66-32

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 66-32

MONT LAURIER AND KEMPT LAKE MAP-AREAS, QUEBEC

(31J and 31O)

A preliminary report on the Grenville Project

(Report, figure and Map 11-1966)

H. R. Wynne-Edwards, A. F. Gregory, P. W. Hay,
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ABSTRACT

The preliminary results of a reconnaissance survey of 13,000 square miles in the central part of the Grenville Province in Quebec are briefly reported. The rocks form a plutonic and metamorphic complex of Precambrian age, and can be divided into 5 tectonic categories relative to the Grenville orogeny, as judged by their field relations, texture, and structure. These categories are: (1) a pretectonic basement complex of mafic and leucocratic gneisses and granulites, which may correlate with the volcanic, sedimentary, and granitic Archaean rocks across the Grenville front near Val d'Or; (2) an overlying, pretectonic metasedimentary Grenville Series of paragneiss, quartzite, and marble; (3) pretectonic, coarse-grained plutonic igneous rocks ranging from anorthosite through mangerite to porphyritic quartz monzonite, emplaced in the Grenville Series before the Grenville orogeny and subsequently cataclastically deformed and partly recrystallized; (4) syntectonic and late tectonic plugs of granite, alkali granite, alkali syenite, gabbro, and minor ultrabasic rocks; and (5) post-tectonic diabase dykes.

The area contains 3 distinct structural domains: a northwestern domain where the structures are homogeneous and northeast-plunging; a southeastern domain where the structures are homogeneous and south-plunging, and a heterogeneous central domain where the average plunge is also southward but where the structure is more complex. Statistical analysis of foliation and lineation shows that these domains result from the superposition of folds with northeast-trending, southeast-dipping axial planes (dating from the Grenville orogeny) on a pre-existing set of east-west trends in the northwestern domain and on a set of north-south trends in the central and southeastern domains. The implications of this multiple tectonic history are being investigated further.

MONT LAURIER AND KEMPT LAKE MAP-AREAS, QUEBEC

INTRODUCTION

The Grenville Project, 1964, was intended to devise and test methods of reconnaissance geological mapping in the high-grade metamorphic terrain of the Grenville Province, the largest single portion of the Canadian Shield that has not been mapped completely on any scale. Mont Laurier and Kempt Lake map-areas were selected for this pilot project because the main variety of rock types in the Grenville Province were known to be represented there, the outcrop and access were good, and airborne magnetometer surveys were complete. Further, a part of this area had already been mapped at a scale of one inch to one mile by conventional methods, thus providing a basis for comparison with this reconnaissance. This paper is designed to make the preliminary results of the survey available, but a fuller interpretation and discussion will be published later.

Mont Laurier and Kempt Lake map-areas (31 J and 31 O) comprise 13,000 square miles of southwestern Quebec, from 46°00' to 48°00' N., and from 74°00' to 76°00' W. They include the towns of Ste-Agathe-des-Monts, St-Jovite, Mont Laurier, Maniwaki, and Parent, and together traverse the central part of the Grenville Province from within 30 miles of the Grenville front east of Val d'Or to within 20 miles of the Palaeozoic rocks north of Montreal. In particular, the Montreal-Senneterre Highway (Routes 11 and 58), from Ste-Agathe to the entrance to La Verendrye Park, crosses the Mont Laurier map-area diagonally from southeast to northwest, and provides an unexcelled cross-section of the structure in which most of the map-units are represented.

The area is thickly wooded, primarily hardwood in the south and softwood in the north, and rises from 500 feet in the southwest to 2,000 feet in the northeast and to over 3,000 feet in the Laurentian Hills, which form the southern and southeastern part of the region. The economy of the district is dependent on the major rivers, the Gatineau, Lievre, Rouge, Diable, and Manouane. These provide important water resources, logging routes, and adjacent to their lower reaches lies the only land cleared for agriculture. The area is a major centre of the lumbering industry, and is served by several thousand miles of logging roads in addition to Provincial Highways 11, 18, 30, 35 and 58, and by both Canadian Pacific Railway and Canadian National Railways.

The region is partly mantled by glacial drift and sand, particularly in the southeastern part of Kempt Lake map-area. The thickness and persistence of this cover can be roughly estimated from the density of air-photo lineaments recorded on the structural map, although some lineaments, particularly in Mont Laurier map-area, have also proved to be glacial features. Glacial striae in the area trend within a few degrees of south.

Field work was carried out from June to September, 1964, by 10 geologists, 8 of whom were directly engaged in geological mapping. The participants in the project were as follows:

Project co-ordination, and mapping with aircraft	H.R. Wynne-Edwards, A.F. Gregory
Mapping, Kempt Lake map-area	E.W. Reinhardt (party chief), C.A. Giovanella, V.H. Becker
Mapping, Mont Laurier map-area	P.W. Hay (party chief), A.C. Brown, C.H. Nixon
Special study of magnetic anomalies	E.H. Gaucher
Special study of air photographs	D.T. Anderson
Student assistants	F.J. Allen, R.A. Baker, A.P. Brown, J.W. Clark, A.J.M. Lemay, G.J. Mazerolle, J.F. Roberts, J.P. Rouillard, R.F.A. Wilson
Base camp	T.L. Putnam (manager), H.C. Andersen (cook)
Aircraft pilots	M. Payant, I. Keller, A. Marshall; J. Aubrey (helicopter)

In addition to about 60,000 miles of travel in standard and 4-wheel drive vehicles, over 500 hours were flown with float-equipped aircraft to visit almost 2,000 sites on lakes where outcrop was accessible. A helicopter was used for 45 hours near the end of the season to visit areas otherwise difficult of access.[1] All outcrops visited are plotted on the geological map; the geological contacts shown are inferred from a combination of this information with a Federal-Provincial airborne magnetometer survey already published, with aerial photographs, with topography, and, in the southern third of the area, with geological maps of the Quebec Department of Natural Resources. Geological information was first plotted at a scale of one inch to two miles on transparent Cronaflex prints showing lakes, rivers, and roads. The maps were later correlated with separate transparent underlays showing aeromagnetic data, air-photo lineaments, and topographic contours.

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[1] Additional details are available in an article by Wynne-Edwards and Gregory (1964).

The initial mapping made use of a notation designed to show on the map the structure, texture, and appearance of an outcrop as well as its lithology, and to minimize differences in nomenclature between observers. Using aircraft, the co-ordinators of the project also contributed a network of consistent observations that covered more than 80 per cent of the area, thus helping to maintain continuity. After the field work was complete, the location, description, field classification, petrography, and the writer's reclassification for each of 2,000 rock specimens were punched onto Keysort cards, and the map-units selected by finding correlating characteristics. The final classification was then punched onto the cards, and each specimen replotted on a further transparent underlay with its appropriate map-unit number. In the ensuing compilation work the map-units were extended from these known points by correlating the observer's notation on adjacent outcrops with that originally applied to the sample, and by extrapolation in accordance with the patterns on aeromagnetic maps and the structural data recorded in the field and from air photographs.

The contoured aeromagnetic maps available for the area[1] were of particular value because their more continuously recorded data add coherence to a map otherwise composed of scattered geological observations. Decisions as to the shape of contacts and the degree of continuity of map-units were thus strongly influenced by the magnetic pattern. Although some rock types possess a definitive 'magnetic texture' revealed by a characteristic pattern of aeromagnetic contours, most map-units have widely ranging magnetic susceptibilities, so that high and low anomalies could not be simply assigned to particular lithologies in the absence of geological information. Magnetic trend lines and certain prominent anomalies are plotted on the structural map accompanying this paper, and a full discussion of the application and interpretation of the magnetic data is in preparation by A.F. Gregory and E.H. Gaucher.

Although the geological contacts shown are subjective to an extent that can be gauged at any point by the observed outcrop density, it is certain that the map-units are distinct, real, and definable, that the basic map pattern and structure have been established, and that the map is internally consistent throughout, the latter being perhaps the greatest strength of such a reconnaissance survey. The extrapolation from scanty data, however, will certainly have led to the mislabelling of parts of the map, and for this reason a 'type' area, where the rocks are typical, accessible, and well exposed, is cited in the description of each map-unit.

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[1] Published jointly by the Quebec Department of Natural Resources, Quebec, and the Geological Survey of Canada, Ottawa.

ACKNOWLEDGMENTS

The project was made possible by the co-operation and enthusiastic effort of each member of the party. H.R. Wynne-Edwards provided the direction and pertinent geological experience that were essential to the unification of the entire project; A.F. Gregory assumed a large share of the burden of organization and co-ordination of the project; E.W. Reinhardt and P.W. Hay took responsibility for the field parties in Kempt Lake and Mont Laurier map-areas respectively. The compilation and assessment of the voluminous data were completed by H.R. Wynne-Edwards, C.A. Giovanella, A.F. Gregory, and P.W. Hay. In particular, C.A. Giovanella was responsible for much of the petrography and organization of specimens; P.W. Hay prepared the structural data for statistical presentation; and, in addition to his other contributions, A.F. Gregory painstakingly edited and criticised the map compilation of this manuscript. Any success of the project is thus a combined one, although individual effort has been acknowledged as far as possible on the maps themselves.

Thanks are extended to Hull Air Services Ltd. and to Autair Ltd. for their service, interest, and goodwill, and to the Lower Ottawa Forest Protection Association, the Canadian International Paper Company, the Consolidated Paper Corporation, the E.B. Eddy Company, the James MacLaren Company, and the Singer Company of Canada, for their help with information and road access.

