomatic masses and idiomorphic crystals, (2) allotriomorphic, interstitial between the idiomorphic plagioclase. Quartz is sparingly present, and magnetite is in large, irregularly scattered grains, some of it allotriomorphically developed about the idiomorphic augite.

In the middle of the dyke the structure is entirely different from either that of a porphyrite or of an ophitic diabase. It is the type of structure characteristic of granite, gabbro, or diorite. All the important constituent minerals interfere with one another, and the only idiomorphic crystals are those of accessory minerals such as apatite. The aspect of a section of this part of the dyke is shown in the drawing, fig. 3. Quartz is abundant, and the augite appears to be entirely replaced by hornblende, so that the rock would be classed with the quartz-gabbros or quartz-diorites according as the hornblende is secondary or original. Considered simply as a hand specimen it is best termed, probably, a uralitic quartz-gabbro.

Mineralogical variation.—The most important mineralogical variation observable in the series of specimens taken across the dyke is the passage from a quartzless rock at the dyke wall to a quartzose one in the middle of the dyke. No quartz can be detected at the side of the dyke. At four feet from the side quartz may be observed in occasional grains, forming an exceedingly small proportion of the constituents; at fifteen feet it is somewhat more abundant, and in the middle of the dyke quartz is a prominent constituent of the rock. Another important change in the mineralogical composition of the rock is the encroachment of hornblende upon the augite as one passes from the dyke walls, and the final complete replacement of the augite in the middle of

the dyke. This change, even though it be due in great part to paramorphism, testifies to an important variation in the character of the rock developed from the same magma at various distances from the dyke walls. The augite nearer the middle of the dyke would appear to be much more susceptible of paramorphic change than that near the dyke walls. The middle part of the dyke is also richer in accessory minerals such as apatite, biotite, epidote, and leucoxene than the lateral parts.

Chemical variation.—The chemical variations observed in this dyke will be gathered from a consideration of the following table of analyses of the specimens above referred to :

Stop Island dyke.

	I.	II.	III.	IV.
SiO_2	47.83	47.08	47.84	57.50
Fe_2O_3+FeO	4.57		6.72	5.07
Al_2O_3	30.28		25.40	23.44
CaO	6.72		8.44	5.62
MgO	4.32		5.25	2.76
K_2O	trace		.60	.45
Na_2O	1.30		2.55	2.01
P_2O_5	2.19		.94	2.02
Loss on ig.	2.05		2.53	2.25
	99.26		100.27	101.12
Sp. g.	3.028	3.060	3.080	2.856

These analyses show a remarkable increase in the proportion of silica in the middle of the dyke over that in the lateral parts. The difference in silica content of about 10 per cent is sufficient to separate the specimens into two distinct rock species according to current methods of classification. The difference is in keeping with the quartzose character of the middle of the dyke as compared with the quartzless character at the side, and also harmonizes with the difference in specific gravities given in the table.

Thus in half the space of a sharply defined dyke only 150 feet wide our study reveals variations in all of those characters which we make use of in the description and classification of rocks. Totally distinct types of texture, structure and composition belong to the same geological unit mass. This fact suggests an interesting commentary upon our system of rock classification. Is such classification in cases like the present, or even generally, anything

more than a classification of hand specimens? Of what philosophic or geological value is a classification of specimens into different species and types when they may all be one and the same rock crystallized from the same magma within a few feet of one another. The geologist who knows his rocks in the field as well as in the laboratory finds such classifications very little expressive of geological truth. But the differentiation in character of this dyke rock suggests other matters than a criticism of classification, namely, a consideration of the conditions under which such differentiation was developed from a common magma. From the nature of the case we are able to form fairly satisfactory conceptions as to two conditions which are commonly regarded as having a para-

FIG. 3.

