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GEOLOGICAL PAPER
GP80-1

GEOLOGY OF THE METAVOLCANIC AND VOLCANICLASTIC METASEDIMENTARY ROCKS IN THE LYNN LAKE AREA

by
H.P. Gilbert, E.C. Syme & H.V. Zwanzig

1980

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DEPARTMENT OF ENERGY AND MINES

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INTRODUCTION

The area described in this report (Fig. 1) covers approximately 3500 km^2 (1352 $miles^2$) within longitudes 100° 20′ and 102° and latitudes 56° 30′ and 57°. The town of Lynn Lake is centrally located in the map area.

Access within the map area is provided by Highways 391 (between Lynn Lake and Thompson), 396 (between Lynn Lake and Fox Mine) and 394 (between Lynn Lake and Kinoosao on Reindeer Lake). A railroad connects Lynn Lake and Cranberry Portage. Areas not accessible by road were reached by float-equipped aircraft or helicopter.

Bedrock exposure is sporadic and comprises on average only 10 per cent of the surface area. Clean exposures are restricted to outcrops on a few large lakes and in small sand pits along roads. Small, partly lichen-covered outcrops occur commonly at the edges of low, drift-covered ridges and hillocks.

PRESENT WORK

The Lynn Lake Project was undertaken in response to two factors: (1) the need for new mineral production at Lynn Lake, resulting from the closure of the Farley Nickel Mine, and (2) a regional programme of updating geological mapping in northwestern Manitoba. This report and the accompanying maps provide a preliminary geological data base for mineral exploration and evaluation in the Lynn Lake area. Concurrent studies of economic geology, geophysics, geochronology and structural geology were carried out at the Mineral Resources Division and at the University of Manitoba. These studies are listed in Table 1.

TABLE 1: LIST OF CONCURRENT WORK.

Airborne Surveys

Airborne Electromagnetic Survey, Dept. Mines, Resources and Environmental Management, Lynn Lake Area, Manitoba (File #18036, 1977).

An Edited Digital Data Set and Interpretation for an Aeromagnetic Survey in the Vicinity of Lynn Lake, Manitoba (Hall, Millar and Mok, in prep.)

Mineral Inventory

Manitoba Mineral Inventory File, Geoscience Data Section, Man. Min. Res. Div.

Mineral Potential Studies

A Geological Evaluation of Precambrian Massive Sulphide Deposit Potential in Manitoba (Gale, Baldwin and Koo, 1980).

Nickle-Copper Mineralization in the Lynn Lake Gabbro (Pinsent, 1980).

Geochronology

Rubidium-Strontium Geochronology in the Lynn Lake Greenstone Belt, Northwestern Manitoba (Clark, 1980).

Theses (M.Sc., University of Manitoba)

Geology of the Fox Orebody, Northern Manitoba (Lustig, 1979).

Structural Geometry of the Laurie Lake Area, Lynn Lake District, Manitoba (Thomas, in prep.).

Structural Geology of the Eager Lake Area, Lynn Lake District (Keay, in prep.).

Field work was started in 1976, and an accelerated programme funded under DREE was carried out in 1977 with analytical work and local mapping in 1978 and 1979. Vertical aerial photographs at a scale of 1 inch to ½ mile (Series A23828 to A24299) and selected photo enlargements at a scale of 1:20 000 were used to locate traverses, which were conducted by standard pace and compass methods. Preliminary maps were prepared at a scale of 1:50 000. For the purpose of this report, the maps were revised (1980) and a compilation map was prepared at a scale of 1:100 000. The maps are listed in Table 2.

TABLE 2: LIST OF CURRENT MAPS.

Geological Maps (revised 1980), 1:50 000

GP80-1-1 Lynn Lake (64C-14)
by H.P. Gilbert, E.C. Syme

GP80-1-2 Cockeram Lake (64C-15)
by E.C. Syme, H.P. Gilbert

GP80-1-3 Laurie Lake (64C-12)
by H.V. Zwanzig, M.W. Thomas, J.P. Keay

GP80-1-4 McGavock Lake (64C-11)
by H.P. Gilbert, H.V. Zwanzig, B. McGill, H.D.M. Cameron, Oliver (1952), Milligan (1960)

GP80-1-5 Sickle Lake (64C-10)
by E.C. Syme, H.V. Zwanzig, Fawley (1952), Milligan (1960)

Compilation Map (1978, revised 1980), 1:100 000

GP80-1-6 Lynn Lake Area

Mapping was carried out in separate field parties led by Herman V. Zwanzig in the southwestern part of the area; H. Paul Gilbert in the north; and Eric C. Syme in the southeast (Fig. 2). Mapping in the gneissic terrane on the south flank of the volcanic belt was carried out by H.D.M. Cameron, J.P. Keay, M.W. Thomas and H.V. Zwanzig. B. McGill assisted in mapping the southwestern part of the area. The project was coordinated by H.V. Zwanzig.

Sampling for chemical analysis was conducted during the routine mapping. Analytical work was undertaken by the staff of the Mineral Resources Division Analytical Laboratory. Chemical analyses are published in the appendix to this report and preliminary findings are discussed in the text.

The focus of this report is on the rocks with the highest base metal potential: the Proterozoic metavolcanic and metasedimentary rocks of the Wasekwan Group. The major units in the group are described in detail and preliminary interpretations of their provenance and depositional environment are given in the text. The stratigraphic and structural framework of the Lynn Lake Greenstone Belt is summarized.

The geology of the Wasekwan Group is discussed with respect to eight subareas. These are separated by bodies of intrusive rocks, faults, fold hinges, areas of little outcrop, and lateral breaks in the stratigraphic succession across which correlations are uncertain (Fig. 3).* Where possible, lithologic units are discussed in chronological order for each subarea, and the evolution of the local volcanic and sedimentary piles is discussed. A single unit is used for

*in folder

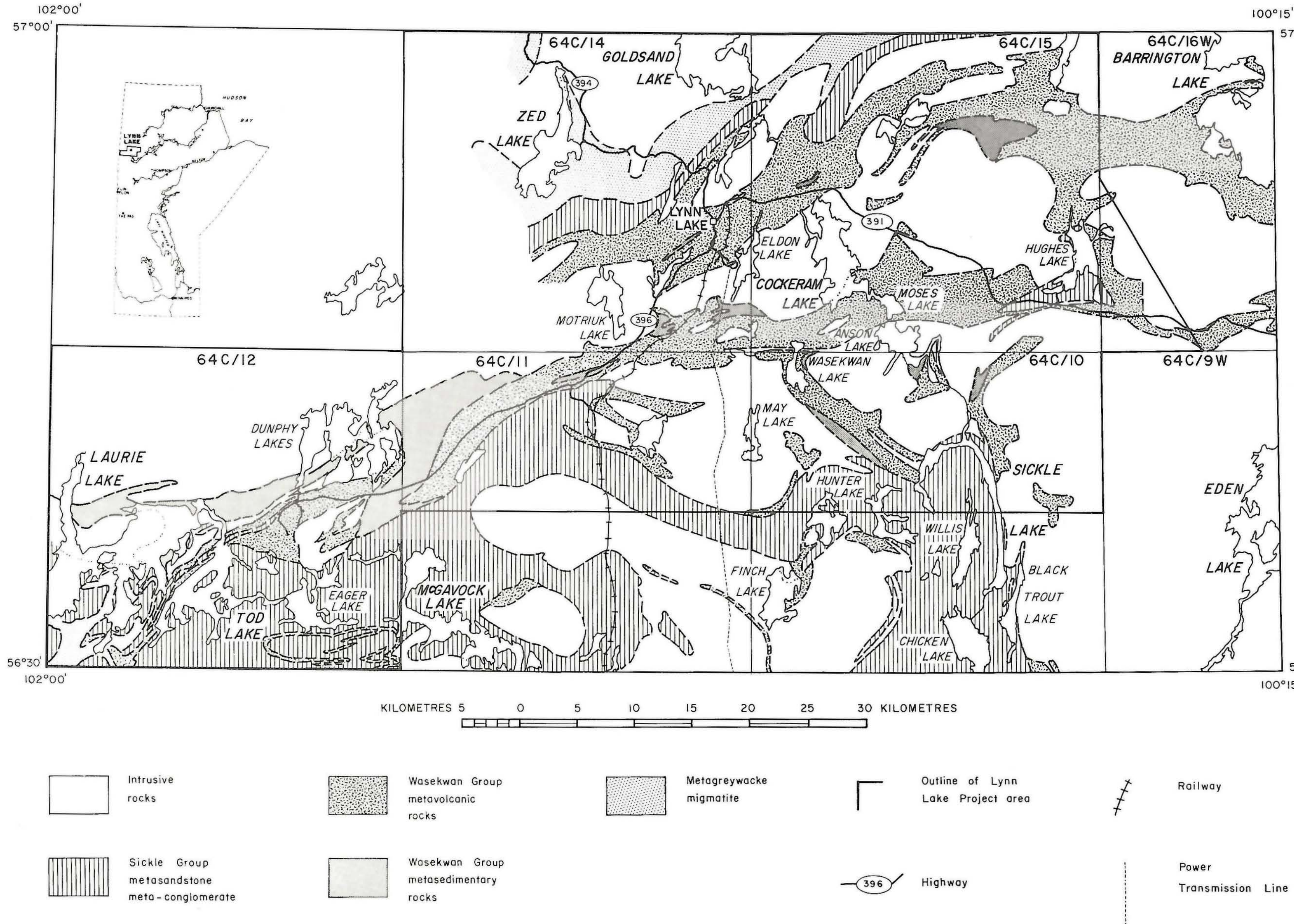

FIGURE 1: Location and simplified geology of the Lynn Lake area.

each lithology throughout the Lynn Lake belt regardless of stratigraphic position. Most lithologies are discussed more than once because they occur in more than one subarea.

Rocks of the lowest metamorphic grade occur southeast of Cockeram Lake near the geographic centre of the Lynn Lake Belt (Fig. 3). These rocks, which are interpreted to comprise the oldest part of the Wasekwan Group, are described first. The overlying sequences at McVeigh, Eldon and Fraser Lakes are described in the next section of this report. The upper part of the volcanic succession farther east is described in the section on Hughes Lake.

Belts of Wasekwan Group rocks which occur south of the Cockeram Lake area are isolated from the main volcanic belt by granitic rocks and a prominent strike fault. They are exposed in the Miskwa Lake area and along the Keewatin River north of Sickle Lake. Descriptions of similar rocks at Counsell Lake, Eager Lake, Hunter Lake and Black Trout Lake are in preparation.

North of Cockeram Lake a separate belt of volcanic rocks, the "northern belt", extends from Motriuk Lake through Lynn Lake town to Eagle Lake and beyond the present study area to Barrington Lake.

Volcanic and sedimentary rocks in the southwestern part of the Lynn Lake Belt (Fox Mine-Gemmell Lake area) are moderately to highly metamorphosed and correlations there are even more uncertain than in the east.

Predominantly sedimentary rocks and migmatites on the north flank of the Kisseynew Belt are separated from the predominantly volcanic successions by faults. Nevertheless the amphibolites at Laurie Lake provide a stratigraphic link between the Wasekwan Group in the Lynn Lake Belt and the Burntwood River Metamorphic Suite in the Kisseynew Belt.

Studies are in preparation which will include descriptions of the Sickle Group and the remaining units in the Wasekwan Group (e.g. Gemmell Lake area), as well as general chemistry, structure and stratigraphy.

The terminology used in this report is that of primary rock types wherever the metamorphic grade ranges from low to medium. However, certain metamorphic mineral names are used to modify the primary terms where they indicate distinctions in original composition. The terminology of metamorphites is used only for highest grade rocks in which primary structures are generally absent. The volcanic rocks are classified by chemical composition augmented by mineral content. Arbitrary SiO_2 class limits for volcanic rocks, based on average rock composition (LeMaitre, 1976), are: basalt, 46 - 54%; andesite, 54 - 62%; dacite, 62 - 70%; rhyolite, 70 - 78%. Classification of magma series is after Irvine and Baragar (1971). Terminology of volcanic breccia is after Fisher (1966) and Parsons (1969), that of epiclastic rocks is after Pettijohn (1957). Definition of clast- and grain-size in volcanic and sedimentary rocks is according to the Wentworth scale.

PREVIOUS WORK

Geological reconnaissance mapping of the Granville Lake area was initiated in 1932 by the Geological Survey of Canada (Norman, 1934, 1936). Earlier mapping had been conducted in the adjacent area of Reindeer Lake to the west (Stockwell, 1928); mapping of the Brochet area to the north and Uhlman Lake area to the east was accomplished later (Gadd, 1950; Wright, 1953, respectively). Early economic interest was focussed on gold; diamond drilling was reported in 1928 at Reindeer Lake, and in 1933 a claim (R Double J.) was staked at Black Trout Lake. A gold occurrence was found at Cartwright Lake in 1934. The Caribou claim (Cu, Mo) at Barrington Lake was staked in 1930, but there was little prospecting for sulphide mineralization at this time. The first substantial gold deposit was discovered in 1937 at Lasthope Lake by R. Madole; this find resulted in extensive staking, with the consolidation of 417 claims under Lasthope Gold Mines Limited, a subsidiary of Sherritt Gordon; diamond drilling had confirmed 140 000 tons of ore by 1939. In 1941 Bateman mapped the Madole vein and several other gold properties in detail while mapping the McVeigh Lake area at a scale of 1 inch = 1500 feet (Bateman, 1945). The Wasekwan series was defined at that time as an assemblage of volcanic and sedimentary rocks which were unconformably overlain by the sedimentary Sickle series earlier defined by Normal (1933). Bateman also subdivided intrusive rocks into pre-Sickle and post-Sickle groups.

In 1941 massive pyrrhotite was discovered by Austin McVeigh in an outcrop of what was later termed the "A" orebody of Sherritt Gordon's Farley mine at Lynn Lake. Sherritt Gordon acquired a large area of adjacent ground (353 claims), and a staking rush followed confirmation of the large orebody in 1945. In 1947, the nearby EL orebody was located, and by 1950 drilling had established sufficient ore at Lynn Lake (14 million tons) for development to proceed. Several substantial Cu/Zn sulphide bodies were found on properties staked at this time, including Sherritt Gordon's "Z" deposit in 1946 (153 000 tons) and the Goodenough body in 1947 (182 000 tons). Central Manitoba Mines, who were also active in the early exploration, acquired the Agassiz property, originally staked in 1946, which contains a gold deposit over 1.5 million tons. The Barrington Lake property and the D.H. and F.L. property (with 250 000 tons and 500 000 tons of Cu ore, respectively) were also staked in 1946. Extensive prospecting continued until 1949, but subsequent activity was mainly directed to these major properties and a few other localities notably Nickle Lake and Tow Lake.

During the phase of extensive exploration, the Manitoba Mines Branch initiated a regional mapping programme, resulting in the publication of fourteen 15-minute map sheets. The maps focused on the identification of lithologic units, and served as a basis for the regional synthesis by Milligan (1960). The later report of Davies *et al.* (1962) provides a review of the economic geology of the area, whereas Milligan's work serves as a reference to both the general and economic geology of the Lynn Lake district. Exploration in the last twenty-five years has been directed largely towards Cu-Ni prospects associated with gabbro intrusions, and Cu-Zn deposits within the Wasekwan Group rocks. Prospecting has continued on the older properties and there have been a few new finds. A silver showing was staked in 1955 (George group), and four copper occurrences were staked in 1961 including the TAR and RYE groups, LAR group (subsequently cancelled) and the FOX group, which led to the discovery of Fox Mine. (The mine was opened in 1970 and by 1971 was producing 3 000 tons of ore per day. Estimated reserves in 1977 were 7 093 000 tons grading 1.83% Cu, 2.12% Zn; total production for that year was 890 000 tons of ore — Sherritt Gordon Mines Ltd. Annual Report, 1977). Exploration received a new impetus following discovery of the Ruttan Lake orebody in 1969, and with the release of the results of an airborne geophysical survey of the Southern Indian Lake area by the Manitoba Mines Branch later in that year. Further stimulus to exploration was provided by publication of Questor airborne geophysical maps of the Fox Lake, Lynn Lake and Barrington Lake areas in 1976 and 1977, and a new Cu/Zn sulphide body close to Counsell Lake was reported by Sherritt Gordon in 1977.

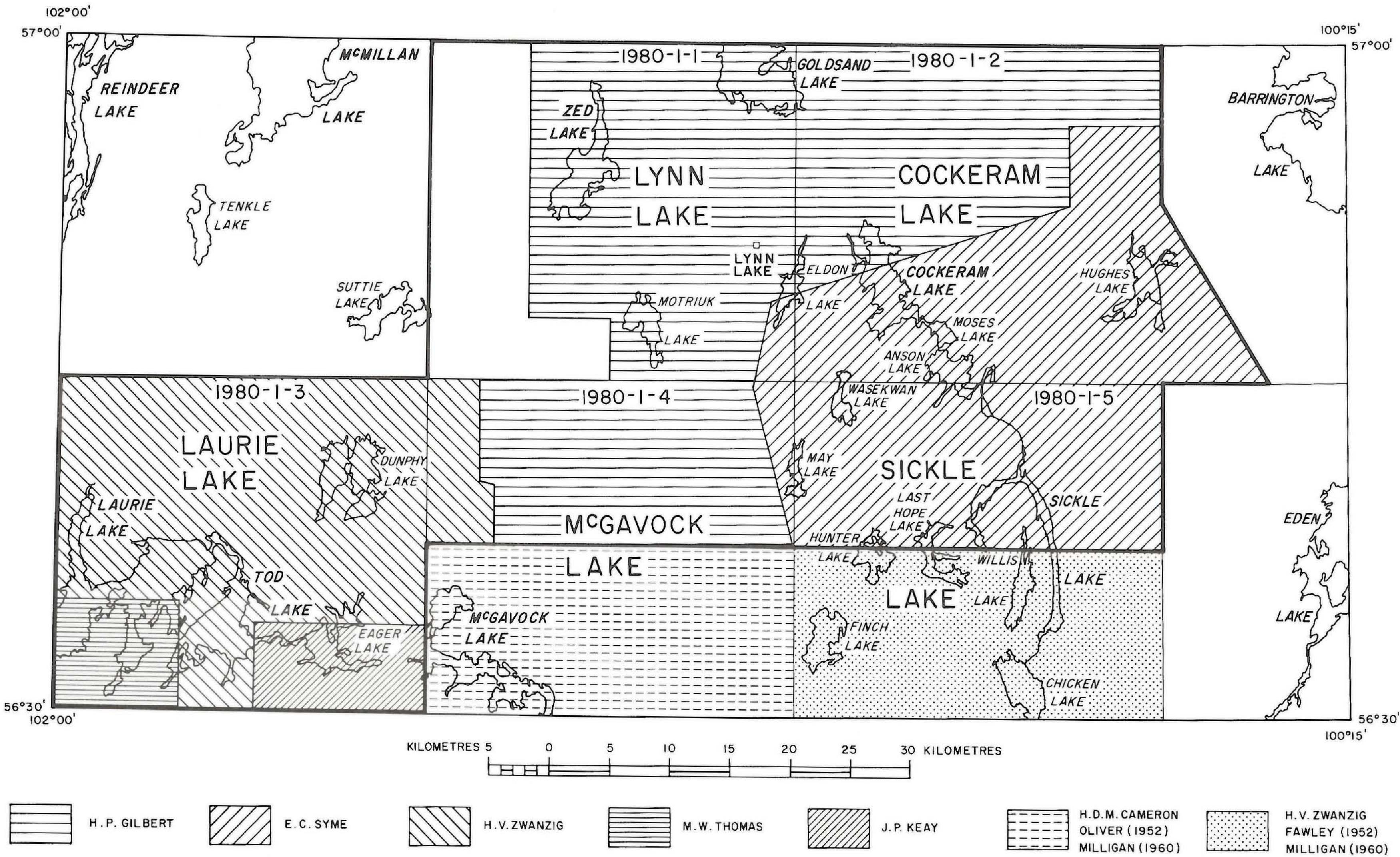

FIGURE 2 : Individual map areas and location of 1:50 000 scale geological maps in the Lynn Lake area.

FIGURE 2: Individual map areas and location of 1:50 000 scale geological maps in the Lynn Lake area.

SUMMARY GEOLOGY

REGIONAL SETTING

The Lynn Lake Project area lies in the Churchill Structural Province and straddles three Aphebian lithostructural belts: (1) the larger part of the Lynn Lake Greenstone Belt; (2) the northern margin of the Kisseynew Sedimentary Gneiss Belt; and (3) the southern margin of the Southern Indian Gneiss Belt (Fig. 4).

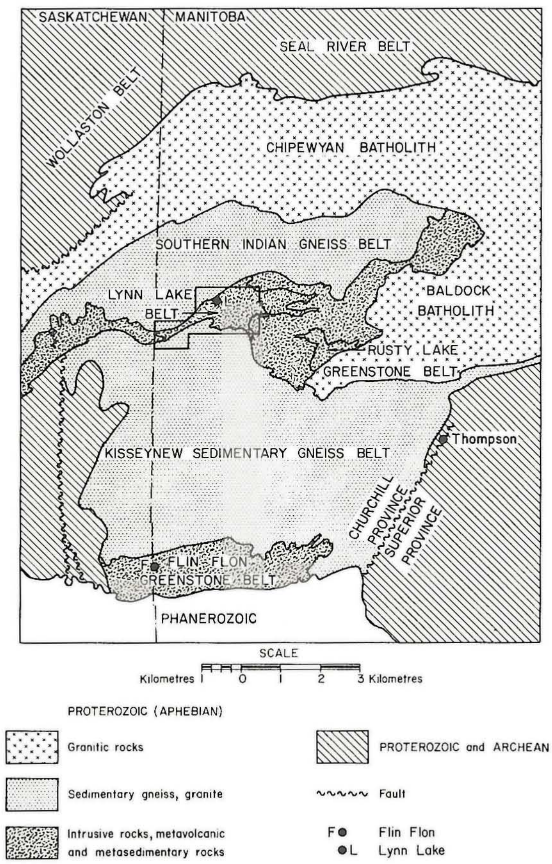

FIGURE 4: Structural setting of the Lynn Lake Greenstone Belt.

LYNN LAKE GREENSTONE BELT

The Lynn Lake Greenstone Belt is a domain of metamorphosed volcanic, sedimentary and plutonic rocks extending for 130 km from Laurie Lake in the west to Magrath Lake in the east. The belt has a maximum width of 60 km in the area between Eagle Lake and Beaucage Lake. It lies at the centre of a lithostructural belt, underlain by largely granitic rocks and greenstone, extending from La Ronge, Saskatchewan (Johnson, 1979) northeast for 500 km to Partridge Breast Lake, Manitoba (Corkery and Lenton, 1979). Extensive greenstones also occur southeast of Lynn Lake in the Rusty Lake Belt (Steeves and Lamb, 1972).

Rocks in the Lynn Lake Belt have an Aphebian age of deposition, intrusion and metamorphism (Clark, 1980). The volcanic rocks and volcaniclastic sedimentary rocks belong to the Wasekwan Group* (Bateman, 1945). They have been intruded by small subvolcanic plutons, and subsequently folded, faulted and intruded by larger mafic and felsic plutons. Sandstone and conglomerate of the Sickle Group* (Norman, 1933) were deposited unconformably on the Wasekwan Group and the early intrusions. Regional metamorphism in the upper greenschist to upper amphibolite facies and, at the margins of the greenstone belt, extensive deformation and plutonism took place after the deposition of the Sickle Group.

KISSEYNEW SEDIMENTARY GNEISS BELT

The Kisseynew Belt is underlain by paragneiss, amphibolite, and migmatite derived from Aphebian (Clark, 1974) sedimentary and minor volcanic strata. The belt extends south to the Flin Flon Greenstone Belt, east to the Thompson Nickel Belt and west into Saskatchewan. This belt and portions of the adjacent greenstone terrane have undergone upper amphibolite facies metamorphism and polyphase deformation. The sedimentary succession in the Kisseynew Belt consists of lower and upper divisions, herein called the "Burntwood River Metamorphic Suite" and "Sickle Metamorphic Suite" (terminology modified after McRitchie, 1974).

The Burntwood River Metamorphic Suite comprises quartzo-feldspathic paragneiss and migmatite derived from greywacke-mudstone, and thin, conformably overlying amphibolite derived from mafic volcanic and mafic sedimentary strata. The sediments were probably deposited contemporaneously with the volcanic and sedimentary rocks of the Wasekwan Group at Lynn Lake and the Amisk Group at Flin Flon (Bailes, 1971; McRitchie, 1974). However, the Burntwood River Metamorphic Suite has a shorter structural history than the Wasekwan Group.

The Sickle Metamorphic Suite comprises quartz and feldspar-rich paragneiss. These gneises were derived from lithic sandstone, calcareous sandstone, arkose and conglomerate which conformably overlie the greywacke-derived gneisses of the Burntwood River Metamorphic Suite. The younger felsic gneisses are stratigraphically equivalent to the Sickle Group and occupy a similar stratigraphic position to the Missi Group at Flin Flon. A stratigraphic outline for the Lynn Lake region is given in Table 3.

SOUTHERN INDIAN GNEISS BELT

The Southern Indian Belt lies north of Lynn Lake and extends from Southern Indian Lake west into Saskatchewan where it probably corresponds to the northwestern part of the western La Ronge domain and the southeastern part of the Rottenstone domain (terminology after Lewry *et al.* in press). This belt is lithologically similar to the Kisseynew Belt, and was developed from an equivalent stratigraphic sequence comprising greywacke, thin volcanic and mafic sedimentary strata, overlain by arkosic rocks (Table 3). The structural data from a small area of well preserved rocks south of Dunsheath Lake suggests that the greywacke and volcanic rocks correlate with the Wasekwan Group, and the overlying conglomerate with the Sickle Group (Zwanzig, 1978). However, the age of these units is not firmly established. If the predominantly sedimentary rocks of the Southern Indian Belt and the predominantly volcanic rocks of the Lynn Lake belt are contemporaneous as suggested, then there is an abrupt facies change or break between them. The break is covered by "Sickle" conglomerate and intruded by granite.

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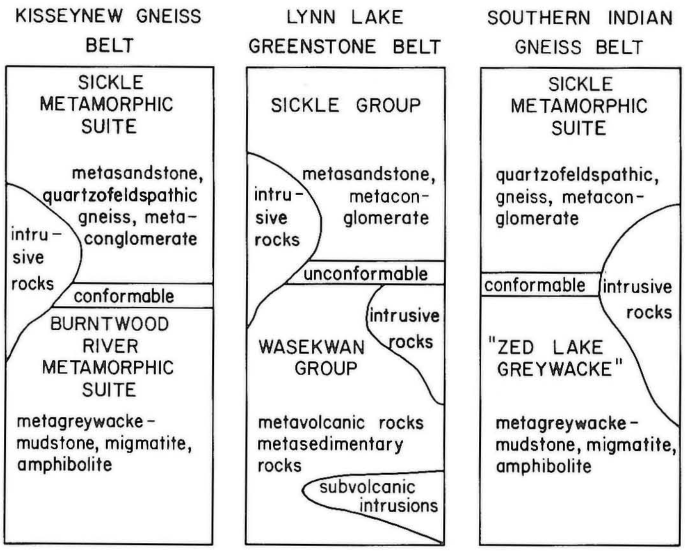
*The Wasekwan and Sickle Series of Bateman and Norman were revised to Wasekwan and Sickle Groups by Campbell (1969).

TABLE 3: STRATIGRAPHIC OUTLINE FOR THE LYNN LAKE REGION.



WASEKWAN GROUP

The Wasekwan Group consists of volcanic and sedimentary rocks which occupy structural belts separated by large, oval granitic plutons. Variations in volcanic stratigraphy take place *along* strike between partly overlapping bodies of volcanic rock and *across* strike between different structural belts, so that a general correlation of all units in the Lynn Lake area cannot be made with certainty. The most extensive successions define two northeasterly trending belts: a "northern belt" between Motriuk Lake and Eagle Lake, and a "southern belt" between Fox Mine and Hughes Lake (Fig. 3). Smaller areas of greenstone occur in the south, in the predominantly granitic terrane between Counsell Lake and Sickle Lake.

The oldest rocks in the Lynn Lake area are interpreted to occur in the southern belt. These rocks comprise over 2000 m of tholeiitic, aphyric and porphyritic basalt exposed in the Cockeram Lake area (Table 4, and Fig. 3). Slightly more mafic porphyritic basalt at the base of the succession south of Fox Mine is tentatively correlated with the Cockeram Lake succession.

The basalts are overlain by discontinuous units of sedimentary rocks, including up to 1500 m of turbidite in the western part of the southern belt. A variety of mafic, intermediate and felsic volcanic rocks overlie the basalts elsewhere. For example, in the Hughes Lake area over 2500 m of calc-alkaline rocks overlie the Cockeram Lake basaltic sequence; the calc-alkaline succession is in turn overlain by tholeiitic basalt.

A heterogeneous volcanic and sedimentary succession extends from McVeigh Lake southwest for 30 km to the area west of Wilmot Lake. Intercalated felsic volcanic rocks, tuffs, fine grained sedimentary rocks and iron formation occur in the Gemmell Lake area near the probable top of the succession. The heterogeneous volcano-sedimentary succession in the Gemmell Lake area, the calc-alkaline rocks in the Hughes Lake area, and a thin slightly more mafic succession at Fox Mine, all occupy a similar stratigraphic position above the early, extensive tholeiitic basalt.

The northern belt consists largely of mafic volcanic rocks intercalated with felsic and intermediate units. The mafic part of this sequence extends from an area north of Motriuk Lake for approximately 70 km eastward to the vicinity of Barrington Lake. Equivalent rocks have been mapped for approximately 30 km eastward to Magrath Lake (Kilburn, 1956). These rocks are chemically distinct from those of the southern belt; they comprise tholeiitic basalt and andesite interlayered with high-alumina basalt and andesite ($Al_2O_3 > 18\%$). The sequence is divided into six main parts: a large felsic volcanic body comprises the lowest division (A); it is overlain by a relatively hererogeneous volcanic division (B) containing abundant fragmental rocks in the vicinity of Lynn Lake town. A discontinuous sedimentary succession (C) separates division B from the upper, generally mafic volcanic divisions (Table 5).

ROCKS OF PROBABLE WASEKWAN AGE

The Burntwood River Metamorphic Suite comprises paragneiss and migmatite derived from greywacke-mudstone, overlain by a discontinuous unit of up to 50 m of layered amphibolite. The upper 600 m of the Burntwood River Metamorphic Suite is exposed at Laurie Lake. Thicker successions of these rocks occur throughout the Kisseynew Belt. A structurally compressed succession of 1000 m of greywacke-migmatite occurs on Kamuchawie Lake (Zwanzig, 1975). Its primary thickness was probably about 3000 m. Similar rocks can be traced northeast into the Lynn Lake Belt at Hatchet Lake and Dunphy Lakes. The upper 300 m of the succession at Laurie Lake is rich in garnet, cordierite, sillimanite and graphite — minerals derived from black mudstone. Thin beds interpreted as felsic tuff occur at several horizons near the top of the succession.

The Zed Lake greywacke forms an extensive terrane of fine grained sedimentary rocks and derived gneisses north of the conglomerate formation along the north flank of the Lynn Lake Belt. The unit is similar to the Burntwood River Metamorphic Suite and it too contains a thin mafic unit at the top.

SICKLE GROUP

The Sickle Group (Norman, 1933) comprises a minimum of 3900 m of conglomerate and sandstone. A basal polymictic conglomerate rests with angular unconformity on Wasekwan Group rocks and on felsic and mafic plutonic rocks in the central and southern parts of the Lynn Lake Greenstone Belt. The conglomerate is a maximum of 540 m thick at Sickle Lake and contains sub-rounded pebbles and cobbles of quartz-feldspar porphyry, granodiorite, arkose, mafic and felsic volcanic rocks, chert, iron formation and epidosite. The overlying arkosic sequence is predominantly medium grained sandstone and minor pebbly sandstone derived from a granitic terrane.

A thick (1000 m?) polymictic conglomerate formation with a hornblende-bearing matrix extends for 70 km along the north flank of the northern belt. This cobble and boulder conglomerate has been assigned to the Sickle Group but its composition is more mafic than the conglomerate at Sickle Lake. Present mapping suggests that it rests with slight angular unconformity on the Wasekwan Group volcanic rocks.

Approximately 1500 m of highly metamorphosed arkosic rocks rest conformably or disconformably on the Burntwood River Metamorphic Suite in the Kisseynew Belt. The arkosic gneisses are high-grade equivalents of the Sickle Group and comprise six units with characteristic mineral assemblages (Table 6). Quartz-rich rocks containing potash-feldspar + muscovite ± sillimanite constitute a basal unit of arkose and local conglomerate. Up to 250 m of polymictic conglomerate with greywacke matrix containing magnetite, biotite ± hornblende, epidote and calcite overlies the arkose. The conglomerate thins laterally away from the Lynn Lake Belt. Locally a thin unit of biotite gneiss (lithic sandstone?) occurs instead of the conglomerate. Up to 300 m of fine grained, finely layered gneiss containing hornblende and other calc-silicate minerals (apparently derived from calcareous sandstone) overlies the conglomerate and forms a distal facies of the conglomerate.

TABLE 4: STRATIGRAPHIC SECTIONS AND CORRELATION IN THE SOUTHERN BELT.

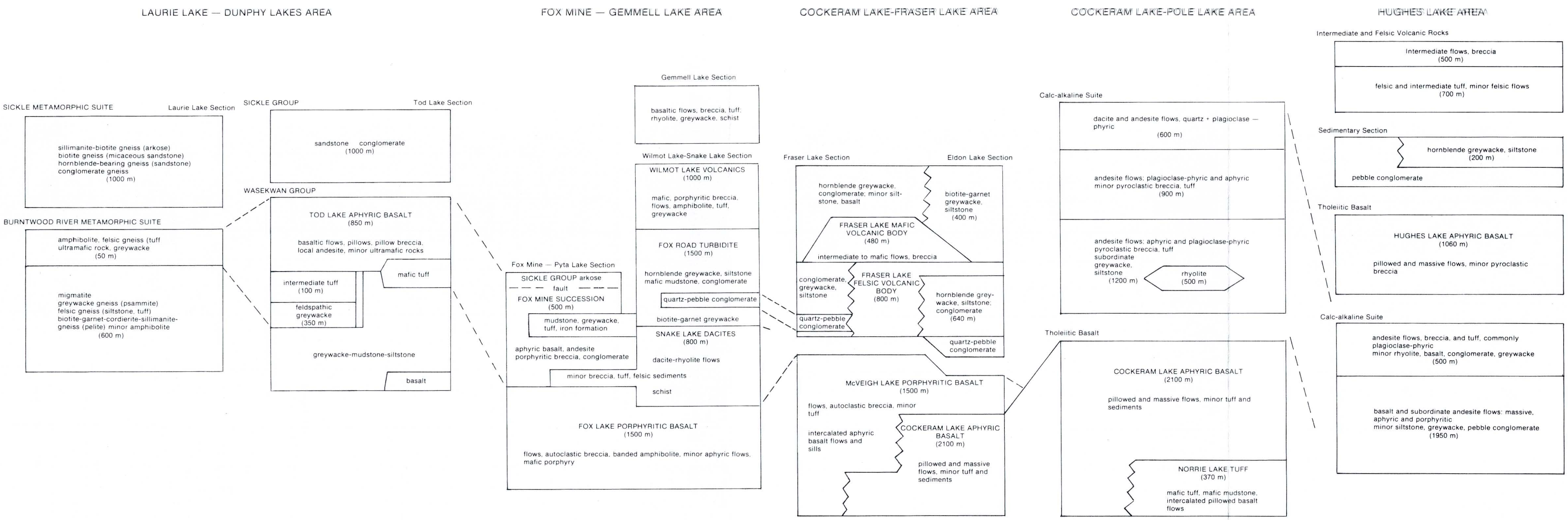


TABLE 5: STRATIGRAPHIC SECTIONS IN THE NORTHERN BELT.