PREVIOUS WORK

Work by the Geological Survey of Canada began in the Mont Laurier map-area as early as anywhere in Canada, and by the beginning of the twentieth century the major valleys had been traversed, and reconnaissance maps of parts of the district by Adams (1897) and Ells (1902) were published. The report by F.D. Adams dealt with an area centred east of the present survey but overlapping it around the Morin anorthosite, and must receive particular comment. Although written more than 70 years ago, its observations and interpretations were encountered by the writer with recognition and delight, their point of view leaving little doubt that Adams would have enthusiastically endorsed the broad conclusions of the present investigation.

Systematic one mile mapping of areas along the Montreal-Senneterre Highway (Routes 11 and 58) was begun by the Quebec Bureau of Mines in 1934. In the ensuing 30 years, maps of about two-thirds of the Mont Laurier map-area have been completed, the main contributors being F.F. Osborne (1935, 1936), E. Aubert de la Rue (1948, 1953, 1956 a, b), D.W. Pollock (1956 a, b, 1959, 1960) and M. Katz (1964, 1965). Other references to map-units described in this paper are included in the last column of the Table of Formations.

GENERAL GEOLOGY

All the bedrock of Mont Laurier and Kempt Lake map-areas is Precambrian, and all but a few rock units have been metamorphosed to amphibolite or granulite facies. With the exception of one determination on biotite from quartz monzonite of map-unit 18 (see below), potassium-argon age determinations on mica and hornblende from the rocks studied here are close to the mean value of 945 million years assigned as the data of the Grenville orogeny by Stockwell (1964), and confirm that the major metamorphism and the last recrystallization took place at that time (Table I).

Table I. Age Determinations for the Grenville Project in Mont Laurier and Kempt Lake Map-areas

K/Ar Age Determination No.***	Map-unit	K/Ar Age (m.y.)	N.T.S. Location*	Lat. and Long.	Sample No.
1054	1	914±30	31 O 3E*	47°08'30" N. 75°06'30" W.	RMG-42-3[illegible]-64
1055	8	928±30	31 J 7W	46°18'30" N. 74°47'30" W.	WE-49-65-64
1056	20	985±30	31 J 11W	46°33' 0" N. 75°15' 0" W.	WE-GH-4-64
1059	4	1010±95**	31 O 14E	47°46'30" N. 75°00'30" W.	RMG-15-16-64
1061	21	967±30	31 J 11W	46°31' 0" N. 75°00'30" W.	WE-GH-5-64
1169	18	1205±43	31 J 9W	46°34' 0" N. 74°25' 0" W.	WE-GN-2-64

*Numbers refer to 15 minute by 15 minute quadrangles (East and West) in Mont Laurier (31 J) and Kempt Lake (31 O) map-areas, as indexed in the National Topographic System.

**Determination on hornblende. All other determinations are on biotite.

***Age determinations by the Isotopic and Nuclear Geology Section, Geological Survey of Canada, 1965.

Until recently sight had been lost of the possibility of rocks older than the Grenville Series being exposed in the Grenville Province, and quartzo-feldspathic rocks not belonging to the Grenville Series were generally assigned to a syntectonic suite of orthogneisses formed during the Grenville orogeny. The emergence of a pattern of K/Ar ages close to a mean value of 945 million years for all these rocks might at first sight reinforce this viewpoint. The writer (Wynne-Edwards, 1964) has recently argued, however, that criteria formerly applied to establish relative age in deep-zone terrain are more correctly applicable to an order of relative mobility, that a quartzo-feldspathic rock will simply recrystallize to more quartzo-feldspathic rock if re-subjected to high temperature and pressure, and that K/Ar ages date only the period of last recrystallization of a rock, not its actual age.

The older rocks of Mont Laurier and Kempt Lake map-areas have not, however, invariably completely recrystallized in response to the Grenville orogeny. Many of the coarse-grained plutonic rocks related to the Morin anorthosite mass (map-units 14-18) have well-preserved relict igneous textures, and biotite from porphyritic quartz monzonite of this group (K/Ar Age Determination No. 1169, Table I) gave a potassium-argon age of 1205 ± 43 m.y. The roughly contemporaneous emplacement of the large masses of anorthosite and related rocks in Labrador and in the Grenville Province of Quebec during the events of the Elsonian 'orogeny' seems likely (Stockwell, 1964). The age determination, which is somewhat less than the postulated range of the Elsonian orogeny (1220-1520 m.y.) is consistent with this hypothesis, the rock having initially crystallized from a magma during the Elsonian event, but subsequently having lost some argon during the later deformation and partial recrystallization of the Grenville orogeny.

The present survey suggests that less than 5 per cent of the rocks exposed in Mont Laurier and Kempt Lake map-areas might properly be labelled 'syntectonic' as far as the Grenville orogeny is concerned, and that most of the rocks have been subjected to a protracted series of older events extending back to Archaean time and involving up to four distinguishable episodes.

A deeply eroded orogenic terrain of high-grade metamorphism such as the Grenville Province can logically be expected, on purely theoretical grounds, to contain any or all of the following types of tectonic units: (1) metamorphosed or unmetamorphosed folded basement rocks now (re)metamorphosed and refolded; (2) younger metasedimentary and meta-volcanic rocks with a simpler structure than the basement and perhaps a more hydrous mineralogy depending on the extent of dehydration of the basement rocks by earlier metamorphism; (3) pretectonic intrusive rocks emplaced in (1) and (2) and now deformed and recrystallized; (4) syntectonic intrusive rocks emplaced in (1), (2), or (3); and (5) still younger post-tectonic intrusive rocks. In the Table of Formations the map-units are grouped into five such tectonic categories in relation to their role during the Grenville orogeny; the evidence governing this classification is briefly stated in the descriptions of units that follow.

Each of the tectonic categories in the Table of Formations has been tentatively assigned a place in the time classification proposed by Stockwell (1964). This is based on evidence that all the major "orogenies" which dominate the other provinces of the Canadian Shield are also represented here, and that each of them has contributed to the tectonic history of the area and to the sum total of rock types represented. This part of the Grenville Province, therefore, far from representing a new contribution to the continental crust some 1000 million years ago, has apparently been shaped by a succession of tectonic events with a history extending back perhaps 3000 million years, so that more than half of the bedrock of Mont Laurier and Kempt Lake map-areas (map-units 1-7) is as old as Archaean. The discussion of the basis of this time classification and of the complex history that preceded the Grenville orogeny will be presented in a later publication.

TABLE OF FORMATIONS

EON	ERA	TECTONIC AGE RELATIVE TO GRENVILLE OROGENY	MAP-UNIT	FORMATION	LITHOLOGY	EARLIER NAME AND REFERENCE
	HADRYNIAN OR YOUNGER	5. POST-TECTONIC INTRUSIONS	22	DIABASE	Small dykes of fresh, ophitic-textured, pyroxene-labradorite diabase	
					intrusive contact	
PROTEROZOIC	NEOHELIKIAN AND OLDER	4. LATE TECTONIC AND SYNTECTONIC		PEGMATITE	Minor occurrences of quartz-microcline-muscovite-(or biotite) pegmatite	
					intrusive contact	
			21	BIOTITE SYENITE	Pink to grey, coarse-grained, massive, biotite-pyroxene syenite, alkali syenite, alkali gabbro, and mica pyroxenite forming discrete sub-cylindrical plutons	includes Loranger series (Osborne, 1935)
					intrusive contact	
			20	PINK GRANITE	Fine- to medium-grained, homogeneous, massive or faintly foliated, pink, biotite alaskite	Guenette granite (Osborne, 1933)
			19	MIGMATITE	Granitic rocks, (20) intermixed with Grenville Series and other gneisses	
					intrusive contact	
	PALAEOHELIKIAN (?) AND OLDER	3. PRETECTONIC INTRUSIONS	18	PORPHYRITIC QUARTZ MONZONITE	Coarsely porphyritic, grey to brown monzonite and quartz monzonite; includes minor diorite, derived cataclastic augen gneisses and related biotitic augen gneiss with pink to grey porphyroblastic perthitic alkali feldspar	Pine Hill series (Osborne, 1936)
					intrusive contact	
			17	MANGERITE	Coarse-grained, homogeneous, massive, locally porphyritic mangerite (hypersthene syenite) and quartz mangerite, characterised by brown weathering green perthitic feldspar, hypersthene and garnet	Quartzose rocks of the Morin series (Osborne, 1936)
					transitional contact ?	
			16	ANORTHOSITE	Anorthosite, noritic anorthosite, norite, ilmenite gabbro and derived cataclastic rocks, characterized by grey, brownish or mauve plagioclase crystals up to 10 inches in diameter	Morin anorthosite mass (Adams, 1897)
					intrusive contact	
			15	GABBRO AND META-GABBRO	Medium- to coarse-grained two-pyroxene or hornblende meta-gabbro and gabbro, probably not all of one age	Buckingham series (Wilson, 1920)
			14	GREEN-ROCK COMPLEX	Undivided migmatite of massive mangerite (14), granulite (5, 6, 7), and intimately intercalated Grenville quartzite and paragneiss (8-13), all in granulite facies and not separable at map scale	Green-rock unit (Osborne and Morin, 1962)

