PROVINCE OF MANITOBA

DEPARTMENT OF MINES AND NATURAL RESOURCES

HON. HARRY J. ENNS
Minister

W. WINSTON MAIR
Deputy Minister

MINES BRANCH

J. S. ROPER
Director

PUBLICATION 61-5

GEOLOGY

of the

WATT LAKE AREA (East Half)

N.T.S. Map 64C-7

THE PAS MINING DISTRICT
MANITOBA

by

DONALD A. CRANSTONE

Winnipeg, 1968

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LOCATION AND ACCESS

The Watt Lake map-area (east half) is comprised of approximately 170 square miles, and covers the west-central portion of Granville Lake. The map-sheet is bounded by latitudes 56°15′ and 56°30′ north, and by longitudes 100°30′ and 100°45′ west. The corresponding sheet of the National Topographic Series is 64C/7E.

The area is situated approximately 30 miles southeast of the mining town of Lynn Lake, in the Granville Lake Mining Division. Granville Lake is most easily reached by chartered aircraft from Lynn Lake, or by canoe along the Churchill River, commencing at Pawistick station, the point where the C.N.R. Lynn Lake line crosses the Churchill River. This trip requires several short portages, the longest of which is 12 chains at Granville Falls. A second canoe route commences at Lynn Lake and follows the Keewatin River, but involves numerous portages and rapids, making travel very difficult and slow. In 1961 the portages just north of Granville Lake were overgrown and difficult to follow. Granville Lake may also be reached via the Laurie River, commencing at Drybrough on the Lynn Lake railway or alternately from the power station, just west of Trophy Lake on the Laurie River. A canoe route along Beatty Creek (locally known as Lynx River) leads north from Granville Lake to Beaucage Lake. This route has four portages and several shallow rapids, which make navigation by canoe difficult at times of low water.

The settlement of Pickerel Narrows, located one mile south of the south boundary of the map-area, has a population of about 80 persons. An independent trader is located at the settlement, and during the summer fishing season unscheduled aircraft arrive regularly from Lynn Lake.

GENERAL CHARACTER OF THE AREA

In general the area is similar to other parts of the Canadian Shield, and is covered by small muskegs, swamps, and lakes, and by glacial deposits. Granville Lake covers much of the southern portion of the map-area, and the narrow northwest arm of this Lake cuts diagonally across the area from southeast to northwest. Rock exposures are numerous and of large areal extent.

Topographic relief in the area does not exceed 250 feet. The Granville Lake gabbro intrusion at the western edge of the area, is resistant to weathering and presents the maximum relief, rising sharply along its northeastern contact with the Sickle greywacke, and then more gradually as the central area of the intrusion is approached. Black Trout diorite is resistant and generally forms high, steep ridges, particularly in the area immediately adjacent to Beaucage Lake. The granitic bodies along the eastern edge of the area also form high areas of extensive outcrop in many places. Scattered resistant pegmatite bodies stand 50 to 75 feet above the enclosing sedimentary rocks. Rocks of the Sickle series also form extensive high rock ridges in some places, in contrast to those of the Wasekwan series which tend to underlie areas of lower ground.

The entire area has been swept by forest fires within the past 40 to 50 years, and much of it is a tangled second growth of spruce and jackpine. Other species are poplar and birch, with scattered tamarack in the low swampy areas. Timber suitable for mining purposes is scarce. The maximum diameter noted was 8 or 9 inches, but this size is rare..

A few local residents are engaged in commercial fishing; the total allowable catch in recent years from Granville Lake has been 100 tons per year. Fish are transported to Lynn Lake by aircraft in the summer season and by winter road during winter months. Species available are pickerel, whitefish, jackfish, goldeye and tullibee. Commercial fishing is predominantly for pickerel and whitefish.

GLACIATION

In common with the rest of the Canadian Shield, the area was glaciated during Pleistocene time. Glacial deposits are thin, except for an area to the north and northwest of Beaucage Lake, where outcrops are not common. Glaciation has removed the weathered surface rock, and left the more resistant rock as generally rounded hills. In places where the Sickle rocks have a steep dip, steep rock faces have been developed, probably by ice plucking. These are best developed along the west shore of Beaucage Lake.

Glacial striae are common, and indicate an almost north to south direction of ice movement. Rock ridges parallel the strike of the bedding rather than the direction of glacial movement, and are probably a reflection of pre-glacial topography. Minor local diversion of glacial ice flow by the comparatively narrow and deep valley of the northwest arm of Granville Lake is indicated by a few anomalous striae noted along the shores of this arm. These striae suggest a diversion of ice flow to the southeast.

PREVIOUS WORK

Early geological exploration of the Granville Lake region is summarized by McInnes (1913). The Granville Lake district was mapped at a scale of 4 miles to 1 inch by J. F. Henderson in 1932 and G. W. H. Norman and J. F. Henderson in 1933. The results of this work are published in Geological Survey of Canada Summary Report 1933, Part C (out of print). Following further geological investigations by Downie in 1935, the work of Henderson and Norman was also incorporated into the Map 344A, at a scale of 4 miles to 1 inch. In 1950, G. C. Milligan mapped the "Beau Cache" Lake area, which covers the northeast portion of the present map-sheet, on a scale of ½ mile to 1 inch. Milligan's report was published as Manitoba Mines Branch Publication 50-8, "Geology of the Beau Cache Lake Area" (out of print). Following additional work by Milligan in 1957 the geology of the "Beau Cache" Lake area was revised slightly. The revised map was published in 1960 at a scale of 1 mile to 1 inch, as Map No. 7, Beaucage Lake, part of Manitoba Mines Branch Publication 57-1, "Geology of the Lynn Lake District".

PRESENT WORK AND ACKNOWLEDGEMENTS

This report is based on field work carried out during the period June 6 to September 1, 1961. Vertical aerial photographs at a scale of ½ mile to the inch were available for the map-area. Compass and pace traverses were run at intervals of 1500 feet, and never exceeding 2000 feet, over the entire map area. In the area of complicated geology immediately east of Beaucage Lake, the traverse interval was approximately 1000 feet. All traverse locations were plotted on the air photos in the field, and geology then transferred to a base map at a scale of ½ mile to the inch.

It is a pleasure to acknowledge the capable assistance provided by Mr. W. Lambo, senior assistant, and by Messrs. G. D. S. Brisbin, W. A. Gibbins, and K. Day, who acted as junior assistants.

Aircraft service was provided by the Manitoba Government Air Service, and radio communications with Wabowden was assisted by the Manitoba Forest Service stations at South Indian Lake, and Lynn Lake.

A study of the Granville Lake gabbro was made at the University of Manitoba under the guidance of Dr. H. D. B. Wilson; the results were submitted as a thesis for the M.Sc. degree.

Throughout this report the writer has used rock names based on the igneous rock classifications of the Geological Survey of Canada, and the sedimentary rock classification of Pettijohn (1957).

GENERAL GEOLOGY

INTRODUCTORY STATEMENT

The consolidated rocks of the Watt Lake area (east half) are of Precambrian age. Norman (1934) and Downie (1935) mapped and named the Sickle series, an extensive series of sedimentary rocks intermediate between greywacke and arkose. They and subsequent workers considered this series to unconformably overlie an older pre-Sickle series of volcanic and sedimentary rocks for which the name Wasekwan series was proposed by Bateman (1945). The Wasekwan and Sickle series have since been extended by various geologists mapping for the Manitoba Department of Mines and Natural Resources to include similar rocks throughout the Lynn Lake district, including the Watt Lake map-area.

Wasekwan rocks in the map-area are a series of sediments (greywacke, arkosic greywacke, arkose, conglomerate, iron-formation) and intermediate to mafic amphibolitic volcanic rocks. The Sickle series is a remarkably uniform series which consists predominantly of well-bedded greywackes to arkosic greywackes and their slightly recrystallized equivalents. The contact between the Sickle and Wasekwan series is marked by the Sickle conglomerate. In the southwest corner of the map-area a sequence of volcanic rocks several hundred feet thick has been established as part of the Sickle series. These intermediate to mafic volcanic rocks lie about 1500 feet stratigraphically above the top of the Sickle conglomerate. These had not been recognized as an integral part of the Sickle series until 1961, and must wedge out to the north. Prior to then the Sickle series was considered to completely lack volcanic rocks. These Sickle meta-volcanic rocks are stratigraphically overlain by a sequence of metamorphosed arkoses and related rocks which is another new addition to the Sickle series and which must also wedge out to the north. The arkose sequence is overlain by the more typical Sickle arenites.

Wasekwan and Sickle rocks have been intruded by many types of igneous rocks. These are mainly granitic to granodioritic intrusions along the eastern side of the map-area, but also include the Granville Lake gabbro and Black Trout diorite. The internal structure of the Granville Lake gabbro, a differentiated intrusion, indicates that it was intruded in a near horizontal position and later tilted into an almost vertical position by folding. The relative ages of the Granville Lake gabbro, Black Trout diorite, and the granitic intrusions are not known. Following a period of complex folding of the rocks of the area, uplift, erosion and Pleistocene glaciation have combined to form the present topographic surface.

WASEKWAN SERIES

The term Wasekwan series was originally used by Bateman (1945) for an assemblage of metamorphosed volcanic and sedimentary rocks in the vicinity of Wasekwan Lake, approximately twenty miles to the northwest of Beaucage Lake. The recognized aerial extent of the Wasekwan series was enlarged by Fawley in 1948 and 1949 (Fawley 1949, 1952) and by Milligan in 1950 (Milligan, 1951) to

TABLE OF FORMATIONS

		Map Unit	
Recent and Pleistocene			Sand, gravel, glacial till and boulders
GREAT UNCONFORMITY			
PRECAMBRIAN	Post-Sickle Intrusive Rocks (not necessarily in chronological order)	22	Pegmatite.
		21	Complex of plagioclase-quartz-biotite schist derived from Sickle arenites with pegmatite.
		20	Grandiorite to quartz monzonite—"Granite zone" (Granville Lake gabbro)
		19	Diorite, minor quartz diorite—"Transition zone" (Granville Lake gabbro)
		18	Gabbro, minor quartz gabbro—"Gabbro zone" (Granville Lake gabbro)
		17	Pegmatite with remnant inclusions of Sickle meta-arenites.
		16	Migmatitic lit-par-lit gneiss.
		15	Grey granodiorite.
		14	Mixed rocks (a) Mixed Wasekwan sedimentary and volcanic rocks, hornblende syenodiorite, and pink granodiorite. (b) Mixed Wasekwan sedimentary rocks, hornblende syenodiorite, and pink granodiorite. (c) Mixed Wasekwan sedimentary and volcanic rocks, iron-formation, Sickle arenites, Black Trout diorite, hornblende syenodiorite, and pink granodiorite.
		13	Pink granodiorite to quartz monzonite.
		12	Porphyritic quartz monzonite to porphyritic granodiorite.
		11	Hornblende syenodiorite.
		10	Black Trout diorite—diorite to quartz diorite
	INTRUSIVE CONTACT		
	Sickle Series	9	Venites formed by partial anatexis of Sickle arenites (unit 5).
		8	Strongly recrystallized Sickle arenites with common muscovite-quartz-sillimanite knots (derived from unit 5).
		7	Meta-arkose, granitoid meta-arkose, granite, minor quartz grit.
		6	Intermediate to mafic lavas, volcanic breccia, and tuffaceous rocks. Minor derived plagioclase amphibolite.
		5	Sickle arenites—impure arkose to feldspathic grewacke and metamorphic equivalents.
		4	Conglomerate.
	Wasekwan Series (not necessarily in chronological order)	3	Intermediate to mafic lavas and derived plagioclase amphibolites, minor interbedded sediments and minor amygdaloidal flows (interbedded with unit 1a).
		2	Conglomerate (interbedded with unit 1a).
		1b	Feldspathic greywacke and metamorphic equivalents.
		1a	Greywacke, subgreywacke, arkose, subarkose, and metamorphic equivalents; minor iron-formation and minor interbedded volcanic rocks.

include similar rocks in the present map-area. Bateman subdivided the Wasekwan series into eight map-units. In the vicinity of Beaucage Lake, Milligan and the present writer have been able to distinguish only three units which are mappable at the present scale. The three map-units of the writer conform in general to those of Milligan although they are not strictly identical. The most extensive Wasekwan unit (1a) mapped by the writer in the vicinity of Beaucage Lake is predominantly sedmentary. The chief rock types are subarkose, arkose, and greywacke, and their metamorphic equivalents, with minor interbedded volcanic rocks and siliceous iron formation. The arenites which comprise this unit are highly variable in character, distribution and appearance. In rare cases volcanic rocks comprise as much as 50 per cent or more of local small outcrops.

The map-unit second in importance at Beaucage Lake consists predominantly of plagioclase amphibolites derived from mafic lavas, with lesser interbedded sedimentary rocks identical to those of unit (1). Sedimentary beds are usually of minor importance, but comprise as much as 40 to 50 per cent of scattered small outcrops.

The Wasekwan conglomerate (2) usually occurs as well-defined sheets and lenses within sedimentary rocks (unit 1a) of the Wasekwan series.

The relative ages of these three subdivisions of the Wasekwan series are somewhat uncertain. In the Watt Lake map-area (east half), the three occur only in the area immediately to the east and north of Beaucage Lake. It would seem that at least in the vicinity of Beaucage Lake, deposition of arenaceous rocks continued throughout Wasekwan time, interrupted by deposition of the Wasekwan conglomerate (2) and by intermittent periods of volcanism with extrusion of mafic lava. However, because of the relatively confused pattern of folding, faulting, and intrusion of Wasekwan rocks in the vicinity of Beaucage Lake, the apparent stratigraphic sequence may now appear to be more complicated than it actually is.

A fourth lithologic unit (1b) consisting of homogenous, uniformly bedded feldspathic greywacke occurs in the extreme southwestern corner of the map-area. These rocks differ distinctly in composition and texture from Wasekwan rocks at Beaucage Lake. Lithologically, they closely resemble the Sickle series which comprises the major part of the map-area, and were originally mapped in the field as Sickle arenites by the writer. During the summer of 1963, G. S. Barry of the Mines Branch mapped the east half of the Trophy Lake area (Barry, 1965), which is immediately adjacent to the southern boundary of the Watt Lake area (east half). Structural and lithologic features observed by Barry and discussed with the writer (September, 1964) indicate that these rocks are probably part of the Wasekwan series, and represent a considerable increase in the hitherto recognized areal extent of the Wasekwan series. The probable Wasekwan age of these rocks has an important bearing on the interpretation of the stratigraphic sequence and structure of the Sickle series within the Watt Lake map-area (east half). This matter is discussed in later sections of this report.

ARENITES (1a and 1b)

ARKOSE, SUBARKOSE, SUBGREYWACKE, GREYWACKE (1a)

An area of Wasekwan sedimentary rocks to the east and northeast of Beaucage Lake consists of complexly interbanded greywacke, subgreywacke, arkose, subarkose and the metamorphic equivalents of these arenaceous rocks. All gradations between these rock types are found, and the distinction between an arkose and a greywacke is necessarily problematical and in some places further obscured by subsequent recrystallization. Siliceous iron-formation and plagioclase amphibolites derived from volcanic rocks occur as minor interbands.

Wasekwan arenites vary in colour from light grey to medium grey. The predominant variety is fine grained, and massive to moderately foliated. Biotite is ubiquitous, in amounts ranging from a trace to 15 per cent, but is generally a minor constituent. Rocks with a relatively high biotite content generally have a moderately well-developed foliation, with original bedding planes obscured, and in many places could be described as quartz-feldspar-biotite schist. Arkose to subarkose is probably the predominant rock type. The original texture and composition of the greywackes and subgreywackes has been considerably modified by subsequent metamorphism.

Microscopically, the more massive Wasekwan arenites from Beaucage Lake appear as jagged, fine-grained intergrowths of quartz and plagioclase, with lesser microcline and biotite in some specimens. A few grains of garnet, amphibole, chlorite, magnetite, and zircon are found in some rocks. The foliated varieties have been moderately recrystallized. Significant quantities of muscovite are found only in strongly sheared rocks.

The following range in composition was estimated from seven thin sections of typical Wasekwan arenites from the Beaucage Lake area:

Quartz	65-88%
Plagioclase	0-36%
Microcline	0-3%
Biotite	0-12%
Muscovite	0-15%
Chlorite	0-Tr.
Amphibole	0-Tr.
Magnetite	0-2%
Garnet	0-Tr.
Zircon	0-Tr.

Gritty arkose is minor in amount but widespread in occurence, particularly near the east shore of Beaucage Lake close to the Sickle conglomerate. This rock contains up to 20 or 25 per cent well-rounded, glassy quartz grains or "eyes" which range up to 3/16 inch in diameter. This rock type consists of 65 to 70 per cent quartz, 30 to 35 per cent plagioclase plus mirocline, and 2 to 4 per cent muscovite plus biotite.

A band of siliceous iron-formation occurs within the Wasekwan arenites immediately east of Beaucage Lake, near the mouth of Beatty Creek. The iron-formation consists of 1/8 to 1/4 inch layers of fine, granular quartz intercalated with similar layers which consist of a granular intergrowth of quartz and an unidentified pleochroic green amphibole that is apparently an iron-rich variety. These layers contain 50 to 80 percent amphibole. The rock contains numerous magnetite-rich bands up to a few inches in width, which are composed of as much as 90 per cent magnetite. Exposure of the iron-formation is poor, so that it is impossible to arrive at an accurate estimate of the overall magnetite content or of its areal extent. The average magnetite content for the entire iron-formation is probably 10 or 15 per cent. Three or four other narrow bands of iron-formation are indicated by strong magnetic deflection of the compass needle over Wasekwan rocks east of Beaucage Lake.

An outcrop of iron-formation is exposed in the small and isolated area of Wasekwan rocks which is found along the contact between hornblende syenodiorite and the Sickle arenites about ¾ mile east of the southeast bay of Beaucage Lake. No exposures were found of the iron-formation which are probably responsible for the other observed magnetic anomalies. However, outcrops are small and widely scattered in these areas. The various occurrences of iron-formation probably represent an originally continuous band in the Wasekwan arenites which has been greatly disturbed and offset by complex folding and faulting of the enclosing rocks.

Considerable doubt exists as to the age of those rocks designated as Wasekwan arenites on the wide peninsula which separates the southeast bay of Beaucage Lake from the main body of this lake. These rocks are intermediate in composition between arkose and greywacke, and resemble both the Wasekwan and Sickle arenites. However, there is little doubt that the rocks designated as Wasekwan immediately to the north of this peninsula and between Beaucage Lake and the long narrow lake ½ mile to the east belong to the Wasekwan series.

FELDSPATHIC GREYWACKE (1b)

The southwestern portion of the map-area is underlain by homogeneous, moderately well-bedded feldspathic greywacke (Pettijohn) originally assigned by the writer to the Sickle series. It is in contact to the north with the Sickle conglomerate, which was originally mapped by the writer as an inter- (or intra-) formational conglomerate within the Sickle series. This rock is medium grey and has an average grain size of 0.04 to 0.10 millimeters. It is composed predominantly of plagioclase, quartz and biotite, and has a weak foliation parallel to bedding manifested by alignment of tiny flakes of brownish black biotite. Thin section examination shows that this rock is an irregular mosaic of plagioclase, quartz and biotite, with trace quantities of magnetite, garnet and zircon. The biotite is in the form of elongated flakes and laths which contain numerous minute grains of zircon surrounded by pleochroic haloes.

An outcrop of greywacke precisely on the southern boundary of the map-area and approximately 1700 feet east of the western boundary contains many irregular flakes and knots composed of intergrown quartz and muscovite. The knots, about 1/8 inch across, consist of an irregular intergrowth of roughly 50 per cent quartz and 50 per cent muscovite. In addition many muscovite and quartz grains contain scattered needle-like inclusions of sillimanite. Other local areas in the feldspathic greywacke have scattered quartz-muscovite knots, but these are not as well developed as in the outcrop described above. Table 1 gives the mineralogical composition of 3 typical feldspathic greywackes, including one of the knotted variety. Larger and more rounded quartz-muscovite knots are common in the Sickle series (map-unit 9) about 4 miles to the northeast.

TABLE 1

Average composition and range for 3 feldspathic greywackes (1b).

	RANGE	AVERAGE
Plagioclase	50–69%	59%
Quartz	14–32%	22%
Biotite	11–23%	17%
Muscovite (knotted specimen only)	0–4%	—
Garnet	0–Trace	Trace
Zircon	0–½%	Trace
Magnetite	—	Trace

The biotite has presumably formed by the recrystallization of an original chloritic matrix. The rock closely resembles the Sickle arenite (5) except that it is generally somewhat darker in colour because of the higher ferromagnesion content. A comparison (Tables 1 and 4) shows that the ferromagnesian content is 17 per cent for the Wasekwan feldspathic grewyacke and 6.6 per cent for the Sickle arenites (5) and that the ferromagnesian minerals are chiefly biotite in both cases.

It should be noted here that both the Wasekwan feldspathic greywacke (1b) and the adjoining southern band of Sickle conglomerate differ considerably in lithology from their counterparts in the Beaucage Lake area.

CONGLOMERATE (2)

The Wasekwan conglomerate occurs as bands and lenses up to 4000 feet long and 400 feet wide within the Wasekwan arenites. The conglomerate consists of 60 to 65 per cent pebbles. Pebbles are predominantly off-white to light grey, fine-grained quartzite. In some outcrops up to 25 per cent of the pebbles are massive to coarsely granulated grey-white quartz. Scattered pebbles of the gritty arkose described above were noted in many outcrops. The matrix material is fine grained and dark grey to grey-black in colour.

Pebbles vary in shape from subrounded to well rounded. In some places they are almost spherical, and up to 3 inches or more in diameter. In other outcrops pebbles have been strongly deformed, so that they are now rod-shaped, with diameters up to 2 inches, and lengths of 8 to 10 inches. These elongated pebbles usually plunge steeply, and as a result they appear to be almost spherical in shape when viewed in a horizontal outcrop surface.

Thin section examination indicates that the quartzite pebbles consist of more than 95 per cent strained, granular, intergrown quartz. Others resemble vein quartz that has been granulated by intense deformation. The matrix material is a fine-grained, allotriomorphic granular intergrowth of hornblende, plagioclase, biotite and quartz in order of relative abundance. Hornblende is greatly predominant, and the biotite is slightly altered to chlorite. Zoisite and calcite are minor accessories.

Milligan (1951, p. 6) stated that:

> "The Wasekwan conglomerate has been included with some hesitation. It is possible that some occurrences of conglomerate, which have been shown as Wasekwan, are complexly infolded and faulted remnants of the Sickle conglomerate".

After re-examination of the outcrops Milligan (1960, p. 38) later stated:

> "There is now very little doubt that a conglomerate does occur interbedded with the Wasekwan volcanics, though, perhaps, not all the conglomerate east of Beaucage Lake should be so considered".

The present writer concurs that the conglomerate bands and lenses in the Wasekwan rocks are of Wasekwan age. This conglomerate may represent one of the following:

a) a series of conglomerate lenses of variable stratigraphic position interbedded with the Wasekwan rocks;

b) a single discontinuous horizon in the Wasekwan series;

c) a single bed in theWasekwan series which has been complexly folded and faulted with the rest of the Wasekwan rocks.

Detailed mapping would be required to settle this matter.