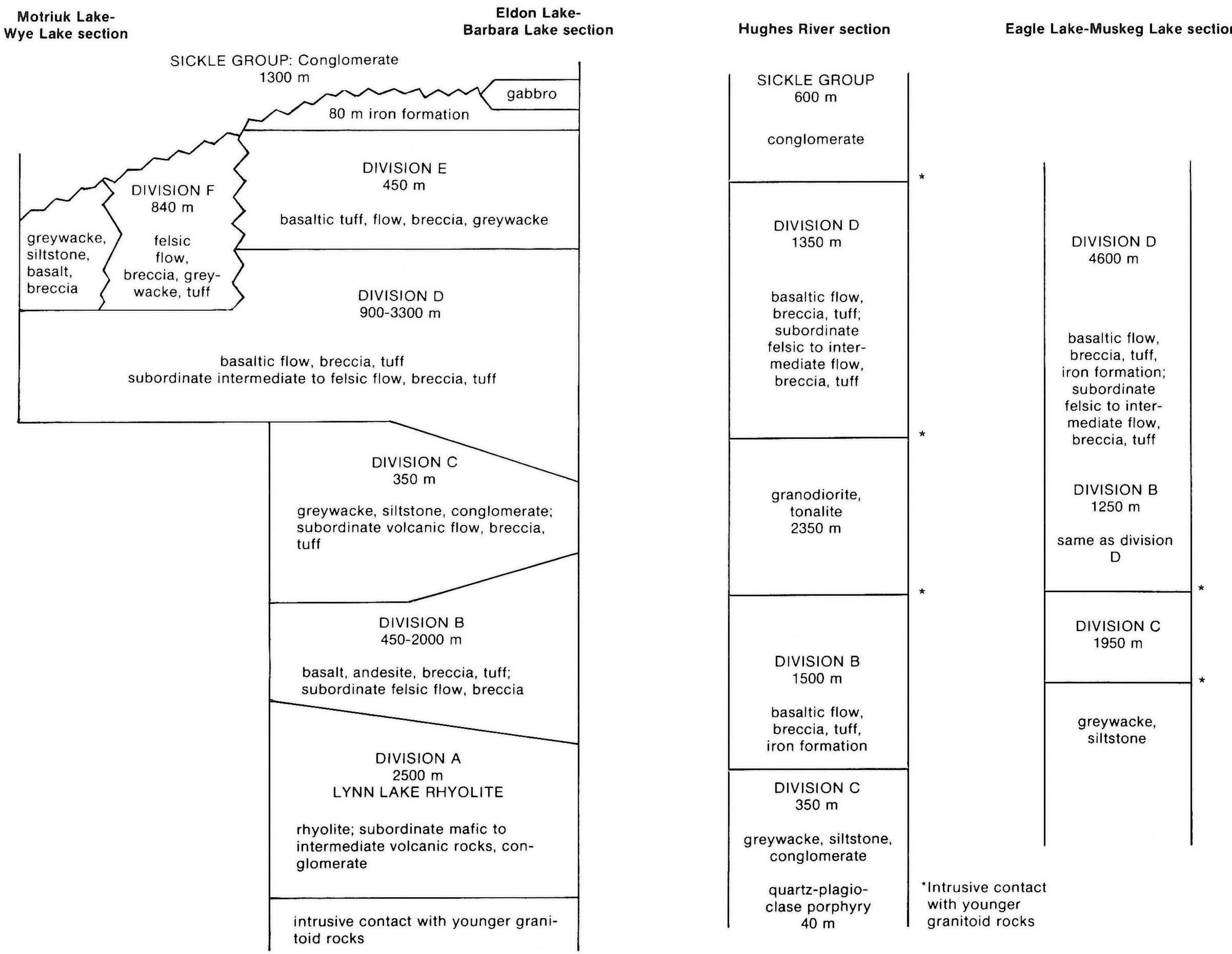
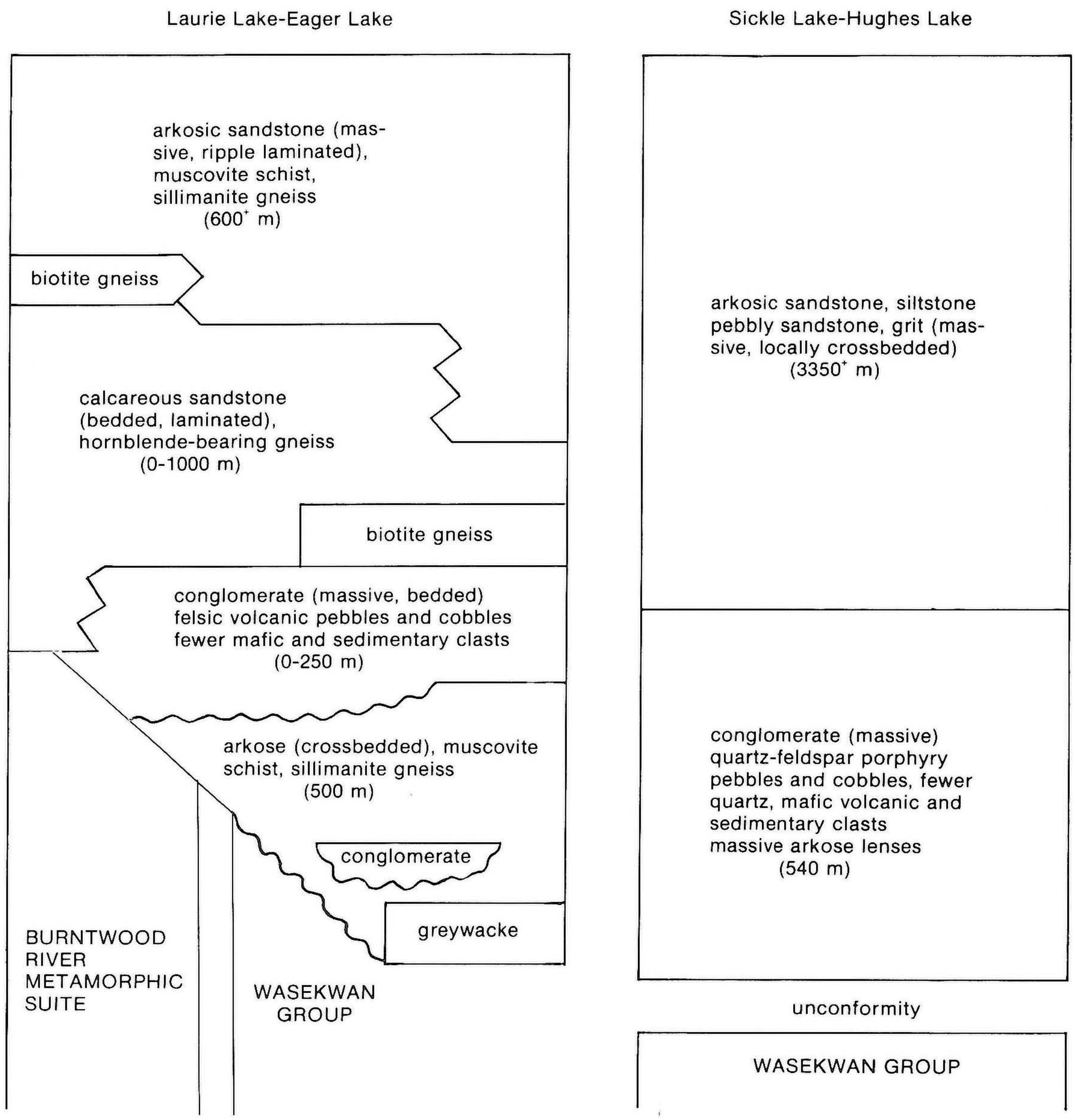


TABLE 6: STRATIGRAPHY OF THE SICKLE GROUP AND SICKLE METAMORPHIC SUITE.



Away from the Lynn Lake Belt the hornblende-bearing gneiss overlies, in lateral succession, the arkosic gneiss, the biotite gneiss and the Burntwood River Metamorphic Suite. More than 500 m of fine grained muscovite schist or coarse grained sillimanite (faserkiesel) gneiss forms the upper unit in the Sickle Metamorphic Suite. The least-metamorphosed varieties of this rock resemble the arkosic sandstone at Sickle Lake and Hughes Lake.

DEFORMATION AND PLUTONISM

Deformation and plutonism took place in the Lynn Lake region during and after the deposition of the Wasekwan Group, and again after the deposition of the Sickle Group. The early faulting, folding and intrusion of composite plutons was restricted to the greenstone belt; the post-Sickle deformation and associated metamorphism was most pronounced in the adjacent sedimentary belts but also involved the greenstones and early intrusions (Table 7).

Block faulting during Wasekwan Group sedimentation is suggested by conglomeratic turbidites that apparently filled tectonic depressions in the western part of the Lynn Lake Belt. The abrupt facies change between a thick mafic volcanic succession and greywacke suggests that a structural discontinuity exists along the northwestern boundary of the Lynn Lake Belt. The "break" is overlain by a conglomerate formation and is intruded by granite. Similar faults, presently occupied by rows of intrusions, may have defined the margins of the southern greenstone belt. However, only late faults can be identified with certainty.

TABLE 7: TECTONIC EVOLUTION OF THE LYNN LAKE REGION

	LYNN LAKE GREENSTONE BELT	KISSEYNEW SEDIMENTARY GNEISS BELT (north margin only)	
	faulting, northerly, e.g., Muskeg Lake; northwest, e.g., Lynn Lake		
D5	continued development of foliation, cataclasis (northeasterly); open cross folding	folding, faulting (northeasterly)	D3
		pegmatite intrusion	
	felsic intrusion e.g., Burge Lake Rb-Sr w.r. age: 1765 ± 100 Ma		
	metamorphism locally retrograde		
D4	shearing, faulting (east and northeasterly, e.g., Cartwright Lake)		D2
	formation of basins and domes (north- and east-trending)		
	e.g., Hughes Lake	e.g., Eager Lake	
	development of foliation, regional metamorphism		
		anatexis, Rb-Sr w.r. age 1.74-1.78 ± 0.1 Ga	
	mafic to felsic intrusion, e.g., Laurie Lake		
D3	thrusting at the belt margins e.g., Tod Lake	recumbent folding e.g., Laurie Lake	D1
	diorite intrusion (Black Trout)		
	sedimentation		
	Sickle Group (shallow water, terrestrial)	Sickle Metamorphic Suite (terrestrial(?) and shallow marine)	
D2	uplift, erosion, faulting, tilting		
	felsic intrusion e.g., Hughes Lake Rb-Sr w.r. age: 1940 ± 75, 1825 ± 210 Ma		
	mafic intrusion, e.g., Lynn Lake		
D1	folding, faulting (east-northeasterly)		
	Wasekwan Group	Burntwood River Metamorphic Suite	
	mafic to felsic intrusion mafic to felsic tholeiitic and calc-alkaline volcanism	volcanism and sedimentation	
	felsic volcanism, faulting, sedimentation	deep water sedimentation	
	mafic tholeiitic volcanism		

The oldest plutons (units 13, 14) are small mafic and felsic subvolcanic intrusions with compositions similar to the volcanic host rocks.

The Wasekwan Group is isoclinically folded on steeply dipping, east-northeast-trending axial surfaces. The folds are truncated by pre-Sickle tonalite-granite intrusions (16, 17), dated at 1940 ± 75 Ma and 1825* ± 210 Ma (Clark, 1980). The folds also predate the Lynn Lake gabbro (15) and ore-bearing breccia pipes (which were emplaced into vertical strata). Large early folds dominate the structure of the southern greenstone belt and occur east of Muskeg Lake in the northern belt. Axial traces are gently curved, parallel to the regional foliation. Axial surfaces are generally spaced over 2 km apart, and early minor folds are absent. Major anticlines are developed in tholeiitic basalt (2, 3): an anticline extends from Nail Lake 25 km east to Norrie Lake and another anticline may extend from DD Lake to east-Dunphy Lake. A syncline-anticline pair occurs in the calc-alkaline rocks (5, 6, 7) at Pole Lake and a syncline occurs in greywacke (9) and heterogenous volcanic rocks (4) west of Wilmot Lake.

The northern belt is interpreted as a dominantly monoclinal sequence younging towards the north; late (?) folding in the sedimentary section, as indicated by reversals in graded bedding, apparently does not affect the overall stratigraphic sequence indicated by facing criteria in the volcanic rocks. A large anticline occurs west of Muskeg Lake in the lower part of the sequence. It is truncated by pre-Sickle tonalite-granodiorite.

The deformed Wasekwan Group rocks were intruded by gabbro, norite and minor ultramafic rocks (15); (see Pinsent, 1980). Subsequently, large composite plutons of diorite, tonalite, granodiorite, and granite (16, 17) were intruded between the northern and southern greenstone belts. Similar plutons separated by narrow belts or screens of Wasekwan Group rocks underlie much of the Sickle Group in the southern part of the Lynn Lake Belt (Zwanzig, 1979). Northwest-trending structures dominate the narrow supracrustal belts between Counsell Lake and Sickle Lake. They are parallel with the margins of the plutons and were apparently formed during granite intrusion.

The Sickle Group lies unconformably on the early plutons and on the deformed Wasekwan Group rocks. East-northeast-trending structures (D1) and northwest-trending structures (D2) are truncated by the unconformity. The basal Sickle conglomerate contains clasts of the underlying volcanic, plutonic, and hypabyssal rocks, and pebbles fill rare fissures in the underlying rocks. Some clasts show evidence of spheroidal weathering.

The Sickle Metamorphic Suite comformably overlies the Burntwood River Metamorphic Suite in the Kisseynew Sedimentary Gneiss Belt. Layers of felsic volcanic gneiss within the Burntwood River Suite and a unit of amphibolite at the top of the suite are parallel to the overlying Sickle strata and indicate that the whole succession escaped the pre-Sickle deformation. However, the change from greywacke-gneiss and amphibolite to arkosic gneiss constitutes a major break in the stratigraphic column. Uplift of the greywacke-mudstone turbidite terrane is implied by the presence of large-scale cross-bedding in the overlying arkose.

Between Tod Lake and Laurie Lake, Sickle rocks disconformably overlie tholeiitic basalt, high-Mg basalt and minor ultramafic rocks. The mafic rocks can be correlated across major post-Sickle faults with basalt which is unconformably overlain by Sickle rocks. The pre-Sickle folds apparently die out at the edge of the greenstone belt.

The absence of early folds and early intrusions in the Burntwood River Metamorphic Suite indicates that the rocks are separated from the Wasekwan Group by a major structural break or that the Burntwood River Suite and the basalt in the western fault slices are slightly younger than the main Wasekwan Group. A structural interpretation of the Laurie Lake area suggests that the early deformed igneous rocks were thrust over an undeformed, lateral basin facies after the deposition of the Sickle Group. However, a younger age for the Burntwood River Metamorphic Suite cannot be ruled out.

The high-grade gneisses in the Burntwood River and Sickle Suites occupy large sheet-like recumbent folds which are apparent only from reversals in the stratigraphic succession. The recumbent structures were refolded on Laurie Lake and Eager Lake into domal complexes produced by north- and east-trending folds. Folding was accompanied by high-grade metamorphism, anatexis, and development of a regional foliation parallel to bedding. These domes, together with small, elongate, synkinematic intrusions of post-Sickle granodiorite, tonalite and gabbro (18, 19, 20) were affected by a set of late, northeast-trending folds.

North of the Lynn Lake Belt the distribution of greywacke-gneiss (1) and polymictic conglomerate (10) is controlled by east-northeast-trending folds, openly refolded about northeast-trending axial surfaces. The earlier structures are parallel to folds in the Wasekwan Group but they are interpreted to be relatively younger because associated minor folds are developed in the post-Sickle foliation and granitic veins.

Structures developed in the Sickle Group within the Lynn Lake Belt comprise north- and east-trending folds, forming basins at Hughes Lake, Sickle Lake and Conglomerate Lake. The post-Sickle deformation and metamorphism produced the secondary foliation in the Wasekwan Group, Sickle Group and early plutons. Generally, the foliation passes from one group to another without deflection and with little change in intensity. Locally, the strain changes across the unconformity, such as northwest of Sickle Lake where deformed clasts in the Wasekwan Group are flat (oblate) and those in the Sickle Group are rod-shaped (prolate). Apparently the regional (late) foliation developed co-planar to a pre-Sickle foliation.

Generally, the Wasekwan Group was not refolded during the later events. The structural basin containing Sickle rocks at Hughes Lake is underlain by a homoclinal Wasekwan succession. The early folds elsewhere became more appressed during the development of the foliation. Brittle structures were formed locally: a zone of cataclasis and kink folding separates the southern greenstone belt from the dominantly plutonic terrane to the south. The fault zone extends from Franklin Lake, where it truncates the Miskwa Lake belt, to east of Hughes Lake, where it cuts off the local volcanic section. A splay fault from the main zone trends northeast across Moses Lake. Other late faults trend north or northwest.

The latest phase of northeast-trending folding locally produced a cross-cutting foliation. The Burge Lake granodiorite dated as 1765 ± 100 Ma (Clark, 1980) was apparently emplaced during this phase. Much of the granitic rock north of the Lynn Lake Belt may have a similar age.

METAMORPHISM

The grade of metamorphism of Wasekwan Group rocks ranges from medium to high. Upper greenschist facies assemblages are developed in the Cartwright Lake-Hughes Lake area and locally in the northern belt (e.g. east of Tulune Lake). Middle amphibolite facies assemblages are much more widespread and comprise the greater portion of the Lynn Lake belt whereas upper amphibolite facies assemblages are restricted mainly to the Fox Mine area, the western extremity of the belt.

Low grade, intermediate volcanic rocks in the Cartwright Lake-Hughes Lake area, are characterized by assemblages containing albite, epidote, quartz, pale green actinolite and/or biotite, chlorite, leucoxene and carbonate. The grade of metamorphism in the southern belt increases progressively westwards from Cartwright Lake. Greenschist-amphibolite transition facies assemblages (dark green hornblende, albite, epidote, and minor quartz, magnetite, and

*probably up-dated during post-Sickle metamorphism.

biotite) are developed in the mafic volcanic rocks of north of Moses Lake. Amphibolite facies assemblages characterized by plagioclase compositions in the oligoclase-andesine range are developed west of Moses Lake. In the northern belt pale green chlorite, tremolite, epidote, clinozoisite, sphene, albite, and carbonate are locally predominant in the mafic volcanic rocks; it is not clear whether these are contemporary with more widespread amphibolite facies assemblages or whether they represent a later retrogressive metamorphism.

Lower-to-middle-amphibolite facies assemblages are developed throughout the northern belt, in the western part of the southern belt, and in the Miskwa Lake and Keewatin River belts. Mafic volcanic rocks are characterized by assemblages containing green hornblende and/or cummingtonite and oligoclase or andesine (± quartz ± epidote ± biotite ± sphene). Some rocks contain labradorite which probably reflects the primary magmatic plagioclase composition. Mafic volcanic rocks are locally strongly recrystallized in the western part of the northern belt, where porphyroblasts of cummingtonite are well developed. A weak foliation of green hornblende occurs in some sedimentary and volcanic rocks, truncating the earlier formation (green hornblende or biotite) which is parallel to stratification. Sedimentary rocks in the Eldon Lake area, in the Miskwa Lake belt, and in the Keewatin River belt contain staurolite-free amphibolite facies assemblages as follows:

1) quartz + oligoclase + biotite + hornblende ± garnet ± epidote ± magnetite;
2) quartz + oligoclase + biotite + garnet + epidote + magnetite;
3) quartz + oligoclase + biotite + epidote + magnetite;
4) quartz + oligoclase + biotite + muscovite + epidote ± chlorite ± magnetite;

The metamorphic grade of the southern belt southwest of Nail Lake is apparently slightly greater than in the area to the east. Staurolite is relatively common in fine grained sedimentary rocks and in chloritic schist, occurring as medium grained porphyroblasts to very coarse prisms (up to 2 cm long). Assemblages in the sedimentary rocks include the following:

1) quartz + plagioclase + garnet + biotite ± muscovite;
2) quartz + plagioclase + staurolite + biotite;
3) quartz + plagioclase + staurolite + muscovite + biotite;
4) quartz + plagioclase + staurolite + andalusite + biotite;
5) quartz + plagioclase + staurolite + garnet + biotite;
6) quartz + staurolite + cordierite + biotite + muscovite;
7) quartz + staurolite + cordierite + andalusite + biotite + muscovite.

The occurrence of corroded kyanite porphyroblasts within cordierite in this area (e.g. 1 km northeast of the eastern end of Stear Lake) is indicative of two phases of amphibolite facies metamorphism since these minerals do not co-exist under stable conditions (Hietanen, 1967). Relicts of staurolite and andalusite within cordierite have been observed in the Gemmell Lake-Wilmot Lake area.

Both andalusite and kyanite occur as relicts within cordierite in biotite schist derived from intermediate volcanic breccia west of Boiley Lake, where the following assemblages are developed:

8) quartz-andesine-cordierite-kyanite-biotite;
9) quartz-plagioclase-cordierite-andalusite-sillimanite-biotite;
10) garnet-cummingtonite-chlorite.

The latter is characteristic of the upper amphibolite facies at intermediate pressure (Guitard, 1970). Alteration of biotite to chlorite is widespread in the areas west of Nail Lake and west of Boiley Lake. Porphyroblasts of chlorite occur sporadically in these areas, and in the northern belt.

Amphibolite facies mineral assemblages throughout the northern and southern belts are commonly partly altered as follows:

1) biotite→chlorite;
2) biotite→prehnite (rare);
3) green hornblende→biotite or chlorite;
4) plagioclase→chlorite or sericite;
5) plagioclase→epidote or clinozoisite;
6) cordierite, andalusite, staurolite→fine grained white mica;
7) garnet→biotite or chlorite.

Upper amphibolite facies mineral assemblages are developed in the western part of the Lynn Lake Belt. Sillimanite appears first in greywacke south of east-Dunphy Lake. Knots of fibrolitic sillimanite, partly retrograded to muscovite, occur with staurolite in the Fox Mine area. Assemblages in altered dacite and sedimentary rocks at Snake Lake include

1) quartz + plagioclase + cordierite + biotite + sillimanite;
2) quartz + plagioclase + cordierite + anthophyllite + garnet + magnetite;
3) quartz + plagioclase + cordierite + anthophyllite + biotite + magnetite;
4) quartz + plagioclase + staurolite + sillimanite + biotite + garnet;
5) quartz + plagioclase + staurolite + anthophyllite ± garnet.

Greywacke north of Hatchet Lake contains the assemblages

1) quartz + plagioclase + K-feldspar + biotite + staurolite ± garnet;
2) quartz + plagioclase + biotite + sillimanite;
3) quartz + plagioclase + biotite + garnet.

Assemblages (2) and (3) contain inclusions of staurolite in garnet or plagioclase and assemblages (1) and (2) contain muscovite probably replacing K-feldspar and sillimanite.

Metamorphic mineral assemblages in the Burntwood River Metamorphic Suite indicate conditions above the second sillimanite isograd and reaching anatexis. Diagnostic assemblages include:

1) quartz-plagioclase-biotite-garnet-sillimanite ± cordierite;
2) quartz-plagioclase-biotite-K-feldspar ± sillimanite-(muscovite).

Muscovite is apparently a retrograde phase.

Migmatites occur south of the line (Map 1980-1-6 and Zwanzig, 1979) extending through Laurie Lake east of Eager Lake and Finch Lake. The first granitic veins apparently formed in mudstone as a result of feldspar blastesis and during prograde reactions involving a melt phase. The volume of *lits* increases towards the south, with granitic *lits* comprising 40 per cent of the greywacke-gneiss south of Laurie Lake. South of Laurie Lake mineral assemblages are similar to those on the north shore of the lake but cordierite and garnet are much more abundant, and sillimanite occurs mainly in flattened, partly resorbed *faserkiesel* and as inclusions in plagioclase and cordierite.

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COCKERAM LAKE-FRASER LAKE AREA

INTRODUCTION

Wasekwan Group stratigraphy in the Cockeram Lake-Fraser Lake area is dominated by lens-shaped units 1 - 2 km thick separated by chemical and, locally, depositional discontinuities. Three major associations are recognized; in order of decreasing age these are:

1) A mafic platform consisting of two partially overlapping, lens-shaped units: Cockeram Lake aphyric basalt (2) and McVeigh Lake porphyritic basalt (3).
2) Cover rocks overlying the basalt platform, including the Fraser Lake felsic volcanic body (6 and 7) and Eldon Lake sedimentary rocks (8 and 9).
3) Intermediate to mafic volcanic flows and breccias (4) similar to northern belt mafic rocks.

The rocks are exposed on the limbs of an isoclinal, west-trending anticline which extends through the centre of the volcanic belt, from Motriuk Lake to north of Cartwright Lake. The fold allows limited three-dimensional reconstruction of the relationships between major units.

COCKERAM LAKE APHYRIC BASALT (2) AND ASSOCIATED MINOR ROCK TYPES

The mafic pile centred south of Cockeram Lake comprises the largest volume of aphyric basalt within the Lynn Lake Project area. The unit extends from the Muskeg Lake fault at Cartwright Lake, 26 km west to Franklin Lake. Two westerly-trending isoclinal folds produce structural repetition and thickening of the basalt pile; the major fold (McVeigh Lake anticline) extends almost the entire strike length of the unit. A maximum stratigraphic thickness of 2100 m is exposed on the south limb of the anticline north of Moss Lake, but the unit thins to less than 500 m at Franklin Lake.

Aphyric basalt forms the base of the Wasekwan Group in the Cockeram Lake area. It is in part the same age as the suite of porphyritic and aphyric basalt (3) at McVeigh Lake in that portions of the aphyric pile both underlie and overlie part of the porphyritic sequence. At Cartwright Lake, aphyric basalt is overlain by intermediate flows and tuff of the Pole Lake andesite-dacite-rhyolite suite (5 and 7). North of Wasekwan Lake basalt is overlain by hornblendic greywacke and siltstone (9b) which is interpreted to have been derived from the Pole Lake calc-alkaline centre.

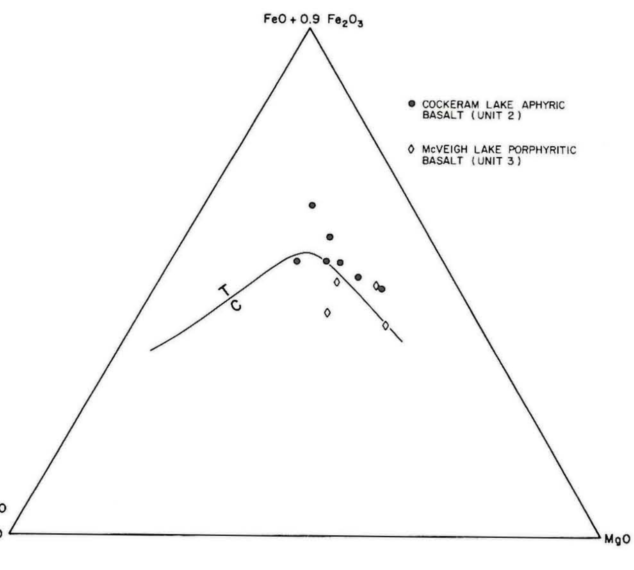


FIGURE 5: Ternary igneous AFM diagram showing analyses of Cockeram Lake aphyric basalt (2) and McVeigh Lake porphyritic basalt (3). Dividing line separating the tholeiitic field (T) from the calc-alkaline field (C) is after Irvine and Baragar (1971).

The Cockeram Lake basalts are grey-green to greenish black on weathered surfaces, dark grey-green on fresh surfaces, and fine grained. Flows are commonly pillowed, but massive flows are intercalated with the pillowed facies throughout the unit and are the dominant flow type west of Wasekwan Lake. Pillow breccia, mafic tuff, volcanogenic greywacke, and pebble conglomerate occur sporadically and comprise less than 10 per cent of the unit. The uppermost 300 - 700 m of the unit locally contains plagioclase-phyric and glomeroporphyritic flows and related breccias.

North of Moses Lake the typical basalt mineralogy is green hornblende + plagioclase (An_9) + epidote + quartz + magnetite + biotite, representing the greenschist-amphibolite transition facies (Turner, 1968). The Cockeram Lake basalts are quartz-normative, low-Ni tholeiites (Fig. 5; analyses 1 to 7, Appendix). Details of the geochemistry will be included in a subsequent report.

PILLOWED FLOWS (2b)

Pillowed flows occur throughout the entire Cockeram Lake basalt unit. Pillowed flows, massive flows, and rare pillow breccias are interlayered on a scale of 5 - 30 m, but the relationships between flow types and the internal organization of pillowed flows are poorly known due to heavy lichen and moss cover on outcrops. The size and shape of individual pillows could be determined in many localities; these criteria form the basis of the following interpretation of the origin of the pillowed flows.

Three varieties of pillow structures are recognized. These are:

1) Normal-sized, bun-shaped pillows 40 - 150 cm long, molded upon one another (Fig. 6, a and b). This type occurs throughout the aphyric unit.
2) Medium- to large-sized (1 - 2 m) pillows characterized by irregular shapes, pillow buds, incomplete selvages, and re-entrants of pillow crust (Fig. 6, c, d, e and f). These are most common in the thickest part of the unit, north of Moses Lake.
3) Large (to 3 m long), mattress-shaped pillows without re-entrants. This type occurs in association with the other two pillow varieties. or in piles of large pillows weakly molded upon one another (Fig. 6, g). Large pillows are restricted to the thickest part of the basalt pile, north and west of Moses Lake.

By analogy with detailed work by Dimroth *et al.* (1978) and Hargreaves (1978), the large pillows (3 m) are interpreted as tubes, and the interconnected pillows (variety (2) above) are probably bifurcating or budded tubes. According to this interpretation most of the pillows were formed by the budding and digital advance of subaqueous pahoehoe flows. Discrete pillows (e.g. Fig. 6, a and b) may be closed lava sacs (Dimroth *et al.*, 1978) or sections across lava tubes (Hargreaves, 1978).

Pillowed and massive flows are mineralogically and texturally similar. North of Moses Lake the primary, randomly-oriented-plagioclase microlite texture is preserved. Albite (An_9) laths 0.2 - 0.7 mm long are pseudomorphs after primary calcic plagioclase. The laths are polysynthetically twinned, and slightly embayed by secondary hornblende. The hornblende (α = yellow green, γ = grass green) occurs as xenomorphic granular or hypidiomorphic grains 0.1 - 0.3 mm in diameter, interstitial to plagioclase. Some flows contain 7 - 10 per cent hornblende pseudomorphs after euhedral pyroxene phenocrysts 0.1 - 0.7 mm in diameter. Minor phases include interstitial quartz, epidote, brown biotite (overprinting hornblende), disseminated magnetite, and carbonate (Table 8). Where tectonite fabrics are developed the plagioclase is recrystallized to aggregates of untwinned subgrains, hornblende prisms define a strong preferred orientation, and primary textures are obliterated.

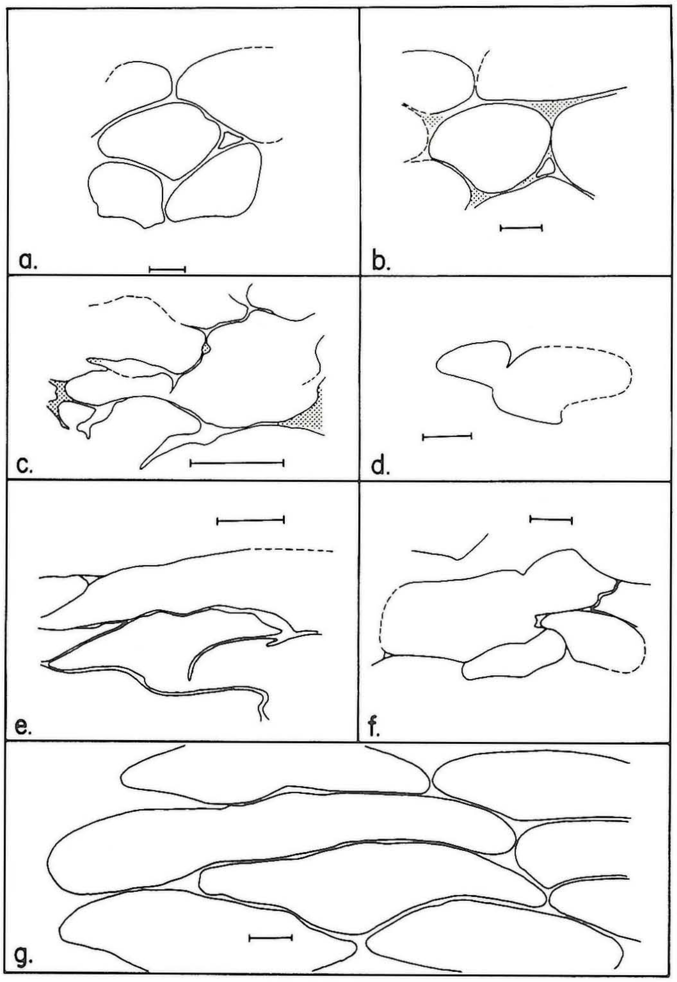


FIGURE 6: Examples of pillow morphologies present in the Cockeram Lake aphyric basalt (2b). See text for discussion. Figures a, b, d and f are field sketches, c and e are tracings from photographs, and g is an interpretive composite, based in part on a photograph. Scale bar represents 25 cm. Interpillow chert is indicated by a dot screen.

Pillows have dark green weathering, chilled selvages 2 - 15 mm thick. A thin section of the outermost 4 cm of one pillow displays the following sequence of textural zones: selvage (90% hornblende, 10% carbonate, minor epidote); very fine grained equigranular basalt (5 mm thick); fluial-textured basalt with plagioclase microlites oriented parallel to the pillow margin (17 mm thick); and randomly oriented plagioclase microlite basalt. The maximum plagioclase grain size increases gradually from 0.1 mm near the selvage to 0.3 mm at 3 cm inside the pillow.

