



MANITOBA
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GEOLOGICAL REPORT GR79-1

GEOLOGY OF THE McKNIGHT-McCALLUM LAKES AREA

By
P. G. Lenton

1981



**MANITOBA
DEPARTMENT OF ENERGY AND MINES**

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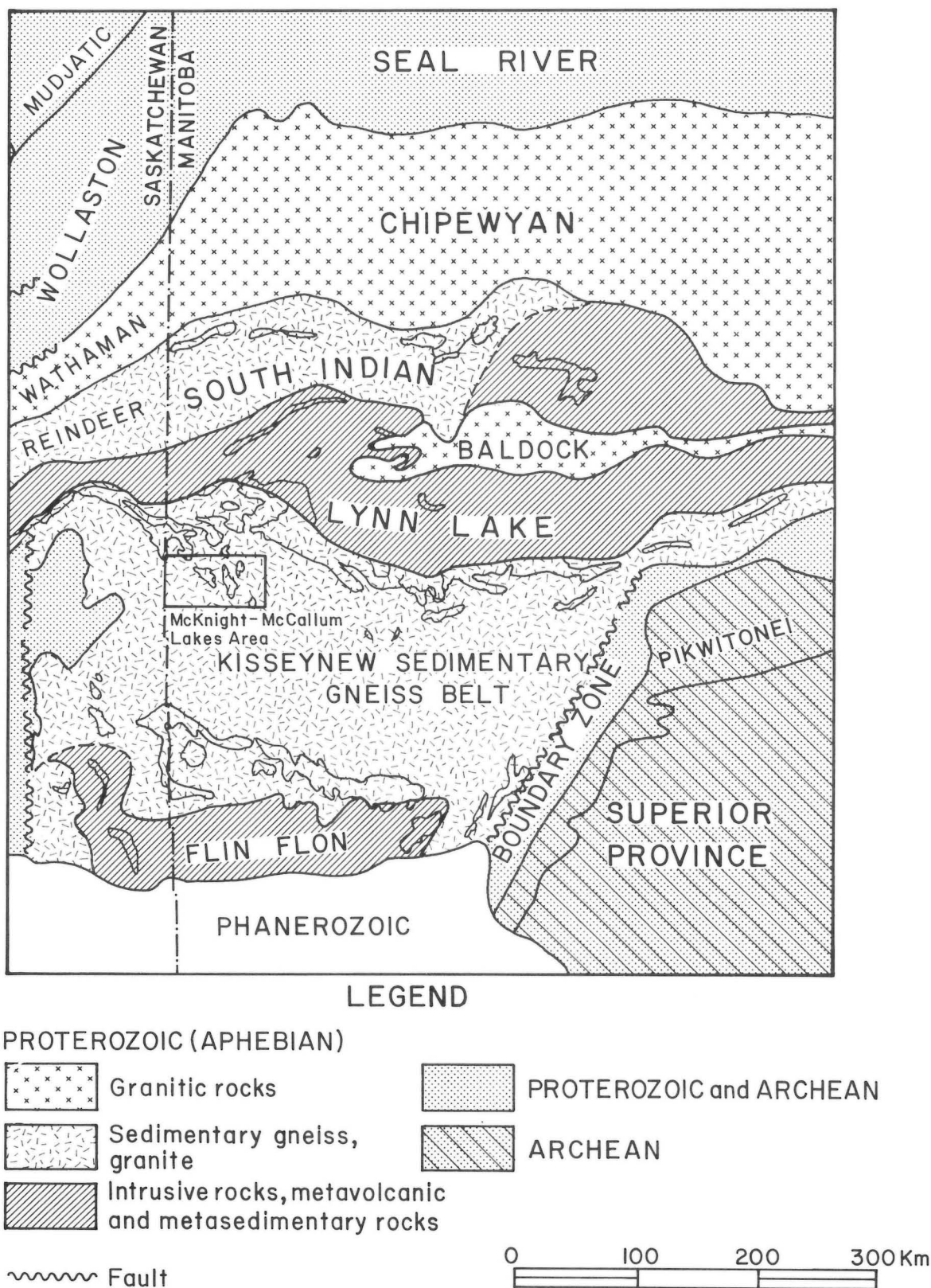


Figure 1: Location of the McKnight-McCallum Lakes area within the Kiseynew sedimentary gneiss belt.

INTRODUCTION

The McKnight-McCallum Lakes area is underlain by Aphebian age gneiss derived from predominantly sedimentary rock. The area lies in the northern portion of the Kiseynew sedimentary gneiss belt (Bruce, 1918; Bailes, 1971).

LOCATION AND ACCESS

The McKnight-McCallum Lakes area is located 80 km southwest of Lynn Lake in central western Manitoba. It comprises approximately 1750 km² extending between latitudes 56°00' and 56°15' north and longitudes 101°00' and 102°00' west. This area is covered by sheets 64C/3 (McKnight Lake) and 64C/4 (McCallum Lake) of the National Topographic Series. The area is readily accessible from Lynn Lake by commercial float aircraft. The central region of the McKnight Lake sheet is accessible from the Canadian National rail line with stops at J'etait and Hone. The Russell-McCallum Lakes water system is accessible from the CNR line at Herriott on the northeast end of Russell Lake. In addition, there is a gravel airstrip approximately 805 m (2800 feet) long located beside the Canadian National line at the north boundary of the McKnight Lake sheet. This airstrip is owned by Manitoba Hydro and is linked by road to the Laurie River power station.

Water access within the area is excellent. The McKnight-Wolfpack Lakes water system is navigable with short portages giving access to Abrey and Elvyn Lakes. The Russell-McCallum Lakes water system gives excellent access to the central regions. The Loon River is only navigable for short distances.

PREVIOUS WORK

The McKnight-McCallum Lakes area was previously mapped by Downie (1936) on a reconnaissance scale of four miles to the inch. A large part of the McKnight Lake sheet was mapped by Hunter (1953) on a scale of two miles to the inch. Preliminary mapping on the shoreline of Russell Lake was carried out by McRitchie (1975) on a scale of two inches to one mile.

The adjoining areas have been mapped for the Manitoba Geological Survey by McRitchie *et al.* (1972, 1973), Zwanzig and Wielezynski (1975) and Baldwin (1974) on a scale of two inches to one mile and Pollock (1966) on a scale of one inch to one mile. The area adjoining to the west was mapped by Gilboy (1976) on a scale of 1:100 000.

PRESENT WORK AND ACKNOWLEDGEMENTS

The present work is based on six months of field work carried out during the summers of 1975, 1976 and 1977. Rock exposures on all major lakes were examined in detail. Vertical aerial photographs at a scale of 1 inch to 2640 feet and 1 inch to 1320 feet were used to locate traverses which were conducted using standard pace and compass methods. Less accessible areas were reached by helicopter. Data collected in the field were plotted on base maps at a scale of two inches to one mile. The maps have been reduced to a scale of 1:50 000 for publication.

The author acknowledges the capable assistance of senior assistants M. Cameron and P. Wielezynski and junior assistants, L. Stewart, M. Sanford, R. Schmidt, F. Schick, J. Corkery, D. Scharein and J. Peters, all of whom performed their duties in a capable and efficient manner.

The author gratefully acknowledges the work done by W. D. McRitchie in 1975 on the main structure centered on Russell Lake. Most of his data has been incorporated into the present maps of the area.

Valuable assistance has been rendered through discussions with colleagues at the Manitoba Mines Resources Division, par-

ticularly H. Zwanzig and D. Baldwin. Active support has been given by W. D. McRitchie on all phases of the project, and his constructive criticism is particularly appreciated.

AVAILABLE MAPS AND AERIAL PHOTOGRAPHS

National Topographic Series Map 64C, Granville Lake, at a scale of 1:250 000 covers the McKnight-McCallum Lakes area. Also available are National Topographic Series 1974 Provisional Maps 64C/3, McKnight Lake and 64C/4, McCallum Lake at a scale of 1:50 000. These maps can be obtained from the Map Distribution Office, Ottawa, or from the Surveys Branch of the Manitoba Department of Natural Resources. Vertical aerial photographs at a scale of 1 inch to 1320 feet and corrected aerial photograph mosaics covering individual townships at scales of 1 inch to 2640 feet are available for the entire area.

GENERAL PHYSICAL FEATURES

The area is dominated by three main water systems: the Loon River, Russell-Laurie Lake, and McKnight Lake. Drainage is generally northward feeding the Laurie River system. These represent three extensive navigable water systems. Although they all drain into the Laurie River, there is no navigable connection between them.

Outcrop is generally good but somewhat erratic in distribution. Areas of 40 per cent outcrop exposure are separated by belts of pleistocene overburden with low relief and poor drainage. Bedrock exposures are rare and generally inaccessible in these areas. Areas of high outcrop exposure consist of north-trending parallel ridges separated by narrow swamp-filled valleys. The area between McCallum Lake and the Loon River is particularly rugged with closely spaced 40 to 60 m high rock ridges.

Most of the area shows evidence of forest fires of various ages ranging from 10 to 30 years old. Areas of mature tree growth are relatively small in extent. Burned areas have poor access because of heavy growths of 1 to 3 m high black spruce and jackpine. This is particularly true of the west half of the McKnight Lake sheet and northwest of Russell Lake.

Resources in the area are rather limited. Commercial fishing operations for whitefish and pickerel are run on Russell Lake approximately every three years. Several local residents run trap-lines around Russell Lake and McKnight Lake. A small permanent staff is resident at the Manitoba Hydro power dam on the Laurie River.

GLACIATION

Glacial striae on ice-rounded outcrop surfaces are common throughout the area. The general ice movement direction was southwest although local directions of 260° to 270° were noted. Large glacial erratics of a wide variety of rock types occur throughout the area.

A north-south-trending dissected esker ridge runs through the west central area of the McKnight Lake map sheet. Sand and gravel are being quarried from the esker on the northern edge of the map sheet. To the south of the quarries the esker dies out in a broad sand and clay belt of little economic potential.

South of McCallum Lake and across most of the southern part of the McCallum Lake sheet is an area of thick glacial moraine deposits. This is the eastern termination of the Cree Lake terminal moraine that is quite extensive in Saskatchewan. The area is poorly drained with pothole lakes and numerous clay ridges. Where the Loon River crosses the moraine the river banks are broad mud flats and the river contains numerous clay shoals.

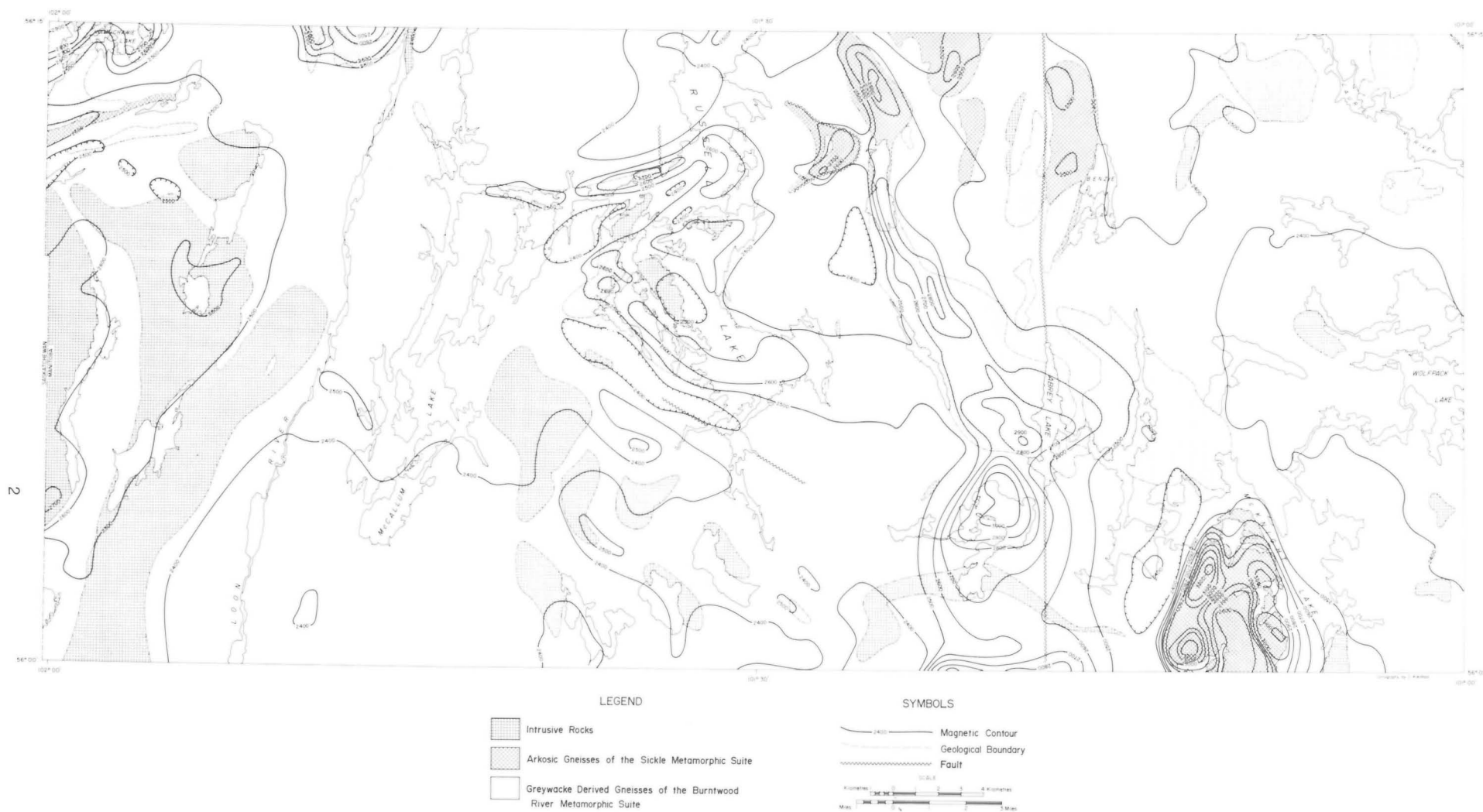


Figure 2: Aeromagnetic trends overlain on a map of the generalized geology of the McKnight-McCallum Lakes area.

GEOLOGIC SETTING

The McKnight-McCallum Lakes area lies near the northern flank of the Kiseynew sedimentary gneiss belt (Fig. 1) in the south-western Churchill Geologic Province. It lies completely within an area of Aphebian age meta-sedimentary and intrusive rocks. The age of the sedimentary and igneous rocks of the Kiseynew belt ranges from 1722 ± 43 to 1940 ± 75 Ma (Sangster, 1978; Clark, 1980). The Kiseynew belt is flanked on the north and south by the Lynn Lake-Rusty Lake and the Flin Flon greenstone belts.

The Kiseynew belt comprises three main lithologies:

- Migmatite gneisses derived from greywacke turbidites with minor intercalated mafic rocks of the Burntwood River Metamorphic Suite.*
- Gneisses of the Sickle Metamorphic Suite derived from greywacke and arkose.
- Intrusive rocks of various ages and composition.

The Burntwood River Metamorphic Suite is the oldest unit in the area. Its base is not exposed so that the thickness of greywacke is not known. The top of the suite (see Table 1) usually comprises a thin unit of amphibolites. The Sickle Metamorphic Suite overlies the Burntwood Metamorphic Suite in an apparently conformable manner.

Rocks of the Sickle Metamorphic Suite are distributed along a northwesterly trend as a series of discrete bodies and narrow belts. They contain magnetite in variable amounts whereas Burntwood metagreywackes are graphitic magnetite-free rocks. Aeromagnetic maps show a low flat response over the graphitic greywacke rising sharply to high values generally with a steep gradient over exposures of Sickle rock. The distribution of the two suites can be delineated on aeromagnetic maps (see Fig. 2) with the contact occurring between 2400 and 2600 gammas.

BURNTWOOD RIVER METAMORPHIC SUITE

METAGREYWACKE (1)

Gneisses and migmatites derived from greywacke-shale turbidites are the most abundant rock types in the two map sheets. The metagreywacke forms grey to greyish-brown outcrops of layered garnetiferous gneiss. The metagreywacke has a complex and variable internal stratigraphy, but lacks any unit of sufficiently distinctive appearance and regional continuity to use as a marker horizon. As a result, the subdivision of the unit has been based largely on metamorphic character and not stratigraphy. Unit 1a designates areas of paragneiss where the total amount of granitic *lit* is less than 5 per cent of the total outcrop. Unit 1b designates migmatites with 5 to 60 per cent of granitic *lit*. Above 60 per cent granitic mobilize the entire rock becomes homogenized losing all remnants of primary layering, and has been designated unit 1c, diatectic gneiss. Unit 1d, a layered amphibolite, occurs sporadically as discontinuous layers or large boudins within the metagreywacke. Its origin is uncertain but it is probably a sedimentary rock derived from mafic volcanic material.

Layering, both primary and metamorphic, is a distinctive feature of the metagreywacke. Primary layering occurs mainly as alternating layers (of variable thickness) of psammitic and pelitic greywacke (Fig. 3) or as graded and laminated units in thicker sections of psammitic greywacke (Fig. 4). The primary layering, where identified, is generally parallel to a strong micaceous fol-



Figure 3: Interlayered psammitic (light coloured) and pelitic (darker) metagreywacke (unit 1a) of the Burntwood River Metamorphic Suite; central McCallum Lake area. Note the preferential development of migmatite *lit* in the pelite.

iation. Preservation of top indicating structures is rare and apparent indications are commonly not consistent within a single outcrop. Complete transposition of primary layering over large areas by axial planar foliations is a common feature. This is particularly evident in highly mobilized areas. All cases of transposition of layering noted involved both the primary layering and at least one generation of the metamorphically derived granitic *lit*.

Psammitic gneiss is the most abundant of the metagreywacke rocks. Bedding thickness is highly variable, ranging from 1 cm to 1.5 m. The psammitic is a grey to greyish-white, foliated rock with a granoblastic texture. Pink garnets of 1 mm diameter and graphite are ubiquitous. The psammites are mineralogically simple although there is a broad range of modal composition. The range and mean modal composition in volume per cent for the psammitic is quartz 25-55 per cent (41%), total feldspar 30-55 per cent (42%), biotite 10-25 per cent (16%) and garnet trace to 5 per cent (1%). Microcline is always subordinate to plagioclase and seldom exceeds 10 volume per cent. Graphite, apatite, and zircon are always present in trace amounts. Rare traces of rutile, sphene, tourmaline, pyrite and pyrrhotite are present. Magnetite has not been iden-

* The terminology Burntwood River Metamorphic Suite and Sickle Metamorphic Suite is used here instead of the previously established Burntwood River Supergroup (McRitchie, 1974) and Sickle Group (Henderson, *et al.*, 1936). The change in terminology was made to follow-up suggested revisions of the Code of Stratigraphic Nomenclature (1961) for metamorphic rocks named by mineralogy instead of lithology.

TABLE 1: TABLE OF FORMATIONS — MCKNIGHT-McCALLUM LAKES AREA.

Pleistocene
and Recent

Sand, gravel, clay and till deposits

PRECAMBRIAN (APHEBIAN)		
Intrusive and Metamorphic rocks	UNCONFORMITY	
	17	Felsic pegmatite
	16	Quartz-feldspar porphyry
	INTRUSIVE CONTACT	
	15	Syenogranite
	14	Muscovite syeno-granite
	13	Leucogranite to leucogranodiorite
	12	Magnetiferous granite and granodiorite
	11	Granodiorite and tonalite
	10	Porphyroblastic granite
9	Clinopyroxene tonalite	
Sickle Metamorphic Suite	INTRUSIVE CONTACT	
	8	Meta-arkose
	7	Feldspathic metagreywacke
	6	Pelitic gneiss
	5	Hornblende-plagioclase psammitic gneiss
	4	Polymictic metaconglomerate
Burntwood River Metamorphic Suite	CONFORMABLE ?	
	3	Layered amphibolite and metavolcanic rocks
	2	Amphibolite
	1	Metagreywacke

tified in the metagreywacke. The garnet generally occurs as rounded corroded grains, and locally as highly poikiloblastic "sieve" garnets. Graphite is generally interlayered with the biotite. Megablastesis is not common in the psammitic gneiss, although 5 mm blasts of plagioclase have been noted. A common feature in the psammitic greywacke layers is the formation of calc-silicate minerals in calcareous concretions. These knots of quartz-plagioclase-garnet-hornblende-diopside (epidote) can occur as isolated concretions, as discontinuous layers (Fig. 5) or as multicentered amoeboid masses (Fig. 6). The concretions are commonly zoned with garnet (grossular-rich) rims and diopside (epidote) cores. Metamorphism generally obliterates the bedding within the concretions leaving simple oval concentrically ringed bodies ranging

from a few centimetres to a metre or more in length. Layers of white protoquartzite from 1 to 10 cm thick occur in areas dominated by the psammitic gneiss. The protoquartzite is most abundant on Elvyn and Wolfpack Lakes where it forms continuous layers of high relief. Areas containing layers of protoquartzite are usually rich in calc-silicate concretions.