VOLCANIC ROCKS (3)

Flows of intermediate to mafic lavas with related rocks, up to 1000 feet thick, occur interbedded with the Wasekwan arenites throughout the series east of Beaucage Lake. The present distribution of these volcanic rocks is complicated by extensive folding and faulting. Volcanic rocks comprise less than 15 to 20 per cent of the Wasekwan series east of Beaucage Lake. Milligan (1960, Map No. 7) indicates a relatively large area of predominantly volcanic rocks between the north end of Beaucage Lake and Beatty Creek. Outcrops are sparse in this area, and Milligan's interpretation is the most logical for the outcrops he observed. However, additional outcrops found during the 1961 field season indicate that this area is underlain predominantly by sedimentary rocks belonging to the Wasekwan arenites (1), but containing volcanic interbands.

The volcanic rocks of the Wasekwan series are varable in texture, colour and composition. They are predominantly medium to dark greenish grey to greenish black, and vary in composition from andesite to basalt. Milligan (1951, p.6) describes what he considers to be thin flows of acid lavas having the composition of rhyolite or quartz latite. None of these were observed by the writer, and it is probably that such rocks have been interpreted as metasediments in the present mapping. In any case, such rocks are rare in the map-area.

The majority of Wasekwan volcanic rocks have been metamorphosed to a medium to coarse-grained plagioclase amphibolite. The most highly recrystallized material consists of 70 to 80 per cent fibrous amphibole. In finer-grained phases the fibrous nature of the amphibole is not well developed.

In most outcrops the lavas are almost massive, commonly with distinct flow structure. Foliation is moderately well developed in only a few outcrops. Amygdaloidal flow tops, though not common, were observed by the writer in volcanic rocks along the west shore of the long narrow lake about half a mile east of Beaucage Lake. Milligan (1951, p.5) reports that vesicular flows occur near Lynx River (Beatty Creek).

Thin sections of typical Wasekwan lava show 76 per cent hornblende, 22 per cent plagioclase and 1 per cent magnetite, with traces of quartz, garnet, and calcite. However the hornblende content varies from 20 to 85 per cent and plagioclase from 9 to 75 per cent. Hornblende is pleochroic from light green to dark green or blue green, and generally in the form of irregular to fibrous growth or grains. Plagioclase is normally granular and untwinned, and patchy retrograde saussuritic alteration is common. Garnet constitutes up to 2 per cent of the rock. The quartz content does not exceed 1 or 2 per cent.

Milligan reports plagioclase compositions ranging from An_{35} to An_{45}. Owing to absence of twinning, the writer was able to make positive determinations for only two specimens. These gave An_{35} and An_{54}, corresponding to a composition range of andesite to basalt.

Some volcanic rocks between Beaucage Lake and the long narrow lake one-half mile to the east have the appearance of a conglomerate with elongated pseudo-pebbles up to 2 inches across and 10 to 20 inches long in a garnetiferous volcanic matrix. However, closer examination reveals that the apparent "pebbles" are a fine granular mass of white carbonate; thin sections show calcite, quartz and a lesser mineral having an anomalous Berlin blue birefringence, probably zoisite. The origin of this peculiar rock is not known.

SICKLE SERIES

The Sickle series was named by Norman (1934) from its type locality at Sickle Lake, a few miles north of the present map-area. Norman considered the Sickle series to consist of two units (a) a relatively thin basal conglomerate overlain by (b) a thick sequence of arkosic sediments and greywacke.

In the Watt Lake map-area (east half) Norman (1934) and Downie (1935) show a gradational contact between the Sickle series to the northeast and a more highly metamorphosed "biotite gneiss" or "granulite" phase to the southwest. Their gradational contact is parallel to (and 2 to 3 miles northeast of) the northwest arm of Granville Lake, passing about 1 mile south of Beaucage Lake. However, there is little significant difference between rocks included in the Sickle series by Norman, Downie, Fawley, Milligan and other geologists and the greater part of those rocks which Norman has included in his metamorphic granulite or biotite gneiss and schist phase.

Many of the rocks which constitute Norman's "metamorphic granulite" phase are slightly recrystallized Sickle arenites which retain most of their sedimentary bedding features, including fine crossbedding. Such rocks are generally recrystallized, but no more so than many of the rocks considered by other geologists as Sickle series On the other hand, there definitely is an irregular increase of metamorphic grade in Sickle rocks to the south and west of Beaucage Lake. Some Sickle arenites immediately west of Beaucage Lake consist of fine irregular intergrowth with an average grain size of 0.01 ot 0.03 millimeters; the metamorphic grade corresponds to the chlorite zone of regional metamorphism (quartz-albite-muscovite chlorite subfacies of the greenschist facies). Sickle arenites at the western edge of the map-area (south of the northwest arm of Granville Lake) and also in the south-east are recrystallized to a coarser mosaic (average size 0.15 millimeters or greater) and belong in the sillimanite zone of regional metamorphism as manifested by the appearance of quartz-muscovite-sillimanite knots. In a small area at the east edge of the map-area anatexis has resulted in partial fusion of the original sediments.

Throughout the map-area the degree of recrystallization varies gradationally and somewhat irregularly from place to place within the Sickle arenites and generally it is difficult to represent this on a map. Apart from map-unit 21, Norman's term biotite gneiss and schist cannot be correctly applied to any of the rocks of the Sickle series which occur within the Watt Lake map-area (east half), because the biotite in these rocks occurs only in the form of very tiny flakes which are not well aligned. The rock does not have a schistose or gneissoid foliation or cleavage. The term metamorphic granulite, also used by Norman, might correctly be applied to some portions of map-unit 5 (Sickle arenites) and to map-units 7 (Sickle meta-arkose), 8 (knotted meta-arenite) and 9 (Sickle venite). However, because of ambiguity regarding its meaning, the writer prefers to avoid the use of the term granulite.

Meta-arkose (7), knotted meta-arenite (8), and venite (9), as well as a plagioclase amphibolite of probably volcanic origin (6) are all part of the Sickle series. Norman (1934) suggests that the plagioclase amphibolite band may be an upfolded or upfaulted band of pre-Sickle rocks, but this interpretation is incorrect and the meta-arkose and plagioclase amphibolite are actually an integral part of the Sickle series which had not been recognized as such prior to the mapping of the Watt Lake area. In addition to the three previously undifferentiated Sickle map-units, Norman has also included the portion of the Wasekwan series (1b) at the southwest corner of the area in his metamorphic phase derived from Sickle rocks.

CONGLOMERATE (4)

Conglomerate is found at the base of the Sickle series at Beaucage Lake and along the southern shore of Granville Lake. At Beaucage Lake the conglomerate varies in thickness from 25 to 1000 feet or more, with an average of about 500 feet. Pronounced stretching of pebbles, and shearing of the matrix suggests that deformation has probably modified the original thickness.

At Beaucage Lake the Sickle conglomerate normally consists of 30 to 60 per cent pebbles in a fine-grained grey to greenish grey arkosic matrix. Pebbles are rounded from 1 inch to 3 inches across on horizontal outcrop surfaces, but a few pebbles exceed 6 inches in diameter. They consist of fine-grained, greyish pink granite, white quartz and white to dark grey quartzite in that order of abundance, with a few pebbles of dark grey felsite. On the weathered surface the conglomerate is reddish grey to reddish green. Most pebbles are stretched with long axes pitching steeply in the plane of foliation, but they range in shape almost spherical to ellipsoidal with lengths 20 times their widths. Many pebbles are also slightly flattened parallel to bedding. Commonly the arenaceous matrix has developed foliation parallel to the bedding. Quartz pebbles are only slightly elongated, granite and quartzite pebbles much more so.

A band of Sickle conglomerate approximately 800 feet thick is found near the southwest corner of the map-area, striking parallel to the south shore of Granville Lake and dipping 30 to 60 degrees south. The conglomerate is composed of up to 70 per cent light grey pebbles ranging in composition from subarkose to arkose in a greywacke matrix. The pebbles are greatly elongated with long axes plunging 18 to 38 degrees in a direction S 15° E. A few pebbles are as large as 4 inches by 12 inches in horizontal section, but the great majority are less than 2 inches across.

The ratio of the short, intermediate, and long axes varies from 1:3:5 to 1:3:10. Mineralogical composition of two typical pebbles are estimated in table 2.

TABLE 2

Mineralogical Composition of Pebbles in the Sickle Conglomerate (4).

	SPECIMEN NUMBER	
	C61–1165	C61-1171
Quartz	57%	58%
Plagioclase	38%	38%
Biotite	5%	Nil
Amphibole	Nil	2%
Muscovite	Nil	2%
Magnetite	Nil	Trace

Thin sections show the matrix material as fine-grained, medium grey, feldspathic greywacke, (table 3).

TABLE 3

Mineralogical Composition of the Matrix of the Sickle Conglomerate (4)

	SPECIMEN NUMBER	
	C61–1165	C61–1171
Quartz	62%	31%
Plagioclase	23%	57%
Biotite	15%	12%
Muscovite	Trace	1%
Magnetite	Nil	Trace
Zircon	Trace	Nil
Apatite	Trace	Trace

Both pebbles and matrix consist of fine, granular intergrowths. Scattered quartz-muscovite knots were observed in the conglomerate matrix in two outcrops. Norman (1934, p. 33c) describes this band as biotite gneiss derived from a fragmental rock. However, within the present map-area this rock has every appearance of conglomerate, with stretched pebbles as in the Sickle conglomerate at Beaucage Lake. Norman suggests the possibility that the conglomerate band may represent the highly metamorphosed equivalent of the Sickle conglomerate. The present writer concurs that this is the Sickle conglomerate, overturned to the north.

NATURE OF THE CONTACT BETWEEN THE WASEKWAN AND SICKLE SERIES

The contact between the Wasekwan feldspathic greywacke and the Sickle conglomerate in the southwest was observed in one outcrop, 4800 feet east of the western map boundary. The contact is gradational over a distance of 2 or 3 feet from a Wasekwan feldspathic greywacke with scattered quartz-muscovite knots to Sickle conglomerate with identical quartz-muscovite knots.

Because of the remarkably similar appearance of the Wasekwan feldspathic greywacke and the Sickle conglomerate matrix, the unconformity (if such exists) was not located. More detailed study of this outcrop might yield critical evidence as to the possibility of an unconformity, but no angular discordance or disconformity and no significant contrast in deformation or metamorphism was observed. At Beaucage Lake, on the other hand, there is a sharp increase in deformation, and a distinct change in lithology on passing from the Sickle to the Wasekwan series; Milligan (1960, p. 82-83) describes an angular discordance (not observed by the writer) of approximately 30 degrees between the Sickle series and the Wasekwan rocks to the east. He states:

> "... at the contact, the Sickle shows a strong development of muscovite and is quite schistose; there is a strong possibility that this represents movement at the contact. Thus an angular discordance might be produced by means other than folding and subsequent deposition".

During the present mapping it was observed that the Sickle arenite (5) is moderately to strongly sheared for a continuous distance of 3 miles along the east shore of Beaucage Lake, and faulting along the Wasekwan-Sickle contact seems a very distinct possibility, particularly because the Sickle conglomerate is apparently missing at the exposure described by Milligan. Hence this exposure neither proves nor disproves the existence of an angular unconformity between the Wasekwan and Sickle series. The nature of the Wasekwan-Sickle contact at Beaucage Lake has also been obscured by the intrusion of a wide sill of Black Trout diorite.

ARENITES AND META-ARENITES (5)

Fine-grained Sickle arenites and corresponding meta-arenites underlie three-quarters of the map-area. They are normally well bedded with individual beds varying in thickness from a fraction of an inch to 3 or 4 inches and rarely as much as 1 foot. Bedding planes are commonly marked by paper-thin layers of fine biotite. Fine crossbedding is commonly found west of Beaucage Lake, particularly in the finest silty beds. In this vicinity the beds dip steeply east with the tops facing west. Crossbedding is rarely visible elsewhere but has probably been obliterated by recrystallization.

The Sickle arenites consist of a thick sequence of metamorphosed, predominantly fine-grained sedimentary rocks probably gradational in composition between impure arkose and feldspathic greywacke. The rocks called Sickle arenites by the writer have in the past been referred to in various parts of the Lynn Lake area as arkose, greywacke, sandstone, feldspathic quartzite, impure quartzite and quartzite. This multiplicity of rock names indicates the problem of precise classification of the rocks involved, insofar as the rocks of unit 5 are remarkably homogeneous in composition and appearance. Milligan (1960, p. 90, Beaucage Lake) describes rocks consisting predominantly of quartz and various feldspars (orthoclase, microcline, andesine and oligoclase) with minor biotite, magnetite and garnet. He concludes that such rocks were originally arkoses or protoquartzites.

A total of 29 thin sections of Sickle arenites were examined by the writer (Table 4). Two of the specimens were too fine grained for distinction of feldspar from quartz; these contained 85 per cent combined quartz plus feldspar. Otherwise, the average quartz content (26 per cent) is considerably lower than Milligan's estimates. Hence the terms, impure arkose, arkose, and greywacke are preferable to quartzite in the Watt Lake area, according to the classification of Pettijohn (1957, p. 283-339).

TABLE 4

Estimated mineralogical composition of 29 Sickle arenites.

	RANGE	AVERAGE
Plagioclase	41–70%	59%
Quartz	10–50%	26%
Biotite	1–12%	5.5%
Microcline	tr–14%	3.1%
Hornblende	0–8%	1.1%
Magnetite	0–6%	2.2%
Muscovite	tr–8%	1.9%
Chlorite	0–3%	
Apatite	0–1%	tr
Carbonate	0–tr	tr
Sphene	0–tr	tr
Zircon	0–tr	tr
Total Ferromagneisian minerals plus magnetite	1.5–19%	8.8%

Sickle arenites are predominantly grey, weathering to reddish grey and buff. They are remarkably uniform in texture, colour and composition through an apparent stratigraphic thickness of many thousands of feet. In the area adjacent to, and up to one mile west of Beaucage Lake, the Sickle arenites have been subjected to only low grade metamorphism; they are grey, extremely fine-grained, silty, impure arkose or feldspathic greywacke, showing little evidence of recrystallization. A typical specimen has an average grain size of less than 0.02 millimeters (maximum 0.2 millimeters) and consists of irregular detrital grains (75% of the rock) of calcic albite and quartz, and a little microcline, in an extremely fine matrix of albite, quartz, sericite, chlorite, magnetite and calcite with rare zircon. Actinolite and epidote are present in some specimens. Much of the chlorite shows incipient alteration to biotite, so that the rock lies in the upper chlorite zone or lower biotite zone of regional metamorphism. Fifty per cent of the rock consists of coarse plagioclase fragments, 25 per cent quartz, and 3 per cent microcline; the remainder of the rock is the much finer-grained interstitial material. No rock fragments were observed in thin sections and the term greywacke siltstone, or impure arkosic siltstone seems appropriate (Pettijohn, 1957, p. 20). It is also notable that the rocks immediately west of Beaucage Lake show no preferred orientation of mica flakes, in contrast to recrystallized Sickle arenites common elsewhere in map-area. Delicate crossbedding is thus preserved only in this area of low grade metamorphism.

Throughout most of the map-area the Sickle arenites are recrystallized and coarser grained than those described above, but bedding is generally well preserved. With increasing metamorphism, biotite appears and constitutes several per cent of most Sickle arenites. A characteristic texture results from the uniform distribution of tiny biotite flakes through an equally fine-grained quartzo-feldspathic matrix. Alignment of the mica flakes usually parallels bedding planes, but locally, micaceous foliation cuts the bedding. This is best seen immediately east of the southeast end of the Granville Lake gabbro intrusion.

Despite the rather uniform mineralogical composition and gross general appearance of the rocks of map-unit 5, minor but fairly distinctive variations in colour, texture, and degree of recrystallization of these rocks can be distinguished in the Watt Lake area. These variations are generally characteristic of areas up to several square miles in extent. It should be emphasized that the distribution of the various phases is somewhat irregular; hence the following descriptions of these phases and their distribution represents only the gross lithologic features of large areas rather than detailed descriptions of individual outcrops.

In the area between the northwest arm of Granville Lake, the western and northern boundaries of the map-area, Chicken Lake, Deane Lake, and Kilgour Lake the rocks are medium grey with average grain size less than 0.04 millimeters (maximum 0.25 millimeters). Hand specimens show distinct strong parallel micaceous foliation, best seen 2½ miles south of Beaucage Lake, and at the south end of Chicken Lake. Microscopically the rocks show a granular mosaic of plagioclase and lesser quartz, with 3 to 10 per cent aligned biotite and lesser muscovite laths. Microcline, magnetite and apatite are present as accessory minerals. The fragmental nature of the original arkosic greywacke has been largely obliterated by recrystallization Crossbedding was recognized in only one outcrop, about 2000 feet west of the northwest corner of the map-area (dip 67° west, tops facing east).

Another phase of pale grey to buff grey arenites is found in the area between the long narrow lake immediately southwest of the Granville Lake gabbro, the northwest arm of Granville Lake, the west boundary of the map-area, and the large fingering sill of Black Trout diorite in the southwest part of the map-area. Similar rocks occur on the 2 mile-long peninsula on the north shore of the northwest arm of Granville Lake southeast of the gabbro intrusion, and extend eastward to Beatty Creek, about 2 or 3 miles to the east of the peninsula. These rocks are thoroughly recrystallized to a granular mosaic of average grain size varying from 0.04 to 0.20 millimeters and generaly coarser than 0.07 millimeters. They contain aligned biotite and muscovite flakes up to 2 millimeters lomg, with the alignment less obvious than in the arenites near Chicken Lake. Original bedding is clearly preserved in outcrop and hand specimen.

Immediately adjacent to map-unit 8 (knotted meta-arenite) the Sickle arenite is strongly recrystallized to a granular mosaic with average grain size 0.15 to 0.20 millimeters. The rock has a well-developed "salt and pepper" texture caused by parallel mica flakes up to 1.5 millimeters in length. The coarser beds are usually well preserved. Scattered quartz-muscovite knots up to ¼ inch across are found in a few outcrops.

East of the junction between Beatty Creek and Granville Lake, the strongly recrystallized Sickle arenite consists of a relatively coarse mosaic of untwinned plagioclase (60%), quartz (25%), biotite (6%), microcline (5%), muscovite (2%) and magnetite (1%) and rare zircon in biotite. These rocks grade into venite (map-unit 9) derived from the Sickle arenite by partial anatexis.

The sill-like intrusion of Black Trout diorite which cuts across the southern portion of the map-area defines an approximate metamorphic boundary. North of this sill recrystallization of the Sickle arenites has been more pronounced than to the south. The arenites of map-unit 5, between this sill and the meta-arkose (7) to the south, are slightly darker grey than those to the north; in addition to the normal minerals, specimens from this locality contain up to 5 per cent hornblende, lesser tremolite-actinolite, and epidote, as well as minor calcite. These minerals occur as fine, green, calc-silicate bands up to ½ inch thick, parallel to indistinct bedding planes, and also as irregular disseminated grains. The calc-silicate rocks are best seen on water-washed outcrops along the mainland and island shorelines south of the diorite and almost impossible to distinguish inland. Average grain size varies from 0.05 to greater than 0.10 millimeters.

Sickle arenites in the southwest, between the Sickle conglomerate (4) and the Sickle volcanic rocks (6), consist of a recrystallized granular mosaic (average grain size 0.05 to 0.10 millimeters). A typical specimen is composed of 60 per cent oligoclase, 25 per cent quartz, 8 per cent biotite, 5 per cent microcline, 1 per cent muscovite, 1 per cent magnetite and a trace of apatite. A few peculiarly flat quartz-muscovite knots, not found elsewhere, were observed in these rocks on the south shore of the 2 mile-long island which consists primarily of Sickle volcanic rocks.

Three or four 6-inch beds of an angular intraformational conglomerate or breccia were observed in the area between Beaucage Lake and the western boundary of the map-area. The pebbles or fragments are fine-grained siltstone or slightly recrystallized argillite, medium to dark grey in colour. Under the microscope a typical fragment shows a very fine inter-growth of plagioclase (60%), biotite (20%), quartz (11%), magnetite (6%), and white mica (3%). The matrix of the breccia is fine-grained, but considerably coarser than the constituent minerals of the fragments and has the following composition: plagioclase (60%), quartz (25%), biotite (12%), muscovite (2%) and magnetite (1%).

Rare 6-inch to 1-foot beds of "argillite", similar to the fragments described above, were observed locally throughout the map-area, mainly in the relatively unmetamorphosed rocks north of Granville Lake.

The contact between the Sickle conglomerate and the overlying Sickle arenites is best exposed 400 feet to the east of the small lake which cuts the northern boundary of the map-area about 9500 feet directly northwest of Beaucage Lake. There the contact is sharp, with the transition from typical basal conglomerate to typical thinly bedded fine-grained Sickle arenite taking place across a distance of less than 2 feet. The arenite is slightly sheared, but there is no indication of actual faulting along the contact. The same contact is exposed in at least 3 localities along the east shore of Beaucage Lake, but there the overlying Sickle arenites have been highly sheared so that they are now well-developed plagioclase-quartz-muscovite schists; hence faulting is a distinct possibility at this locality.

VOLCANIC ROCKS (6)

A band of plagioclase amphibolite is exposed on the long narrow island in the southwest corner of the map-area. The band is 500 to 1000 feet thick and dips 35 to 45 degrees to the southwest. In hand specimen the rock appears to be weakly foliated grey-green andesite or basalt. The foliation is the result of a planar orientation of tiny elongate hornblende crystals and grains. Four thin sections show a fine-grained intergrowth of plagioclase, hornblende and lesser quartz, with accessory magnetite and a few microscopic euhedral garnets. Plagioclase (identified in one thin section as An_{50}) is unaltered, and contains dusty inclusions of an unidentified black opaque mineral. Hornblende occurs as anhedral to euhedral grains, pleochroic from light to dark olive-green. Quartz and magnetite grains are irregular in shape. Only one thin section contained biotite (1%). The estimated composition is summarized as follows:

Plagioclase	43–49%
Hornblende	40–45%
Quartz	7–11%
Magnetite	0–2%
Biotite	0–1%
Garnet	0–Trace

Norman (1934, p. 33c) describes the band of plagioclase amphibolite as follows:

> "A band of basic, green hornblende gneiss follows the south shore of Granville Lake. Well-preserved pillow structures are present in this band and it is clearly derived from basic lava. It is in part banded and in part massive, and is composed of hornblende, andesine, and biotite. Occasional pyroxene rich bands with titanite are present. Its lithology suggests that it is an upfolded or up-faulted band of pre-Sickle rocks but definite proof that it belongs to this group is lacking".

G. S. Barry of the Mines Branch (personal communication, September, 1964) reports pillow structures within the band, and in one outcrop the writer observed a 10-foot layer of irregular volcanic fragments, up to 1 inch across, enclosed in a slightly paler groundmass. This bed is apparently a pyroclastic breccia, which supports a volcanic origin for the plagioclase amphibolite. In one outcrop, near the east end of the long island, a contact between Sickle arenites and plagioclase amphibolite is marked by a series of 1/8-inch to 2-inch interbeds of both rock types, suggesting that part of the plagioclase amphibolite is a metamorphosed tuffaceous sediment.

