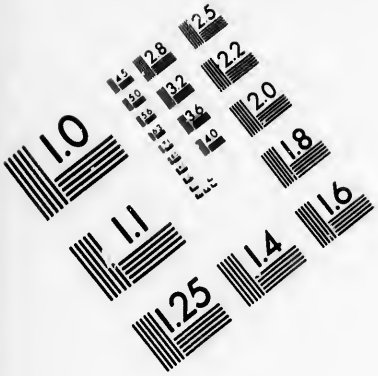

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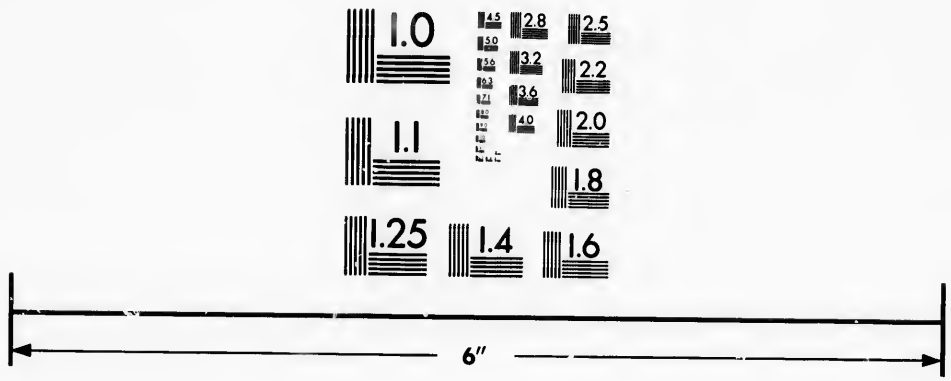

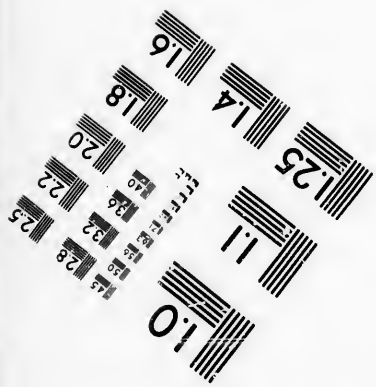

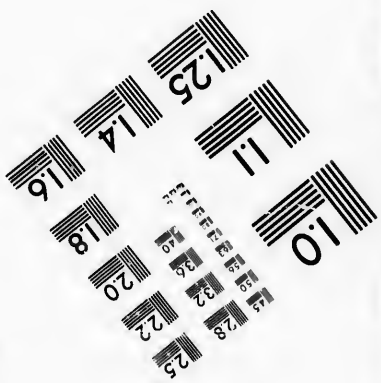

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LAURENTIAN AREA TO THE NORTH AND WEST OF ST. JEROME

SOUTH-WEST QUARTER-SHEET MAP OF THE EASTERN TOWNSHIPS, PROVINCE OF QUEBEC.

BY

F. D. ADAMS, Ma.Sc., Ph.D.

(*Reprinted from Annual Report, Geological Survey of Canada, Vol. VII., New Series.*)

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GENERAL STATEMENT.

Laurentian protaxis.

The continent of North America, as is well known, has been gradually built up by an accumulation of sediment about certain very ancient land areas which are known as its protaxes. Of these the largest and most important is the great northern protaxis, which forms the greater part of northern Canada, having an area of somewhat over 2,000,000 square miles and constituting what Suess has termed the Canadian shield or boss.

The Laurentian area which forms the extreme north-west corner of the sheet at present under discussion, is a portion of the southern margin of this great northern protaxis and thus represents a part of an extremly ancient land area, from the waste of which the elastic Palæozoic strata to the south were derived.

The area of these ancient rocks embraced in the sheet is small, amounting to about 400 square miles; it forms, however, part of a much larger district, stretching to the north beyond the limits of this map, the geology of which has been worked out, and a map of which, with full explanatory report, will appear shortly. In the following pages, therefore, merely a brief general description of that portion of this district lying within the limits of the map accompanying the present report will be given, leaving the more detailed discussion of the district as a whole, and the many problems which it presents, for the fuller report which will appear later.

Character of country.

In the aspects of its relief, this Laurentian country is sharply marked off from the plains, underlain by the Palæozoic—which bound it on the south. It is a somewhat uneven plateau, the edge of which when viewed from the plains appears as a range of hills running in a north-east and south-west direction. The plateau slopes gently to the south-east from an average elevation of about 1000 feet above sea-level at the north-west corner of the map, to about 450 feet above sea-level along the edge of the plain.

The depressions in its surface are generally filled with drift, forming extensive flats, in which are many picturesque lakes of clear water

the largest being Lake L'Achigan in the township of Kilkenny. Four rivers also cross it, namely the North River, the River L'Achigan, the Saint Esprit and the Lac Ouareau River.

The landscape of this Laurentian country is of a pronounced type which, while lacking on one hand the grandeur and sublimity of high mountain regions and on the other the tranquil beauty of the well cultivated lowlands, has a certain rugged beauty of its own, especially when clothed with the brightly coloured foliage of autumn.

The area is about equally divided between the rocks of the Laurentian system and intrusions of anorthosite which break through these.

The Laurentian consists of red and gray orthoclase gneisses, presenting great variations both in structure and composition, with which are associated crystalline limestones, quartzites and amphibolites. These rocks often occur in the form of bands or beds alternating with one another, but in some places the banding is replaced by a more or less distinct foliation due to a parallel arrangement of the individual grains of the various constituents which go to make up the rock. Both structures are often found in the same rock, and when thus occurring together they coincide in direction. In order that a purely objective attitude may be preserved, the term band, rather than bed, is employed in the present report, the latter term being usually associated with the idea of a sedimentary origin, which, however probable, for certain parts at least, of the present district, cannot be considered by any means as demonstrated for the system as a whole.