PROTEROZOIC	APHEBIAN (?)	2. PRETECTONIC SEDIMENTARY ROCKS (Grenville) Series)	13	GRENVILLE SERIES UNDIVIDED	Metasedimentary sequence containing quartzite, or marble, or aluminous biotite gneiss, each considered diagnostic of the Grenville series	Grenville series (Logan, 1863)
			12	HORNBLENDE GNEISS	Medium-grained hornblende-plagioclase gneiss and amphibolite (lithologically indivisible from unit 2)	
			11	MARBLE	White or grey, medium- to coarse-grained marble	
			10	WHITE ROCK	Calcsilicate rocks, white pegmatite, white granite, rusty, pyritic and graphitic gneiss, all characterized by predominantly white colour, and spatially and genetically related to marble unit	
			9	QUARTZITE	Medium- to coarse-grained, white to grey, vitreous quartzite	
			8	BIOTITE GNEISS	Layered quartz-feldspar-biotite paragneiss, garnet-biotite gneiss, muscovite-biotite gneiss, sillimanite-biotite gneiss, hypersthene-biotite gneiss	
ARCHAEAN (?)		1. PRETECTONIC BASEMENT COMPLEX	7	MAFIC GRANULITE	Dark, medium to fine-grained, homogeneous, massive or locally streaky granulite of dioritic composition, with salt and pepper texture, two pyroxenes and hornblende, and brown-weathering, greenish-grey feldspar	? Pyroxene granulite (Adams, 1897)
			6	LEUCOCRATIC GRANULITE	Fine-grained, homogeneous, massive to streaky, locally cataclastic, leucocratic, quartzofeldspathic granulite, with brown weathering, greenish-grey feldspar	Fundamental gneiss (Logan, 1863) Trembling Mountain gneiss (Adams, 1897); Labelle series (Osborne, 1935)
			5	CATACLASITE	Fine-grained, streaky, pink, buff, or grey, cataclastic leucocratic granite gneiss	Leaf-gneiss (Adams, 1897)
			4	PYROXENE-HORNBLENDE GNEISS	Medium-grained, dark, two pyroxene-hornblende-plagioclase gneiss, characterized by brown hornblende, hypersthene, aluminous diopside, and brown weathering green perthitic feldspar	Green-rock unit (Osborne and Morin, 1962)
			3	CHARNOCKITIC GNEISS	Medium- to coarse-grained, streaky, locally layered, leucocratic gneiss with brown-weathering green perthitic feldspar, hypersthene, brown hornblende, biotite, and garnet	
			2	HORNBLENDE GNEISS	Medium-grained, equigranular, dark, hornblende-plagioclase gneiss, typically with 30 per cent hornblende and minor biotite (same lithology as 12); also includes garnetiferous and more biotitic varieties (2a), and some amphibolite	Map Unit 1(a) includes Lacoste series (Osborne, 1935)
			1	GRANITE GNEISS	Well foliated, typically layered, leucocratic biotite and hornblende-biotite granite gneiss, pink to grey in colour, medium grained, and equigranular; unit also includes homogeneous, grey, quartz-oligoclase-biotite gneiss (1a)	

DESCRIPTION OF FORMATIONS

1. Pretectonic basement complex (map-units 1-7)

The leucocratic and mafic gneisses and granulites composing map-units 1-7 are grouped on the basis of their common composition, their generally foliated structure, and their large scale homogeneity. Collectively they make up more than half of the bedrock of Mont Laurier and Kempt Lake map-areas.

These rocks are composed of a simple granular mosaic of feldspar, quartz, and from 3 to 80 per cent of the mafic minerals - hornblende, biotite and pyroxene. The dark and light varieties of gneiss have been mapped separately, and although the boundary between them was somewhat arbitrarily fixed at a dark-mineral content of 25 per cent, gradational varieties are not numerous, and the abundance distribution of dark minerals is clearly bimodal, leucocratic rocks generally having less than 10 per cent dark minerals and mafic rocks 30 per cent or more.

Three separate sets of these dark and light rocks are included in the tectonic category of the basement complex, each having a similar bulk composition and homogeneity, but with a distinctive appearance, metamorphic grade, structure, and geographic distribution. The sets are as follows:

Set	Area Found	Leucocratic map-unit	Mafic map-unit
A	northwest and central	1	2
B	northeast	3	4
C	southeast	5, 6	7

Set A consists of quartzo-feldspathic gneisses metamorphosed to middle or upper amphibolite facies and characterized by hornblende and biotite. These rocks grade into set B, in which the gneisses are metamorphosed to granulite facies and are characterized by brown hornblende, hypersthene, and clinopyroxene. Set C, although compositionally and mineralogically equivalent to set B is structurally and texturally distinct, being fine grained with a streaky lineation or foliation, and characterized by a cataclastic texture or by a fine-grained, equant aggregate of grains that is evidently the result of the mechanical granulation and partial recrystallization of a formerly more coarsely crystalline rock, a feature also described by Adams (1897). The similar composition and degree of homogeneity of each of these three sets of rocks seem to demonstrate that they had a common origin. Their present distinctive texture and geographic distribution is due to their somewhat different subsequent histories in different parts of the map-area.

Where this group of gneisses and granulites is associated with the Grenville Series, the grade of metamorphism (dating from the Grenville orogeny) is the same in each and has been sufficient to obliterate any direct evidence of unconformity between the two. The rocks of map-units 1-7 cannot be the same age as the Grenville Series, nor can they be younger than it, for the following reasons: (1) the occurrence of identifiable members of both the Grenville Series and of map-units 1-7 in all parts of the area precludes any major lateral facies change being responsible for the two types; (2) their homogeneity, lithology, and foliation are more consistent with an igneous or plutonic predecessor than a sedimentary one (with the exception of map-unit 2a); but (3) map-units 1-7 do not contain included masses of identifiable Grenville Series that cannot be attributed to infolding; and (4) map-units 1-7 cannot be a suite of plutonic rocks intrusive into the Grenville Series because such rocks are otherwise well represented in the area (map-units 14-21), and these have quite different textures and appearance. Hence the only conclusion can be that they are older than the Grenville Series and that they represent the basement on which the Grenville Series was deposited. Map-units 1-7 have thus been assigned to a basement complex that comprises the oldest rocks in the area, and that is dominantly composed of acid and basic orthogneisses in different metamorphic and structural states in different parts of the area. To cite here as additional evidence the lithological and structural correlation between this basement complex and the Archaean rocks of the Superior Province to the west may perhaps involve a somewhat circular argument, but this is an intriguing possibility to be considered later.

Granite gneiss (map-unit 1)

Most of the southern half of Kempt Lake and the central part of Mont Laurier map-areas are underlain by medium-grained, leucocratic gneisses of granitic to quartz-dioritic composition, designated as map-unit 1. These rocks are equigranular, grey, buff, or pink in colour, and well foliated. Discontinuous compositional layering is evident in most outcrops, and zones and lenses of mafic material (map-unit 2) are abundant. Biotite and hornblende are the characteristic mafic minerals and most commonly occur together. Although the proportion of biotite and hornblende, the total mafic mineral content, and the colour of the feldspar may vary considerably, they evidently do so in no readily mappable or systematic manner, so that the overall impression is one of a homogeneous granitic gneiss terrain. Typical outcrops are predominantly pink in colour, with grey interlayers, and contain only 5 per cent biotite and hornblende aligned parallel to the foliation, about 30 per cent quartz, and both microcline and oligoclase feldspars. Some of the best exposures occur on Petawaga Lake (31 J/13W and 31 O/4W) and Lac Maxime (31 O 5/W).

A grey variety of the leucocratic gneisses, in which oligoclase is the principal mineral and potash feldspar is rare or absent, predominates in Mont Laurier and in the southeastern part of Kempt Lake map-areas. These grey gneisses are distinguished as map-unit 1a, and include rocks named the Lacoste Series by Osborne (1935). Typical and accessible exposures are the small quarries south of Lacoste and east of the village of Lac-des-Ecorces on Route 11 (31 J/7W and 31 J/11W). In both exposures filaments and stringers of pink leucogranite like that of map-unit 20 are common.

The granitic gneisses change as they grade into the charnockitic gneisses of map-unit 3. Rocks of the transitional variety are exposed in the areas lying between the upper and lower metamorphic isograds in Kempt Lake map-area, and are characteristically buff in colour, tending to weather brown, but commonly with a whitish crust where recently uncovered. The hornblende in these rocks is brown in thin section and the potash feldspar tends to be poorly twinned and perthitic in contrast to the well-twinned, nonperthitic microcline of the gneisses of lower metamorphic grade. Rocks of this intermediate type also occur within the area mapped as charnockitic gneiss (map-unit 3), but are not distinguished.

A small body of garnet granite in the northwest corner of Kempt Lake map-area around Obabcata Lake (31 O/13E) has been included in map-unit 1, although garnets are not elsewhere common. The rock is pink, homogeneous, poorly foliated, contains biotite and garnet, and apparently grades into the garnetiferous biotite gneisses of map-unit 2a.

In all the gneisses of map-unit 1 the plagioclase is oligoclase, ranging in composition from An_{10} to An_{30}. The potash feldspar is predominantly microcline, usually well twinned and nonperthitic. Biotite is the commonest mafic mineral and is invariably present, and olive green hornblende also occurs in 70 per cent of the thin sections examined. Apatite and magnetite are constant accessories; zircon, sphene, muscovite, allanite, and epidote are common, and tourmaline, calcite, and traces of secondary chlorite are also found. The distribution of twinned microcline, epidote, and muscovite in these rocks was used to establish the lower metamorphic isograd shown on the geological map.