Amygdales occur throughout the entire unit. Minerals that commonly occur in amygdales include quartz, plagioclase, epidote, carbonate, hornblende, biotite, chlorite, and magnetite; quartz occurs at the rims of polymineralic amygdales. The amygdales are spherical to ovoid and range in size from 1 mm to 2 cm; some are concentrically zoned. Small amygdales (1 - 3 mm) are concentrated beneath the chilled selvage in the outer 5 - 15 cm of the pillow whereas large amygdales occur mainly in the central portion of the pillow. At one locality, densely packed pipe vesicles 3 - 4 mm in diameter and 3 - 5 cm long are radially disposed beneath pillow selvages. Amygdales comprise 25 per cent by volume of the outer one-quarter of many pillows. The large size and relative abundance of infilled vesicles suggests that the flows were extruded in shallow water (Jones, 1969). Amygdale size and abundance decreases west of Wasekwan Lake, corresponding to the decrease in thickness of the basalt unit.

Epidosite, a granoblastic mosaic of epidote, quartz, and amphibole, forms domains that are common in both pillowed and massive aphyric basalt. In pillowed flows the epidosite weathers light yellow-green and replaces the interiors of most pillows, commonly preserving quartz amygdales. Contacts between dark green "unaltered" basalt and epidosite vary from sharp to gradational.

Chert commonly occurs in the interstices between adjacent pillows in the thickest part of the mafic pile, north of Moses Lake. It occurs only on the southern limb of the McVeigh Lake anticline, and becomes gradually less abundant in pillow basalts east towards Cartwright Lake and west across the Keewatin River. It is completely absent from the basalts on the northern limb of the anticline. The chert is grey to white on weathered surfaces and grey to almost black on fresh surfaces. It is aphanitic to very fine grained, and non-magnetic. Chert occurs sporadically in the tricuspate voids between three adjacent pillows (Fib. 6, b), and as ribbons 1 - 2 cm thick between adjacent pillow selvages. Where chert is particularly abundant some pillows are enveloped by a layer of chert up to 10 cm thick. Sinuous chert bands up to 15 cm thick and over 2 m long are not uncommon, but the chert is in every instance interstitial to pillows and does not form continuous strata. Rarely, chert occurs as infolded brecciated bands enclosed within pillows, or as blocks (5 - 10 cm) mixed with mafic material (hyaloclastite?) in breccia which fills large voids in a pillowed flow. These relationships demonstrate that deposition of the chert was contemporaneous with extrusion of the basalt flows.

MASSIVE FLOWS (2a)

Massive basalt flows are interlayed with pillowed flows throughout unit 2 and are predominant west of Wasekwan Lake. Flow thickness ranges from 5 m to more than 20 m. In exceptional exposures a lateral or vertical gradation from massive to pillow basalt could be observed.

The randomly-oriented plagioclase microlite texture of massive basalt is similar to that of the pillowed flows, but some massive flows have a slightly coarser grain size (up to 1.5 mm).

Amygdales are common in the massive flows south of Cockeram Lake and north of Moses Lake, but they are smaller and less common in the flows west of Wasekwan Lake. The size range, shape, and amygdale mineral assemblages are similar to those in associated pillowed flows. The distribution of amygdales within flows is variable: in some flows they are localized in planar zones, whereas in other flows they are evenly dispersed. Densely amygdaloidal flow tops are rare.

Massive flows characteristically contain light yellow-green epidosite alteration domains similar to those described by Reed and Morgan (1971) and Smith (1968). Epidosite commonly comprises 20 - 30 volume per cent of the flows. These alteration domains can be mistaken for breccia fragments, from which they are distinguished by (1) gradational contacts with "green" basalt, (2) absence of unaltered or less-altered fragments, and (3) irregular shapes. They are structures resulting from significant element re-distribution: the epidosites are enriched in calcium, and the apparently unaltered dark green basalt is enriched in sodium and magnesium (Reed and Morgan, 1971). *The widespread element re-distribution places serious reservations on the reliability of commonly used magma-type discriminants, particularly those using alkalis and calcium.*

Epidosite domains are a few centimetres to over 1 m in size and are ovoid, angular, or irregular in shape. Contacts between epidosite and dark green basalt vary from sharp to gradational over a few centimetres, and some contacts are joint- or fractured-controlled. A variety of shapes and contact relationships are represented in any

TABLE 8: AVERAGE, ESTIMATED MODES OF COCKERAM LAKE APHYRIC BASALT (UNIT 2), McVEIGH LAKE PORPHYRITIC BASALT (UNIT 3a), POLE LAKE PORPHYRITIC ANDESITE (UNIT 5a) AND DACITE (UNIT 5b), CARTWRIGHT LAKE RHYOLITE (UNIT 7b)

	unit 2	unit 3a	unit 5a	unit 5b	unit 7b
Quartz: total	2	3	1	7	30
: phenocrysts				2	2
Plagioclase: total	45*	42	70*	65*	40*
: phenocrysts		30	15	6	2
White mica					25
Biotite	1	5	3	10	1
Chlorite	tr		local	local	
Amphibole: total	45	53	15'	5'	
: phenocrysts		25#			
Epidote	3	5	10	8	tr
Carbonate	1	1	1	3	2
Magnetite	2	1	tr	tr	1
Pyrite	tr	tr			local
Hematite	tr	tr			tr
Leucoxene			local	local	
Colour index (C.I.)	46	48	18	15	1
Normative C.I.	39	39	24	16	1

*Albite
'Actinolite
#Pseudomorphs after pyroxene
trTrace

given exposure. Elongation of epidosite masses is parallel to regional foliation. Quartz amygdales, identical in size and shape to amygdales in the dark green basalt, are preserved within epidosite domains but the epidosites do not necessarily occur within *all* densely amygdaloidal zones within a flow. Synvolcanic mafic dykes and sills also contain sporadic epidosite domains. Some of these epidosites appear to have fracture- or joint-controlled margins, whereas others are identical in shape and contact relationship to the typical ovoid morphology developed in massive flows. Reed and Morgan (1971) ascribe epidosite development to chemical alteration of homogeneous flows by circulation of fluids with high oxidation potential through fissure systems or permeable zones within the flows. This mechanism is appropriate for the Cockeram Lake massive basalts, and explains the often highly irregular nature of the epidosite masses, their sporadic fracture-controlled contacts, and their appearance in vesicular zones within the flow.

Element re-distribution which produced the calcium-rich domains occurred after crystallization of the flows but before deposition of the unconformably overlying Sickle Group. Epidosite clasts (some with amygdales) in the basal Sickle conglomerates are identical to epidosite bodies in basalt.

PILLOW BRECCIA, HYALOCLASTITE (2c)

Pillow breccias are produced by the intense interaction of lava and water, resulting in quenching and fragmentation of the flow (Dimroth *et al.*, 1978). Pillowed flow-pillow breccia-stratified hyalotuff successions can be used for upward facing of flows in a manner similar to the way Bouma divisions are utilized in turbidites (Carlisle, 1963; Dimroth *et al.*, 1978).

Pillow breccias in the Cockeram Lake basalt pile are normally underlain by pillowed flows. The pillowed flows grade upward to a division in which small pillows are slightly isolated in a hyaloclastite matrix. This is in turn succeeded by a true pillow breccia composed of small, irregularly shaped pillows and minor pillow fragments, set in a hyaloclastite matrix. The breccias are directly overlain by the succeeding pillowed or massive flow. Units of pillow breccia are never much more than 10 m thick, and their lateral continuity could not be established. All of the breccias occur in the thicker portions of the basalt sequence, north of Moses Lake and south of Cockeram Lake. They comprise in total only 1 - 2 per cent of the pile.

Amoeboid-pillow breccias are characterized by isolated, complexly involuted blobs of lava set in a medium grained clastic-textured matrix. The amoeboid pillows (3 - 30 cm) have dark green, very fine grained selvages 5 mm - 1 cm thick which contain abundant 1 mm amygdales. The matrix consists of dark green, very fine grained, angular basalt granules (up to 5 mm) presumably derived from fragmentation of the pillow rims, and a light grey, more feldspar-rich material.

Pillow-fragment breccias contain a significant proportion of angular fragments (2 mm - 10 cm in diameter) derived from the fragmentation of pillow selvages and entire pillows. Small (5 - 40 cm) irregular and bun-shaped pillows comprise a small but variable proportion of the breccia. Much of the pillow brecciation occured *in situ*; locally, shattered pillows with identifiable pillow outlines are recognizable. The matrix is similar to the matrix of the isolated-pillow breccias, and probably has the same origin: fragmentation by thermal strain of small glassy globules and pillow rims (Dimroth *et al.*, 1978).

The presence of pillow breccia and hyaloclastite cannot be used as an environmental indicator because pillow breccia has been described in flow sequences emplaced in deep water (Dimroth *et al.*, 1978) and in shallow water (Carlisle and Susuki, 1974). Large (1 cm) amygdales in the isolated pillows of some breccias suggest emplacement in shallow water.

Fragmentation of subaqueous flows, the production of hyaloclastite deposits, and subsequent reworking of the volcaniclastic material by currents or wave action may be the source of some of the mafic mudstones (9f) and pebbly mudstones (8c) which occur locally within the basalt pile.

PLAGIOCLASE-PHYRIC BASALT (2e)

Plagioclase-phyric and glomeroporphyritic basalt flows and related breccias are locally interlayered with aphyric flows within the upper 300 - 700 m of unit 2, south of Cockeram Lake and north of Moses Lake. Coarsely prophyritic flows south of Cockeram Lake contain 5 - 20 per cent, 1 - 8 mm euhedral plagioclase phenocrysts in a fine grained matrix similar in composition and texture to aphyric basalts. Flows include massive, pillowed, and flow-brecciated varieties. Glomeroporphyritic flows contain 2 - 5 per cent, 2 mm plagioclase crystal aggregates.

The local appearance of coarsely plagioclase-phyric flows in the upper portion of the Cockeram Lake basalt pile could be the result of a number of different factors: (1) evolution of the magma to a more aluminous composition, (2) sporadic crystallization of plagioclase phenocrysts within the magma chamber, or (3) on-lapping of flows from another source onto the aphyric pile. There is not sufficient evidence to determine whether the plagioclase basalts are a cognate part of the aphyric sequence.

MAFIC TUFF (2d), MAFIC MUDSTONE (9f)

Layered mafic rocks occur in one body of mappable extent (the deposit at Norrie Lake), and as minor units within the sequence of flows. The distinction between primary pyroclastic deposits, reworked pyroclastic deposits, and volcanogenic sediments is often ambiguous in metamorphosed and recrystallized rocks. In the following discussion the term "tuff" is used as in Fisher (1966) for a strictly *pyroclastic* rock composed of sand-sized particles. "Reworked tuff" is a rock composed of particles of presumed pyroclastic origin which shows evidence, such as well developed fine-scale layering with marked compositional contrast between layers, of having been sorted and/or redeposited. "Mafic mudstone" has features such as chert layers or pebbly beds which indicate that the material was deposited as a sediment and is not a primary *pyroclastic* deposit.

The mafic tuffs and mudstones at Norrie Lake are on the southern limb of the McVeigh Lake anticline, and form the base of unit 2. At that locality the tuff is at the base of the Wasekwan Group, and is apparently one of the oldest rocks in the Lynn Lake region. The base of the unit is in intrusive contact with one of the large pre-Sickle quartz diorite plutons. A total of 370 m of mafic tuff, reworked tuff, and intercalated flows are exposed.

The section east of Norrie Lake is interpreted as a proximal facies. The lower 240 m comprises finely layered (2 mm - 5 cm) fine grained mafic tuff or reworked mafic tuff, in which layering and lamination are defined by variation in the proportion of hornblende to plagioclase and quartz. Compositional contrast between layers is not pronounced, and hornblende comprises between 40 and 50 per cent of the rock. The upper 150 m of the proximal facies consists of foliated amphibolite and minor massive basalt flows. Weakly defined layering and scattered 1 mm feldspar grains suggest a tuffaceous origin for the amphibolite. The tuff section east of Norrie Lake is directly overlain by pillowed basalt, suggesting that the tuff was deposited in a subaqueous environment.

The section west of Norrie Lake is interpreted as the distal facies of the mafic tuff-mudstone unit. In contrast to the proximal facies the rocks display features indicative of considerable reworking and subsequent deposition in a relatively quiet sedimentary environment: (1) delicate lamination or fine layering 1 mm - 2 cm thick consisting of alternating amphibole-rich, feldspar-rich, and epidote-rich layers, (2) considerable compositional contrast between layers (maximum 70% amphibole, minimum 40% amphibole), and (3) interlayers of white chert, 2 mm to 1 cm thick, comprising up to 15 per cent of the rock. Intercalated pillowed basalt flows make up a small proportion of the section, and pillowed flows overlie the mafic mudstones. Modal compositions of both the proximal and distal facies of the mafic tuffs are basaltic (subequal amounts of amphibole and plagioclase, with minor quartz, epidote and magnetite).

Mafic tuffs that occur within the aphyric flow sequence form less than 3 per cent of the pile. South of Cockeram Lake a 50 m thick pyroclastic unit consists of (from base to top): 30 m of non-layered tuff with 3 per cent scattered, epidotized lapilli; 3 m of medium-layered tuff with abundant feldspathic lapilli; 6 m of pillowed basalt; and 10 m of non-layered tuff with abundant feldspathic lapilli. The three tuff units are carbonate-bearing. Four kilometres north of Moses Lake a thin unit of lapilli-crystal tuff is characterized by beds 3 - 30 cm thick of interlayered plagioclase-crystal-bearing tuff and crystal-free tuff. Sporadic cobble-sized blocks of vesicular, epidotized basalt occur throughout the deposit.

The scarcity of pyroclastic deposits within the monotonous succession of pillowed and massive basalt flows indicates a quiet, effusive mode of origin for the Cockeram basalts.

FINE GRAINED SEDIMENTS (9), CONGLOMERATE (8b)

Interflow clastic sediments are a minor constituent of the basalt pile. Most of the sediments either contain sporadic pebbles or are conglomeratic. Fine grained sediments (mafic mudstone, biotite-rich siltstone) occur interlayered with the pebbly beds or as rare interflow strata. Bedding (1 to 20 cm thick) is defined by grain size in the fine grained sediments and by clast abundance in the pebbly units. Clasts (2 - 20 cm, commonly less than 6 cm) are flattened into the plane of foliation; pebble lithologies include siltstone, aphanitic rhyolite-dacite, basalt, and vein quartz. Hornblende-biotite greywacke, biotite-rich mudstone, or amphibole-rich mudstone forms the matrix for the pebbly beds.

At one locality, 1.5 km northeast of Moses Lake, trace amounts of pyrrhotite and chalcopyrite occur in an interflow siltstone. The disseminated sulphides are associated with anastomosing, irregular alteration zones rich in biotite.

Rhyolite, siltstone, and quartz pebbles in the interflow sedimentary units are allochthonous components derived from an evolved volcanic centre older than, or contemporaneous with, the Cockeram flows.

INTERPRETATION

Several features displayed by the Cockeram Lake aphyric basalt suggest that the unit is an isoclinally folded shield volcano:

(1) Size and shape. The unit has a lens shape, with a maximum

exposed stratigraphic thickness of at least 2100 m and a strike length of 26 km. The eastern part of the lens is abruptly truncated at the Muskeg Lake fault. A basalt pile this size is well within the size range of modern shield volcanoes (McDonald, 1972).

(2) Lithologic make-up. Like modern basalt shields, the Cockeram Lake basalt is composed almost entirely of the products of effusive eruptions. Pyroclastic and sedimentary deposits are minimal in volume and extent.

(3) Stratigraphic setting. The basalt shield is overlain by a variety of volcanic and sedimentary lithologies. At Cartwright Lake the upper flank of the shield is overlain by andesitic tuff and flows comprising the Pole Lake calc-alkaline suite (5). Fine grained sediments (9) interpreted to be derived from the calc-alkaline volcanic rocks directly overlie the flank of the basalt shield, north of Wasekwan Lake and Foster Lake. These relationships suggest that the basalt shield was a positive topographic feature during the calc-alkaline volcanism and related sedimentation. On the northern limb of the McVeigh Lake anticline, the flank of the basaltic shield is interlayered with porphyritic basalt presumably derived from a more westerly source.

The eruptive centre for the Cockeram Lake flows has not been identified (it need not lie in the present plane of exposure), but the source area of the flows must correspond generally to the thickest part of the pile, north of Moses Lake. It is in that area that pillow structures interpreted as lava tubes or budded tubes are most common. These large pillows may be part of the main feeding system of the pillowed flows (Hargreaves, 1978). Facies relationships in the Norrie Lake tuff-mudstone unit suggest that the source of the basaltic detritus lies to the east of Norrie Lake, but that source is not necessarily the source of the subsequent flows.

The entire aphyric shield is a subaqueous deposit. Amygdale size in the thick part of the pile indicates the flows were emplaced in relatively shallow water, whereas the decrease in amygdale size in flows west of Wasekwan Lake might indicate that the flank of the shield lay at somewhat greater depth. Very little clastic sediment derived from external sources was deposited on the evolving pile; the most common sediment in the pile is inter-pillow, syn-volcanic chert. The near absence of allogenic tuff or clastic sediment indicates that the aphyric pile was largely isolated from other volcanic centres during much of its development. The rare sedimentary rocks which *are* present suggest that the shield is not the oldest volcanic unit in the belt.

McVEIGH LAKE PORPHYRITIC BASALT (3)

A distinctive unit of porphyritic basalt extends 23 km from Cockeram Lake in the east to the Gemmel Lake area in the west. The unit is lens-shaped, with a maximum thickness of approximately 1500 m exposed at McVeigh Lake. West of McVeigh Lake unit 3 occurs in the core of the McVeigh Lake anticline, and constitutes the base of the Wasekwan Group in that area. East of McVeigh Lake unit 3 occurs only on the north limb of the anticline.

McVeigh Lake porphyritic basalt (3) and unit 4a porphyritic basalt are in contact northwest of Franklin Lake. On average, unit 3 porphyritic basalt is distinguished by the following major field characteristics:

1) Hornblende pseudomorphs after euhedral pyroxene phenocrysts are large (2 - 10 mm) and abundant (average 25%).
2) Plagioclase phenocrysts (average 30%) are invariably small (0.5 - 1.5 mm) and lath-shaped.
3) Monolithologic, autoclastic breccias are common.
4) Porphyritic basalt and aphyric basalt are interlayered, but intermediate or felsic interlayers are absent.

Porphyritic basalt is approximately equivalent in age to the Cockeram Lake aphyric basalts (2), as indicated by the following relationships: (1) a 600 m thick salient of porphyritic basalt occurs *within* the flank section of the aphyric shield southwest of Cockeram Lake, (2) aphyric basalt overlies unit 3 on the south limb of the McVeigh Lake anticline, and (3) aphyric basalt flows similar to Cockeram Lake unit 2 flows are intercalated with porphyritic basalt throughout most of unit 3.

South of Eldon Lake unit 3 is overlain by 1 km of greywacke and siltstone (9). Only one small outcrop of what may be the contact between the volcanic and sedimentary successions was located; there the porphyritic basalt is overlain by interlayered hornblende-rich greywacke and mafic mudstone. The contact between the volcanic group and the sedimentary group is considered to be essentially conformable.

West of Ace Lake, intercalated porphyritic and subordinate aphyric basalt comprises the core of the McVeigh Lake anticline. The porphyritic basalt is in gradational contact with mafic tuff and flows (4a) and minor greywacke (9b) to the south. Porphyritic basalt is intimately interlayered with intermediate to mafic volcanic breccia and tuff (4c, 4d) in the area 3 km west of Nail Lake.

East of Ace Lake the portion of unit 3 on the north limb of the McVeigh Lake anticline can be subdivided into two stratigraphic divisions. The lower division, approximately 800 m thick, is characterized by porphyritic and aphyric basalt intercalated in approximately equal proportion (3d). The porphyritic basalt is predominantly autoclastic breccia, and the aphyric basalt comprises fine- to medium-grained flows and sills. Individual members are too thin to delineate at the present scale of mapping. The upper division (700 m maximum) comprises porphyritic basalt flows (3a) and flow breccias (3c); aphyric basalt interlayers are relatively insignificant.

Mafic tuff, lapilli tuff, crystal tuff, gabbro, and siltstone are most abundant in the thickest part of the unit, near McVeigh Lake, but nevertheless comprise less than 5 per cent of the volcanic section.

Lower amphibolite facies mineral assemblages are developed in porphyritic basalt (Table 8). Plagioclase phenocrysts are commonly recrystallized to aggregates of tiny, untwinned subgrains, and pyroxene phenocrysts are pseudomorphed by hornblende.

McVeigh Lake-type porphyritic basalt shares certain chemical features with porphyritic basalt in the Fox Mine area, and is chemically distinct from Cockeram Lake aphyric basalt and most unit 4 porphyritic basalts. Pertinent chemical characteristics of the McVeigh Lake porphyritic basalt (analyses 14 to 17, Appendix) are:

1) Relatively low FeO*/MgO ratios** (1.03 - 1.67), and Al_2O_3 contents less than 16.5%.
2) Abnormally high K_2O contents (0.48% - 2.02%). The McVeigh Lake porphyritic basalts plot well outside the range of "normal" igneous rocks on a ternary diagram depicting normative anorthite, albite, and orthoclase. Pervasive K-metasomatism of the groundmass of the porphyritic basalts is probable (below).
3) Low Ni/Cr ratios relative to Cockeram Lake aphyric basalt with comparable Ni contents. The high Cr content is probably related to an abundance of Cr-bearing pyroxene phenocrysts. High Cr contents are also characteristic of pyroxene-rich prophyritic basalts in the Fox Lake—Pyta Lake area and the Miskwa Lake area.

Unit 3 has a distinctive aeromagnetic signature consisting of a belt of magnetic highs (Questor airborne magnetometer survey, 1976). Areas outlined by the 60750 gamma contour enclose much of the outcrop extent of the unit.

MASSIVE FLOWS (3a)

Massive porphyritic basalt flows occur throughout the entire unit and predominate in the area west of McVeigh Lake. The flows weather light brown or brownish grey, mottled with green-black amphibole pseudomorphs and abundant white, lath-shaped plagioclase crystals up to 1 mm long. Fresh surfaces are dark grey, studded with glistening black amphibole pseudomorphs. Epidotized and strongly foliated rocks are yellow-green to light grey.

**FeO* represents total iron expressed as FeO.

Few exposures are large enough to map out entire flows. Flows which could be measured range from 2 m to 6 m thick, but these may be minimum thicknesses. Massive prophyritic flows are interlayered with aphyric flows and sills, and with porphyritic basalt breccia. In exceptional exposures massive flows were observed to grade to breccia (3c); some thin flows consist of two-thirds breccia and one-third massive basalt. Quartz-filled amygdales occur locally in massive flows but are not common.

The abundance of large, euhedral pyroxene phenocrysts makes unit 3a highly distinctive. The phenocrysts range in size from 0.5 mm to 10 mm (average 3 mm) and in abundance from 20 to 30 per cent (average 25%). The maximum phenocryst size, size distribution and abundance varies slightly from flow to flow.

Single crystals of amphibole are pseudomorphic after euhedral pyroxene. The simple, and more rarely polysynthetic, twinning on (100) of the original pyroxene is commonly preserved in the secondary amphibole. Small, turbid patches of relict clinopyroxene were noted in only one thin section. The pseudomorphic amphibole is composed of two species in apparent optical continuity. The darker species (γ = bluish green) occurs as isolated patches within the lighter species (γ = light green), and as local, discontinuous epitaxic overgrowths on the original pyroxene crystal. The dark species is commonly partly altered to biotite ($\pm$ epidote $\pm$ sphene); the lighter coloured amphibole, in contrast, only contains scattered 0.03 mm epidote inclusions. The lighter coloured amphibole also has a higher birefringerence than the dark green amphibole. The occurrence of two amphiboles in pseudomorphs of pyroxene probably reflects a two-stage replacement process: the dark green amphibole may have developed first, as small oriented patches, rim replacements, and minor epitaxic overgrowths on the pyroxene host. The light green amphibole is considered to be a later alteration product probably related to regional metamorphism.

Euhedral, lath-shaped plagioclase phenocrysts are preserved in the least-deformed porphyritic basalts, but they are generally obliterated in recrystallized basalts possessing a moderate to strong metamorphic fabric. Plagioclase phenocrysts range in size from 0.3 mm to 1.5 mm and average less than 1 mm in length. Their abundance varies from 20 to 40 per cent, in inverse relation to the abundance of pyroxene phenocrysts. Albite twin lamellae are commonly poorly defined, and the crystals contain abundant tiny (0.03 - 0.05 mm) epidote, hornblende, and biotite inclusions. Partial or complete recrystallization to aggregates of untwinned subgrains is typical; a plagioclase composition of An_{30} was determined from one well preserved sample.

The groundmass in porphyritic basalt is very fine grained (0.05 - 0.1 mm) and lacks any preserved primary texture. The principal components are: (1) green hornblende (10-30%, average 18%), as xenomorphic or prismatic grains partly altered to biotite, (2) brown biotite (1-10%, average 5%), as isolated flakes and an alteration product of amphibole, and (3) granular, yellow epidote (3-10%). Recrystallized, untwinned feldspar, minor quartz, and magnetite are largely interstitial to mafic phases (see Table 8 for an average, estimated mode). A weak foliation is defined by the orientation of hornblende prisms and biotite flakes.

A linear zone of schistose rocks extends through unit 3 between McVeigh Lake and Cockeram Lake. The zone is approximately 100 m wide and is the locus for disseminated trace pyrite and chalcopyrite mineralization. Strongly foliated porphyritic basalt within the zone is enriched in biotite. Amphibole pseudomorphs are altered to hornblende-biotite lenticles 1 mm thick, and plagioclase phenocrysts are unrecognizable. The groundmass is recrystallized to a coarser grained assemblage of acicular hornblende, biotite, and feldspar. This zone is similar in outcrop expression and trend to the Moses Lake shear zone and is probably a realted structure.

The abundance of biotite in porphyritic basalt relative to unit 2 aphyric basalt (Table 8) is a reflection of the high K content of the rocks. Stained slabs of porphyritic basalt show that there is little if any potassium feldspar in the groundmass. Biotite is a retrograde phase which is particularly abundant in strongly deformed basalts; it is therefore probable that the high K_2O content of the basalts is due to metasomatism and is not a primary chemical characteristic.

AUTOCLASTIC BRECCIA (3c)

Porphyritic basalt breccia occurs throughout the entire unit east of Ace Lake, and is the predominant porphyritic lithology south of Elb Lake and east of McVeigh Lake. The breccias are monolithologic and lack stratification or fragment sorting. The fragments weather light grey to buff and are set in a darker grey matrix; epidotized fragments weather light yellow-green. Amphibole pseudomorphs and plagioclase laths occur in both fragments and matrix. The breccias are interlayered on a scale of approximately 3 - 10 m with massive porphyritic basalt and aphyric basalt. Massive flows grade into breccia over 1 m or less.

Fragments range in length from 1 cm to 30 cm, and average 10 cm. There is no systematic distribution of fragment sizes either on an outcrop or regional scale. The fragments are commonly lens-shaped, but in the least-deformed breccias they are angular to subangular. They comprise from 30 to 70 per cent of the breccias, and average approximately 40 per cent. Amphibole pseudomorphs and plagioclase phenocrysts occur in the same size range and abundance as in massive flows. The fragments are relatively richer in epidote than the breccia matrix; consequently the fragments weather light colours belying their basaltic character. Vesicles and amygdales are rare.

The breccia matrix commonly contains amphibole pseudomorphs and plagioclase phenocrysts similar in abundance and size range to the enclosed fragments. The texture is magmatic, identical to that of the massive flows. In rare cases the amphibole pseudomorphs are few or absent and the matrix is uniformly fine grained and foliated; this type of matrix may have originally been finely fragmented crystalline or glassy material, produced by friction and shearing after consolidation of the flow (Parsons, 1969). The matrix of one breccia, near the top of the unit north of McVeigh Lake, consists of 1 - 2 mm amphibole pseudomorphs in a fine grained carbonate matrix.

The structural features of the breccias and the character of the fragments and matrix are entirely consistent with an autoclastic origin (Parsons, 1969). The abundance of flow-brecciated material in unit 3 stands in sharp contrast to the almost total absence of autoclastic breccia in unit 2 aphyric basalt.

PORPHYRITIC AND APHYRIC BASALT (3d)

Intercalated porphyritic and aphyric basalt is characteristic of the lower division of unit 3 on the north limb of the McVeigh Lake anticline. The same association prevails on the entire southern limb of the anticline. The porphyritic components of this subunit have been described (above), therefore attention here is directed to the aphyric basalts.

In several respects the aphyric basalts of unit 3d are similar to aphyric basalts in unit 2a. They weather dark grey to dark grey-green and fresh surfaces are dark grey. They are fine- to medium-grained and are invariably aphyric. Primary textures have been largely obliterated by recrystallization but traces of the original randomly-oriented plagioclase microlite texture are locally preserved. A typical mode includes 50 per cent green hornblende (0.3 - 1 mm, anhedral to stubby subhedral grains); 45 per cent recrystallized plagioclase (0.05 - 0.2 mm), 2 per cent magnetite (0.1 - 0.5 mm), 1 - 2 per cent quartz, minor epidote, and 1 per cent brown biotite (overprinting hornblende). Some basalts contain a distinct hornblende foliation. A single analysis of unit 3d aphyric basalt is broadly similar to analyses of Cockeram Lake basalts (analysis 18, Appendix).

The most significant distinctions between unit 3d aphyric basalt and unit 2 basalt are the scarcity of amygdales and absence of pillows in the former. Neither amygdales nor pillows, however, are particularly abundant in the western extremities of unit 2.

Most of the aphyric basalt sheets are conformable to lithologic layering in unit 3, and are probably flows. Some aphyric basalt sheets display chilled and/or discordant contacts and are interpreted as intrusions which presumably fed the aphyric flows. These dykes and sills are relatively coarse grained (1 - 2 mm), and some contain a diabasic texture.

TUFF (3e)

Crystal tuff comprises less than 1 per cent of unit 3. The best exposure of tuff occurs in a small outlier of unit 3 rocks, overlying unit 2 aphyric basalt, on the east shore of Cockeram Lake. There the tuff is well bedded (2 - 15 cm), with crystal- and lapilli-bearing layers and fine grained interlayers. Amphibole pseudomorphs after pyroxene comprise 10 - 30 per cent of crystal tuff beds; the crystals include concentrically zoned euhedra and crystal fragments 1 - 3 mm in diameter. Subhedral plagioclase crystals up to 1 mm long and angular porphyritic basalt lapilli (1 - 2 cm) occur in some beds. The fine grained interbeds are delicately laminated and contain only a few amphibole pseudomorphs. They probably represent intercalations of fine ash which settled out after deposition of the coarser, crystal-bearing tephra. Directly associated with the tuff is a small exposure containing irregular to fusiform bombs 10 - 20 cm long in a crystal tuff matrix. The bombs have narrow (3 mm) selvages and are variably epidotized.

Layered mafic tuff or reworked tuff is locally associated with aphyric flows west of McVeigh Lake. The tuff weathers grey-green and is delicately laminated or finely layered, and contains sporadic aphyric basalt lapilli.

Southeast of Ace Lake 60 m of tuff occurs at the contact between unit 3 and overlying unit 2 flows. The tuffaceous section, from the top of the porphyritic basalt to the base of the aphyric flow sequence, includes: (1) 30 m of green weathering, finely banded mafic tuff with minor felsic tuff interlayers 1 - 2 m thick, (2) 20 m of banded intermediate tuff, and (3) 10 m of bedded (1 - 10 cm), light- to dark-green weathering mafic tuff with intercalated massive basalt flows. The mafic tuffs contain subequal amounts of prismatic hornblende and anhedral plagioclase, with minor quartz, carbonate, magnetite, and sphene; a lamination produced by variation in the ratio of hornblende to plagioclase and quartz is locally preserved.

INTERPRETATION

Unit 3 has a lens shape and is much longer than it is thick; therefore in section the porphyritic basalt pile resembles a small shield volcano. Like the Cockeram Lake aphyric basalt shield the McVeigh Lake porphyritic shield contains very little externally-derived sediment or tuff. The rare occurrence of pillowed flows suggests that the porphyritic basalt shield was formed in a subaqueous environment.

Petrographic, field, and limited chemical data suggest that the aphyric flows (3d) within the porphyritic sequence may be coeval with, or part of, the Cockeram Lake tholeiite suite (2). The spatial relationships between the porphyritic (McVeigh) and aphyric (Cockeram) volcanic centres are demonstrated by the distribution of aphyric basalt within unit 3, and by the contact relationships between unit 3 and overlying units:

1) On the north limb of the McVeigh Lake anticline aphyric flows possibly derived from the Cockeram shield occur only within the lower half of unit 3. Massive porphyritic flows and autoclastic breccias comprising the upper half of the unit are overlain by greywacke.
2) On the south limb of the anticline aphyric and porphyritic basalt flows are intercalated throughout all of unit 3, and unit 3 is overlain by Cockeram Lake aphyric basalt.

The north limb of the anticline is interpreted to display a cross section through a thicker portion of the porphyritic shield, which ultimately rose above the flanks of the aphyric shield (Fig. 14). In this model the south limb of the anticline displays a cross section through the relatively thin flank section of the porphyritic shield, where aphyric flows from the Cockeram centre became intercalated with, and later covered, the basal porphyritic flows (Fig. 14).

The two partially overlapping basalt shields comprise a mafic platform upon which later, less extensive, and more diverse volcanic and sedimentary formations were deposited.

FRASER LAKE FELSIC VOLCANIC BODY (6, 7)

Massive felsic volcanic and related volcaniclastic rocks comprise a lensoid body extending from the area south of Fraser Lake for at least 5 km to the east (Fraser Lake felsic body). The thickness of these rocks is greatest south of Fraser Lake (approximately 750 m): the body terminates abruptly to the west of this area, where it is in conformable contact with sedimentary rocks (units 8 and 9). The felsic rocks are interlayered with mafic volcanic rocks (unit 4) at the northern margin of the body. The southern margin of the felsic body is flanked by an elongate quartz diorite intrusion; minor intermediate greywacke (9b) occurs locally between the felsic volcanic and quartz diorite bodies.

MASSIVE APHYRIC AND PORPHYRITIC DACITE AND RHYOLITE (6a, 6b, 7a, 7b)

The felsic volcanic rocks are typically buff to cream weathering, very fine grained and slightly laminated to massive. The most extensive exposure of these rocks is north of Ace Lake, where a continuous section at least 50 m wide comprises relatively homogeneous quartz-plagioclase porphyry with sporadic garnet and up to 5 per cent euhedral magnetite. Streaky grey micaceous zones (5 mm - 1 cm thick and 10 - 50 cm long) are characteristic, and the rock is very similar to typical exposures of the Lynn lake rhyolite (for example at Frances Lake). The quartz diorite is probably intrusive into the porphyry, but this could not be confirmed on field evidence. The porphyry itself may be intrusive at this locality; felsic stringers in mafic volcanic rocks to the north may represent porphyry veins. Rare pebble-sized fragments at this locality, however, are interpreted as products of brecciation related to extrusion of the porphyry.