Two divisions.

In many other parts of the Laurentian, two divisions can be recognized in the system, namely, an upper series characterized by the presence of crystalline limestones, quartzites and gneisses, having the chemical composition of ordinary sediments as well as a preponderating banded structure, which is called the Grenville series, from a township of that name in the County of Argenteuil where it is well developed, and a lower series of gneisses much more monotonous and uniform in character, in which are no limestones, &c., and which possess a foliated rather than a banded structure. This latter series is known as the Fundamental Gneiss, and in many cases closely resembles igneous rocks.

Grenville series.

In the area at present under discussion the two series cannot be so clearly distinguished. Certain parts of the area can be recognized as belonging to the Grenville series, as, for instance, the extreme easterly portion lying to the south of Rawdon and the westerly portion in the St. Sauveur district. Other portions, as much of the St. Jérome

district, has the appearance rather of the Fundamental Gneiss. It has been found impossible, however, to separate the two series and delimit them on the map. Fundamental Gneiss.

Breaking through the gneisses are four masses of anorthosite, an intrusive rock belonging to the gabbro class, but characterized by a great preponderance of plagioclase felspar. Of these the two largest, comprising portions of the townships of Abercrombie and Kilkenny respectively, are really portions of a single very large area, which extends to the north-west beyond the limits of the map, and has a total area of about 1000 square miles. This is known as the Morin anorthosite area, and is rudely circular in shape. The anorthosite occurring in the north-west corner of the present sheet, including the township of Abercrombie, is a portion of the southern extension of the mass, while the anorthosite in the Kilkenny district is the extremity of a large spur, which starting from the eastern side of the mass runs south, following the strike of the gneiss, and finally passes beneath the flat-lying Palæozoic strata of the plains, being at its southern extremity split in two longitudinally by a wedge of gneiss which runs up into it.

Six miles to the north of the limit of the present sheet, these two masses of anorthosite come together and pass into one another, and they will, therefore, be treated of as one and the same mass, which they really are. Anorthosite.

The other two areas, situated about St. Jérome and in the Gore of Chatham respectively, are much smaller and less important.

These anorthosite masses are now known to be intrusive. Owing to the fact that in some places they possess a more or less distinct foliation coinciding with that of the gneiss through which they cut, Logan and the other early Canadian geologists who first examined the area, thought that they, together with a portion of the associated gneisses and crystalline limestones, formed a series of stratified rocks distinct from and reposing upon the Grenville series. This supposed upper series was, therefore, termed the Upper Laurentian, and the anorthosites were considered to be its most characteristic members. The name Norian was also proposed by Sterry Hunt for these rocks, owing to their petrographical resemblance to the norites of Scandinavia, which rocks are now also recognized as intrusive. Although intruded through the Laurentian at a time long preceding the Potsdam, the appearance of these anorthosites antedated at least the termination of the great earth movements which affected the Laurentian in pre-Potsdam times, so that they have been squeezed and foliated together with the gneisses through which they cut.

Overlain by the Palæozoic.

On the upturned edges of these deeply eroded Archæan rocks, both gneiss and anorthosite, the Potsdam sandstone and other Cambro-Silurian rocks repose in flat and undisturbed beds. At some points along the edge of the protaxis, as at St. Canut, to the west of St. Jérome, the Potsdam sandstone is observed resting upon the gneiss; but as the plains are for the most part mantled with drift the actual contact is not in all cases seen, so that the Palæozoic exposures nearest to the Laurentian, in some places consist of the magnesian limestone of the Calcifercus, as to the south of St. Jérome, or even of the Trenton limestone, as between New Glasgow and Ste. Julienne.

A small outlier of these Palæozoic rocks occurs on the third and fourth ranges of the township of Abercrombie, about nine miles north of the edge of the protaxis, and proves that the Palæozoic strata once extended considerably further to the north than they do at present, although this outlier probably does not by any means mark their northerly limit.

The Palæozoic strata cover up the gneisses and anorthosites alike, and are evidently of much more recent age, being separated from the Laurentian by the long interval occupied in the upheaval and erosion of the Laurentian area. How long before Upper Cambrian times this folding and erosion took place cannot be determined from a study of this area, but investigations in other portions of the margin of the protaxis makes it very probable it took place in pre-Cambrian times.

THE LAURENTIAN PROPER.

This great system consists, as has been stated above, of orthoclase gneiss, presenting many varieties both in form and composition, alternating and interbanded with plagioclase gneisses, crystalline limestone, quartzite, amphibolite and other crystalline rocks.

Gneiss.

These rocks present many transitional forms. Thus bands of quartzite, holding more or less orthoclase, represent varieties intermediate between true quartzites and quartzose gneisses. Crystalline limestones, again, in certain places become very impure, owing to the presence of grains of various silicates, and may thus be classed as calcareous gneisses.

Orthoclase gneiss preponderates largely, and would, if the crystalline schists were classified in the same detail as the intrusive rocks, be separated, owing to variations in its composition, into a number of varieties, equivalent respectively to the various orthoclastic intrusive rocks, as well as the various transitional members between these

and the plagioclase rocks of the diorite and gabbro families. A common characteristic of all these orthoclase gneisses is the presence of a banding or foliation which may be and often is as well pronounced as the lamination of any sedimentary rock, but which, on the other hand, in some cases is so indistinct that it can only be detected by the examination of large weathered surfaces. Some of the gneisses are highly acid, consisting essentially of quartz and orthoclase feldspar. Most of them, however, contain in addition a considerable quantity of biotite or hornblende, while others, owing to the presence of a considerable proportion of plagioclase as well as of hornblende or pyroxene, with a corresponding diminution in the amount of quartz present, are properly classed as basic gneisses.