The pelite beds have undergone recrystallization and blastic growths such that all internal primary structures have been destroyed. The coarse grained, dark grey to brown biotite gneisses have a strong micaceous foliation that curves around poikiloblasts of garnet, cordierite, sillimanite, potassium feldspar and plagioclase. Sillimanite-quartz-plagioclase-*faserkiesel* are a common feature of the metapelites. Bed thickness is variable and difficult

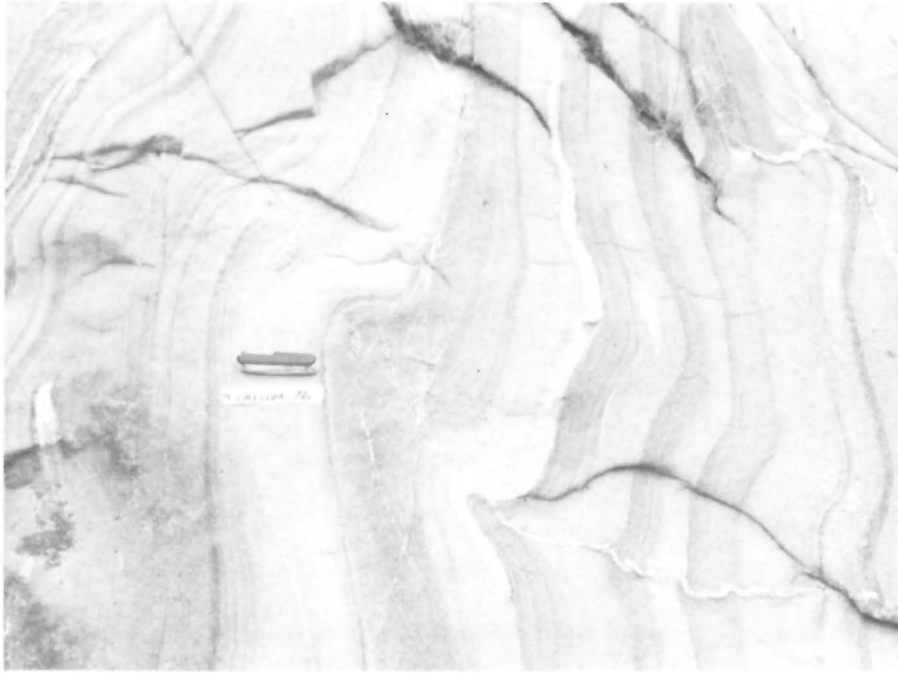


Figure 4: Finely layered and graded beds of metagreywacke (unit 1a) on the southeast shore of McCallum Lake.

to determine as the pelites show a tendency towards preferred anatexis so that the beds are often cut by anatectic *lit*. The range and mean modal composition for the metapelite in volume per cent is: quartz 21-44 per cent (29%), total feldspar 30-60 per cent (46%), biotite 5-26 per cent (19%), garnet trace to 8 per cent (2%), cordierite 0-10 per cent (3%) and sillimanite 0-1 per cent (< 1%). Graphite is always present, and can reach sufficient concentrations to form strong electromagnetic conductors. Trace minerals include zircon, apatite, rutile, tourmaline, sphene, and pyrite. Microcline contents range from 0 per cent to 15 per cent, averaging about 2 per cent. Garnet forms poikiloblasts up to 1.5 cm with numerous inclusions of quartz, feldspar and biotite. Cordierite and feldspar blasts are xenoblastic grey masses up to 1 cm wide with abundant inclusions of quartz and biotite. The large blasts can show some rolling in the foliation plane and commonly have quartz or feldspar pressure shadows. Cordierite blasts commonly contain needles of sillimanite and show moderate to advanced pinitization.

The base of the metagreywacke section has not been identified and the thickness of the section is unknown. Although the lack of marker units and the numerous structurally produced repetitions have prohibited an accurate stratigraphic breakdown of the greywacke section, some generalization can be made based on the distribution of pelitic and psammitic components. In the metagreywacke section psammitic beds are dominant with an approximate average of 70 per cent. However, there are areas where pelite is dominant. A broad belt through northern Wolfpack Lake, Elvyn Lake, Reid Lake and the western Laurie River area is composed almost entirely of psammatic gneisses. West of Van Hende Lake, west of Runner lake and the northern half of McCallum Lake are areas where 60 to 80 per cent of the beds are of pelitic composition. The sillimanite-cordierite-rich pelitic gneisses centered on McCallum Lake may represent the oldest metagreywacke exposed in the area. If this assumption is correct then there appears to be a general upward coarsening trend in the exposed section of the Burntwood River Metamorphic Suite with pelitic gneisses dominating the lower section and psammitic gneiss the upper section. The high metamorphic grade, structural complexity, and the



Figure 5: Calc-silicate concretions in a psammite bed (unit 1a) on central McCallum Lake.



Figure 6: Amoebooid growth of calc-silicate concretions in psammitic gneiss (unit 1b) on the south shore of McCallum Lake.

probability of extensive lateral facies change in the greywacke makes it very difficult to prove this assumption.

Two types of amphibolites represent minor components of the Burntwood River Metamorphic Suite. Isolated bodies of layered hornblende-diopside amphibolite (unit 1d) with thin iron formation layers occur throughout the area. Normally, they occur as oval bodies 1 to 2 m wide and 3 to 5 m long, although one body southwest of Van Hende Lake is 20 m thick and approximately 150 m long. Their general appearance is similar to unit 3a, para-amphibolite. Small boudins, rarely exceeding 1 m in length, of black hornblende-biotite amphibolite are found sporadically throughout the area. These massive, featureless amphibolite boudins occur as trains in the gneisses, locally cross-cutting the layering. They

are probably remnants of an early group of diabase dykes.

White to pink mobilizate *lit* represent a prominent feature on outcrops of greywacke migmatites. The mobilizate has a highly variable composition, ranging from tonalite to granite (Fig. 7). The texture varies from coarse grained phaneritic to pegmatite. Typically, the mobilizate will have a phaneritic texture with irregular patches of pegmatite. In addition to quartz, plagioclase, microcline and biotite, common accessory minerals in the mobilizate are garnet (typically sieved), xenomorphic aggregates of cordierite and quartz, muscovite and graphite. Andalusite was identified in the pegmatitic mobilizate in one location west of Reichert Lake. The distribution of mobilizate through the map area is highly irregular. The average content of mobilization in the area is approximately

TABLE 2: CHEMICAL ANALYSES OF PSAMMITIC GREYWACKE (NUMBER 1 AND 2) AND PELITIC GREYWACKE (NUMBER 3 AND 4) OF UNIT 1.

	1	2	3	4
SiO ₂	67.80	74.00	64.10	65.75
Al ₂ O ₃	14.87	13.88	16.83	15.83
Fe ₂ O ₃	0.63	0.73	0.91	0.90
FeO	4.21	2.40	5.34	5.12
CaO	2.38	2.78	1.22	1.37
MgO	2.30	0.95	2.91	2.70
Na ₂ O	3.53	2.83	1.96	2.20
K ₂ O	2.53	1.32	3.64	3.94
TiO ₂	0.63	0.48	0.71	0.69
P ₂ O ₅	0.12	0.20	0.21	0.07
MnO	0.05	0.05	0.05	0.07
H ₂ O	1.10	1.00	2.08	1.44
S	—	0.01	TRACE	0.01
CO ₂	0.15	0.05	0.13	0.40
C (graphite)	—	0.07	0.16	0.12
TOTAL	100.30	100.75	100.25	100.61
TOTAL Fe as Fe ₂ O ₃	5.31	3.40	6.84	6.59

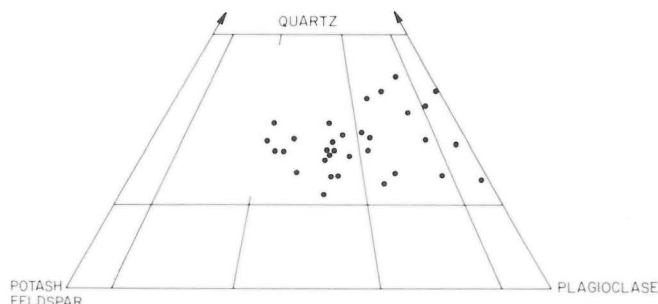


Figure 7: Modal composition of the granitic mobilizate fraction of greywacke-derived migmatite (unit 1b).

25 to 30 per cent. Pelitic beds show a preferred tendency towards mobilization so areas dominated by pelitic greywacke generally have a higher percentage of mobilizate.

The top of the metagreywacke section in contact with unit 3 amphibolite is rarely exposed. The majority of cases observed showed a sharp contact of amphibolite resting directly on a layer of psammitic metagreywacke. In one locality in central Russell Lake the amphibolite rests in sharp contact on a 1 to 2 m thick bed of mafic hornblende-bearing metagreywacke. This is the only location found where the metagreywacke of unit 1 contains hornblende as a major mafic mineral.

AMPHIBOLITE (2)

This highly variable unit lies within the metagreywackes of the Burntwood River Metamorphic Suite. The unit is variable in thickness, ranging from 5 m up to 300 m, with a typical thickness of 100 m. The amphibolite occurs in close proximity to the contact with the Sickie rocks, generally 100 to 300 m below the contact. Occurrences of the amphibolite are restricted to the vicinity of two outliers of Sickie suite rocks, at Benzie Lake and around the main outlier on Russell Lake. It does not occur as a continuous layer, but as a series of lenses of variable length and width.

The amphibolite comprises two rock types, a mesocratic hornblende gneiss (unit 2a) and a massive hornblende \pm orthopyroxene amphibolite with a gabbroic texture (unit 2c). The mesocratic amphibolite is the dominant variety, locally being the only rock

type occurring in some lenses of the unit. When present, the gabbroic amphibolite is flanked on both sides by mesocratic amphibolite.

The mesocratic amphibolite is a homogeneous, equigranular, medium grained, foliated, granoblastic gneiss. It is a dark brownish-black weathering rock comprising approximately equal amounts of plagioclase and green-brown hornblende, variable amounts of quartz (5-15%) and trace apatite, zircon and pyrite. Lens-shaped 5 to 30 cm inclusions of diorite and hornblende are common. The amphibolite in general cut by numerous white tonalite *lit* (Fig.8). The unlayered nature and uniform phaneritic texture suggest that this rock is a diorite intrusive. In some localities amphibolite was observed interlayered with and grading into metagreywacke as a mafic metasedimentary rock or tuff. Of less common occurrence are pods of intermediate composition coarsely fragmental rocks (Fig. 9). This variety consists of buff to light brown angular or rounded fragments of plagioclase-hornblende amphibolite (medium grained) in a darker, finer grained matrix of approximately the same composition. Most fragments have approximately the same intermediate composition although some lighter coloured finer grained fragments are present. The fragmental rock rests on the gabbroic-textured amphibolite (2c) and contains several large angular clasts of the "gabbro" near the contact.

Unit 2c is a massive, weakly to non-foliated, coarse grained, greenish-black amphibolite with a gabbroic texture. It consists of anhedral hornblende crystals with variable amounts of plagioclase (5 to 30%), quartz (trace to 5%), biotite (2 to 4%) and traces of magnetite. Up to 10 per cent of the rock comprises 1 to 3 cm poikiloblastic plates of hornblende that are pseudomorphous after orthopyroxene.

Unit 2 amphibolite may comprise a group of rocks, that include epiclastic, intrusive and possibly extrusive or tuffaceous varieties. No definite origin is established for the fragmental rock. It may be a conglomerate, but then the underlying gabbroic amphibolite must be a coarsely recrystallized volcanic rock which contributed clasts.

AMPHIBOLITE (3)

The top of the Burntwood River Metamorphic Suite is marked intermittently by a layer of amphibolite. The amphibolite is of variable thickness and continuity. It commonly shows considerable thickening around the nose of large folds and is attenuated or absent on the flanks of the folds. The rock weathers deeply and usually forms low rounded outcrops in swamp or valley bottoms.



Figure 8: Hornblende-plagioclase amphibolite (unit 2a) containing numerous sills of white tonalite; south shore of Russell Lake.



Figure 9: Mafic fragmental unit, a part of unit 2a amphibolite; south-east Russell Lake.

The composition, texture and structure of the amphibolite is highly variable, but can be grouped in two classes: layered para-amphibolite (3a) and massive metavolcanic rocks (3b, c). Unit 3a occurs throughout the area, whereas units 3b and 3c are restricted to Russell Lake where they lie on the upper (proximal) limb of the D_1 recumbent isoclinal fold (see the section on tectonic synthesis).

Unit 3a occurs at the contact between the Burntwood River and Sickle Metamorphic Suites. It is a distinctive well layered unit of mafic gneiss (Fig. 10). Black hornblende-rich layers and pale green diopside-rich layers alternate with thin (1 to 5 cm) layers of rusty weathering sulphide iron formation and layers of white calc-silicate rock (Table 3, Analysis 8). Hornblende-rich layers comprise 40 to 65 per cent dark green hornblende, 10 to 45 per cent plagioclase, 0 to 15 per cent biotite, 5 to 20 per cent quartz, 0 to 3 per cent garnet, 0 to 15 per cent diopside and 1 to 2 per cent opaque minerals (pyrite, arsenopyrite, pyrrhotite and magnetite). Diopside-rich layers have a compositional range of 20 to 55 per cent diopside, 5 to 30 per cent green hornblende, 5 to 10 per cent quartz, 0 to 8 per cent biotite, 15 to 40 per cent plagioclase and 2 to 4 per cent sulphides and magnetite. Common accessory minerals in both types of layers are sphene, ilmenite, leucosene, carbonate, apatite and zircon. In one location on the west shore of McKnight Lake the amphibolite consists almost entirely of a pale green to yellow spongy weathering rock made up of 55 per cent scapolite, 24 per cent diopside, 14 per cent carbonate, 2 per cent sphene, 1 per cent brown grossular-rich garnet, 1 to 2 per cent quartz, 1 per cent plagioclase and 1 per cent sulphide with non-foliated polygonal granoblastic texture.

Textures in the layered amphibolite vary from well segregated layers of granoblastic hornblende-plagioclase and diopside-plagioclase gneiss to granoblastic hornblende-plagioclase gneiss cut by irregular anastomosing masses of diopside gneiss. On Granville Lake rocks of this texture grade into pillow basalt in which diopside comprises much of the pillow core (meta-epidosite) and hornblende the selvages. Where the amphibolite comprises diverse rock types such as amphibolite, diopside gneiss, calc-silicate rocks and iron formation the origin may have been as mafic sedimentary rocks.

Units 3b and 3c lie at an equivalent stratigraphic level to unit 3a, but are much different in their composition and texture. Both

3b and 3c appear to be metamorphosed mafic extrusive rocks. Although highly metamorphosed, volcanic structures such as pillows can still be recognized on some outcrops (Fig. 11). Unit 3b is a massive black hornblende amphibolite with irregular green clots of diopside and plagioclase. Individual layers are difficult to recognize, varying mainly in texture. The layers range from 1 to 4 m thick, whereas the whole section of amphibolite averages approximately 60 m thick. Where preserved the pillows commonly have diopside-rich cores and hornblende selvages. The massive amphibolite is composed of hornblende, diopside, plagioclase, biotite, minor quartz and traces of sulphides, carbonate and sphene. Unit 3c is a coarse grained gabbroic textured rock with the composition of a high magnesium basalt (Table 3, Analyses 6 and 7) that occurs irregularly within the massive 3b unit. It forms rounded greenish-brown outcrops with abundant megacrysts of hypersthene weathering in relief on the surface. The outcrops are not layered and generally show no foliation. The massive hypersthene-bearing unit is rarely found in contact with other rocks, usually occurring as small reefs in the lake or isolated outcrops in swamps. The stratigraphic position of unit 3c is uncertain as it is not a single continuous unit, but appears to occur most commonly near the base of the combined 3b and 3c unit. In thin section the rock consists of masses of felted pale green to colourless amphibole surrounding 1 to 2 cm poikiloblasts of hypersthene and remnants of recrystallized clinopyroxene and olivine. Serpentine with abundant magnetite inclusions is common as pseudomorphs of olivine. Other common constituents are talc and chlorite as alterations of pyroxene, a pale yellow sheet silicate (possible margarite), magnetite, hematite, and hercynite. Several thin sections contained remnants of olivine. The composition of these olivines, as determined by x-ray diffraction, ranged from 73.2 to 83.1 weight per cent forsterite with an average composition of 78.9 weight per cent forsterite. Optical determinations of the orthopyroxene composition indicate it is a bronzite (83% of 100 Mg/Mg + Fe + Mn).

The origin of the orthopyroxene-olivine amphibolite is uncertain. The coarse gabbroic texture is consistent with an intrusive rock whereas the stratigraphic continuity and relationship to the metabasalt suggest an extrusive origin. Extensive metamorphic growth of olivine and orthopyroxene has obliterated the original



Figure 10: Layered amphibolite, unit 3a, showing hornblende-rich layers (black) and diopside-rich layers (grey in the figure). The thin white layers are plagioclase-rich calc-silicate layers. Southwest shore of Russell Lake.

texture but whether this produced a coarse gabbroic texture from a fine grained or porphyritic extrusive is unknown.

SICKLE METAMORPHIC SUITE

POLYMICTIC METACONGLOMERATES (4)

Metaconglomerate was identified at three locations on Russell Lake in the core of the large fold structure. It lies directly on the volcanic-derived amphibolites and grades upward into hornblende-plagioclase psammitic gneiss (unit 5). The matrix of the conglomerate is very similar in composition to the overlying hornblende gneiss. In zones of high deformation and mobilization the clasts are difficult to identify and much of the rock is indistinguishable from the hornblende gneiss. The conglomerate is probably more extensive than recognized and has been mapped as unit 5 in area of extreme deformation. The three localities where the conglomerate was recognized are local areas of moderate to low deformation as compared to the general pattern of deformation on Russell Lake.

The conglomerate appears to be matrix-supported with approximately equal volumes of "matrix" and clasts (Fig. 12). The uniform part of the gneiss, identified as matrix is a quartz-rich hornblende psammite with approximately 40 per cent quartz, 10 to 14 per cent hornblende and the remainder being plagioclase with minor biotite, magnetite and sphene. Clast types identified include medium grained grey tonalite, vein quartz, coarse grained to pegmatitic quartz-rich granite, grey psammitic gneiss, fine grained white felsic clasts possibly derived from felsic volcanic rocks, and amphibolite clasts derived from mafic volcanic rock. The mafic clasts recrystallize and deform much more extensively than the felsic clasts and are difficult to distinguish from the amphibole-rich matrix.

HORNBLLENDE-PLAGIOCLASE PSAMMITIC GNEISS (5)

This unit occurs extensively in the McCallum Lake area but only in one location in the McKnight Lake area. Where present it occurs as the lowest unit of the Sickle Suite except on Russell Lake where it is the lowest unit on the lower (distal) limb of the structure but is underlain by a thin conglomerate (unit 4) on the upper (proximal) limb of the structure. The lower contact with the amphibolite is sharp, but adjacent to conglomerate the contact is gradational. The upper contact of unit 5 with the overlying meta-greywacke (unit 7) is gradational over a distance of 30 to 100 cm.

Figure 11: Contact between a pillowed flow (left) and a massive flow (lower right) in unit 3b amphibolite. West side of Russell Lake in the channel leading to McCallum Lake.



TABLE 3: CHEMICAL ANALYSES OF UNITS 2 AND 3 AMPHIBOLITE.

Number	5	6	7	8
Unit:	2a	3c	3c	3a*
SiO ₂	61.00	43.15	46.00	49.65
Al ₂ O ₃	12.10	10.64	9.63	20.43
Fe ₂ O ₃	1.09	2.05	4.03	0.78
FeO	5.79	9.48	7.16	2.63
CaO	6.08	7.44	9.65	13.50
MgO	8.31	19.90	18.80	2.03
Na ₂ O	1.75	1.28	1.14	2.99
K ₂ O	1.84	0.27	0.19	1.22
TiO ₂	0.57	0.77	0.66	1.52
P ₂ O ₅	0.09	0.08	NIL	0.22
MnO	0.12	0.16	0.18	0.06
NiO	0.01	0.10	0.11	NA
Cr ₂ O ₃	0.10	0.30	0.30	NA
H ₂ O	1.34	3.45	2.08	2.31
S	—	0.27	0.08	NA
CO ₂	0.19	0.96	0.16	2.28
C	—	—	—	0.07
TOTAL	100.38	100.19	100.14	99.69
TOTAL Fe as Fe ₂ O ₃	7.52	12.59	11.99	3.70

* Analysis of white calc-silicate layer in para-amphibolite (3a).