The exposed contacts of the plagioclase amphibolite band are gradational, and interbedded across a distance of 4 to 5 feet with the Sickle arenites. There is no sign of faulting along the contacts to indicate an up-folded or up-faulted band of pre-Sickle lava as suggested by Norman. There is evidence, however, that the plagioclase amphibolite represents volcanic activity during the deposition of the Sickle series. Evidence of such volcanic activity during Sickle time has not previously been reported. The plagioclase amphibolite band appears to have been deposited near the base of the Sickle series and must wedge out to the north, as it does not appear at Beaucage Lake.

META-ARKOSE, GRANITOID META-ARKOSE AND RELATED ROCKS (7)

Rocks believed to have been derived from arkosic sediments of the Sickle series are found immediately north of the Sickle volcanic rocks (6) in the southwest. The rocks included in map-unit 7 are variable in composition and appearance, and distinctly different in composition, texture and overall appearance from the Sickle arenites of map-unit 5. The predominant rock type is highly variable, greyish pink fine-grained meta-arkose, which in some outcrops contains flattened quartz-muscovite knots up to ¾ inch in length. A typical specimen of this meta-arkose has the following estimated composition: quartz 54 per cent, plagioclase 24 per cent, microcline 17 per cent, biotite 3 per cent, magnetite 2 per cent, quartz-muscovite knots 2 per cent. The rocks has a grain size of 0.4 millimeters. The arkose is considerably richer in quartz and muscovite than the average arenite. Outcrops are commonly cut by small irregular granitic bodies. Some outcrops show *lit-par-lit* migmatite; other outcrops are best described as granitoid arkose and granitoid paragneiss.

The arkosic material locally contains interbeds (1–50 feet thick) of quartzo-feldspathic grit consisting predominantly (90%) of angular quartz grains (1 mm to 3 mm), with minor plagioclase and microcline grains; muscovite, biotite, and magnetite are accessory minerals.

A few small outcrops near the western boundary consist of meta-arkose or granitoid paragneiss, interbedded with similar rocks consisting of quartz, muscovite (as much as 60 per cent), and minor oligoclase. Accessory sillimanite is commonly found in the quartz-muscovite beds, which locally constitute up to 30 per cent of some outcrops.

The relatively large amount of granitic material included in this map-unit may have resulted from partial melting of the arkose and injection of the granitic material thus formed. Meta-arkose found about 1½ miles south of the southeast corner of the map-area is similar to the typical specimen described above, but lacks the granitic material which characterizes the meta-arkose near the western boundary of the area. It is probable that the two occurences are part of the same meta-arkose formation which underlies the southern portion of Granville Lake, and is therefore not exposed over the distance of 7 miles between these two locations.

The contact between the meta-arkose and the Sickle volcanic rocks is exposed at the west end of the island near the southwest corner of the map-area. There, the contact is gradational from dark green tuffaceous sediments to greyish orange meta-arkose across a distance of 4 or 5 feet. Passing from tuffaceous volcanic rocks to meta-arkose, the rock becomes progressively lighter in colour, with interbeds ½ inch to 2 inches thick, of light-coloured meta-arkose and dark grey-green tuffaceous sediment, A few ½ inch beds of tuffaceous material contain numerous 1/8 inch reddish brown garnets. The depositional sequence from mafic lavas and agglomerates to tuffaceous sediments and then to arkosic sediments is thus transitional, with no evident hiatus.

After deposition of the arkosic and quartzitic clastic sediments there must have been a sharp change in sedimentation, at which time the extensive fine-grained Sickle arenites (5) were laid down. Similar sediments had been deposited over the Sickle conglomerate preceding the period of Sickle volcanism. The northern contact between the arkosic rocks of map-unit 7 and the arenites of map-unit 5 is not exposed. However, about 1300 feet east of the west boundary of the area two outcrops about 300 feet apart on the shoreline of Granville Lake define the contact between the Sickle arkose (7) and the more predominant Sickle arenites (5).

KNOTTED META-ARENITE (8)

A knotted variety of Sickle meta-arenite underlies two separate areas totalling 15 to 20 square miles in the south-central portion of the map-area, respectively north and south of the northwest arm of Granville Lake. The rock contains approximately 5 per cent muscovite-quartz knots enclosing microscopic sillimanite. Knots are ellipsoidal in shape and up to ¾ inch across. The knotted meta-arenite is derived through metamorphism from the less recrystallized arenites of unit 5. Knots stand out as rounded knobs on the weathered surface.

The fine-grained rock matrix represents recrystallized arkosic greywacke with speckled appearance due to parallel alignment of tiny mica flakes. Average grain size varies from 0.15 to 0.25 millimeters. Despite the extensive recrystallization, remnant sedimentary bedding can invariably be discerned.

Knots consist of 60 to 80 per cent muscovite, and 20 to 40 per cent quartz, usually in an intergrowth in which grain boundaries are rounded and muscovite grains contain many rounded inclusions of quartz. In some knots muscovite is crystallographically continuous throughout the knot, though twisted and contorted. Sillimanite occurs only in the knots, as tiny microscopic needles and clusters of needles in quartz and less commonly in muscovite, and constitutes no more than 1 per cent of the knots. Sillimanite needles seldom exceed 1 or 2 millimeters long and 0.004 millimeter wide.

A few outcrops contain rare anhedral, irregularly shaped, porphyroblasts of pinkish orange microcline up to 3/8 inch across, containing many remnant inclusions of the associated minerals but excluding sillimanite.

The compositional range of 7 thin sections of knotted Sickle meta-arenite (matrix only) is given in Table 5.

TABLE 5

Estimated Mineralogical Composition of the Matrix Material for 7 Thin Sections of Knotted Meta-arenites (8):

	RANGE	AVERAGE
Plagioclase	48–72%	59%
Quartz	16–29%	25%
Biotite	2–8%	5.1%
Microcline	2–17%	6.6%
Muscovite	1–5%	2.6%
Magnetite	1–2%	1.5%
Apatite	Tr–1%	Tr
Zircon	0–Tr	Tr

The above figures include one unusual thin section which contains 17 per cent microcline; otherwise, the microcline content would average 4.5 per cent, plagioclase 61 per cent and quartz 25 per cent.

Overall rock composition (including the knots) differs only slightly from that indicated by the table. Comparison of the average Sickle knotted meta-arenite (8) given above with the average Sickle arenite (map-unit 5, Table 4) indicates little significant compositonal difference between the rocks of the two map-units, except for an apparent slightly higher content of muscovite and microcline in the knotted variety.

Various origins have been proposed for similar knots in adjacent map areas by Milligan (1960), Barry (1965), and by Godard (1966). This problem is further discussed under metamorphism.

VENITE (9)

Venite occurs in an area slightly greater than 1 square mile at the east boundary of the map-area about 3 miles east of the mouth of Beatty Creek; it grades to the south and west into strongly recrystallized Sickle arenites, and has apparently formed by partial anatexis of these rocks. Typical outcrops consist of strongly recrystallized, grey-pink Sickle arenites impregnated with a network of irregular veinlets (up to 3 inches wide) of fine-to medium-grained pinkish granodiorite. The granodiorite varies in composition and texture, and merges imperceptibly into the meta-sedimentary rocks Granodiorite may comprise up to 50 per cent of some venite outcrops but probably averages 10 to 25 per cent; both massive and pegmatitic phases occur.

A typical specimen of granodiorite with a small amount of remanent sedimentary material consists of 60 per cent plagioclase, 20 per cent quartz, 13 per cent microcline, 5 per cent biotite, 1 per cent muscovite, 1 per cent magnetite, with trace zircon. The plagioclase is oligoclase (An_{16}) with a fairly well-developed (010) polysynthetic twinning. The granodiorite is considerably richer in potash feldspar than typical Sickle arenite, and the remnants of arenite are depleted in potash feldspar. This is consistent with the probable anatectic origin of the venite.

The venite phase grades into meta-arenite across a distance as great as 2000 feet, and the degree of recrystallization of the meta-arenite decreases away from the venite zone.

BLACK TROUT DIORITE (10)

Diorite mapped by Fawley (1949) at Black Trout Lake is continuous with that mapped near Beaucage Lake by Milligan and the present writer. Similar diorite has been mapped by the Manitoba Mines Branch (Fawley 1949, 1952, Milligan 1960; and others) northwest towards Lynn Lake.

Other occurrences of Black Trout diorte, now mapped by the writer in the Watt Lake area, comprise an extensive sill complex extending from the west boundary to the southeast corner of the area. This sill has a maximum width of 3000 feet in the west, narrows to less than 100 feet in the southeast, and has a total length of 12 miles within the map-area. It extends beyond the boundaries of the Watt Lake area to the northwest and southeast.

A smaller elliptical intrusion, about ½ mile long and 1000 feet wide, was mapped 3 miles east of the mouth of Beatty Creek. Another outcrop was noted on the largest sland in Beaucage Lake and other small intrusions are included in the area of mixed rocks 3 miles east of the south end of this lake.

The diorite usually occurs as sill-like bodies at various horizons in the Sickle arenites (5), but occasional dyke-like bodies are also found. Around Beaucage Lake and elsewhere, the diorite forms high ridges; contacts with the enclosing Sickle sediments are marked by steep hill slopes.

The diorite near Beaucage Lake is predominantly massive, but weak foliation is developed within 100 to 200 feet of its contacts. The extensive sill in the south shows weak foliation parallel to the bedding in the adjacent Sickle arenites. On the largest island, 2½ miles northeast of Pickerel Narrows, where this sill has a width of 70 feet, the diorite has chilled margins in contact with the Sickle arenite.

In hand specimen, the diorite is slightly weathered, brownish black, with a speckled appearance caused by tiny lens-like concentrations of greyish feldspar that are most pronounced in the foliated varieties. Microscopically, Black Trout diorite is a fine- to medium-grained, allotriomorphic granular intergrowth of plagioclase, biotite, hornblende and quartz, with accessory magnetite, apatite, and sphene, and rare zircon and carbonate. Hornblende is pleochroic from olive-green to bluish olive-green. Biotite is brown and pleochroic. Apatite is common as subhedral to euhedral rods and grains. Sphene occurs as granular aggregates and euhedral grains surrounding irregular grains of magnetite. Biotite is weakly aligned. Zircon occurs as minute grains surrounded by pleochroic haloes in biotite. Table 6 gives the estimated range in mineralogical composition for 10 thin sections from various localities in the map-area.

TABLE 6

Range and Average Composition of Black Trout Diorite (10).:

MINERAL CONSTITUENT	RANGE IN COMPOSITION	AVERAGE COMPOSITION
Plagioclase	47–69% (An_{36} to An_{47})	57% (An_{39})
Quartz	5–20%	12%
Biotite	5–20%	14%
Hornblende	0–30%	11%
Biotite and Hornbende	18–40%	25%
Magnetite	0–6%	2%
Apatite	1–4%	2%
Sphene	Tr–4%	2%
Zircon	0–Tr	Tr
Carbonate	0–Tr	Tr

The diorite intrudes both the Wasekwan and the Sickle series and is cut by pegmatite. Its age relations with hornblende syenodiorite (12), porphyritic quartz monzonite (13), and pink granodiorite (14) are not known.

Fawley (1950) and Milligan (1951) both considered that the Black Trout diorite was probably intruded after the main folding of the Sickle series. No conclusive evidence for this was observed by the present writer.

GRANITIC ROCKS EAST OF BEAUCAGE LAKE

An extensive area to the east and southeast of Beaucage Lake is underlain by a large intrusive body of granitic rocks, which was mapped by Milligan (1951, 1960) as "granite and related rocks", and which extends an unknown distance to the east. In the present work, the granitic mass was subdivided into three distinct mappable varieties. These three varieties are hornblende syenodiorite (11), porphyritic quartz monzonite (12), and pink granodiorite (13).

HORNBLENDE SYENODIORITE (11)

Hornblende syenodiorite occurs in the east, generally as a band from 800 to 4000 feet in width, situated between porphyritic quartz monzonite (12) and pink granodiorite (13), and rocks of the Wasekwan and Sickle series. Hornblende syenodiorite has a uniform orange-pink colour and is fine to medium-grained. Faint foliation and lineation is imparted by greenish black hornblende. The mineralogical composition is approximately: plagioclase (An_{15}–An_{22}) 70 per cent, microcline 20 per cent, hornblende 5 per cent, quartz 3 per cent, sphene 1 per cent, with trace amounts of magnetite, epidote, biotite and apatite; the texture is allotriomorphic granular. Plagioclase is well twinned, unaltered and of constant composition in any individual specimen. Hornblende is pleochroic from grass-green to slightly bluish green. Microcline shows well-developed gridiron twinning, and appears to have crystallized slightly later than plagioclase. Quartz is faintly strained. Sphene occurs as small subhedral grains scattered throughout the rock.

This unit contains a few melanocratic areas, up to several hundred feet across, which are pinkish grey in colour and have an abnormally high content of hornblende (15%) and biotite (5%).

PORPHYRITIC QUARTZ MONZONITE (12)

Porphyritic quartz monzonite occurs as a uniform body, about 4 square miles in area, east of Beaucage Lake and as three small bodies south of the main intrusion. It is closely associated with hornblende syenodiorite and pink granodiorite.

Porphyritic quartz monzonite has a medium grey-orange colour, and is medium grained, with 15 to 20 per cent (rarely 10 per cent) tabular, pinkish grey microcline phenocrysts up to 2 centimeters in length.

Most of the rock is quartz monzonite with a relatively low potash feldspar content, but grades to a granodiorite comparatively rich in potash feldspar. The greater portion of the feldspar occurs as phenocrysts.

The average mineral content of porphyritic quartz monzonite is plagioclase (An_{16}–An_{19}) 45 per cent, microcline 30 per cent, quartz 20 to 25 per cent, hornblende 2 per cent, with minor biotite, magnetite, sphene, and apatite. The texture is allotriomorphic granular. Plagioclase grains are mainly in the form of phenocrysts, but much of the microcline occurs in the groundmass. Microcline phenocrysts contain numerous tiny inclusions of plagioclase, quartz and the accessory minerals. Hornblende is pleochroic from green to blue-green.

PINK GRANODIORITE (13)

Pink granodiorite covers an area of several square miles along the eastern edge of the map-area. It is massive and medium grained, with a pale pinkish orange colour imparted by feldspar. Generally, the granodiorite has no discernible gneissosity or foliation, but at the south end of Beatty Lake and ¾ mile further south it has a strong gneissic foliation.

Thin sections show the granodiorite to consist of a medium-grained allotriomorphic granular intergrowth of plagioclase, quartz, and microcline, with accessory biotite, hornblende, magnetite, apatite and sphene. The observed range in mineralogical composition is:

Plagioclase	50–55% (An_{10} to An_{15})
Quartz	23–35%
Microcline	15–25%
Biotite and hornblende	0–1%
Magnetite, sphene and apatite	trace

Plagioclase shows well-developed albite twinning and faint normal zoning. Quartz is slightly strained, and microcline has well-develpoed gridiron twinning. Biotite is pleochroic from light to dark brown and hornblende from grass-green to blue-green.

CONTACT RELATIONS OF THE GRANITIC ROCKS EAST OF BEAUCAGE LAKE

It is likely that the three granitic rock types east of Beaucage Lake are of approximately similar ages. The probable sequence is hornblende syenodiorite (11), porphyritic quartz monzonite (12) and pink granodiorite (13). The evidence is as follows:

1. Contacts between porphyritic quartz monzonite and hornblende syenodiorite are gradational, and similar microcline phenocrysts occur in both rocks near the contact zone.

2. In the mixed rocks (14a) north of Beaucage Lake, hornblende syenodiorite (11) occurs as xenolithic blocks in pink granodiorite (13). These blocks vary in size from less than one foot to as large as 15 feet across. The foliation in all blocks is parallel, and hence it is inferred that they have undergone little or no rotation. Elsewhere, contacts between hornblende syenodiorite and pink granodiorite appear to be gradational.

3. Contact relations between porphyritic quartz monzonite (12) and pink granodiorite (13) were not observed.

MIXED ROCKS (14)

Mixed rocks east of Beaucage Lake were mapped from north to south as map-units 14a, 14b and 14c.

Map-unit 14a lies along Beatty Creek near the north boundary of the area, and consists of a complex mixture of Wasekwan sedimentary and volcanic rocks (1a, 3), hornblende syenodiorite (11), and pink granodiorite (13).

Map-unit 14b, located about two miles east of Beaucage Lake, consists of mixed Wasekwan sediments (1a), hornblende syenodiorite (11), and pink granodiorite (13).

Map-unit 14c, about 3½ miles southeast of Beaucage Lake, consists of mixed Wasekwan sedimentary and volcanic rocks (1a, 3), Sickle arenites (5), Black Trout diorite (10), hornblende syenodiorite (11), and pink granodiorite (13).

Because of complex intrusive relations, detailed mapping would be required to differentiate the various rock types of these map-units.

GRANITIC COMPLEX

In the southeast, adjacent to Granville Lake, a granitic complex composed of grey granodiorite (15), *lit-par-lit* gneiss (16), and pegmatite (17) occupies 4 square miles within the map-area, and extends an unknown distance to the east. It forms an anticlinal core in recrystallized Sickle meta-arenite. The central core of granodiorite is rimmed by a concentric band of *lit-par-lit* gneiss, which is enclosed by a coarse pegmatitic band containing numerous remnants of the meta-arenite.

GREY GRANODIORITE (15)

The grey granodiorite is a fine-grained, light grey rock composed of grey feldspar and quartz, with evenly disseminated biotite which imparts a faint foliation. The outer 1/4 to 3/8 inch of the exposed rock surface is weathered to a pale buff-grey colour.

Thin sections show an allotriomorphic intergrowth of plagioclase, quartz, and microcline, with lesser biotite, and accessory zircon, apatite and clinozoisite.

The quartz and feldspar have rounded interlocking grain boundaries. Biotite occurs as laths and rounded patches, with rare zircon. Plagioclase has sharply defined albite twinning. Microcline shows polysynthetic twinning, and quartz is slightly strained. The estimated range in composition is:

Plagioclase	55–70% (An_{15} to An_{18})
Quartz	25–35%
Microcline	3–7%
Biotite	2–4%
Zircon	Trace
Apatite	Nil to Trace
Clinozoisite	Nil to Trace

Grey granodiorite (15) differs from pink grandiorite (13) in texture and in the much lower microcline and higher plagioclase content grey of granodiorite.

MIGMATITIC LIT-PAR-LIT GNEISS (16)

The gneiss occurs as a band 500 to 3000 feet in width, surrounding the grey granodiorite. It consists of fine-grained, grey, biotitic quartzo-feldspathic layers, with 40 to 60 per cent granitic material introduced as pink irregular layers (¼ inch) and augen like lenses. The augen and lenses are fine-grained aggregates of quartz and pink feldspar, with the composition of alaskite.

The overall composition of the gneiss ranges from quartz monzonite to granodiorite depending on the relative proportion of introduced potash feldspar. Estimated composition of two representative thin sections containing respectively 35 per cent and 60 per cent introduced material are given in Table 7.

TABLE 7

Composition of Migmatitic Gneiss (16)

Mineral	Composition of Gneiss with 35% Introduced Material	Composition of Gneiss with 60% Introduced Material	Approximate Average *Lit-par-lit* Gneiss
Plagioclase	55% (An_{17})	32% (An_{19})	44%
Quartz	25%	35%	30%
Microcline	17%	30%	24%
Biotite	3%	3%	3%
Garnet	Nil	Tr	Tr
Zircon	Tr	Tr	Tr
Apatite	Tr	Tr	Tr
Muscovite	Nil	Tr	Tr

Mineralogical compositions in Table 7 indicate that the more highly granitized *lit-par-lit* gneiss is richer in microcline and poorer in plagioclase than the less granitized variety. These variations would be expected if potassium-rich alaskite was introduced into the Sickle arenite to form the *lit-par-lit* gneiss.

Field evidence also indicates that *lit-par-lit* gneiss formed as the result of extensive recrystallization and granitization of an originally well-bedded Sickle meta-greywacke, with granitic material introduced along bedding planes. The original Sickle arenite has undergone metasomatic "soaking" and strong recrystallization so that boundaries between granitic and meta-sedimentary foliae are indistinct and gradational.

PEGMATITE WITH SICKLE INCLUSIONS (17)

The outermost zone of the granitic complex is a band of pegmatite with meta-sedimentary inclusions, varying in thickness from 1000 to 4000 feet, but generally about 2500 feet. It consists of coarse pegmatite, with large remnants of strongly recrystallized well-bedded Sickle arenite. These inclusions have been extensively invaded by pegmatite dykes and sills; many inclusions consist of 75 per cent meta-arenite and 25 per cent pegmatite. The entire area mapped as pegmatite probably consists of 80 to 85 per cent pegmatite, and 15 to 20 per cent meta-arenite.

The pegmatite is a coarse intergrowth of pinkish orange feldspar and grey-white quartz. Feldspar crystals are commonly as large as 12 inches or greater, and appear to be microcline and microcline perthite, although this identification was not checked by thin section.

The Sickle meta-arenite surrounding the granitic complex is extensively injected by pegmatite in a zone varying in width from a few hundred feet to 1000 feet or more. Some outcrops contain as much as 10 to 15 per cent pegmatitic material, commonly in the form of *lit-par-lit* sills and lenses, but also as irregular dykes. However, the contact between pegmatite and enclosing pegmatite-injected sediments is well defined and easily mapped.

GENERAL DISCUSSION OF THE GRANITIC COMPLEX

In summary, the granitic complex forms the core of a large well-defined anticline in the Sickle meta-arenite (map-unit 5). In the map-area, the complex has an interior zone of grey granodiorite, surrounded by successive zones of *lit-par-lit* gneiss, and pegmatite respectively.

Attitudes of foliation, *lit par-lit* layering, and bedding of sedimentary inclusions, in the granitic complex conform closely to bedding in the enclosing Sickle sediments. All rocks are mutually concordant, except the minor pegmatitic dykes which cut surrounding sediments.

The only observed contact between grey granodiorite and the gneiss is marked by a one foot band of biotitic schist grading into gneiss and granodiorite. Nearby pegmatite dykes containing biotite books cut *lit-par-lit* gneiss, but were not seen in the granodiorite.

The contact between *lit-par-lit* gneiss and the pegmatite band was not observed.

Lit-par-lit gneiss appears to have formed by metasomatic introduction of silica and potash along bedding planes in folded Sickle arenites. The granodiorite core is low in potash feldspar, the *lit-par-lit* gneiss more potassic, and the outermost pegmatitic band richest in potash feldspar.

Grey granodiorite is apparently the oldest rock of the complex and pegmatite the youngest.

GRANVILLE LAKE GABBRO (18, 19, 20)

The Granville Lake gabbro consists of a tabular differentiated intrusion, with five or more adjacent satellite intrusions. The intrusion, which has been tilted to an almost vertical position, consists of a thick basal gabbro zone, overlain by thinner transition and granitic zones. Rocks of the transition zone are diorite to quartz diorite, and those of the granitic zone are granodiorite to granite, with minor syenite. The Granville Lake gabbro intrudes the Sickle arenites (5), and is cut by dykes of pegmatite (22), but its age relations with other intrusive rocks in the map-area is not known.

The Granville Lake gabbro consists of six or more contemporaneous masses intruded concordantly along the core of what appears to be an overturned isoclinal fold in well-bedded Sickle arenites. The main body is about 5 miles long, and 4000 to 5000 feet wide. The satellite intrusions range from approximately 5000 feet by 4000 feet to 4000 feet by 500 feet. The outcrops stand as high as 250 feet above the surrounding sedimentary rocks, and the contacts are generally marked by steep scarps. The main intrusion is a tabular body, striking northwest and dipping 70° to 85° southwest. The intrusion has been mapped as a gabbro zone, a transition zone, and a granite zone, as shown in Figure 1.