Some probably of igneous origin.

Many of the basic gneisses are closely related to and associated with the anorthosite masses.

Many of these gneisses differ in no way in composition from igneous rocks. This is especially true of those which from their uniform character and absence of all associated limestones, quartzites, etc., are referable to the Fundamental Gneiss rather than to the Grenville series, although many gneisses in the Grenville series belong to this class as well. These gneisses usually show in a marked manner what is known as a cataclastic structure, produced by the mechanical breaking down of the original web of the crystalline rock, by movements induced by great pressure, which movements cause in the rock a foliation or parallel arrangement of constituents more or less distinct, according to their intensity. In this way a coarse-grained granite may be converted first into an augen-gneiss, and finally into a very finely foliated gneiss in which all the original quartz grains have the form of thin leaves. This structure is also remarkably well seen in the anorthosite, in most places where it occurs in this area, and will be more particularly described in treating of this rock. Many of these gneisses, at least, were originally of igneous, probably of intrusive, origin. Examples of these are abundant in that part of the area lying between St. Columban and St. Jérome and between this latter place and Ste. Sophie.

In order to ascertain the chemical composition of a typical gneiss of this class, Logan's typical Fundamental Gneiss from Trembling Mountain was selected. An analysis of it is given under No. 1.

Analysis.

	I. Gneiss. Trembling Mt.	II. Granite. Carlingford.
Silica	69·24	70·48
Alumina	14·85	14·24
Ferric oxide	2·62	3·72
Manganous oxide	·45	
Lime	2·10	1·48
Magnesia	·97	·40
Soda	4·30	3·66
Potassa	4.33	4·26
Loss on ignition	·70	1·59
	99.56	99·83
Total alkalies	8·63	7·92

It forms almost the entire mass of Trembling Mountain, a long ridge rising on the east side of Trembling Lake to a height of 2500 feet and forming the highest point in the Laurentians of this part of Canada. The mountain does not occur within the area embraced by the present sheet, but lies about twenty miles to the north-west of its north-western corner. The rock, however, resembles closely that occurring at a number of points in the Laurentian area of this sheet. It is rather a fine-grained gneiss, uniform in character and is under the microscope plainly seen to be a crushed or granulated hornblende granite. The analysis shows it to possess a chemical composition quite different from that of the other gneisses and slates described below. The silica is high but the alumina comparatively low. The alkalies are also high, while the lime preponderates largely over the magnesia.

The composition is that of an ordinary granite. The analysis of a granite from the Carlingford District in Ireland, by Haughton, given under No. II., will serve to emphasize this identity.

The composition of most, if not all the gneisses belonging to the lower or Fundamental Gneiss, could be paralleled among the true igneous rocks.

Others probably of sedimentary origin.

The greatest variety in character is found among the gneisses occurring in the vicinity of the limestone bands. Here the gneisses are usually garnetiferous and often contain sillimanite, graphite, rutile, pyrite, and other accessory minerals, the last mentioned mineral when present causing the rock to weather in a very rusty manner. These rusty gneisses are not found except in association with the limestone bands and it is the exception to find the limestone unaccompanied by them.

Owing to the peculiar character of these several gneisses and their continuous association with the limestones and with bands of quartzite, which rocks are certainly not of igneous origin, but are met with in all highly metamorphosed sedimentary series, it was believed that some evidence might be obtained, pointing to a sedimentary origin in the case of these gneisses also. A large number of them were therefore carefully examined.

Under the microscope these do not show the cataclastic structure usually presented by the crushed and granulated igneous rocks of the system. They seem to have recrystallized under the influence of the pressure which has served to crush these other rocks. They are, however, now completely crystalline, no clastic material can be detected in them, although the character and arrangement of the constituent minerals is often suggestive of the metamorphosed rocks found in granite contact zones. The quartzites also, which are very frequently associated with these gneisses and which seldom occur elsewhere, do not, under the microscope, afford anything which could be taken as conclusive evidence of a clastic origin.

Important evidence, however, bearing on their origin was obtained from a study of their chemical composition. Four typical representatives of these gneisses were selected and analysed.

Evidence from chemical composition.

The analyses are given in the accompanying tables, together with analyses of three slates for purposes of comparison. Only one of these gneisses, No. V., is taken from the Laurentian area actually embraced in this sheet, the others however come from the continuation of this area immediately to the north. Analyses Nos. II., V., VII. and VIII. were made for me by Mr. Walter C. Adams, and analysis No. I. was made by Mr. Nevil Norton Evans, Lecturer in Chemistry in McGill University. To both gentlemen I desire to acknowledge my great indebtedness.

I. Gneiss from St. Jean de Matha, province of Quebec. A fine-grained garnetiferous sillimanite-gneiss, containing also much quartz and orthoclase. Graphite and pyrite are also present, the latter causing the gneiss to weather to a very rusty colour. It occurs in thick bands interstratified with white garnetiferous quartzite, the whole lying nearly flat.

II. Gneiss from the west shore of Trembling Lake, province of Quebec. A fine-grained dark-gray gneiss composed of quartz and orthoclase with much biotite, and containing little white streaks which were evidently at one time continuous little bands. These are composed of sillimanite. Garnets appear here and there in

the darker portion of the rock. It occurs near a band of crystalline limestone which occupies the bed of Trembling Lake.