The psammitic gneiss forms pinkish-green to pale brown outcrops with prominent metamorphic layering, but rare primary bedding. The unit appears to have deformed in a plastic manner such that in a single large fold the thickness of the layer can vary from 1 to 2 m up to 100 m or more. The average thickness of the gneiss is about 50 to 70 m. The psammitic gneiss is of variable composition both vertically and laterally. An average composition for the base of the unit is: quartz 45 per cent, hornblende 20 per

cent, plagioclase 20 per cent, microcline 10 per cent, biotite 5 per cent, and traces of magnetite, diopside, sphene, apatite and zircon. The quartz content increases up-section with a corresponding decrease in the contents of hornblende and microcline. Unit 5a is a variation of the hornblende-plagioclase psammitic gneiss that occurs locally in the proximal limb of the Russell Lake fold structure. It is a quartz-rich (up to 60%), hornblende-free psammitic gneiss characterized by small amounts of 1 mm wide blood-red

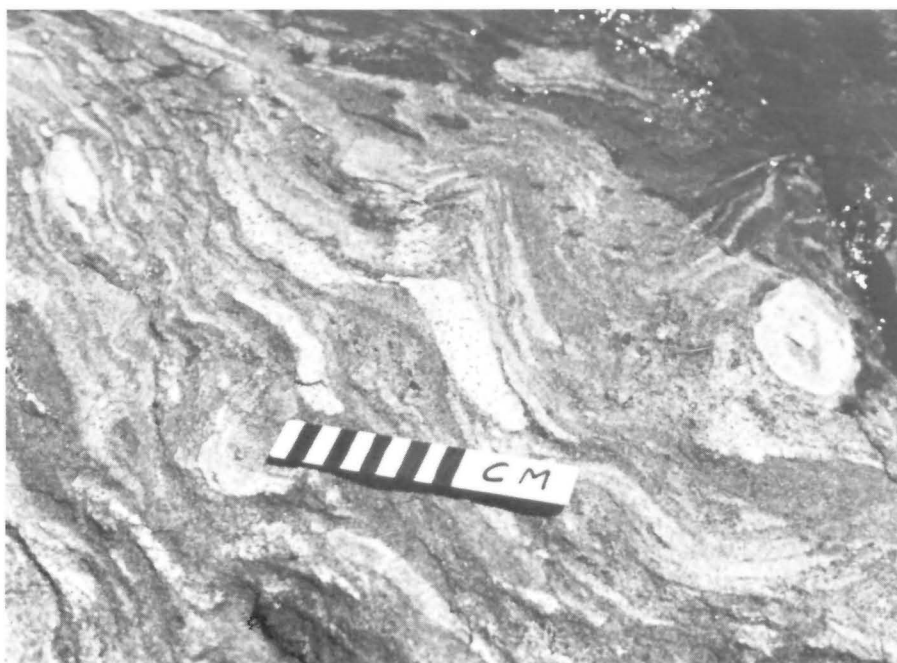


Figure 12: Metaconglomerate (unit 4) on the west shore of Russell Lake.

garnet and rare sillimanite *faserkiesel*. This can either represent unit 5 completely or be present in the upper half of the unit.

A common feature of unit 5 is the presence of numerous 1 to 10 cm thick discontinuous layers of fine grained black or dark green amphibolite and oval bodies of diopside-rich calc-silicate material. These are most abundant near the base of the unit and decrease up-section. The psammitic gneiss becomes enriched in hornblende where amphibolite pods are numerous.

PELITIC GNEISS (6)

Throughout much of the McKnight Lake area and the Kadeniuk Lake area (Baldwin, 1974) the Sickle Suite rocks contain a distinctive layer of pelitic greywacke-derived gneiss. The stratigraphic position of the unit is variable. In the Abrey Lake belt and in the Kadeniuk Lake area the metagreywacke occurs at the base of the Sickle suite, immediately above and conformable to the upper amphibolite of the Burntwood River Suite. At McKnight Lake the metagreywacke occurs near the base of the Sickle, in the upright internal section of the dome of arkosic rocks, whereas in the inverted section of the dome it is stratigraphically much higher (assuming that there are no thrust faults). The thickness of the unit ranges from 180 m at McKnight Lake to 90 m in the Abrey Lake belt.

The composition of the metagreywacke and its distinctive appearance are quite constant throughout the McKnight Lake area. The base of the unit is a dark greyish-brown cordierite-rich gneiss that forms a sharp contact with the underlying rocks. The rocks show no visible bedding, and granitic mobilizate is rare. Where a granitic fraction is present it consists of microcline-bearing coarse granitic veins with abundant cordierite. The unit becomes more felsic upward (c.f. Table 4). Near the top of the section layering starts to appear and mobilizate layers become more common. The upper section is a light grey semi-pelitic garnetiferous gneiss with white tonalite mobilizate *lit*, that is very similar to the metagreywacke of the Burntwood River Suite. The base of the unit is rich in magnetite, but this decreases upward to be replaced by pyrite in the upper section. In the Abrey Lake belt the base of the unit is locally magnetite-free with traces of graphite.

Northwest of Benzie Lake, in the most northerly occurrence of unit 6, the highly pelitic basal section is absent and the rock consists of a light grey psammitic wacke interbedded with feldspathic metagreywacke (unit 7). This interlayered transitional section is continuous into the Kadeniuk Lake area (Baldwin, op. cit.).

TABLE 4: AVERAGE MODAL COMPOSITION (IN VOLUME PER CENT) FOR THE PELITIC GNEISS (6) AT THREE LEVELS IN THE UNIT. SAMPLES FROM MCKNIGHT LAKE AND THE ABREY LAKE BELT ARE INCLUDED IN THE AVERAGES.

	Base	Middle	Top
Quartz	38	38	49
Total feldspar	26	44	34
Biotite	16	14	14
Cordierite	14	1	0
Garnet	2	2	3
Sillimanite	3	0.5	0
Magnetite	1	0.5	0
Pyrite	0	0	0.5

Apatite and zircon are minor accessories. Traces of hercynite are found in the basal portion of the unit.

TABLE 5: CHEMICAL COMPOSITION (IN WEIGHT PER CENT OXIDES) OF SAMPLES OF THE BASE OF UNIT 6 FROM MCKNIGHT LAKE (9) AND ABREY LAKE (10).

	9	10
SiO ₂	62.50	60.85
Al ₂ O ₃	17.94	17.74
Fe ₂ O ₃	1.26	0.76
FeO	6.40	6.72
CaO	1.33	2.17
MgO	3.31	3.60
Na ₂ O	2.23	2.67
K ₂ O	2.72	2.47
TiO ₂	0.85	0.81
P ₂ O ₅	0.09	0.15
MnO	0.08	0.07
H ₂ O	1.35	2.32
S	0.01	0.04
CO ₂	0.34	0.26
C (graphite)	NIL	0.06
TOTAL	100.41	100.68

FELDSPATHIC METAGREYWACKE (7)

This biotite gneiss, derived from feldspathic greywacke, is present in all bodies of Sickle Suite rocks examined. A well layered grey to pink gneiss, it is of variable thickness but averages 200 to 300 m thick. Where an overlying unit is exposed it is always meta-arkose (unit 8); however, the underlying unit may comprise units 1, 3, 5 or 6. Where exposed, both the upper and lower contacts are sharp with no interlayering with other units except for unit 6 northwest of Benzie Lake.

A distinctive feature of the metagreywacke is the layering. Two varieties have been distinguished (units 7 and 7a) based on the character of the layering or bedding. Unit 7, the most abundant type, exhibits a range in bedding thickness from 5 to 100 cm, averaging 30 cm. These beds have a massive homogeneous character with no internal lamination and no primary structures other than rare cases of grading. On Russell Lake the bottom of the unit was noted to have a few granitic pebbles randomly distributed through the layers. Small pods of amphibolite and zoned calc-silicate concretions are present but in a much lower abundance than in the underlying units. Unit 7a is a delicately layered feldspathic greywacke gneiss. This unit is found in the lower (distal) limb of the Russell Lake outlier. Layering ranges from 1 to 5 cm in the unit (Fig. 13). Primary structures such as grading are rarely preserved because the units tend to recrystallize very easily. Calc-silicate nodules are absent; however, thin fairly continuous amphibolitic layers do occur.

Both units 7 and 7a, have similar compositions averaging quartz 30 per cent, feldspar 55 per cent (microcline variable from 5 to 20 per cent), biotite 15 per cent, and traces of magnetite, apatite, zircon and muscovite. Development of pink to red granitic mobilize is pronounced in this unit. The mobilize is phaneritic in texture with irregular clots of pegmatite material. Small amounts of garnet and cordierite are common in the mobilize of unit 7 but are not present in the restite gneiss.

META-ARKOSE (8)

The uppermost unit of the Sickle Suite exposed is a pink to red, coarse grained, quartz-rich sillimanite gneiss derived from an arkose. This unit is characterized by an abundance of sillimanite aligned along foliation planes or as quartz-sillimanite knots (*faserkiesel*). The sillimanite-bearing meta-arkose is present in most of the bodies of Sickle Suite rocks in the area. The top of the

meta-arkose is not exposed and no estimate of the thickness of the unit is possible. The rock was deformed in a plastic manner such that the section thickens in fold noses and is attenuated on the limb of folds. This style of deformation is particularly evident in the central part of Russell Lake (see Map GR79-1-3) where unit 8 has formed a large triangular body filling the core of an F_3 disharmonic box-like fold.

The meta-arkose is leucocratic and forms rounded pinkish-white to red outcrops. Layering, other than metamorphic, is usually not a prominent feature of unit 8. Where present the layering is quite delicate (Fig. 14) but recrystallization during metamorphism appears to be more severe in this unit than in the greywackes such that primary layering is commonly obliterated. The sillimanite gneiss also develops mobilize *lit* in greater abundance. On McKnight, Benzie and Abrey Lakes the units underlying the meta-arkose are metatectic gneisses with 30 to 40 per cent mobilize whereas the meta-arkose is highly mobilized and homogenized arkosic diatexite.

The unit is quartz-rich, with an average composition of quartz 55 per cent, feldspar 33 per cent, biotite 7 per cent, magnetite 1 to 2 per cent and sillimanite 3 per cent. Trace minerals include apatite, zircon, pyrite, garnet and cordierite. Muscovite is locally common as a retrogressive metamorphic mineral. The content of microcline is highly variable from about 1 per cent to 20 per cent of the rock. It does not appear to be a consistent stratigraphic feature of the unit. The mobilize associated with unit 8 is commonly a red syenogranite with a coarse grained to pegmatitic texture. Muscovite is commonly more abundant than biotite in the mobilize. Sillimanite, muscovite, cordierite, green apatite and rare pink garnets are common accessory minerals in the mobilize.

Faserkiesel vary in size, shape and abundance. Typically, they occur as pencil-like bodies elongate parallel to the F_3 fold axis and flattened slightly in the foliation plane. Knot-size ranges from an average of 1 x 2 x 5 cm to a maximum observed size of 1 x 6 x 45 cm. The knots comprise quartz or quartz-feldspar aggregate penetrated by sub-parallel acicular sillimanite crystals. Subhedral magnetite crystals commonly occupy the cores of *faserkiesel*.

Discontinuous pods of melanocratic black to olivine-black hornblende-biotite amphibolite (unit 8a) occur within the meta-



Figure 13: Finely layered feldspathic meta-greywacke (unit 7a) on western Russell Lake. The pen is resting on a thin amphibolitic layer. (Lighter part of outcrop is dry; the remainder is wet.)

TABLE 6: CHEMICAL ANALYSIS OF SICKLE SUITE ROCKS OF UNITS 5, 7, 7a AND 8.

NUMBER:	11	12	13	14	15	16
UNIT:	5	7	7a	7a	8	8
SiO ₂	64.30	72.80	68.65	71.80	79.55	79.00
Al ₂ O ₃	15.12	13.13	14.51	13.84	9.69	10.91
Fe ₂ O ₃	2.80	1.33	1.77	1.34	1.50	0.74
FeO	3.68	1.85	2.67	1.88	1.85	1.56
CaO	5.15	1.50	2.51	2.38	1.09	0.69
MgO	3.11	1.60	2.34	1.73	1.11	0.87
Na ₂ O	2.69	2.39	3.26	3.25	1.72	1.57
K ₂ O	1.55	3.83	2.69	2.47	2.10	3.30
TiO ₂	0.71	0.46	0.60	0.47	0.47	0.36
P ₂ O ₅	0.12	0.07	0.12	0.03	0.02	0.01
MnO	0.11	0.05	0.07	0.05	0.03	0.02
H ₂ O	1.18	0.71	0.88	0.83	0.72	0.72
S	0.03	—	—	—	—	—
CO ₂	0.14	0.23	0.17	0.30	0.17	0.10
TOTAL	100.68	99.95	100.24	100.37	100.02	99.85
TOTAL Fe as Fe ₂ O ₃	6.89	3.39	4.74	3.42	3.56	2.47

arkose. The amphibolite comprises green hornblende and biotite (70%), andesine (25%), and quartz (5%) with a massive, weakly foliated, granoblastic texture. The pods, which range in size from 30 x 60 cm up to 5 x 15 m, occur throughout the meta-arkose but are most abundant near the top of the section. The largest bodies occur near the top of the inverted section (proximal) on Russell Lake. The amphibolite represents remnants of an early series of mafic sills intruded into the meta-arkose.

INTRUSIVE ROCKS

CLINOPYROXENE TONALITE (9) AND PORPHYROBLASTIC GRANITE (10)

Tonalite and a related porphyroblastic granite are common west of the Loon River and along the southern margin of the map-area. The majority of the bodies are small 2 to 4 km plug-shaped intrusions, although two larger bodies crop out; a 1 by 11 km sill-



Figure 14: Meta-arkose (unit 8) showing prominent development of quartz-sillimanite faserkiesel.

like body south of Van Hende Lake and a 5 by 20 km complex intrusive body centered on Runner Lake. The bodies show complex metamorphic and deformational histories. Although the age of the intrusions is uncertain, it is evident that they are the oldest intrusive rocks in the area.

The tonalite (9) is a distinctive grey homogeneous rock commonly cut by intersecting networks of 5 to 30 cm wide veins of white granodiorite. Inclusions of diverse rock types are common in the tonalite. The included rock types comprise siliceous grey paragneiss, hornblende, pegmatite, biotite gneiss, grey granodiorite and layered hornblende-diopside amphibolite. The inclusions typically are highly deformed and partially digested or nebulitic.

The modal composition of the tonalite is: microcline 3 ± 2 per cent, plagioclase 53 ± 5 per cent, quartz 22 ± 5 per cent, mafics (biotite and clinopyroxene) 23 ± 7 per cent and trace minerals allanite (metamict), apatite (up to 1%) and magnetite. Field mapping and petrographic studies have shown that the porphyroblastic granite (10) is an endomorphic equivalent of the tonalite (9) formed by potassium metasomatism. Metasomatism is evident in outcrops from microcline porphyroblasts up to 3 by 8 cm (typically 1 by 2 cm) which grew in the original tonalite matrix. The transition from tonalite to granite takes place over a 50 to 70 m wide zone in which the abundance of microcline blasts increases gradually. In the transition zone plagioclase is altered to microcline, clinopyroxene and biotite are altered to green hornblende, and the magnetite is altered to pyrite, hematite and sphene. The modal composition of the porphyroblastic granite is: microcline 18 ± 10 per cent, plagioclase 45 ± 11 per cent, quartz 18 ± 10 per cent, hornblende plus biotite 19 ± 8 per cent and traces of apatite, allanite, pyrite and sphene (see Fig. 15).

The contacts of the tonalite and granite with the surrounding paragneisses are intrusive in nature. The greywacke is commonly sheared for 3 to 5 m from the contact. The intrusives contain numerous inclusions of the country rocks in the immediate vicinity of the contact. Field observations indicate that the metasomatism on the tonalite is related to assimilation of the surrounding pelitic gneiss (1). The development of microcline blasts is most abundant near the contact with pelitic metagreywacke (the most potassium-rich and most easily melted rock). Large rafts of metagreywacke included in the porphyroblastic granite are surrounded by aureoles of granite rich in microcline porphyroblasts. The hybrid porphyroblastic granite (10) formed by the assimilation has a tonalite matrix containing large porphyroblasts of microcline. Very little microcline was added to the groundmass. The alteration of biotite to hornblende is also responsible for the formation of microcline

blasts. These reactions are discussed later in the section on metamorphism.

GRANODIORITE AND TONALITE (11)

The core of the Sickle Suite inlier on Russell Lake is occupied by a distinctive white to pink gneissic tonalite. The tonalite occurs as sill-like bodies intruding the Sickle rocks. Screens of inclusions of paragneiss and amphibolite are common along the contact. Inclusions commonly show advanced degrees of digestion and granitization. The rock has a layered appearance in outcrop with stringers of pink pegmatite separating white and grey layers. Compositional variation between the layers is present, ranging from leucotonalite to leucogranodiorite. Late pegmatite and aplite dykes are abundant, locally producing an agmatite of the tonalite.

The outcrops weather a streaky white to buff. The texture is fine to medium grained granoblastic. The compositional range is: quartz 26 - 35 per cent; potassium feldspar 4 - 12 per cent; plagioclase 50 - 65 per cent and biotite 2 - 5 per cent. Magnetite and small red garnet crystals can occur in trace amounts.

MAGNETIFEROUS GRANITE (12)

The metagreywacke gneisses in the western part of the McCallum Lake area are intruded by two bodies of buff magnetiferous granite. The smaller body is a nearly circular plug 3 km wide and the larger an elongate north-trending body 15 km long and 3 to 6 km wide. They form low broad ridges that are generally well exposed. Dykes of the granite intrude the metagreywacke (1) away from the contact and cross-cut a small body of porphyroblastic granite (10b). Inclusions of migmatized greywacke (1b) are common in the centre of the intrusions. One large 45 x 17 m inclusion of hornblende-plagioclase amphibolite (2a) was found in the core of the larger body. No inclusions were found near the margins of the bodies.

The rock ranges from monzogranite to granodiorite. It is siliceous (averaging 36% quartz) and very leucocratic (maximum 5% biotite). Magnetite content can reach 1.5 per cent and is easily visible in the outcrop surface. The high magnetite content gives the intrusion a distinctive magnetic signature on aeromagnetic maps (cf. Fig. 2).

Foliation development is variable, being strong near the contact with the paragneiss and weak or absent in the cores of the intrusions. Shearing parallel to the contacts of the intrusions can produce a layered gneissic appearance.

LEUCOGRANITE AND LEUCOGRANODIORITE (13)

This rock type is the most common intrusive unit in the map area. It forms many discrete bodies of irregular shapes and sizes varying from 1 km to 6 by 10 km. Although bodies of the leucogranite occur throughout the area, they are most abundant east of the Abrey Lake fault and the south of Russell Lake. The contacts of the intrusions are not sharply defined, but consist of gradational zones up to 100 m wide in which the granitic *lit* of the enveloping paragneisses increase in proportion until the granodiorite is the dominant rock type and the paragneiss occurs as subordinate inclusions. The contacts are generally marked on the maps at the point where the granite constitutes 50 per cent of the outcrop. Inclusions of paragneiss are abundant in the intrusions, ranging from 5 to 35 per cent of the outcrop. Commonly a stratigraphic relationship is maintained by the inclusions in the granite. In intrusions east of Abrey Lake, west of Benzie Lake and west of the Laurie River areas can be delineated within the granite in which paragneiss inclusions are derived only from Sickle Suite rocks. Outside of these areas all inclusions are composed of metagreywacke (1). The boundaries between these areas are delineated by trains of inclusions of layered amphibolite (3). The transition from metagreywacke, through amphibolite to meta-arkose inclusions occurs over a 100 to 150 m zone.

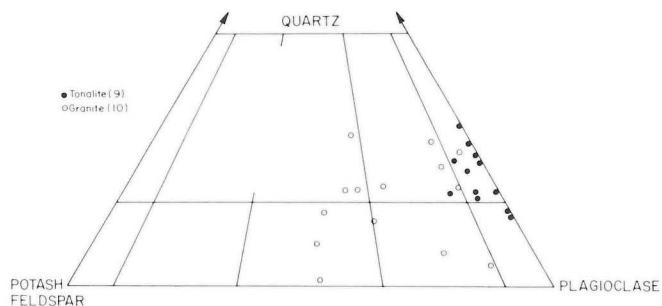


Figure 15: Modal composition of tonalite (9) and porphyroblastic granite and granodiorite (10). Note the restricted composition of the tonalite (9) and the dispersion toward potassic compositions of the porphyroblastic granite (10). The ternary quartz-plagioclase-potassium feldspar classification of Streckeisen (1973) is used.

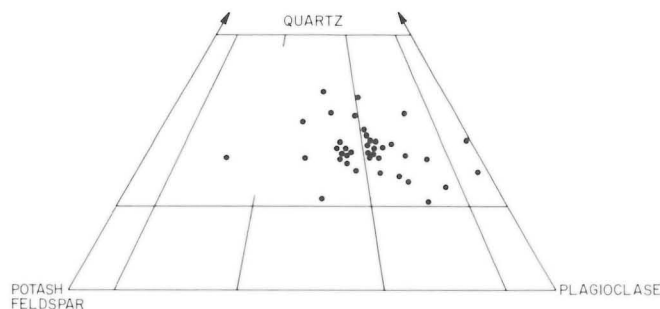


Figure 16: Modal composition of leucogranite and leucogranodiorite (unit 13).

The composition of unit 13 spans a broad range (Fig. 16) from tonalite to granite. The mafic content is quite low (3 - 7% biotite). Garnet is a common accessory mineral. The texture of the rock is variable also. The typical medium grained phaneritic texture becomes locally pegmatitic. These pegmatoid patches have the same composition as the host granite and contacts are gradational, so the pegmatoid is not a later intrusive phase.

It seems likely that the leucogranite-leucogranodiorite represents segregated bodies of anatectic material derived from the surrounding migmatites. The modal composition of the mobilized material in the surrounding metagreywacke is very similar to unit 13 (cf. Figs. 7 and 16). The gradational contacts, abundance of partially digested inclusions, the mineralogy and texture support this hypothesis. Sillimanite knots grew through the granite between inclusions of sillimanite-bearing arkose but were not observed in the rest of the granite.