Hornblende gneiss (map-unit 2)

The distribution of the dark hornblende gneisses is more widespread than the geological map indicates, because thin, discontinuous layers and lenses of it are a feature of most outcrops of map-unit 1. As a discrete and mappable unit, however, map-unit 2 is largely confined to the northwestern part of Kempt Lake map-area. Typical exposures, such as those around Echouani Lake (31 O/13E), are of dark grey, equigranular, medium-grained, homogeneous hornblende-plagioclase gneisses containing some quartz and biotite. The rocks are gneissic but not prominently layered.

The plagioclase is typically calcic oligoclase or andesine (average An_{31}), but becomes as calcic as labradorite in some mafic varieties of gneiss. Potash feldspar is rare. Quartz is present in all but the darker varieties, most commonly in the range 5 to 15 per cent but locally in amounts up to 50 per cent. Apatite and magnetite are constant accessories, and calcite, epidote, zircon, sphene, and garnet are common. In addition to green or olive green hornblende and brown biotite, green diopsidic pyroxene is present in 25 per cent of the specimens examined. Included in the map-unit are small masses of amphibolite, which may be virtually monomineralic or contain either clinopyroxene or garnet as well as hornblende.

A large part of the northwestern part of Kempt Lake map-area has been designated map-unit 2a. The rocks of this unit are heterogeneous, layered, garnet-biotite-hornblende gneisses that range in composition from varieties as leucocratic as map-unit 1 but with a more regular and pronounced layering, to mafic varieties equivalent to those in map-unit 2. The sequence as a whole is characterized by well-developed layering and by the prevalence of garnet, and appears to represent a metasedimentary unit, perhaps a meta-greywacke. Although an outcrop of rusty calcsilicate gneiss was found within the outcrop area (shown as map-unit 10 in 31 O/13W), its relationship to the other rocks is uncertain, and there appears to be no valid basis for correlating the metasedimentary gneisses of map-unit 2a with the Grenville Series (map-units 8-13).

Charnockitic gneiss (map-unit 3)

The charnockitic gneisses are concentrated in the northeastern part of Kempt Lake map-area. The rocks are homogeneous, equigranular, medium-grained, quartzo-feldspathic gneisses characterized by dark green feldspars. A dark green colour is always associated with feldspar in charnockitic rocks and in rocks of the granulite facies generally, but can be seen only on freshly broken surfaces. Commonly, a maple-sugar brown discoloration penetrates down for several feet below the surface of the outcrop. For this reason, the best exposures of both map-units 3 and 4 are in cuttings along the Canadian National Railways near Parent (31 O/14E). Whether brown or green in outcrop, the dark colour of the feldspar tends to make dark minerals and compositional layering less conspicuous than in map-unit 1, but the rocks are similar in these respects to those of the latter unit, generally containing less than 10 per cent mafics, typically brown hornblende with minor hypersthene and biotite aligned along the foliation.

As already noted, the charnockitic gneisses grade into a buff variety of map-unit 1 which predominates between the mapped upper and lower metamorphic isograds, and then into the pink and grey variety more typical of map-unit 1. These changes, taken in reverse order, accompany an increase in metamorphic grade from the mid-amphibolite to the granulite facies, marked by the following mineral reactions:

map-unit 1		map-unit 1		map-unit 3
pink microcline + grey oligoclase	LOWER ISOGRAD	buff, poorly twinned, slightly perthitic microcline + oligoclase	UPPER ISOGRAD	green, generally monoclinic, mesoperthitic potash feldspar + green oligoclase or antiperthite
brown biotite + green hornblende		brown biotite + olive brown hornblende		brown hornblende + hypersthene (with biotite, garnet, or clinopyroxene)

The plagioclase of the charnockitic gneisses is antiperthitic in many places, and on the average a little more calcic (average An_{23}) than the average plagioclase of map-unit 1. The potash feldspar is untwinned for the most part, largely monoclinic, and typically appears as a fine, string mesoperthite. All the gneisses contain quartz. Brown hornblende is the commonest mafic mineral, particularly in the darker varieties, but is generally accompanied by pale hypersthene and a little biotite, in addition to accessory magnetite, apatite, and zircon. Garnet and/or clinopyroxene occur in about 10 per cent of the gneisses studied, and here and there sphene and traces of secondary chlorite and epidote are found.

Pyroxene-hornblende gneiss (map-unit 4)

As map-unit 1 grades into map-unit 3 with an increase in metamorphic grade, so map-unit 2 becomes map-unit 4 in granulite facies. The distribution of map-unit 4 as small zones and lenses in the more leucocratic gneisses of map-unit 3 is again more widespread than the map indicates, but the bulk of the dark gneisses represented by map-unit 4 are in the northern third of Kempt Lake map-area.

Dark gneisses in the granulite facies contain brown hornblende, pale hypersthene, green aluminous diopside, with or without biotite and pink Fe-Mg garnet. The rocks are dark green, weather rusty brown, and are generally homogeneous with a streaky foliation. The plagioclase andesine (average An_{35}), forms 20 to 60 per cent of the rock, and they may contain in addition small amounts of quartz, perthite, apatite, titaniferous magnetite, zircon, calcite and sphene.

Cataclasite and leucocratic granulite (map-units 5 and 6)

The rocks of map-units 5 and 6 are concentrated in the eastern half of Mont Laurier map-area. Map-units 5, 6, and 7 also form a recognizable but small part of the composite green rock unit (14) in the western part of Mont Laurier map-area, but in masses too small to be distinguished separately. These rocks do not occur in Kempt Lake map-area apart from a few outcrops of granulite in its southeastern corner.

Typical exposures of cataclasite may be found around Lac des Trois-Montagnes west of La Conception (31 J/2E) or near Lac Macaza (31 J/7E and W). The best exposures of leucocratic granulite are in Mont Tremblant Park near Lac St-Louis (31 J/8W), but more accessible outcrops around ski trails are numerous on Mont Tremblant (31 J/2E), a region Logan cited a century ago as the type area of his 'fundamental gneiss' (later known as 'Trembling Mountain gneiss'). The cataclasite and leucocratic granulites have similar compositions, with less than 10 per cent dark minerals, but whereas the cataclasite is strongly foliated with smeared and elongated quartz and feldspar, a marked cataclastic texture, and a pinkish colour, the typical leucocratic granulite is grey to greenish, fine grained, and massive or with only a streaky foliation and lineation. These two types grade into each other through all intermediate stages, and the segregation of them into geographically separate units is not as complete as the geological map might suggest, but the areas shown as map-unit 5 are dominantly of cataclasite.

The cataclasites are medium- to fine-grained, leucocratic, quartzo-feldspathic rocks, usually with less than 5 per cent dark minerals. Although hypersthene, garnet, and hornblende do occur within them, the commonest dark minerals are magnetite and biotite, and many outcrops are virtually free from mafics. The plagioclase is sodic oligoclase, with an average composition of An_{20}; the abundant potash feldspar is most commonly an untwinned perthite. Quartz is abundant, usually as sinuous, discontinuous sheets, which led Adams (1897) to term the rock 'leaf gneiss'. The prominent foliation and lineation, and the elongation of mineral elements, are clearly due to the mechanical granulation, accompanied by some recrystallization of a previously more coarsely crystalline rock of granitic composition. The present mineralogy is consistent with the granulite facies.

Leucocratic granulites (map-unit 6) are fine-grained, homogeneous rocks that typically weather pinkish brown and have a greyish green fresh surface. The predominantly pink colour of the 'Trembling Mountain gneiss' noted by Adams (1897) and later by Osborne (1936) on Mont Tremblant was not seen during the present survey but may refer to the weathered surface. Massive varieties of the rock are tough and brittle, but foliated types are more friable and contain dark minerals drawn out into cigar-shaped spindles that impart a pronounced streakiness to the rock. The granulites consist essentially of small equant grains of quartz and untwinned, mesoperthitic, alkali feldspar. Plagioclase, typically oligoclase, is less abundant except as a component of the perthite. Hypersthene is the commonest of the mafic minerals; but, clinopyroxene, brown biotite, brown hornblende, and pink garnet also occur. Magnetite and apatite are common accessories.

Mafic granulite (map-unit 7)

Like map-units 2 and 4, mafic granulite is more common as small lenses and zones in its leucocratic counterpart (map-units 5 and 6) than the geological map suggests, but only a few masses are large enough to be shown. Good examples of the rock type occur within the leucocratic granulite of Mont Tremblant (31 J/2E).

Mafic granulite is fine- to medium-grained, dark grey or brown in colour, and has a characteristic salt and pepper texture. The rocks tend to be streaky or massive, and are homogeneous and unlayered. They have the composition, and to some extent the appearance, of diorite, the essential minerals being andesine and brown hornblende, usually accompanied by hypersthene and clinopyroxene or garnet. Biotite, apatite, and magnetite are common accessory minerals, and quartz, perthite, zircon, and calcite occur in some specimens.

2. Pretectonic sedimentary rocks (Grenville Series) (map-units 8-13)

The metasedimentary units, marble (11), quartzite (9), and aluminous (garnet-sillimanite) biotite gneiss (8) that occur in places within the Grenville province, have long been assigned to the Grenville Series. Each of these lithologies is here considered diagnostic of the Grenville Series, so that the occurrence of any one of these rock-types within a metasedimentary sequence has been taken as evidence for the correlation of the whole sequence with the Grenville Series. As far as possible areas where the different lithologies predominate have been distinguished on the geological map, and elsewhere, where the local variation in lithology is too great or the outcrop too sparse, the Series has been shown undivided (map-unit 13).