III. An ordinary roofing slate from Wales. Analysed by T. Sterry Hunt. (Phil. Mag., 1854, p. 237.)

IV. A similar roofing slate of Cambrian age, from the large quarries in the township of Melbourne, in the southern portion of the province of Quebec. Analysed by T. Sterry Hunt. (Geology of Canada, 1863, p. 600.)

V. Gneiss from Darwin's Falls near the village of Rawdon, range V. of the township of Rawdon, province of Quebec. It is a highly quartzose garnetiferous gneiss and occurs in well-defined bands interstratified with quartzite, which is often highly garnetiferous, the bands being from a few inches to several feet in thickness.

VI. Red slate from near Tinzen in the district north of the Engadine, Switzerland. Highly siliceous, containing 9·12 per cent of silica as quartz. (Vom Rath, Z. d. G. G., 1857, p. 242.)

VII. Gneiss, lot 20, range VII. of the township of Rawdon. Gneiss composed essentially of malacolite, scapolite and orthoclase, and holding a considerable amount of graphite and of pyrite. Weathers very rusty. Occurs in well-defined bands, interstratified with a grayish-weathering garnetiferous gneiss.

Microscopical structure.

The four gneisses I., II., V. and VII., show no cataclastic structure, but when examined with a microscope seem to have undergone complete recrystallization under the pressure to which they have been subjected, no signs of crushing being now visible in the thin sections.

The analyses show that the first three of these gneisses have the composition of slates. Nos. I. and II. have the composition of ordinary roofing slate, as will be seen by comparing these analyses with analyses III. and IV., and are quite different in composition from any igneous rock. The high content in alumina, the low percentage of alkalies and the great preponderance of magnesia over lime, characteristic of slates will be noted.

No. V. is a gneiss which is so highly quartzose that it might almost be termed an impure quartzite, and also has a composition differing from that of any igneous rock, but one which is identical with many highly siliceous slates. No. VI. is such a slate from the Engadine district in Switzerland, and is, as will be seen, almost identical in composition with No. V. Siliceous bands from the Canadian slate quarries also have a similar composition. The alumina here is low on account of the preponderance of quartz, which also lowers the con-

tent of alkalies. The magnesia preponderates over the lime as before. No. VI. lost 1·92 per cent on ignition before analysis, and these figures do not therefore appear in the analysis as given above.

Analysis of sedimentary gneisses.

	I. Gneiss. St. Jean de M.	II. Gneiss. Trembling Lake.	III. Slate. Wales.	IV. Slate. Melbourne.	V. Gneiss. Rawdon.	VI. Slate. Tinzen.	VII. Gneiss. Rawdon.
Silica	61·96	57·66	60·50	64·20	74·70	79·97	54·89
Titanic oxide	1·66	.....	.....	.....	.....	.....	1·66
Alumina	19·73	22·83	19·70	16·80	8·88	8·62	13·67
Ferric oxide	.....	.....	.....	.....	9·64	6·63	1·35
Ferrous oxide	4·60	7·74	7·83	4·23	.....	.....	.....
Ferric sulphide	4·33	.....	.....	.....	.....	.....	4·43
Manganous oxide	trace.	trace.	trace.	.....	·50	.....	·62
Lime	·35	1·16	1·12	·73	1·07	·76	5·63
Magnesia	1·81	3·56	2·20	3·94	1·87	1·52	4·70
Soda	·79	·60	2·20	3·07	·42	·64	1·95
Potassa	2·50	5·72	3·18	3·26	·95	2·30	8·34
Loss on ignit.	1·82*	1·50	3·30	3·42	1·05	.....	(2·76†)
	99·55	100·77	100·03	99·65	99·08	100·44	100·00
Total alkalies	3·29	6·32	5·38	6.33	1·37	2·94	10·29

The fourth of these gneisses, No. VII., differs entirely from the others. The low content of alumina, combined with low silica, the high alkalies and the preponderance of lime over magnesia mark it off as quite distinct from the slates and gneisses just considered. If it be an altered sediment it is one which has suffered very little leaching during deposition, and must have been of the nature of a tuffaceous deposit, or one formed from the rapid disintegration of an igneous rock having the composition of a basic trachyte or syenite. It is, therefore, a rock which, so far as its composition is concerned, might be either an altered sediment or an altered igneous rock ; and it is impossible, consequently, to draw from its chemical composition any definite conclusions as to its origin.

In the case of those gneisses, then (Nos. I., II., V. and VII.,) whose stratigraphical relations and microscopical character suggest a sedimentary origin, the first three have the composition of slates, that is to say, of clay ; in the case of No. V., of clay mixed with sand, while in the case of No. VII., no definite conclusion can be drawn. To sum up, therefore, it may be said concerning the gneisses of this class, that : (1) their association with numerous and heavy beds of limestone and quartzite ; (2) their prevailing banded character, accompanied by a

*Water.
†Water and graphite (by difference.)

very extensive recrystallization ; (3) the frequent occurrence of graphite in all rocks of the class, and (4) the fact that the gneisses of this class have in many cases at least the composition not of igneous rocks but of sands and muds—combine to make it extremely probable that we have, in the case of many of these rocks at least, extremely altered forms of very ancient sediments.

Quartzite. The quartzite occurs in well-defined bands, in the vicinity of the limestones. It is sometimes quite pure, consisting of translucent or transparent vitreous quartz, but frequently holds garnet, sillimanite or other minerals. It is well seen at Darwin's Falls and elsewhere, near the village of Rawdon, as well as all through the Laurentian district to the south of that place. Amphibolite is a common rock, occurring in association with the gneisses in all parts of the area, but usually in comparatively small amount. It is dark or nearly black in colour, and is seen under the microscope to be composed essentially of plagioclase felspar and dark-green hornblende. The latter mineral occasionally holds a core of pyroxene, suggesting that the rock was originally a gabbro or diabase.