Stop Island dyke.—Section of dyke-rock seventy-five feet from dyke wall (middle of dyke). ×38. f. plagioclase; h. hornblende; q. quartz; m. magnetite. Illustrating allotriomorphic-granular or granitic structure.

mount influence upon the solidification of rock from magma. These are (1) the relative pressure, and (2) the relative rate of cooling under which the different parts of the magma solidified. The magma being confined between parallel sharply-cut fissure walls may fairly be assumed to have been under the same constant hydrostatic pressure in any given horizontal plane during the

time of its solidification. It may also be fairly assumed that those portions of the magma adjacent to the fissure walls cooled more rapidly and solidified earlier than did the middle portion. Thus although we have in current petrographical literature numerous references to great pressure as one of the chief causes of the development of the coarser texture and granitic structure of the plutonic rocks as compared with that manifested by rocks which solidify at or near the surface, the present case seems to establish the fact that both types of rock structure may be developed under one and the same pressure. Difference in pressure under which magmas solidify is, therefore, probably, not so important a cause of the difference in structure and texture of rocks as is generally supposed. On the other hand we have in the case under consideration strong presumptive evidence that the rate of cooling which must have been rapid at the sides and slow in the middle, exercised the controlling influence over the character of the rock developed from the magma in any given part. With regard to the conditions which determined the chemical and mineralogical differentiation of the dyke rock very little can be definitely affirmed. It seems probable, however, that the explanation lies in the earlier separation of the more basic minerals accompanied by a transference of more acid residues (or solvents) to the middle portions, which transference was facilitated by the gradual solidification of the magma from the dyke walls toward the middle, and by the movement of the water constituent of the magma towards the middle. The water of the magma, so long as the latter remained liquid, would have a tendency to escape to the surface. This tendency, taken with the tendency of the higher portions of the dyke to solidify more rapidly than the deeper-seated portions would create a current obliquely through the magma, upward and inward from both sides. This current would aid in the transference from the sides to the middle of the more acid portions of the magma from which the more basic had separated out.

Numerous other dykes have been examined with the same general result as that arrived at by a study of Stop Island dyke. In none of these, however, was the differentiation in character found to be quite so strongly accentuated as in the Stop Island dyke. A series of specimens taken across the dyke which cuts the southeast shore of White-fish bay, and which is referred to in former

notes as the White-fish Bay dyke, was analyzed with the following results :

White-fish Bay dyke.

	I	II	III	IV
SiO_2	47.50		48.08	52.47
Fe_2O_3+FeO	7.40		9.07	6.31
Al_2O_3	22.44		23.67	25.54
CaO	10.21		10.99	6.62
Mg O	3.71		3.92	2.31
K_2O	1.29		.49	.54
Na_2O	1.62		1.92	3.23
P_2O_5	.34		1.11	1.16
Loss on Ig	2.85		.83	1.28
	97.36		100.08	99.46
Sp. g.	2.927	3.081	3.030	2.870

I near contact with dyke wall.

II six feet from contact.

III thirty feet from contact.

IV sixty feet from contact (middle of dyke).

In this dyke the gradation in texture is as pronounced as in the Stop Island dyke but the differentiation of structure is not so marked. In I the ground mass has the character of a fine-grained ophitic diabase and the porphyritic constituents present no great contrast in size to those of later generation which have crystallized around them ; and in IV the ophitic structure is not entirely replaced by the granular. This dyke is noteworthy for the abundance of hypersthene which is present near the dyke walls. This hypersthene is a porphyritic constituent, and has well defined crystallographic form. It has not been observed in specimens from other portions of the dyke and its occurrence recalls the similar occurrence of enstatite in the Jack-fish Lake dyke and in the Rat-root Bay dyke which has been noted in a former paper. There is as in the Stop Island dyke a regular increase in the proportion of quartz in passing from the dyke walls to the middle and in the latter part of the dyke the augite is entirely replaced by hornblende. The analyses of this dyke rock and of the Stop Island dyke rock show throughout an unusually high percentage of alumina.