The gabbro zone comprises about 75 per cent of the main intrusion. The contact between the gabbro and transition zones is gradational across a distance of 200 to 500 feet. The latter zone comprises about 10 per cent of the main intrusion. The contact between the transition and granite zones is generally gradational over a distance of 5 to 50 feet but in one place the contact is sharp, and dips steeply to the southwest, parallel to the plane of the intrusion. Transition rocks immediately adjacent to the granite zone are cut by a few small granitic dykes, which have poorly defined contacts.

Both the granite and transition zones are widest at the southeast end of the main intrusion, where the widths are approximately 1200 and 500 feet respectively. Both zones taper to about 100 feet to the northwest.

Gabbro within 200 feet of the gabbro-Sickle arenite contact (which is generally obscured by overburden) has a lighter grey colour than typical gabbro, due to a lower hornblende and higher plagioclase content. The granite-Sickle contact is not exposed, but one outcrop of Sickle arenite, less than 100 feet from a granite outcrop contains 10 per cent of albite porphyroblasts, up to 1/8 inch across. The porphyroblast content of the arenite progressively decreases to zero within another hundred feet.

Small outcrops of breccia were observed at six localities along various gabbro-sediment contacts. This breccia consists of angular arenite fragments as much as 2 inches across, cemented in one place by biotite, in others by pulverized rock flour, and elsewhere by chilled magma.

Unlike the main intrusion, the satellite intrusions have knife sharp chilled contacts with the enclosing arenites; grain size increases towards the centre of each intrusion.

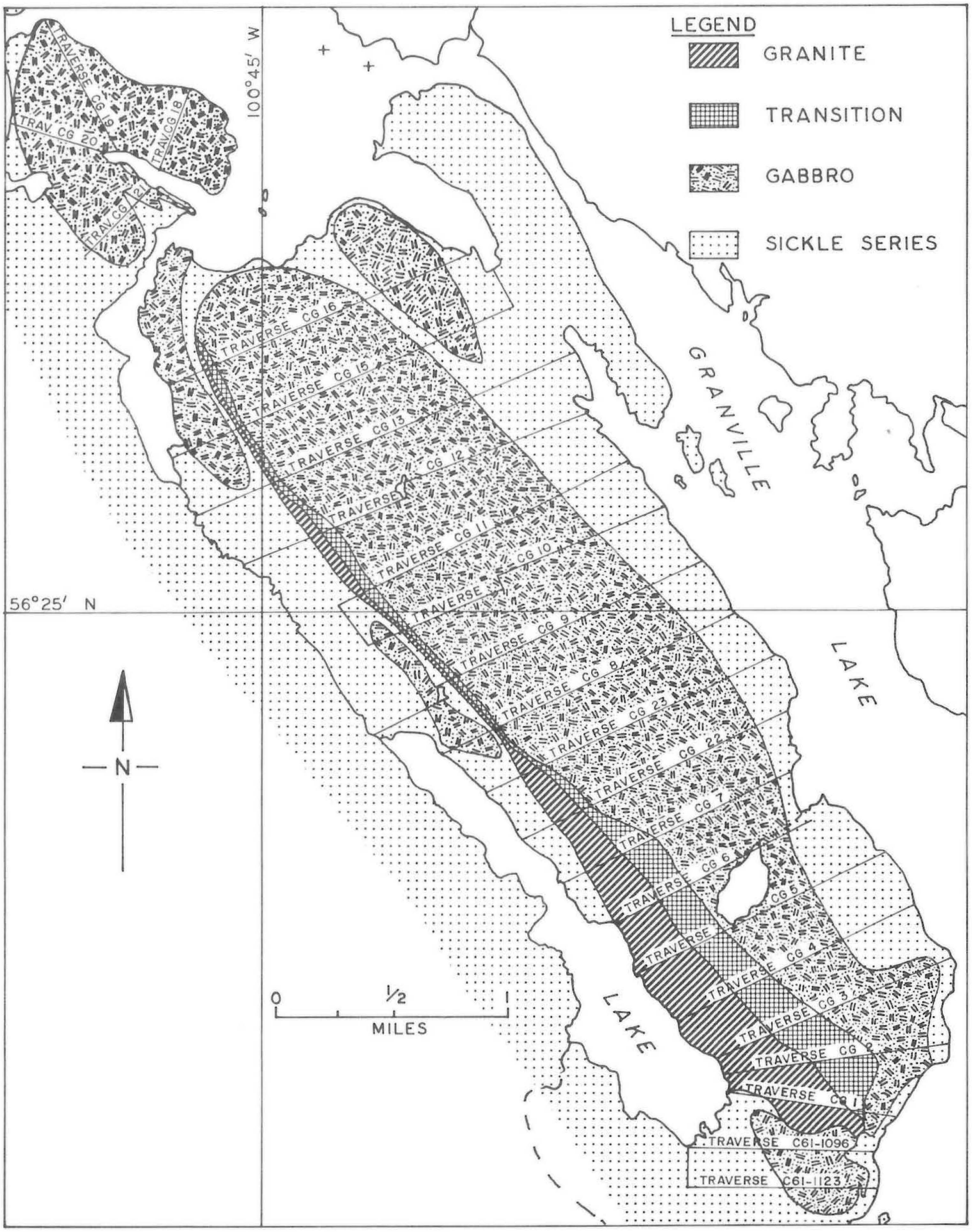


FIGURE 1. *Map of the Granville Lake gabbro showing locations of traverses.*

The entire complex, and contact arenites, are cut by a variety of pegmatites. A few small dykes of white to pinkish aplite occur in the main gabbro body within 200 feet of the northeast sedimentary contact.

Rhythmic layering and igneous lamination were not observed in the intrusion.

Vertical sections across the intrusion are shown in figure 2.

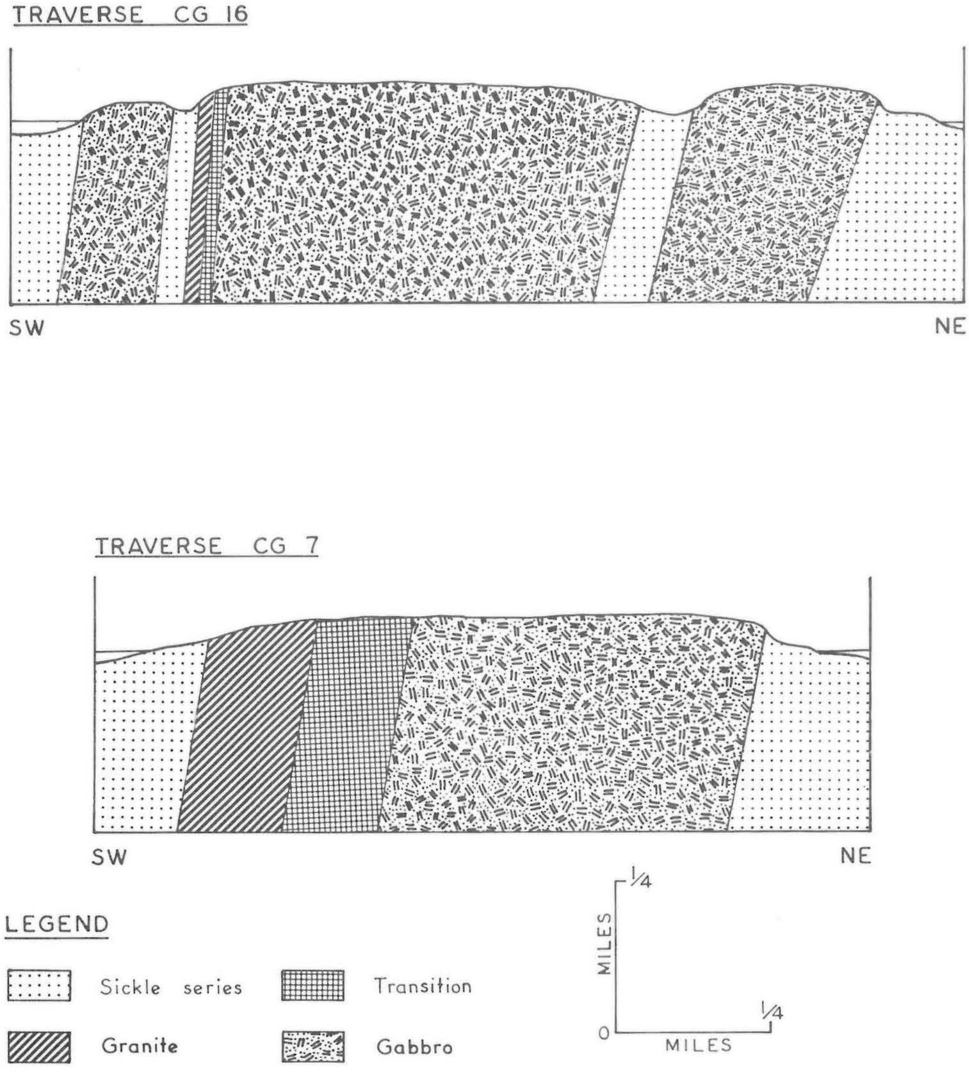


FIGURE 2. *Vertical geological cross sections of the Granville Lake gabbro along traverses CG 16 and CG 7, looking northwest.*

PETROLOGY

GABBRO ZONE (18)

Rocks of the gabbro zone grade from gabbro to diorite with subsidiary quartz gabbro and quartz diorite. Typical gabbro is massive, uniform in composition and texture, medium-to coarse-grained, and medium to dark grey in colour. It contains from 43 to 78 per cent plagioclase, the average being 58 per cent. Plagioclase, invariably zoned, occurs as large anhedral laths and smaller anhedral grains. The most calcic crystals noted ranged from An_{71} at the core to An_{54} at the outer edge of the crystal. The most sodic ranged from An_{53} to An_{28}. Plagioclase is locally saussuritized.

Amphibole content of the gabbro zone ranges from 12 per cent to 51 per cent, the average being 31 per cent. Most amphibole probably formed by deuteric lateration of primary pyroxenes; remnants of partially altered clinopyroxene were observed in some thin sections from the northwest half of the main intrusion, and amount to as much as 6 per cent of the rock. Pyroxene is mainly diopside, with some hypersthene.

There are three varieties of amphibole; coarse equigranular hornblende, pleochroic from light brown to green and blue-green and less commonly olive shades of these colours; a finer-grained, green to blue-green hornblende; and colourless to pale green and blue-green uralitic hornblende, most commonly in bladed aggregates. The coarse hornblende commonly contains numerous lamellae of magnetite in a Schiller-like network. Brown biotite is present in amounts ranging from a trace to 16 per cent, averaging 4.7 per cent. It occurs as subhedral laths and granular intergrowths, grain size ranging from coarse to very fine.

Small quantities of quartz and opaque oxides in the form of irregular grains are almost ubiquitous. Apatite and sphene are common accessory minerals with scattered pyrite grains, rare zircon, and rare primary clinozoisite. Scapolite (dipyre, Me_{37} Ma_{63}) is present in about one-quarter of the thin sections from the gabbro zone; it occurs in patches and veins derived from alteration of plagioclase. Chlorite and leucoxene are rare alteration products.

Grain size in the gabbro zone is generally 3 to 5 millimeters, with many plagioclase laths as long as 8 to 10 millimeters. Weathered surfaces are normally grey to buff, but locally, a pinkish shade accompanies strong saussuritization of plagioclase. Ophitic texture is common in the central portion of the gabbro zone, in the northwest half of the main intrusion.

TRANSITION ZONE (19)

The transition zone ranges from diorite to quartz diorite with minor granodiorite. Diorite predominates. These rocks can be roughly classified into two gradational types. The most common is a porphyritic, fine-to medium-grained uneven-textured variety, grey to medium pinkish grey in colour. It contains 15 to 20 per cent poorly formed pinkish orange feldspar phenocrysts up to 4 millimeters in length. The groundmass is a fine-grained intergrowth of the same feldspar with lesser hornblende and biotite; grain size varies from 1 to 2 millimeters. The other variety is a massive, medium-grained intergrowth of pinkish plagioclase and black hornblende. The texture and appearance of this type, with the exception of the pink plagioclase, is identical to that of typical gabbro zone rocks.

All variations between the two types are common. The porphyritic variety is greatly predominant, particularly in the southeast half of the main intrusion. The non-porphyritic variety is predominant in the northwest half of the main intrusion, where the diorite and granite zones are thin. It is chemically intermediate between the porphyritic diorite and the gabbro.

Rocks of the transition zone are hypidiomorphic to allotriomorphic granular intergrowths of plagioclase with anhedral green hornblende. Plagioclase content ranges from 45 to 89 per cent, and averages 66 per cent; composition ranges from An_{23} to An_{35}. Normal zoning is invariably present, but is not as strong as in the gabbro zone. Some grains are lath shaped (but less so than in the gabbro zone) and invariably serrated. Hornblende content ranges from 12 to 38 per cent, and averages 21 per cent; grains are equidimensional and pleochroic from light brown to intense green and blue-green, with lesser amounts of a lighter coloured hornblende as irregular grains. No lamellar magnetite inclusions are present, and pyroxene was not observed. Biotite content ranges from 1 to 15 per cent, and averages 5 per cent; grains are subhedral to anhedral, characteristically olive-coloured, less commonly brown.

Quartz content ranges from 1 to 9 per cent and averages 3.4 per cent; it occurs commonly as an irregular granophyric intergrowth with feldspar. Microcline, as interstitial grains and perthitically intergrown with plagioclase, may constitute as much as 11 per cent of the rock; the average microcline content is 2.8 per cent.

Sphene, opaque oxides, and apatite are common accessories, with traces of pyrite. Saussurite, scapolite, epidote, leucoxene, chlorite, and hematite were observed as minor secondary alteration products in some specimens, as described for the gabbro zone.

GRANITE ZONE (20)

Grout (1932) would classify rocks of this zone as true granite, whereas by the Geological Survey of Canada classification they are granodiorite to quartz monzonite. In this zone all rocks are massive, and generally uniform in composition, colour and texture. They are fine-to medium-grained and dull orange-pink in colour, with scattered black specks of mafic minerals. The weathered surface is rusty brown to orange.

The rocks are irregular, allotriomorphic granular intergrowths of plagioclase, quartz, and microcline, with lesser hornblende and/or biotite. Plagioclase content ranges from 47 to 91 per cent and averages 70 per cent. It is typically a calcic albite, ranging from An_{7} to An_{13}. Zoning is rare and very weak. Quartz content ranges from zero to 31 per cent, and averages 17 per cent. It is complexly intergrown with plagioclase and to a lesser extent with microcline. This texture, which is not well developed in all specimens, might be described as granophyric but is not the normal graphic or patchy graphic intergrowth prevalent in the late granitic portions of many differentiated intrusions. Quartz is absent in two specimens from the northwest half of the intrusion, where the granite zone is very narrow. Both specimens came from within 50 to 100 feet of the granite-Sickle contact, and consist of an intergrowth of albite (90 per cent) and hornblende (10 per cent). Specimens containing normal amounts of quartz were collected from the granite zone both to the northwest and southeast.

Granite zone rocks have an average microcline content of 10 per cent, varying from 0 to 27 per cent. The microcline occurs as irregular grains or is intergrown with plagioclase in a patch perthite. The content of intensity coloured green to blue-green hornblende and a less common brownish green variety, ranges from zero to 9 per cent of the rock, and averages 4 per cent. Sphene, opaque oxides, and apatite are minor accessory minerals. Traces of chlorite and leucoxene are present in some specimens as alteration products of biotite and sphene, respectively. Traces of saussurite, sericite, epidote, carbonate, and dusty hematite are present in some specimens.

DEUTERIC ALTERATION AND CONTACT EFFECTS

The intrusion shows no evidence of significant regional metamorphism, but deuteric alteration is particularly evident in the gabbro zone, where primary pyroxenes have been replaced by hornblende and minor uralite. The blue-green colour of the hornblende, suggesting a sodic variety, is consistent with alteration of pyroxenes by sodic fluids from late differentation. Calcic plagioclase shows only minor and local saussuritic and scapolitic alteration, again attributed to late deuteric reactions. Local contact brecciation of the Sickle arenites may represent either a cataclastic breccia zone which acted as a zone of weakness along which magma was intruded, or, more likely, is the result of forcible injection of the magma.

The smaller gabbro bodies are chilled against baked, fine-grained arenites. The contact arenites within ¼ mile of the main intrusion are finely schistose, with unusually well developed alignment of fine biotite and lesser muscovite flakes. This is attributed to stress inducted by later folding when the intrusion was tilted to its present, nearly vertical attitude. Recognizable assimilation of these sediments has, however, occurred in a three-feet wide contact zone along the northeast side of the main intrusion. Other contact effects are recognizable in thin section over a distance of several hundred feet from the intrusion by the destruction of albite twinning, presumably by contact metamorphic heating of Sickle sediments.

MINERALOGICAL VARIATION AND PETROGENESIS

Modal analyses of single standard-sized thin sections of Granville Lake gabbro specimens are listed in Table 8. Modal analyses and specific gravities of specimens collected on traverses CG 2, CG 6, CG 11 are plotted in Figure 3, 4, and 5. Mineralogical variation across the intrusion follows a pattern typical of differentiated intrusions, particularly as regards quartz, opaque oxides, microcline, apatite, and sphene.

Plagioclase, clinopyroxene, orthopyroxene, minor biotite and possibly some amphibole, were the first minerals to crystallize from the primary magma. As the water content of progressive liquid differentiates became higher and temperature decreased, the pyroxenes were altered to hornblende which also began to crystallize directly from the magma. Formation of plagioclase continued until crystallization of the intrusion was complete. Crystallization of opaque oxides was irregular in the gabbro zone, reaching one or more peaks. Formation of apatite became pronounced when about half the magma had crystallized, with maximum apatite accumulation near the top of the gabbro zone. Apatite then decreased gradually to almost zero in the granitic rocks due to impoverishment of the residual differentiate in P_2O_5. As apatite crystallization reached its maximum, crystallization of sphene increased rapidly, reaching a pronounced peak at the transition zone.

Concentrations of apatite are common to many differentiated gabbroic intrusions. In the well-known Sudbury intrusion a concentration occurs near the top of the norite zone. Hunter (1958, p. 10, 19) in his study of the Tow Lake gabbro

TABLE 8

Modal analyses, specific gravity, and colour indices,
Granville Lake gabbro
(1000 points counted on single standard-sized thin sections)

Specimen	Colour Index	Specific Gravity of Rock	Plagioclase	Amphibole	Quartz	Microcline	Biotite	Sphene	Opaque Oxides	Apatite	Pyroxene
CG 2–2	1.4	2.60	76.7	1.1	22.0	tr	—	0.2	0.1	—	—
CG 2–4	5.6	2.62	56.5	3.9	16.4	21.5	0.5	0.2	0.9	0.1	—
CG 2–7	5.6	2.64	47.1	4.0	20.0	27.2	0.8	0.3	0.4	0.1	—
CG 2–8	9.9	2.66	62.2	5.7	15.7	12.3	3.3	0.6	0.3	tr	—
CG 2–10	6.4	2.65	61.1	4.8	11.9	19.6	0.1	1.3	1.1	0.1	—
CG 2–11	12.3	2.70	74.0	8.9	2.6	11.1	—	1.8	1.4	0.2	—
CG 2–12	20.6	2.71	70.9	18.2	0.6	7.6	0.1	1.1	1.0	0.2	—
CG 2–14	33.1	2.82	61.6	16.9	3.6	1.5	15.0	0.6	0.3	0.3	—
CG 2–15	34.8	2.87	58.4	18.7	6.8	tr	15.4	0.1	0.2	0.4	—
CG 2–17	7.7	2.77	88.7	1.8	0.7	1.6	2.2	2.2	2.5	0.2	—
CG 2–19	48.4	2.92	44.9	38.4	5.3	1.1	6.3	2.8	—	0.9	—
CG 2–21	34.8	2.86	53.5	13.6	11.6	—	16.0	0.3	3.7	1.2	—
CG 2–23	30.9	2.87	62.6	19.9	6.3	—	9.1	—	0.8	1.1	—
CG 2–25	28.3	2.81	70.9	19.9	0.8	0.1	4.6	1.7	1.4	0.7	—
CG 6–1	22.1	2.86	77.8	11.5	0.3	—	6.6	2.0	1.8	0.2	—
CG 6–4	29.7	2.88	64.5	22.9	4.7	—	7.5	—	0.2	0.1	—
CG 6–6	38.4	2.91	59.0	29.0	2.6	—	7.8	—	1.1	0.5	—
CG 6–8	28.2	2.82	65.0	18.3	6.5	—	8.5	tr	0.7	0.8	—
CG 6–11	36.9	2.90	57.6	32.2	5.5	0.1	4.2	0.4	—	0.1	—
CG 6–14	37.9	2.86	61.8	32.6	1.1	0.3	3.9	1.0	—	0.4	—
CG 6–19	33.1	2.78	50.0	26.1	8.2	8.7	5.5	1.4	—	0.1	—
CG 6–21	25.3	2.77	54.6	21.4	8.7	11.3	2.6	1.1	0.2	tr	—
CG 6–22	5.8	2.67	73.5	2.9	16.5	3.9	—	1.2	1.7	tr	—
CG 6–24	4.7	2.65	70.7	—	22.1	2.2	3.3	tr	1.4	tr	—
CG 6–25	3.5	2.64	53.4	0.3	23.4	19.6	1.5	0.6	1.1	tr	—
CG 6–26	4.7	2.62	61.5	—	30.9	2.7	4.3	0.1	0.2	0.1	—
CG 9–25	31.4	2.86	67.9	27.3	0.8	—	0.8	1.6	0.4	0.4	—
CG 10–5	42.6	2.92	51.7	38.0	0.3	—	4.3	tr	0.3	—	—
CG 10–23	35.5	2.78	64.0	24.4	0.5	—	7.9	1.7	1.1	0.4	—
CG 11–1	9.3	2.65	90.6	8.8	—	—	—	0.5	tr	—	—
CG 11–2	12.1	2.65	87.9	10.3	0.1	—	—	1.1	0.1	0.6	—
CG 11–3	18.1	2.72	79.7	13.3	1.7	0.1	1.1	1.8	2.3	0.1	—
CG 11–4	24.7	2.74	72.8	17.8	1.7	0.9	1.8	2.9	1.8	0.4	—
CG 11–5	38.5	2.86	56.3	30.3	5.1	tr	7.0	—	0.5	0.7	—
CG 11–7	47.8	2.94	48.5	45.3	3.3	0.1	1.3	0.9	0.1	0.2	—
CG 11–9	43.0	2.92	54.0	38.4	2.6	0.1	3.8	—	0.3	0.5	—
CG 11–11	39.9	2.94	59.6	37.0	0.5	—	0.4	—	0.5	0.1	1.9
CG 11–14	57.3	2.89	42.7	51.0	—	—	5.4	0.1	0.5	0.1	—
CG 11–16	34.9	2.90	65.0	32.6	0.1	—	0.7	—	1.4	—	—
CG 11–18	42.3	2.95	57.5	33.4	0.2	—	1.1	—	2.2	—	5.6
CG 11–21	40.0	2.91	59.1	38.4	0.8	—	1.4	—	0.1	0.1	—
CG 11–23	49.0	2.89	48.8	44.8	2.0	—	3.3	—	0.9	tr	—
CG 12–21	15.9	2.71	82.3	11.6	1.9	—	1.5	1.2	1.3	0.3	—
CG 15–17	45.3	2.91	54.5	43.8	0.2	—	0.1	0.2	1.1	0.1	—