MUSCOVITE SYENOGRAHITE (14)

Three small bodies of muscovite granite crop out south of Russell Lake and on McCallum Lake. They resemble the leucogranite (unit 13) common in the central and eastern part of the area, having a generally low mafic content and an abundance of paragneiss inclusions. The inclusions are foliated and appear to have undergone most of the deformational events sustained by the area. However, all paragneiss inclusions have discrete granitic mobilized layers, so intrusion was synchronous with or postdated the main event of partial melting and migmatization.

A distinctive feature of these small bodies is a consistent magnetite content that produces discrete magnetic signatures on aeromagnetic maps. These small bodies of magnetite-bearing potassic granite extend on a linear trend of 125° into the core of the Kiseynew belt as far as Burntwood Lake. A second feature common to these intrusives is the occurrence of thin coatings of hematite-stained muscovite and/or sillimanite along fracture planes in the granite. This appears to have formed during a retrogressive metamorphic event associated with the late brittle deformation. In rare instances the muscovite/sillimanite coating will form knots similar to the *faserkiesel* common in the Sickie sediments.

Southwest of Russell Lake a body of magnetite-bearing syenogranite contains an indistinct area of hornblende-alkali feldspar syenite. The rock weathers pale orange with stubby brownish-green crystals of hornblende (up to 20%), quartz, plagioclase, magnetite and accessory minerals (less than 10%) and perthitic microcline (70%). The hornblende appears to be pseudomorphous after clinopyroxene and exhibits local clinopyroxene remnants in crystal cores.

SYENOGRAHITE (15)

An irregular dyke-like body of syenogranite intrudes metagreywacke along the Loon River in the north-central McCallum Lake area.

The red weathering granite has a medium grained poikiloblastic texture. Megacrysts of potassium feldspar are sparsely developed and average 2 x 2 mm. An average composition, by volume, of the syenogranite is: 46 per cent microcline; 25 per cent quartz; 24 per cent oligoclase and 5 per cent biotite. Trace minerals include magnetite, zircon and apatite.

The rock shows only a weak, erratic biotite foliation visible in hand sample. Strained quartz grains and weakly granulated grain boundaries visible in thin section resulted from brittle deformation. The megacrysts appear to be a product of potassium metasomatism of plagioclase and commonly have remnants of corroded plagioclase in the core.

Strong foliation may mark a major shear zone along the Loon River. The syenogranite has intruded this zone of weakness but postdates the major shearing event.

QUARTZ-FELDSPAR PORPHYRY (16)

One 3 m wide dyke of quartz-feldspar porphyry crops out northwest of McKnight Lake. It forms a linear ridge which projects 1 to 1½ m above the core of a body of leucogranite (unit 13) through which it cuts. It weathers light brown with prominent 1 cm perthitic microcline and 3 mm quartz megacrysts in a fine grained matrix of quartz, feldspar and biotite. In outcrop the fresh and homogeneous porphyry shows no visible deformation, however, in thin section an erratic biotite foliation is apparent. The perthitic microcline megacrysts show minor recrystallization of the albitic lamellae and a rind of plagioclase. Well developed parallel strain patterns in quartz and minor chloritization of biotite indicate the dyke has undergone metamorphism.

FELSIC PEGMATITE (17)

Pegmatites of various ages occur throughout the map area. The largest bodies occur as stratiform sills in the paragneiss and formed relatively early as they show effects of extensive deformation. Younger pegmatites generally cross-cut the layering in the paragneiss and commonly occupy extension fractures normal to the axes of major folds. The youngest pegmatites are undeformed.

The mineralogy and appearance of the pegmatites are often a reflection of the country rocks containing them. Bodies in the metagreywacke, such as those in the northwest of the McKnight Lake map sheet, are white to pale pink microcline-plagioclase-quartz-biotite pegmatites. Muscovite is rare and always subordinate to biotite whereas microcline and plagioclase are in equal proportion. Common accessory minerals are red garnet, cordierite and apatite. One occurrence of andalusite was noted west of Reichert Lake. Pegmatites in Sickie rocks, such as those at McKnight Lake and Russell Lake, are generally pink to brick red and contain microcline-plagioclase-quartz-muscovite and biotite. Plagioclase is subordinate to microcline which commonly occurs as large graphic blocks. Muscovite and biotite are abundant in many pegmatites. Common secondary minerals are sillimanite, magnetite, cordierite, apatite and sporadic garnet. The correlation between pegmatite and country rock suggest that fluid melts were either derived from the surrounding rocks or reacted with them extensively during intrusion. It is probable that both factors were involved in controlling the mineralogy and appearance of the pegmatites.

Sulphide mineralization was never noted in pegmatites in the metagreywackes; however, traces of sulphides are common in pegmatites in Sickie Group rocks. A small 3 m wide pegmatite on the south shore of Kamuchawie Lake contains a 1 m long, 5 mm thick seam of chalcopyrite, bornite and malachite and disseminations of copper sulphides in biotite clots near the seam.

An excellent 20 m exposure of symmetrically zoned pegmatite crops out on the southeast shore of McCallum Lake. This body is very rich in sillimanite, muscovite and black tourmaline and contains traces of powder blue dumortierite.

METAMORPHISM

INTRODUCTION

Interpretation of the metamorphic history of the McKnight-McCallum Lakes area has been based on textures identified on outcrops and in thin sections. From the textures it has been possible to deduce a series of metamorphic reactions from which inferences can be made regarding P-T conditions in the northern Kiseynew belt. The majority of the reactions contribute either to the production of a melt or the production of potassium feldspar that is subsequently consumed in other reactions.

The metamorphic history (see Table 7) has been interpreted to reflect two prograde events of uppermost amphibolite grade, both of which produced anatectic *lit*, and two retrograde metamorphic events (greenschist and amphibolite grades). The separation of the two prograde events is difficult as the M_2 event has overprinted the M_1 event. In thin section the mineral assemblages and textures observed can be interpreted as the result of a single prograde event of considerable duration. The separation

of the M_1 and M_2 events has been based largely on textural and structural evidence noted in outcrop. This interpretation is also consistent with the findings of Schledewitz (1972), Bailes (1975) and Bailes and McRitchie (1978) elsewhere in the Kiseynew basin. The textural evidence used to separate to prograde metamorphism into two events is:

1. Three ages of mobilize are recognized in the metasedimentary rocks. The oldest, a white leucotonalite with a phaneritic texture, is cross-cut by the younger pegmatitic mobilize. It shows evidence of recrystallization and remobilization along the contacts with the gneiss restite and the younger *lit*. The two younger generations of *lit* are interpreted as arising from a single period of metamorphism that bridges a change in structural style. Thus the mobilize *lit* have two separate directions and can be observed in cross-cutting relation but are formed during protracted partial melting.

TABLE 7: SUMMARY OF STRUCTURAL, METAMORPHIC AND PLUTONIC EVENTS

Deformation Folding Fabric			Structure	Metamorphism	Metamorphism	Plutonism
D_1	F_1	S_1	Large scale recumbent isoclinal folding; nappe-like folds produced inversion of sections	M_1	Regional upper amphibolite grade; local development of metamorphic mobilize	Tonalite (9) and its metamorphic equivalent granite (10) intruded synchronous with or late in the D_1 Granodiorite-tonalite (11) intruded into F_1 folds
D_2	F_2	S_2L_2	NW-trending subhorizontal isoclinal folds formed with axial surfaces dipping moderately to the east			Granites and granodiorites of units 12 and 13 intruded along the F_2 fold trend, probably occupying antiformal structures
D_3	F_3	S_3L_3	NE-trending folds of irregular form plunging to the east at 30° . Axial traces curved and bifurcated.	M_2	Regional metamorphism of uppermost amphibolite grade; extensive partial melting of gneisses with the formation of mobilize <i>lit</i> parallel or at a low angle to bedding	Small bodies of a feldspathic pegmatite emplaced along F_3 axial surface
D_4		S_4	NW-trending brittle deformation, weak development of cataclastic fabric	M_3	Sillimanite-muscovite-hematite coatings along a weak S_4 cataclastic cleavage	Emplacement of small bodies of syenogranite and syenite (unit 14) along the NW trend
D_5		S_5	Brittle deformation forming major NNE trending faults. Minor development of cataclastic fabric	M_4	Greenschist grade retrogression associated with S_5 cataclastic foliation	Syenogranite (15) emplaced in D_5 shear zone?

2. Garnet is an early-formed mineral phase that, although ubiquitous is not stable in the current assemblages. Mineral lineations formed by crushed garnets with elongate quartz-feldspar pressure shadows are interpreted from available orientation to be aligned with an F_2 fold axis which is in turn folded about an F_3 axis (Table 7). Thus the garnets appear to have been involved in at least two deformational events.
3. Large garnet blasts have been identified that contain inclusions aligned in an early micaceous foliation.
4. Cordierite-sillimanite blasts are commonly overgrown by coatings of sillimanite-free cordierite.
5. In the lowest metamorphic grade, blasts of muscovite are aligned in the foliation plane that is cross-cut by the sillimanite (fibrolite) knots forming at the expense of the muscovite.

While it is conceivable that these textures could be the result of a single prograde event it does not seem possible as the duration of the metamorphic event would have outlined two deformational events.

It is apparent from field observation of two periods of mobilize development that both M_1 and M_2 reached uppermost amphibolite to hornblende granulite facies metamorphism. The pressure and temperature conditions present during the peak of a metamorphism cannot be estimated for M_1 event because of the overprinting effect of the M_2 event. Mineral assemblages and reactions attributed to M_2 indicate a range of temperature — pressure conditions. Two areas, one centered on the south end of McCallum Lake and the other a narrow belt extending north from Elvyn and Reid Lakes up the Laurie River into the Kadeniuk Lake area (Baldwin, 1974), are below the limits of partial anatexis and represent the minimum temperature regions. The maximum temperature at thermal climax was attained in regions of diatectic garnet-cordierite-gneisses. The preserved assemblages in these areas indicate pressures of 2 to 3 kilobars and a temperature range of 600° to $700^\circ + C$.

M_1 EVENT

The M_1 mineral assemblages have been preserved in part in psammitic gneisses but have been largely overprinted in pelitic gneisses. Textures that could indicate metamorphic reactions responsible for the formation of the M_1 minerals have been masked by the M_2 event. In psammites the mineral assemblages interpreted as typical of M_1 are:

plagioclase + quartz + biotite,
 plagioclase + quartz + biotite + potassium feldspar,
 plagioclase + quartz + biotite + garnet \pm potassium feldspar,
 and
 plagioclase + quartz + biotite + muscovite + potassium feldspar.

Bailes and McRitchie (1978) identified M_1 cordierite in the assemblage garnet + cordierite + orthoclase + biotite + quartz + plagioclase in psammites of the Kiseynew belt, but cordierite was not identified in psammitic gneisses of the McKnight-McCallum Lakes area. The identifiable textures that can be associated with M_1 in psammites are the recrystallization of the groundmass into a coarser polygonal granoblastic texture, the growth of xenomorphic sieve garnets and the growth of poikiloblastic plates of muscovite.

In pelitic rocks the M_1 mineral assemblages are not preserved. The only mineral assemblages attributed to M_1 are:

plagioclase + quartz + biotite + cordierite + garnet + sillimanite
 and

plagioclase + quartz + biotite + cordierite + garnet + hercynite (only in the magnetite-bearing pelite, unit 6). The textures associated with M_1 are the development of a coarse biotite foliation, growths of subidiomorphic blasts of garnet with quartz,

plagioclase and biotite inclusions in the cores and inclusion-free rims and the growth of oval blasts of cordierite permeated with needles of sillimanite. The characteristic M_1 assemblage of cordierite + garnet + sillimanite is attributed to the breakdown of staurolite, however, remnant staurolite has not been observed.

In arkosic rocks (unit 8) the M_1 assemblage appears to be quartz + plagioclase + potassium feldspar + biotite + muscovite, but this is largely overprinted by the M_2 assemblage.

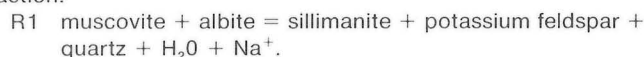
M_2 EVENT

The M_2 metamorphism is characterized by the instability of garnet in the presence of potassium feldspar and the initiation of various reactions producing a granitic melt. Only in the two previously mentioned lower grade areas was the temperature at the thermal climax below the minimum granitic melt temperature (as discussed by Winkler, 1976). The majority of the area was above the minimum granitic melt temperature at the thermal climax with the availability of potassium feldspar and water controlling the amount of melt that formed in the rocks.

Psammitic rocks show very little change during M_2 other than a slight coarsening of the grain size. The only M_2 assemblage identified in the psammites is quartz + plagioclase + biotite + sillimanite + potassium feldspar. The reaction that resulted in this assemblage will be discussed later.

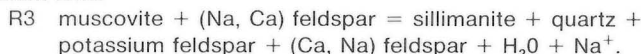
In the pelitic and semipelitic gneisses the reaction textures and mineral assemblages visible in thin section are dominantly of M_2 origin. The reactions and their resulting textures will be discussed individually.

In low grade areas around McCallum, Elvyn and Reid Lakes sillimanite formed at the expense of muscovite according to the reaction:



The choice of R1 instead of the equivalent reaction:

$R2 \quad \text{muscovite} + \text{quartz} = \text{sillimanite} + \text{potassium feldspar} + H_2O$ is inferred from textural evidence. Textures associated with the reaction are: formation of knots of fibrolite intergrown with and enveloped by quartz; the formation of xenomorphic blasts of potassium feldspar containing inclusions of quartz and biotite but free of plagioclase inclusions; corrosion of plagioclase in contact with potassium feldspar; corrosion of muscovite around fibrolite knots except where it is armoured by quartz (Fig. 17). The fact that plagioclase was consumed and quartz produced indicated R1 was active and not R2. The mechanism of the reaction appears to be cation exchange (as described by Carmichael, 1969). Alumina is immobile during the reaction whereas cations diffused between the nucleation centres of the product phases. The reaction takes place in two stages starting with muscovite breaking down to sillimanite, quartz and potassium cations in solution. The cations were then involved in a sodium-potassium exchange in albite at an adjacent location in the rock. The observed texture of fibrolite-quartz knots surrounded by, but not in contact with, potassium feldspar blasts supports this reaction mechanism. The plagioclase in the greywacke is oligoclase-andesine and accordingly the aggregate reaction (R_3) would have involved calcium and sodium ions:



Examination of the potassium feldspar blasts shows that they formed from the groundmass plagioclase by simple cation exchange with little recrystallization, readily accounting for the abundance of quartz and biotite inclusions in the blasts.

The formation of sillimanite and potassium feldspar blasts by reaction R1 is significant in that it is the only reaction identified that be used to indicate the maximum pressure of metamorphism (see Figure 23). At pressures much below 2 kb the aluminosilicate product would be andalusite, not sillimanite. At pressures above

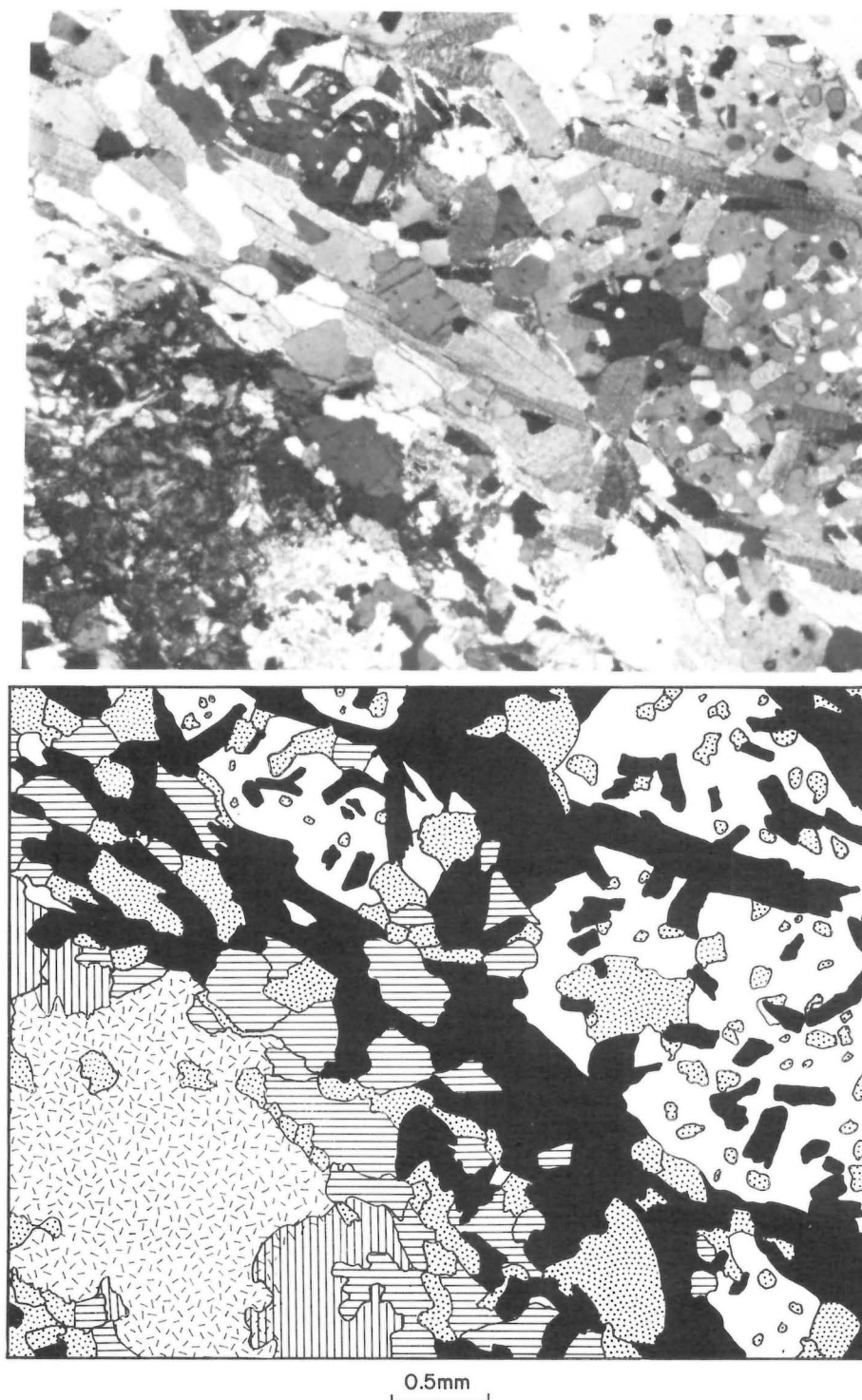
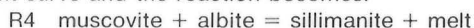


Figure 17: Photomicrograph and sketch of the textures associated with the breakdown of muscovite forming sillimanite and blastic potassium feldspar (reaction R3) in a semi-pelitic greywacke (unit 1a) from Elvyn Lake.

3 kb the muscovite + albite reaction line intersects the minimum melt curve and the reaction becomes:



Two reactions involving the breakdown of garnet in the presence of potassium feldspar have been identified. Since most metagreywackes are deficient in potassium feldspar the reactions rarely went to completion and disequilibrium assemblages representing both reactants and products remain in the rock. These reactions are:

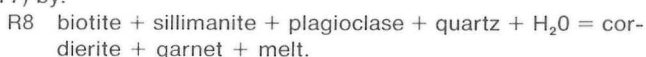


The textures associated with R5 display cordierite coronas on garnets, overgrowths of M_2 cordierite (free of sillimanite) on M_1 cordierite-sillimanite blasts (Fig. 18) and the formation of cordierite-quartz and biotite-quartz symplectites on the edges of corroded garnet blasts (Fig. 19). Reaction R6 resulted in biotite and plagioclase crystals embaying garnet blasts and the formation of biotite-plagioclase and biotite-quartz symplectites (Fig. 20). The development of symplectic zones, even within large biotite crystals, can preserve the size and shape of the M_1 garnets. Reaction R5 and R6 initiate at a higher temperature than R1 and have been identified only in rocks near the zone of partial melting.

Within the zone of partial melting two reactions involving the decomposition of biotite have been identified in pelitic rocks. The first reaction:

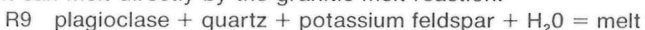


has been identified in only the most pelitic of rocks. The texture associated with this reaction is the corrosion of biotite in contact with M_1 sillimanite and the formation of a cordierite halo around the reaction point (Fig. 21). The potassium feldspar produced is commonly not preserved, but is either consumed in R5 or R6 if garnet is present or lost to the system in a granitic melt. This reaction is succeeded at higher temperature (Blümel and Schreyer, 1977) by:



This reaction was dominant in the formation of the garnet-cordierite-rich pelite-derived diatexites to the southwest of Van Hende Lake. Reaction textures are rarely preserved (Fig. 22) in these diatexites as the whole system is more or less mobile and the products of R8 concentrate in the mobilizate. The megascopic features associated with the reaction are the formation of concentrations of cordierite along the edges of granitic mobilizate *lit* and the growth of uncorroded poikiloblastic garnets in the mobilizate. Reaction R8 is the highest temperature reaction identified in the area, initiating at about 680°C at 2.5 kb (Fig. 23).