Several concordant sills and veins of quartz-plagioclase porphyry intrude basalt and fine grained sedimentary rocks south of Fraser Lake, at the southern margin of the felsic body. The sills are up to 5 m thick, and characterized by strongly hiatal texture with medium grained, subhedral and anhedral phenocrysts of quartz (5 - 10% of the rock) and plagioclase (15 - 20 per cent) in a very fine grained matrix. Garnet occurs as sporadic subhedral porphyroblasts and smaller euhedral grains within plagioclase phenocrysts. Biotite (5 - 10 per cent of the rock) is disseminated and also comprises lenticles and stringers (0.5 - 3 mm long).

DACITE AND RHYOLITE TUFF (6d, 7e)

Felsic tuffaceous rocks occur within and at the margins of the felsic body south of Fraser Lake, where these rocks are locally interlayered with intermediate greywacke, siltstone and conglomerate. The felsic tuffs are very similar to the porphyritic (magmatic) facies and it is commonly difficult to distinguish between the two lithologies. The tuffaceous facies may be recognized by the preservation of a detrital texture and/or internal lamination, but these features are not commonly well preserved. The tuffs are characterized by a hiatal to slightly seriate texture, with prominent anhedral to subhedral grains of quartz (0.5 - 1 mm), and plagioclase in a very fine grained matrix. Rare embayments in detrital quartz grains indicate an intimate association with the porphyry. Several occurrences of fine grained tonalite granules in the tuffs are considered to be derived from minor intrusive rocks related to the felsic volcanics. Several bodies contain highly attenuated felsic granules or pebbles, represented by very fine grained quartzo-feldspathic or saussuritic zones. Poorly defined bedding consists of variations of grain size (very fine- to fine-grained) and/or content of biotite or muscovite at a scale of 1 mm to 5 cm. Thin (1 mm - 2 mm) laminae with up to 25 per cent green hornblende occur in several beds at the margins of the felsic body. Graded bedding southeast of Fraser Lake is defined by grey silty zones in the upper parts of the beds. Tuffaceous rocks, however, commonly occur as massive units up to at least 1.2 m thick.

The majority of the tuffs are dacitic, with a total mafic mineral content (biotite ± muscovite) of 10 to 15 per cent; the micas occur as very fine grained subparallel flakes and porphyroblasts. Porphyroblasts of garnet are common and staurolite was observed in one rock. Sericite and chlorite after biotite are widespread and several rocks contain up to 10 per cent carbonate.

ENVIRONMENT AND MODE OF ORIGIN OF THE FELSIC VOLCANIC AND TUFFACEOUS ROCKS

The porphyritic felsic volcanic and tuffaceous rocks are considered to be related to the same volcanic event. Hyalotuffs have been related to subaqueous pyroclastic eruption or fragmentation of unstable felsic volcanic spines by collapse, with subsequent emplacement by turbidity flow (Dimroth, 1977). Such tuffs are commonly very similar to felsic volcanic flows with which they are commonly intercalated. The tuffaceous facies of the Fraser Lake felsic body may represent such deposits; the extent of reworking and admixture of unrelated sedimentary debris may be reflected by the degree of preservation of primary crystal forms of detrital quartz and plagioclase, by the development of sedimentary structures and by the composition (local occurrence of hornblende, and more intermediate composition). Reworking has apparently been very limited in the Fraser Lake felsic body.

FRASER LAKE-ELDON LAKE SEDIMENTARY SECTION (8, 9)

INTRODUCTION

A succession 900 - 1200 m thick of rhyolite, conglomerate, greywacke and siltstone is exposed in the Fraser Lake-Ace Lake-Eldon Lake area. The succession lies with apparent conformity upon a suite of porphyritic and aphyric basalts (3). The western part of the succession comprises a "proximal", dominantly conglomeratic facies flanking the Fraser Lake felsic volcanic body. The section south of Eldon Lake is the finer grained, apparently more "distal" part of the sequence. The lower part of the proximal facies, and the Fraser Lake felsic volcanic body, are overlain by intermediate to mafic flows and breccias (4); the upper part of the proximal facies overlies unit 4. The upper 600 m of the distal facies is laterally equivalent to the unit 4 volcanic rocks.

SEDIMENTARY SECTION WEST OF THE FRASER LAKE MAFIC VOLCANIC BODY (PROXIMAL FACIES)

The southern part of the sedimentary section south of Fraser Lake (Fig. 7) is characterized by hornblende and biotite greywacke, siltstone and conglomerate which are interlayered with mafic volcanic units at the southern margin, indicating a probably conformable relationship with porphyritic basalt (3a) to the south. A thin (>3 m <15 m) quartz-pebble conglomerate member (8a), equivalent to that mapped southeast of Eldon Lake, occurs close to the southern margin of the Fraser Lake section. The section 0.5 - 1.0 km north of the quartz-pebble conglomerate consists of biotite greywacke, siltstone and conglomerate, with subordinate siliceous greywacke interlayers derived from the Fraser Lake felsic body. The northern part of the section consists of both hornblende and biotite greywacke, siltstone and very minor pebble conglomerate. The fine grained sedimentary rocks are intimately intercalated and locally deformed together, apparently during sedimentation. A cobble conglomerate member (8c) at the northern end of the section, close to the southern shore of Fraser Lake, probably underlies the hornblende and biotite greywackes, which occupy the core of the fold structure south of Fraser Lake (Fig. 7). Minor mafic volcanic units and sills occur in the sedimentary section close to the southern shore of Fraser Lake.

The sedimentary section south of Fraser Lake is divided into two parts (northern and southern) by the western termination of the Fraser Lake mafic volcanic body (Fig. 7). Interlayering between the sedimentary and volcanic rocks indicates a probably conformable sequence where the Fraser Lake mafic volcanic body is in contact with the central part of the sedimentary section, but the relative ages between the sedimentary rocks (9) and the mafic volcanic body (4) are uncertain because of the absence of reliable top indicators. The equivalent section to the east (Eldon Lake sedimentary section) comprises a north-facing monocline. By extrapolation, the southern part of the section south of Fraser Lake would underlie the Fraser Lake mafic volcanic body. The northern part of this section, however, which occurs at the western margin of the mafic volcanic body, comprises the core of a fold structure interpreted as synclinal on the basis of bedding/fold plunge relationships. According to this interpretation the mafic volcanic rocks (4), which comprise the limbs of the fold, are overlain by the northern part of the sedimentary section.

QUARTZ-PEBBLE CONGLOMERATE (8a)
CONGLOMERATE WITH VOLCANIC AND SEDIMENTARY CLASTS (8b)

Conglomerate is best developed in the southern part of the Fraser Lake sedimentary section (in the vicinity of the western end of the Fraser Lake felsic volcanic body) and in the equivalent section at the eastern margin of the felsic volcanic body and quartz diorite intrusion (Fig. 7). Conglomerate also occurs close to the southwestern shore of Fraser Lake in the northern part of the section and sporadic units occur in the sedimentary section east of the Fraser Lake mafic volcanic body.

The conglomerates typically comprise unsorted or poorly sorted deposits of largely volcanic cobbles and pebbles. These units are interlayered with fine grained sedimentary rocks at a scale of 1 to 10 m in the southern part of the Fraser Lake sedimentary section. The lithologies are more thinly bedded at the northern end of the section, just south of Fraser Lake; one section comprises interlayered cobble conglomerate (beds greater than 1.2 m thick), pebble conglomerate (1 - 30 cm) and fine grained sedimentary rocks (2 - 8 cm). The latter include both hornblende greywacke and biotite greywacke, siltstone, and mafic (hornblendic) mudstone. Some hornblendic beds are partly disrupted and reworked into the coarser layers.

The most abundant clasts are felsic to intermediate volcanic and tuffaceous lithologies (Table 9); siltstone and very fine grained intermediate fragments of uncertain origin are common; amphibolite (probably volcanic) and tonalite (probably subvolcanic) are rare. Conglomerates at the southern end of the Fraser Lake sedimentary section are polymictic and contain quartz clasts, probably derived from vein quartz, comprising up to 15 per cent of the rock. The most southerly unit, which is probably close to the base of the section, contains a variety of pebbles and small cobbles up to 10 cm by 5 cm. The majority of conglomerates consist of predominantly cobble size clasts, with small boulders (up to 40 by 12 cm). The conglomerates are commonly well foliated and the clasts are attenuated, especially in the southern part of the section. Primary shapes are well preserved, however, in the pebble beds at the northern end of the section, which contain angular to subrounded fragments. Clasts in adjacent cobble beds are flattened to ellipsoidal bodies which are oriented at approximately 15° to the bedding, and lineated steeply to the northwest at that locality. The conglomerates are typically clast supported, with a fine grained greywacke or siltstone matrix (biotite and/or hornblende-bearing ± garnet).

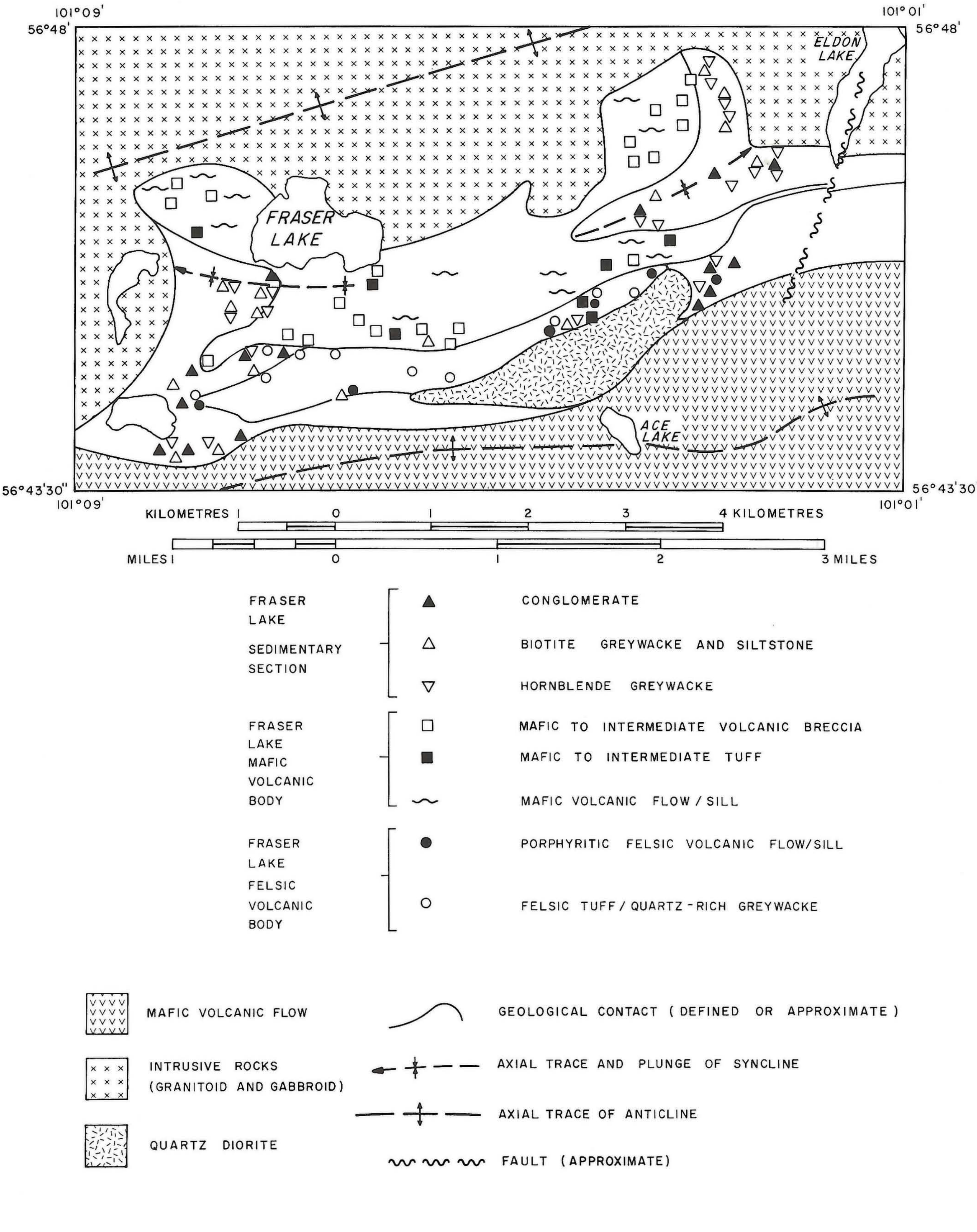


FIGURE 7: Facies relationships within and between the Fraser Lake mafic volcanic body, felsic body, and related sedimentary section.

TABLE 9: CLAST-TYPES IN CONGLOMERATE (8a, 8b) OF THE FRASER LAKE SEDIMENTARY SECTION.

Clast-type		Abundance (% total clast)
Felsic volcanic	White weathering; very fine grained equigranular felsic mosaic; may include chert fragments	generally >50% up to 98%
Porphyritic felsic volcanic	White, gray and beige weathering; probably rhyolitic and dacitic types; phenocrysts of plagioclase (± quartz); rarely with epidote-rich cores	
Felsic tuff or siliceous greywacke	Equivalent to tuffaceous lithology of Fraser Lake felsic body; medium-grained quartz (± plagioclase) grains in a very fine grained matrix	
Intermediate volcanic	Grey to green, andesitic; some clasts contain plagioclase phenocrysts; may include some sedimentary fragments	0 - 5%
Mafic volcanic	Medium to dark green, aphyric or, less commonly, porphyritic (plagioclase); hornblende pseudomorphs rare	0 - 5%
Siltstone	Equivalent to siltstone of unit 9; some clasts display fine bedding	0 - 25%
Intermediate volcanic or sedimentary rock	Very fine grained quartzo-feldspathic mosaic with variable epidote (5 - 50%), biotite (5 - 10%) and magnetite (up to 3%); some clasts have hornblende (5 - 10%) in place of epidote	
Quartz	Medium- to coarse-grained mosaic; probable vein quartz; occurs in conglomerate close to the southern margin of the Fraser Lake sedimentary section	0 - 15%
Tonalite	Fine- to medium-grained, with anhedral quartz and plagioclase (An_{40-45}); some fragments are subporphyritic, with 1 mm subhedral plagioclase grains; occurs as subordinate granules in conglomerate close to the southwestern shore of Fraser Lake.	<1%
Amphibolite	Medium grained	<1%

HORNBLENDE GREYWACKE, BIOTITE GREYWACKE AND PEBBLY GREYWACKE, SILTSTONE AND MAFIC MUDSTONE (9a), 9b, 9c, 9e)

Feldspathic greywacke is the predominant lithology in the sedimentary section south of Fraser Lake; the rock varies from grey to beige (biotite-bearing) to green (hornblende-bearing) on weathered surfaces. There is complete gradation between medium- to fine-grained, micaceous greywacke and siltstone. The fine grained sediments comprise units up to several metres thick. Bedding is locally prominent where micaceous or hornblendic lithologies are interlayered in units up to 50 cm thick, but primary layering is generally not well defined. Biotite greywacke commonly displays fine micaceous trails (0.25 - 1 mm) and relatively pelitic laminae up to 3 cm thick occur in some beds. Rare pebbly horizons up to 15 cm thick occur locally in the northern part of the Fraser Lake section. Graded bedding was not observed in the section, although detrital texture with prominent quartz and plagioclase is commonly well preserved. Thin mafic laminae (0.5 - 5 cm thick) containing porphyroblasts of garnet and chlorite or garnet and green hornblende occur in several beds but these are not common.

Feldspathic greywacke contains prominent subangular to subrounded grains (0.5 - 2 mm) of quartz and well twinned plagioclase (andesine) and felsic lithic granules (1 - 3 mm). The detrital grains, comprising approximately 10 to 20 per cent of the rock, are set in a fine- to very fine-grained matrix. Four types of lithic fragments have been identified:

(a) very fine grained felsic volcanic,
(b) fine grained, subporphyritic felsic volcanic with plagioclase phenocrysts in a fine grained quartz-plagioclase matrix,
(c) fine- to medium-grained tonalite, and
(d) basalt (subordinate).

The greywacke typically displays a seriate texture, but tendency to hiatal distribution of grain-size (medium grained detrital grains in siltstone matrix) is not uncommon, probably reflecting a lower degree of maturity. Hornblende greywacke contains 15 - 20% green hornblende, up to 10% biotite and 50 - 75% quartz and plagioclase. Biotite greywacke and siltstone contain 10 - 20% biotite, 60 - 85% quartz and plagioclase. Accessory minerals include sphene, epidote, magnetite and apatite. Garnet occurs localy in both hornblende and biotite greywacke; one hornblende greywacke contains anhedral to subhedral garnet porphyroblasts (1 - 2 mm across, comprising approximately 15% of the rock) surrounded by haloes depleted in mafic minerals.

Mafic mudstone (9e) is interlayered with biotite greywacke, siltstone and conglomerate at a scale of 5 - 20 cm in the northern part of the Fraser Lake sedimentary section, just south of Fraser Lake. The mudstone is dark green and hornblende-rich (up to 65 per cent hornblende); internal pale green laminae in some beds are defined by lower hornblende content. Some layers have been attenuated and disrupted, and are now represented by horizons of ovoid calc-silicate bodies up to 25 cm across. The structures are commonly zoned with pale green or cream-weathering, epidote-rich cores, and dark green hornblende-rich margins. Similar zoned calc-silicate bodies occur sporadically in several hornblende greywacke beds in the northern part of the section. These structures are ovoid, elongate, or highly irregular and clearly metasomatic because the primary detrital texture and grain size of the rock is continuous through the bodies. Zoning is defined by cream, epidotic cores (± garnet) and green hornblende rims. The boudinage of the mudstone layers is interpreted as a tectonic structure, but an early diagenetic stage of development cannot be ruled out. Primary folding and dislocation of bedding occurs in siltstone in the same section, south of Fraser Lake. Some siltstone beds contain tabular to highly irregular mafic bodies derived from hornblendic greywacke interlayers. Internal lamination of the siltstone is deflected round the structures which are considered to have been incorporated before induration of the siltstone.

MASSIVE PORPHYRITIC BASALT (4a)

Porphyritic basalt comprises interlayers up to at least 3 m thick within the sedimentary rocks in the northern part of the Fraser Lake section. The basalt contains prominent euhedral to subhedral hornblende pseudomorphs after pyroxene (1 - 3 mm, comprising 15 - 40 per cent of the rock). Plagioclase (An_{45}) phenocrysts (0.5 - 1 mm, up to 10% of the rock) occur in some units. The rock is lithologically and geochemically similar to the porphyritic basalt body (3a) which underlies McVeigh Lake; relatively high Ni and Cr contents are characteristic. However, the mafic volcanics within the Fraser Lake sedimentary section are considered to be younger than the McVeigh Lake basalt, which underlies the Fraser Lake-Eldon Lake sedimentary section.

The porphyritic basalt interlayers probably include both extrusive and shallow intrusive units. The layers are essentially parallel to bedding in the host rocks. One layer is locally slightly discordant to the bedding of the greywacke, and displays a 3 cm thick, aphyric chilled margin. This unit is characterized by a highly irregular, undulatory contact, and the host rock displays evidence of soft sediment deformation, indicating the mafic volcanic body was injected before cosolidation. Some interlayers display arcuate feldspathic/epidotic bodies and stringers possibly derived from pillowed selvages, but definitive flow structures have not been recognized.

SEDIMENTARY SECTION EAST OF THE FRASER LAKE MAFIC VOLCANIC BODY

A body of predominantly fine grained sedimentary rocks occurs just east of the Fraser Lake mafic volcanic body (Fig. 7); limited structural data indicate that these sedimentary rocks overlie the mafic volcanic body in a synclinal structure analogous to that south of Fraser Lake. The sedimentary rocks are in contact with younger granitoid intrusions to the north and east. The section east of the mafic volcanic body is very similar to the northern part of the section to the west, and contrasts with the southern part of the latter section in the relative paucity of conglomerate and the absence of siliceous greywacke interbeds. Porphyritic basalt (4a) with hornblende pseudomorphs after pyroxene comprises interlayers (1 - 7 m thick) within the section east of the mafic volcanic body; these are generally concordant but local truncation of the greywacke bedding indicates at least some units are intrusive. Structures indicating soft sediment deformation occur in the sedimentary sections both east and west of the Fraser Lake mafic volcanic body.

HORNBLENDE GREYWACKE, BIOTITE GREYWACKE AND PEBBLY GREYWACKE, SILTSTONE AND MAFIC MUDSTONE (9a, 9b, 9c, 9e)

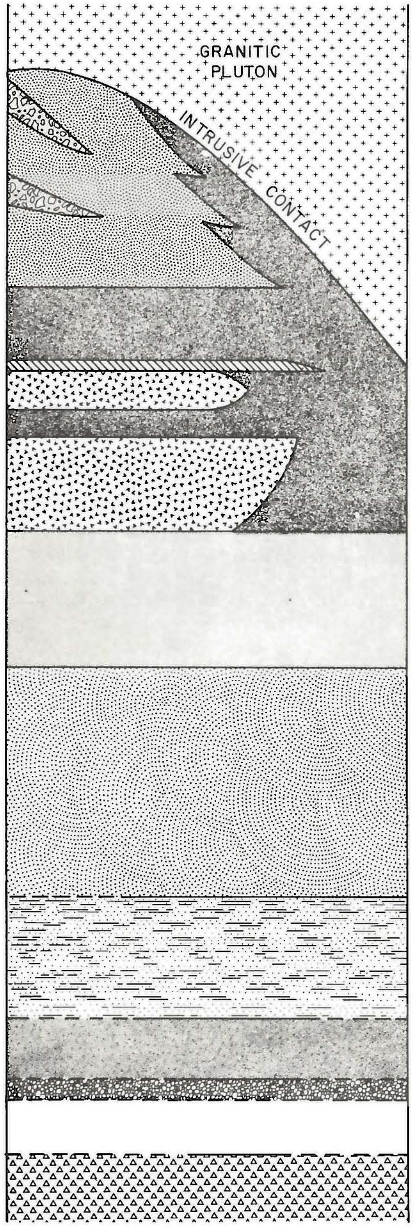
Hornblende greywacke and biotite greywacke with siltstone occur as exclusive lithologies or intercalated at a scale of 2 - 50 cm; hornblendic beds have been disrupted and incorporated into siltstone interlayers at several places. Hornblende greywacke is predominant at the southern margin of the sedimentary body, but micaceous and hornblendic lithologies are equally abundant in the northern part of the body. The hornblendic rocks to the south are characterized by prominent medium- to coarse-grained detrital quartz, plagioclase, felsic and mafic volcanic microclasts and feldspathic granules up to 3 mm across. The granules consist of medium- to coarse-grained, interlocking grains of subhedral to anhedral plagioclase - An_{35-40} ($\pm$ minor quartz). These probably are derived from phenocryst aggregates of volcanic origin but a plutonic derivation cannot be ruled out. Detrital quartz comprises single optical units and related, recrystallized mosaics. Detrital grains range in seriate texture to a very fine grained matrix. The dark green or grey hornblendic greywacke comprises massive beds (up to at least 1 m thick) which locally contain subordinate siltstone laminae. Rare, zoned calc-silicate pods have been observed in these rocks. The average composition of the greywacke is hornblende (15 - 20%), biotite (5 - 10%) and quartz and plagioclase (65 - 75%); magnetite, sphene and zircon are accessory.

Biotite greywacke and siltstone are generally better layered than hornblende greywacke, with cream, beige or grey laminae reflecting variable grain size and composition. Mafic mudstone is not common, but locally occurs as sharply defined laminae (1 - 5 cm) in siltstone beds. Rare pebbly horizons contain up to 15 per cent rounded clasts of felsic to mafic volcanic rocks. Feldspathic granules equivalent to those in hornblende greywacke have also been observed in biotite greywacke. Garnet and hornblende porphyroblasts are widespread, generally evenly distributed, but locally strata-bound. Irregular sedimentary folds (with amplitudes of 5 cm) were observed in one siltstone bed. Minor siliceous siltstone laminae consist of up to 90% quartz and plagioclase, with 5% biotite and up to 5% magnetite. The biotite-bearing sedimentary rocks typically contain 10 - 20% biotite, locally accompanied by green hornblende (up to 10%), garnet (up to 10%) and epidote (5%); quartz and plagioclase comprise 65 - 80% of the rocks.

PROVENANCE AND ENVIRONMENT OF DEPOSITION OF SEDIMENTARY ROCKS (8, 9)

The sedimentary rocks in the section south of Fraser Lake and in the area east of the Fraser Lake mafic volcanic body are partly derived from a felsic volcanic source. Polymictic conglomerate (8) in the section contains felsic volcanic and subordinate mafic clasts (Table 9). Some fine grained sedimentary rocks have been redeposited in conglomeratic beds. Tonalitic and subporphyritic felsic fragments in conglomerate (8) and lithic greywacke (9) are considered to be derived from synvolcanic intrusive bodies coeval with the Wasekwan Group volcanic rocks. The paucity of mafic volcanic clasts may not accurately reflect the nature of the source terrane, because mafic volcanic lithologies are less resistant to erosion during transport than felsic rocks. No clasts of porphyritic basalt characteristic of the McVeigh Lake basalt (3a) south of the sedimentary section have been recognized in the conglomerate. This may indicate that the mafic terrane was not elevated during deposition of the conglomerate. Alternatively, the relatively older age interpreted for the porphyritic basalt (3a) may be erroneous, owing to complexities of structure that have not been recognized.

The conglomerates and fine grained sedimentary rocks are more characteristic of the resedimented facies (Turner and Walker, 1973) than non-marine deposits in which large scale cross bedding, channel deposits, scour, etc. would be expected. Alternation of hornblendic and biotite-bearing fine grained units is interpreted to indicate two contemporaneous sources of sediment, characteristic of resedimented sequences. Fine grained mafic (hornblendic) mudstone may represent a relatively calcic basinal facies, with coarser grained greywacke and conglomerate resulting from periodic incursions of turbiditic deposits. The relative paucity of conglomerate in the northern part of the Fraser Lake section may indicate this part of the sedimentary basin was more distal from the volcanic source and/or the volcanic terrane was at a relatively lower elevation. Structures reflecting soft sediment deformation in the northern part of the section could have developed on the relatively steep slopes of levées or inter-channel areas of a turbidity flow dispersal system. Alternatively, these structures may be the result of disturbances related to the contemporaneous emplacement of mafic volcanic rocks.



METRES 500 — 0

STRATIGRAPHIC DIVISION	LITHOLOGY	STRUCTURES AND TEXTURES	BEDDING THICKNESS (cm)	MAXIMUM SIZE PEBBLES (cm)	MICROCLASTS mm PLAG.	MICROCLASTS mm QUARTZ
DIVISION D	*Hornblende greywacke, pebbly greywacke, conglomerate*	Mafic composition Massive to thickly bedded Coarse textured Poorly sorted Pebbles common Coarsening - upward cycle(s) Rare graded beds	> 100 40 - >100 6 - 200	20 ↑ 3 2 6	2.5 2 2.5	2.5
Sharp contact						
DIVISION C	*Garnet - biotite greywacke* *Siltstone and semi-pelite interbeds* *Intercalated plagioclase - phyric intermediate flows and flow breccia* *Chert, mudstone, sulphide formations*	Felsic composition Thinly bedded Fine grained Well sorted Clast free Biotite, garnet content increases upwards Calc - silicate nodules	5 - 20 1		0.3 0.3 0.3	0.4 0.7
DIVISION B	*Siliceous volcaniclastic rocks* *Rhyolite, dacite*	Thinly bedded to massive Fine grained Moderately sorted Massive lavas, rare volcanic breccia	<1 - 2			0.7
Interlayered at contact						
DIVISION A	*Hornblende greywacke, siltstone* *Siltstone and mafic mudstone* *Minor garnetiferous amphibolite*	Thinly to moderately bedded Poorly sorted Sporadic pebbles	3 - 45 > 10	2 X 5 2 X 10	0.5 1.0 1.5	0.7 1.7
	Siltstone and mafic mudstone	Thinly bedded to laminated Few microclasts	2 - 30 (siltstone) 1 - 10 (mafic mud-stone)		0.4	
	Interlayered hornblende greywacke, siltstone	Siltstone pebbles Calc - silicates	1 - 10		1.0	1.0
	Quartz - pebble conglomerate	Greywacke interbeds	10 - >100	20		
	(COVERED)					
	PORPHYRITIC BASALT (UNIT 3)	Massive flows, autoclastic breccia				

FIGURE 8: Stratigraphic section through unit 9, south of Eldon Lake (Eldon Lake Section, distal facies).

ELDON LAKE SECTION (DISTAL FACIES)

The Eldon Lake section represents the fine grained, more distal part of the Fraser Lake-Eldon Lake sedimentary sequence. It contains a well defined stratigraphy which cannot be traced either to the west, into the proximal conglomerates, or to the east, where the units are truncated by a tonalite pluton. The compositions, mineral assemblages, and grain-size of the constituent sediments are used to define six lithologies:

Unit number	Lithology
9b, 8b	Hornblende-bearing greywacke with abundant plagioclase crystal fragments; polymictic conglomerate
9c	Biotite-bearing greywacke, siltstone
9d, 7	Quartz-rich volcanic wacke, rhyolite
9b	Hornblende-bearing greywacke, siltstone, mafic mudstone
9e	Siltstone and mafic mudstone
8a	Quartz-pebble conglomerate

The stratigraphic arrangement of the six lithologies and their corresponding clast populations and bedding characteristics define four sedimentary divisions, each of which is interpreted to have a different provenance (Fig. 8). The four sedimentary divisions (A, B, C and D) are as follows:

(1) Division A comprises the major portion (640 m) of the Eldon Lake section. It overlies porphyritic basalt (3), and is laterally equivalent to proximal conglomerates which flank the Fraser Lake rhyolite body. Up to 80 m of hornblende-bearing greywacke and mafic mudstone may be present between the porphyritic basalt and the basal member (8a) of the division; the contact zone between units 3 and 8a is poorly exposed. Division A contains two fining-upward sequences. The lower sequence consists of quartz pebble conglomerate (30 m thick maximum), overlain by interlayered hornblende-bearing greywacke and siltstone (90 m thick), topped by interlayered siltstone and mafic mudstone (180 m thick). The second fining-upward sequence consists of interlayered hornblende-bearing greywacke, siltstone, and mafic mudstone (340 m thick); maximum pebble and mineral microclast size in greywacke decreases progressively from the base to the top of the sequence (Fig. 8). Division A is interpreted as a relatively distal volcaniclastic apron derived in part from the Fraser Lake rhyolite body.

(2) Division B comprises fine grained, thinly layered, siliceous volcaniclastic rocks and intercalated flows and breccias. The unit is 200 m thick and overlies Division A greywackes; quartz-rich volcaniclastic rocks and hornblende greywacke are interlayered at the contact between the two divisions. Division B is correlated with the Fraser Lake rhyolite and its associated volcaniclastic facies. South of Eldon Lake Division B *overlies* detritus which was derived in part from the Fraser Lake rhyolite; it therefore probably represents the final stage of felsic volcanism.

(3) Division C biotite-garnet-bearing greywacke comprises a unit approximately 400 m thick, at the top of the sedimentary section southeast of Eldon Lake. It is apparently intercalated with hornblende-bearing greywacke (Division D, Fig. 8) southwest of Eldon Lake. The biotite-garnet-bearing greywackes are thinly bedded, clast free, and are better sorted than the hornblende-bearing greywackes. Division C is stratigraphically equivalent to intermediate to mafic volcanic rocks (4) southeast of Foster Lake but its provenance is probably a felsic volcanic terrane. Two thin intercalations of plagioclase-phyric intermediate flows and flow breccias occur within the greywacke section; graphitic argillite-chert-pyrite formations (exhalites?) occur at the tops of the volcanic units.

(4) Division D comprises coarse grained greywackes characterized by abundant plagioclase crystals, scattered pebbles, local conglomerate, thick bedding, and at least one coarsening-upward cycle. The sediments have undergone only limited transport and little reworking. The mafic nature of the rocks, and the abundance of plagioclase microclasts, suggests that they were derived primarily from a plagioclase-phyric intermediate to mafic volcanic terrane.

QUARTZ-PEBBLE CONGLOMERATE (8a)

Polymictic conglomerate with abundant vein-quartz clasts occurs in Division A, at or near the base of the Eldon Lake greywacke section. Outcrops of the conglomerate are rare and very small: minimum (exposed) thickness of the unit is 3 m but neither the top nor bottom contacts are exposed.

Bedding (5 cm - 1 m) is defined by thin interlayers of grit and pebbly hornblende greywacke. One conglomerate bed 1 m thick has quartz cobbles (20 cm) at the base grading upwards to pebbles (2 - 3 cm) near the top. The conglomerate is in general poorly sorted and clast-supported.

White vein-quartz pebbles comprise more than 80 per cent of the clast population. The quartz clasts are fine grained and saccharoidal; they range from 3 mm to 20 cm in length and average 3 cm. The pebbles have been tectonically flattened into pancake-shaped forms with a cross-sectional length to width ratio of approximately 3:1, but they have rounded terminations suggesting an original rounded form. Subordinate clast lithologies include grey, very fine grained chert, white aphyric rhyolite, and amphibolite. The matrix is fine- to medium-grained, and consists of randomly-oriented amphibole prisms with interstitial plagioclase, chert, quartz, and felsic granules.

The conglomerate is a thin, highly mature deposit containing materials very resistant to abrasion and decomposition. The quartz pebbles are a concentrate derived from the erosion of a large volume of rock transected by quartz veins. Orthoconglomerates of this type are deposited from highly turbulent waters, and may be either beach or alluvial in origin (Pettijohn, 1975). The occurrence of this conglomerate at or close to the base of a thick, non-fluviatile greywacke-siltstone succession suggests that the conglomerate is a beach deposit.

SILTSTONE AND MAFIC MUDSTONE (9c)

Finely interlayered buff, micaceous siltstone and dark green, amphibolitic mudstone occurs throughout most of Division A (Fig. 8). It occurs interlayered with hornblende-bearing greywacke and as a unit 180 m thick at the top of the first fining-upward sequence.

Micaceous siltstone beds are 1 - 30 cm thick and the amphibole-rich mudstone interbeds (30-40% of the rock) are 5 mm - 10 cm thick. Beds are internally laminated (at a scale of 2 - 5 mm) and parallel-sided; contacts between siltstone and amphibolitic beds are sharp. Amphibolitic layers are locally boudinaged, resulting in either pinch-and-swell structures or complete disruption of layering. Disrupted amphibolitic layers form pods, ribbons, and pseudo-clasts in the siltstone.

Siltstone consists of a fine grained (0.02 - 0.1 mm), equigranular, granoblastic mosaic of untwinned plagioclase, quartz, and biotite, commonly with up to 5 per cent hornblende poikiloblasts (up to 1 mm long). Epidote, magnetite, and pyrite are minor components. Lamination of the strongly foliated rock is defined by variations in biotite content (20-50%). Contacts between internal laminae are relatively sharp, and may be accompanied by slight changes in the grain size of quartz and feldspar. The prismatic hornblende poikiloblasts (α = yellow green, γ = bluish green) are commonly oriented with long axes parellel to the biotite foliation, but some poikiloblasts truncate the foliation. Rounded to subrounded plagioclase and quartz microclasts (0.1 - 0.4 mm) occur in some siltstone beds but they are not common.