The Grenville Series occurs in all parts of the map-area, but is dominant only in the region comprising central and southwestern Mont Laurier map-area. The western part of this region is predominantly marble (11), the central part dominantly quartzite (9), and the eastern part predominantly aluminous gneiss (8).

As shown by the composite metamorphic isograd on the geological map, two distinct metamorphic grades of the Grenville Series are present, and the change from one to the other is abrupt and without intermediate stages. The first, or lower metamorphic grade, corresponds roughly to the sillimanite-almandine-muscovite or sillimanite-almandine-orthoclase subfacies of the upper-middle almandine amphibolite facies, and the higher (found in areas where map-units 5-7 and 14-18 also occur) corresponds to the granulite facies. The lower metamorphic grade is characterized by the prevalence of muscovite (with or without microcline) and the local appearance of epidote in addition to oligoclase in quartz-feldspar-almandine-biotite schists and gneisses, and the higher metamorphic grade by hypersthene and greenish string perthite in rocks of the same composition. Other metamorphic assemblages are described under their appropriate lithology.

Biotite paragneiss (map-unit 8)

The paragneisses of the Grenville Series are well-layered micaceous rocks, commonly with about 30 per cent dark minerals. The essential constituents are quartz, biotite, and feldspar, usually accompanied by garnet and sillimanite. Accesory minerals include magnetite (locally hematite), apatite, tourmaline, green spinel, and calcite. As already noted, hypersthene occurs in the gneisses metamorphosed to the higher metamorphic grade, and muscovite and epidote occur in many places in the other rocks. Consistent with these changes, the potash feldspar may be greenish, finely perthitic and untwinned (granulite facies), or well-twinned microcline, or absent altogether in some richly micaceous rocks (amphibolite facies). Plagioclase in both metamorphic states ranges in composition from oligoclase to labradorite; the average composition is about An_{37}.

The rocks are all well foliated and medium to coarse grained, varying in structure from quartz-mica schists to layered granulites, but most commonly appear as layered, biotite rich gneisses. Typical outcrops are near Lac Saguay on Route 11 (31 J/6E). Hypersthene-bearing varieties are best developed south of Lac Forbes (31 J/9E) and muscovite-rich schistose types are commonest around Lac Tourbis (31 O/SE).

Quartzite (map-unit 9)

White to grey, vitreous, medium- to coarse-grained quartzite is a prominent part of the Grenville Series, and judging by scattered outcrops forms thick homogeneous sequences in the central part of Mont Laurier map-area. As well as quartz (usually more than 90 per cent of the rock), garnet, sillimanite, biotite and feldspar are common constituents. The rock is interlayered with other members of the Series on all scales, and may be massive, weakly foliated, or compositionally layered.

White rocks (map-unit 10) and Marble (map-unit 11)

Crystalline limestone and calcsilicate rocks form the main bedrock of the southwestern part of Mont Laurier map-area. All known smaller occurrences are also indicated on the geological map. The marble itself is usually fairly pure, being composed of calcite with lesser amounts of graphite, phlogopite mica, diopside, apatite, pyrite, quartz, and feldspar. Associated with the marble are quantities of white quartzo-feldspathic and calcsilicate rocks, collectively designated the White-rock unit of map-unit 10, but usually occurring in masses too small to be distinguished on the geological map. The unifying feature of these rocks is the preponderance in them of white feldspar uncoloured by hematite, and by the total absence of ferric iron in any form. Their occurrence is spatially related to that of marble in this as in other parts of the Grenville province (e.g. Wynne-Edwards, 1959), so that places in which only the White-rock unit is exposed can be confidently correlated with the marble zones themselves.

The commonest of the rocks of map-unit 10 is a massive or faintly foliated white pegmatite in which small quantities of phlogopite, pyrite, graphite, apatite, and diopside are typical, all of these being minerals also common in the adjacent marble. The pyritic varieties have rusty outcrops, but the main minerals in addition to quartz are white microcline and white oligoclase (or string mesoperthite at the higher metamorphic grade, where the feldspar may take on the greenish cast of the granulite facies, producing what might be called 'green white-rock' or perhaps 'white green-rock' in the sense of map-unit 4). Calcsilicate masses, as individual outcrops or as small knots in marble and white pegmatite are also common. Most masses consist essentially of diopside and quartz, but biotite, scapolite, tremolite, hornblende, calcite, and sphene are typical constituents and there are varieties containing epidote, grossularite, cummingtonite, forsterite, chondrodite, and spinel. The common accessories are pyrite, graphite, and apatite. Coarse aggregates of phlogopite with minor green diopside are associated with thin marble and calcsilicate zones in the charnockitic gneisses east of Parent (31 O/16W). The phlogopite-diopside rocks, known as suzorite after this occurrence in Suzor township, have recently been investigated as a source of mica for a variety of industrial uses.

Layered, rusty, graphitic paragneisses form an additional part of the calcareous sequence and are included in map-units 10 and 11. They occur as coherent sequences or as segmented blocks scattered by flow of the marble. They consist essentially of quartz, white feldspar, biotite, diopside, graphite, calcite, and pyrite, the latter accounting for the rusty colour. Good exposures occur on Route 11 in the areas mapped as map-unit 11 east of Lac-des-Ecorces and northeast of Guénette (31 J/11E and W).

Hornblende gneiss (map-unit 12)

Hornblende-plagioclase gneisses of the same appearance and lithology as either map-unit 2 or map-unit 4 (depending on metamorphic grade) occur here and there within the Grenville Series, and are assigned to map-unit 12. The distinction between these rocks and those of map-units 2 and 4 is thus based only on their association with units 8, 9, 10, or 11, and no new description is necessary. Most of the occurrences in the Grenville Series are too small to be mapped individually, but are commonest in the south-central part of the Mont Laurier map-area.

3. Pretectonic intrusive rocks (map-units 14-18)

The southeastern and south-central parts of Mont Laurier map-area contain large masses of plutonic rocks mapped as units 16, 17 and 18. These rocks (respectively anorthosite, mangerite, and quartz monzonite) are each distinctive species, but local gradations among them do occur, serving to demonstrate that they form a comagmatic sequence. The igneous or relict igneous texture of the suite coupled with the occurrence of identifiable members of the Grenville Series as inclusions within it, establishes the rocks as younger than the Grenville Series and intrusive into it, and numerous signs of deformation and recrystallization further show them to be older than the Grenville orogeny.[1]

The main structural and textural characteristics shared by all the rocks are: (1) coarse grain-size and a prevalent porphyritic or porphyroblastic texture; (2) a mineralogy or relict mineralogy that includes perthite and hypersthene, both characteristic of crystallization in an environment equivalent to that of the granulite facies; (3) a degree of homogeneity and, in places, a porphyritic or a subophitic texture found only in plutonic igneous rocks and therefore diagnostic of this mode of origin; and (4) widely developed cataclastic textures, granulation, and partial recrystallization; in some rocks these produce augen gneisses and in others a coarse mortar texture.

The green-rock complex of map-unit 14 consists dominantly of mangerite (map-unit 17), in places associated with minor amounts of other members of the suite, but in such a complex relationship with older rocks (5-13) that they are inseparable at map scale. This map-unit may be regarded as a metamorphosed and refolded migmatite complex related to the more homogeneous igneous masses shown as map-units 16-18.

With the exception of the noritic phases of the anorthosite, which belong to the suite above and are mapped as unit 16a, alkali gabbros in syenite plutons (21a), and diabase dykes (22), all gabbros and metagabbros in the map-area have been assigned to map-unit 15. Whereas some masses undoubtedly date from the same tectonic period as those above and share many of their textural characteristics, the tectonic age of many gabbros cannot be assigned with confidence, and those with a relatively fresh ophitic texture may be younger.

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[1] A K/Ar age determination on greenish brown biotite from coarse, massive, porphyritic quartz monzonite (map-unit 18) at Lac Mocassins (31 J/9W) gave 1205 ± 43 m.y. This date is significantly older than ages determined on metamorphic rocks in the area, which are close to the mean for the Grenville orogeny (945 m.y.).

Green-rock complex (map-unit 14)

Map-unit 14 designates regions in which the intrusive rocks of this tectonic category, but most commonly the mangerite of map-unit 17, are intimately intermixed with the Grenville Series (8 - 13) metamorphosed to granulite facies and with cataclasite and granulite (5 - 7) in places. Within these areas, which have been termed green-rock complexes (after Osborne and Morin, 1962), the green feldspars of the granulite facies, the brown hornblende, hypersthene, perthite, and garnet characteristic of this grade of metamorphism, are ubiquitous and, in general, an equant metamorphic fabric is common to all rocks. A further distinguishing, but not invariable, characteristic is a fine-textured pattern of aeromagnetic contours made up of small, discontinuous ovoid features of strong magnetic relief. The structure of the rocks varies from cataclastic to massive granular to layered gneissic in different rocks depending on their earlier history and on their competence during the Grenville orogeny. The green-rock complex evidently was at one time a migmatitic mixture of mangerite and older country rocks, but the separation of the components of this mixture has been made still more difficult by the metamorphism and deformation accompanying the Grenville orogeny which post-dates its initial formation. Some of the complexity of this terrain has been described by Pollock (1962) on the basis of mapping at a larger scale.