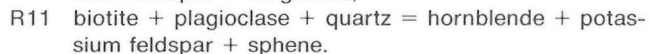
The M_2 metamorphism of arkosic rocks (unit 8) resulted in the formation of granitic melt by two reactions. The meta-arkose is composed mainly of quartz, plagioclase and potassium feldspar so it can melt directly by the granitic melt reaction:



There are no reaction textures that can be related to R9 other than the formation of quartz-plagioclase myrmekite in zones depleted in potassium feldspar. With increasing degree of partial melting the restite becomes progressively depleted in potassium feldspar (which is subordinate to plagioclase). The formation of sillimanite *faserkiesel* takes place in the meta-arkose as a result of the breakdown of muscovite by reaction R4 (a combination of R1 and the granitic melt reaction R9). The *faserkiesel* consists of sillimanite needles surrounded by a zone enriched in quartz and free of potassium feldspar.

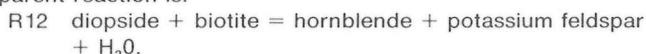
The only rock in the area that is devoid of muscovite and potassium feldspar is a clinopyroxene tonalite (unit 9). The only phase in the rock that contains appreciable potassium is biotite.

During M_2 biotite became unstable in the presence of plagioclase and quartz forming:



The potassium feldspar produced was in part consumed in the granitic melt reaction (R9) producing a network of leucogranodiorite mobilizate veins. Much of the potassium feldspar remained in the rock as microcline blasts. The textures associated with R10 and R11 are the alteration of biotite to green hornblende with the development of synantetic sphene or magnetite along the reaction boundary, the alteration of plagioclase to coarsely perthitic microcline and the albitization of plagioclase in contact with microcline blasts.

Alteration of biotite to hornblende is accompanied by alteration of clinopyroxene, in contact with biotite, to hornblende. The apparent reaction is:



The texture associated with R12 is the development of a fine grained eutectoid of hornblende and feldspar along the contact between the biotite and clinopyroxene. Single grains of hornblende developed through reactions R10 (R11) and R12 are homogeneous and inclusion-free adjacent to biotite and plagioclase aggregates and symplectitic adjacent to clinopyroxene and biotite.

Reactions R10 and R11 were recognized by Winkler (1976, p. 311-313) during the experimental anatexis of rocks composed of plagioclase, quartz, and biotite. Winkler found that anatexis took place between 650° and 700° C. at 2 kb, depending on the proportions of the reactants and volatiles and the compositions of the biotite and plagioclase. The temperature of metamorphism may have been near the lower limit proposed by Winkler as very little melt formed, but potassium feldspar blasts are abundant. This temperature is consistent with the estimates derived for reactions in the metagreywackes.

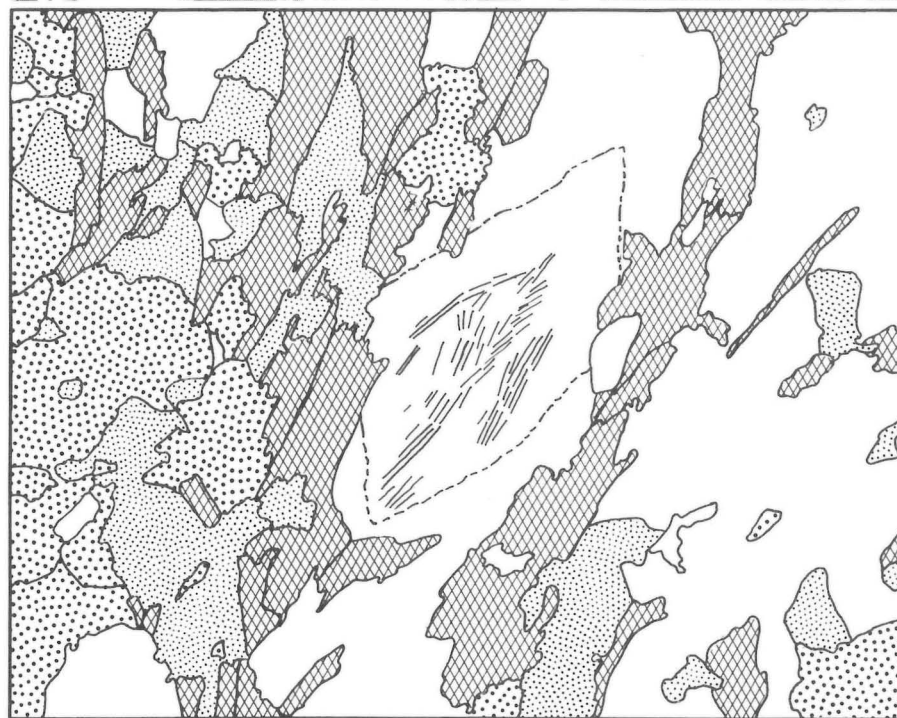
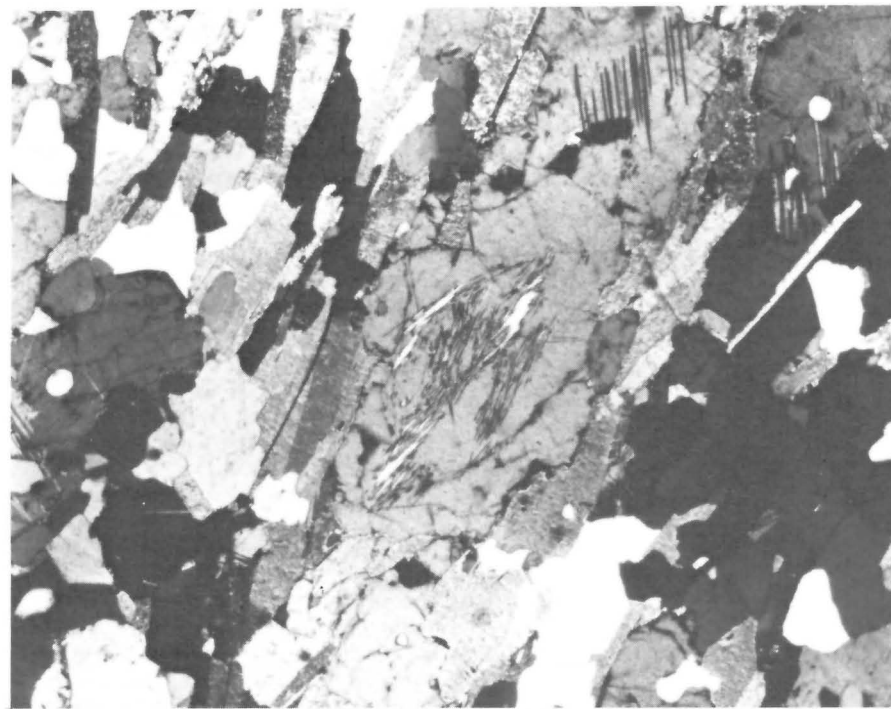
M_3 AND M_4 EVENTS

Retrogressive metamorphic effects were found associated with the faults and shears formed during D_4 and D_5 brittle deformation. The M_4 retrogressive event comprises a lower amphibolite grade metamorphism characterized by coatings of sillimanite-muscovite-hematite on D_4 shear planes. The metamorphic effects are irregularly distributed over a wide belt in association with minor shear zones. This retrogressive metamorphism can probably be correlated with the M_3 - D_3 event of McRitchie *et al.* (1972 and 1973) for the central Kiseynew belt.

The metamorphism associated with the D_5 faulting direction comprises a retrogression to greenschist grade assemblages (M_4). The effects associated with this event are: partial chloritization of biotite, saussuritization of plagioclase, local alteration of plagioclase and diopside to epidote and pinitization of cordierite. These retrogressive effects are most highly developed in the vicinity of D_5 faults, but the effects have been found in scattered outcrops throughout the area suggesting the retrogressive metamorphism was more extensive than the brittle deformation.

SUMMARY

Textures and mineralogy indicate that most of the McKnight-McCallum Lakes area underwent at least one and probably two major prograde metamorphic events that peaked at pressure-temperature conditions above those necessary for the formation of anatectic melts in gneisses. Only the McCallum Lake and Laurie River areas failed to reach the lower limit of granitic melt formation. These two areas peaked at a lower temperature, possibly in the range of 600° to 630° C at 2.5 kb pressure. The limits of these areas of thermal low are not clearly defined. They may rep-



0.5mm

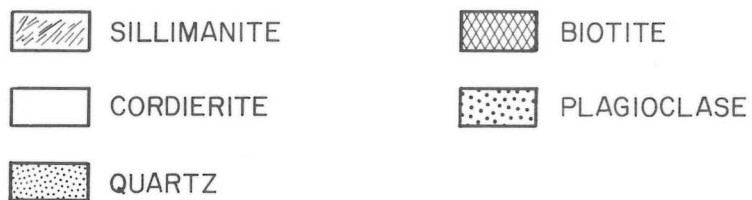
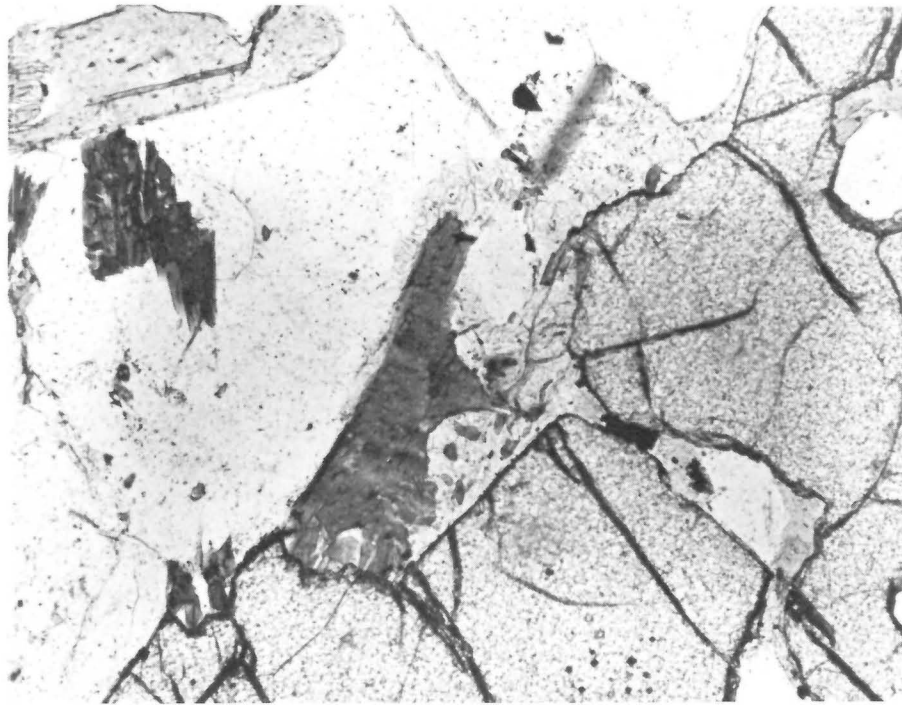


Figure 18: Photomicrograph showing M_2 cordierite-biotite overgrowing an M_1 cordierite-sillimanite blast. Inclusions in the cordierite show the shape of the M_1 blast which may be pseudomorphous after staurolite. Rock is a pelitic metatextite (unit 1b).



0.1 mm

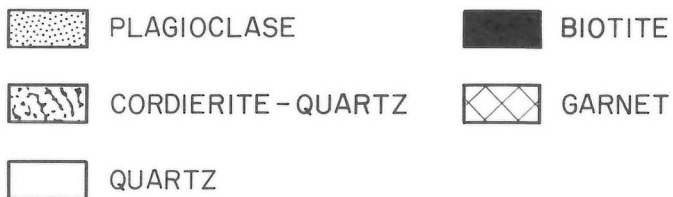


Figure 19: Photomicrograph and sketch illustrating the texture associated with the breakdown of garnet by reaction R5 in a pelitic gneiss (unit 6) on McKnight Lake. The cordierite-quartz has a vermicular intergrowth texture.

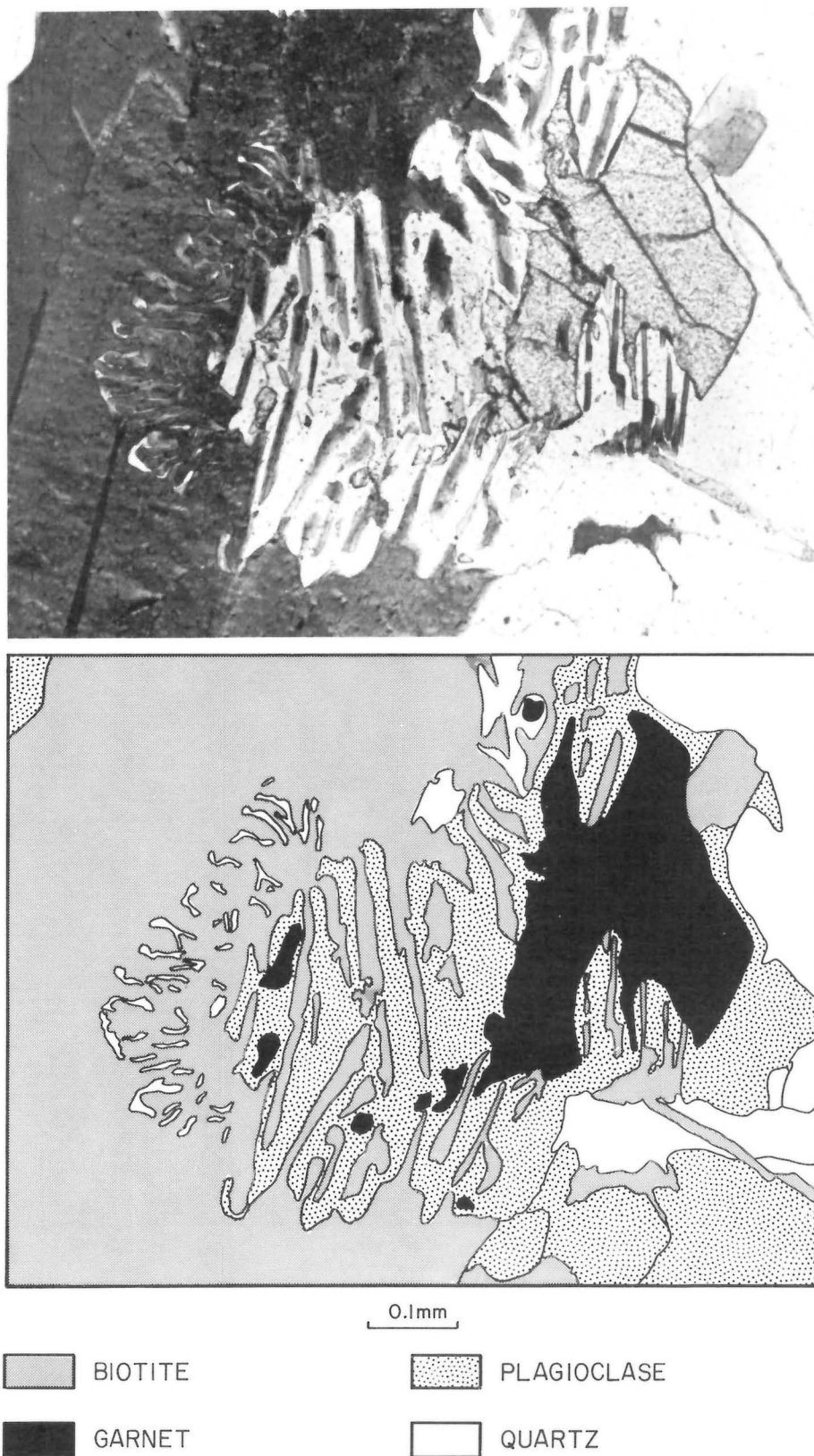
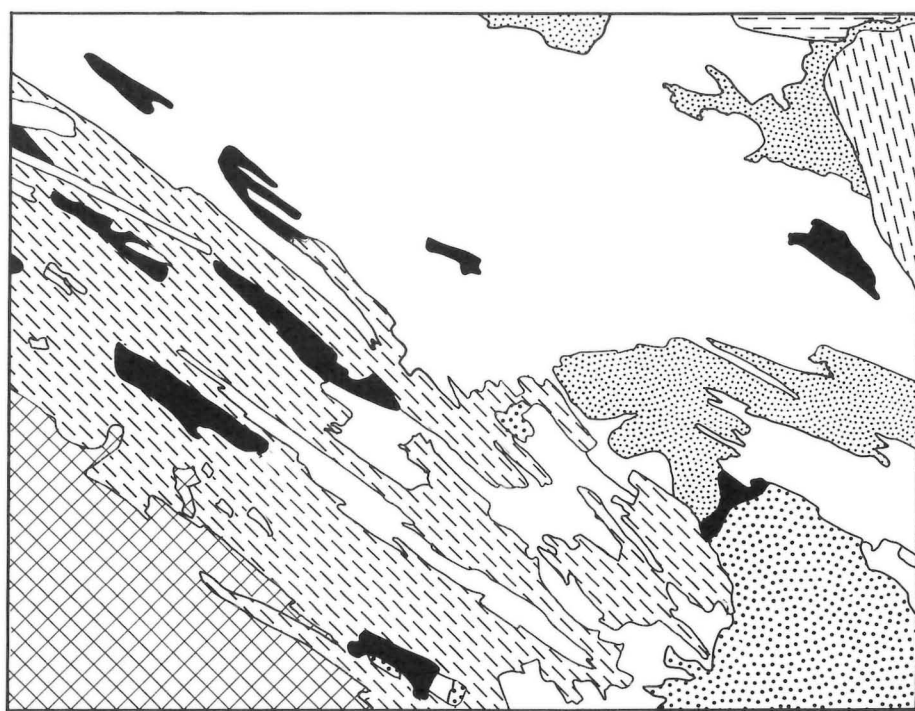
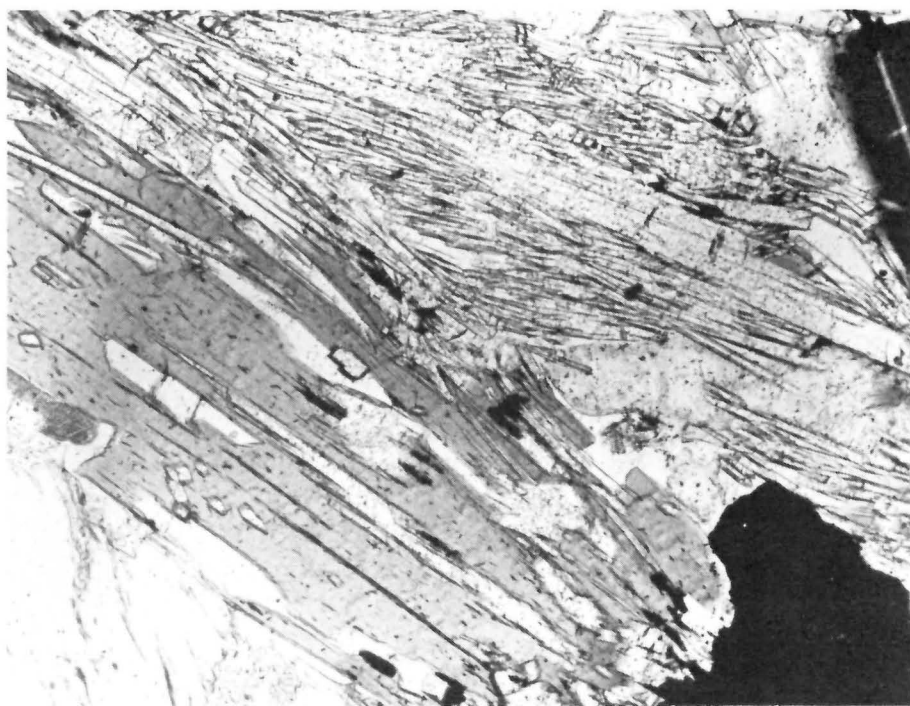


Figure 20: Photomicrograph and sketch illustrating the texture associated with the breakdown of garnet by reaction R6 in a pelitic gneiss (unit 6).