A dyke sixty-five feet wide cutting biotite gneiss with a northwest strike on the north shore of Shoe Bay, Rainy Lake,

afforded three specimens taken in the same sequence as before. The first, from the contact, shows a pronounced porphyrite structure consisting of a fine ground mass of plagioclase, augite and magnetite in which are imbedded lath-shaped crystals of rather cloudy plagioclase of an earlier generation and polysomatic aggregates of pyroxene, which in many cases is partially altered to a serpentinous, greenish-yellow substance either on the periphery, having a fresh core, or in patches and shreds through the section. In the second specimen, taken at six feet from the contact, the structure is ophitic and in marked contrast to that of the last. The plagioclase is fresh, the augite is in scattered grains and in polysomatic aggregates and is more or less altered to hornblende. Quartz is present and is intergrown with the feldspar after the manner of pegmatite. Magnetite occurs in skeletal forms and apatite in slender needles. In the specimens taken from the middle of the dyke the general structure is granular rather than ophitic although the latter structure is observable. Augite is seen in occasional large polysomatic grains with a good deal of filmy or shreddy perimorphic hornblende and some chlorite. Hornblende also occurs in independent masses. Quartz is very abundant and is nearly all intergrown with feldspar in pegmatitic structure. Magnetite and apatite are present, the former in irregular scattered grains and the latter in slender needles. A partial chemical examination of the specimens from this dyke gave the following figures for the percentage of silica and the specific gravity :

	Contact.	Middle.
SiO_2	49.26	51.04
Sp. g.	3.077	3.007

Near the mouth of Sloe Bay, on the north side is another dyke similar to the last. It is about seventy feet wide. Thin sections of three specimens taken from the same parts of the dyke as before, present the same general features as in the dyke last described. The rock at the contact is a porphyrite with the usual plagioclase crystals and augite aggregates imbedded in a fine-grained base. The latter is remarkable for the uniformly even distribution of the magnetite grains. The porphyritic augite has no crystallographic boundaries and its alteration is for the most

part marginal. No quartz was observed. At six feet the structure is again ophitic. Quartz is present. Magnetite is in large sized, sparsely scattered grains. A little pyrite also occurs. The structure of the middle part of the dyke is for the most part granular but with some idiomorphic plagioclase. The augite is generally fresh, but has associated with it hornblende and chlorite as alteration products. Quartz is abundant with uniform orientation over wide, and in the section isolated, areas. The following are the figures for the silica percentage and specific gravity of the three specimens:

	Contact.	Six feet from contact.	Middle.
SiO_2	48.65	47.92	49.28
Sp. g.	3.088	3.079	3.016

Similar specimens were taken from a dyke on Risky Island, Rainy Lake, which is nearly in a line with the Stop Island dyke and the Shoe Bay dyke last described. The contact rock is as before distinctly a porphyrite similar to that represented in fig. I. The minerals are all fresh. Plagioclase in large crystals and augite in single and in polysomatic grains, are imbedded in the usual fine ground mass, which in this, and in all the dykes described, is apparently holocrystalline and micro-ophitic. At six feet from the dyke wall the structure is ophitic but with some allotriomorphic plagioclase. The augite is mostly replaced by hornblende. Quartz is plentiful in pegmatitic development. Magnetite or titanic iron is abundant but without any trace of leucoxene. In the middle of the dyke the ophitic structure is still observable but most of the constituent minerals are allotriomorphic. The augite is very largely replaced by hornblende. Quartz is observed to present the same ophitic relations to the idiomorphic plagioclase as does the augite, and it contains inclusions of apatite and microlites. Leucoxene with cleavage traces of titanic iron is abundant and in large grains. The following are the figures for the percentage of silica and specific gravity of these specimens:

	Contact.	Six feet from contact.	Middle.
SiO_2	49.77	49.64	52.31
Sp. g.	3 100	3.044	3.016

On the south side of Rainy river opposite Sec. 20, Tp. 5 S., R. XXVIII of the Canadian township survey, a dyke was observed having a width of from 150 to 200 feet and cutting hornblende schists with a north-northwest strike. No specimen was here obtained at the immediate contact, and in one a little removed from the contact the porphyritic structure was only represented by blebs of polysomatic augite imbedded in an ophitic base which approached in texture that of the specimens taken at four or six feet from the contact in other dykes. The ophitic structure prevailed in two other specimens, one taken at six feet from the contact and one from the middle. Quartz was observed in both of these but not in the first. The percentage of silica and specific gravity of the first and third specimens is as follows :