Mafic mudstone layers are distinguished from siltstone layers by greater amphibole content (up to 30%), and a lower biotite content (up to 20%). The amphibole occurs either as acicular crystals oriented parallel to the biotite foliation, or as randomly oriented porphyroblasts. Some amphibolitic layers contain internal laminations defined by variable biotite content.

The interlayered micaceous siltstone and mafic mudstone was deposited in a low-energy environment, as indicated by the absence of fluviatile or turbidite structures and the semi-pelitic nature of the siltstone.

HORNBLENDE GREYWACKE, SILTSTONE (9b)

Hornblende-bearing greywacke occurs in divisions A and D. In division A it occurs at two stratigraphic intervals: (1) overlying quartz-pebble conglomerate, and (2) throughout the upper fining-upward sequence. Division A greywackes weather light brown to light grey, and are light to dark grey on fresh surfaces. Division D hornblende-bearing greywackes are thicker bedded, contain a greater proportion of plagioclase microclasts, and contain more hornblende than division A greywackes. The following description refers only to division A hornblende greywacke; division D greywacke is described separately (9b and 8b).

Bedding ranges in thickness from 3 cm to approximately 45 cm. Beds are parallel sided and lack obvious grading or cross bedding; the apparent absence of sedimentary structures may be a function of metamorphic recrystallization and very poor exposure. Pebbly greywacke, fine grained greywacke, and siltstone occur as interbeds; garnetiferous amphibolite layers and biotite-garnet greywacke beds are rare.

Pebbles occur sporadically in the greywacke and have been tectonically flattened into lens-shaped forms. Most of the pebbles are white, aphyric rhyolite; one vein quartz clast was noted. Plagioclase and quartz microclasts each comprise 3 - 10 per cent of the greywacke. Plagioclase microclasts include angular crystal fragments and subordinate subhedral crystals; they are commonly recrystallized, and embayed by hornblende and chlorite. Quartz microclasts are subrounded to subangular in shape, and include single, strained crystals and annealed, mosaic-textured grains. One embayed quartz crystal was observed. Lensoid rock fragments up to 5 mm long occur in some beds; most lithic fragments are very fine grained aphyric rhyolite or chert. A systematic decrease in maximum microclast grain size, from 1.7 mm near the base of the upper fining-upward sequence to 0.5 mm near the top is coincident with decreasing maximum pebble size (Fig. 8); pebbles are very rare at the top of the sequence.

The greywacke displays hiatal texture, with microclasts dispersed in a fine grained (0.1 mm) recrystallized mosaic of untwinned plagioclase and quartz. Magnetite (2%), epidote, and locally garnet are minor components. Subparellel hornblende porphyroblasts and later brown biotite and minor chlorite overprint the matrix. Green hornblende comprises 10 - 25 per cent of the greywacke and biotite comprises 2 - 10 per cent.

Hornblende greywacke is laterally equivalent to proximal conglomerates derived in part from the Fraser Lake rhyolite. Rhyolite pebbles and quartz microclasts (some clearly of volcanic origin) in hornblende greywacke were probably derived from the quartz-plagioclase-phyric rhyolite. Plagioclase microclasts may have been derived either from the rhyolite or plagioclase-phyric intermediate or mafic volcanic rocks. The considerable hornblende content of the sediment suggests a mafic volcanic input, presumably as fine grained material which has been subsequently recrystallized.

QUARTZ-RICH GREYWACKE (9d), RHYOLITE (7)

The siliceous sediments and intercalated felsic volcanic rocks in division B (Fig. 8) can be correlated with the Fraser Lake felsic volcanic body. Within the Eldon Lake section the siliceous rocks comprise a unit 200 m thick that overlies division A and underlies biotite-garnet-bearing greywacke and intercalated intermediate flows (division C). Quartz-rich sediments are interlayered with hornblende greywacke at the base of division B. Exposures of division B lithologies are sparse and small; consequently the exact nature of the relationship between the clastic and felsic volcanic rocks is uncertain.

The clastic rocks weather buff to light greenish grey. They are fine grained, moderately sorted, and finely bedded (2 cm) to massive. Rounded to subangular quartz microclasts (0.3 - 0.7 mm, 3%), are enclosed in a very fine grained (0.05 mm) recrystallized matrix of quartz and untwinned plagioclase. Brown biotite (1 - 10%), green biotite (3 - 20%), and white mica (0 - 5%) flakes and lenticular aggregates define the foliation; amphibole and garnet occur sporadically. Layering is defined by variable biotite content and/or grain size. The epiclastic origin of many of the siliceous volcaniclastic rocks is indicated by the thin bedding, interlayering with hornblende greywacke, and the rounded nature of the quartz microclasts.

Felsic volcanic rocks within sub-division E include porphyritic and aphyric rhyolite and dacite. All of the felsic rocks weather light grey to white.

The best exposure of rhyolite, 1850 m east of the south end of Eldon Lake, occurs in three small outcrops representing a total stratigraphic thickness of 30 m. Flinty, aphyric, finely flow-banded rhyolite at the base of the exposure is overlain by foliated felsic hyaloclastite or tuff. At the top of the exposure is a felsic fragmental deposit composed of closely-packed, lensoid, dense to scoriaceous rhyolite fragments up to 4 x 20 cm in cross-section. The matrix of the fragmental deposit consists of finely granulated felsic material, amphibole, and garnet.

Division B siliceous volcanic rocks and sediments overlie hornblende greywackes which are interpreted as a volcaniclastic apron derived largely from the Fraser Lake felsic body. The felsic volcanic rocks south of Eldon Lake must therefore represent the final and most extensive period of Fraser Lake felsic volcanism.

BIOTITE GREYWACKE, SILTSTONE (9c)

Biotite-garnet-bearing greywacke comprises the top 300 - 400 m of the Eldon Lake section (division C, Fig. 8). It conformably overlies the siliceous volcanic and volcaniclastic rocks of division B, and is intruded by a granitic pluton (16b) at its northern contact. Biotite greywacke is intercalated with a wedge of coarse grained hornblende greywacke (division D) southwest of Eldon Lake.

South of Eldon Lake the biotite greywacke contains two intercalations (140 m and 60 m thick) of plagioclase-phyric intermediate flows and flow breccia. These thin volcanic units pinch out to the east, and are the distal facies of a much thicker, more proximal intermediate to mafic volcanic complex which overlies the rhyolite-conglomerate-siltstone suite south and east of Fraser Lake.

Biotite greywacke weathers brownish-buff to light grey, and is light to medium grey on fresh surfaces. It is commonly thinly layered (1 - 5 cm); thicker beds (up to 20 cm) are rare. The greywacke is fine grained, well sorted, clast free, and is interlayered with subordinate siltstone and/or semi-pelitic beds. Calc-silicate nodules (hornblende-plagioclase-epidote) occur locally; they are ovoid to lenticular in cross section, and are oriented parallel to the biotite foliation. Some nodules are concentrically zoned with epidote-rich cores and amphibole-rich margins.

The mineral assemblage developed in greywacke (quartz-plagioclase-(An_{33})-biotite-garnet-epidote) is representative of the lower amphibolite facies. Apatite and magnetite-hematite are accessory phases, and chlorite is locally abundant (overprinting biotite). The rocks have a fine grained (0.1 - 0.3 mm), granoblastic polygonal texture, with a good biotite preferred orientation. Mineral microclasts are rare and relatively small (0.3 - 0.6 mm): they include subangular plagioclase crystal fragments and subrounded quartz granules. One embayed quartz microclast was noted, indicating a volcanic provenance. Garnet blasts up to 1.5 mm in diameter are commonly recrystallized to fine grained pseudomorphic aggregates which are partly replaced by biotite. The sediments become increasingly pelitic upwards through the unit: near the base, greywacke contains 10 per cent biotite + chlorite and 3 per cent garnet, whereas near the top of the unit greywacke contains 25 per cent biotite + chlorite and 10 per cent garnet.

Graphitic argillite-chert-pyrite formations occur at the tops of intermediate volcanic intercalations (4). One formation, exposed at the south end of Eldon Lake, is approximately 12 m thick. It is composed mainly of very fine grained, gossaned, light grey cherty material with disseminated pyrite crystals and remobilized pyrite along fractures. Black, very fine grained graphitic argillite with 10 per cent disseminated pyrite occurs as a thin (40 cm) layer within the cherty rocks. A magnetic anomaly coincides with the sulphide-bearing formation. The overlying biotite greywacke and underlying plagioclase-phyric intermediate flow are unmineralized. The pyritic formations may be exhalite horizons, associated with unit 4 volcanism.

Division C biotite-garnet-bearing greywackes are, like the underlying sediments in the Eldon Lake section, almost certainly volcaniclastic deposits (indicated by the rare embayed quartz microclasts). They were deposited, probably in a basinal environment, contemporaneous with the intermediate to mafic volcanic flows and breccias (4) southeast of Fraser Lake, but the composition of the sediment does not indicate a genetic relationship with mafic volcanic rocks. The thin, even nature of the bedding, and the absence of conglomerates, pebbly beds, and large microclasts, suggests that the greywackes are distal deposits. They were derived from an unidentified, probably felsic, volcanic terrane.

HORNBLENDE GREYWACKE (9b), CONGLOMERATE (8b)

A wedge of immature, hornblende-bearing volcaniclastic sediments (division D), apparently laterally intercalated with biotite-bearing greywacke, lies southwest of Eldon Lake and extends for 2100 m to the west from the area south of Eldon Lake. The thickness of the unit is uncertain because the northern margin is truncated by granite; the maximum width of the unit is 330 m just west of Eldon Lake. In the west the hornblende greywackes are directly underlain by unit 4 intermediate to mafic volcanic rocks. Southwest of Eldon Lake, however, 120 m of garnet-biotite greywacke occurs between the volcanic unit (4) and younger hornblende greywacke. The contact between the hornblende greywacke and the biotite greywacke is sharp.

Division D includes coarse-textured greywackes with abundant plagioclase microclasts, pebbly greywackes, and subordinate polymictic conglomerates. The sediments are massive, thickly bedded (commonly 30 to 200 cm), with minor fine grained greywacke or siltstone interbeds and laminae. One north-facing graded bed 6 cm thick was noted, but otherwise the beds are devoid of internal structure. Sorting is poor, and many greywacke beds contain isolated pebbles.

The greywackes weather medium grey to green and dark grey on fresh surfaces. Subangular to subhedral plagioclase microclasts are conspicuous on weathered surfaces and commonly comprise 40 - 50 per cent of the sediment. They range in size from a fraction of a millimetre to 2.5 mm and are partially to completely recrystallized. Subrounded quartz microclasts (up to 2.5 mm) are subordinate. The matrix consists of subidioblastic hornblende (25 - 40%, 0.1 - 1 mm; α = pale yellow green, γ = green), fine grained (0.1 - 0.2 mm) recrystallized quartz and plagioclase, disseminated fine magnetite (2%), minor brown biotite (in part overprinting hornblende), and minor epidote and sericite replacing plagioclase. Relatively fine grained greywacke interbeds contain fewer microclasts, but hornblende content is similar to that of the coarser greywackes. Sporadic, oval pebbles (up to 3 cm across) include siltstone, rhyolite, basalt, and rare vein quartz.

Pebble and cobble conglomerate beds (8b), one to several metres thick, occur throughout the hornblende greywacke section. The conglomerates are polymictic and matrix-supported; they lack internal organization or fabric. Clast lithologies include rounded to subrounded felsic volcanic rocks and vein quartz, angular and slabby laminated mafic greywacke, and subrounded aphyric basalt and epidosite (some with quartz amygdales). The matrix is hornblende greywacke with plagioclase microclasts.

One coarsening-upward sequence at least 30 m thick was mapped in the upper portion of the unit. From the base to top of the exposure, the lithologies include: (1) poorly-sorted, thick-bedded greywacke with rare isolated pebbles, (2) thick bedded greywacke with numerous 3 cm pebbles, (3) 9 m of matrix-supported polymictic conglomerate with a maximum clast-size of 20 cm and quartz pebbles up to 4 cm long. The conglomerate is abruptly overlain by hornblende greywacke devoid of pebbles.

The mafic composition and extraordinary abundance of coarse-sand-sized plagioclase microclasts indicates that the hornblende greywackes were probably derived largely from a plagioclase-phyric intermediate to mafic volcanic terrane. The common occurrence of felsic volcanic components, their rounding and the presence of quartz pebbles suggests that at least part of the source area was exposed to subaerial erosion. The poor sorting, coarse texture, thick bedding, presence of pebbles and conglomerate interbeds, and absence of shaley partings are structures consistent with the "proximal-exotic" turbidite facies of Walker and Mutti (1973). They are probably not far removed from the source volcanic centre, considered to be within the volcanic section (4) southeast of Fraser Lake.

INTERPRETATION

The Eldon Lake greywacke-siltstone section is an assemblage of overlapping volcaniclastic lenses which are related to successive eruptive centres. The sedimentary rocks are interpreted to have been deposited in an intravolcanic basin, only the western portion of which is preserved. Development of the basin can be subdivided into four stages, corresponding to the four sedimentary divisions.

(1) Division A records the inception of basin subsidence, marine transgression over a land area composed of porphyritic basalt (3) and possibly rhyolite (7), and continued (episodic) subsidence of the basin. During the initial stage the basal quartz-pebble conglomerate was deposited, possibly in a high-energy beach environment. Subsequent transgression(s) and the continued influx of felsic pebbles and subrounded quartz grains (derived from the Fraser Lake felsic volcanic body) and plagioclase crystal fragments (derived from a nearby intermediate to mafic volcanic source?) produced two fining-upward sequences within the thick greywacke-siltstone succession. Conglomerates are absent above the basal deposit.

(2) Quartz-rich volcaniclastic rocks, massive felsic flows, and felsic breccias comprising division B represent the products of the final rhyolitic eruptions which issued from the Fraser Lake felsic volcanic centre. These deposits overstepped the basin facies greywackes of division A.

(3) A fine grained, deeper water(?) greywacke facies (division C) was deposited within the basin, synchronous with the intermediate to mafic flows and breccias (4) which overlie the Fraser Lake felsic eruptive centre. These distal greywackes may have been derived from a distant felsic source.

(4) Division D immature greywackes and conglomerates were deposited as a locally coarsening-upward wedge derived from the unit 4 intermediate to mafic volcanic centre. The clastic wedge prograded over the basin facies division C greywackes, and its position presumably marked the margin of the sedimentary basin during the period of active unit 4 volcanism.

The Eldon FLake sedimentary succession thus records the parallel development of volcanic centres and their associated volcaniclastic aprons. The resulting pattern of overlapping volcanic and volcaniclastic deposits is typical of present-day volcanic arcs (Dickinson, 1974).

FRASER LAKE MAFIC VOLCANIC BODY (4)

Predominantly mafic volcanic flows and volcanic breccias, comprising the Fraser Lake mafic volcanic body, extend from the vicinity of Fraser Lake eastward to the southern extremity of Eldon Lake. These rocks locally contain subordinate interlayers of mafic and intermediate tuffs and fine grained sedimentary rocks especially in the southeastern part of the body, which may represent a relatively more distal environment than the area to the west, where flows and volcanic breccias are predominant. Minor aphyric and hornblende-phyric diabase intrusions are not uncommon, especially near the southern margin of the body.

VOLCANIC BRECCIA (4c, 4d)

Intermediate to mafic volcanic breccia, which is the most abundant lithology in the Fraser Lake mafic volcanic body, includes both autoclastic and pyroclastic types. These rocks are similar to the fragmental rocks of division D in the northern belt (Fig. 16), and the same criteria for recognition of facies type have been applied in both areas. Volcanic breccia with a recognizable magmatic matrix which is commonly quartz-amygdaloidal is interpreted as autoclastic. These deposits commonly contain various basaltic fragments distinguished by variable content of quartz amygdales and plagioclase phenocrysts (up to 35%). Hornblende pseudomorphs (after pyroxene) also occur in a minor proportion of the fragments. Clasts are generally tectonically flattened and unsorted; pebble to small cobble size fragments are typical, but larger clasts (up to 45 x 12 cm) have been observed. Fragments generally comprise 20 to 30 per cent of the rock; densely packed epidosite bodies in narrow zones (20 cm to 1 m) are interpreted as flow-top breccia.

Volcanic breccia with very pale or white felsic clasts in a basaltic tuff matrix is interpreted as pyroclastic. These rocks are polymictic with felsic to mafic fragments characterized by various porphyritic textures. The range of clast-size is equivalent to that in autoclastic deposits. Subangular to rounded fragment shapes and a detrital matrix structure are locally preserved but these features are not common. The rocks are generally moderately to strongly foliated and recognition of facies type is uncertain. The nature of intercalated volcanic units (flows with autoclastic rocks, tuffs with pyroclastic breccia) is locally indicative of breccia-type.

MASSIVE PORPHYRITIC AND APHYRIC BASALT AND ANDESITE (4a)

MAFIC AND INTERMEDIATE TUFF (4e, 4f)

Mafic flows (4a) are common within both breccia and tuff sequences. Plagioclase (andesine) phenocrysts (0.5 - 2 mm, comprising 10 - 35 per cent of the rock) and quartz amygdales (1 - 3 mm) are widespread. The plagioclase and quartz are locally concentrated in streaky zones or layers (1 - 30 cm thick) probably parallel to the original flow direction. These rocks alternate with massive and finely laminated amphibolite units which are locally boundinaged. Hornblende pseudomorphs after pyroxene have been observed but are not common; the section also contains subordinate aphyric basalt flows. Two horizons of pillowed basalt (within mafic tuff) have been reported by Emslie and Moore (1961), and disrupted pillow selvages were observed in the area west of Fraser Lake. Deformation is intense in the latter area, which is close to the axial zone of the east-trending fold just north of the Fraser Lake mafic volcanic body. The rocks west of Fraser Lake are commonly gneissic, with hornblendic/epidotic layering and sporadic garnet. Volcanic breccias in this section contains clasts with elongation ratios up to 25:1. The clasts have undergone attenuation and subsequent tight to isoclinal folding. Strata bound, ovoid epidotic boudins (10 - 15 cm across) within laminated amphibolite in this area are attributed to the earlier phase of deformation.

Mafic and intermedite tuffs (4e, 4f) comprise minor interlayers (50 cm to 5 m) and thicker formations (up to 200 m) in the Fraser Lake mafic volcanic body. These rocks are very similar to analogous lithologies in the northern belt. The tuffs contain 20 - 60 per cent green hornblende and up to 10 per cent biotite with very fine grained quartz and plagioclase; medium grained detrital plagioclase is also commonly present. Bedding is poorly preserved or absent. Strongly foliated very fine grained amphibole-chlorite-schist is generally interpreted to be derived from mafic and intermediate tuff. However, distinction between volcanic flows and tuffs is not clear where the rocks are strongly metamorphosed.

FELSIC VOLCANIC AND SEDIMENTARY ROCKS (6, 7, 8, 9) WITHIN THE FRASER LAKE MAFIC VOLCANIC BODY

Rare quartz-plagioclase porphyry intrusions (20 cm to 2 m thick) occur in the mafic volcanic body and subordinate felsic volcanic flows or sills have also been reported within the section (Emslie and Moore, 1961). Several layers of fine grained felsic tuff or quartz-rich greywacke occur within the mafic volcanic breccia close to the southern margin of the mafic body. These rocks contain detrital plagioclase, quartz, and rhyolitic granules, garnet, and euhedral magnetite. Variable hornblende and biotite contents define a slight lamination. The felsic interlayers (2 - 12 m thick) are probably equivalent to tuff and quartz-rich greywacke related to the Fraser Lake felsic volcanic body to the south. The southern margin of the Fraser Lake mafic volcanic body also contains porphyritic felsic volcanic interlayers, indicating a conformable relationship between the felsic and mafic volcanic bodies.

Sporadic interlayers of grey- to beige-weathering intermediate greywacke and siltstone (9b, 9c) comprise a very minor part of the Fraser Lake mafic volcanic body. Conglomerate beds are interlayered with volcanic breccia close to the contact with the sedimentary section south of Fraser Lake; the conglomerate is distinguished by a beige-weathering siltstone matrix, and the presence of arkosic wacke fragments in an assemblage of predominantly volcanic clasts.

STRATIGRAPHIC AND STRUCTURAL RELATIONSHIPS OF THE FRASER LAKE MAFIC VOLCANIC BODY

The mafic volcanic body is apparently laterally equivalent to the central part of the Fraser Lake sedimentary section (south of Fraser Lake); the southern and northern parts of that section are, respectively, older and younger than the mafic volcanic body (Figs. 7 and 9). Limited structural data indicate the volcanic rocks are overlain by an irregular-shaped sedimentary body occupying the core of a syncline structure southwest of Eldon Lake. Younger gabbro and granitoid rocks occur at the northern margin of the Fraser Lake mafic volcanic body, which is approximately 9 km long and 2 km wide. The true thickness of the volcanic rocks is not known as a result of their uncertain structure; the volcanic body is apparently deformed in a doubly-plunging syncline.

The lithologic assemblage of the Fraser Lake mafic volcanic body is similar to the intermediate to mafic volcanic section of the northern belt, especially that of division D (Fig. 16). Correlation of this part of the Wasekwan Group suggests repetition by folding or faulting across the granitoid terrane between the northern and southern belts. An east-northeast-trending syncline was mapped in this area by Allan (1946) and later by Emslie and Moore (1961), but the available evidence indicates this structure is anticlinal. (The Lynn Lake rhyolite (4) at the southern margin of the northern belt is interpreted as north facing; the southern limb of the proposed anticline consists of the Fraser Lake mafic volcanic body (4), which is considered to be deformed in a synclinal structure).

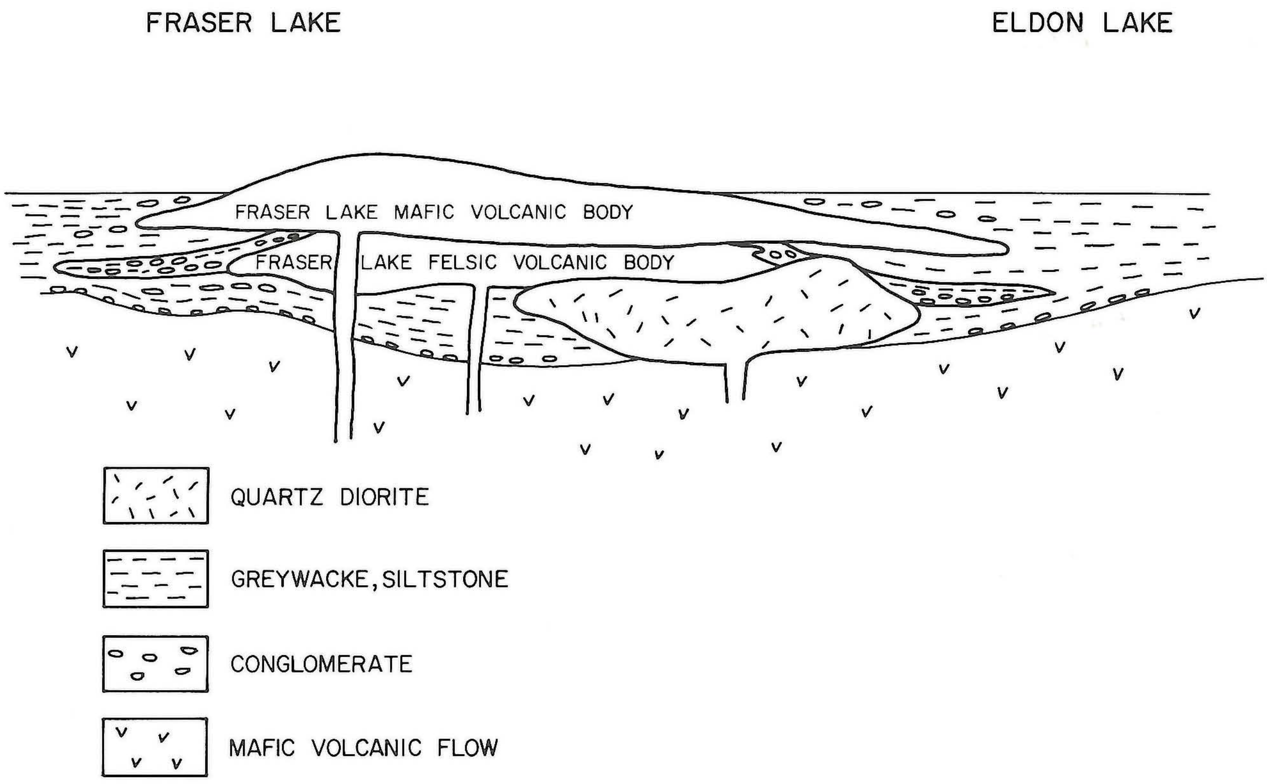


FIGURE 9: Schematic section showing relationships between the Fraser Lake mafic volcanic and felsic volcanic bodies and related sedimentary section.

TABLE 10: SUMMARY OF COMPONENTS COMPRISING THE HUGHES LAKE CALC-ALKALINE SUITE

POLE LAKE AREA		HUGHES LAKE AREA		CHEPIL LAKE AREA	
LITHOLOGY	**THICK-NESS (m)**	**LITHOLOGY**	**THICK-NESS (m)**	**LITHOLOGY**	**THICK-NESS (m)**
— Top not exposed —		Felsic tuff, minor rhyolite	700	— Top not exposed —	
CALC-ALKALINE SUCCESSION		Conglomerate, greywacke	200	CALC-ALKALINE SUCCESSION	
DIVISION C Porphyritic dacite, andesite; minor rhyolite	600	Tholeiitic basalt	1060	Laharic breccia, tuff; minor andesite	500?
				Rhyolite, aphyric and porphyritic andesite	500
DIVISION B Plagioclase-phyric and aphyric andesite, pyroclastic breccia, tuff; minor rhyolite	900	CALC-ALKALINE SUCCESSION		Massive and pillowed basalt (possibly equivalent to Hughes Lake LOWER SERIES)	800?
		UPPER SERIES Pebble conglomerate, pebbly mudstone siltstone, rhyolite	Local	— Base not exposed —	
DIVISION A Aphyric and porphyritic andesite, tuff, rhyolite; minor greywacke, siltstone	1200	Plagioclase-phyric and aphyric andesite, flow breccia, tuff; subordinate basalt	500		
Cockeram Lake aphyric basalt (tholeiitic)	2100 (max)	LOWER SERIES Aphyric and porphyritic basalt, basaltic andesite, local greywacke, siltstone, pebbly mudstone, laharic breccia	1950		
		— Base not exposed —			

HUGHES LAKE AREA

INTRODUCTION

A calc-alkaline suite including basalt, andesite, dacite, and minor rhyolite occurs in three geographic segments within the Hughes Lake area. The Hughes Lake suite is chemically and petrographically distinct from tholeiitic basalts in the Cockeram Lake area and plagioclase-phyric basalts in the northern belt.

The calc-alkaline suite overlies Cockeram Lake tholeiitic basalt (2) at Cartwright Lake and is overlain by olivine-normative tholeiitic basalt (2) southeast of Hughes Lake. The three segments of the suite (Pole Lake, Hughes Lake, and Chepil Lake) each contain an internal stratigraphy defined by lithology and composition (Table 10). Stratigraphic units cannot be confidently correlated between segments so the complete thickness of the suite is unknown; a minimum of 2500 m is exposed in each of the Pole Lake and Hughes Lake segments.

Massive and pillowed andesite flows predominate; basalt is common in the lower part of the Hughes Lake succession and low-silica dacite occurs at the top of the Pole Lake succession (Table 10). Rhyolite flows occur at several stratigraphic intervals within each individual succession, but are not common. Pyroclastic breccias occur only in the Pole Lake segment, and laharic breccias, greywacke, and siltstone are components of the Hughes Lake segment.

The suite has typical calc-alkaline petrochemical characteristics including (1) a limited range of FeO*/MgO ratios (1.11 - 1.91 for andesites), (2) no significant iron enrichment through the stratigraphic sections (for example, Fig. 12), (3) moderate Al_2O_3 contents (average 16.4% for andesites), and (4) definition of a typical calc-alkaline trend on an AFM diagram (Fig. 10). Andesites in the Hughes Lake Upper Series and Pole Lake divisions A and B are virtually identical in composition despite differences in field and petrographic parameters. These andesites have high contents of Ni and Cr (Table 11). It is noteworthy, however, that andesites in the Hughes Lake suite are geochemically distinct from those in the northern belt (Table 11).

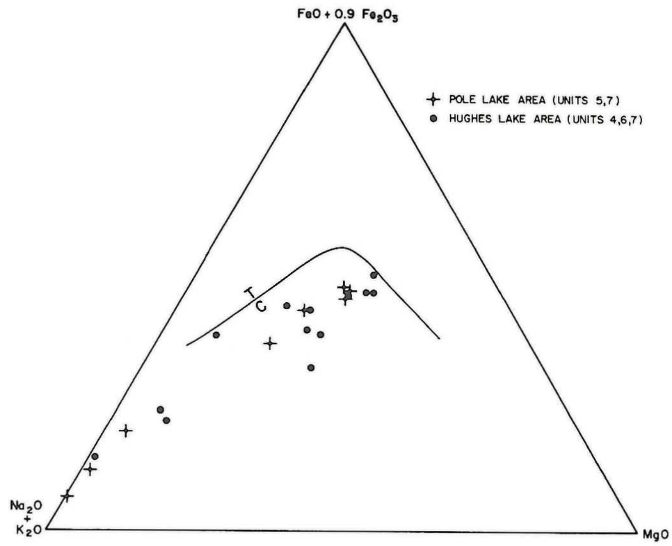


FIGURE 10: Ternary igneous AFM diagram showing analyses from the Hughes Lake calc-alkaline suite. Dividing line separating the tholeiitic field (T) from the calc-alkaline field (C) is after Irvine and Baragar (1971).

TABLE 11: COMPARISON OF GEOCHEMICAL CHARACTERISTICS OF ANDESITES FROM THE HUGHES LAKE CALC-ALKALINE SUITE AND THE NORTHERN BELT

	Hughes Lake	Northern Belt
Number of Samples	10	10
Al_2O_3 (wt. %)		
Average	16.42	18.12
Range	15.01 - 17.65	15.56 - 21.38
100 x FeO*/(FeO* + MgO)		
Average	62.7	73.6
Range	52.7 - 70.3	61.7 - 78.6
Ni (ppm)		
Average	55	8
Range	24 - 80	<1 - 30
Cr (ppm)		
Average	68	27
Range	32 - 98	8 - 90
Mg/Ni*		
Average	424	2872
Range	305 - 673	1142 - 4403*

*Ratio not calculated for Ni contents below detectable limits.

INTERMEDIATE AND MAFIC VOLCANIC ROCKS (4)

HUGHES LAKE AREA

A band of predominantly intermediate and mafic flows and breccias extends from One Island Lake, along the eastern margin of Hughes Lake, to join the northern volcanic belt in the Low Lake-Key Lake area. Chemical and petrographic data suggest that the Hughes Lake portion of the unit comprises a different magmatic suite than the Low Lake-Key Lake segment, which has affinites with the Northern Belt basalt suite. The two magmatic groups must come into juxtaposition in the area north of Hughes Lake but limited outcrop and sparse chemical data do not permit their separation.

The base of the unit is intruded by granitoid plutons; consequently the volcanic section varies considerably in thickness along its length. East and southeast of Hughes Lake the unit faces southwest, and has a maximum thickness of 2500 m. Southeast of Hughes Lake unit 4 is overlain by aphyric, olivine-normative basalt flows (2; Figs. 11 and 12). In the Marrow Lake-Chepil Lake area the intermediate and mafic volcanic rocks are overlain by a suite of interlayered andesite and rhyolite flows (5a, 7). Between Stan Lake and the north end of Hughes Lake unit 4 is uncomfortably overlain by Sickle Group conglomerate and arkose.

HUGHES LAKE

In the Hughes Lake area a thick (maximum 2 km) aphyric basalt-basaltic andesite section (Lower Series) is overlain by approximately 500 m of plagioclase-phyric andesite and local rhyolite (Upper Series). The Upper Series andesites are compositionally similar to andesites in the Pole Lake area (divisions A and B, Table 10).

LOWER SERIES

The lower, mafic portion of unit 4 southeast of Hughes Lake (Fig. 11) has a maximum thickness of 1950 m northwest of One Island Lake. The Lower Series thins to the north, and probably terminates in the vicinity of the Hughes River at the east shore of Hughes Lake. The flows weather dark green to grey-green, and are medium grey to grey-green on fresh surfaces. They are almost invariably massive: flow breccia is rare and pillowed flows are absent. Most of the flows are aphyric, but sparsely plagioclase-phyric and pyroxene-plagioclase-phyric flows are locally interlayered with aphyric basalt in the southeastern portion of the unit. Amygdales (1 - 5 mm in diameter) occur locally, and may be concentrated in irregular or planar zones. Epidosite domains, which occur sporadically throughout the mafic succession, are ovoid, irregular, or diffuse zones 10 - 50 cm across, commonly (but not exclusively) associated with densely amygdaloidal zones in flows. The epidosite domains are probably similar in origin to those developed in the aphyric basalt (2) at Cockeram Lake.

Fine grained sedimentary interlayers (up to several metres thick) occur intercalated with massive flows in the lower part of the unit. Siltstone with a well developed amphibole blastesis is most common; some interlayers consist of alternating siltstone and mudstone.

The basalts have an upper greenschist or lower amphibolite facies mineral assemblage consisting of green hornblende (40 - 50%), plagioclase (30 - 40%), epidote (2 - 10%), magnetite (2 - 5%), biotite (overprinting amphibole; 0 - 5%), quartz (2%), and local pyrite. Primary textures are commonly obliterated. The basalts are fine grained (0.1 mm), equigranular, with equant to acicular hornblende and recrystallized, interstitial, untwinned plagioclase. Locally, traces of the primary plagioclase-microlite texture are preserved. Epidosite domains consist of a mass of fine grained, anhedral interlocking clinozoisite (80%), intersititial quartz (20%), and quartz-filled amygdales.

UPPER SERIES

The top 500 m of unit 4 in the Hughes Lake area consists of intermediate flows (commonly plagioclase-phyric), flow breccia, and tuff, with subordinate basalt. Pebble conglomerate, pebbly mudstone, siltstone, and locally rhyolite occur at or near the top of the unit. The sediment and rhyolite assemblage commonly marks the break between the underlying calc-alkaline succession (4) and the overlying tholeiitic basalt (2; Fig. 11).

Intermediate flows in the Upper Series are massive, and weather grey-green to medium grey; basaltic flows weather dark green. In contrast to the Lower Series mafic flows, many Upper Series flows are porphyritic with 5 - 25 per cent plagioclase phenocrysts (0.5 - 1.5 mm) and, locally, up to 10 per cent amphibole pseudomorphs after pyroxene phenocrysts (0.2 - 0.5 mm). Ovoid polymineralic and quartz amygdales (1 - 3 mm) are common, concentrated in zones within individual flows. These densely amygdaloidal zones are commonly sites of intense epidotization; they do not appear to represent flow tops.