CORDIERITE



SILLIMANITE



BIOTITE



QUARTZ

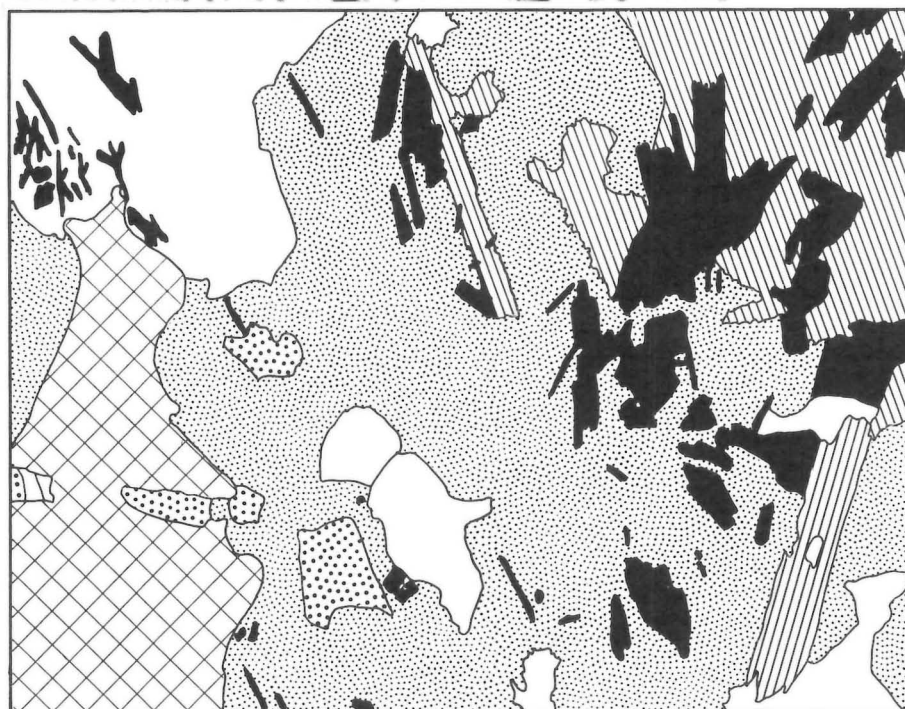
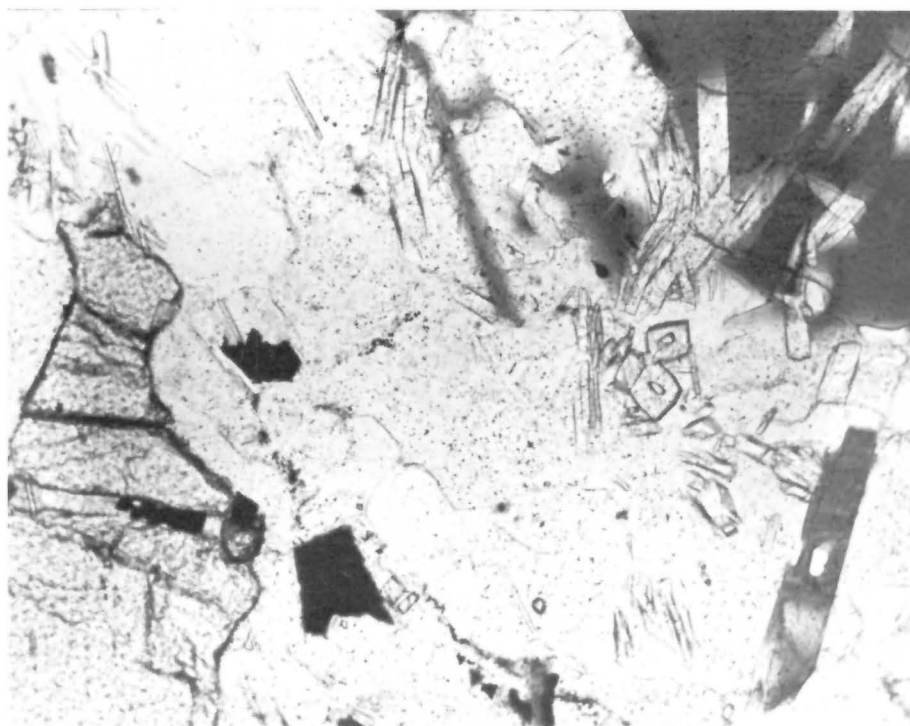


MICROCLINE



MAGNETITE

Figure 21: Photomicrograph and sketch illustrating the texture associated with the breakdown of sillimanite by reaction R7 in a pelitic diatexite (unit 6).



0.1mm



Figure 22: Photomicrograph and sketch illustrating the texture associated with the breakdown of sillimanite by reaction R8 in a pelitic diatexite (unit 6).

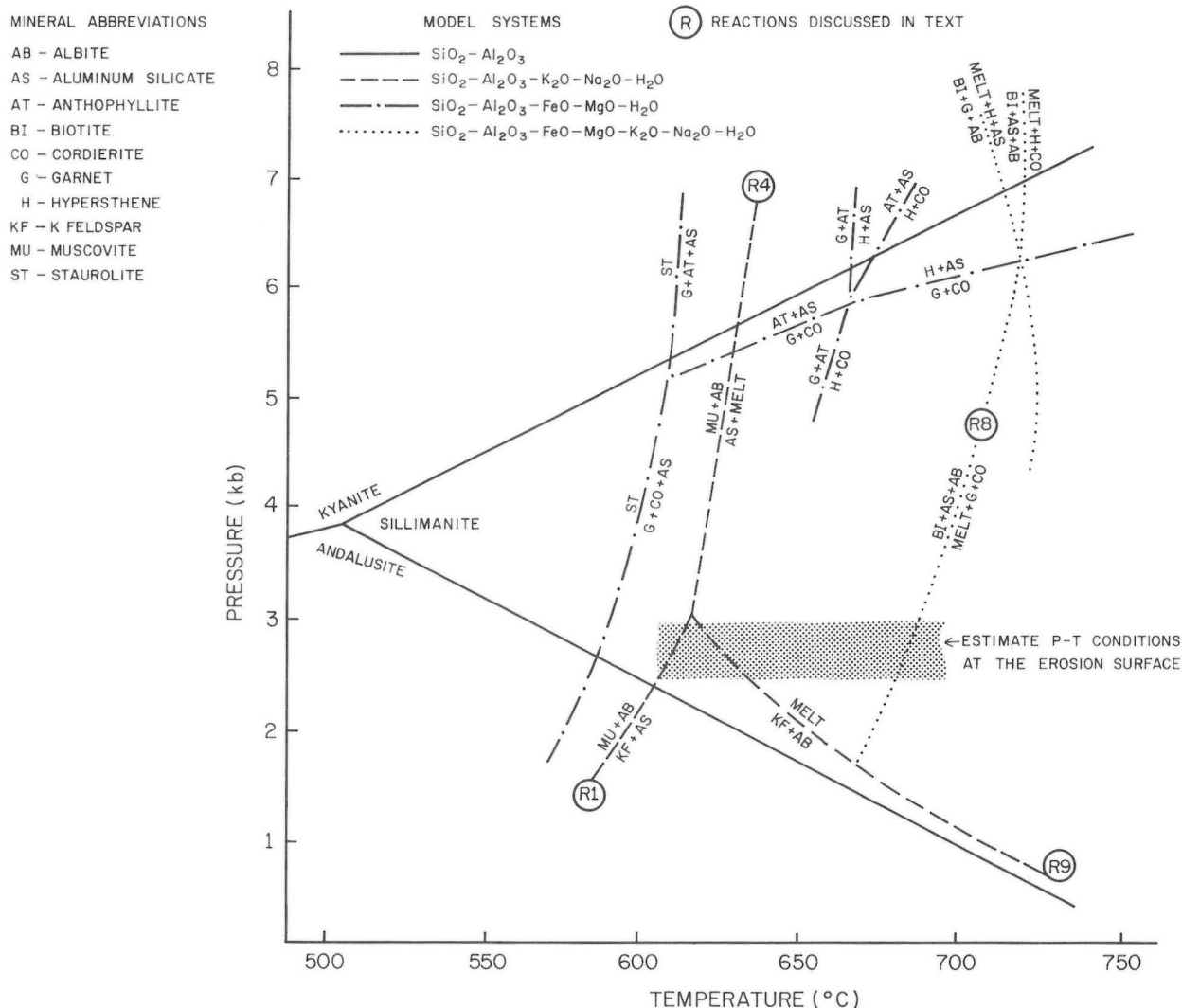


Figure 23: Calibrated petrogenetic grid simplified after Bailes (1979). The reactions noted in the McKnight-McCallum Lakes area are indicated and the approximate pressure-temperature conditions indicated by the stippled area.

resent local cool spots in the regional thermal gradient, or the isograd may be folded preserving the lower grade rocks in structural basins.

In the majority of the area partial anatexis of the metasedimentary rocks resulted in the formation of abundant phaneritic to pegmatitic mobilizate *lit*. The mobilizate formed by the granitic melt reaction (R9). Quartz and plagioclase comprise the bulk of the mineralogy of the gneisses so the controlling chemical factors in the formation of a melt phase were the availability of potassium feldspar and water. Reactions R1, 7, 8, 10 and 11 produced potassium feldspar as a product and thus promoted melting in the gneisses. Both pelitic and psammitic gneisses contained very little primary potassium feldspar to contribute to melt formation. However, pelitic gneisses are rich in potassium-bearing sheet silicate

minerals that can react to form potassium feldspar so they show a preferential development of mobilizate (Fig. 3) whereas psammitic gneisses contribute little to the melt phase. Partial melt formation appears to have been most pronounced in pelitic rocks and resulted in the formation of diatexite or schlieric granite containing discontinuous layers and rafts of partially melted psammitic gneiss. Reaction R8 is encountered at temperatures of 700°C+. This reaction was used by Bailes and McRitchie (1978) to subdivide the migmatites of the Kisseynew Belt into a very high grade core zone designated High Grade B and a flanking area designated High Grade A. The boundary between the two high grade zones lies at the south margin of the McKnight-McCallum Lakes area.

INTRODUCTION

The McKnight-McCallum Lakes area lies on the north flank of the Kisseynew gneiss belt, an east-trending belt of sedimentary-derived gneisses and associated intrusive rocks of Aphebian age. All the rock units encountered have strong tectonic fabrics. The general trend of the fabric is northwesterly in the east, shifting to a strong northerly trend west of McKnight Lake (see Fig. 31 in map pocket).

Structural data has been interpreted in terms of deformation comprising five components: three sets of folds with different styles, and two sets of brittle fractures in different directions. Consistent relative ages among these components suggest that they may relate to separate tectonic episodes or "events" but alternate interpretations are possible. Synchronous refolding by a deformational field of horizontal (east-west and north-south) constriction and vertical extension could form a basin-and-dome terrane in a single event. Faults interpreted as unique to an episode may be long-lived features subject to a periodic reactivation.

All deformation appears to postdate the deposition of the Sickle Metamorphic Suite rocks. The pre-Sickle deformation identified to the north in the Lynn Lake area (Gilbert *et al.*, 1980) has not been recognized in the Kisseynew Belt.

The major structures recognized in the map-area are:

- 1) large recumbent isoclinal folds, F_1 , possibly of nappe-like dimensions defined by major inversions and repetitions of stratigraphy;
- 2) northwest-trending shallow plunging inclined isoclinal folds, F_2 ;
- 3) northeast-trending open cross-fold, F_3 , resulting in east plunging tongue-shaped structures;
- 4) a zone of northwest brittle fractures delineated by minor cataclasis with attendant amphibolite grade retrogressive metamorphism; and
- 5) north-trending faults marked by minor cataclasis, offset of stratigraphic units and minor greenschist grade retrogressive metamorphism.

Interpretation of the fold pattern as representing three events is based on the geometric relationship of folds and associated fabrics. The sequence of fold development is evident in that F_1 axial surfaces are folded by F_2 structures which are folded by F_3 structures. That these folds formed during three events is suggested by:

- 1) The early phaneritic mobilize lying parallel to the F_1 schistosity is folded by F_2 and F_3 ;
- 2) mineral lineations co-axial to F_2 folds are folded by F_3 structures; and
- 3) the F_3 axial planar schistosity cuts across F_2 minor folds.

In the following sections the main characteristics of deformation are outlined. A description of the Russell Lake structure is included. Russell Lake is a unique structural setting that provided the fundamental insight into the F_1 structures. Excellent exposures of consistent, identifiable lithologic sequences occur throughout central Russell Lake. Unique sequences occur in the limbs of the F_1 fold that are sufficiently contrasting in composition to be diagnostic and consistently recorded throughout the strike length of the folds.

The main deformational features are illustrated in Figure 31 and listed in relation to metamorphism and plutonic events in Table 7.

D_1 : RECUMBENT FOLDS

The oldest structures in the McKnight-McCallum Lakes areas

are large-scale isoclinal folds, F_1 , with major inversions and repetitions of the stratigraphic sequence. Recognition of F_1 folds is difficult because similar stratigraphic inversions formed during later deformation (F_2). However, F_2 axial surfaces are inclined approximately 50 degrees to the east whereas F_1 axial surfaces are folded about F_2 structures and the same F_1 axial surface re-appears in consecutive F_2 folds. The dip of F_1 axial surfaces must have been shallow before cross-folding took place. Consequently, F_1 folds are interpreted as large recumbent nappe-like structures. Only two F_1 folds, on Russell and McKnight Lakes have been recognized.

Recumbent folds developed during the early deformation must have had amplitudes of several kilometres as opposing limbs can have significant differences in stratigraphy. This aspect will be discussed in more detail in the description of the Russell Lake structure.

The only fabric associated with D_1 is a biotite schistosity. The foliation is generally parallel to primary layering of the rock, but locally diverges by as much as 5 degrees from the bedding. Minor folds and linear structures of D_1 age were not observed. Lineate garnets formed during M_1 are co-axial to F_2 structures suggesting that F_1 and F_2 may be co-axial or that M_1 recrystallization took place during D_1 and D_2 .

An early nebulous white leucogranodiorite mobilize is interpreted to have formed during the early period of M_1 metamorphism and F_1 folding. It occurs as irregular, highly deformed and recrystallized pods with diffuse boundaries which contrast markedly with the regular dyke- and sill-like habit of a younger pegmatitic segregation. The younger mobilize is complexly intergrown with the earlier phase and commonly occupies two sets of cross-cutting fractures. M_2 metamorphic minerals such as sillimanite *faserkiesel* commonly occupy pods of early mobilize that intruded layers rich in sillimanite. The amount of granitic mobilize developed during M_1 probably did not exceed 5 per cent of the rock.

Large sills of clinopyroxene tonalite (unit 9) and white leucotonalite (unit 11) were intruded during the waning stages of D_1 . The leucotonalite invades an F_1 syncline (see Fig. 26) and is deformed by F_2 and F_3 folds. Inclusion screens of paragneisses oriented parallel to the intrusive contact and primary layering are common. The clinopyroxene tonalite was also deformed by F_2 and F_3 folds but it is uncertain whether it was intruded during or after D_1 . It contains numerous inclusions of paragneiss but none contain a granitic mobilize phase which suggests emplacement before a significant amount of partial melting took place.

Elsewhere in the Kisseynew gneissic belt the inversion of the stratigraphic section was interpreted by Pollock (1964, 1965), Schledewitz (1972) and Bailes (1975, 1980) to be the result of F_1 folds they were not able to identify mesoscopically in the field. The Russell Lake structure represents a unique case where it is possible to identify the position of the F_1 axial surface.

D_2 : NORTHWEST-TRENDING DEFORMATION

Inclined asymmetrical isoclinal folds which occur throughout the area have been attributed to the second deformational event. The fold axes trend north to northwesterly with a horizontal or shallow northerly plunge. Axial surfaces are inclined approximately 50 degrees to the east. The F_2 folds have a very large amplitude-to-wavelength ratio so fold limbs are parallel, fold nose are rarely observed and the presence of the folds is recognized mainly by repetitions of the stratigraphic section. A continuous 400 m exposure of Sickle Metamorphic Suite rocks on the east shore of Russell Lake consists of well layered uniformly dipping

gneisses without evidence of major or minor folds but with six complete repetitions of the basic Sickie section of units 5, 7 and 8.

Northwest-trending minor folds are present throughout the area but because of the horizontal axis they are visible only on vertical exposures. An axial planar schistosity is present in the hinges of minor folds that cuts the earlier foliation developed during the D_1 deformation. Except in fold hinges the axial planar foliation (S_2) associated with F_2 folding parallels the earlier foliation (S_1). Three types of linear structures associated with the northwest trend have been identified. The most common is a mineral lineation comprising elongate garnet porphyroblasts enveloped in plagioclase that developed in pelitic layers of unit 1. Less common is a mullion-like structure of rolled quartz or mobilize veins. Microcrenulations within F_1 minor fold hinges mark the intersection of the two foliations S_1 and S_2 .

Brittle deformation was an important feature of many F_2 folds. It occurs as ruptured short limbs of asymmetric folds. These fault zones contain only minor cataclastic textures. The east contact of the crescent-shaped body of Sickie Suite rocks in the northeast corner of the McKnight Lake area is proposed as an F_2 fault that brings units 1 and 8 into juxtaposition. Evidence for cataclasis can be found for 1 to 3 m from the contact. The fault surface is occupied by a 1 m thick granite aplite dyke. The faults that occur along the channel between Russell and McCallum Lakes may be related to F_2 folding but their nature is not fully known.

The field relationships between F_2 folds and the granitic *lit* and larger granitic bodies is complex and suggests that anatexis overlapped D_2 . Sill-like bodies of white granodiorite to granite occur in most of the rocks in the area. The granitic *lit* are generally parallel to the dominant foliation but are both folded by F_2 structures and cross-cut F_2 structures indicating that anatexis took place during and after development of the northwest-trending folds. Units 12 and 13 occur as elongate bodies with a northwest trend, probably intruded into large F_2 antiforms. Unit 12 appears to be a late kinematic or a dynamic, probably diapiric intrusive with an internal foliation which is parallel to the contact with the country rocks. The margins of unit 12 bodies are commonly moderately to heavily sheared. Unit 13 comprises large segregations of granitic mobilize intruded passively or derived from the surrounding gneiss by partial melting. The fabric in unit 13 does not follow the contact but generally corresponds to the regional trend of the foliation. The contact is gradational between the granodiorite and the surrounding gneisses with no cataclasis developed.

D_3 : NORTHEAST-TRENDING DEFORMATION

The youngest folds are open, irregularly-shaped and disharmonic. Their axes maintain a constant attitude (see Figs. 24 and 25) plunging 30 degrees to the east. Axial surfaces have variable strikes but retain a fairly constant dip at steep angles to the south. The axial surfaces are curved or even bifurcated into box folds. Pinching and swelling of rock units, especially unit 8, is a common feature in F_3 folds and major folds can die out over a short distance. This style of folding suggests that there was large scale flow within the folded layers.

The F_3 folds are associated with strong linear and planar fabrics. Most linear structures identified are aligned in the direction of the F_3 fold axes. The best development of L_3 lineations is sillimanite-quartz knots (*faserkiesel*) developed in unit 8, particularly on Russell Lake. The *faserkiesel* form triaxial ellipsoidal-shape knots highly elongate in the F_3 axes and flattened in the F_3 axial planar foliation (see Fig. 14). The L_3 direction is also the major elongation direction of clasts in metaconglomerate.

The plane of flattening is also a phyllosilicate foliation. It is not completely penetrative, but is easily visible in the noses of F_3 minor folds. The F_3 minor folds, the most commonly noted structures in the field, have constant axial trends but are commonly dishar-

monic with a wide dispersion of axial surfaces.

There are no northeast-trending fault zones and there is no obvious relationship between F_3 folds and other brittle structures. Axial planar pegmatite dykes may have minor offsets along them as a space adjustment during folding, but there is no penetrative shearing or cataclasis that can be related to F_3 folds.

The F_3 folds postdate formation of the majority of M_2 mobilize and no large plutonic bodies have been assigned to D_3 , but small bodies of felsic pegmatite occupy F_3 axial surfaces.

D_4 AND D_5 : BRITTLE DEFORMATION

Fault zones and cataclastic zones that postdate all folds occur in two distinct directions. Each set of faults has different characteristics and appear to have a different age but as they were never observed to intersect no method exists to determine their relative ages. To differentiate the two directions they will be referred to as D_4 , a northwest-trending zone of cataclasis and D_5 northerly-trending faults with a weak cataclastic fabric.

The weak D_4 cataclastic fabric occurs sporadically over a zone several kilometres wide but is not related to distinct faults. This zone trends northwest through the southwest corner of the McKnight Lake map sheet to the south half of McCallum Lake. It appears to die out near McCallum Lake and was not identified to the west of the Loon River. The zone is characterized by numerous, small, hematite-stained shear zones and small intrusive bodies of syenogranite to syenite (unit 14). These magnetiferous intrusions have a weak cataclastic fabric with sillimanite-muscovite-hematite coatings on shear planes. The zone appear to be the continuation of the "Flatrock Lake Trend", a zone of shearing and intrusion extending from Flatrock Lake (McRitchie and Frohlinger, 1979) to the northwest approximately 100 km to the McCallum Lake area. The trend can be delineated on an aeromagnetic map by the presence of small isolated magnetic highs that correspond to small bodies of unit 14. That the zone does not cross the Loon River which is a D_5 shear zone may indicate that D_4 is older than the north-trending D_5 .

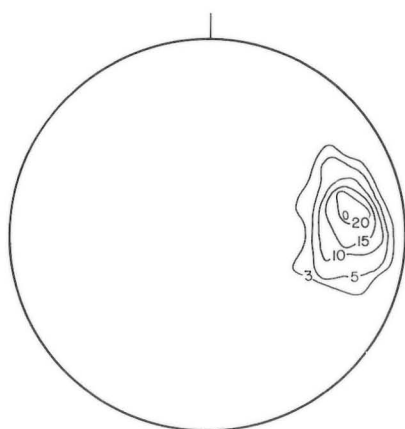
The possibly younger D_5 structures include zones of strong foliation and retrogression with little apparent displacement such as the Loon River lineament and well defined faults that produce offsets in stratigraphic section such as the Abrey Lake fault west of McKnight Lake. D_5 shear zones are more intense than D_4 zones but are commonly only a few metres wide. They are generally accompanied by a greenschist grade retrogressive metamorphism. Only one intrusive rock, a red syenogranite (unit 15) postdates the D_5 zones. It occupies the Loon River shear zone but is not in itself sheared.