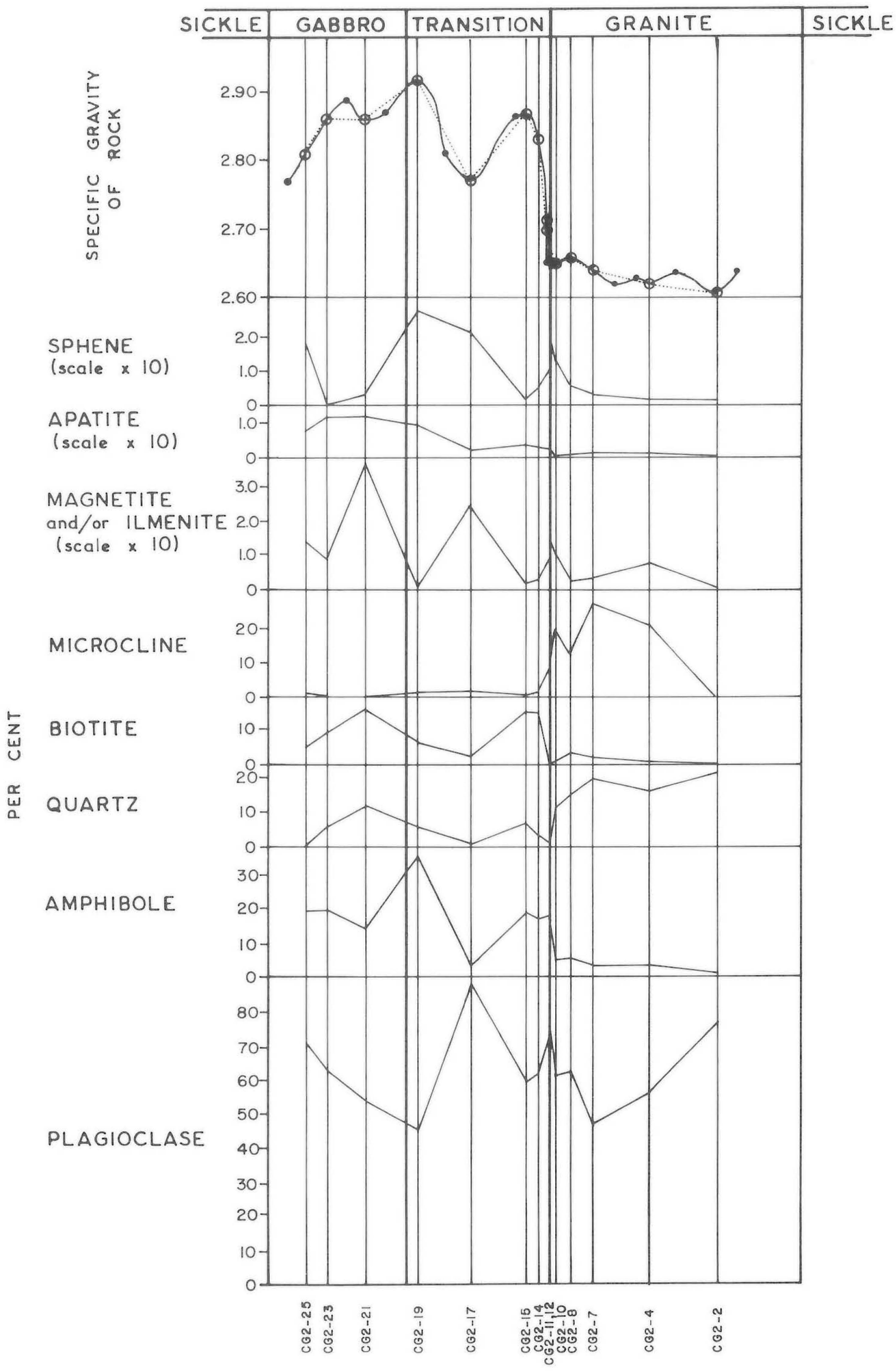


FIGURE 3. *Plot of modal analyses along traverse line CG 2, Granville Lake gabbro.*

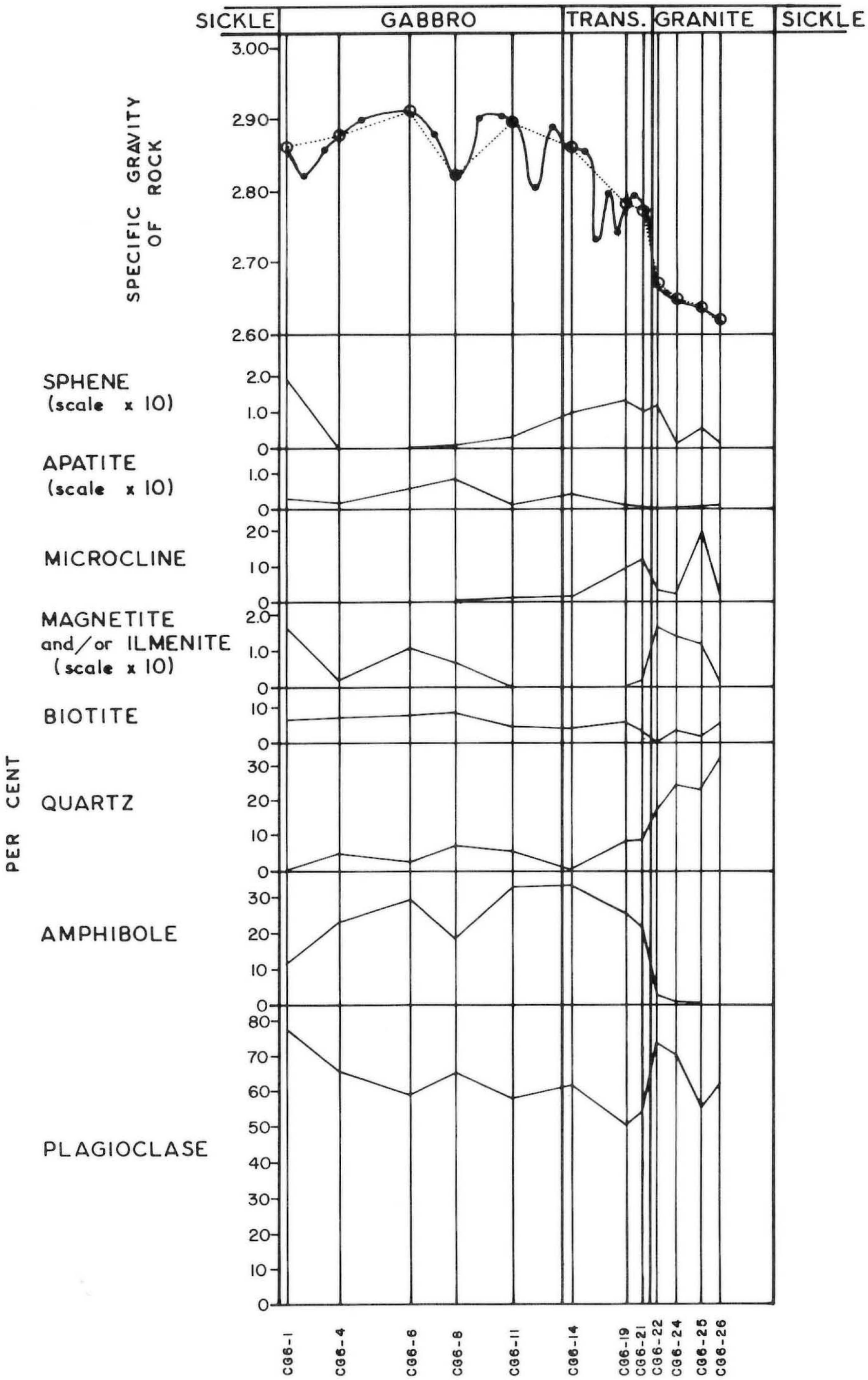


FIGURE 4. *Plot of modal analyses along traverse line CG 6, Granville Lake gabbro.*

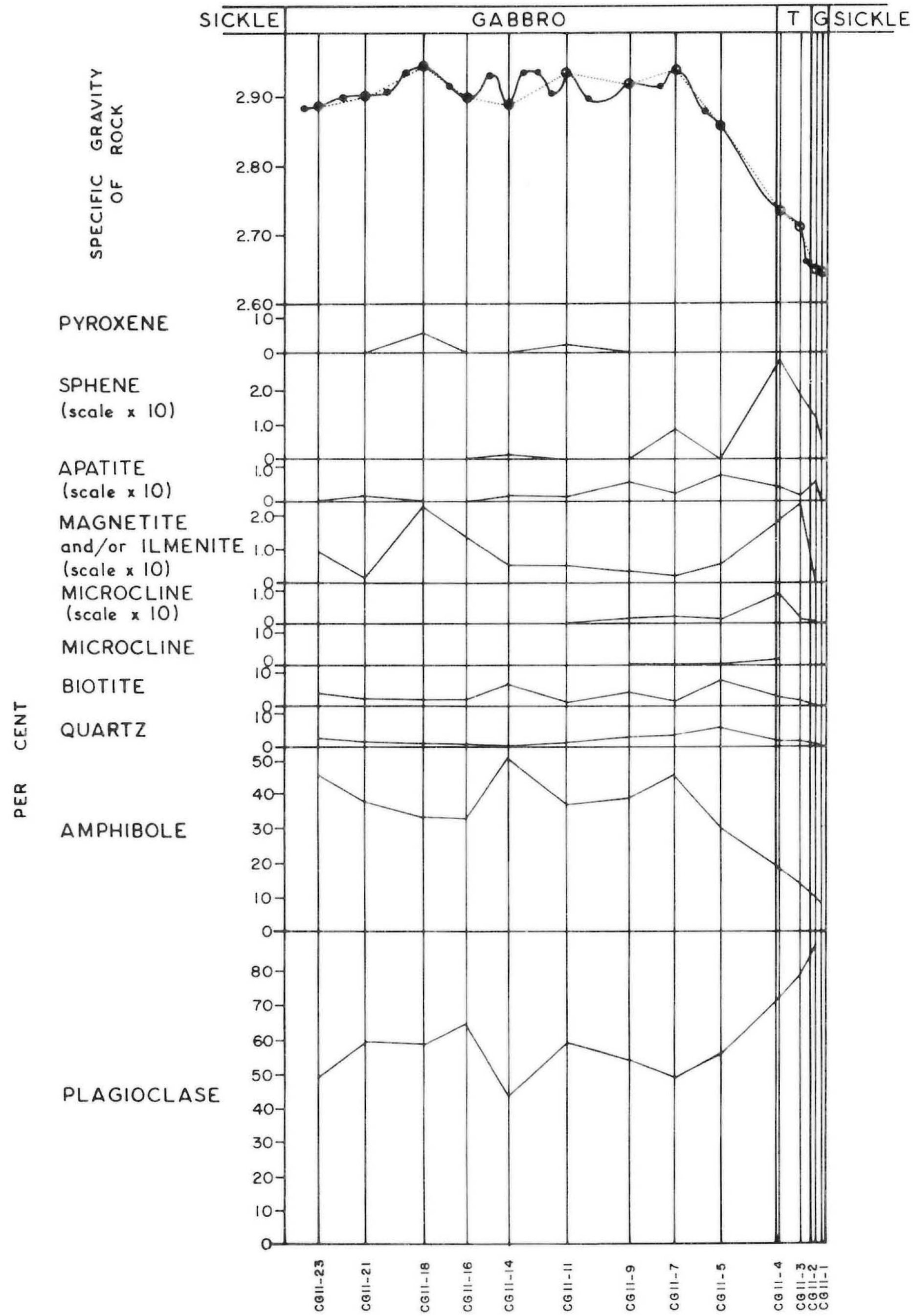


FIGURE 5. *Plot of modal analyses along traverse line CG 11, Granville Lake gabbro.*

found a sharp apatite peak in the "B" or intermediate gabbro. Apatite concentration also occurs in the upper zone of the Lynn Lake gabbro; sphene is limited almost entirely to the upper zone (Emslie, 1961, p. 35, 46).

After crystallization of the transition zone rocks, the residual magma was depleted in magnesium, calcium, and iron, thus inhibiting the formation of hornblende. Plagioclase composition changed abruptly from approximately An_{23} to An_{13}. This resulted in the relatively sharp boundary between hornblende-rich transition rocks and hornblende-poor granite. A pronounced peak in opaque oxide content is evident at this stage.

Concentrations of opaque iron oxides which apparently correspond to that at the Granville Lake transition zone-granite zone boundary are found in the Sudbury intrusion (Collins, 1934), the Lynn Lake gabbro (Emslie, 1961, p. 35), and the Tow Lake gabbro (Hunter, 1958, p. 18).

Quartz is found in small quantities throughout the gabbro and transition zones. Generally, quartz content is highest near the top of the granite zone, where it reaches 30 per cent. However, on traverse CG 11, maximum quartz is found in the gabbro zone, and the transition and granite zones contain little quartz. This may be due to floating of albite crystals to the top of the magma chamber, where they were trapped by irregularities in the upper surface, which prevented their migration to the uppermost southeast portion of the intrusion. A more plausible explanation is filter-pressing and migration of the late silica-rich differentiate from its albite crystal mush before crystallization of quartz began. Such filter pressing would be the result of gravitational settling of the crystal mush and consequent displacement of the remaining fluid to the higher southeast end of the main intrusion. This is confirmed by the progressive increase of quartz and microcline in rocks from traverses CG 11, CG 6, and CG 2, respectively.

Crystallization of microcline began in the upper portion of the gabbro zone, and reached its maximum in the transition or lower granite zone. Microcline is absent or negligible at the top of the granite zone.

CHEMICAL ANALYSES AND RELATED DATA

Eight specimens were chosen for chemical analysis. Unfortunately, it was necessary to select these specimens before any thin sections were available, and as a result, pyroxene gabbro, chilled gabbro, and late-stage granite were not included. It is, therefore, improbable that the available analyses represent the maximum compositional variation. From Figure 4 it is obvious that the analyzed specimen highest in SiO_2 (CG 6–25) is not the most silicic rock found in the intrusion.

Chemical analyses, molecular norms, and modes of chemically analyzed specimens are listed in Table 9.

Figure 6 is a silica variation diagram for the Granville Lake intrusion. The trends of the major oxides are consistent with those expected for a differentiated intrusion. The drop in Na_2O and corresponding increase in K_2O in specimen CG 6–25 is due to its high microcline content. TiO_2 and P_2O_5 show peaks which may be similar to the maxima of apatite and sphene in the modal analyses diagrams.

TABLE 9

Analyses of the Granville Lake gabbro

	Gabbro Zone CG 10–5 K. Ramlal - analyst	Gabbro Zone CG 15–17 K. Ramlal - analyst	Gabbro Zone CG 9–25 K. Ramlal - analyst	Transition Zone CG 2–14 K. Ramlal - analyst
SiO_2	49.6	51.2	52.9	53.7
Al_2O_3	21.1	20.1	18.5	18.2
Fe_2O_3	3.5	2.9	4.9	4.51
FeO	5.8	6.0	4.7	5.12
MgO	4.9	4.7	3.1	3.1
CaO	9.1	9.3	6.6	6.0
Na_2O	3.23	2.87	5.36	5.7
K_2O	0.82	0.48	1.18	1.85
TiO_2	0.80	1.06	1.19	0.90
P_2O_5	0.17	0.15	0.34	0.24
MnO	0.11	0.13	0.02	0.07
CO_2	tr	nil	0.10	nil
H_2O+) H_2O-)	0.47	0.69	0.73	0.65
	99.60	99.58	99.62	100.14

Molecular Norm

q	—	3.4	0.3	—
c	—	—	—	—
or	5.0	3.0	7.5	11.0
ab	29.0 } An_{42}	26.5 } An_{39}	47.5 } An_{33}	48.8 } An_{29}
an	41.0 }	41.0 }	23.3 }	18.5 }
wo	—	2.0	2.6	—
en	9.3	13.4	8.8	0.1
di	3.2	—	—	7.6
fs	3.7	6.0	2.2	—
fo	2.6	—	—	4.2
fa	1.0	—	—	1.9
mt	3.8	3.0	5.1	4.7
hm	—	—	—	—
il	1.2	1.4	1.6	1.2
ap	0.3	0.3	0.8	0.5
cc	—	—	0.2	—
ne	—	—	—	1.3

Mode

Plagioclase	51.7(An_{39-63})	54.5(An_{36-64}+)	67.9	61.6(An_{26-31})
Amphibole	38.0	43.8	27.3	16.9
Quartz	0.3	0.2	0.8	3.6
Microcline	—	—	—	1.5
Biotite	4.3	0.1	1.7	15.0
Sphene	tr	0.2	1.6	0.6
Opaque oxides	0.3	1.1	0.4	0.3
Apatite	—	0.1	0.4	0.3
Chlorite	tr	—	0.5	—
Pyrite	—	tr	—	tr
Epidote	—	—	—	tr
Hematite	—	—	—	—

TABLE 9 (concluded)

	Transition Zone CG 10-23 A. M. MacKay D. F. G. Brown - analyst	Transition Zone CG 12-21 A. M. MacKay D. F. G. Brown - analysts	Granite Zone CG 6-22 K. Ramlal - analyst	Granite Zone CG 6-25 K. Ramlal - analyst
SiO_2	55.93	62.15	67.0	70.3
Al_2O_3	17.59	16.81	16.3	15.2
Fe_2O_3	2.73	3.76	5.7	3.8
FeO	4.88	2.23	0.39	0.39
MgO	3.44	2.05	0.1	0.03
CaO	6.10	3.60	1.9	1.4
Na_2O	5.80	6.16	7.0	5.5
K_2O	1.04	0.97	1.2	3.3
TiO_2	0.74	0.68	0.41	0.25
P_2O_5	0.22	0.22	0.10	0.06
MnO	0.04	0.04	0.05	0.02
CO_2	nil	nil	nil	nil
H_2O+) H_2O-)	0.80	1.18	0.42	0.35
	99.31	99.85	100.57	100.60

Molecular Norm

q	1.3	11.0	20.7	20.9
c	—	—	2.3	0.4
or	5.5	6.0	7.5	19.5
ab	52.0 } An_{27}	55.5 } An_{21}	56.0 } An_{13}	49.5 } An_{11}
an	19.3	15.0	8.5	6.0
wo	3.8	0.6	—	—
en	9.6	5.6	0.4	0.2
di	—	—	—	—
fs	3.4	1.4	—	—
fo	—	—	—	—
fa	—	—	—	—
mt	3.2	1.6	0.3	0.3
hm	0.3	1.8	3.7	2.5
il	1.2	1.0	0.6	0.4
ap	0.5	0.5	0.3	0.3
cc	—	—	—	—

Mode

Plagioclase	64.0(An_{24-56})	82.3(An_{26-33})	73.5(An_{10})	53.4(An_{10-13})
Amphibole	24.4	11.6	2.9	0.3
Quartz	0.5	1.9	16.5	23.4
Microcline	—	—	3.9	19.6
Biotite	7.9	1.5	—	1.5
Sphene	1.7	1.2	1.2	0.6
Opaque oxides	1.1	1.3	1.7	1.1
Apatite	0.4	0.3	tr	tr
Chlorite	tr	—	0.2	—
Pyrite	—	—	—	—
Epidote	—	tr	tr	—
Hematite	—	—	tr	tr

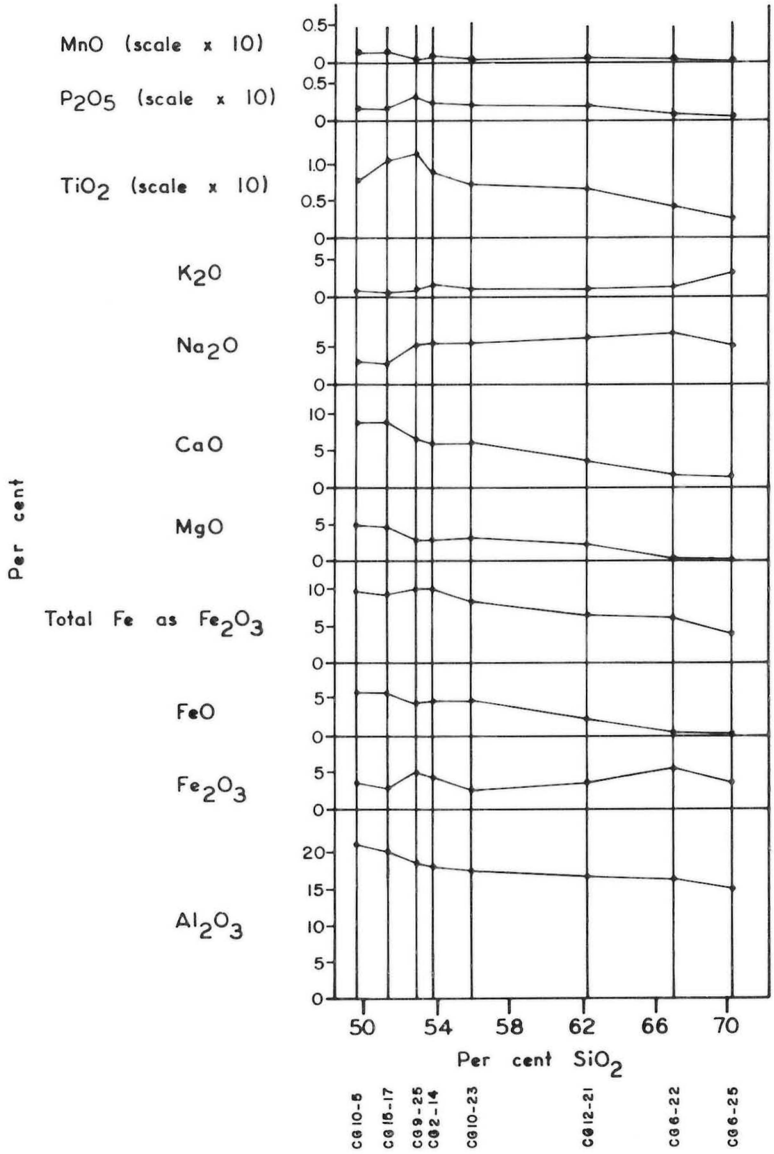


FIGURE 6. *Silica variation diagram for the Granville Lake gabbro.*

Figure 7 is a plot of CaO and (Na_2O+K_2O) against SiO_2. These curves cross at a silica content of approximately 53 per cent. The value of the alkali-lime index is therefore 53, and corresponds to alkali-calcic in the Peacock (1931) classification.