Gabbro and meta-gabbro (map-unit 15)

Small masses of gabbro and meta-gabbro are common throughout the map-area, but are most numerous in the south. As already noted, map-unit 15 includes rocks of more than one age, so that all varieties from fresh, ophitic-textured, pyroxene-labradorite rocks to granular meta-gabbros containing metamorphic hornblende and biotite are represented. Individual masses may show considerable variation, possessing amphibolitic margins and a fresh, unaltered core. All the rocks are homogeneous, and most are massive and medium to coarse grained. They are generally dark in colour, although plagioclase, the predominant mineral, may be white, or black, or greenish. The plagioclase is labradorite or calcic andesine with a recorded range from An_{28} to An_{65}. In the least altered varieties the mafic minerals are mainly augite and hypersthene, but in the meta-gabbros hornblende, clinopyroxene, and biotite predominate. Apatite, magnetite, and sphene are the main accessories, and some meta-gabbros contain quartz and FeMg garnet in addition.

Anorthosite (map-unit 16)

The southeastern part of Mont Laurier map-area (31 J /1 E and W, 31 J/8E) contains part of the Morin anorthosite, a subcircular mass some 30 miles in diameter once assigned by Logan to his Upper Laurentian System, and later mapped and named by Adams (1897). There are many excellent outcrops of the rock along Route 11 between Val David and St-Faustin.

The anorthosite is a coarse-grained, homogeneous rock, but variable in colour, appearance, and texture. Individual plagioclase crystals are 6 inches or more in length in some outcrops. The more massive varieties of anorthosite are dark grey, mauve, or brownish grey, but cataclasis tends to lighten the colour and the rock becomes whitish. All degrees of cataclasis are present. Large sections of the anorthosite mass are relatively undeformed and are very coarse grained, approximately equigranular, and have a crude subophitic texture. Elsewhere the rock is strongly cataclastic; in its extreme form this deformation results in a number of ovoid 'eyes' of grey or brown plagioclase set in a lighter coloured cement of powdered and granulated feldspar. In some places the anorthosite also has a metamorphic texture formed of a granular mosaic of recrystallized plagioclase. The distribution of zones of cataclasis and recrystallization does not appear to be systematic.

Plagioclase forms from 70 to 100 per cent of the rock and is usually twinned calcic andesine (average An_{45}). The commonest mafic mineral is hypersthene, followed in order by augite, and in places by secondary hornblende and biotite, and by titaniferous magnetite. Apatite appears to be confined to the more mafic varieties distinguished as map-unit 16a on the geological map. These rocks are also characterized by concentrations of ilmenite and titaniferous magnetite, and commonly by strong positive magnetic anomalies in contrast to the flat negative magnetic response of the anorthosite mass itself.

Mangerite (map-unit 17)

Coarse-grained mangerite and quartz mangerite form a partial envelope for the anorthosite on its western side, and also occur within the green-rock complex of map-unit 14 still farther west. The mineralogy and appearance of the mangerite suggest that it is comagmatic with the anorthosite, and although the relationships have not been examined in detail, rocks of an intermediate composition appear to be developed in places. Excellent outcrops of mangerite occur on Route 11 two miles south of La Conception (31 J/2E), and at the entrance to Mont Tremblant Provincial Park east of Mont Tremblant (31 J/7E).

The mangerite is a coarse-grained, locally porphyritic rock with the dark green perthitic feldspar characteristic of crystallization under granulite facies conditions. As in rocks already described, this green feldspar weathers to the familiar maple-sugar brown of charnockite and granulite outcrops. The rocks are typically massive, but here and there cataclasis and partial recrystallization have produced streaky augen and flaser gneisses.

In mineralogy the mangerite (17) is similar to map-units 3 (charnockitic gneiss) and 6 (leucocratic granulite), but its massive, homogeneous habit, and spatial and textural association with anorthosite show it to have had a different origin. The differentiation of these three distinctive map-units in place of the single 'green-rock unit' suggested by Osborne and Morin (1962) is regarded as an important result of the present survey and a necessary key to the tectonic history of the area. The granulite facies mineralogy of the rocks reflects a particular environment of crystallization rather than a common source or origin.

More than two thirds of the specimens of mangerite examined contain some quartz, usually between 5 and 10 per cent. From 30 to 70 per cent of the rock consists of fine string mesoperthite in which the potash feldspar is untwinned or only poorly twinned and appears monoclinic. The plagioclase is typically calcic oligoclase, but near the anorthosite large eyes of grey or brownish feldspar similar to that in the anorthosite are common. In addition to hypersthene which is the commonest dark mineral, augite, hornblende, biotite, and garnet occur roughly in that order of abundance, and the rock contains apatite, zircon and opaque minerals as accessories. Hornblende in part mantles pyroxene and the hypersthene of some varieties is totally replaced by an aggregate of olive green hornblende and brown biotite. Fine, bead-like grains of garnet are present in most outcrops and give the rock a pinkish cast.

Quartz monzonite (map-unit 18)

Porphyritic quartz monzonite, monzonite, and diorite, form large bodies in the eastern part of the area, and numerous smaller bodies are more widely distributed, particularly in Mont Laurier map-area. The best outcrops occur within the large masses (31 J/9, 31 J/16, 31 O/1), but more readily accessible exposures are between Lac Preston and Lac Gagnon (31 J/3E) and within the small, but not entirely typical, mass on the road between Conception and Mont Tremblant Village (31 J/2E).

The quartz monzonites are pink, buff, or brown, coarse grained, porphyritic, homogeneous, and massive where post-crystalline deformation has been slight. Up to 50 per cent of the rock consists of pinkish tabular crystals of perthitic alkali feldspar up to an inch long. The matrix of these large crystals is also coarse grained and consists essentially of plagioclase, brown biotite, olive hornblende, and quartz. Hypersthene and augite occur in a few varieties transitional to the mangerite of map-unit 17. The common accesory minerals are apatite, magnetite and sphene. Quartz forms coarse aggregates that make up 20 per cent of typical rocks, although quartz-free varieties do occur. The large crystals of alkali feldspar are generally string or bead perthite, and may include either twinned or untwinned potash feldspar. The plagioclase in the matrix ranges in composition from An_{20} to An_{45}, but is commonly calcic oligoclase.

Associated with the quartz monzonites are more basic diorites which are roughly equivalent to the matrix of the former freed from phenocrysts of alkali feldspar. The porphyritic quartz monzonite, like the other rocks of tectonic category 3, is locally cataclastic or recrystallized, and may become a spectacular augen gneiss, which in its extreme form (e.g. at Lac Maison-de-Pierre (31 J/15E)), may approach the texture of the cataclasite of map-unit 5. More commonly, however, the parentage of these augen gneisses is readily apparent, and in many places in the larger masses they grade into a more massive, undeformed variety.

Augen gneisses more rich in biotite are common in the western part of Mont Laurier map-area and have been grouped with these rocks as map-unit 18a. They are well developed between Mont Laurier and Lac-des-Ecorces (31 J/11W), and are exposed along Route 11 and on the road east of the lake. Like the rocks already described, they consist of perthitic microcline augen set in a homogeneous matrix of biotite, hornblende, oligoclase, and quartz, but they differ in having a metamorphic fabric, a higher proportion of biotite, and a pronounced foliation. These augen gneisses appear to be recrystallized equivalents of the porphyritic quartz monzonites and appear to result from small masses being metamorphosed under the conditions ot the middle amphibolite facies in company with the Grenville Series rocks that enclose them.

The quartz monzonites are the oldest rocks to which a relative age can be assigned by the preservation of cross-cutting intrusive contacts. Inclusions of Grenville Series and of granulite are common, and in places these are traversed by sharp-walled dykes of the porphyritic rock. In turn, the quartz monzonite itself is cut by dykes of a medium-grained pink alaskite (map-unit 20), a relationship well displayed, for example, in a large rock-cut on Route 11 two miles east of Mont Laurier.

4. Syntectonic and Late Tectonic Intrusions (map-units 19-21)

Several different types of syntectonic and late tectonic intrusive rocks were emplaced during the Grenville orogeny. The criteria used to determine this tectonic age are that the rocks lack a metamorphic fabric, a pronounced gneissosity or a cataclastic texture, and locally form well-defined dykes that crosscut the rocks with which they are associated. Their K/Ar ages all fall within the known time-span of the Grenville orogeny. The rocks include gabbro of a type exposed on Route 11 near Lac Gatineau (31 J/12E) and already described as part of map-unit 15; medium-grained pink granite (map-unit 20) such as that long quarried at Guénette (31 J/11E); a migmatite (map-unit 19) formed of granite (map-unit 20) mixed with gneisses; alkali granites of similar texture confined to the Kempt Lake map-area (map-unit 20a); and discrete plutons of coarse-grained alkali syenite, alkali gabbro, and mica pyroxenite (map-unit 21). A number of pegmatite dykes also date from this time.

In view of the many published statements to the contrary, it may be noted that the only rocks of the area with a true age equivalent to that of the Grenville orogeny, about 1000 m.y., are the rocks of this tectonic category (map-units 19-21). These 'new' rocks together comprise less than 5 per cent of the total surface exposed in Mont Laurier and Kempt Lake map-areas.

Migmatite (map-unit 19)

Parts of the area are underlain by an intimate mixture of rocks belonging to the Grenville Series with quartzo-feldspathic gneisses and amphibolites that may belong to map-units 1 and 2, and with granite of map-unit 20. In general such areas were not well sampled, but the known outcrops are largely composite in character, consisting of granite mixed with other rocks on a small scale. They appear to be migmatites formed during the Grenville orogeny, and have been designated as map-unit 19.