North-trending, moderately plunging minor folds younger than F_3 were observed on Russell and McCallum Lakes. D_3 lineations are deformed by these folds. They are upright, open, symmetrical flexures which have a low amplitude to wavelength ratio and no associated planar or linear fabrics. These folds may be related to a compressional component of the late brittle deformation.

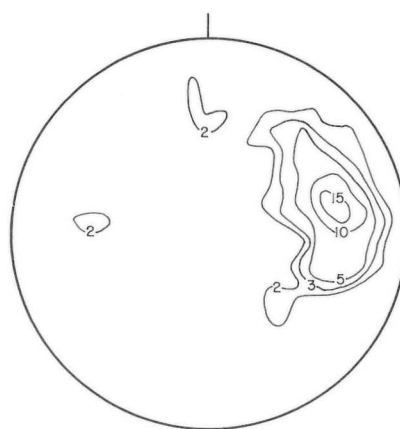
RUSSELL LAKE STRUCTURE

The Russell Lake structure is a well exposed body of Sickie Suite rocks that illustrates the geometric relationship of the three major fold types. A description of the major folds and associated fabrics are presented in this section.

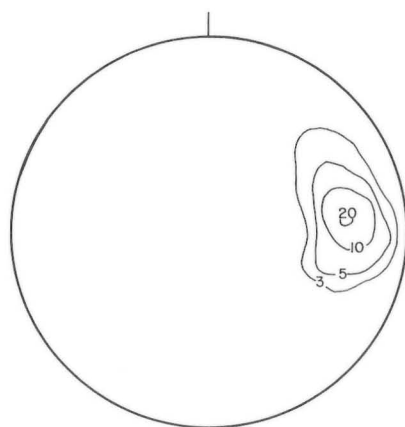
The Sickie Suite outlier comprises a single large F_1 syncline that is cross-folded in two directions to form a large Z-shaped, east-plunging structure. The F_1 axial surface lies within the upper Sickie section with two complete stratigraphic sections facing each other (see Map 79-1-3). Although the fundamental sequence of units is the same in both upright and inverted sections, facies are significantly different. These facies variations are listed in Table 8. The upper inverted limb (core section) of the fold is an allochthonous terrane characterized by coarse clastic rocks and gen-



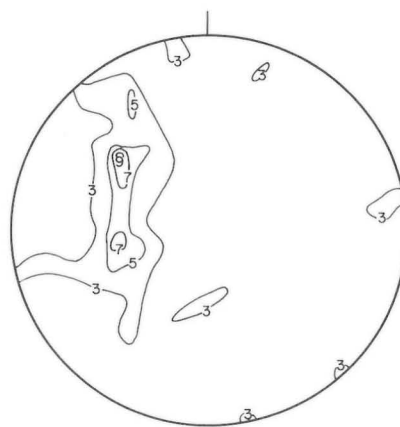
a) Lineations, n=174



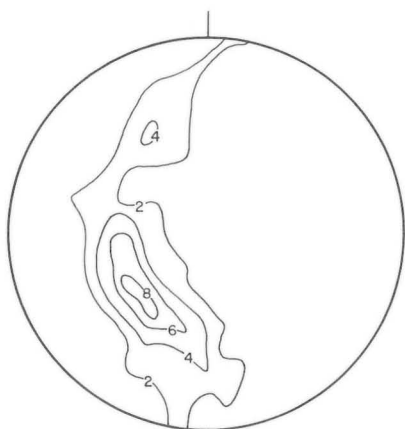
b) Minor fold axes, n=133



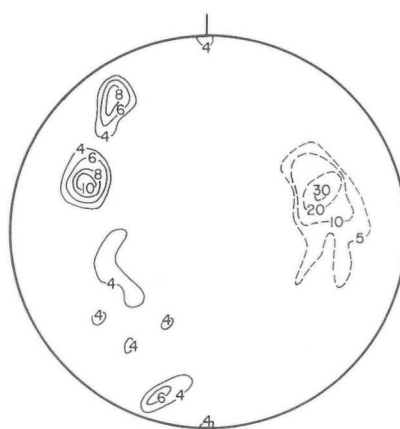
c) All linear structures, n=307



d) Axial planes of minor folds, n=77



e) Foliations and layering, n=465



f) SE McCallum area, foliations (solid contours) n=104
linear structures, (dashed contours) n=42

Figure 24: Equal area projections of linear features and poles to planar features in the Russell Lake structure. Diagram (f), S.E. McCallum Lake, is for comparison.

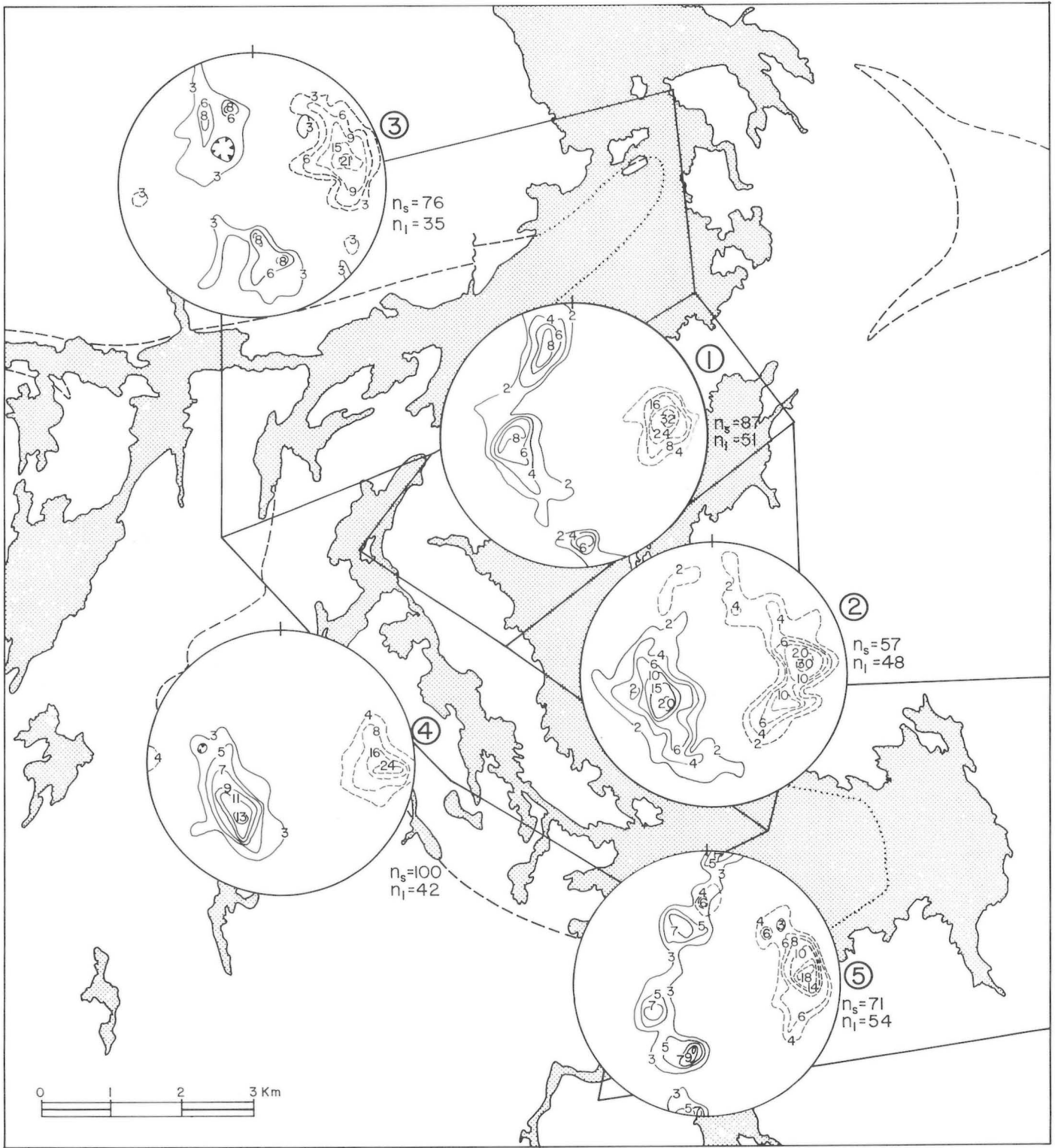


Figure 25: Equal area projections of the Russell Lake structure using the same data as Figure 24 but plotted for five discrete subareas. The numbers of planar features is indicated by N_s and linear features as N_l .

**TABLE 8: VARIATIONS IN STRATIGRAPHIC SECTION
FOR THE UPRIGHT SECTION (THE RIM OF THE STRUCTURE) AND
INVERTED SECTION (CORE OF THE STRUCTURE) ON RUSSELL LAKE.**

RIM (distal)	CORE (proximal)
sillimanite-bearing arkosic gneiss (8)	sillimanite-bearing arkosic gneiss (8)
feldspathic metagreywacke (7a)- bedding 1 to 3 cm	feldspathic metagreywacke (7) - bedding 30 to 50 cm
hornblende gneiss (5) - quartz- rich \pm garnet-sillimanite (5a)	hornblende gneiss (5) - quartz- poor
	polymictic metaconglomerate
well layered hornblende-diopside amphibolite + iron formation	massive amphibolite, pillow basalt, hypersthene-olivine- bearing ultramafic

erally more massive bedding suggesting deposition in a higher energy environment than the upright (rim) section. This, combined with the presence of volcanic flows indicates deposition of the core section in closer proximity to the Lynn Lake greenstone belt (the probable source for the sediments; Zwanzig, pers. comm. 1981) than the rim section. The marked differences in sections implies an amplitude for F_1 folds on the order of tens of kilometres. The tonalite core intrusion is a large sill lying over the upper "proximal" limb. The direction of transport on the F_1 fold is not known because the root of the fold has not been identified. The entire structure appears to be synformal (as discussed later) but two interpretations of the transport direction are possible:

- 1) If the fold is rooted above the erosion surface (a simple recumbent syncline) transport was from the north with the proximal facies overriding the distal facies;
- 2) alternatively, if the structure is rooted at depth in the north (possibly in the east-west-trending tail of the structure) then the initial overriding could have been from the south.

The F_1 structure was folded like a layer by one very large and five or six associated major F_2 folds. The trace of the large F_2 fold lies within the core intrusive (see Map GR 79-1-3 and Figs. 26 and 27). Because the fold axis is near horizontal the F_2 structures have remarkable continuity. The narrow belt of Sickle Suite rocks trending west and north of the structure is an F_2 fold structure averaging 500 m in width but with a strike length exceeding 10 km. The northeast-southwest compression that is implied in the F_2 fold geometry produced strong planar and linear fabrics within the original layering. The inclined isoclinal style of F_2 folds produced a uniform east-dipping attitude of planar features as shown in Figure 25, subarea 4. This area straddles the largest F_2 synform and shows the strong northwest trend of the F_2 planar features whereas linear structures are concentrated in the F_2 eastward direction. The distribution of planar features in stereoplots of other subareas shows that while there is a dispersion to a great circle distribution with concentrations corresponding to the F_3 limbs, the strong northwest F_2 trend is retained. Thickening of units both real and apparent, is a prominent feature of the F_2 structures. This is particularly significant on the west side of the main synform in unit 8.

The youngest folds, large, open, disharmonic flexures warped the structure into a basin and dome terrane. The largest of F_3 structures, an antiform, warped the whole northern part of the F_2

structure into a Z-shape. The narrow west-trending belt is the north limb of the antiform. In the central region (subarea 1) large F_3 structures are developed only on one limb of the major F_2 synform, dying out at the F_2 axial surface. The large synform-antiform pair penetrate only to the core tonalite with space adjustments comprising flow within the layers, particularly in the meta-arkose. This flow adjustment resulted in the large triangular-shaped area of meta-arkose in the core of the box-shaped antiform. In this region the stretching lineations remain in the F_2 axial direction but the F_3 axial planar foliation becomes highly erratic, in places approaching horizontal in the fold core (see Fig. 14). The southern portion of the structure comprises a single large antiform closing in the southeast bay of Russell Lake.

Much of the above discussion is based on the ability to recognize synformal and antiformal structures. In the case of Russell Lake the interpretation of the structure as synformal is based largely on aeromagnetic data. The grade of metamorphism prohibits reliable determination of stratigraphic facing directions based on sedimentary features. The problem is further complicated by the uniform eastward plunge and the inclined attitude of folds. The aeromagnetic signature of the Sickle Suite rocks can be used to differentiate the shape of the folds. On McKnight Lake the Sickle rocks form a distinctly domal structure. The magnetic anomaly associated with this structure has a relief of approximately 800 gammas. Russell Lake shows only a 300 gamma anomaly with a much flatter gradient implying a much thinner section of Sickle rocks. Aeromagnetic surveys have a sampling depth of approximately 1.5 km. If the Russell Lake structure were a tongue-shaped antiform plunging to the east at 30 degrees it would behave as a rod-shaped body of infinite length. The effect of this would be for the magnetic anomaly to continue to the east with continually decreasing intensity for about 2.5 km past the last surface exposure of Sickle rocks. On Russell Lake the anomaly dies out within less than a kilometre of the eastern contact of the Sickle Suite implying that Sickle rocks do not exist in the subsurface for any significant distance to the east. Similarly, the Benzie Lake structure which shows almost no aeromagnetic anomaly should be interpreted as a shallow synformal structure. Conversely, Abrey Lake with a very high aeromagnetic expression is apparently an antiformal structure with considerable subsurface volume of magnetiferous Sickle Suite rocks.

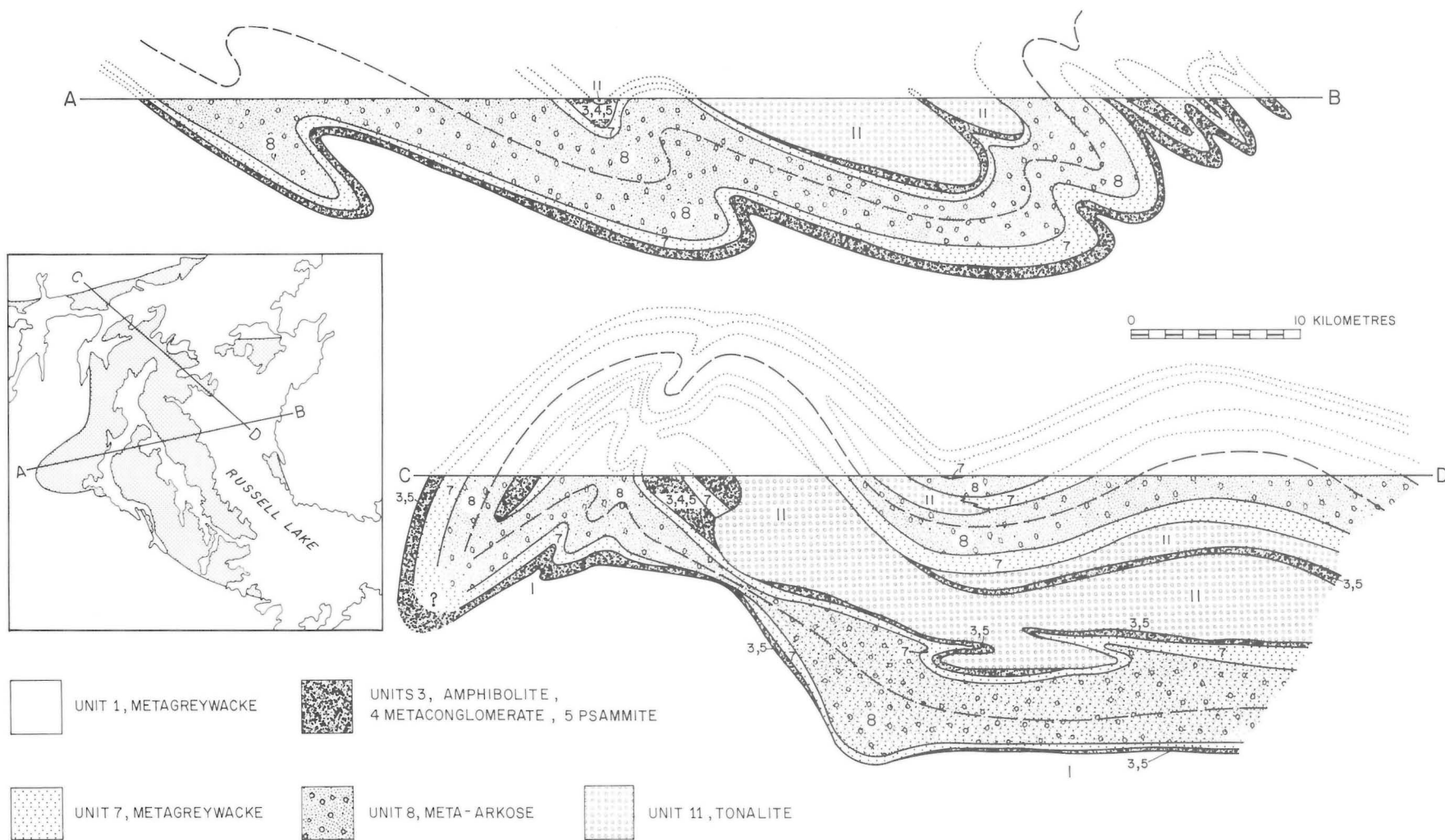


Figure 26: Vertical cross-sections through the Russell Lake structure. The vertical scale is uncertain but probably approximately equals the horizontal scale.

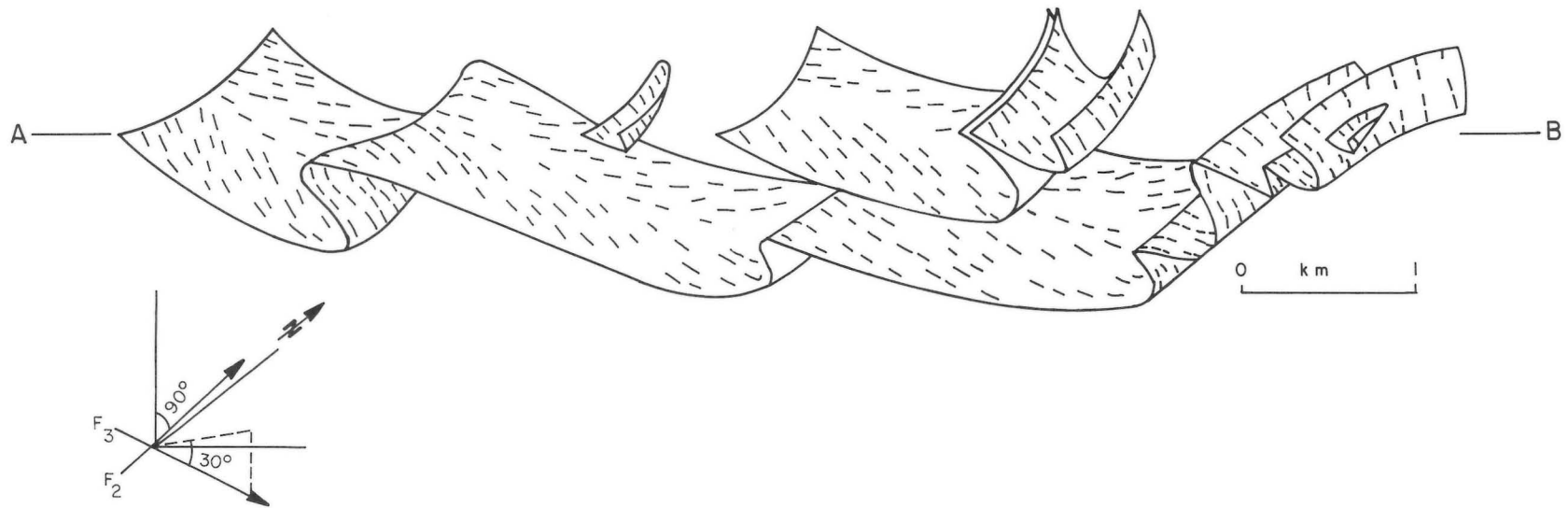


Figure 27: Schematic projection of section line A-B from Figure 26, showing the relationship of F_2 to F_3 . The surface drawn is the lower contact of unit 3.

TECTONIC SYNTHESIS

The structural pattern in the McKnight-McCallum Lakes area has been interpreted as resulting from the basin and dome refolding of early, very large recumbent folds. The F_1 structures may behave as a series of overlapping layers resulting in repetitions of entire suites of rocks. It is possible to define two major stratigraphic affinities to link individual belts of Sickle Suite rocks. The two associations are based on the presence or absence of units 2, 5 and 6. These associations can be referred to as the McKnight-type and the Russell-type of stratigraphy. The McKnight-type of stratigraphy is characterized by the presence of a pelitic metagreywacke (unit 6) and the virtual absence of hornblende-bearing rocks (unit 5) in the Sickle. In the Russell-type of section unit 6 is absent and unit 5 is the basal unit of the Sickle section. A distinctive amphibolite (unit 2) is often present in the Burntwood River Suite near the base of the Sickle Suite in the Russell-type section but is never found near the McKnight-type section. The structural settings of two types of section are unique: the McKnight section (including McKnight Lake, Van Hende Lake, Abrey Lake and north into the Kadeniuk area) occurs in antiformal structures

whereas the Russell section (including Russell Lake, a small crescent-shaped body east of Russell Lake and Benzie Lake) occurs in synformal structures. This suggests the possibility of two structural sheets of arkosic rocks with the Russell-type layer structurally above the McKnight-type layer. The order of the layers could be reversed if the Russell structure is rooted at depth in the north.