Plagioclase phenocrysts are subhedral and generally turbid, with concentric zones and/or cores preferentially replaced by epidote and amphibole. Relict normal and oscillatory zoning was noted in one specimen. The groundmass in least-recrystallized flows has a felted texture, with turbid plagioclase microlites (0.2 - 0.4 mm) and interstitial mafic minerals. The range of typical modes includes plagioclase (50 - 60%), amphibole (10 - 40%), biotite (0 - 10%), chlorite (0 - 20%), epidote (5 - 10%), magnetite (3%), and quartz (2 - 5%). A zone of locally intense recrystallization and amphibole blastesis extends 3 km southeast of Hughes Lake and obliterates primary textures. Within the zone, randomly-oriented, acicular, bluish green hornblende blasts (to 1.5 mm) are commonly associated with biotite-chlorite aggregates.

Flow breccia occurs predominantly southeast of Hughes Lake. The breccias are monolithologic, unsorted, non-stratified, and matrix supported. They are interlayered with massive flows and subordinate tuffs. Fragments comprise 15 - 25 per cent of the deposits; they are 2 - 50 cm long but are generally less than 10 cm long. Their shape is extremely variable (lensoid, subrounded, and subangular) and most fragments are densely amygdaloidal. The matrix has a magmatic texture; it is commonly plagioclase-phyric and contains only a few amygdales.

The distribution of pyroclastic rocks (tuff, lapilli tuff, and breccia) corresponds approximately with the distribution of flow breccia. Tuff and lapilli tuff deposits are stratified (2 mm - 50 cm) and interlayered at a scale of several metres with flows and autoclastic breccia. Fine grained tuff is commonly laminated; one plagioclase crystal-bearing bed displays normal grain-size grading. Lapilli tuff occurs as thin interbeds in fine grained tuff or as thick (up to 5 m) poorly layered deposits. Lapilli (3 mm - 3 cm) are rounded, subrounded, or subangular, and are commonly replaced by epidote. Weak normal grading of lapilli was noted in one unit at least 5 m thick. Undifferentiated volcanic breccias are monolithologic, and range from relatively coarse, non-stratified, matrix supported deposits to finer, stratified (30 - 70 cm) deposits. A coarse amphibole blastesis is developed in the matrix of some breccias.

NORTH OF HUGHES LAKE

Unit 4 rock types in the largely drift covered area between Hughes Lake and Low Lake are very similar to those in the Hughes Lake segment. At the north end of Hughes Lake massive aphyric mafic flows, with subordinate pillowed flows and pillow breccia, underlie a suite of interlayered andesite (5a) and rhyolite (7) flows. East of Marrow Lake unit 4 comprises massive aphyric to weakly plagioclase-phyric mafic flows, minor pillow breccia, and mafic lapilli tuff. The tuff is a crudely stratified deposit at least 50 m thick, consisting of 50 - 60 per cent epidotized, subangular lapilli (1 mm - 2 cm) in a fine grained matrix. In the area north of Hughes Lake and at Marrow Lake mafic flows are amygdaloidal (1 - 3 mm) and commonly contain ovoid epidosite domains. Between the Hughes River and Low Lake a more diverse assemblage is exposed, including aphyric, plagioclase-phyric, and pyroxene-phyric intermediate flows, aphy-

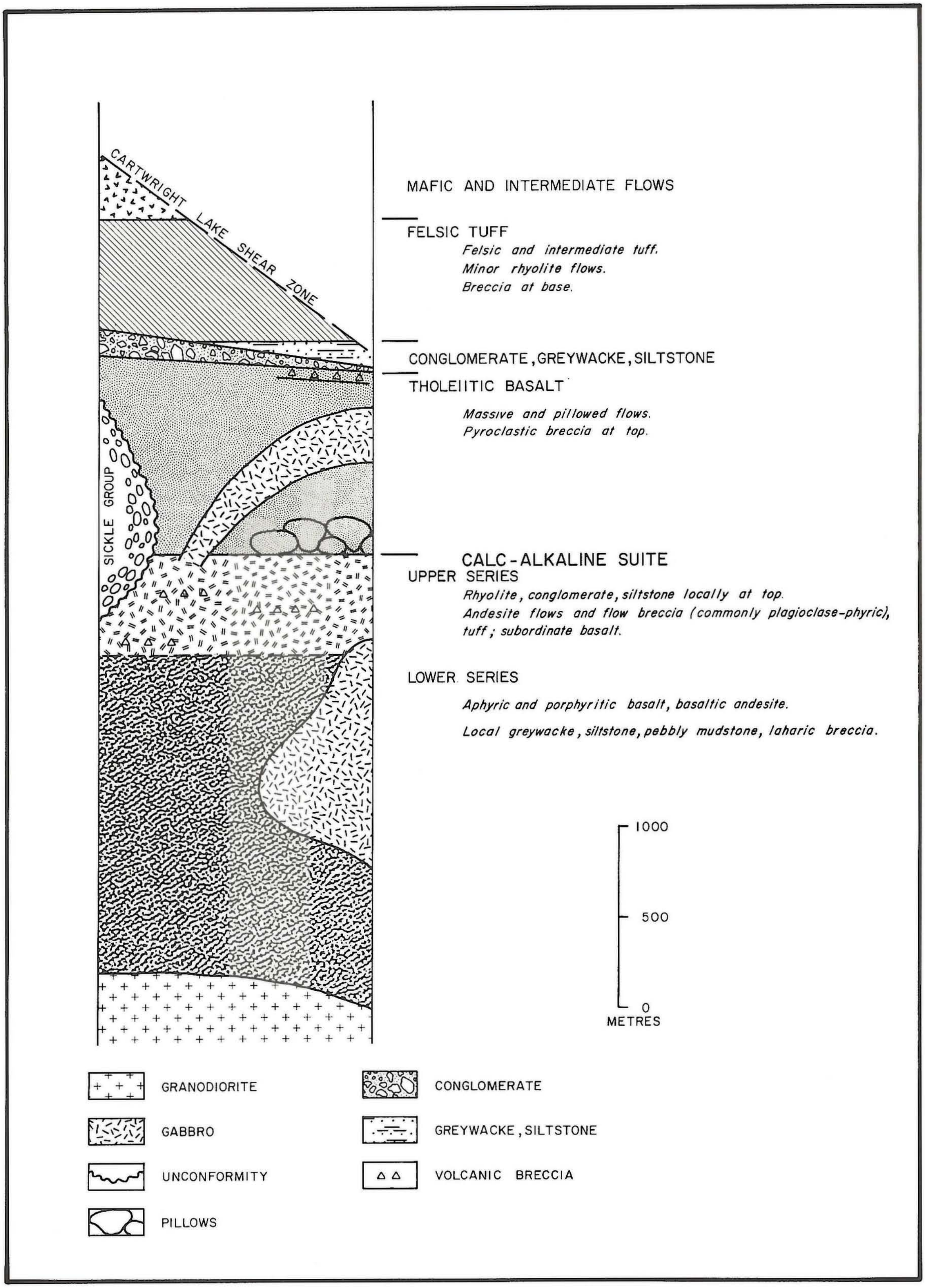


FIGURE 11: Stratigraphic relationships in the volcanic section southeast of Hughes Lake, between the Hughes River and Westdal Lake.

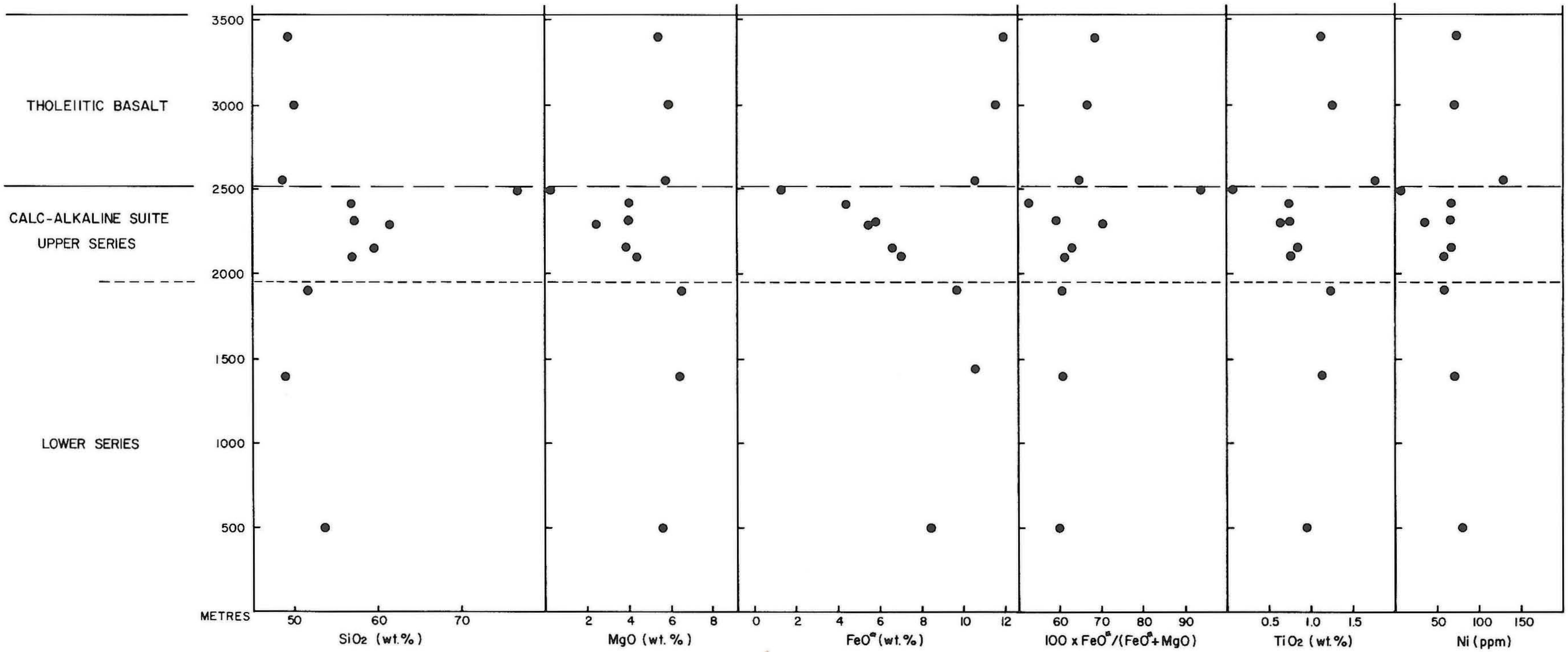


FIGURE 12: Variation in chemical composition with stratigraphic elevation, in the volcanic section southeast of Hughes Lake. The contact between the calc-alkaline suite and the overlying tholeiitic basalt is chemically abrupt.

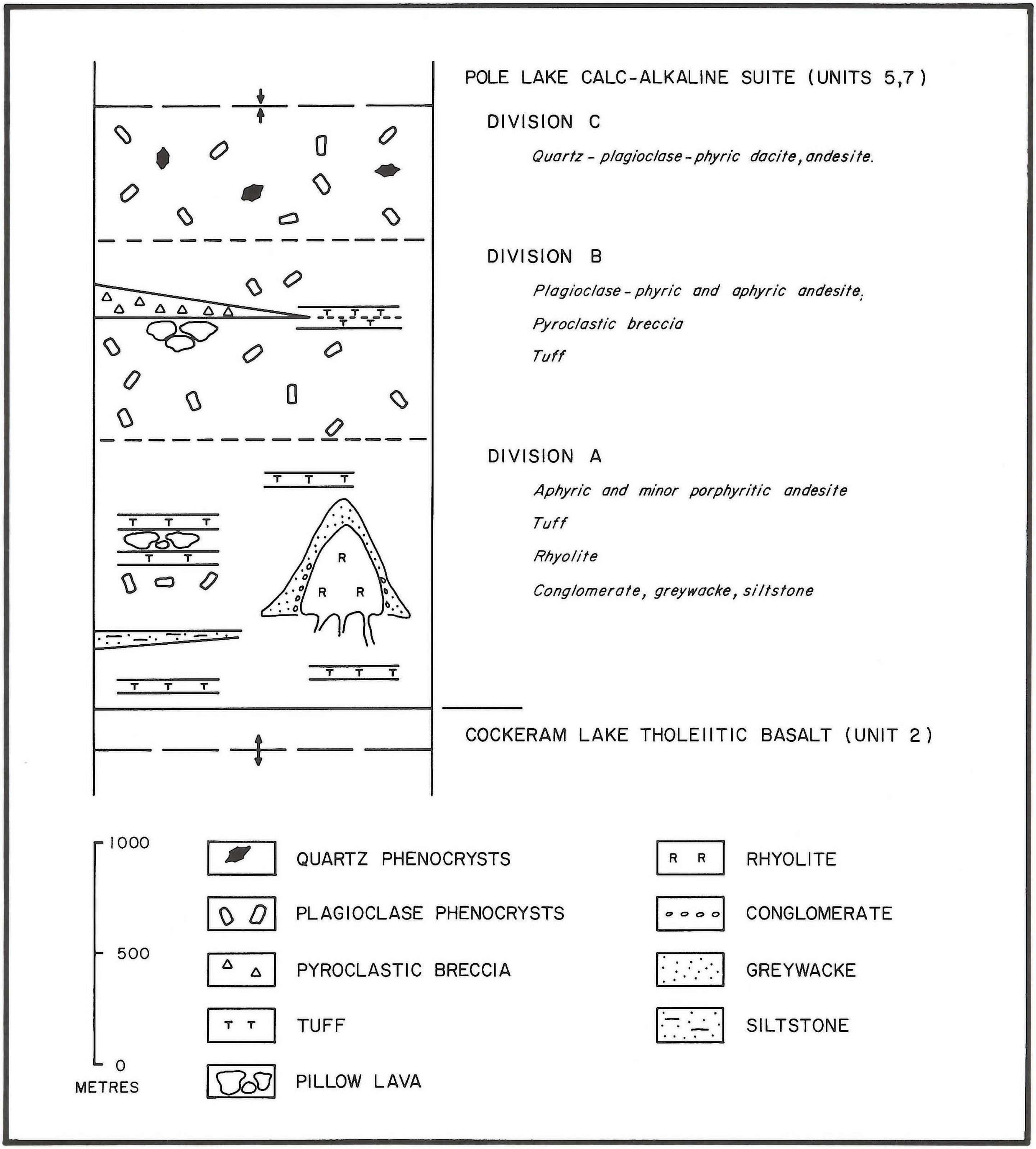


FIGURE 13: Stratigraphic relationships in the Pole Lake segment of the Hughes Lake calc-alkaline suite.

ric mafic flows, polymictic pebble conglomerate, and massive rhyolite flows.

INTERPRETATION

Unit 4 in the Hughes Lake area represents a calc-alkaline basalt-andesite succession with a maximum exposed thickness of 2500 m. The uppermost 500 m comprises predominantly andesitic material which is chemically similar to the Pole Lake andesite (5).

A subaqueous environment of deposition is inferred for the Hughes Lake flows, even through pillowed flows are absent. The occurrence of intercalated water-laid pebbly mudstone, siltstone, and mudstone deposits, and the absence of thick fragmental units (which typically occur in subaerial intermediate volcanic sequences (Ayres, 1978) supports this interpretation.

INTERMEDIATE AND FELSIC VOLCANIC ROCKS (5), POLE LAKE AREA

A calc-alkaline suite consisting of andesite, dacite and minor rhyolite is located between Cartwright Lake and Ron Lake. The suite is contained in two northeast-trending folds, and is in large part bounded by pre-Sickle plutons and by fault zones (Cartwright Lake shear zone, Moses Lake shear zone, Muskeg Lake fault). A total stratigraphic thickness of approximately 2700 m is present between the anticlinal axial trace passing through Cartwright Lake (exposing the base of the unit) and the synclinal axial trace passing through Pole Lake (the top of the succession is not exposed). The calc-alkaline rocks lie with apparent conformity on pillowed aphyric basalt (2) at Cartwright Lake. The unconformable contact with Sickle conglomerate (11a), which truncates the stratigraphy of the volcanic unit, is masked by zones of intense schistosity.

Three stratigraphic divisions are recognized in unit 5 (Fig. 13). The lowermost division (A), overlying pillowed basalt (2), is lithologically the most diverse. It comprises approximately 1200 m of predominantly aphyric intermediate flows, intermediate and felsic tuff, minor clastic sediments, and a small rhyolite extrusive centre (Cartwright Lake rhyolite, 7) flanked by fine grained sediments (9c, 9g). The middle division (B) consists of approximately 900 m of plagioclase-phyric and aphyric andesite flows; a unit of pyroclastic breccia (100 m thick) occurs in the upper part of the division. The uppermost division (C) consists of at least 600 m of quartz-plagioclase-phyric dacite and andesite flows, and rare rhyolite flows. The succession is intruded by numerous small, fine grained quartz diorite and hornblende diorite plugs and dykes (14; analysis 61, Appendix) which may be hypabyssal equivalents of the intermediate flows.

The volcanic rocks contain greenschist facies mineral assemblages: the amphibole is commonly pale green actinolite, and primary calcic plagioclase is pseudomorphed by albite. Primary structures and textures are preserved in areas not immediately adjacent to major shear-zones.

Chemical analyses of members of the suite (Appendix) are typical of the calc-alkaline series. The rocks plot well within the calc-alkaline field on an AFM diagram (Fig. 10) and appear to represent two populations defined by SiO_2 content: (1) an andesite-low silica dacite group (55 - 64% SiO_2) and (2) rhyolite group (76 - 77% SiO_2). The Pole Lake andesites are chemically similar to unit 4 andesites southeast of Hughes Lake.

ANDESITE (5a)

Andesite is the predominant lithology in the Pole Lake area. The flows weather shades of buff, grey-green, blue-green, and light green, and are light grey or light green on fresh surfaces. In the lower part of the unit (division A, Fig. 13) the flows are predominantly aphyric, and are interlayered with intermediate and subordinate felsic tuff. Flows in division B are commonly plagioclase-phyric, and are not interlayered on a small scale with pyroclastic deposits. Andesite and low-silica dacite flows in the upper part of the unit are characterized by the presence of both plagioclase and quartz phenocrysts, and are discussed separately (5b, below).

Simple, massive andesite flows predominate; flow breccias, although present, are rare. Individual flows could rarely be measured; those interlayered with tuff range from 3 m to 10 m thick. Pillowed flows occur in division A, east of Cartwright Lake, and in division B, south of Pole Lake.

Mineral assemblages developed in the andesites include:
(1) plagioclase - biotite - epidote - chlorite - quartz;
(2) plagioclase - actinolite - epidote - biotite - quartz;
(3) plagioclase - actinolite - epidote - quartz.

Leucoxene, carbonate, and apatite are accessories. Biotite, which locally replaces amphibole, is partly altered to chlorite. The amphibole (probably actinolite) is commonly pale green, weakly pleochroic, and fibrous or prismatic. Dark green, strongly pleochroic, subidioblastic hornblende is rare. Plagioclase phenocrysts and microlites are largely pseudomorphed by albite; the local occurrence of more calcic plagioclase (andesine) probably reflects relict primary compositions.

Porphyritic flows contain 10 - 20 per cent plagioclase phenocrysts 0.5 to 1.5 mm in size. The phenocrysts are euhedral to slightly corroded. Polysynthetic and simple twinning is common. Alteration of phenocrysts varies from cloudy incipient saussuritization to complete pseudomorphic replacement by coarse grained epidote. Some phenocrysts are partially recrystallized to untwinned subgrains. A few flows contain 2 per cent amphibole pseudomorphs after pyroxene phenocrysts (0.2 - 1 mm in diameter). The groundmass consists of plagioclase microlites (0.1 - 0.3 mm) with interstitial amphibole, biotite, epidote, quartz, and leucoxene. The plagioclase laths are partially recrystallized, and are variably (0 - 70%) altered to saussurite and granular epidote. In most of the flows the groundmass microlites are randomly oriented, but some samples display a distinct pilotaxitic texture.

The majority of flows contain amygdales which range from less than 1 mm to 3 cm in diameter (generally less than 5 mm). Small amygdales (up to 1 mm) are spherical; larger ones are ovoid. Amygdales are generally composed of fine grained aggregates of quartz (commonly at the rim), epidote, carbonate, and plagioclase in granoblastic texture; accessories include biotite, chlorite, amphibole, sphene, pyrite, chalcopyrite, hematite, microcline, and sericite. Amygdales are generally randomly distributed throughout a flow, but concentrations of large amygdales in streaky zones occur locally; some are interpreted as flow tops. The pillowed flows near Pole Lake contain concentrically zoned, ovoid amygdales 1 - 5 mm in diameter.

Aphyric flows, which are the prominent type in division A, are intercalated with porphyritic flows in division B. Aphyric flows are texturally and mineralogically similar to the groundmass of porphyritic types, and many have a subporphyritic texture.

DACITE (5b)

Flows characterized by the presence of both plagioclase and quartz phenocrysts comprise the top of the calc-alkaline succession (division C, Fig. 13). Silica content of the flows range from 57.55 per cent to 63.40 per cent (analyses 38 to 40, Appendix) so some of the rocks are andesites *sensu stricto*; however, flows of unit 5b have on average more biotite, less amphibole, and lower normative and modal colour indices than the underlying andesites (Table 8). Rhyolite flows comprise a minor part of the division C.

Massive, homogeneous dacite flows weather light grey-green, greenish white, or buff, and fresh surfaces are light grey. The nature and distribution of amygdales is similar to that in the underlying andesites.

Euhedral plagioclase phenocrysts (0.5 - 2.5 mm) comprise 2 - 10 per cent of the flows. They are similar in habit and alteration to plagioclase phenocrysts in andesites. Some phenocrysts display continuous normal zoning or, less commonly, oscillatory zoning.

Quartz phenocrysts (0.5 - 1.5 mm) comprise 2 per cent of the flows. They include single, strained crystals and recrystallized, granoblastic, rounded aggregates; some crytals are deeply embayed. The groundmass consists of randomly-oriented plagioclase microlites (0.1 - 0.2 mm) and interstitial amphibole, biotite, quartz, and epidote. Pilotaxitic textures occur locally but are not common.

TUFF (5c)

Intermediate tuff occurs predominantly within the lower portion of the calc-alkaline suite (Fig. 13). Mappable units of intermediate tuff are those at the northeast end of Cartwright Lake, east of Pole Lake, and between Moses Lake and Wasekwan Lake. In addition, intermediate tuff is intercalated with flows or sediments in the Cartwright Lake area. Each deposit has a characteristic fragment and crystal assemblage, range of bed forms, and range of composition. Metamorphic recrystallization and deformation has produced in all tuff a schistose matrix composed of fine grained plagioclase, quartz, chlorite, biotite, epidote, magnetite, and carbonate; their proportions vary with the composition (intermediate, felsic) of the tuff. Plagioclase and rarely quartz crystal fragments also occur in the matrix. Plagioclase crystals are replaced by epidote and albite.

NORTHEAST END OF CARTWRIGHT LAKE

Light brownish-green lithic crystal tuff forms a unit 100 m thick, exposed in the northeastern part of Cartwright Lake. It directly overlies Cockeram Lake aphyric basalt (2) and underlies massive and pillowed intermediate flows. A crude medium-scale layering is defined by variation in the content of plagioclase crystals and lithic fragments. Contacts between beds are not sharply defined. Euhedral plagioclase crystals (0.5 - 1.5 mm) comprise approximately 15 per cent of the tuff, and flattened intermediate to felsic lapilli 3 mm to 2 cm long comprise up to 20 per cent of some strata. A diffuse lamination defined by variable mafic content is locally developed. The coarse nature of the crystal and lithic components indicates a relatively proximal environment of deposition (Walker, 1971).

The lithic tuff is laterally gradational (to the west) to a well layered, fine grained, possibly reworked tuff which contains only minor small plagioclase crystal fragments and no lithic fragments. This lateral gradation suggests that the source area of the tuff lies to the east of Cartwright Lake.

EAST OF POLE LAKE

Stratified intermediate tuff, felsic lithic-crystal tuff, and rare intercalated rhyolite flows comprise a deposit at least 100 m thick and 1 km long, within the upper part of stratigraphic division B (Fig. 13). The tuffs lie on strike with a major unit of pyroclastic breccia (5d, below); one stratum in the tuff is interpreted as the distal facies of the breccia. The tuff deposit is overlain by plagioclase-phyric andesite flows, but the underlying rocks are not exposed.

The intermediate tuff weathers grey to greyish buff, and is light grey or grey-green on fresh surfaces. Rhyolitic tuff is light buff in colour. Bedding (5 mm - 2 m) is defined by: (1) the content of plagioclase crystals, quartz crystals, and mafic minerals, and (2) intensity of foliation (intermediate tuffs are relatively better foliated than felsic types). One graded bed 10 cm thick was observed, with a quartz and plagioclase crystal-rich base grading to a crystal-poor top.

Quartz crystals (0.3 - 2 mm) and plagioclase (0.4 - 1 mm) are subhedral to subrounded in shape and are variably fractured, corroded, and embayed. Quartz and plagioclase crystals may each comprise up to 5 per cent of the tuff. Lithic fragments are not readily observed in outcrop but are visible in thin section: the fragments (aphyric rhyolite and microlitic andesite) are up to 3 mm long and comprise up to 10 per cent of some beds. A felsic tuff unit contains oval spherulites 0.5 - 2 mm in diameter composed of radiating blade-like crystals of feldspar.

EAST SIDE OF CARTWRIGHT LAKE

A 210 m thick volcanic section in an area of moderate exposure consists of interlayered proximal pyroclastic deposits and flows. Tuff units are 3 - 15 m thick and intercalated flows are 3 m to at least 20 m thick. Contacts between tuff and flows are planar, slightly undulatory, or (rarely) irregular.

The pyroclastic deposits include moderately sorted lapilli tuff and subordinate crystal tuff; units with the largest fragments display the poorest sorting. Stratification within individual layers is absent or very crude. Fragment-supported breccias commonly have a carbonate matrix and matrix-supported lapilli tuffs have a matrix of fine grained volcaniclastic material. The composition and texture of these fragments and the associated flows are similar, indicating a common source.

The lapilli tuffs are monolithologic. Plagioclase-phyric andesite lapilli weather light grey, buff, or light grey-green; their colour is largely governed by the degree of epidote replacement. The lapilli are subangular to rounded, but are locally tectonically flattened. Amygdales (up to 5 mm in diameter) are common, and some lapilli are densely amygdaloidal.

Massive crystal tuff weathers buff and contains abundant 1 mm euhedral plagioclase crystals. One crystal tuff unit contains sporadic blocks and slabs of chert probably derived from interpillow chert at the top of the underlying plagioclase-phyric pillowed flow. Lensoid bodies rich in lapilli (e.g. 0.5 x 2 m in size) occur locally in the crystal tuff. The incorporation of fragments from the substrate and the occurrence of coarser pyroclastic lenses are characteristic of the basal parts of pyroclastic flow deposits (Walker, 1971). The association of these deposits with pillowed lavas indicates a subaqueous depositional environment.

The pyroclastic deposits and intercalated flows comprise a proximal assemblage, in contrast to the fine grained tuff-siltstone assemblage at the south end of Cartwright Lake (below).

SOUTH END OF CARTWRIGHT LAKE

Fine grained tuff and sediments comprise a 200 m thick unit adjacent to the Cartwright Lake shear zone. The detrital rocks are underlain(?) to the north by intermediate flows.

The rocks include plagioclase-crystal tuff, very fine grained, pinkish felsic tuff, and siltstone. They weather light brown or buff, are finely layered (2 mm - 3 cm). The crystal tuff contains 15 per cent subhedral plagioclase crystals and angular crystal fragments (0.4 - 1 mm). Strongly developed tectonite fabrics and abundant carbonate and quartz stringers are structures related to the nearby Cartwright Lake shear zone.

The fine grained, finely interlayered tuff and sediment is interpreted as relatively distal material derived from the Pole Lake volcanic centre. The unit may be laterally equivalent to strongly deformed intermediate tuff and sediment adjacent to the Cartwright Lake shear zone south of Shortie Lake, 12 km to the west (below).

MOSES LAKE—WASEKWAN LAKE

A heterogeneous assemblage of intermediate plagioclase-crystal tuff, felsic crystal tuff, mafic tuff, and minor fine grained sediments forms a unit 400 m thick, exposed along a prominent ridge between Moses Lake and Wasekwan Lake. The Cartwright Lake shear zone, which marks the contact between the volcanic terrane to the north and a plutonic terrane to the south, is coincident with this unit. The rocks are strongly foliated, crenulated, and contain retrograde, greenschist facies mineral assemblages. Primary structures other than gross lithologic layering and relict plagioclase phenocrysts have been obliterated.

Intermediate tuff weathers brownish-tuff to light grey-green, and contains 2 - 20 per cent subhedral plagioclase crystals (1 - 3 mm). Felsic tuff weathers buff to white, and contains sporadic plagioclase crystals (0.5 mm) and rounded quartz crystals (1 mm) in a fine-grained matrix containing white mica. Near Wasekwan Lake these lithologies are intercalated with mafic tuff and flows.

The high aeromagnetic signature of this unit (1976 Questor Input airborne magnetometer survey) is presumably due to the presence of desseminated magnetite blasts which comprise approximately 2 - 3 per cent of intermediate tuffs. The linear magnetic "high" can be traced into the Cartwright Lake area.

The tuffaceous rocks overlie a thin (200 m) unit of fine grained volcaniclastic sediments which in turn overlie the flank of the Cockeram Lake tholeiite shield. The sediments and tuff comprise a westward-thinning, relatively distal deposit, considered to be derived from the Pole Lake volcanic centre and shed onto the older basaltic volcano.

PYROCLASTIC BRECCIA (5d)

A unit of pyroclastic breccia occurs in the upper part of division B (Fig. 13), immediately south of Pole Lake. The unit has a maximum thickness of approximately 150 m at Pole Lake, and thins eastwards. The distal portion of the deposit is a thin bed of carbonate-matrix lapilli-crystal tuff 2 km east of Pole Lake.

The breccia overlies massive and pillowed andesite. At Pole Lake the deposit overlies altered, heavily carbonatized, massive andesite which grades locally to a densely pitted, scoriaceous andesite. Zones of breccia occur within the massive and scoriaceous material. The carbonatized, scoriaceous and brecciated andesite directly underlies the thickest part of the breccia, and may represent a near-vent deposit. The top of the breccia unit is expressed topographically as a north-facing scarp; rocks directly overlying the breccia are not exposed. The breccia is laterally equivalent to aphyric andesite flows and more distal intermediate and felsic tuff.

The breccia is clast supported and cemented by fine grained, white, granular carbonate. The top of the unit has a matrix of biotite and carbonate. Outcrop surfaces of the breccia are characterized by strong differential weathering with conspicuous pitting and excavation of the carbonate matrix.

Stratification is not developed but the lower third of the deposit is graded. At the base, fragments range in size from 5 mm to 25 cm, and 40 per cent of the fragments are greater than 5 cm in diameter. The large fragments are angular, fine grained, and dense to moderately vesicular. Smaller fragments in the basal zone are tectonically flattened pumice lapilli. Twenty metres above the base the average fragment size is 2 cm, and the fragment size remains more or less constant from that point to the top of the exposed section.

Two fragment types occur in the basal zone of the breccia: a grey-green andesite (analysis 37, Appendix), and a subordinate grey-white, hard, "felsic" variety (Table 12). The grey-white fragments may represent epidotized, silicified equivalents of the green andesite, in which case the breccia is monolithologic. Small fragments in the upper two-thirds of the breccia include pumice lapilli (2 - 3 cm) and chips of microlitic andesite (Table 12). The pumice fragments contain up to 60 per cent ovoid vesicles (0.1 - 1 mm) filled with chlorite, epidote, quartz, feldspar, or carbonate. Sporadic vesicular bombs (up to 15 cm across) also occur in the upper part of the unit.

The absence of stratification or interbeds in the breccia, and the uniformly eastward-thinning nature of the deposit, suggests that most if not all of the breccia was emplaced during a single event. This event may have been a pyroclastic eruption incorporating Vulcanian and Strombolean elements (Parsons, 1969): the basal zone of the deposit (with a concentration of large, angular, dense fragments) may represent debris from the explosive fragmentation of a crystalline lava plug. Subsequent eruption of a large volume of gas-charged magma produced abundant vesicular lapilli and sporadic bombs, accompanied by progressively fewer accessory fragments from the plug and vent walls. The environment of deposition may have been subaqueous, inasmuch as the deposit directly overlies pillowed andesite southeast of Pole Lake.

TABLE 12: COMPOSITION AND TEXTURE OF FRAGMENTS IN THE POLE LAKE PYROCLASTIC BRECCIA (UNIT 5d).

	LARGE FRAGMENTS		SMALL FRAGMENTS	
	Grey-green	**Grey-white**	**Pumice**	**Andesite**
Plagioclase microlites	45		10	50 (An_5)
Untwinned plagioclase		10	X	
Quartz	minor	25		5
Actinolite	45			
Biotite	5	5		5
Chlorite	minor	minor	X	25
Epidote		60	X	10
Carbonate	minor			5
Texture	Pilotaxitic Amygdaloidal	Microlitic (Altered)	Densely vesicular Microlitic	Pilotaxitic Subporphyritic Amygdaloidal
Microlite grain size	0.1 - 0.3 mm	0.1 - 0.2 mm	0.15 mm	0.15 - 0.25 mm

X = present, abundance variable.

INTERPRETATION

The andesite-dacite-rhyolite suite represents a segment of a composite, calc-alkaline edifice which developed at least in part on the upper flank of an older, tholeiitic shield volcano (Cockeram Lake aphyric basalt, unit 2). A thin wedge of distal pyroclastic deposits and fine grained sediments derived from the calc-alkaline centre flank the andesitic pile and cover the tholeiitic shield; these deposits occur as far west as Foster Lake.

The source of the voluminous andesite flows and subordinate pyroclastic deposits is probably located east of Cartwright Lake. A near-vent environment is interpreted for the fragmental rocks at Pole Lake. The relatively minor development of fragmental unit and the local occurrence of pillowed flows implies that much of the deposition occurred in a subaqueous environment; subaerial environments are typically characterized by thick fragmental units (Ayres, 1978). The presence of large amygdales in pillowed andesite flows indicates emplacement in relatively shallow water.

CARTWRIGHT LAKE RHYOLITE (7)

A lens-shaped body of rhyolite approximately 1300 m long and up to 500 m thick occurs within the lower, lithologically diverse part of the Pole Lake calc-alkaline succession (division A, Fig. 13). The body is incompletely exposed, but bedding attitudes and bedding-cleavage discordance indicates that the rhyolite body is folded, in the hinge area of a tight northeast-trending anticline.

The rhyolite body conformably overlies rocks typical of the lower stratigraphic division (A) of unit 5 (Fig. 13), including aphyric and plagioclase-phyric andesite flows, intermediate hypabyssal intrusions, and layered intermediate to felsic tuff with intercalations of mudstone. A small, strongly deformed lens of rhyolite-pebble conglomerate, greywacke, and mudstone overlies the rhyolite. The lithology and petrography of pebbles and microclasts in the greywacke clearly indicate that the sediments were derived largely from the rhyolite.