Silica content ideally should increase from base to top of a differentiated intrusion. The close relationship (Fig. 8) between silica content and specific gravity

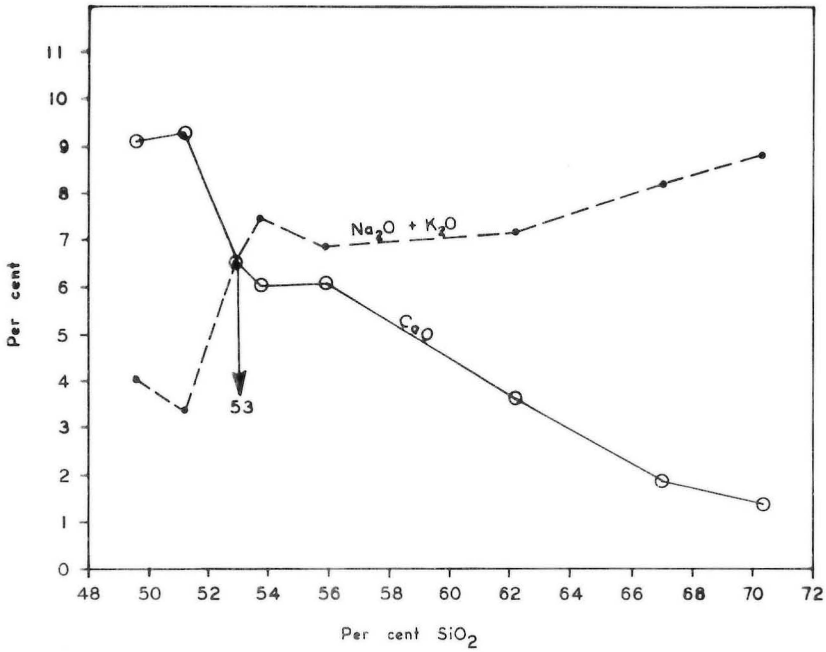


FIGURE 7. *Alkalic-lime index, Granville Lake gabbro.*

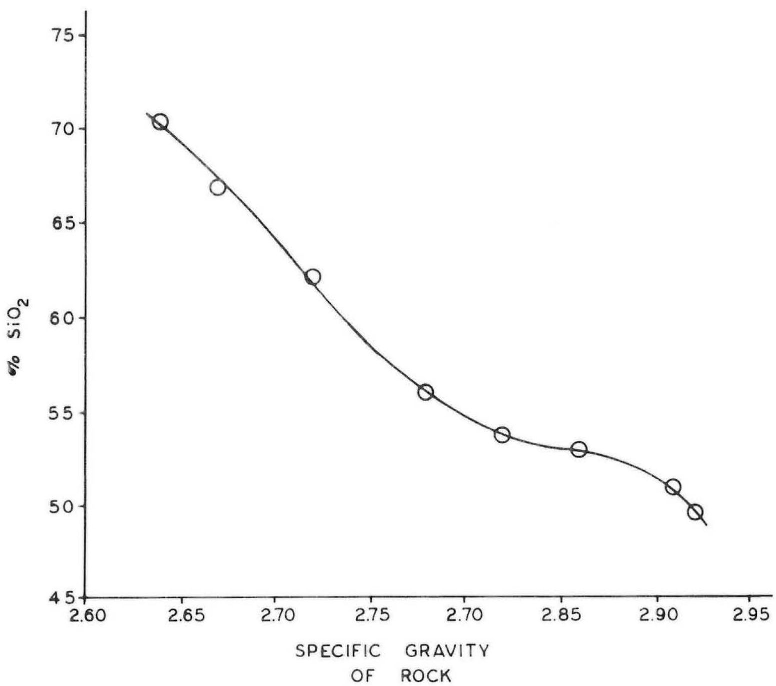


FIGURE 8. *Relationship between silica content and specific gravity, Granville Lake gabbro.*

in the Granville Lake intrusion allows use of specific gravity as a differentiation index. Average specific gravity of 448 specimens from the intrusion is 2.84.

The specific gravity contour map (Fig. 9) should, therefore, indicate variation in silica content. An upward tilt of the southeast end of the intrusion during cooling is inferred from this map, rocks of highest specific gravity being concentrated near the northwest end.

The remarkable uniformity in specific gravity of the gabbro zone indicates that crystallization of plagioclase and ferromagnesian minerals began almost simultaneously and the relative proportion remained more or less constant until crystallization of the gabbro zone was almost complete.

Along the lower gabbro-sediment contact of the main intrusion, a zone of lower specific gravity (approximately 2.85) is evident, due in part to a slightly high plagioclase and slightly low amphibole content. Plagioclase determinations suggest that anorthite content of the grain cores is identical near the base of the intrusion to that higher up in the intrusion, but that grain rims near the base are more sodic than those somewhat higher in the intrusion. This could indicate that lower specific gravity along the base is due to chilling or to enrichment of plagioclase in the earliest crystal differentiate. There is no evidence of chilling along the upper contact of the main intrusion. This may be due to modification by reaction with later granitic differentiates. Emslie found a similar chilled zone along the base of the Lynn Lake gabbro, but not along its roof.

The satellite intrusions are all chilled, and minor differentiation effects were found only in the southernmost satellite, where the uppermost rocks are fine grained and intermediate between those of the diorite and granite zones of the main intrusion.

Table 10 shows the value of various indices of differentiation for chemically analyzed specimens of the Granville Lake gabbro compared with specific gravity. The ratio $\frac{K_2O+Na_2O}{CaO+K_2O+Na_2O}$ is commonly used as an index of differentiation (the felsic index). It decreases fairly regularly with increasing specific gravity. Similarly, the ratio $\frac{FeO+Fe_2O_3}{MgO+FeO+Fe_2O_3}$, also used as an index of differentiation (the mafic index), decreases with increasing specific gravity. Colour index (Table 8) increases somewhat erratically with increasing specific gravity.

VARIATION IN PLAGIOCLASE COMPOSITION

Plagioclase composition of 26 specimens was obtained with the universal stage, by determination of the maximum extinction angle on (010). The location and plagioclase composition for each specimen are shown in Figure 10. Because of the strong compositional zoning of plagioclase, it is possible that more calcic plagioclase may exist in any specimen from the transition zone and particularly from the gabbro zone.

Plagioclase composition is relatively constant on any one traverse in the lower one-half to two-thirds of the gabbro zone. Anorthite content gradually decreases

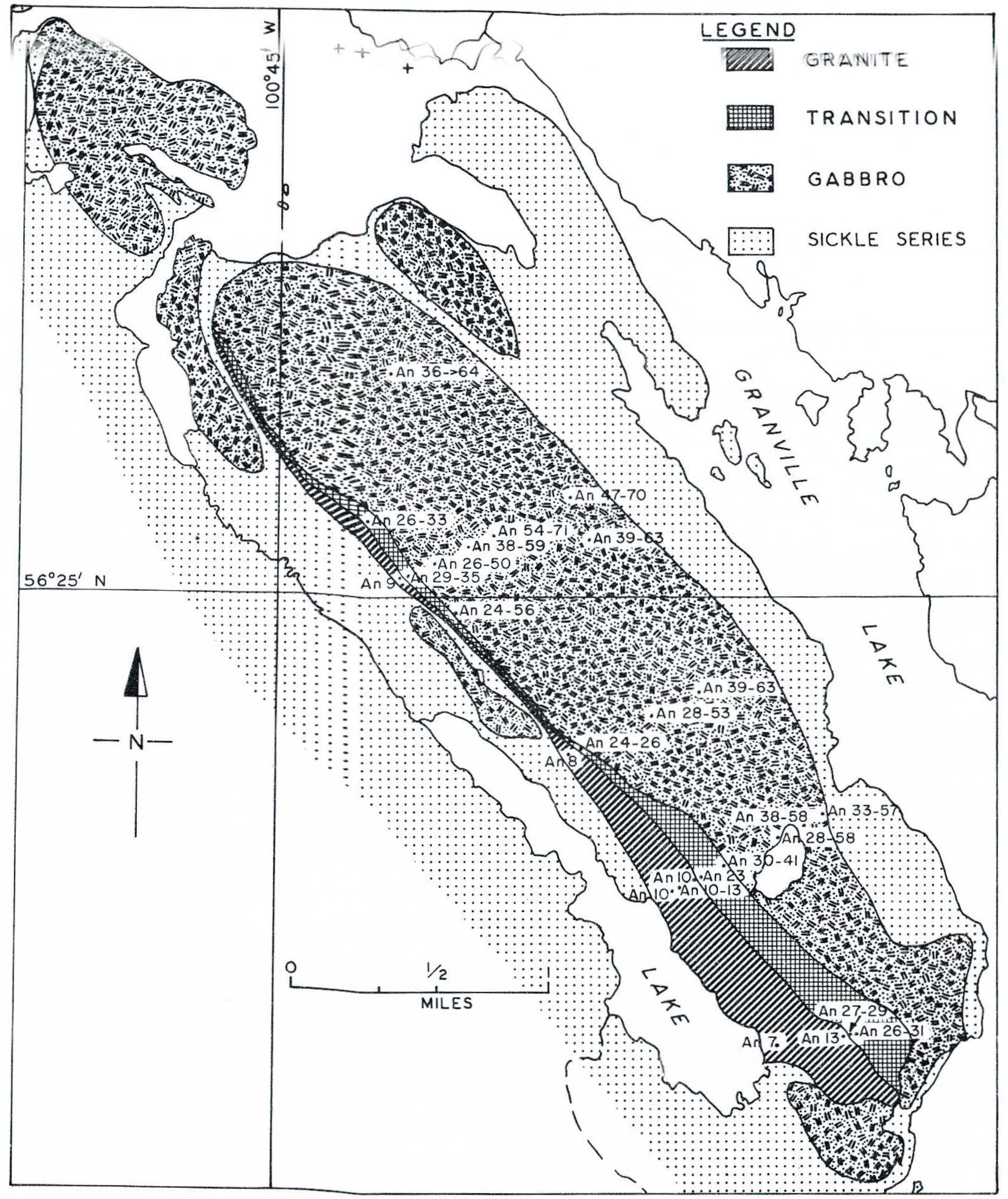


FIGURE 10. *Composition of plagioclase, Granville Lake gabbro.*

through the upper portion of the gabbro and transition zones, with a sharp decrease at the granite zone boundary. An apparent gap in the plagioclase range is evident at this boundary since compositions between An23 and An13 were not found. Collins (1934) indicates that a compositional gap of An25 to An12 may exist in the

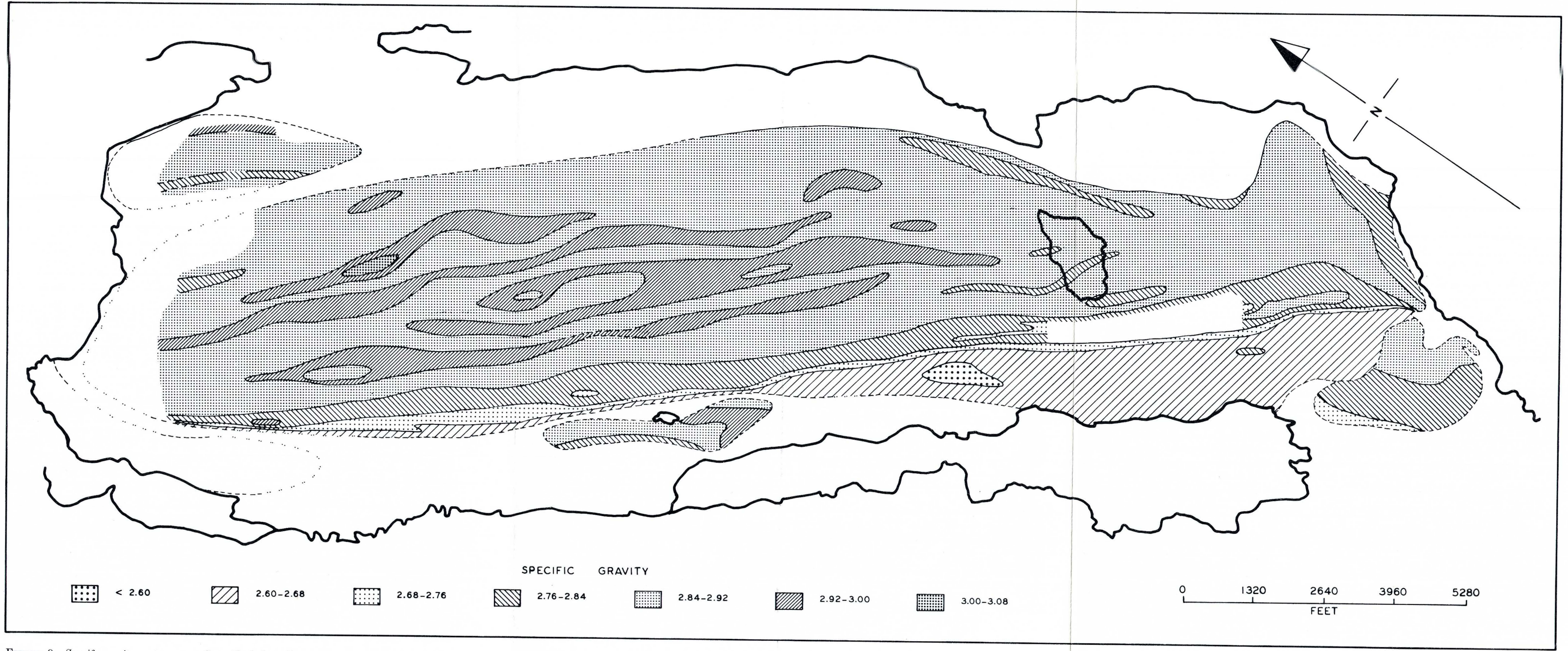


FIGURE 9. *Specific gravity contour map, Granville Lake gabbro.*

Sudbury intrusion. Similarly, for the Skaergaard intrusion, Wager and Deer (1939) report an apparent gap in plagioclase composition between An_{20} and An_9.

At Granville Lake, anorthite content in the gabbro zone generally increases from southeast to northwest, corresponding to the general increase in specific gravity (Fig. 9). The compositional gap occurs within the specific gravity range 2.71 to 2.68. This corresponds to an approximate silica content of 63 to 66 per cent (Fig. 8).

ORIGIN OF THE GRANITIC AND TRANSITION PHASES

Differentiation in place of an original gabbroic magma seems the most probable explanation for all the features of the Granville Lake intrusion. However, other possible origins must be considered. These are as follows:

(1) Fusion of Sickle arenites by gabbroic magma to form the granite zone: There is no field or petrographic evidence that the Sickle arenites were melted, and the presence of granite on only one side of the intrusion is inconsistent with this mode of origin.

(2) Granitization of arenites by late differentiates to produce the granite zone: Evidence of extensive granitization is lacking.

(3) Multiple intrusion: There are two possibilities here. Reaction of the second magma with the previously consolidated first phase produced the transition zone; or mixing of the second magma with the crystal mush of the first phase produced the transition zone. The sharpness and regularity of the contact between the transition zone and the granite zone is not consistent with this hypothesis.

(4) Differentiation in place of an original gabbroic magma: The relatively sharp contact between the transition and granitic phases is not inconsistent with this hypothesis, since many other differentiated intrusions have relatively sharp phase boundaries. Differentiation is strongly supported by petrographic, mineralogical and chemical data, and variations in plagioclase composition. Specific gravity variations, especially across the southeast satellite intrusion, are particularly significant.

It is, therefore, concluded that the Granville Lake intrusion originated by differentiation in situ of an original gabbroic magma.

GEOLOGIC HISTORY OF THE GRANVILLE LAKE GABBRO

The Granville Lake gabbro crystallized as a concordant, sub-horizontal, sill-like mass in well-bedded arkosic greywacke of the Sickle series. Pronounced differentiation took place during cooling, resulting in the formation of a thick lower gabbro layer, a transitional diorite layer, and an upper granite layer. The granite and transition layers are widest, and the gabbro layer narrowest near the southeast end of the intrusion, indicating an original slight upward tilt towards the southeast. As crystallization proceeded upwards from the base, there was presumably gravitational accumulation of mafic crystal mush downwards, and of successive dioritic and then granitic differentiates at higher levels. Later folding of the enclosing Sickle rocks tilted the intrusion to its present nearly vertical position.

Figure 11 indicates that the differentiation trend of the Granville Lake gabbro corresponds to that of the calc-alkaline series rather than that of the Skaergaard type in which there is a pronounced enrichment in iron relative to magnesia.

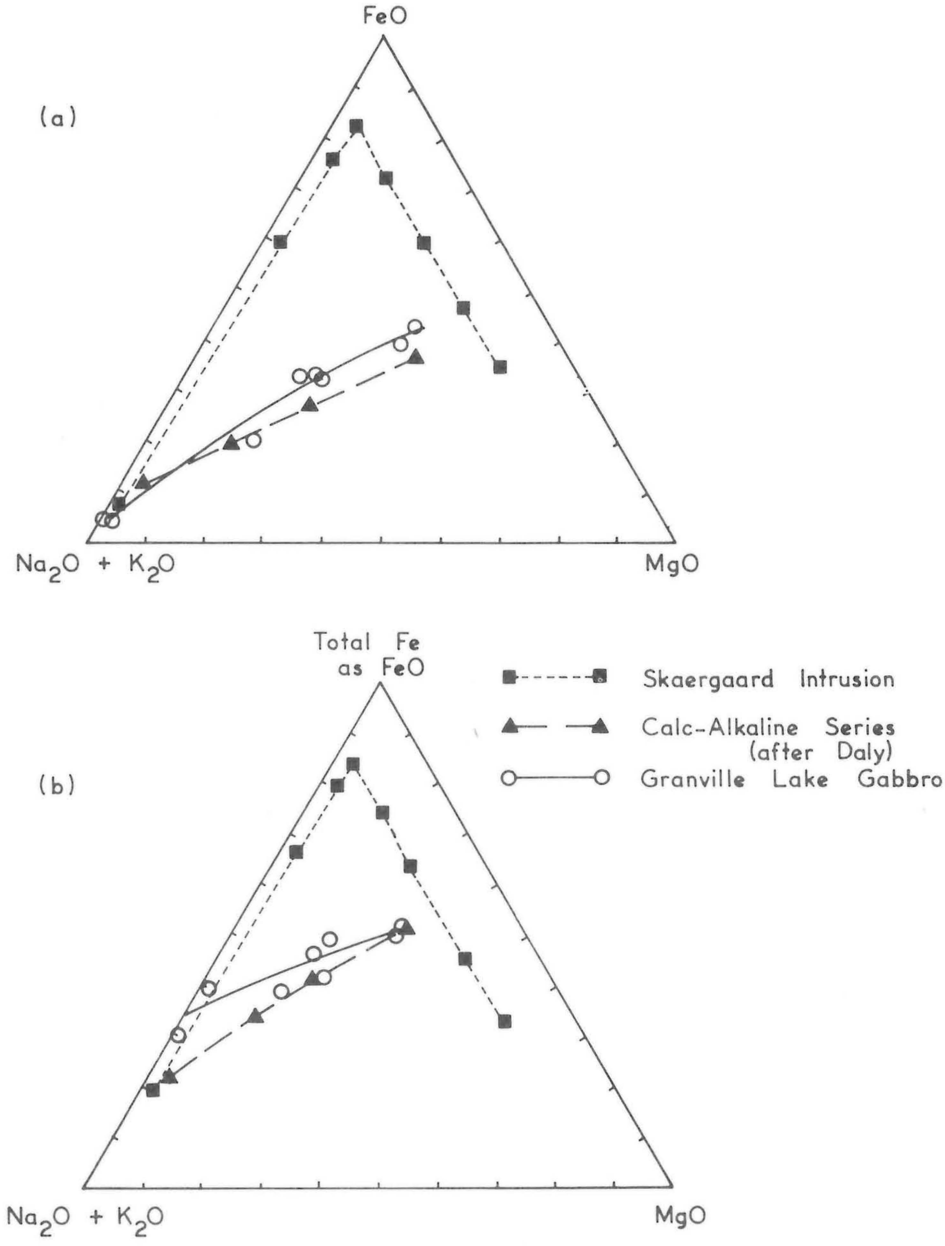


FIGURE 11. *Differentiation trend of the Granville Lake gabbro.*

Differentiation of basaltic magma can result in any gradation between two main trends, which are:

(a) the tholeiitic trend consisting of pronounced enrichment of iron relative to magnesia until late stages of crystallization, followed by a decrease in iron and enrichment of alkalies (e.g. Skaergaard intrusion of Greenland);

(b) the calc-alkaline trend with continuous enrichment in alkalies; the Granville Lake gabbro is a good example of this type of differentiation.

Osborn (1959) has shown that the partial pressure of oxygen (pO_2) during fractional crystallization is the chief control determining whether basaltic magmas follow a calc-alkaline or tholeiitic trend. The former occurs where pO_2 remains constant or increases, the latter where pO_2 decreases during crystallization. Water content is probably the principal factor: Osborn concludes that if water pressure is appreciable, the total pO_2 in the magma will remain constant or will increase as a magma crystallizes. This results in a continuous increase in the silica content, and a decrease in iron oxide (calc-alkaline trend).

Basic rocks of the Granville Lake intrusion appear to be of the calc-alkaline types as indicated by scarcity of pyroxene, high hornblende content, and scapolitic alteration of plagioclase.

Kennedy (1948) states that the ratio of ferrous to ferric oxide in a rock melt depends upon the partial pressure of oxygen (pO_2). The reaction involved is:-

$$2Fe_2O_3 \rightleftarrows 4FeO + O_2.$$

TABLE 11

Value of FeO/Fe_2O_3 ratios for the Granville Lake gabbro

Specimen	% FeO	% Fe_2O_3	FeO/Fe_2O_3	Zone
CG 6–25	0.39	3.8	0.1	Granite
CG 6–22	0.39	5.7	0.1	zone
CG 12–21	2.23	3.76	0.6	Transition
CG 10–23	4.88	2.73	1.8	zone
CG 2–14	5.12	4.51	1.1	
CG 15–17	6.0	2.9	2.1	Gabbro
CG 10–5	5.8	3.5	1.7	zone
CG 9–25	4.7	4.9	1.0	

Table 11 shows the $FeO:Fe_2O_3$ ratio of specimens from the Granville Lake gabbro; this ratio ranges from 2.1 to 0.1. An average weighted value of $FeO:Fe_2O_3$ was computed for the intrusion as a whole, assuming that the exposed surface areas are approximately proportional to the volume of each of the three map units. The value obtained, 1.3, is believed to represent a reasonable approximation of the actual $FeO:Fe_2O_3$ ratio in the intrusion. In the Skaergaard intrusion, typical of the dry magmas (Wager and Deer, 1939, table XXXXI), the ratio varies between four and thirteen, falling to two only in the latest rocks to crystallize. Wager and Deer propose a ratio of 6.4 for the undifferentiated magma. The relatively low $FeO:Fe_2O_3$ ratio of the Granville Lake intrusion is further evidence that this intrusion formed by crystallization of a wet magma.

Similar calculations indicate the silica content of the primary Granville Lake magma as 53.9 per cent. This is confirmed by the average specific gravity of 2.84 for the 448 specimens collected from the intrusion, corresponding to a silica content of 53.8 per cent (Fig. 8). These figures indicate that the overall composition of the mass is intermediate beteeen Daly's (1933) average gabbro and average diorite.

PLAGIOCLASE-QUARTZ-BIOTITE SCHIST-PEGMATITE COMPLEX (21)

A complex of plagioclase-quartz-biotite schist and pegmatite occurs on the mile-long peninsula immediately south of the Granville Lake gabbro and on scattered islands extending 6½ miles to the southeast.