The significance of brittle deformation on the overall structural development of the area is uncertain. The D_4 direction appears to be a long-lived structural feature. Even though the fabric and metamorphism attributed to D_4 has affected some of the youngest intrusions and cross-cuts D_3 structures there is some indication that these features may be reactivated older structures. Geological mapping to the south, the Burntwood Project of McRitchie, *et al.* (1979) shows that the Flatrock Lake trend marks the northern limit of abundant enderbite sills. It also delineates a shift from dominantly granite-granodiorite compositions of intrusions in the southwest to granodiorite-tonalite compositions in the northeast. The D_5 north-trending faults do not appear to be as long-lived a feature. They are probably late extension faults.

ECONOMIC GEOLOGY

The McKnight-McCallum Lakes area has received little in the way of mineral exploration activity to the present. A survey of cancelled assessment files shows only nine reports for the area: one for 1954 and eight for the period 1961 to 1963. As of 1981 the only valid mineral claims held are a series of claims south of Russell Lake registered to Manitoba Mineral Resources Ltd.

Most of the work was carried out on a claim block, the Jet claims (Hudson Bay Exploration and Development) located between the southeast end of Russell Lake and the Canadian National Railway line. The work comprised airborne EM, ground EM and 10 diamond drill holes with a total length of 658 metres. The drill holes, targeted on the basis of EM anomalies, were located in the layered amphibolite (unit 3) and the upper part of the Burntwood Suite metagreywackes (unit 1). Mineralization encountered included zones from 1 to 20 m of disseminated pyrite and graphite, 30 to 60 cm layers of massive pyrite and pyrrhotite with traces of chalcopyrite and 1 to 1.5 m of massive graphite. Evidence of further work involving diamond drilling was found on McKnight and Benzie Lakes, but no record of this work exists in the Assessment Report Files.

The McKnight-McCallum area was covered by an airborne gamma-ray spectrometer survey as part of the Federal Government's Uranium Reconnaissance Program (1978). The results show a very flat radiometric response with no anomalous areas. The radiometric survey did indicate a slightly anomalous response for equivalent thorium in the western part of the McCallum Lake sheet. This can be correlated with units 9 and 10. These tonalite-gran-

odiorite intrusions contain abundant apatite which formed pleochroic haloes in biotite and traces of metamict allanite. These two minerals probably account for the slight thorium anomaly.

In the course of field mapping several occurrences of sulphide mineralization were encountered (Figure 28, Table 9). These mainly comprise dissemination of pyrite, pyrrhotite and arsenopyrite in the layered amphibolite (unit 3a).

SUMMARY

The principal method of investigation employed in past studies has been electromagnetic surveys. No studies have been done that could detect sulphide occurrences other than massive sulphide (electromagnetic conductors). Recent studies have indicated mineralized environments other than massive sulphides may exist in the Kisseynew gneissic belt.

The discovery of disseminated copper mineralization in the Kadeniuk Lake area (Baldwin, 1976) at the base of the Sickle Suite demonstrates a new potential for areas with exposures of Sickle-type rocks. This represents a particularly attractive environment as exploration targets are easily defined by the occurrences of the distinctive Sickle Suite rocks.

Recent studies by Gale (1979, 1980) and Tuckwell (1979) indicate the metagreywackes of the Burntwood River Metamorphic Suite are a potential host for lead-zinc sulphide deposits. This type of deposit is not easily detected by electromagnetic survey methods so considerable work must be done on determining suitable environments to establish exploration targets.

**TABLE 9: LOCATIONS OF SULPHIDE MINERAL OCCURRENCES
IN THE MCKNIGHT-McCALLUM LAKES AREA
(SEE LOCATION MAP, FIGURE 28).**

Location No.	Mineralization	Unit	Description
1	chalcopyrite, malachite, bornite	7	narrow seams in a pegmatitic mobilizate layer in meta-greywacke
2	pyrite, pyrrhotite, graphite	1b	iron stained gossan zone showing some silicification - sulphides disseminated
3	pyrite	3a	dissemination in amphibolite
4,5,6	pyrite, pyrrhotite	3a	dissemination associated with thin iron formation layers
7	pyrite, pyrrhotite	3a	dissemination in amphibolite
8	arsenopyrite, pyrite, pyrrhotite	3a	disseminations and thin seams in garnetiferous amphibolite
9	pyrite, minor chalcopyrite	3a	disseminations in carbonate-bearing amphibolite

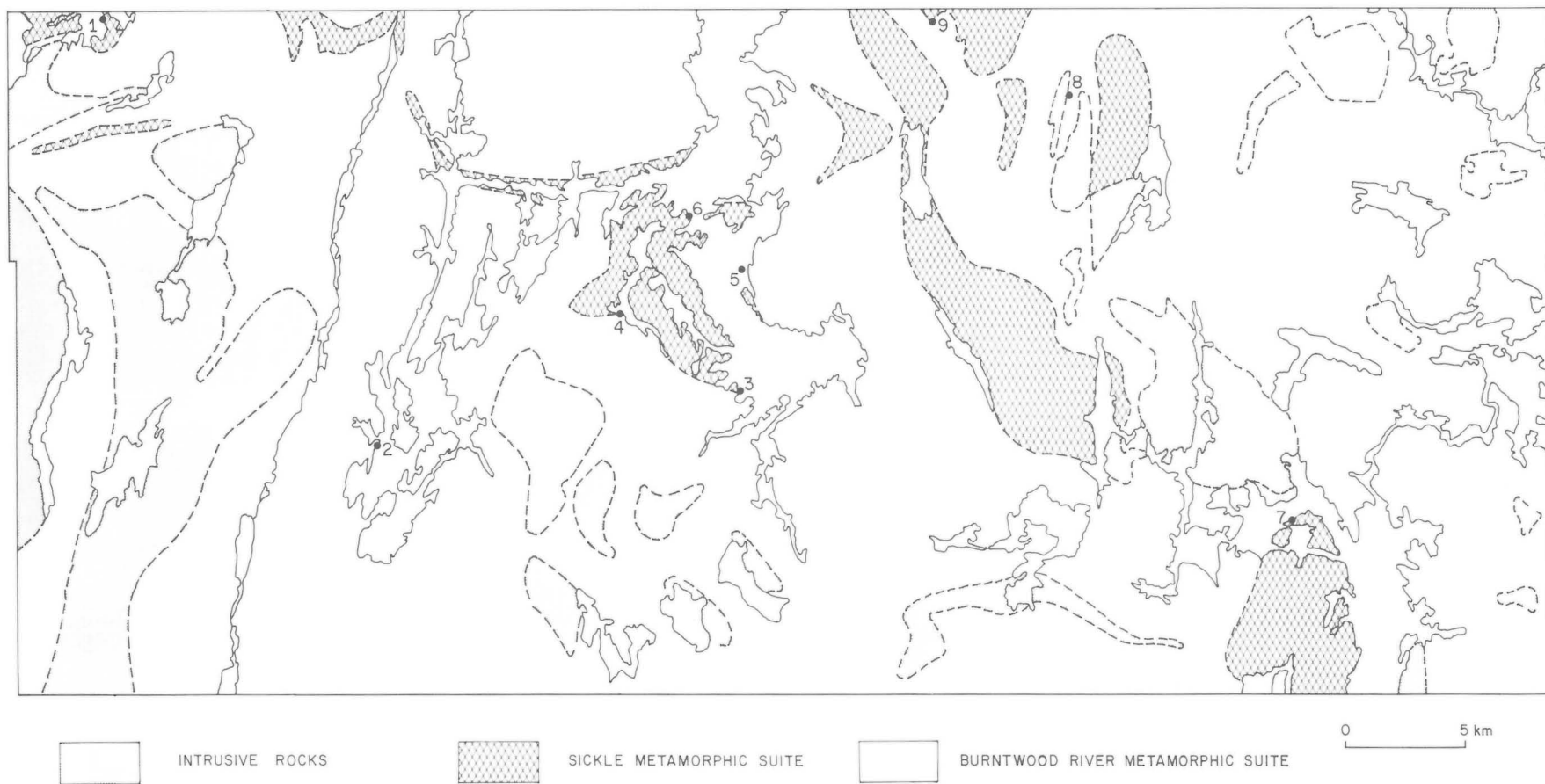


Figure 28: Location map to sulphide occurrences listed in Table 9.

APPENDIX A GEOLOGY OF TROPHY LAKE (PART OF 64C/2 NW)

As part of a regional correlation program in progress during the mapping of the McKnight-McCallum Lakes area the shoreline exposures on Trophy Lake were examined. Rocks previously mapped as metagreywackes equivalent to the Burntwood River Metamorphic Suite (Pollock, 1966), but showing an anomalously high aeromagnetic signature, were found to be meta-arkose and metagreywacke of the Sickie Metamorphic Suite.

The Sickie rocks occupy a north-trending body that appears to be an F_2 synform that was cross-folded by east-trending F_3 folds. The southern part of the structure is largely intruded by

massive red pegmatite that contains numerous inclusions of the country rocks. The stratigraphic section encountered appears to be equivalent to the distal facies of the Sickie Suite as found on McKnight Lake, but lacks the pelitic unit (unit 6). All exposures examined showed some development of anatectic *lit*, but in general the degree of preservation of the rocks is quite good. Sedimentary bedding is recognizable in most exposures.

The aeromagnetic anomaly associated with the Sickie Metamorphic Suite rocks continues to the southeast of Trophy Lake with a second closed anomaly straddling the Onion River.

LEGEND

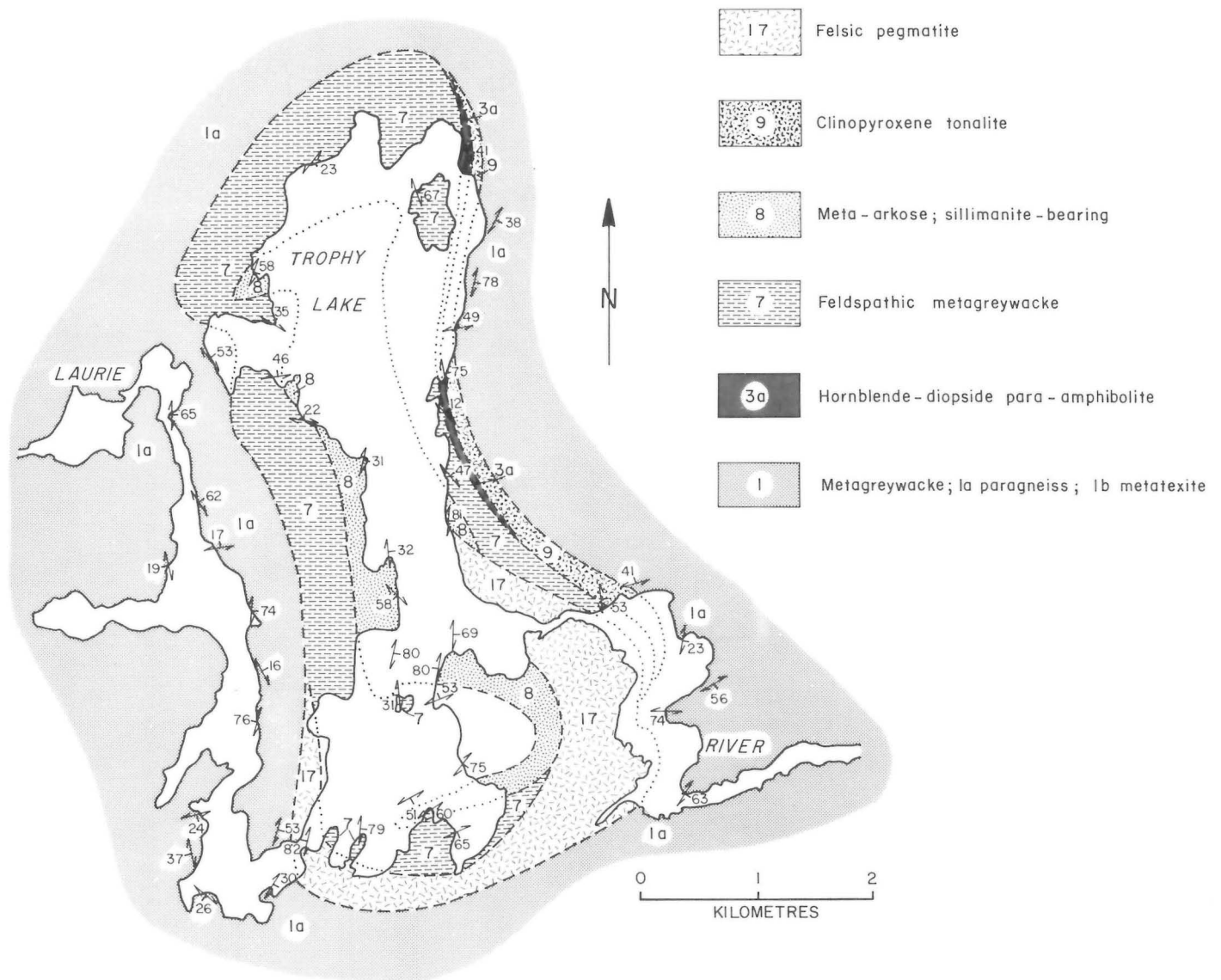


Figure 29: Geological map of Trophy Lake.

APPENDIX B
TABLE 10

Index to chemically analyzed samples* from the McKnight-McCallum Lakes Area

No.	Location	Description
1	56°06'13"N, 101°31'21"W	Well layered garnet-poor psammitic gneiss (unit 1b)
2	56°10'43"N, 101°04'27"W	Muscovite \pm garnet-bearing psammitic metagreywacke (unit 1a)
3	56°03'20"N, 101°45'00"W	Sillimanite-cordierite-garnet-bearing pelitic metagreywacke; potassium feldspar blastic (unit 1b)
4	56°05'43"N, 101°00'07"W	Sillimanite-bearing pelitic metagreywacke (unit 1b)
5	56°06'48"N, 101°29'00"W	Amphibolite breccia (unit 2a)
6	56°11'12"N, 101°36'11"W	Orthopyroxene-olivine-bearing ultramafic (unit 3c)
7	56°09'20"N, 101°35'12"W	Orthopyroxene-olivine-bearing ultramafic (unit 3c)
8	56°08'05"N, 101°36'25"W	White plagioclase-rich calc-silicate layer in amphibolite (unit 3a)
9	56°00'50"N, 101°07'31"W	Cordierite-sillimanite-magnetite-rich pelitic gneiss (unit 6)
10	56°11'55"N, 101°24'28"W	Garnet-cordierite-sillimanite-rich pelitic gneiss (unit 6)
11	56°08'05"N, 101°35'38"W	Hornblende-bearing psammitic gneiss (unit 5)
12	56°10'15"N, 101°33'40"W	Feldspathic metagreywacke (unit 7)
13	56°10'03"N, 101°33'45"W	Well layered feldspathic metagreywacke (unit 7a)
14	56°10'10"N, 101°33'00"W	Well layered magnetite-rich feldspathic metagreywacke (unit 7a)
15	56°06'53"N, 101°32'26"W	Pink layered sillimanite-rich meta-arkose; contains numerous <i>faserkiesel</i> (unit 8)
16	56°08'03"N, 101°31'02"W	Light weathering sillimanite-rich feldspathic meta-arkose (8)

*Analyses performed by the Analytical Laboratory of the Manitoba Mineral Resources Division, Winnipeg, Manitoba.



Figure 30: Locations of chemically analyzed samples. Numbers as listed in Table 10.

REFERENCES

- Bailes, A.H.
 1971: Preliminary compilation of the geology of the Snow Lake-Flin Flon-Sherridon area, Manitoba; Manitoba Mines Branch, Geological Paper 1/71.
 1975: Geology of the Guay-Wimapedi Lakes area; Manitoba Mineral Resources Division, Publication 75-2.
 1979: Sedimentology and metamorphism of a Proterozoic volcanoclastic turbidite suite that crosses the boundary between the Flin Flon and Kiseynew belts, File Lake, Manitoba, Canada; University of Manitoba, Ph.D. thesis (unpublished) 154 pp.
 1980: Geology of the File Lake area; Manitoba Mineral Resources Division, Geological Report 78-1.
- Bailes, A.H. and McRitchie, W.D.
 1978: The Transition from low to high grade metamorphism in the Kiseynew sedimentary gneiss belt, Manitoba; *in* Metamorphism in the Canadian Shield (A. Fraser and W.W. Heywood, Eds.); Geological Survey of Canada, Paper 78-10, pp. 155-177.
- Baldwin, D.A.
 1974: The geology of the Kadeniuk Lake area; *in* Summary of Geological Fieldwork 1974; Manitoba Mines Branch, Geological Paper 2/74.
 1976: Evaluation of disseminated base metal environment; *in* Non-renewable Resources Evaluation Program, First Annual Report; Manitoba Mineral Resources Division, Open File Report 77/1.
- Blümel, P. and Schreyer, W.
 1977: Phase relations in pelitic and psammitic gneisses of the sillimanite-potash feldspar and cordierite-potash feldspar zones in the Moldanubicum of the Lam-Bodenmais area, Bavaria; *Journal of Petrology*, Vol. 18, Part 3, pp. 431-459.
- Bruce, E.L.
 1918: Amisk-Athapapuskow Lakes district; Geological Survey of Canada, Memoir 105.
- Carmichael, D.M.
 1969: On the mechanism of prograde metamorphic reactions in quartz-bearing pelitic rocks; *Contributions to Mineralogy and Petrology*, 20, pp. 244-267.
- Downie, D.L.
 1936: Granville Lake area, Manitoba, West half; Geological Survey of Canada, Map 343A with descriptive notes.
- Gale, G.H.
 1979: Reconnaissance of the Flin Flon — Sherridon areas; *in* Report of Field Activities 1979; Manitoba Mineral Resources Division, Report GS-10
 1980: Mineral Deposit Studies — Flin Flon/Kiseynew; *in* Report of Field Activities 1980; Manitoba Mineral Resources Division, Report GS-10.
- Gilbert, H.P., Syme, E.C. and Zwanzig, H.V.
 1980: Geology of the metavolcanic and volcanoclastic metasedimentary rocks in the Lynn Lake area; Manitoba Department of Energy and Mines, Mineral Resources Division, Geological Paper GP80-1.
- Gilboy, C.F.
 1976: Reindeer Lake, South (S.E. quarter); *in* Summary of Investigations 1976; Saskatchewan Geological Survey, Department of Mineral Resources, pp. 36-43.
- Henderson, J.E., Norman, G.W.H. and Downie, D.L.
 1936: Granville Lake (east half) area, Manitoba; Geological Survey of Canada, Map 344A.
- Hunter, H.E.
 1953: Geology of the McKnight Lake area; Manitoba Mines Branch, Publication 52-3.
- McRitchie, W.D.
 1974: The Sickle-Wasekwan Debate: a review; Manitoba Mines Branch, Geological Paper 1/74.
 1975: Russell Lake South; *in* Summary of Geological Fieldwork 1975; Manitoba Mines Branch, Geological Paper 2/75.
- McRitchie, W.D. and Frohlinger, T.G.
 1972: Geological Map 78-3-7, Flatrock Lake; *in* Geology of the Nelson House-Pukatawagan Region (Burntwood Project); Manitoba Mineral Resources Division, Geological Maps 78-3-1 to 78-3-22.
- McRitchie, W.D., Frohlinger, T.G.,
 Baldwin, D.A. and Zwanzig, H.V.
 1972: Burntwood Project; *in* Summary of Geological Fieldwork 1972; Manitoba Mines Branch, Geological Paper 3/72.
 1973: Burntwood Project; *in* Summary of Geological Fieldwork 1973; Manitoba Mines Branch, Geological Paper 2/73.
 1979: Geology of the Nelson House-Pukatawagan Region (Burntwood Project); Manitoba Mineral Resources Division, Geological Maps 78-3-1 to 78-3-22.
- Pollock, G.D.
 1964: Geology of the Duval Lake area; Manitoba Mines Branch, Publication 61-6.
 1965: Geology of the Russick Lake area; Manitoba Mines Branch, Publication 63-2.
 1966: Geology of the Trophy Lake area (west half); Manitoba Mines Branch, Publication 64-1.
- Sangster, D.F.
 1978: Isotopic studies of ore-leads of the circum-Kiseynew volcanic belt of Manitoba and Saskatchewan; *Canadian Journal of Earth Sciences*, 15, pp. 1112-1121.
- Schledewitz, D.C.P.
 1972: Geology of the Rat Lake area; Manitoba Mines Branch, Publication 71-2B.
- Streckeisen, A.L.
 1973: Report of the Commission on Systematics in Petrology; *Geological Newsletter* 1973, 2, pp. 110-127.
- Tuckwell, K.
 1979: Stratigraphy and mineral deposits of the Sherridon area; *in* Report of Field Activities 1979; Manitoba Mineral Resources Division, Report GS-11.
- Winkler, H.G.F.
 1976: Petrogenesis of metamorphic rocks, Fourth edition; Springer-Verlag, New York, Inc., New York.
- Zwanzig, H.V. and Wielezyski, P.
 1975: Geology of the Kamuchawie Lake area; *in* Summary of Geological Fieldwork 1975; Manitoba Mines Branch, Geological Paper 2/75.