The rhyolite body can be subdivided into lower and upper divisions. The lower division is 60 - 180 m thick, and consists of a stratified (3 - 30 m) succession of massive porphyritic rhyolite flows and sills(?), rhyolite microbreccia, rhyolite-globule rock (froth flows?), felsic tuff, rare plagioclase-phyric intermediate flows, and pebbly mudstones. The upper division, approximately 180 - 280 m thick, consists of massive, structureless, porphyritic rhyolite and rare strata of layered felsic tuff.

Mineral assemblages developed in the rhyolite (below and Table 8) represent the greenschist facies of metamorphism. Primary calcic plagioclase phenocrysts are pseudomorphed by albite. Tectonite fabrics, including rodding parallel to the axis of the anticline and a moderate northeast-trending cleavage, are developed but primary structures and textures are well preserved.

Chemical analyses (analyses 42, 43; Appendix) indicate the rhyolite is depleted in Mg0, Ca0, total iron, and TiO_2 relative to an average rhyolite composition (e.g. Le Maitre, 1976). The K_20/Na_20 ratios are comparable to those of calc-alkaline rhyolites.

MASSIVE PORPHYRITIC RHOLITE (7b)

Rhyolite weathers cream, light grey, or light greenish buff, and is light grey to light buff on fresh surfaces. It is hard and flinty, and breaks along closely-spaced fractures and joints. All of the flows are massive, and homogeneous in composition and texture. Flow margins contain small (1 - 2 mm) vesicles with bleached margins. Contacts between flows and intercalated microbreccia are sharp to finely brecciated. Contacts between flows could not be identified in the upper part of the body; in the lower part, flows interlayered with fragmental units are 10 m to more than 20 m thick.

Flow banding is not conspicuous on rhyolite outcrops but is apparent in some etched slabs. The bands are 2 mm to a few centimetres thick and are distinguished in thin section by minor but abrupt variations in ground-mass texture. At one locality, *approximately 50 cm of finely flow-banded, ultrasilicic, aphanitic* rhyolite occurs at the top of a flow overlain by microbreccia. The aphanitic rhyolite may represent a primary obsidian carapace on the porphyritic flow; similar relationships are described by Lowder and Carmichael (1970).

All of the flows are porphyritic and the proportion, size and distribution of phenocrysts is constant throughout the unit. Plagioclase phenocrysts (0.5 - 2 mm, 2 - 3%) are subhedral with slightly rounded corroded margins. The crystals display polysynthetic twinning and patchy sericite and carbonate alteration. Most plagioclase phenocrysts are pseudomorphed by albite (An_1-An_5); andesine (An_{33}) phenocrysts in one sample probably represent the primary plagioclase composition. Anhedral to subhedral strained quartz phenocrysts (0.5 - 2 mm, 1 - 3%) are commonly deeply embayed. The groundmass is a recrystallized, very fine grained (0.02 - 0.05 mm) mosaic of quartz, untwinned feldspar, sericite, biotite, carbonate, magnetite-hematite, and local pyrite (an average, estimated mode is listed in Table 8). In some thin sections the groundmass has a mottled texture defined by subparallelism of feldspar grains in ovoid to irregular areas 0.2 mm in diameter. These are presumably devitrification textures. Feldspar spherulites 1 mm in diameter and quartz-carbonate amygdales 0.5 mm in diameter are relatively uncommon. A parallel orientation of sericite flakes and quartzo-feldspathic lenticles defines the foliation.

RHYOLITE MICROBRECCIA (7d)

Finely fragmented rhyolitic material in a biotite-rich matrix occurs at several localities in the lower part of the rhyolite body. The best exposure of the fragmental material, a 30 m thick deposit sandwiched between rhyolite flows, displays all of the characteristics of the group and is described below.

White-weathering rhyolite fragments range from 1 mm to 3 cm in diameter but the majority are less than 5 mm. They are equant, subangular to highly irregular in shape, and many are characterized by microbrecciated margins. Some of the larger fragments are interconnected. They are composed of very fine grained, amoeboid mosaic of feldspar, quartz, and sericite; a few subhedral plagioclase phenocrysts (0.3 - 1 mm) and corroded quartz phenocrysts (0.3 mm) occur at the fragment margins. The matrix of the microbreccia consists of fine grained brown biotite, minor magnetite, small quartz and plagioclase crystal fragments, and finely comminuted rhyolite particles.

Massive rhyolite lava tongues 30 cm thick occur in the central zone of the fragmental deposit. The upper margins of the rhyolite tongues are finely brecciated, and the massive lava grades abruptly into microbreccia. The lower contacts of the rhyolite tongues are sharp and display minor fragmentation. This relationship, and the microbrecciated, irregular nature of the fragments themselves, suggests that the deposits are hyaloclastites, produced by quenching and thermal fragmentation of flows. The hyaloclastite subsequently underwent partial sorting resulting in: (1) local, crudely developed stratification, and (2) vague grading across the 30 m thickness of the deposit, defined by upward decrease in fragment abundance. The top of the deposit consists of laminated, fine grained felsic material without fragments.

ASSOCIATED MINOR ROCK TYPES

RHYOLITE—GLOBULE ROCKS

Strata composed of abundant 1 - 6 mm spherical or ovoid rhyolite globules in a biotite-rich matrix appear superficially to be a textural variety of rhyolite microbreccia. In fact, their origin was probably not related to thermal fragmentation of glassy flows but rather to disruption of the flow top by an explosive degassing process.

The relationship between rhyolite globule rocks and massive flows is not known due to poor exposure. Rhyolite globules comprise

50 to 80 per cent of the deposits, which are vaguely bedded at a scale of 1 cm to 1 m and contain some interlayers of laminated felsic material. The globules occur as isolated, discrete entities or, more commonly, as coalesced bodies with highly irregular, bulbous forms. The globules are composed of a recrystallized mosaic of quartz, feldspar, sericite, epidote, and biotite; corroded plagioclase phenocrysts up to 2 mm long commonly occur at globule margins. Patches of carbonate in some globules may represent recrystallized amygdales. The matrix of the rock is composed of fine grained biotite (50%), a chaotic mixture of small, corroded quartz and plagioclase crystals and crystal fragments, and porphyritic rhyolite granules.

The rhyolite-globule rocks probably originated by explosive vesiculation and disruption of the tops of lava flows; similar rocks have been described by Johnson (1968). In this interpretation explosive vesiculation produced rhyolite fragments which were sufficiently liquid to attain globular forms; many globules subsequently coalesced. The crystal and lithic debris in the matrix was produced during the process of vesiculation, either by quenching at the flow top or during a process of gas-steaming (Johnson, 1968). The globule rocks form relatively thick (metres), vaguely stratified deposits which closely resemble globule flows (Johnson, op. cit.) "sheets ... emplaced as emulsions of hot globules and gas that flowed down the slopes of the primitive volcano".

CRYSTAL TUFF

Rare strata of fine grained crystal tuff occur in both the upper and lower divisions of the rhyolite body. Crystal-rich tuffs are massive; the finer grained, crystal-poor tuffs are finely layered or laminated. One massive crystal tuff contains 30 per cent corroded, broken plagioclase crystals (0.3 - 1.5 mm) and 10 per cent irregular to bi-pyramidal quartz crystals (0.4 - 1 mm). The matrix consists of very fine grained crystal fragments, biotite, epidote, carbonate, and magnetite. Crystal fragments in laminated tuff are relatively smaller (0.2 mm) and less abundant.

The fine grained "tuff" may have been produced together with microbreccia by quenching and fragmentation of lava flows. The presence of laminated "tuff" at the top of the microbreccia deposit strongly suggests such a relationship.

PEBBLY MUDSTONE

Rocks interpreted as reworked fragmental material occur as units 3 - 18 m thick, interlayered with massive rhyolite and finely-layered reworked felsic tuff, within the lower division of the rhyolite body. The pebbly rocks lack stratification or sorting, and are matrix-supported. Densely vesicular white rhyolite pebbles (1 mm - 1 cm in diameter and up to 4 cm long) occur in a biotite-rich matrix.

FORM AND ENVIRONMENT OF DEPOSITION

The high thickness to length ratio of the unit and the interlayered nature of the lithologies suggests that the rhyolite body is a small, composite, dome-like extrusive centre. Discordant rhyolite dykes which occur subjacent to the rhyolite body may represent feeders to the massive flows.

There is some evidence that the flows in the lower part of the rhyolite body were extruded in a shallow water or shoaling environment and that the overlying rhyolite flows were extruded in a subaerial environment: (1) the restriction of microbreccia, most tuff, and pebbly mudstone to the lower half of the body suggests that fragmentation process(es) ceased to operate during the later development of the rhyolite centre. The microbreccia/hyaloclastites were produced by thermal stresses generated at a lava-water interface (Dimroth and Rocheleau, 1979); therefore, the absence of hyaloclastite in the upper part of the body might indicate that the ryolite became emergent; (2) globule flows, interpreted as the products of explosive vesiculation, occur in the lower division of the body and indicate a very shallow marine or subaerial environment of deposition; (3) part of the rhyolite body must have been subject to subaerial erosion to result in deposition of the overlying rhyolite pebble conglomerate, greywacke, and mudstone (9).

The Cartwright Lake rhyolite body is the largest of several small, isolated rhyolites within the Pole Lake calc-alkaline succession. These bodies occur within all three stratigraphic divisions of unit 5 and are not restricted to any particular horizon.

CHEPIL LAKE RHYOLITES (7)

Massive rhyolite flows are interlayered with massive and brecciated andesite flows (5a) in the area east of Chepil Lake. Flow attitudes and the distribution of lithologies suggest that the rhyolite and andesite suite forms a stratigraphic unit approximately 500 m thick, overlying massive and pillowed mafic flows at the north end of Hughes Lake. Rhyolite and andesite are overlain by heterolithologic volcanic breccias (lahars?, 8d) and subordinate andesite flows comprising the top of the calc-alkaline succession at Chepil Lake (Table 10).

The rhyolite flows are relatively thin, massive, tabular bodies; measured thicknesses range from 18 to 27 m. They weather light grey to buff and are light grey on fresh surfaces. Contacts with intercalated andesite flows are sharp. Phenocrysts are variable in abundance: subhedral plagioclase crystals (0.3 - 1 mm, glomerocrysts to 3 mm) comprise up to 10 per cent of the flows and rounded quartz crystals (0.3 - 1 mm) comprise only 1 per cent. Pinhead-sized vesicles (with bleached margins) and polymineralic amygdales occur in most flows. They may be distributed randomly throughout the flow or, more commonly, within zones near the flow margins. Trains of epidote amygdales or replaced spherulites (2 mm - 2 cm in diameter) occur in a marginal zone 3 m thick on one flow; the trains are oriented parallel to the flow contact.

The rhyolites have a mineral assemblage dominated by plagioclase (50 - 70%), quartz (10 - 20%), sericite (10 - 25%), and biotite (2 - 10%). Carbonate, epidote, magnetite, and chlorite are minor components. Subhedral plagioclase phenocrysts are partly altered to sericite and saussurite, and are locally recrystallized. The groundmass consists of a very fine grained mosaic of lath-shaped plagioclase (0.1 - 0.2 mm, An_5), recrystallized quartz and untwinned feldspar, and sericite. Primary textures are completely obliterated in some flows.

The rhyolites contain between 74 per cent and 76 per cent SiO_2, and have slightly more FeO, CaO, MgO, and TiO_2 than the Cartwright Lake rhyolite (analyses 46 & 47, Appendix). Total alkalis and K_2O are lower than those in the Cartwright Lake flows.

HUGHES LAKE APHYRIC BASALT (2)

A unit of aphyric basalt 1060 m thick is exposed east of Stan Lake and in the southeast bay of Hughes Lake. Only a small strike length (6 km) of the unit is preserved. It is truncated by a post-Sickle granodiorite pluton north of One Island Lake, and at Stan Lake the basalt is truncated by pre-Sickle quartz diorite and unconformably overlain by Sickle Group conglomerate.

Tops determined from pillowed flows indicate that the unit faces southwest. The basalt overlies 2500 m of calc-alkaline volcanic rocks (4, east of Hughes Lake; Fig. 11) and underlies a thin clastic wedge comprising pebble conglomerate (8b) and greywacke-siltstone (9b). The basalt directly overlies conglomerate, pebbly mudstone, siltstone, and rhyolite that occurs locally at the top of the calc-alkaline succession; elsewhere the contact between mafic flows of unit 2 and unit 4 is drawn where the flows take on a massive, greenish-black aspect. The contact between unit 4 and unit 2 is chemically abrupt (Fig. 12).

Pillowed flows, with intercalated massive flows, are confined to the lower 300 m of the unit. Massive flows and associated fine grained fragmental rocks (hyaloclastites?) are predominant in the upper 400 m of the units, and stratified pyroclastic breccia and tuff occurs at least locally in the uppermost 60 m. The unit is exclusively basaltic: intermediate or felsic volcanic rocks and sedimentary interlayers are absent.

The major element compositions of the Hughes Lake aphyric flows (analyses 8 to 11, Appendix) are similar to the compositions of the Cockeram Lake aphyric flows. Both suites are tholeiitic; the Cockeram basalts display limited iron enrichment whereas the Hughes suite is relatively uniform in composition from the base to the top of the unit (Fig. 12). The Hughes basalts are olivine-normative; in contrast, the Cockeram basalts are quartz-normative.

MASSIVE FLOWS (2a)

Massive flows weather greenish black and are dark grey-green on fresh surfaces. Contacts between flows are planar with only slight irregularities, and interflow breccia or chert is absent. Flow thicknesses are in the range of several metres but limited exposure prevented measurement of individual flows. Lath-shaped plagioclase phenocrysts (0.5 - 2 mm) comprise up to 30 per cent of some flows, and amphibole pseudomorphs presumably after pyroxene (1 mm) occur locally but are not abundant. Most flows contain ovoid quartz- or epidote-filled amygdales (0.5 - 2 mm); the small amygdales are randomly distributed throughout the flows but large (1 cm) amygdales occur only near the top and bottom contacts.

The flows are fine grained and contain an upper greenschist or lower amphibolite mineral assemblage comprising pleochroic green hornblende (50 - 70%), plagioclase (20 - 40%), epidote (3 - 10%), magnetite and leucoxene (3 - 5%), biotite (trace - 3%), and quartz (1 - 2%). Retrograde chlorite is a minor phase in some samples. Some flows retain the primary randomly-oriented plagioclase microlite texture; the plagioclase laths (0.2 - 0.7 mm) in one specimen are normally zoned with cores approximately An_{45}. Anhedral to subhedral hornblende is interstitial to the plagioclase laths. Recrystallized flows are composed predominantly of felted or structureless masses of fibrous amphibole; very fine grained, recrystallized plagioclase is interstitial.

PILLOWED FLOWS (2b)

Pillowed basalts occur only in the lowermost 300 m of the unit, where they are interlayered with massive flows. The pillowed flows weather pale yellow-green, in response to pervasive epidotization. Individual pillows are bun-shaped, 50 - 100 cm in maximum dimension, with narrow (1 - 3 mm) selvages. The outer one-half to one-third of some pillows has a concentric structure, defined by nested amygdaloidal shells 5 mm - 1 cm thick. Epidote amygdales are 0.5 - 1 mm in diameter at the pillow margins and 1 - 2 mm in the pillow cores. There is a suggestion in one series of exposures that the pillow size decreases up-section.

The texture of the pillowed basalt is similar to that of the massive flows, comprising a felted or swirled mass of plagioclase microlites (0.2 - 0.3 mm) with interstitial epidote and amphibole. Plagioclase phenocrysts (to 1 mm long) are lath-shaped, and commonly occur in cross- or star-shaped interpenetrant glomerocrysts.

PYROCLASTIC DEPOSITS (2d)

Stratified pyroclastic breccia and tuff locally constitutes the top 60 m of unit 2. The breccia is well exposed at a Manitoba Telephone System microwave relay station 1 km west of One Island Lake, and is remarkable for its excellent preservation of primary structures. The fragmental material sharply overlies massive flows and underlies pebble conglomerate (8b).

The deposit west of One Island Lake is stratified (2 - 50 cm), with beds defined by the abundance and size of basalt fragments. Thin beds (less than 10 cm) of lapilli tuff are crudely lenticular and contacts between strata are poorly defined. Interbeds of fine grained, internally laminated tuff are thin (up to 5 cm) and have sharp contacts with the coarser fragmental material. Sorting is poor, with slight positive correlation between maximum fragment size and bed thickness. Weak reverse grading was observed across one 40 cm thick lapilli tuff bed.

Basalt fragments are fine grained, weakly plagioclase-phyric, and variably amygdaloidal; amygdales (0.5 - 2 mm) are largest in the centres of the larger fragments. Most fragments are less than 5 cm in diameter, but blocks up to 27 cm across in some beds. The fragments are angular to subrounded and some have a dark green margin 1 - 2 cm thick. Some fragments, notably those which had a high primary vesicularity, are replaced by a coarse epidote-amphibole intergrowth.

Mafic tuff strata within the pyroclastic section are commonly 1 - 10 cm thick but range up to 2 m. Spherulites (0.5 - 3 mm in diameter), with a concentric internal structure composed of epidote and amphibole, are abundant in some laminae. Selective epidote and amphibole replacement of some beds is so coarsely developed that primary structures are destroyed.

The fragmental material is interpreted as pyroclastic debris deposited in a subaqueous environment. Subrounded vesicular masses of lava with quench selvages are essential fragments, whereas dense, subangular fragments may be shattered pyroclasts or accessory fragments. The delicately laminated nature of the tuff interbeds suggests subaqueous deposition.

INTERPRETATION

Most if not all of the aphyric basalt was emplaced in a subaqueous environment, as indicated by the occurrence of pillowed flows at the base of the unit and subaqueous pyroclastic deposits at the top. The morphology of the volcanic edifice is unknown because only a small segment is preserved.

The Cockeram Lake quartz-normative tholeiites and Hughes Lake olivine-normative tholeiites are not equivalent lithologies, despite gross petrographic similarities: the entire Hughes Lake calc-alkaline suite (4, 5 and 7) occurs stratigraphically between the two aphyric basalt units. Abrupt litholigic and major-element chemical discontinuities mark contacts between the tholeiitic and calc-alkaline successions.

HILL LAKES SEDIMENTARY SECTION (8b, 9b)

A unit of epiclastic rocks near the top of the volcanic succession at Hughes Lake (Fig. 11) consists of a basal conglomerate and overlying fine grained sedimentary rocks. The sedimentary sequence conformably overlies olivine-normative tholeiitic basalt (2) and underlies felsic tuff (7e); it is exposed between One Island Lakd and Gold Lake.

CONGLOMERATE (8b)

West of One Island Lake a conglomerate occurs at the base of the 200 m thick, south-facing sedimentary succession. The minimum exposed thickness of the conglomerate at that locality is 8 m; the maximum thickness must be less than 50m. At Hill Lakes the conglomerate is at least 100 m thick; the overlying and underlying rocks are not exposed, and the southern margin of the outcrop is intensely sheared. At Gold Lake the conglomerate is directly overlain by felsic tuff and subordinate felsic fragmental rocks (7e).

The conglomerate is polymictic, matrix-supported, partly sorted, and stratified (Table 13). Clast are subrounded and comprise predominantly mafic and felsic volcanic lithologies. Basalt clasts are dark green, fine grained, aphyric, and contain a felted plagioclase-microlite texture. Some are amygdaloidal. The basalt clasts contain up to 70 per cent hornblende and are commonly difficult to distinguish from the matrix, in contrast to the more conspicuous felsic pebbles. These weather light pink to light buff or white and consist of a very fine grained, largely recrystallized mosaic of lath-shaped plagioclase (0.1 - 0.2 mm), equant quartz, and minor biotite (5%), epidote, and magnetite. Phenocrysts of plagioclase and/or quartz occur in some of the felsic pebbles. The fine grained mafic mudstone matrix of the conglomerate consists of subequal amounts of hornblende and plagioclase, with minor quartz.

Interbeds of mafic mudstone are internally laminated; some beds contain isolated pebbles. A pronounced amphibole blastesis

TABLE 13: CHARACTERISTICS OF PEBBLE CONGLOMERATE (UNIT 8b) SOUTH OF HUGHES LAKE. GAP LAKE CONGLOMERATES (UNIT 10a) INCLUDED FOR COMPARISON

	Gold Lake (West)	Hill Lakes	One Island Lake (East)	Gap Lake (unit 10a)
WEATHERING COLOUR	Grey-green	Dark green	Medium grey	Light grey
LAYERING	1 - 4 m; stratified sequence of pebbly mudstone, mafic mudstone, mafic flows	20 cm - 1 m, defined by abundance, size, and lithology of clasts, and by mafic mudstone interbeds.	None	No layering in conglomerates. Rare greywacke interbeds.
CLAST SHAPE, LENGTH:WIDTH RATIO	Lensoid in section. L:W = 3 - 4:1	Lensoid in section. Some are rounded to subrounded. L:W = 2 - 3:1	Lensoid in section L:W = 2 -3:1	Strongly attenuated. L:W = 6 - 10:1 to 40:1
CLAST SIZE	Range = 5 mm - 5 cm long.	Range = 2 mm - 12 cm long. Average approximately 5 cm.	Range = 1 mm - 10 cm long.	Range = 2 - 40 cm long.
CLAST LITHOLOGY, IN DECREASING ORDER OF ABUNDANCE	(1) Felsic volcanic:aphyric and feldspar-phyric. Rare amygdales. (2) Mafic volcanic:amygdaloidal	(1) Mafic volcanic:quartz, epidote amygdales, some clasts weakly plagioclase-phyric. (2) Felsic volcanic:aphyric, feldspar-phyric, and quartz-feldspar-phyric varieties. (3) Mafic mudstone (4) Siltstone (5) Epidosite (rare) (6) Vein quartz (rare) (7) Chert (rare)	(1) Siltstone (2) Mafic volcanic (3) Intermediate-felsic volcanic	(1) Spotted felsic: 15% flattened amphibole aggregates (2) Buff felsic volcanic (3) White rhyolite (4) Mafic volcanic (5) Vein quartz (6) Granitoid: pink, medium grained (7) Tonalite?:grey-white, fine grained (8) Greywacke
SORTING	Possible local lithologic sorting but poor size sorting	Moderate	Poor	Poor
MATRIX	Mafic mudstone. Matrix supported.	Mafic mudstone. Clast-supported and matrix-supported beds.	Mafic mudstone. Matrix-supported.	Hornblende greywacke. Probably clast-supported.
INTERBEDS	(1) Mafic mudstone (2) Mafic flows: massive, 20 cm - 2 m thick, weakly amygdaloidal	Mafic mudstone, 5 - 50 cm thick.	None	Rare hornblende greywacke beds less than 1 m thick.
INTRUDED BY	(1) Felsic dykes or sills: 20 cm - 1 m thick, aphyric. Some have weakly amygdaloidal margins.	(1) Quartz-plagioclase-phyric felsic dykes: 20 cm - 1 m thick. Commonly subparallel foliation and bedding but locally discordant. (2) Mafic sills: 15 cm - 1 m thick. Amygdales to 5 mm concentrated in centre of sills.	(1) Mafic sill: 20 cm thick, subparallel foliation.	Dykes and sills are rare. (1) Mafic flow or sill: 20 cm thick, amygdaloidal. (2) Feldspar porphyry sills: 10 cm thick, parallel foliation.
MINIMUM THICKNESS	20 m	100 m	10 m	200 m

commonly obliterates primary textures. Dark green mafic mudstone clasts similar in composition to the interbeds are common in the thick conglomerate section at Hill Lake.

Vertical variation in the conglomerate can be recognized only at Hill Lakes. From the base to the top of the exposure (1) the maximum clast size decreases from 12 cm to 6 cm, (2) the pebble population changes from polymictic to predominantly felsic, (3) the proportion of pebbles to matrix increases, and (4) the composition of the matrix changes from mafic to intermediate.

The provenance of the conglomerate is apparently a diverse, predominantly mafic, volcanic terrane. The basalt clasts are petrographically similar to aphyric basalt flows (2) which underlie the conglomerate. The abundance of felsic volcanic pebbles is probably a function of their greater resistance to abrasion. Siltstone and mafic clasts are intraformational.

In summary, the wedge-shaped conglomerate body is thickest in the west, where it is directly overlain by felsic pyroclastic rocks, and thinnest in the east, where 200 m of fine grained sediments lies between the conglomerate and the felsic tuff. These relationships suggest that the source area of the conglomerate lay generally to the west.

HORNBLENDE GREYWACKE, SILTSTONE (9b)

Approximately 200 m of hornblende-blastic, fine grained sedimentary rocks overlie the basal pebble conglomerate west of One Island Lake. The unit wedges out to the west and is truncated by the Cartwright Lake shear zone in the east; it is exposed best in the vicinity of a Manitoba Telephone System microwave relay station 1 km west of One Island Lake.

Greywacke and pebbly greywacke occur as relatively minor interlayers in siltstone, near the base of the sequence. The greywackes weather light buff and do not contain amphibole blasts; a medium grained (0.5 - 1 mm) clastic texture is preserved. Beds (12 - 100 cm thick) are commonly massive or internally laminated. One bed 80 cm thick displays normal grading: grit with isolated pebbles occurs at the base and grades to fine sand with sporadic granules; siltstone occurs at the top of the bed. Pebbly beds (2 - 20 cm thick) contain subrounded, grey-weathering, feldspathic pebbles up to 2 cm in diameter.

Siltstone and fine grained greywacke are the predominant lithologies in the unit. The fine grained sediments comprise subunits 7 - 18 m thick defined by grain size, amphibole content, and degree of stratification. Bedding (5 - 20 cm thick) is defined by slight colour contrast and variable amphibole content, but lamination (1 - 5 mm) is more common than thicker bedding. Primary structures and textures other than stratification have been destroyed by recrystallization and amphibole blastesis. A typical siltstone comprises a very fine grained mosaic of untwinned plagioclase and quartz (60%), brown biotite (20%), blue-green hornblende (15%), epidote (5%), and magnetite (1%). The acicular hornblende blasts (0.5 - 2 mm) have random orientations, quartz and epidote inclusions, and biotite-depleted envelopes.

Primary compositional control on the development of amphibole blastesis is indicated by: (1) accentuation of primary vague lamination by preferential growth of amphibole in some laminae, and (2) restriction of amphibole to the fine grained fraction — for example, hornblende occurs in the silty top of a graded greywacke bed but is not developed in the sandy portion. Locally, however, an irregular blastesis is developed that is in part fracture-controlled: hornblendic lamination is absent, and equigranular siltstone grades in an irregular manner laterally to a hornblende-blastic siltstone.

Dark green amphibolitic strata occur near the middle of the sedimentary succession. The amphibolites are bedded (6 - 20 cm), internally laminated (5 - 15 mm), and have interlayered contacts with beds of buff, amphibole-bearing siltstone. The amphibolites are composed of hornblende, quartz, epidote and carbonate, with layering defined by variation in the ratio of hornblende to quartz. Mafic layers contain up to 70 per cent hornblende (20% quartz), and more leucocratic layers contain up to 50 per cent quartz (15% hornblende, 15% carbonate).

The preservation of graded bedding in some of the greywackes suggests that at least part of the sedimentary sequence was deposited from turbidity currents. The siltstones represent either deposits from weak turbidity currents or sedimentation of fine grained material through normal subaqueous settling. The amphibolites are probably derived from thin-bedded marly sediments. The vertical distribution of rock types though the unit (conglomerate and greywacke at or near the base, siltstone throughout, and subordinate limey sediments in the upper portions) indicates a decreasing rate of sedimentation with time.

The epiclastic wedge may represent a period of block faulting, which resulted in local subsidence of the underlying tholeiitic basalt and lead to deposition of conglomerate and later fine grained sediments.

GOLD LAKE FELSIC TUFF (7e)

A stratified assemblage of fine grained felsic tuff, intermediate tuff, rhyolite flows, and subordinate felsic fragmental rocks is exposed east of Gold Lake and east of Westdal Lake. The unit is at least 6 km long and approxiately 700 m thick. It is truncated at Gold Lake by quartz diorite, and is cut off east of Westdal Lake by the Cartwright Lake shear zone. The tuff overlies southwest-facing greywacke and conglomerate (9b and 8b, respectively) and thus comprises the uppermost portion of the Hughes Lake volcanic section (Fig. 11). Strongly deformed, poorly exposed, mafic and intermediate flows west of Gold Lake apparently overlie the felsic tuff.

The Gold Lake locality, described below, is the most complete section through the unit. East of Westdal Lake the felsic rocks have been intruded by gabbro sills and subsequently deformed in tight chevron-folds with transposition of layering; this section is incomplete due to faulting along the Cartwright Lake shear-zone. The section at Gold Lake also is locally intensely deformed: the rocks closest to the shear zone are veined by quartz, strongly foliated, and chevron-folded. Tectonite fabrics are less pervasive in the area to the north, but a very strong foliation and local quartz veining persist to the northernmost exposures. Most primary structures except lithologic layering have been destroyed.

Coarse grained fragmental deposits, consisting of two breccia strata with a 10 m thick interlayer of tuff, occur in one exposure close to the base of the unit. The lowermost breccia (9 m exposed) is composed of white aphyric rhyolite fragments in a fine grained, buff, fragmental matrix. The breccia is poorly sorted, matrix-supported, and southward-facing; maximum fragment size is 15 x 60 cm at the base of the exposure and 2 x 4 cm at the top of the stratum. The uppermost "breccia" (9m exposed) consists of large, highly elongate, white rhyolite bodies up to 20 cm x 2 m set in a fine grained fragmental matrix. These structures are vesicular and slightly flow-banded, and are interpreted as large bombs or lava tongues.

Fine grained felsic and intermediate tuff is locally well layered in the lower 200 m of the unit. Layering (8 - 40 cm thick) is defined primarily by moderate compositional contrast between beds, expressed in outcrop by variation in colour, hardness, and intensity of foliation. Felsic beds weather light grey and are hard, poorly foliated, and massive. Intermediate beds are light greyish green, soft, moderately foliated, and locally internally laminated. Contacts between beds of different composition are sharp.

Layering in the upper 500 m of the unit is typically poorly defined. Slight colour or compositional variations and some strata with plagioclase crystals and small lithic fragments suggest that the rocks are tuffs. Bedded (5 - 30 cm) siliceous tuff is interlayered with dark green argillaceous sediment, at a scale of 1 - 3 m, near the top of the unit. Massive felsic flows were recognized at two localities. In contrast to the tuff, the flows are homogeneous in composition and texture, are not as strongly foliated, and contain sporadic ovoid amygdales. The flows are at least 12 m thick and include aphyric and porphyritic varieties.

The tuff is composed of a very fine grained (0.02 - 0.5 mm) recrystallized mosaic of untwinned feldspar, quartz, and biotite. Very fine grained white mica is a major component of the felsic members of the suite, and chlorite occurs locally. Magnetite-hematite, epidote, and carbonate are minor phases disseminated throughout most lithologies. Intergranular hematite imparts a yellow-brown colour to some rocks, particularly those in close proximity to the Cartwright Lake shear zone. Plagioclase crystals and crystal fragments (0.15 - 0.6 mm), some clearly embayed, comprise 1 - 2 per cent of many tuff strata and are abundant in some laminae. Compositional variation is expressed primarily by variation in the biotite and chlorite content of the rocks: felsic tuff strata contain less than 5 per cent biotite, whereas more intermediate lithologies contain up to 20 per cent biotite and chlorite, and relatively more magnetite. Well developed tectonite fabrics include micaceous foliation, rotated and deformed plagioclase crystals, tightly folded and transposed quartz stringers, and a finely spaced cleavage defined by biotite partings.

SUMMARY: VOLCANIC EVOLUTION OF THE EASTERN PART OF THE SOUTHERN BELT

The disposition of volcanic and sedimentary rock units in the McVeigh Lake-Hughes Lake area records four major stages in the development of that portion of the southern Lynn Lake belt (below, and Fig. 14).

(1) Basaltic platform

An effusive mafic platform composed of two partially overlapping, lens-shaped basalt units constitutes the base of the Wasekwan Group in the McVeigh Lake area. The lens-shaped basalt bodies are interpreted as small shield volcanoes. The largest edifice consists of tholeiitic, aphyric, pillowed and massive basalt flows (Cockeram Lake basalt, unit 2); it is a minimum of 2100 m by 26 km. The aphyric flows were emplaced in a subaqueous environment; the distribution and size of amygdales suggests that the thickest part of the shield was emplaced in shallower water then the flanks. The aphyric basalt shield was largely isolated from other volcanic centres for much of its development, but the compositions of sparse intercalated sedimentary rocks indicate that the shield lay along strike from or is underlain by an older, more diverse volcanic terrane.

The smaller shield volcano comprises pyroxene-plagioclase-phyric basalt flows and flow breccia, and locally abundant aphyric basalt flows and sills (unit 3); its dimensions are a minimum of 1500 m by 23 km. Rare pillow structures suggest that this volcanic centre too is a subaqueous deposit.

A chemical and lithologic discontinuity exists between the basaltic platform and overlying units. Although the overlying rocks rest with apparent conformity upon the basaltic substrate, the contact may be disconformable. In the McVeigh Lake area porphyritic basalt is overlain by a thin, basal quartz-pebble conglomerate, suggesting that at least part of the basaltic platform was uplifted and subjected to subaerial erosion.

(2) Felsic volcanism and basin development

A small felsic extrusive centre developed on top of the porphyritic basalt shield southeast of Fraser Lake. Epiclastic rocks derived in part from the felsic centre comprise a proximal conglomerate facies (unit 8) and a distal greywacke-siltstone facies (unit 9) 640 m thick. The epiclastic rocks were deposited in a subsiding sedimentary basin. The inception of basin subsidence resulted in the deposition of the basal quartz-pebble conglomerate; subsequent marine transgressions produced two fining-upward sequences in the basin greywackes. The final rhyolitic eruptions produced a unit 200 m thick of quartz-rich volcaniclastic rocks, felsic flows, and felsic breccias within the sedimentary basin.

(3) Intermediate and mafic volcanism, deposition of derived sediment

Eruption of intermediate to mafic volcanic flows and breccias (unit 4) followed the felsic volcanism represented by the Fraser Lake felsic body and its sedimentary apron. A thick accumulation of these mafic rocks was deposited on top of the felsic centre and the flanking conglomerates, and thin mafic units spread into the adjoining sedimentary basin. Fine grained, thin-bedded greywackes (unit 9) were deposited in the basin synchronous with unit 4 volcanism. These greywackes were probably derived from a distant felsic source and not the nearby mafic volcanoes. A clastic wedge at least 330 m thick comprising coarse grained, thick-bedded greywacke (unit 9b) and conglomerate (unit 8b) is prograded over, and laterally intercalated with, the distal greywackes (unit 9c). These immature sediments are interpreted to represent relatively unreworked detritus derived from the adjacent unit 4 volcanoes. In total, a maximum of 1200 m of volcaniclastic sediments were deposited in the Eldon Lake intravolcanic basin. The basin was probably small: the sediments occur ony on the north limb of an isoclinal fold. Mafic volcanic rocks (unit 4) directly overlie porphyritic basalt (unit 3) on the south limb of the fold. Continued sedimentation resulted in deposition of greywacke, siltstone, and conglomerate on top of the Fraser Lake mafic volcanic body (unit 4).