The rocks of the complex are comprised of approximately 50 to 75 per cent schist and 25 to 50 per cent coarse orange pegmatite. The schist, apparently formed by recrystallization of Sickle sediments, is fine to medium grained with "salt and pepper" texture and well-developed schistosity; grain size is coarser than in the normal Sickle arenites. The largest pegmatite bodies are 500 feet long and 150 feet wide. Most of the pegmatite occurs as concordant lens-shaped intrusions wedged into the schist. Small dykes and veinlets are also common, some of them ptygmatically folded.

Typical pegmatite is a coarse intergrowth of orange feldspar and quartz. A much finer-grained phase is found in some of the Manitou group of islands. A few outcrops contain euhedral black tourmaline crystals up to 3 or 4 inches long.

Exposures of the pegmatite-schist complex may be part of a continuous band of such rocks with a length of over 8 miles, but as the larger pegmatite bodies are relatively resistant to weathering, it is more likely that they represent localized injections along a schistose horizon in the Sickle sediments.

LARGER PEGMATITE BODIES (22)

It is probable that the pegmatite bodies grouped under this unit are not strictly identical in origin and age, as they vary greatly in colour, composition, grain size and texture. However, pegmatite is always the youngest rock type in any particular locality. Many pegmatite bodies stand as bald rounded outcrops, 50 to 75 feet above the surrounding terrain. The predominant type is very coarse-grained and orange in colour, but some are white to rose pink and finer-grained. Most pegmatites are tabular dykes or sills, but irregular and rounded intrusions are also common. Well-developed zoning can be seen in some pegmatite intrusions.

Typical pegmatite is composed of coarse pinkish orange feldspar and grey white quartz. Feldspar is microcline perthite, microcline and sodic plagioclase; crystals range from 1 to 12 inches and rarely 3 or 4 feet in length. Mica is rare, but some intrusions contain muscovite, or less commonly biotite, in books up to 2 inches across. Graphic intergrowths of feldspar with 10 to 15 per cent quartz occur rarely and were observed only in the orange varieties of pegmatite.

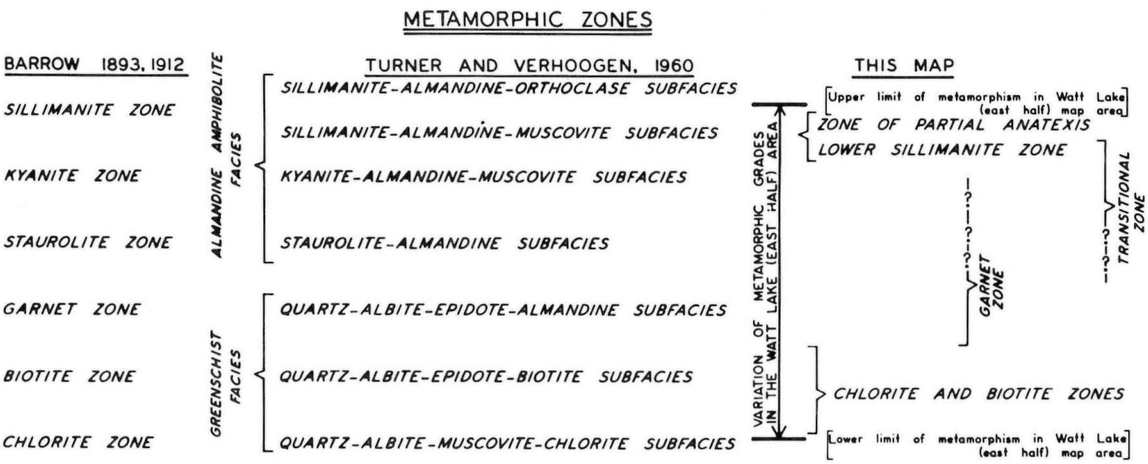
A few outcrops of rose-pink pegmatite were observed, mainly near the Granville Lake gabbro. White pegmatite is rare and appears to be associated with zoned pegmatite intrusions; grain size is usually less than one centimeter; graphic intergrowths of white feldspar and quartz are common.

METAMORPHISM

Metamorphic grade of sedimentary and volcanic rocks of the map-area varies from lower greenschist facies to middle or upper almandine amphibolite facies of Turner and Verhoogen (1960). Regional distribution of the various zones is illustrated in Figure 12, which is based on about 100 thin sections, on field notes, and on hand specimens. Since the Sickle sediments, which underlie virtually the entire area, are not sensitive indicators of metamorphic zoning, Figure 12 indicates only their minimum metamorphic grade. It has been possible, however, to use grain size (degree of recrystallization) as a supplementary indicator in determining metamorphic grade, particularly where mineral assemblages of the biotite or garnet zones have remained stable up to the sillimanite zone.

The least metamorphosed rocks in the area, upper chlorite zone to biotite zone, are found immediately west of Beaucage Lake where extremely fine crossbedding is preserved in silty sediments. A large portion of the Sickle arenites in the northern half of the area has attained at least the biotite zone and probably garnet zone of regional metamorphism. Wasekwan rocks east of Beaucage Lake show diagnostic garnet zone assemblages. From north to south no further change in mineral assemblage occurs until the lower sillimanite zone (almandine-amphibolite facies, sillimanite-almandine-muscovite subfacies) characterized by the presence of microscopic sillimanite needles in quartz-muscovite knots. A zone of partial anatexis is evident in the Sickle arenites about a mile northeast of the mouth of Beatty Creek at Granville Lake. Near the southwest corner of the map-area a zone of lower metamorphic grade trends west-northwest and is surrounded by rocks of the sillimanite zone. The low-grade central portion has probably not exceeded upper greenschist or lower amphibolite facies (greenschist facies, quartz-albite-epidote-almandine subfacies of Turner and Verhoogen, 1960). Further southwest, metamorphic grade rapidly increases to lower sillimanite zone, and partial anatexis of the band of Sickle meta-arkose is common on the large island near the western boundary of the area.

(Continued on page 52)



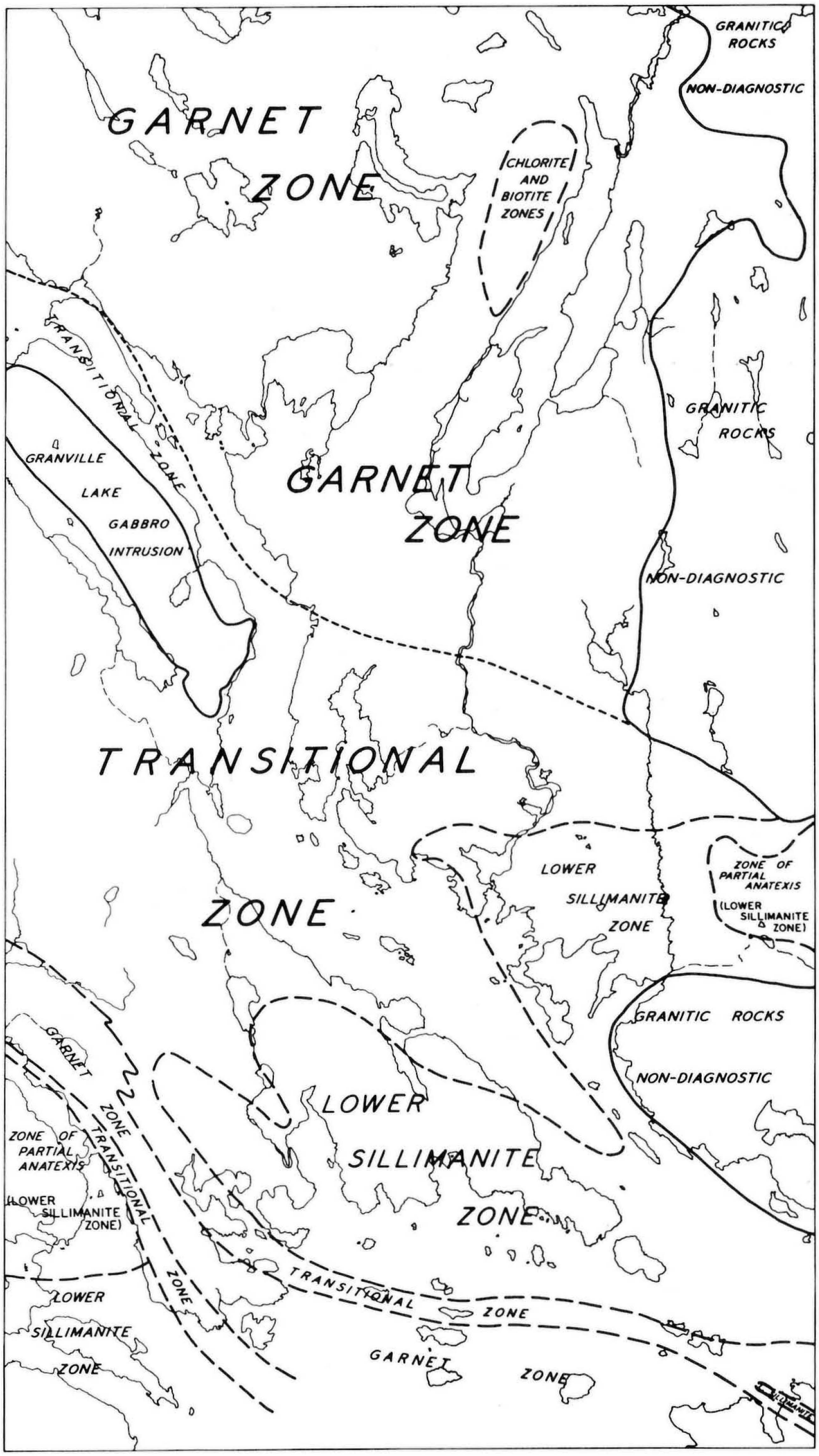


FIGURE 12. *Metamorphic zones of the Watt Lake area (east half).*

Observed mineral assemblages in the Wasekwan and Sickle arenites are as follows, with minerals for each assemblage listed in approximate order of relative abundance:

Wasekwan greywacke to arkose (map-unit 1a)

(a) oligoclase-quartz-biotite
(b) oligoclase-quartz-biotite-chlorite-garnet
(c) oligoclase-quartz-biotite-muscovite-garnet
(d) oligoclase-quartz-microcline-biotite-muscovite-garnet
(e) oligoclase-quartz-microcline-biotite-muscovite-chlorite-garnet
(f) oligoclase-quartz-hornblende-magnetite-garnet
(g) oligoclase-quartz-biotite-hornblende-magnetite-chlorite-garnet
(h) oligoclase-quartz-magnetite-anthopyhllite-garnet
(i) quartz-hornblende
(j) quartz-hornblende-magnetite

Wasekwan feldspathic greywacke (map-unit 1b)

(a) plagioclase (untwinned)-quartz-biotite-garnet
(b) plagioclase (untwinned)-quartz-biotite-magnetite-garnet
(c) plagioclase (untwinned)-quartz-biotite-muscovite-magnetite-garnet (with muscovite-quartz-sillimanite knots)

Sickle arkose to greywacke (map-unit 5)

(a) albite (?)-quartz-microcline-biotite-muscovite-calcite-chlorite
(b) albite (?)-quartz-microcline-muscovite-calcite-chlorite-magnetite
(c) oligoclase-quartz-microcline-biotite-muscovite-calcite-magnetite-apatite-epidote-actinolite
(d) oligoclase-quartz-microcline-biotite-muscovite-calcite-magnetite-apatite
(e) oligoclase-quartz-microcline-biotite-muscovite-magnetite-apatite
(f) oligoclase-quartz-microcline-biotite-muscovite-magnetite-apatite-hornblende
(g) oligoclase-quartz-microcline-biotite-magnetite-apatite
(h) oligoclase-quartz-microcline-biotite-magnetite-apatite-hornblende
(i) oligoclase-quartz-microcline-biotite-magnetite-apatite-hornblende-clinozoisite
(j) oligoclase-quartz-biotite-muscovite-magnetite-apatite
(k) oligoclase-quartz-microcline-biotite-muscovite-calcite-magnetite-apatite-epidote
(l) oligoclase-quartz-microcline-magnetite-apatite-epidote-hornblende

Assemblage (e) greatly predominates; most other assemblages are unimportant.

Knotted recrystallized Sickle arenites (map-unit 8)

(a) oligoclase-quartz-microcline-biotite-muscovite-magnetite-apatite (with muscovite-quartz-sillimanite knots)

Sillimanite normally occurs only in the knots, but not in the finer-grained matrix. The reason for this is discussed below.

Sickle meta-arkose (map-unit 7)

(a) quartz-oligoclase-microcline-biotite-muscovite-magnetite
(with muscovite-quartz-sillimanite knots)
(b) quartz-oligoclase-microcline-biotite-magnetite
(c) quartz-oligoclase-microcline-biotite-magnetite-apatite
(d) quartz-oligoclase-microcline-biotite

Assemblage (a) is greatly predominant.

Mineral assemblages of the Sickle and Wasekwan meta-sedimentary rocks are best understood by use of the methods of graphical analysis of metamorphic mineral assemblages proposed by Thompson (1957; 1961). Thompson's method (1957) involves neglecting H_2O and SiO_2; the latter is assumed to be present in excess, to form quartz. Mineral compositions within the tetrahedrom Al_2O_3–K_2O–FeO–MgO are projected through the point for muscovite, KAl_3O_5 (plus $3SiO_2$ and H_2O) which is also assumed to be always present. Thus various mineral assemblages of the six component systems (SiO_2–Al_2O_3–MgO–FeO–K_2O–H_2O) are represented on a three-component diagram. Similar projections can be constructed for the system K_2O–Na_2O–Al_2O_3–SiO_2–H_2O (Thompson, 1961, and unpublished work).

Figures 13a to 13e and 14a to 14g represent the mineral assemblages at various metamorphic grades for the two systems as commonly observed in various localities throughout the world. These figures represent only some of the important changes in mineral assemblages with changing metamorphic grade. The projections represented should be considered as schematic rather than precisely quantitative in their present form as few analyses of co-existing mineral pairs and three phase assemblages are presently available. Cordierite has been ignored in the construction of the few simple projections presented in this report because the precise metamorphic P-T conditions and mineral assemblages of cordierite-bearing rocks are not well known. The formation of cordierite-bearing assemblages in regionally metamorphosed rocks apparently requires a high content of MgO relative to FeO and also a relatively high Al_2O_3 content. Pelitic and arenaceous rocks of such composition are relatively uncommon; no such rocks are found in the Watt Lake area so that non-representation of cordierite is of little significance here.

With regard to metamorphic assemblages in the system SiO_2–Al_2O_3–MgO–FeO–K_2O–H_2O (Fig. 13a to 13e), Sickle arenites have a bulk composition falling within the two-phase region biotite-K-feldspar (plus quartz and muscovite). Hence the formation of chloritoid, garnet, staurolite, cordierite, andalusite, kyanite and sillimanite is not possible and mineral assemblage of such rocks cannot change beyond the biotite zone.

Similarly, since the bulk composition of the same Sickle arenites lies in the muscovite-K-feldspar-albite triangle of the system K_2O–Na_2O–Al_2O_3–SiO_2–H_2O, kaolinite, pyrophyllite, andalusite, kyanite, and sillimanite cannot stably coexist with K-feldspar (microcline is invariably present in the arenites) except under higher grade conditions than were attained in the map-area. Local development of sillimanite in muscovite-quartz knots (map-units 1b, 5, and 7) has, however, occurred because of the absence of K-feldspar in the knots. This sillimanite would correspond to the so-called "first sillimanite zone" (sillimanite-almandine-muscovite

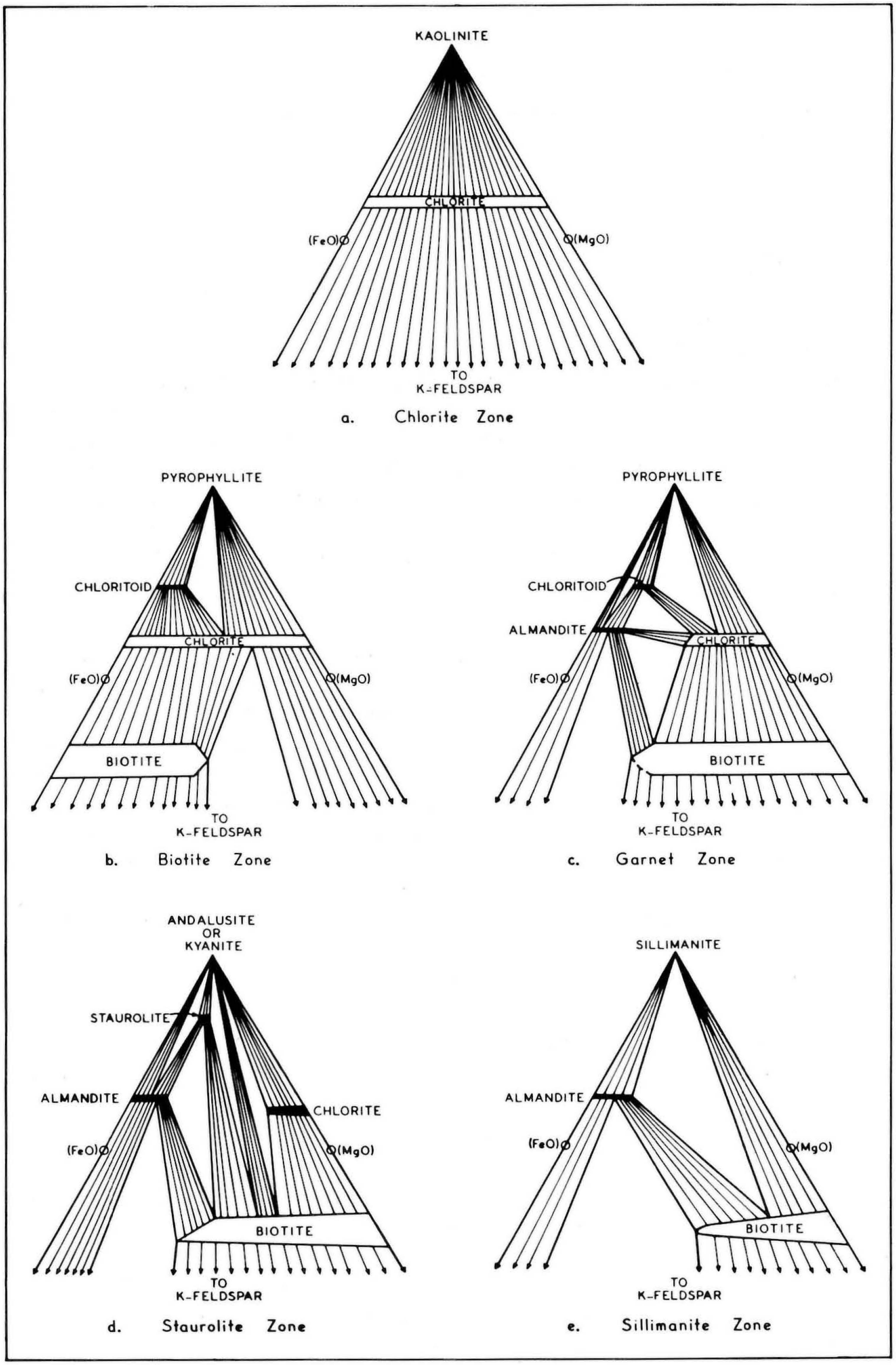


FIGURE 13. *Mineral assemblages (coexisting with quartz and muscovite) in the system* $SiO_2 - Al_2O_3 - MgO - FeO - K_2O - H_2O$.

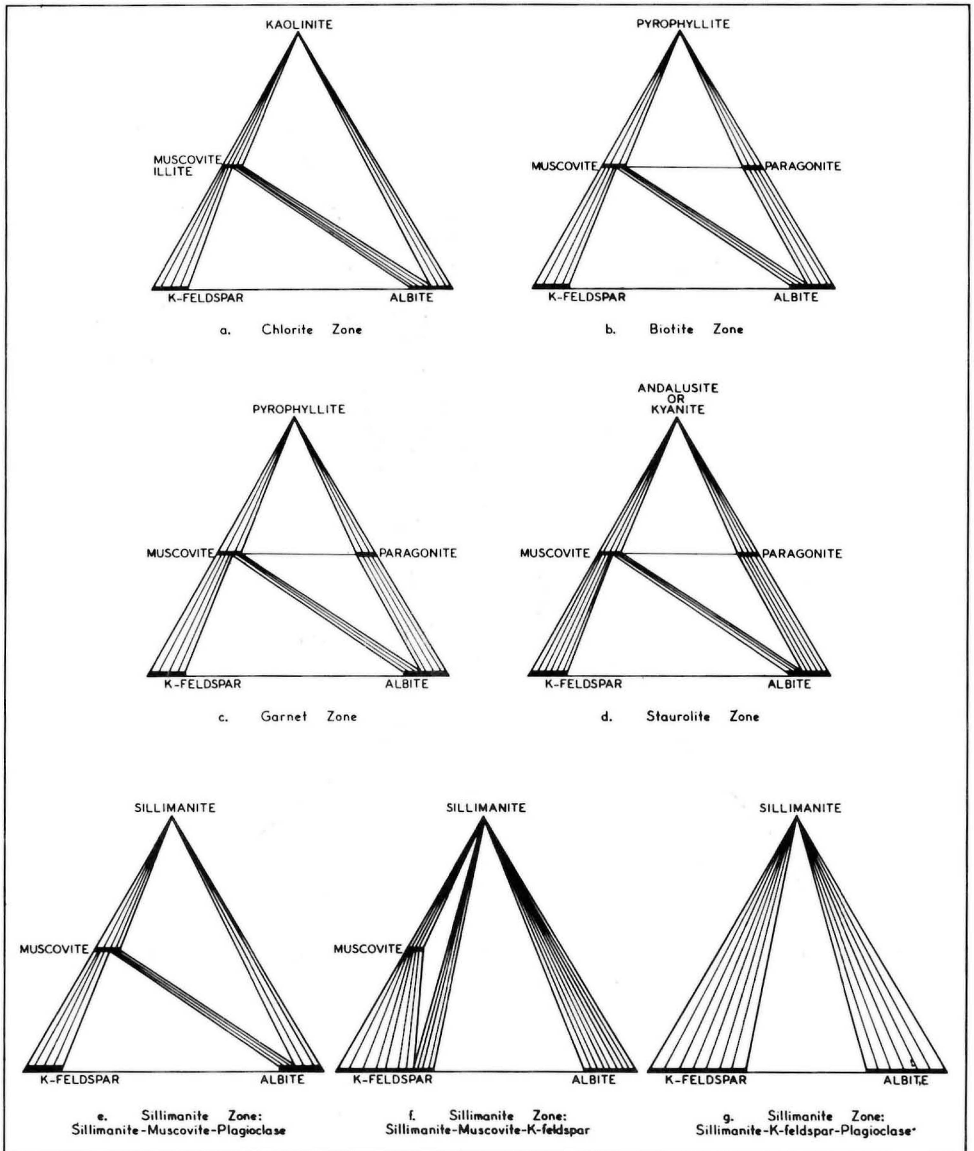


FIGURE 14. *Mineral assemblages (coexisting with quartz) in the system* $K_2O-Na_2O-Al_2O-SiO_2-H_2O$.

subfacies of the almandine amphibolite facies of Turner and Verhoogen, 1960). Nowhere in the Watt Lake area (east half) has the "second sillimanite zone" (sillimanite-almandine-orthoclase subfacies) been attained as indicated by the failure of muscovite and quartz to react and form sillimanite plus K-feldspar.