Granite (map-unit 20)

Medium-grained~~, pink,~~ equigranular granite is common as dykes and filaments in many of the rocks already described. It forms large homogeneous masses, however, in the west-central part of the area, where it is represented by map-unit 20 and occurs within the Grenville Series, possibly at or near a specific stratigraphic horizon. It may thus be the result of partial melting of a part of the Grenville Series during metamorphism. The composition of the granite coincides roughly with the ternary minimum of the hydrous Or-Ab-Q synthetic system (Tuttle and Bowen, 1958), being made up of about equal parts of quartz, microcline, and albite. Excellent exposures of the rock occur, as already noted, in the quarries near Guénette (Osborne, 1933).

The rock is a subsolvus granite; well-twinned, nonperthitic microcline, albite-oligoclase (An_{10}) and quartz form a mosaic of equant separate grains. The main mafic mineral biotite is present as fine flakes making up 5 per cent of the rock or less, and it is commonly aligned to impart a crude foliation. Magnetite and apatite are always present, and small amounts of hornblende, epidote, muscovite, zircon, sphene, chlorite, fluorite, and calcite were seen in different thin sections.

A few bodies of homogeneous, medium-grained alkali granite were encountered during the survey of Kempt Lake map-area. These are classed as map-unit 20a because their texture and appearance is similar to that of the granite of map-unit 20, but their relationship to other rocks is not known. They are characterized by medium-grained equigranular texture, buff colour, and a mineralogy consisting predominantly of perthitic alkali feldspar, albite, soda amphibole (riebeckite ?), aegirine augite, and up to 30 per cent quartz, with accessory magnetite, apatite, and zircon.

Alkali Syenite and Related Rocks (map-unit 21)

Eight large plutons and several smaller bodies dominantly composed of grey or pink biotite syenite occur in the western part of Mont Laurier map-area, all but one (the Loranger syenite pluton southeast of Lac Nominingue (31 J/7W)) being associated with a major positive magnetic anomaly. The plutons have sharply defined margins, a composite character, and appear to be late tectonic in age. The dominant rock types are grey or pink coarse-grained syenites, characterized by a fresh, hypidiomorphic granular texture and the minerals oligoclase, perthitic microcline, biotite, and green clinopyroxene. Most of the rocks contain about 20 per cent biotite, as well as abundant alkali feldspar, and their alkaline character is further confirmed by the presence in places of nepheline, reported from loose boulders south of the Ste-Veronique pluton (31 J/11E) by Osborne (1935), but not encountered during this study. Microcline perthite of the patch, rod, or string variety forms 40 per cent or more of the rocks and is accompanied by plagioclase, typically sodic oligoclase, but locally as calcic as An_{40}. Uralitic hornblende, magnetite, apatite, and sphene are present in most specimens, and tourmaline, calcite, and in one case quartz were also noted. Apatite may be a major constituent in places.

Associated with the syenite of these plutons is a massive, fresh, dark, alkali gabbro containing poikilitic plates of biotite (map-unit 21a). Mafic minerals form about 40 per cent of typical specimens, the order of abundance being biotite, clinopyroxene, and hornblende. The plagioclase is andesine, and the gabbros also contain accessory apatite, magnetite, and sphene, as well as perthite in varieties transitional to syenite.

Ultrabasic rocks (map-unit 21b) are present in a number of the plutons, and also occur as small separate masses. The latter are in some respects similar to metamorphic diopside rocks mapped as map-unit 10, but have a more indurated appearance, a more regular texture and grain size, and a small content of magnetite. The commonest type is a coarse-grained, green, mica pyroxenite, consisting almost entirely of green augite, brown biotite, and magnetite. Included in this map-unit, however, is a unique occurrence of peridotite at Lac Troyes (31 O/1E). The single specimen collected is a tough dense rock consisting of 50 per cent fresh olivine, 25 per cent enstatite and augite, 10 per cent brown biotite, a few laths of calcic plagioclase clouded by opaque minerals, and a little magnetite.

Pegmatite

Pegmatite dykes containing graphic intergrowths of quartz and alkali feldspar and large books of muscovite mica occur here and there. They are distinct from, and later than, the white pegmatite masses associated with marble and already described as map-unit 10. Mica has been recovered from one such dyke close to the eastern edge of Mont Laurier map-area (31 J/16E).

5. Post-tectonic intrusions

Diabase (map-unit 22)

Late, crosscutting, west-trending black diabase dykes cut all other rock types near the southern boundary of the area. They are part of a system of dykes that are more closely spaced southward towards the Ottawa River.

STRUCTURE

Most of the rocks in Mont Laurier and Kempt Lake map-areas possess a prominent foliation that traces out a complex pattern of folds and is commonly parallel to a continuous or discontinuous compositional layering. In many outcrops there is also a well-developed lineation in the same orientation as the locally prevailing fold axes. The detailed pattern of aeromagnetic trends, airphoto lineaments, and recorded structural elements is at first sight a confused and largely random one in which few major folds of constant axial orientation can be discerned, but the use of stereographic projections[1] for the statistical presentation of structural data produces a remarkably regular and simple general structural pattern from which a large part of the tectonic history can be inferred. These projections are set out on the structural map accompanying this paper.

The larger stereograms are centred on the 15 minute quadrangle (NTS) from which their data are drawn, and in these, foliation data for 64 quadrangles are plotted and density contoured. Where possible, a great circle girdle (or girdles) has been fitted to the density maxima. The pole of such a girdle, representing the mean statistical beta pole or cylindrical fold axis of the area, is plotted as a black dot. The smaller stereograms are centred on each of thirty-two 15 by 30 minute quadrangles from which their data are drawn, and show recorded lineations, which are density contoured and compared with the beta poles (black dots) from their two adjoining foliation diagrams. In spite of considerable scatter (partly caused by the arbitrary selection of structural segments defined by geographic rather than geological boundaries), a broad diagonal division of the whole area into a northwestern, a central, and a southeastern structural domain can readily be discerned.

The northwestern domain, extending over the northern half of Kempt Lake map-area and down the western margin of Mont Laurier map-area, contains homogeneous structures plunging gently northeast or less commonly southwest. The foliation conforms to a simple girdle with only

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[1] In all cases the stereograms are equal area projections of the southern hemisphere.

minor scatter in most of the diagrams, and the agreement between the orientation of the beta pole of any girdle and the corresponding lineations is close. The southeastern domain is similarly homogeneous where the data are sufficient for a pattern to emerge, but the fold axes here plunge southward at an average angle of thirty degrees. The central domain has a less homogeneous pattern in which a number of differently plunging foliation girdles may be discerned. Here again, however, southerly plunges predominate.

The boundaries of the domains are diffuse and traverse geological contacts. They do not appear to coincide with any major lithological boundaries, although the isograd that divides the dominantly granulitic and plutonic terrain in the eastern part of Mont Laurier map-area from the dominantly metasedimentary rocks to the west is roughly parallel to the edge of the southeastern domain. The textures of all the rocks involved in all three domains show that the lineations clearly date from the last period of metamorphism, recrystallization, cataclasis, and deformation, the Grenville orogeny, so that the different orientations are not direct relicts of separate periods of folding.

The relationships between the three structural domains are clarified by a synoptic diagram incorporating 113 beta poles and lineation maxima collected from all the stereographic projections and replotted in a diagram among the marginal data of the structural map. The density-contoured distribution of these statistical maxima of linear elements forms a distinct girdle that defines a plane (S^1) striking N42°E and dipping 50°SE.[1] The two maxima on this plane, plunging at 25° toward N60°E and at 30° toward S08°W, correspond to the average fold axes in the northwestern and southeastern domains respectively. As explained by Weiss (1959), such patterns are the geometrical result of the superposition on pre-existing structures of folds formed by slip parallel to the defined lineation girdle, which has the attitude of their axial planes. The plunge of these superimposed folds is determined by the line of intersection of these planes (S^1) with the prevailing attitude of stratification or foliation (S) at any point, and thus changes with the changing attitude of (S) established by earlier deformations. Each different orientation of (S) produces a new line of intersection on (S^1), so that the presence of strong maxima of lineation in two of the domains indicates that the pre-existing structures in each had a strongly developed preferred orientation. The scatter in the synoptic diagram of linear elements has been minimized by plotting only the orientations of statistical maxima, but departure from a simple distribution along the single plane (S^1) is nevertheless present. This can be provisionally explained by local variations in the attitude of (S^1), each of which would produce a new family of linear intersections. The lineations in 31 J/6 and 31 J/11, for example, appear to define a

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[1] This plane is also partly or wholly defined by lineations in the diagrams for areas 31 J/9, J/12, and J/15; and 31 O/3, O/6, O/7, and O/15.

more northerly, west-dipping plane, which may coincide with the axial planes of superimposed folds in those areas.

The structural pattern of the Mont Laurier and Kempt Lake map-areas may thus be summarized as one of dominantly northeast trending slip folds (actually flow folds as defined by similar geometry and the absence of axial plane foliation (Wynne-Edwards, 1963)) superimposed during the Grenville orogeny on two dominant earlier structural trends: in the northwestern domain on a trend that resulted in northeasterly plunging folds, and in the southeastern domain on a trend that gave rise to southerly plunging structures. The central domain between these two evidently contained a variety of trend directions, but here too an orientation giving rise to southerly plunges predominated. The later, superimposed, and now dominant structures have the northeast trending axial planes long associated with the structures of the Grenville Province, and are parallel to its length and to the Grenville front. The more obvious disposition of map-units, however, is determined by their history prior to the Grenville orogeny.