Amphibolite. These amphibolites usually occur as bands in the gneiss and are not confined to the limestone districts, and where the gneiss can be seen to have been greatly stretched or rolled out under the influence of pressure, these amphibole bands can invariably be observed to have been pulled apart into separate pieces, showing that under such pressure they are less plastic than the orthoclase gneiss.

Limestone. The limestones are coarsely crystalline marbles, white or nearly so in colour, sometimes nearly pure, as in portions of the band near St. Sauveur or the occurrence on lot 10 of range VII., of Kilkenny ; but at other times very impure, as in much of the New Glasgow band, the impurities consisting of grains of quartz, pyroxene, phlogopite, graphite and other minerals disseminated through them. So much of this area is occupied by anorthosite intrusions, that the limestones are less abundant than usual in districts underlain by the Grenville series.

As these limestones, however, are important members of the series on account of genetic considerations, as well as owing to the light they throw on the stratigraphical relations of the series as a whole, the several occurrences will be specified.

St. Sauveur. Commencing on the west, there is limestone lying immediately to the west and north-west of the village of St. Sauveur. This is the most extensive development of Laurentian limestone in the area. It, for the most part, underlies a low, undulating drifted tract of country

and is associated with basic, often rusty-weathering gneisses. To the north it is cut off by the Morin anorthosite, whose southern limit here appears as a high and abrupt cliff crossing the country. The limestone has at several points been somewhat extensively quarried for the production of lime, having been burned at intervals for many years—the fact of its being a limestone having been pointed out to the inhabitants by Logan in the early years of the Geological Survey. It is stated to form a very strong lime, but one which from the presence of grains of various silicates disseminated through it, is more or less impure, and which is thus suitable for rough masonry work rather than for interior finishing.

Further south in the augmentation of Mille Isles, similar limestone occurs again, and was supposed by Logan to form a continuation of the same band as that exposed near St. Sauveur.

St. Jérome. Another occurrence of limestone, which, however, is small and unimportant, is that on the west side of the North River near St. Jérome. It is seen crossing the road which runs down the west side of the river, a short distance from the town, while blocks of it may be observed at intervals in the fields to the south of the road. Further south, the strike would carry it across the North River where it would be covered up by the Palæozoic rocks. It does not appear, however, on the banks of the river, nor could any continuation of it be found to the north.

New Glasgow. A more important development of limestone, in the form of a band, which, although it can be traced several miles, is still comparatively thin and impure, is found a short distance to the west of the village of New Glasgow, being exposed in the bed of the River Jordan near the edge of the Palæozoic. From this point it can be traced in a direction a little east of north, skirting along the edge of the great anorthosite mass which occupies this part of the sheet, as far as the third range of Kilkenny, a distance of about six miles, where it is lost sight of. If it holds the course as above described, it would be cut off by the anorthosite a short distance to the north of the point where it is last exposed.

Kilkenny. An isolated occurrence of a fine white crystalline limestone is also found on lot 10 of range 7 of Kilkenny, where it forms a low ridge about 100 yards wide, running north-and-south.

Rawdon. In the northern half of the township of Rawdon, beyond the limits of this map, there is a heavy band of crystalline limestone running through the township from north to south. The southern portion of the township where underlain by the limestone is, however, so heavily

drift-covered that but few exposures are to be seen. On the 4th range, along the road between the village of Rawdon and Ste. Julienne, a few small exposures of limestone protrude through the drift on lots 13 and 15, associated with quartzite and gneiss, which may be a continuation of this limestone to the south, and are so represented on the map. If so, the limestone band is greatly diminished in size to the south.

THE ANORTHOSITE INTRUSIONS.

As has been mentioned above, about one-half of the Laurentian corner of the sheet is occupied by intrusions of anorthosite. Four separate occurrences are represented on the map, but the two larger are really portions of the same intrusion, known as the Morin anorthosite mass, and unite to the north.

Anorthosite intrusions.

This anorthosite is a basic rock belonging to the family of the gabbros, but characterized by the great preponderance of one constituent, namely, the plagioclase felspar, which is so abundant that it often makes up the entire rock. The other constituents are monoclinic and rhombic pyroxenes and ilmenite. No olivine has been found in any of the areas on this sheet. The rock is usually coarse in grain, its structure being especially well seen on the large weathered roche moutonnée surfaces. In its normal condition the rock has a granitoid structure and is deep violet, almost black, on a fresh fracture. The anorthosite in that portion of the area occupying the extreme north-

Morin anorthosite.

west corner of the sheet, in the townships of Morin and Wexford, as exposed along the road and railway between Ste. Adèle and Ste. Agathe, shows these characters. The same is true of much of the anorthosite beyond the limits of the sheet to the north. The rest of the Morin anorthosite embraced within the limits of the sheet, represents peripheral portions of the mass and consequently shows in a marked manner the effects of the great pressure to which the whole area was subjected before the deposition of the Potsdam. The first effect of this pressure is the production of a brecciated structure in the anorthosite, especially well seen on large weathered surfaces about Ste. Marguerite and elsewhere in the eastern part of the township of Wexford. This brecciated structure is produced by the partial granulation

Effects of pressure.

of the rock, the resulting rock consisting of fragments of plagioclase or of the other constituents of the rock, embedded in a species of groundmass made up of smaller grains derived from the breaking-down of the larger individuals. The brecciation being accompanied by a movement of the rock in some definite direction, develops a streaked or irregular banded structure. A very remarkable fact in connection with the

development of this structure is that wherever the rock becomes granulated it becomes much lighter in colour. This can be observed even in microscopical sections, when the phenomena is seen to be due to the disappearance of the dark dust-like inclusions which give to the felspar its dark colour, wherever the mineral becomes broken up or granulated, and so uniformly are these two processes connected, that it is always possible to predict when examining a thin section under the microscope, just how much of the rock has been granulated by observing its colour, before using polarized light, by which the extent of the granulation is at once made visible. So common is the granulation throughout the area, that even in the most massive and granitoid specimens of the anorthosite, traces of it can usually be found.