	Near Contact.	Middle.
SiO_2	49.82	50.10
Sp. g.	3.221	3.068

Series of specimens from several other dykes were also examined, but the limit of space will not permit of further detailed descriptions. Generally, however, it may be said that the porphyrite structure almost invariably characterizes the dyke rock at the contact and that this rapidly grades into an ophitic structure which in turn appears to grade very gradually into the granular structure. The latter, it must be said, is developed to the entire exclusion of the ophitic structure only in a few of the cases observed. The increasing proportion of quartz toward the middle of the dykes is a very constant character. In one dyke, namely that on the south side of Rainy river opposite the town of Fort Frances, well defined crystals of enstatite were observed in the rock at the contact as a porphyritic constituent while none of this mineral was observed in other parts of the dyke.

[From the PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, Vol. XXXVIII.]

PETROGRAPHICAL DIFFERENTIATION OF CERTAIN DYKES OF THE RAINY LAKE REGION. By Dr. A. C. LAWSON and F. T. SHUTT, M. A., F. C. I., Ottawa, Ont.

[ABSTRACT.]

ONE of the writers has described in a former paper certain diabase dykes of the Rainy Lake region. The present paper is the result of a more critical investigation of the same dykes, with others since discovered, having special reference to the petrographical differentiation of the dyke rock in passing from the contact walls to the centre of the dyke. The fact that dykes are very commonly fine grained at their margins and coarse grained in their middle parts is familiar to all geologists. On examination of the dykes in question, it became apparent that this variation in the physical appearance of the dykes is not simply one of *texture* or degree of coarseness of the constituent minerals, but that it is rather the incidental concomitant of important *structural*, *mineralogical* and *chemical* variations which appear very constantly in the same way in different dykes. These variations are chiefly as follows: *Structural* — the passage from the structure of a very fine textured diabase-porphyrite at the contact walls through the characteristic ophitic structure of diabase at a few feet from the contact to the granular structure of gabbro in the middle part of the dyke. (Illustrative drawings were submitted.) *Mineralogical* — the passage from a quartzless rock at the contact to a quartzose one towards the middle of the dyke. *Chemical* — the passage from a more basic rock near the contact to a more acid towards the middle. The results of complete or partial analyses by Mr. Shutt of series of specimens taken across a number of dykes were given in tabular form.

The principal object of the paper is to adduce specific evidence that from a rock mass which is a geological unit of very limited extent, there may be taken specimens which under current methods of classification would receive different names and be relegated to different classes. The fact that a series of specimens, in any given locality, differ from one another texturally, structurally, mineralogically and chemically, is no proof that they are not geologically the same rock crystallized from the same magma. The regular textural and structural differentiation of the dykes from wall to middle is inferred to have been caused by the different rate of cooling under constant pressure. The chemical differentiation is probably due to a selective crystallization of the more basic minerals in the earlier stages of solidification accompanied by the transference of acid residues from the sides to the middle by the agency of included water.

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[From the PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, Vol. XXXVIII.]

NOTE ON THE MAPPING OF THE ARCHÆAN NORTHWEST OF LAKE SUPERIOR.

By DR. ANDREW C. LAWSON, Ottawa, Ont.

[ABSTRACT.]

THE writer exhibited a general geological map of the Archæan country between Red River Valley and Lake Superior, showing the results of recent investigations which he has been conducting for the Geological Survey of Canada. The proof of a new geologically colored map of the Rainy Lake region, shortly to be issued by the survey, was also exhibited to illustrate the details of a portion of the general map. The relative distribution of the Upper and Lower Archæan, as displayed on the map, was shown to be peculiarly interesting and instructive. The Lower Archæan or Laurentian, consisting of various, more or less foliated granites and syenites, which have hitherto been regarded as the oldest rocks, was shown to occupy large, isolated boss-like areas which appear to be irruptive or intrusive through the schists. The general mapping of this portion of the country, where denudation has left the Upper and Lower Archæan in nearly equal proportions, strongly supports the view that the Laurentian rocks are of later age than the schists of the Upper Archæan and were irrupted through them.

The importance of careful mapping as an aid to the solving of the profound problems of Archæan geology was dwelt on, and other evidence which the writer has adduced elsewhere in support of the irruptive nature of the Laurentian was referred to.

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