The attitude of the dominant trends in the northwestern and southeastern domains before the superimposed folding of the Grenville orogeny must next be determined. An infinite number of possible attitudes of (S) planes can intersect the later northeast trending (S^1) in the desired orientation of the statistical lineation maxima in either case so that further independent geological evidence is needed. This is provided by the general distribution of the main lithologic units. In the northwestern domain, the dark gneisses (map-units 2 and 4) are largely confined to the areas north of latitude 47°40'N. and the leucocratic gneisses (map-units 1 and 3) are concentrated in its central part, whereas the main contacts with the Grenville Series again occur roughly along an east-trending zone but still farther south. The broad distribution of lithologies in the northern half of the area is evidently, therefore, east-west. Imprinted on this pattern, and now dominating it, is a marked northeasterly 'grain' which is responsible for most of the large, visible folds, and which also shows clearly as the principal trend on aeromagnetic maps.

In the northwestern domain, therefore, the structure appears to be that of folds with northeast-trending, southeast-dipping axial planes superimposed on an east-west trend. The older generation of east-west S-surfaces must have dipped predominantly northward to produce later the northeasterly lineations of the Grenville orogeny. A correlation seems likely between this pre-Grenville trend and the west-trending Kenoran structures of the Rouyn-Malartic - Val d'Or region that lie on strike in the Superior Province some 30 miles to the west across the Grenville front. Such a correlation has already been suggested by Stockwell (1964, 1965) on lithologic grounds. In the Kempt Lake map-area, the general distribution and the composition of the main units in the northwestern domain correspond at least crudely with those from Rouyn to Val d'Or, with correlatives of greenstones and volcanics (map-units 2 and 4) being associated with those of greywackes (map-unit 2a), lying north of a terrain composed of acid and granitic rocks (map-units 1 and 3).

In the central and southeastern structural domains, by contrast, the broad distribution of map-units is north-south, or perhaps more nearly north-northeast. If the intrusive rocks are ignored, there are crudely defined north-trending zones made up successively from west to east of marble (11), quartzite (9), granite gneiss (1a) and granulite with biotite paragneiss (6 and 8). However, the units are themselves arranged en echelon within these zones, and this again appears to be the result of a superimposed imprint of northeast-trending refolding, but this time a pattern that intersects a north-south, rather than an east-west trending fold system.

To produce the southerly plunging lineation maximum by intersection with the superimposed Grenville structures, the dominant dip of these north-south (S) surfaces must have been roughly vertical. From this, a set of upright, steep-limbed, north trending folds can be inferred to have been present in the southern half of the area prior to the largely obliterating imprint of the northeast trending structures of the Grenville orogeny.

This simple outline of the structure as defined statistically serves to show that different parts of the map-area have had different pre-Grenville tectonic histories. It will be postulated in a later paper that the effects of the Kenoran (ca. 2500 m.y.), the Hudsonian (ca. 1750 m.y.), and the Elsonian (ca. 1300 m.y.) orogenies are all represented in the area by distinguishable metamorphic, intrusive, or tectonic episodes, although all are strongly overprinted by the major deformation and high-grade metamorphism of the Grenville orogeny (ca. 950 m.y.). As the Grenville Province is one of the world's more accessible and well exposed high-grade metamorphic terrains representing an orogenic root zone, this multiple tectonic history may have wide implications.

ECONOMIC GEOLOGY

Quarries, in quartzite for silica at Reservoir Baskatong (31 J/12W) and at St-Donat-de-Montcalm (31 J/8E), in marble for dolomite at Val Barrette (31 J/11W), and in granite for cut stone at Guénette (31 J/11E and W) and at Lacoste (31 J/7W), are currently in operation in Mont Laurier map-area, but there is no other sustained production from the mineral industry. At various times deposits of ilmenite, magnetite, molybdenite, graphite, mica, garnet, radioactive minerals, talc, serpentine, ochre, porcellanite, and kaolinite have been investigated or exploited at places marked on the geological map. Copper, nickel, lead, and zinc have been reported from old workings in a number of places. Previously unrecorded mineral occurrences are: (1) gabbro containing about 20 weight per cent hematite and ilmenite collected by Dr. Gaucher during his investigation of the negative magnetic anomaly near Lac Rossi (31 J/7E); (2) a copper-nickel showing on Cockanogog

Lake (31 J/13E) verbally reported by Mr. A.D. Pudifin of Val d'Or but not visited by the Geological Survey; and (3) a veinlet of chalcopyrite and minor sphalerite in a magnetite-rich hornblende gneiss near Lac Gosselin (31 O/14W), also collected by Dr. Gaucher. An assay[1] of a sample of the latter showed 1.17% Cu, trace Zn, 0.001 ounce a ton Au, and 0.015 ounce a ton Ag. This occurrence and the chalcopyrite at Cou Cou depot (31 O/11W) reported by Retty (1934) are interesting in view of the correlation suggested earlier between their hornblende gneiss host rocks and the basic volcanic rocks of the Rouyn-Val d'Or district to the west. If the rocks of this richly mineralized district do indeed persist east of the Grenville front, the fate of such mineralization during the high-grade metamorphism of the Grenville orogeny becomes a matter of interesting speculation.

REFERENCES

Adams, F.D.
1897: Report on the geology of a portion of the Laurentian area lying to the north of the Island of Montreal; Geol. Surv. Can., Ann. Rept., 1895, pt. J.

Aubert de la Rue, E.
1948: Nominingue and Sicotte map-areas, Labelle and Gatineau Counties; Quebec Dept. Mines, Geol. Rept. 23.

1953: Kensington area, Gatineau and Labelle Counties; Quebec Dept. Mines, Geol. Rept. 50.

1956a: Trente-et-un-Milles Lake area, Electoral Districts of Papineau, Labelle, and Gatineau; Quebec Dept. Mines, Geol. Rept. 67.

1956b: McGill area, Papineau, Labelle, and Gatineau Counties; Quebec Dept. Mines, Geol. Rept. 68.

Ells, R.W.
1902: On the geology of Argenteuil, Ottawa, and part of Pontiac Counties, Province of Quebec, and portions of Carleton, Russell and Prescott Counties, Province of Ontario; Geol. Surv. Can., Ann. Rept., 1899, pt. J.

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[1] Assays by the Analytical Chemistry Subdivision, Mineral Sciences Division, Mines Branch, Ottawa; W.R. Inman, Chief Chemist.

Katz, M.

1964: Geology of Cousineau-Rolland area, Montcalm, Terrebonne, and Joliette Counties; Quebec Dept. Natural Resources, prel. rept. 522.

1965: Legendre area, Joliette and Montcalm Counties; Quebec Dept. Natural Resources, Field work in 1964, summary, p. 12.

Logan, W.E.

1863: Geology of Canada.

Osborne, F.F.

1933: Commercial granites of Quebec: part 2; Quebec Bur. Mines, Ann. Rept., 1932, pt. E.

1935: Labelle-L'Annonciation map-area; Quebec Bur. Mines, Ann. Rept., 1934, pt. E.

1936: Sainte-Agathe-Saint-Jovite map-area; Quebec Bur. Mines, Ann. Rept., 1935, pt. C.

Osborne, F.F. and Morin, M.

1962: Tectonics of part of the Grenville subprovince in Quebec; in Roy. Soc. Can., spec. pub. no. 4, pp. 118-143.

Pollock, D.W.

1956a: Preliminary report on the Addington-Labelle area, Papineau and Labelle Counties; Quebec Dept. Mines, Prel. Rept. 321.

1956b: Preliminary report on Preston-Gagnon area, Electoral Districts of Papineau and Labelle; Quebec Dept. Mines, Prel. Rept. 334.

1959: Preliminary report on Rocheblave area, Electoral Districts of Papineau and Labelle; Quebec Dept. Mines, Prel. Rept. 408.

1960: Preliminary report on Lesage-Rivard area, Electoral Districts of Labelle; Quebec Dept. Natural Resources, Prel. Rept. 441.

1962: Some petrogenetic-structural relationships in an area of Grenville rocks; Trans. Roy. Soc. Can., ser. 3, Sec. III, vol. 56, pp. 127-142.

Retty, J.A.

1934: Upper Gatineau region and vicinity; Quebec Bur. Mines, Ann. Rept., 1933-34, pt. D.

Stockwell, C. H.
1964: Fourth report on structural provinces, orogenies, and time-classifications of rocks of the Canadian Precambrian shield; Geol. Surv. Can., Paper 64-17 (part II), pp. 1-21.

1965: Tectonic map of the Canadian shield; Geol. Surv. Can., Map 4-1965.

Tuttle, O. F. and Bowen, N. L.
1958: Origin of granite in light of experimental studies; Geol. Soc. Am., Mem. 74.

Weiss, L. E.
1959: Geometry of superposed folding; Bull. Geol. Soc. Am., vol. 70, pp. 91-106.

Wilson, M. E.
1920: Buckingham map-area; Geol. Surv. Can., Map 1691.

Wynne-Edwards, H. R.
1959: Westport map-area, Ontario; Geol. Surv. Can., Map 28-1959.

1963: Flow folding; Am. J. Sci., vol. 261, pp. 793-814.

1964: The Grenville province and its tectonic significance; Proc. Geol. Assoc. Can., vol. 15, pt. 2, pp. 53-67.

Wynne-Edwards, H. R. and Gregory, A. F.
1964: New approach in mapping Grenville geology; Northern Miner., Ann. Rev., Nov. 26, p. 45.