Foliation eventually resulting.

When the effects of pressure are more marked, as close to the edge of the area or anywhere in the most easterly development of the anorthosite in the townships of Rawdon and Kilkenny, the granulation becomes much more pronounced and a progressively larger proportion of the rock becomes granulated. This is accompanied by the passage of the streaked structure into a distinct and often perfect foliation, which coincides with the foliation of the surrounding gneiss, and by a bleaching of the rock, until in the varieties showing an advanced stage of granulation only a few small dark remnants of the original coarsely crystalline plagioclase individuals remain, like augen in an augen-gneiss embedded in a mass of finely granulated plagioclase, often so white that at a distance the rock cannot be distinguished from marble. This variety is well seen about New Glasgow, where it has been extensively quarried for paving stones which are used in Montreal. It is also well seen along the contact near the east end of Lake L'Achigan, gradually becoming dark in colour towards the west end of the lake about St. Hippolyte.

The anorthosite undergoes no change in chemical composition during the granulation above described—the process, as studied under the microscope, appears to be a purely mechanical one. It is thus quite different from that commonly observed and which has been described by Lehman and others in the case of sheared gabbros. In all cases of shearing hitherto described, the pyroxenes under the influence of the pressure are altered to hornblende, while the plagioclase is often altered to saussurite, the resulting rock being an amphibolite not a gabbro. There is reason to believe that the movements which affected these anorthosites took place when the rock was deeply buried and probably also very hot, perhaps near its fusing point.

Contact rocks.

Although, in most places, the Morin anorthosite comes against the gneiss without producing any perceptible alteration, at some parts of its

circumference, especially north-east of Echo Lake, where the contact crosses the townships of Abercrombie and Kilkenny, a rather massive, dark, heavy rock, rich in bisilicates and often holding a little quartz and some untwinned felspar, borders the area and may be a contact product of some kind. The boundary of the typical anorthosite against this rock is usually pretty sharp, but the latter passes gradually into the gneiss of the district. This intervening rock, however, has in the main the composition of gabbro, so that it becomes difficult to decide whether it represents a peculiar and abnormal, possibly altered, form of the gneiss or a contact phase of the anorthosite.

Black gabbro.

Close to the edge of the easterly development of the Morin anorthosite at New Glasgow, and running north for about six miles in a direction very nearly parallel to that of the limestone band in the gneiss just west of the contact, is a band of a peculiar gabbro nearly black in colour, which protrudes through the drift in a series of great roche moutonnée bosses, contrasting in a marked manner with the white anorthosite through which it cuts. The band is narrow, and immediately to the north of New Glasgow sends out an arm about a quarter of a mile long from its eastern side, which cuts across the foliation of the anorthosite. Under the microscope, the rock presents an extremely well marked cataclastic structure, the constituent minerals having been completely granulated under the great pressure to which they have been subjected.

Lakefield anorthosite.

Of the two smaller areas, that which lies to the west of St. Columbin, extending over into the Gore of Chatham and known as the Lakefield area, most closely resembles the Morin anorthosite just described. It is four and a half miles long and about a mile wide, only about one half of it, however, being embraced in the accompanying sheet. The outer portions are fine-grained, foliated, very poor in bisilicates and weather white. The inner portion of the area is more massive, and appears on the whole to be rather richer in ferro-magnesian constituents, which vary in amount from place to place, often giving the rock an irregular banded structure. A rapid change in strike is observable in this area, the anorthosite and its surrounding gneisses in the southern part striking on an average N. 30° W., while about the northern extremity both rocks strike N. 35° to 65° E. Less than a mile to the south of the area, at the very edge of the Laurentian escarpment, a diabase dyke cuts through the gneiss, which is here the country-rock. The dyke contains angular fragments of white anorthosite which in many places are so abundant as to make up the greater part of the whole. These fragments, which were brought up

by the molten diabase, probably mark an underground extension of this Lakefield area to the south.

St. Jérome anorthosite.

Only a portion of the St. Jérome area, situated as it is immediately at the edge of the Laurentian axis, is exposed to view. The southern part of it is covered up and concealed by the flat-lying Palæozoic beds which come in a short distance to the south of the town. What proportion of the whole mass is represented by the portion exposed to view it is impossible to say.

It differs considerably from the other areas, in that the anorthosite composing it is not so typical in character, as well as in the fact that there intervenes between it and the gneiss a broad zone of rocks of intermediate character. The anorthosite, or gabbro as it should in this case more properly be called, is seen in its typical development on either side of the Canadian Pacific railway track a few hundred yards south of the station at St. Jérome. The large exposures here are situated about the middle of the area, toward its southern limit as exposed. At this point the rock is fine-grained, weathers brownish-gray and usually has a foliated structure. In some places the structure is more or less distinctly banded, owing to the alternations of portions rather rich in bisilicates with others consisting almost entirely of plagioclase. Individuals of dark-coloured plagioclase, usually small in size but sometimes as much as six inches in length, are abundant in places. They are frequently seen to be curved or twisted and are usually without good crystalline outlines.

Microscopical character.