Milligan (1960, pp. 97-98, 164) has described similar muscovite-quartz knots elsewhere in the Lynn Lake district. He considers that the accompanying sillimanite has formed by the reaction:

$$\underset{\text{muscovite}}{KAl_2(AlSi_3O_{10})(OH)_2} + \underset{\text{quartz}}{SiO_2} \longrightarrow \underset{\text{sillimanite}}{Al_2SiO_5} + \underset{\text{K-feldspar}}{KAlSi_3O_8} + \underset{\text{water}}{H_2O}$$

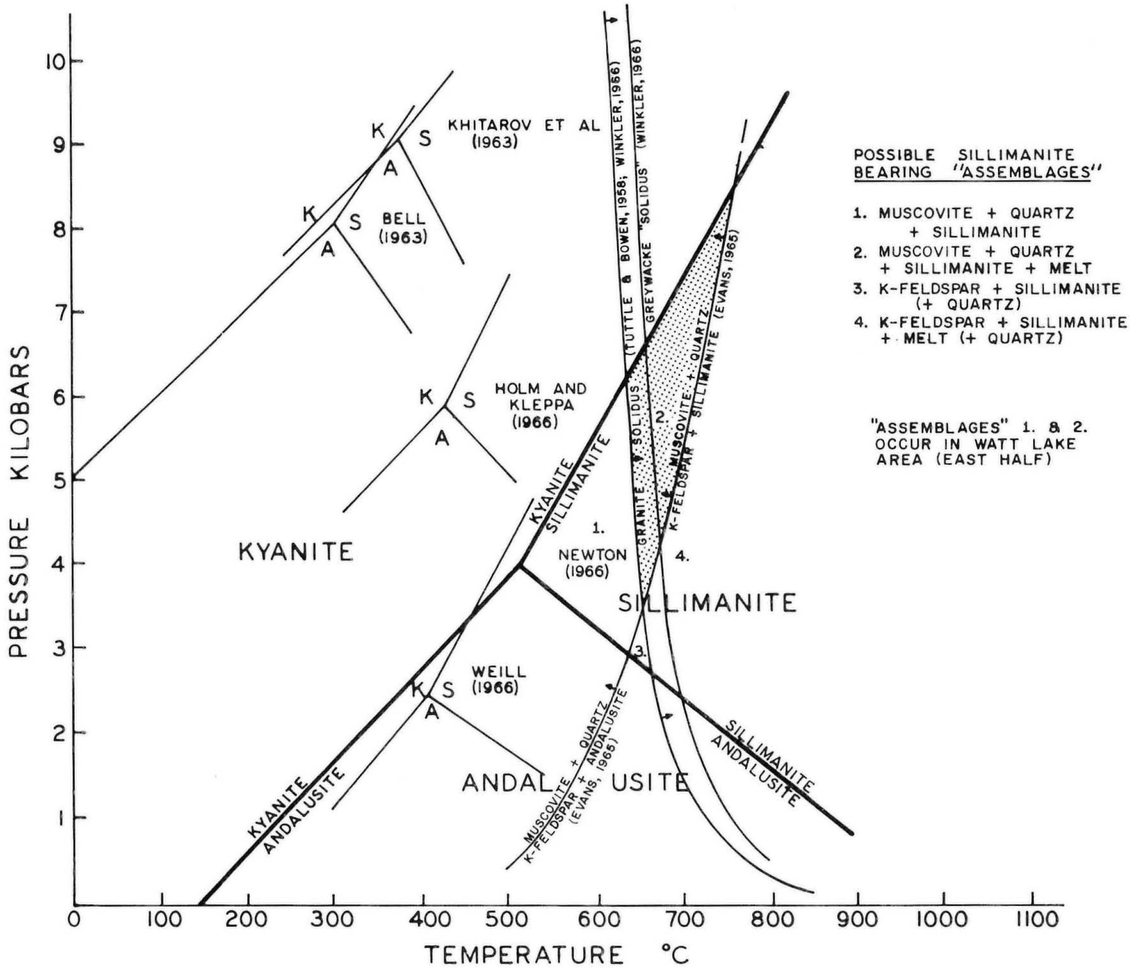


FIGURE 15. *Stability fields for kyanite, andalusite and sillimanite (after Newton, 1966) with additional data.*

He attributes the lack of sillimanite at Tod Lake to a lower metamorphic grade, but his equation fails to explain the complete lack of K-feldspar in the knots and the lack of sillimanite in the rock matrix, which contains both muscovite and quartz and should, therefore, have reacted to form sillimanite.

Barry (1965, p. 11) describes similar knots in Wasekwan rocks of the Trophy Lake area (east half), immediately south of the present map-area. He attributes the muscovite to retrograde metamorphism of quartz-sillimanite knots, (presumably in the presence of K-feldspar). However, at least in the Watt Lake area, such an explanation is questionable because perfect, delicate and often radiating sillimanite needles would not likely be preserved during retrograde reaction sufficient to cause total disappearance of K-feldspar.

The sillimanite-bearing muscovite-quartz knots of the Watt Lake area are, therefore, considered to be a product of prograde rather than retrograde metamorphism. Muscovite-quartz knots have presumably formed by segregation during increasing metamorphism. As the segregated material lacks K-feldspar, sillimanite can coexist with quartz and muscovite in the 'first sillimanite zone'. The matrix rock, however, contains K-feldspar (with which sillimanite is incompatible) thus accounting for the general absence of sillimanite in the matrix. With increasing metamorphic grade the quartz and muscovite of the knots would react upon attaining "second sillimanite zone" conditions to form sillimanite and K-feldspar. This is apparently the case in the Watt Lake area (west half), where Godard (1966, p. 11, 15 and 25) describes quartz-muscovite knots in various rocks, which with an increase in metamorphic grade to the west, apparently become quartz-sillimanite-K-feldspar knots.

AGE AND TEMPERATURE OF METAMORPHISM

Potassium-argon age determinations on biotite and muscovite indicate that the last period of regional metamorphism to affect the Churchill Structural Province occurred during the Hudsonian orogeny 1600 to 1800 m.y. ago (Geol. Surv., Can. Papers 61-17, 62-17, 63-17, 64-17, 65-17). However, separate determinations on biotite and muscovite from a specimen of Sickle meta-arenite (8) collected by C. H. Stockwell on the peninsula in the southwest corner of the map-area (see map) gave a biotite age of 1650 m.y. and a muscovite age of 2670 m.y. (G.S.C. 60-77, Paper 61-17). The latter corresponds to the Kenoran orogeny and represents a minimum age for both the Sickle and underlying Wasekwan rocks. If, as believed by Stockwell (1963), the Hudsonian orogeny in the area was not strong enough to recrystallize the muscovite or drive off the argon, the major metamorphism must have occurred during the Kenoran orogeny.

Figure 15 shows the stability fields for kyanite, andalusite, and sillimanite as given by Newton (1966). Although these differ from those of Bell (1963), Khitarov (et. al. 1963), Holm and Kleppa (1966), and Weill (1966) they are currently (August 1966) considered the most reasonable. Superimposed on these curves are the granite solidus curves of Tuttle and Bowen (1958) and Winkler (1966), as well as Winkler's greywacke "solidus" curve and Evans' (1965) curve for muscovite-quartz conversion to K-feldspar-sillimanite and K-feldspar-andalusite.

Consideration of these curves indicates that rocks which contain muscovite, quartz, and sillimanite and which have undergone anatectic fusion fall in the range 625° to 750°C at pressures of 4 to 8 kilobars. If, as is probable, pH_2O was less than total pressure, the temperature of anatectic fusion would be raised some what, possibly to 650°C. Similarly the muscovite-quartz conversion to K-feldspar-sillimanite would take place at somewhat lower temperatures than those shown by Evans' curve. The maximum temperature for the Watt Lake area, therefore, was probably between 650° and 700°C at pressures of 5 to 8 kilobars (20 to 32 kilometres depth). The lowest metamorphic grade (chlorite-biotite zone) indicates minimum temperatures of 450° to 500°C.

STRUCTURAL GEOLOGY

The dominant structure of the area is a large synclinorium which trends northwesterly in the sothern portion of the map-area and swings to the north in the northern half of the area. The same synclinorium extends north to Sickle Lake, where it swings west again, extending for ar least another 40 miles. The trend of the synclinorium which is apparently overturned to the north, is well defined by the Sickle conglomerate along the east side of Beaucage Lake and in the southwest corner of the map-area. This conglomerate does not, however, define the outer limits of the synclinorium. Sickle strata within the synclinorium have been tilted and folded on a broad scale. Their dip is now steep to almost vertical, and it was not found possible to classify the folds specifically as anticlines and synclines, or in many cases to locate axial planes. Axial planes of clearly defined folds are indicated on the geological map but detailed structure could not be worked out because of the general lack of criteria for the determination of stratigraphic tops in the area.

Immediately west of Beaucage Lake, extremely fine crossbedding in thin beds of silty Sickle arenite indicates overturning with easterly dips of 70 to 80 degrees, and tops facing west. Crossbedding in the Sickle arenites southeast of Beaucage Lake, also gives structural information. Elsewhere crossbedding has been destroyed by recrystallization.

Lineations were recorded where found. East of Beaucage Lake, elongated pebbles plunge strongly eastward, as do corrugations along shear zones in the other Sickle and Wasekwan rocks. Near the northwest end of the Granville Lake gabbro small fold axes in Sickle arenites plunge at 40 to 60 degrees to the south. In the southwest corner of the map-area lineations were mapped from corrugations in Sickle arenaceous beds, and from elongated pebbles in conglomerate.

Faulting is not prominent in the area apart from a few apparent minor east-west faults in the Wasekwan rocks east of Beaucage Lake. A strong north-south fault occurs about 2 miles west of the map-area.

Prior to 1961 the Sickle series was interpreted as overlying an older Wasekwan series with angular unconformity. The stratigraphic sequence has been confirmed in the present area although evidence for an angular unconformity is inconclusive. The potassium-argon age of 2670 million years for Sickle muscovite, indicates that these rocks are considerably older than formerly considered. Unfortunately pre-Hudsonian ages have yet to be found for Wasekwan rocks, so that the actual age difference between these two series is at present unknown.

ECONOMIC GEOLOGY

GOLD

Prospecting in the Watt Lake area (east half) has been primarily for gold. The only known promising showings are located on a property which extends west from the north end of Beaucage Lake to the north end of Deane Lake. This property consisted (1961) of the Star, Sky, Bee, Ham, and Rex claim groups. Four gold bearing shear zones were examined on the portion of the property which lies within the map-area; all are within or associated with irregular quartz veins and veinlets. Nearly all the showings known to the writer within and to the north of the map-area occur either within, or near, the Black Trout diorite. Values appear to be erratic. The showings examined are numbered (1) to (4) on the geological map. Several smaller showings are reported on the claim group but were not examined by the writer.

STAR 1 AND 2 CLAIMS (Locality 1)

In 1947 five trenches were excavated in Black Trout diorite and adjacent rocks on the Star 1 claim (at that time Anna Lou 3 claim). The trenches were examined and described by Milligan (1951, pp. 20 to 23; 1960, pp. 181-183). No further work appeared to have been done by June, 1961.

Milligan took channel samples over a length of 25 feet, with assay results as follows:-

TABLE 12

Gold assays, Star claims

Sample No.	Distance, Ft.	Gold, ozs. per ton	Remarks
M1018-50..............	4–9	.02	west wall of trench
M1019-50..............	9–14	.08	east wall of trench
M1020-50..............	14–19	.68	east wall of trench
M1021-50..............	19–24	.10	east wall of trench
M1022-50..............	24–25	.01	centre of trench btm.

All these values occur in Black Trout diorite which contains a network of pyrite-bearing quartz veins. Detailed sampling of the same trenches in 1958 by Selco Exploration Company Limited confirmed Milligan's 1950 values, but also showed that the .68 oz. value was due to a high gold content in a thickness of only 3 inches. For further details the reader is referred to Milligan (1960).

SKY 2 CLAIM (Locality 2)

On the Sky 2 claim several test pits and trenches have been excavated along a system of quartz veins in Black Trout diorite. The veins vary from ½ inch to 2 or 3 feet wide, and strike northwest *en echelon*. They have been exposed by ten or more trenches which cross and expose the vein system over a strike length of approximately 350 feet.

Chip samples were collected from these trenches; results are shown in Table 9. Location of each trench is indicated by approximate distance to the north, measured in feet from the southernmost trench, along the strike direction of the vein system.

TABLE 13

Gold Assays from Quartz veins, Sky 2 claim

Laboratory No.	Au ozs./ton	Length	Location	Remarks
M3228	0.12	0–2′0″	0 ft. N.	Network of quartz veins in sheared diorite with minor pyrite.
M3229	0.01	0–1′6″	50 ft. N.	Weathered quartz and sheared diorite, disseminated pyrite.
M3230	0.03	0–2′10″	250 ft. N.	Massive quartz vein in diorite.
M3231	tr.	2′10″-8′5″	250 ft. N.	Slightly foliated diorite.
M3232	0.14	8′5″-11′5″	250 ft. N.	Rusty quartz vein in diorite
M3233	1.00	0–4′9″	300 ft. N.	Rusty quartz vein with inclusions of diorite.
M3234	0.10	0–7′0″	320 ft. N.	Rusty vein quartz and diorite
M3235	0.07	0–5′0″	320 ft. N.	Shear zone in diorite, abundant pyrite.
M3236	0.01	—	320 ft. N.	Grab sample from shear zone in diorite.

Analyst, D. F. Brown, Manitoba Mines Branch

REX 4 CLAIM (Locality 3)

Four trenches which vary from 20 to 75 feet long were examined on the Rex 4 claim. The trenches had been excavated across and along a system of quartz veins in Black Trout diorite. The veins contain sparsely disseminated pyrite and have been formed along an almost vertical joint system which strikes N75°W. The largest vein is approximately 3 feet wide. A grab sample of the most highly mineralized quartz assayed 0.04 oz. Au/ton.

HAM 1 CLAIM (Locality 4)

A zone of branching quartz veins occurs in Sickle arenite near the northwest corner of Ham 1 claim. The mineralized zone is roughly 20 feet wide and 300 feet long. Trenches have been excavated across this zone over a strike length of 200 feet. Quartz veins are milky white to greyish white and contain up to 5 per cent disseminated pyrite. A few veins are as wide as 2 feet, but most are only several inches. A grab sample of the most highly mineralized quartz assayed 0.11 ozs. Au/ton.

BERYL (Locality 5)

A pegmatite dyke containing beryl was found by the writer in August, 1961 on the south side of an island in Granville Lake, near the south boundary of the map-area. Beryl has not previously been reported from the Lynn Lake or Granville Lake areas.

The dyke is 16 feet wide, and cuts Sickle arenites. It consists of a coarse graphic intergrowth of microcline-perthite and quartz, with scattered books of muscovite up to 2 inches across, and minor biotite. It strikes S55°E and was exposed only because of the low water-level of Granville Lake during August, 1961. The pegmatite contains a few red-brown garnet crystals and small disseminated grains of a hard grey metallic mineral, which yields a red powder when crushed and might be cassiterite. Scattered, irregularly shaped quartz lenses in the core zone of the dyke are about one foot wide, and contain hexagonal crystals of beryl, apatite, and tourmaline, as well as small books of a pale greenish yellow mica. Beryl crystals are well formed, pale yellow-green in colour, up to 2 inches across and 6 or more inches long. Black euhedral tourmaline crystals are up to 3/8 inch across and 3 inches long. Apatite crystals are well formed, blue-green in colour and up to ½ inch across.

It is doubtful that the beryl content of the dyke is sufficient to be of economic value. However, numerous large and small pegmatite intrusions exist in the Watt Lake area, and prospecting of these for berylium and lithium minerals and other minerals of pegmatitic association is suggested.

BASE METALS

The only occurrences of base metals known within the map-area are associated with the Granville Lake gabbro. The association of copper-nickel sulphides with mafic and ultramafic rocks is well known. Differentiated mafic intrusions present a particularly favourable environment for the accumulation of copper and nickel sulphides in the form of chalcopyrite and pentlandite in association with pyrrhotite.

In view of the favourable environment provided by differentiation of mafic magma, and also the economic significance of the nickel-copper orebodies of the Lynn Lake intrusion, it would seem possible that similar sulphide accumulations might be found in the Granville Lake gabbro.

In the field, rare tiny specks of pyrite were observed in the gabbro and transition zones of the main intrusion. In addition, minor copper sulphides were observed in the satellite intrusion which is located at the northwest end of the main intrusion, between the granite zone and the east shore of the narrow mile-and-a-half long inlet of Granville Lake. This is the same intrusion from which specimens CG 15–1 and CG15–3 were obtained. The one copper sulphide occurrence noted is at the northwest end of this intrusion. It consists of a few 1/8 inch veinlets of mixed bornite and chalcopyrite along chloritic fractures in gabbro, immediately adjacent to the western gabbro-sediment contact. A similar occurrence, not seen by the writer, is reported near the southeast end of this same satellite intrusion. It is the opinion of the writer that the veinlets are probably of hydrothermal origin, apparently deposited at some time after the consolidation of the intrusion. The observed veinlets are of no economic value.

Not one grain of chalcopyrite, pentlandite, or pyrrhotite was noted in the main intrusion either in the field, or in a later careful examination of all rock specimens. The main intrusion is extremely well exposed, particularly along its base where sulphide accumulations might be expected. In contrast to this, the Lynn Lake gabbro contains disseminated grains of pyrrhotite and chalcopyrite throughout the intrusion.

Economic copper-nickel sulphide accumulations are therefore unlikely in the outcrop zone. Field and petrologic evidence indicates that the intrusion was slightly tilted at the time of crystallization and there is a possibility that more mafic rocks and/or sulphide zones might exist at depth.

REFERENCES

Barry, G. S.
1965: Geology of the Trophy Lake Area (East Half); *Man. Mines Br.*, Publ. 63–3.

Bateman, J. D.
1945: McVeigh Lake Area; *Geol, Surv. Can.* Paper 45–14.

Bell, P. M.
1963: Aluminum Silicate System; Experimental Determination of the Triple Point; *Science*, Vol. 139, pp. 1055–1056.

Collins, W. H.
1934: Life History of the Sudbury Nickel Irruptive, I. Petrogenesis; *Roy. Soc. Can.*, 3rd ser. vol. XXVIII, Sec. IV, pp. 123–177.

Cranstone, D. A.
1964: Petrology of the Granville Lake Gabbro; M. Sc. thesis, University of Manitoba, Winnipeg, 150 p.

Daly, R. A.
1933: Igneous Rocks and the Depths of the Earth; McGraw-Hill, New York, 598p.

Downie, D. L.
1935: Granville Lake Sheet (East Half), Manitoba; *Geol. Surv. Can.*, Map 344A.

Emslie, R. F.
1961 : The Petrology and Economic Geology of Two Mafic Intrusions in the Lynn Lake Area, Northern Manitoba; Northwestern Univ., Ph. D. Thesis, 161 p.

Emslie, R. F. and Moore, J. M., Jr.
1961: Geological Studies of the Area betweee Lynn Lake and Fraser Lake; *Man. Mines Br.*, Publ. 59–4.

Evans, B. W.
1965: Application of a Reaction-Rate Method to the Breakdown Equilibria of Muscovite Plus Quartz; *Amer. Jour. Sci.*, vol. 263, pp. 647–667.

Fawley, A. P.
1949: Geology of the Sickle Lake Area; *Man. Mines Br.*, Publ. 48–6.
1952: Geology of the Lasthope Lake Area; *Man. Mines Br.*, Publ. 49–5.

Geological Survey of Canada
Nomenclature of Igneous Rocks (igneous rock classification printed on a 4 x 6 inch card).

Godard, J. D.
1966: Geology of the Watt Lake Area (West Half); *Man. Mines Br.*, Pub 61–4.

Grout, F. F.
1932: Petrography and Petrology; McGraw-Hill, New York, 522 p.

Holm, J. L. and Kleppa, O. J.
1966: The Thermodynamic Properties of the Aluminum Silicates, *Amer. Min.*, vol. 51, pp. 1608–1622.

Hunter, H. E.
1958: A Study of the Tow Lake Gabbro; *Man. Mines Br.*, Publ. 53–5.

Kennedy, G. C.
1948: Equilibrium Between Volatiles and Iron Oxides in Igneous Rocks; *Amer. Jour. Sci.*, vol. 246, pp. 529–549.

Khitarov, N. T.; Pugin, V. A.; Pin Chao; Slutski, A. B.
1963: Relations Between Andalusite, Kyanite and Sillimanite at Moderate Temperatures and Pressures; *Geochemistry*, 1963, pp. 235–244.

McInnes, W.
1913: The Basins of the Nelson and Churchill Rivers; *Geol. Surv. Can.*, Mem. 30.

Milligan, G. C.
1951: Geology of the Beau Cache Lake Area; *Man. Mines Br.*, Publ. 50–8.
1960: Geology of the Lynn Lake District; *Man. Mines Br.*, Publ. 57–1.

Newton, R. C.
1966: Kyanite-Andalusite Equilibrium from 700° to to 800° C; *Science*, vol. 153, pp. 170–172.

Norman, G. W. H.
1934: Granville Lake District, Northern Manitoba; *Geol. Surv. Can.*, Summary Report (1933), Part C. pp. 23–41.

Osborn, E. F.
1959: Role of Oxygen Pressure in the Crystallization and Differentiation of Basaltic Magma; *Amer. Jour. Sci.*, vol. 257, pp. 609–647.

Peacock, M. A.
1931: Classification of Igneous Rock Series; *Jour. Geol.*, vol. 39, pp. 54–67.

Pettijohn, F. J.
1957: Sedimentary Rocks, 2nd edition; Harper and Row, New York.

Stockwell, C. H.
1963: Interpretation of Age Date G.S.C. 62–99; *Geol. Surv. Can.* Paper 63–17, pp. 65–66.

Thompson, J. B. Jr.

1957: The Graphic Analysis of Mineral Assemblages in Pelitic Schists; *Amer. Min.*, vol, 42, pp. 842–858.

1961: Mineral Facies in Pelitic Schists, in : Fiziko-Khimicheskie Problemii Formirovaniya Garnyikh Porod i Rud (Physico-Chemical Problems of the formation of Rocks and Ores), Sokolov, G.A., ed. (in Russian), Acad. Nauk U.S.S.R., Inst. Geo. Ore Deposits, Petrog., Mineral., Gerchem., pp. 313–324, English summary pp. 323–324.

Turner, F. J. and Verhoogen, J.

1960: Igneous and Metamorphic Petrology (2nd Edition); McGraw-Hill, New York.

Tuttle, O. F. and Bowen, N. L.

1958: Origin of Granite in Light of Experimental Studies in the System $NaAlSi_3O_8$–$KAlSi_3O_8$–SiO_2; *Geol. Soc. Amer.*, Mem. 74.

Wager, L. R. and Deer, W. A.

1939: Geological Investigations in East Greenland, Part III, The Petrology of the Skaergaard Intrusion, Kangerdlugssaug, East Greenland; Meddelelser om Gronland, Bd. 105, no. 4.

Weill, D. F.

1966: Stability Relations in the Al_2O_3–SiO_2 System Calculated from Solubilities in the Al_2O_3–SiO_2–$NaAlF_6$ System; *Geochem. Cosmochim Acta*, vol. 30, pp. 223–237.

Winkler,H. G. F.

1966: Petrogenesis of Metamorphic Rocks; Springer-Verlag, New York.