Under the microscope, this rock is seen to be composed essentially of plagioclase and pyroxene, the former largely preponderating, with hornblende, biotite, garnet, iron-ore, and pyrite, as accessory constituents, and a few grains of quartz, calcite, chlorite, and apatite. The pyroxene is light-green in colour and is for the most part augite, which is often decomposed to calcite and chlorite—some of it however is trichroic in red, yellow and green tints and is probably hypersthene. The hornblende, which is green in colour, and the biotite are present in but very small amount. The garnet, which is pink in colour, and perfectly isotropic, is often well crystallized and usually has some approximation to good crystalline form. It is generally associated with iron-ore but often occurs in little strings through the rock. The iron-ore is titaniferous, as shown by the leucoxene which frequently appears as its decomposition-product. The quartz, which is present in very small amount associated with the bisilicates, may also be secondary. The little strings, an inch or even less in thickness, consisting of orthoclase and quartz, which run through the rock sometimes parallel

to the stratification and sometimes across it, are rather abundant but are evidently of later origin.

The rock in its present form probably represents an advanced stage of granulation, for although but little is seen in the way of twisted grains and strain shadows, these are usually not well seen when the granulation is complete. The large remnants of plagioclase crystals on the other hand, which occur abundantly in many parts of the rock, indicate an extensive granulation. At the bridge over the North River at St. Jérome, on the western edge of the area, as well as at a point about a mile and a quarter further north near the northern end of the area, the same rock is well exposed, at the latter locality showing an exceeding well-marked cataclastic structure.

Zone of intermediate character.

This gabbro mass is surrounded by a zone of rocks of varied character, many of which strongly resemble the anorthosite in appearance, but which are quite different in composition. They are well exposed to the west of St. Jérome back from the North River. This zone includes a large quantity of ordinary orthoclase gneiss, and in it occurs the crystalline limestone already described as occurring to the south-west of the village, but it consists chiefly of rocks, which, in addition to augite and plagioclase, contain variable amounts of hornblende, orthoclase and quartz, and which are thus intermediate in character between the gneiss and the anorthosite, some of the many varieties represented approaching more nearly to gneiss and others more nearly to anorthosite in character and composition. It is thus a matter of great difficulty to trace upon a map the exact limits of this zone. In the accompanying sheet, this has been done as accurately as possible by the aid of a microscopical examination of the rocks from a number of points.

This zone surrounding the typical gabbro or anorthosite, probably represents a peculiar border facies of the latter, which in many places has intruded itself into the gneiss parallel to its foliation, giving an appearance of interstratification, while movements, induced by pressure subsequent to the intrusion, serve to render this appearance more deceptive. The orthoclase gneiss and the limestone in this zone are thus of the nature of inclosed or partially inclosed portions of the country-rock.

THE STRUCTURE OF THE AREA.

The foliation or banding of the gneiss in the western part of the Laurentian corner of the sheet has a general north-east strike, which to the east swings around and runs about due north. The change is well shown between St. Jérome and New Glasgow. The northerly

strike is well seen in the narrow mass of gneiss separating the two larger masses of anorthosite, as well as in the Laurentian to the east of the most easterly of these two masses. The anorthosite intrusions also, as has been mentioned, especially toward their sides, show a more or less well-marked foliation which coincides in direction with that of the adjacent gneiss. Thus, in the case of the most westerly of the two large anorthosite masses, which in its extension cuts across the strike of the gneiss, the foliation runs across the contact from the gneiss into the anorthosite; while in the most easterly, which has been intruded into the gneiss in a north-and-south direction, the foliation of the two rocks coincides approximately with the direction of their lines of contact.

Relations of foliation to anorthosite boundary.

The strike in the immediate vicinity of the Lakefield anorthosite, as has been stated in speaking of that area, varies considerably.

North of the limits of the sheet, the strike of the foliation of the gneiss has been found to follow the windings of the boundary of the Morin anorthosite in a remarkable manner, making it evident that although the anorthosite breaks through the gneiss and cuts off the limestone bands in the latter, the foliation of the gneiss is not altogether an original structure, but is, in part at least, secondary, having been caused by the great pressure to which both rocks were subjected after the intrusion of the anorthosite, which has led to movements in the solid rocks.

ECONOMIC RESOURCES.

No mineral deposits of great value have as yet been found within this Laurentian area. The following, however, are worthy of note:—

Iron ore, St. Jérome.

Iron ore—Near St. Jérome, County of Terrebonne.—Two and a half miles south-west of St. Jérome, on the road which follows the northern bank of the river, there is a deposit of magnetic iron-ore. This occurs as several thin bands interstratified with a dark hornblendic rock and with the red orthoclase gneiss of this part of the area—the whole dipping toward the river at a very high angle. As seen in 1886, the ore was exposed by the removal of the drift deposits at a number of points along its strike, and a shallow opening had been made in it at one place. Subsequently, from October, 1891, until March, 1892, the deposit was worked by the Canada Iron Furnace Company; during which time about 365 tons of ore was taken out and shipped to the company's furnaces at Radnor and there smelted. The following information has been kindly supplied to me by Mr. Arthur Cole, B. A. Sc., who was engaged in carrying out the work:—

"Most of the ore was taken out of a pit which when abandoned was about thirty-five feet deep, ten feet broad and twelve feet long. The ore-bed varied from two and a half feet to three feet in width, and was for the most part free from gangue. At a depth of thirty-five feet, the bed had narrowed down to a few inches and was then entirely lost. A drift was driven from the west end of the pit along the bed for about forty feet. The floor of the drift was about fifteen feet from the surface. Work was then discontinued, but was resumed in August, 1892, but this time at a point about one hundred yards further west along the outcrop of the bed. The ore here was in beds varying from a foot to a foot and a half in width. These beds often widened, but they would separate into two beds with an intervening bed of rock. In some places the limits of the beds were very clearly defined, but elsewhere the ore-body gradually faded away into the surrounding rock. About fifty tons were taken out of this opening, which was about ten feet deep and thirty feet long. Work was finally discontinued early in September, as it was found that too much rock was being handled."

A sample of the ore was analysed by me and found to have the following composition :—

Analysis

Ferric oxide	59·059 p. c.
Ferrous oxide	26·807 "
Titanic acid	None.
Phosphoric acid	·015 "
Sulphur	·001 "
Insoluble matter	9·897 "
	62·491 "
Metallic iron	·007 "
Phosphorus	·001 "
Sulphur	

The analysis brings out in an emphatic manner the distinction between the iron-ores of the orthoclase gneiss and those occurring in the anorthosite, the former being usually free from titanium, while the latter are rich in this deleterious constituent. This ore, although occurring so near the anorthosite, is quite free from titanium, while the iron-ores of the adjacent anorthosite areas always contain a large percentage of this element. To these belong the two following deposits.

Iron ore, Ste. Julienne.

Rawdon, Range II., Lot 2.—This deposit is situated near the village of Ste. Julienne, and although it has never been actually worked it has attracted a good deal of attention. It occurs in the Morin anorthosite near the eastern edge of the most easterly of the two larger developments of anorthosite shown in the accompanying sheet. The ore occurs in a foliated white-weathering variety of the anorthosite, rather rich in bisilicates and striking from N. 8° W. to N. 25° W. (magnetic) with a

nearly vertical dip. Several black diabase dykes occur in the vicinity. The ore varies a good deal in character, being much poorer in some places than in others, and often takes the form of bands from a few inches to several feet in width generally conformable, or nearly so, to the foliation of the anorthosite, but in a few cases cutting across it. Both the anorthosite and iron-ore are much twisted and faulted, and it is often difficult to determine whether the ore has been erupted through the anorthosite or whether the cases where it cuts across the anorthosite are to be attributed to faulting. It has, however, a general trend in the direction of the strike of the anorthosite, the principal mass being exposed for about 200 feet at right angles to this direction. The "ore" appears to be in reality a variety of the anorthosite, and in most places is too poor in iron to constitute an ore in the proper sense of the term. It is also highly titaniferous and contains iron-pyrites as a frequent constituent. Dr. Hoffmann found a specimen collected by me to contain :—

Highly titaniferous.

Metallic iron	42·29 p.c.
Titanic acid	Large amount.

Two samples examined by Dr. B. J. Harrington,* gave the following results :—

	I	II.
Metallic iron	38·27 p.c.	40·71 p.c.
Titanic acid	33·67 "	33·64 "

while a third specimen, in which the iron was not determined, was found to contain :—

Titanic acid	35·09 p.c.

Wexford, Range I, Lot 7.—On this lot a small opening has been made in a dark-coloured heavy massive rock containing a certain amount of iron-ore. The field relations indicate that this is merely a local variety of the Morin anorthosite, exceptionally rich in the darker-coloured constituents of the rock, and a microscopic examination proves this to be the case. When thin sections are examined, the rock is seen to be composed essentially of a dark-coloured pyroxene with plagioclase and iron-ore. A not inconsiderable amount of apatite with a few grains of pyrite, garnet and biotite are also present. The proportion of iron-ore present is comparatively small. A specimen collected to represent the richest portion of the mass was examined by Dr. Hoffmann, with the following results :— Iron ore, Wexford.

Metallic iron	20·27 per cent.
Insoluble residue	58·58 " "
Titanic acid	Decided reaction.

*Report of Progress, Geol. Surv. Can., 1876-77, p. 475.

Kilkenny, Range VII., Lot 7.—This deposit is an impure ochre or limonite, occurring near the edge of the Morin anorthosite, and apparently derived from the alteration of iron-pyrites which occurs as an impregnation in a band of anorthosite intercalated in the gneiss near the limits of the main area. The band of rock through which this limonite is distributed has a considerable width, but could not be everywhere examined at the time of my visit owing to a bush fire which was raging. No mass of the iron-ore over one foot in thickness could be found, however, and the deposit is, I should judge, valueless as a source of iron.

A specimen of the limonite was examined by Dr. Hoffmann, and was found to contain:—

Metallic iron	25·75 per cent.
Insoluble matter	Large amount.

It also contained a considerable quantity of manganese, but no titanium.

Anorthosite.

Anorthosite.—This rock, although it has been but little used for building purposes, might in many cases be employed with advantage for decorative construction. It may be obtained in unlimited amount in the Morin area, of any colour from deep violet to white. The opalescent varieties occur but sparingly in this district. To judge of its appearance when cut and polished, two large blocks, one of the violet and one of the white variety were collected and six-inch cubes were prepared from them. These were exhibited in the Colonial and Indian Exhibition held in London in 1886. The violet variety was collected on the eastern side of range II. of the township of Morin, and when polished presented a handsome appearance, but was rather dark in colour. The white variety, which was taken from the large exposures at New Glasgow, took a high polish and in this state was found to bear a striking resemblance to marble. It is more difficult to work than marble, but would be more durable and would retain its polish better, especially in exposed situations, and might well be employed for many purposes in construction.

On account of its toughness and durability, this white anorthosite from New Glasgow has been extensively used for paving stones in the city of Montreal, especially on streets where there is a heavy freight traffic. A number of small quarries have been opened in the vicinity of New Glasgow, while a larger one is operated about two miles to the north of the village. The stone is blasted out in large blocks and is then dressed to the required size by means of large hammers. The industry which has thus sprung up is quite extensive, up to the time of my last visit in August, 1891, 541,000 anorthosite paving blocks having been shippped to Montreal by rail.