(4) Calc-alkaline volcanism

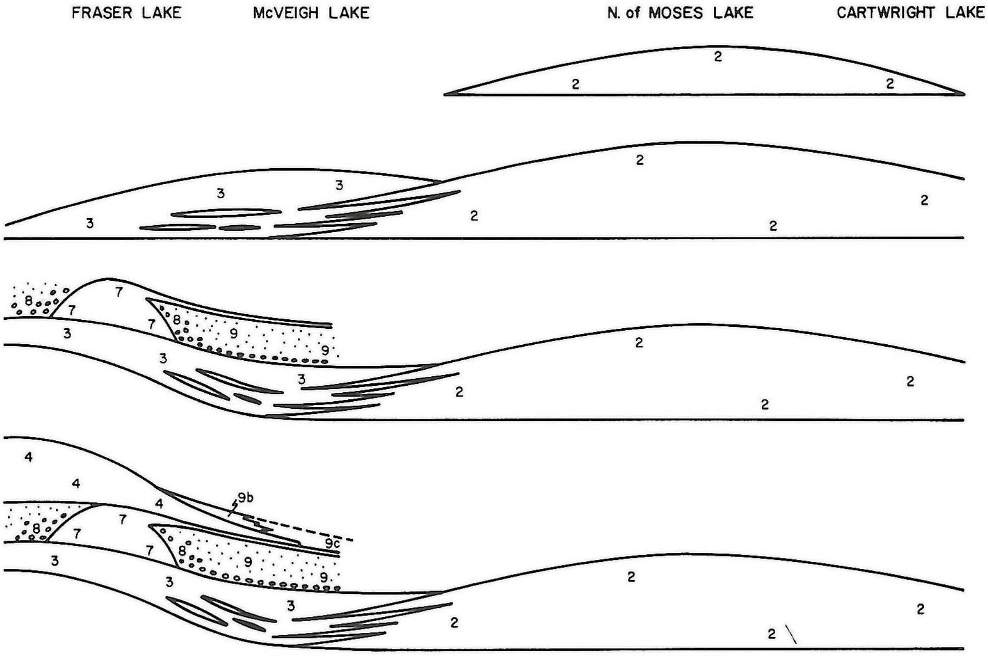
At least 2500 m of calc-alkaline andesite, basalt, dacite, and minor rhyolite was deposited in part on the eastern portion of the basaltic platform. At Cartwright Lake the calc-alkaline succession is interpreted to represent a stratovolcano that developed on the upper flank of the Cockeram Lake tholeiite shield. Fine grained epiclastic and pyroclastic material derived from the stratovolcano was deposited over the lower flanks of the basalt shield. The flows and subordinate pyroclastic rocks comprising the stratovolcano were emplaced in a relatively shallow subaqueous environment. A dome-like rhyolite extrusive centre within the predominantly andesitic succession may have become emergent during its development.

The Hughes Lake segment of the calc-alkaline complex represents a predominantly effusive edifice comprising 2000 m of massive basalt and subordinate andesite, overlain by 500 m of andesite flows, flow breccia, and tuff; local rhyolite and epiclastic rocks occur at the top of the succession. None of the flows are pillowed, but the occurrence of thin interflow siltstone-mudstone units suggests deposition in a subaqueous environment. Stratigraphic sections cannot be correlated between the Hughes Lake and Cartwright Lake-Pole Lake areas, but andesites in the two areas are similar in composition.

The Hughes Lake calc-alkaline suite is conformably overlain by 1060 m of pillowed and massive tholeiitic basalt. Two hundred metres of conglomerate and greywacke overlie the basalt; the sediments are interpreted to be the products of subaqueous slumping possibly related to a period of block-faulting. Felsic tuff and minor rhyolite (700 m) comprise the top of the Hughes Lake volcanic section.

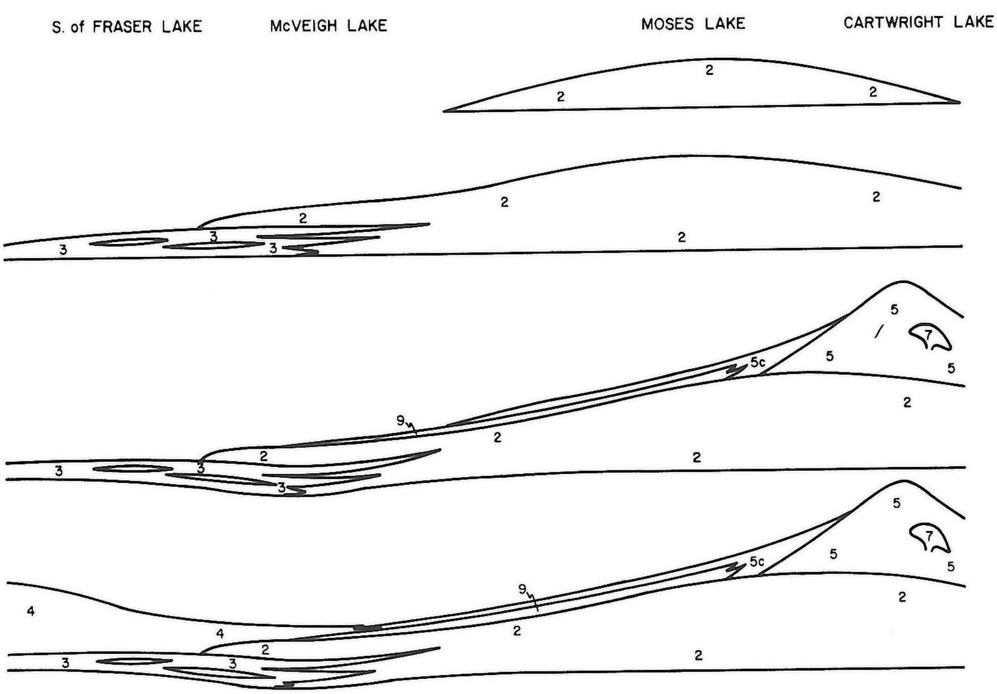
The age of the calc-alkaline suite relative to the Fraser Lake rhyolite (unit 7) and unit 4 intermediate and mafic volcanic rocks is unknown; each at least locally directly overlies the early basaltic platform. It is tempting to correlate the Fraser Lake felsic volcanic body (and its associated volcaniclastic apron) with compositionally similar rocks within the Hughes Lake calc-alkaline suite.

(a) NORTH LIMB OF McVEIGH LAKE ANTICLINE



1. *Eruption of aphyric basalt (2) to form the Cockeram Lake tholeiite shield.*
2. *Intercalation of porphyritic basalt (3) and aphyric basalt (2). Porphyritic flows ultimately rise above the flank of the aphyric shield.*
3. *Eruption of rhyolite and dacite (7), deposition of conglomerate (8) and fine-grained sediments (9) in flanking basins.*
4. *Emplacement of mafic and intermediate flows and breccias (4), deposition of derived sediments (9b), concomitant deposition of unrelated, distal greywacke (9c) within the basin.*

(b) SOUTH LIMB OF McVEIGH LAKE ANTICLINE



1. *Eruption of aphyric basalt (2) to form the Cockeram Lake tholeiite shield.*
2. *Intercalation of porphyritic basalt (3) and aphyric basalt (2). Aphyric basalt ultimately covers part of the flank section of the porphyritic shield.*
3. *Eruption of calc-alkaline andesite, dacite (5) - rhyolite (7) flows and coarse pyroclastics to form a composite stratovolcano. Deposition of derived sediment (9) and fine-grained pyroclastic deposits (5c) on the flanks of the tholeiite shield.*
4. *Eruption of mafic and intermediate flows and breccias (4), covering porphyritic basalt (3).*

FIGURE 14: Reconstructed, simplified stages in the development of the southern belt between Fraser Lake and Cartwright Lake.

MISKWA LAKE BELT

INTRODUCTION

The belt of volcanic and sedimentary rocks extending southeast from Wasekwan Lake is structurally isolated from the adjacent Southern Belt. A major shear zone, occupied by a foliated granitic dyke, truncates the belt at the north end of Wasekwan Lake. Within the Miskwa Lake belt structure and stratigraphy are incompletely known because top determinations are sparse. The belt is interpreted to contain an isoclinal anticline, cored by an elongate tonalite pluton; the axial trace trends northwest, parallel to schistosity. On the north side of the pluton the rocks face northeast and on the south side of the pluton they face southwest. The oldest unit in the belt is considered to be aphyric basalt (2), which occupies the centre of the belt northwest of Miskwa Lake.

On the northeast limb of the anticline the stratigraphic sequence, from oldest to youngest, is interpreted to be: aphyric basalt (2), porphyritic basalt (3), siltstone and mafic mudstone (9e), and greywacke (9). On the southwest limb of the anticline the sequence is ferruginous chert (9h), felsic tuff (7e), siltstone and mafic mudstone (9e), aphyric basalt (2), and biotite-bearing greywacke and siltstone (9c).

PORPHYRITIC AND APHYRIC BASALT (3)

Porphyritic basalt occurs along the entire northeastern margin of the Miskwa Lake supracrustal segment, between Wasekwan Lake and Sickle Lake (15 km). The unit tops to the northeast and varies in thickness between 460 m and 800 m. The northern (upper) margin of the unit between Wasekwan Lake and Sickle Lake is intruded by a pre-Sickle tonalite pluton, and the southern (lower) flank of the unit between Sickle Lake and Miskwa Lake is intruded by an elongate pre-Sickle tonalite stock. The absence of facing indicators in adjacent volcanic units makes interpretation of the stratigraphic position of the porphyritic basalt difficult; a single excellent top determination indicates that unit 3 at Miskwa Lake is underlain by aphyric basalt (2) and is overlain by siltstone and mafic mudstone (9e) east of Wasekwan Lake.

Rock types include pyroxene-plagioclase-phyric basalt, plagioclase-phyric basalt, aphyric basalt, and minor mafic tuff, breccia and fine grained sedimentary rocks. The predominant basalt facies are massive flows and autoclastic breccias; pillowed flows are absent. Although the porphyritic basalts at Miskwa Lake and McVeigh Lake are both designated unit 3, there are differences between the two deposits which preclude definite correlation (Table 14).

The 45 m thick unit of siltstone, greywacke (9b) and subordinate thin basalt flows splits unit 3 into lower and upper divisions. The sedimentary unit is well defined between Miskwa Lake and Sickle Lake, and may be correlated with greywackes in the Wiley Lakes area. The lower division is characterized by a greater proportion of massive porphyritic flows and by locally abundant coarsely porphyritic hypabyssal intrusions. The upper division consists predominantly of autoclastic breccias in the Miskwa-Sickle Lakes area, and of interlayered massive porphyritic and aphyric basalt flows in the Wiley Lakes area.

The major element compositions of pyroxene-plagioclase-phyric basalt and plagioclase-phyric basalt are similar (analyses 19 to 21, Appendix). Significant differences occur in CaO and Na_2O contents, but these elements are commonly redistributed during seafloor alteration and metamorphism (for example, Scott and Hajash, 1976; Hart, 1970), so primary compositional differences may be masked. The plagioclase-phyric basalt has a greater normative plagioclase content (59%) and lower normative colour index (35) than the pyroxene-plagioclase basalt (49% and 44, respectively). FeO^*/MgO ratios are within the same range in the two suites. The

TABLE 14: COMPARISON OF UNIT 3 PORPHYRITIC BASALT AT McVEIGH LAKE AND MISKWA LAKE

	McVeigh Lake	Miskwa Lake
Weathering colour	Light brown or brownish grey. Flow breccia fragments light grey to buff.	Dark green to dark greenish black. Flow breccia fragments light grey.
Rock types	Pyroxene-plagioclase-phyric basalts: massive and autobrecciated flows. Massive aphyric basalt. Minor crystal tuff.	Pyroxene-plagioclase-phyric basalts, plagioclase-phyric basalt: massive and autobrecciated flows, rare differentiated flows. Massive aphyric basalt. Minor mafic tuff, siltstone.
Pyroxene phenocrysts	Euhedral 0.5 - 10 mm, average 3 mm 20 - 30%, average 25% Abundance varies slightly between flows	Euhedral 1 - 7 mm, average 2 mm 2 - 40%, average 15% Abundance varies between and within flows
Plagioclase phenocrysts	Lath-shaped 0.3 - 1.5 mm 20 - 40%, in inverse relation to abundance of pyroxene phenocrysts	Tablet-shaped 0.5 - 2 mm 10 - 25% Abundance varies between and within flows
Amygdales	Rare to absent	Common in both massive flows and flow breccias (especially fragments)
FeO^*/MgO K_2O/Na_2O Cr	1.03 - 1.67 0.12 - 1.06 178 - 362 ppm	1.85 - 2.34 0.20 - 0.26 144 - 200 ppm
Aeromagnetic signature	High ($\geqslant$ 60750 gammas)	Low

pyroxene phenocryst-bearing basalts contain 4 to 5 times the Cr content of the non-pyroxene-bearing basalt (144-200 ppm *vs.* 40 ppm); much of the Cr apparently resides in the pyroxene phenocrysts.

Lower amphibolite facies mineral assemblages are developed in the basalts. Pyroxene phenocrysts are pseudomorphed by hornblende, and primary (?) plagioclase phenocrysts (An_{55}) are pseudomorphed by single andesine-oligoclase crystals or aggregates of untwinned subgrains. The hornblendic matrix is foliated but primary structures and textures are moderately preserved. On a regional scale the basaltic unit has been considerably attenuated.

PORPHYRITIC BASALT: MASSIVE FLOWS (3a) AND AUTOCLASTIC BRECCIA (3c)

Pyroxene-plagioclase-phyric and plagioclase-phyric basalt are virtually identical in outcrop expression, flow morphology, and FeO*/MgO ratio. Pyroxene-plagioclase basalts predominate southeast of Miskwa Lake and in the Wiley Lakes-Wasekwan Lake area; plagioclase basalts are common within 2 km of Sickle Lake and east of Wasekwan Lake. Flows of both types may be interlayered on a scale of several metres.

Autoclastic breccias (3c) are most common between Miskwa Lake and Sickle Lake. The breccias lack stratification or fragment sorting and are invariably monolithologic. Fragments are dispersed in a lava matrix. The breccias are interlayered with massive flows, and many flows are composite, with both massive and brecciated portions. Intraflow contacts between breccia and massive lava are gradational over 50 cm. Interflow contacts are sharp and planar. Individual units of breccia and massive lava are 50 cm - 4 m thick; the thickness of a complete, composite flow ranges between 1 m and 6 m. Massive zones tend to occur towards the base or centre of composite flows. Thick (30 m) accumulations of flow breccia may represent either a single thick brecciated flow or several superimposed brecciated flow units.

Flow breccia fragments are lens-shaped, 2-35 cm long, with an elongation ratio of 5-7:1 on horizontal surfaces. They weather light grey to medium grey in contrast to the dark green-black matrix. Locally the fragments are preferentially epidotized and weather light greenish buff. Phenocrysts in the fragments are either fewer and smaller than, or similar to, those in the matrix. The fragments are slightly more leucocratic than the matrix because (1) they commonly contain less amphibole (ca. 40%) than the matrix (ca. 60%), and (2) most fragments have a greater density of infilled vesicles than the matrix, which is only locally amygdaloidal.

Quartz- or plagioclase-filled amygdales in fragments are up to 5 mm long and commonly have an extremely attenuated cross-section. Some amygdales are moulded around phenocrysts. Brecciation of vesicular flow tops apparently produced semi-plastic fragments which were subsequently incorporated into the upper molten portion of the moving flows. The fragments may have become stretched through viscous flow, resulting in lenticular fragment morphologies and attenuated, partially collapsed vesicles. Subsequent deformation has accentuated the flattening.

Massive porphyritic flows (3a) predominate between Wasekwan Lake and Miskwa Lake. Measured flows range from 50 cm to 5 m thick; these are probably minimum thicknesses. Quartz amygdales (1 - 5 mm) are ovoid and occur in almost all massive flows, but they are abundant only within restricted zones in any individual flow.

One differentiated flow was mapped within unit 3, 500 m northwest of Sickle Lake. The thickness, composition, and texture of the flow are not unusual so presumably flows of this type are not uncommon; poor exposure may have prevented the identification of others. The Sickle Lake flow (Fig. 15) is almost complete, and is exposed for 5.5 m across strike. It comprises a chilled aphyric base (20 cm thick), a cumulate zone enriched in pyroxene phenocrysts (1.3 m thick), a massive portion with abundant plagioclase phenocrysts and few pyroxene phenocrysts (2 m thick), and flow-top breccia (more than 2 m thick). Note that cumulate processes which operated within this single, rather thin flow produced a striking separation of phenocryst phases (Fig. 15). Similar crystal frationation within a high-level magma chamber would produce a vertically zoned magma column. If such a magma chamber was progressively emptied or tapped at different levels during an eruption the resulting flows would vary considerably in their absolute phenocryst content and in their pyroxene: plagioclase phenocryst ratio. This model may account for the locally and regionally variable phenocryst content in the Miskwa Lake unit 3 flows. The pyroxene-plagioclase-phyric basalts and plagioclase-phyric basalts may therefore be comagmatic, as their chemistry would suggest.

Hypabyssal intrusions interpreted to be equivalent to the porphyritic flows are massive, homogeneous, and coarsely porphyritic: the phenocrysts are larger and more abundant than in associated flows. One intrusion contains small aphyric basalt xenoliths. The hypabyssal rocks typically form small isolated outcrops; consequently their relationships to the flows are unknown.

Euhedral pyroxene phenocrysts (1 - 7 mm, average 2 mm) have been completely replaced by hornblende pseudomorphs. In the least-deformed basalts the pseudomorphs are single crystals of hornblende (α = pale yellow green, γ = green) which preserve the primary [100] twinning in pyroxene. In more strongly deformed basalts the phenocrysts have been replaced by fine grained lenticular aggregates of hornblende. Colourless clinopyroxene was observed in the core of only one pseudomorph. The abundance of pyroxene phenocrysts varies markedly from flow to flow (3 - 40%, average 15%), and to a lesser extent within any single flow.

Plagioclase phenocrysts are subhedral to euhedral and are commonly 0.5 - 2 mm in diameter (up to 4 mm). Their abundance (10 - 25%) is variable from flow to flow. The best preserved plagioclase crystals are An_{55} (possibly a primary composition); they display good polysynthetic twinning and have normal or oscillatory zoning at the margins. More commonly the plagioclase phenocrysts are pseudomorphed by single andesine-oligoclase crystals or by a recrystallized aggregate of tiny untwinned plagioclase subgrains, epidote, sericite and amphibole. Plagioclase phenocrysts in the more strongly deformed basalts are almost lenticular in shape and are rotated subparellel to the foliation.

The groundmass is fine grained (0.05-0.1 mm) and consists of stubby hornblende prisms with a moderate to excellent preferred orientation in a granoblastic mosaic of untwinned plagioclase with minor quartz, and epidote, sphene, and magnetite. Hornblende is locally replaced by brown biotite, and magnetite is locally oxidized to hematite. Typical modes of pyroxene-plagioclase-phyric basalt and plagioclase-phyric basalt are listed in Table 15.

APHYRIC BASALT (3d)

Dark green to black weathering aphyric basalt flows are rare in unit 3 between Miskwa Lake and Sickle Lake, but are intercalated with porphyritic flows between Miskwa Lake and Wasekwan Lake. The flows are massive, fine grained, and are commonly amygdaloidal (1 - 5 mm). Contacts between aphyric and porphyritic flows are sharp. The basalts are recrystallized to a fine grained (0.1 mm) mosaic of stubby hornblende (40 - 50%), untwinned anhedral plagioclase (40 - 50%), quartz (5%), epidote (3%) and magnetite (1%). Plagioclase phenocrysts (0.5 mm) and fine grained hornblende pseudomorphs occur in some flows. The hornblendic matrix is moderately foliated. Two analysed flows (analyses 22 and 23, Appendix) contain 54.3 per cent and 56.6 per cent SiO_2 and are therefore better termed basaltic andesites. Relative to the porphyritic basalts they have high FeO*/MgO ratios (3.50 - 3.76), higher silica contents, and unusually low Cr contents (8 ppm). The chemical data do not indicate whether the aphyric flows are comagmatic with the porphyritic flows; the unusually low Cr content suggests the possibility that the aphyric basalts are differentiates produced by crystal fractionation of Cr-bearing pyroxene.

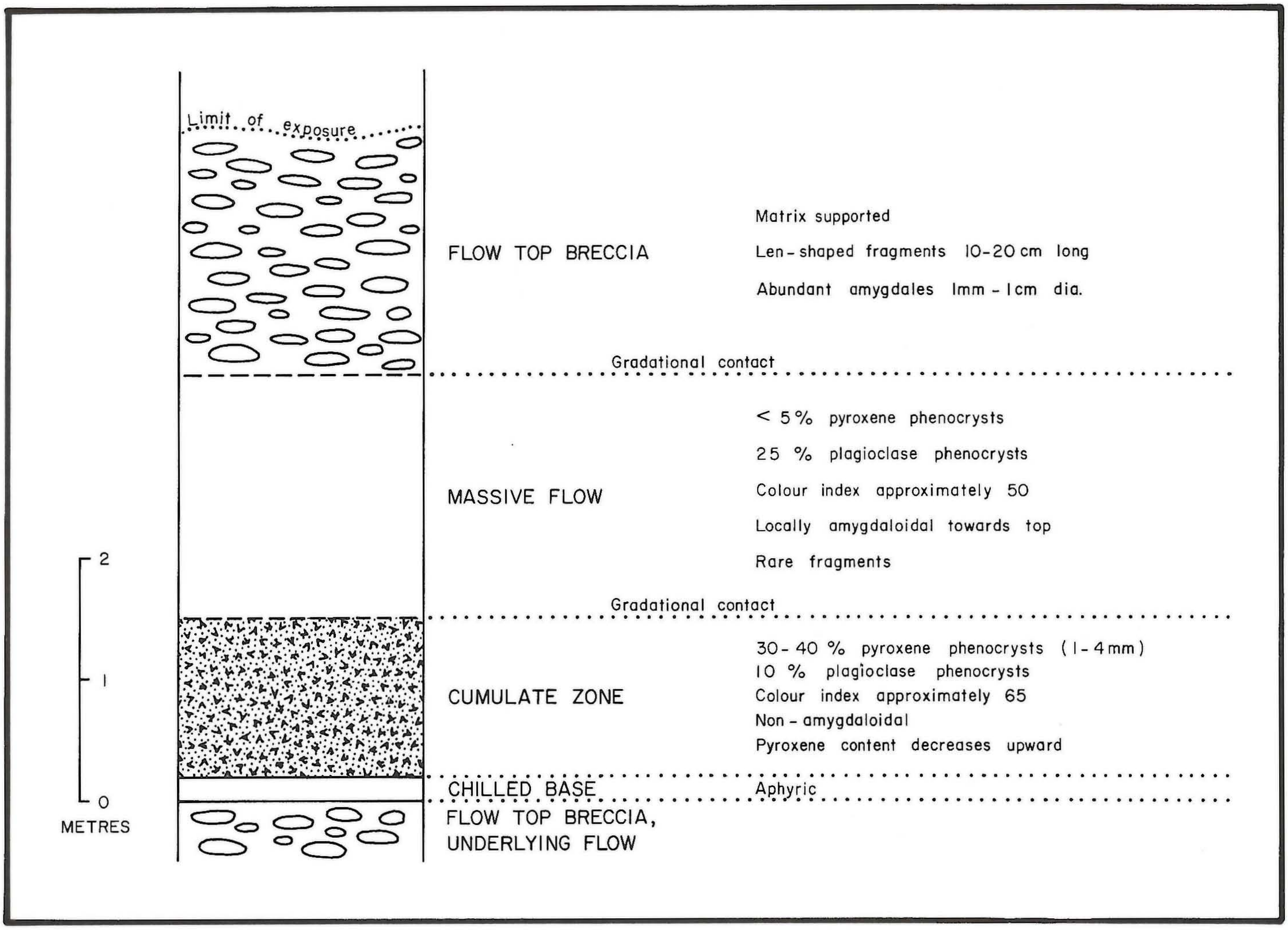


FIGURE 15: Differentiated porphyritic basalt flow. Unit 3, 500 m northwest of Sickle Lake.

TABLE 15: TYPICAL MODES OF MISKWA LAKE PORPHYRITIC BASALTS (UNIT 3)

	Pyroxene-plagioclase-phyric basalt	Plagioclase-phyric basalt
Hornblende pseudomorphs	20	
Plagioclase phenocrysts	20	15
Groundmass		
Hornblende	40	55
Plagioclase	10	20
Quartz	2	3
Epidote	3	3
Sphene	3	tr
Magnetite-hematite	1	2

ASSOCIATED MINOR ROCK TYPES

VOLCANIC BRECCIA (3c)

A small number of exposures of monolithologic volcanic breccia occur within the upper division of unit 3 near Sickle Lake. The breccias lack stratification or fragment sorting; they are matrix-supported and locally interlayered on a scale of several metres with non-fragmental porphyritic basalt. The breccias are characterized by extremely attenuated light grey fragments (3 mm x 5 cm to 1.5 cm x 30 cm) in a grey-green mafic matrix. The fragments consist of a fine grained (0.1 mm) mosaic of epidote, amphibole, plagioclase, quartz, carbonate, and sphene. The abundance of epidote (up to 50%) imparts a light colour and hardness to the fragments. The presence of amygdales (1 mm), plagioclase phenocrysts (1.5 mm) and sporadic lenticular hornblende aggregates (1 mm) suggests that the fragments are altered porphyritic mafic volcanic rocks. The matrix is fine grained (0.1 mm), amphibole-rich (up to 70% hornblende), and is locally plagioclase-phyric. The deposits may be either lapilli tuffs or severely altered and deformed flow breccias.

MAFIC TUFF (3e)

Mafic tuff comprises less than 3 per cent of unit 3. It occurs in only one mappable body, a finely layered tuff (approximately 30 m thick) that locally underlies the thin extensive greywacke-siltstone formation (9b). The tuff is colour-banded, grey and grey-green, with layering (4 - 10 cm thick) defined by contrasting proportions of amphibole and plagioclase. Individual layers are internally laminated. Some beds contain up to 10 per cent 1 - 2 mm flattened garnet blasts, others contain sporadic plagioclase crystals. A small number of very thin plagioclase-phyric basalt flows (10 - 30 cm thick) are interlayered with the tuff.

SEDIMENTARY ROCKS (9)

Two sedimentary associations are present: (1) a greywacke-siltstone formation (20 - 60 m thick) which splits unit 3 between Miskwa Lake and Sickle Lake (9b, described below), and (2) minor intercalated fine grained sedimentary strata within the basalt section. The minor interflow siltstone and greywacke units are up to 2 m thick; they weather brown to light grey and are massive to faintly laminated. They are composed of plagioclase, quartz, biotite, hornblende, epidote, and magnetite-hematite; acicular and poikiloblastic hornblende comprises 3 - 25 per cent of the sediments and brown biotite comprises 10 - 20 per cent. The greywackes are characterized by up to 5 per cent plagioclase microclasts (1 mm). The sediments are locally gossaned, and interlayered with weakly gossaned porphyritic flows.

INTERPRETATION

The original form and extent of the porphyritic basalt body are unknown because it is largely surrounded by granitoid plutons. The three basalt types — pyroxene-plagioclase-phyric, plagioclase-phyric, and aphyric — may be comagmatic and related by high-level crystal fractionation. The local predominance of one basalt type over the others may reflect the presence of several eruptive centres which tapped a vertically zoned magma chamber. The scarcity of interflow sedimentary deposits implies rapid deposition of the volcanic flows and/or isolation of the pile from any contemporaneous source of clastic sediments.

Part of the original morphology of the volcanic edifice may be deduced from the greywacke-siltstone formation (9b) which occurs within the mafic pile between Miskwa Lake and Sickle Lake. The uniform thickness and persistence of this intravolcanic sedimentary unit suggests deposition on a flat or very gently sloping surface (at least on the exposed cross-section of the pile). The basalts therefore may have comprised either a lava plain or small shield volcano. The environment of deposition of the flows is unknown: the absence of pillows may indicate a subaerial environment but positive criteria are lacking.

The Miskwa Lake porphyritic basalts compare broadly with those at McVeigh Lake, but significant differences preclude direct correlation of the two suites. Their stratigraphic relationships are, however, similar (Table 16).

HORNBLENDE GREYWACKE, SILTSTONE (9b)

A thin (20 - 60 m) unit of siltstone, greywacke, and minor basalt flows occurs within unit 3 porphyritic basalt, between Sickle Lake and Miskwa Lake. The unit apparently represents a period of sedimentation during a hiatus in unit 3 volcanism.

The unit is thickest (at least 50 m) in the southeast, near the shore of Sickle Lake. Laterally towards Miskwa Lake the sediments become progressively finer grained, better layered or laminated, and pyritiferous; the unit gradually thins to approximately 20 m near Miskwa Lake.

Light grey, quartz-rich greywackes near Sickle Lake are dominated by recrystallized clastic quartz grains 0.2 mm in diameter, in a finer grained mosaic of feldspar, quartz, chlorite, biotite, and muscovite (Table 17). These rocks are characterized by up to 5 per cent disseminated magnetite octahedra. Bedding was not observed and a weak lamination is only locally developed: compositional variation and thin interbeds of pebble-bearing greywacke and mafic tuff define stratification.

Siltstone with minor interlayers of fine grained greywacke predominates from 2 km northwest of Sickle Lake to Miskwa Lake. Siltstone weathers to light grey to buff and is light to medium grey on fresh surface; some beds have a weak hematitic gossan. Layering and lamination (5 mm - 5 cm) is defined by amphibole content (5 - 15%) and the ratio of biotite to hornblende. More mafic (25% hornblende), laminated interbeds may represent reworked mafic

TABLE 16: STRATIGRAPHIC RELATIONSHIPS OF THE MISKWA LAKE AND McVEIGH LAKE PORPHYRITIC BASALTS

Miskwa Lake	maximum thickness (m)		McVeigh Lake
greywacke	?	1000	greywacke
siltstone, mafic mudstone	180	180	siltstone, mafic mudstone
		80	greywacke, siltstone
		10	quartz pebble conglomerate
porphyritic and aphyric basalt	800	1500	porphyritic and aphyric basalt
aphyric basalt	(base)		aphyric basalt

TABLE 17: MINERALOGY AND FABRIC OF GREYWACKE, SILTSTONE (UNIT 9b) COMPRISING THE SEDIMENTARY FORMATION WITHIN MISKWA LAKE PORPHYRITIC BASALT (UNIT 3).

	Quartz-rich greywacke	Siltstone
Quartz	40 - 50%	} 50 - 70%
Plagioclase	15 - 30	
White mica	2 - 10	0
Chlorite	5 - 10	0 - tr
Biotite	2 - 10	10 - 25
Hornblende	0	5 - 15
Garnet	0	0 - 3
Epidote	3 - 5	0 - 1
Apatite	tr	0
Magnetite	3 - 5	0 - 1
Hematite	tr	tr - 1
Pyrite	0	0 - 2
Carbonate	0	0 - tr
Fabric	Granoblastic polygonal, with rare 1 mm plagioclase microclasts or biotitic lenticles	Recrystallized microgranular mosaic; rare 0.3 mm plagioclase microclasts; local lamination defined by hornblende content and biotite: hornblende ratio

tuff. Buff siltstone laminae locally alternate with light to dark green weathering laminae, similar to unit 9e. Siltstone contains slightly less quartz than the greywacke near Sickle Lake, and more hornblende and biotite (Table 17). It has a fine grained (0.05 - 0.2 mm), foliated, recrystallized microgranular texture. Garnets occur as corroded, flattened, sieve-textured blasts up to 2.5 mm long. Relict pyrite or, more commonly, intergranular hematite is present in some samples.

Intercalated porphyritic basalt flows 1 - 3 m thick occur locally within the sedimentary sequence. They are massive, fine grained, and locally amygdaloidal. One 3 m thick flow is directly overlain by 60 cm of strongly gossaned chert. At another locality plagioclase-phyric mafic sills 10 cm to 15 m thick cut the sedimentary rocks at a shallow angle.

FERRUGINOUS CHERT (9h), BASALT (2)

Pyrite-bearing chert and massive basalt occurs in a series of small exposures 3 km southeast of Miskwa Lake. The unit is a maximum of 150 m wide and is adjacent to, and apparently pinches out against, the elongate tonalite pluton which cores the Miskwa Lake supracrustal belt. It is flanked to the southwest by felsic tuff (7e). Neither the base nor the top of the unit is exposed. Beds or screens of massive, pyrite-bearing chert (less than 1 m to 5 m thick) are separated by thicker, fine grained, dark grey, massive basalt flows or sills. At one locality, very fine grained, pyrite-bearing chert is interlayered (1 mm - 5 cm) with grey siliceous siltstone.

Chert weathers white to greyish-white but an orange-brown hematitic gossan is commonly developed. Pyrite has weathered out of mineralized zones, resulting in a slightly sponge-textured, gossaned, quartz-rich residum. On fresh surfaces chert is light grey to white, with up to 10 per cent pyrite as disseminated cubic crystals, fine fracture-filling, or laminae. The chert consists of a fine grained (0.2 mm) granoblastic polygonal mosaic of quartz (80%), with disseminated white mica (10%), chlorite (5 - 10%), pyrite (0.2 - 1 mm), and intergranular hematite. Pyrite is most abundant in the northwestern portion of the unit.

FELSIC TUFF (7e)

A wedge-shaped unit of siliceous rocks interpreted as rhyolitic tuff has a maximum thickness of approximately 600 m at Sickle Lake, where it is unconformably overlain by the Sickle Group. The unit wedges out 3.5 km northwest of Sickle Lake. Facing indicators are absent in the tuff and adjacent units. A quartz-rich clastic sediment (9e) which occurs along the southwest contact of the unit is interpreted to have been derived from the tuff, and thus the section is assumed to face southwest. Accordingly, the rhyolite tuff is underlain by pyrite-bearing chert (9h) and is overlain by interlayered siltstone and mafic mudstone (9e).

The unit consists of massive to faintly layered porphyritic siliceous rocks and fine grained aphyric basalt sills; the two lithologies occur in approximately equal proportions. The basalt sills range from 1 m to 20 m thick; some may be thicker. The siliceous tuff occurs as screens 1.5 m to at least 12 m thick between sills. Contacts between the sills and tuff are planar, and are locally slightly discordant with respect to layering in the tuff.

The rhyolite tuff weathers light grey, light buff, or white, and is light grey on fresh surfaces. It is very hard, and breaks with a conchoidal or slabby fracture. Weathered surfaces are locally gossaned by the oxidation of up to 2 per cent pyrite, which is disseminated through the rock or occurs in fracture-fillings. The tuff is commonly massive and homogeneous but it locally displays faint layering 1 - 5 cm thick defined by variable biotite content. A lateral transition to a layered (1 - 3 m) assemblage of felsic tuff, siltstone, and mafic flows occurs to the northwest, where the unit pinches out.

The tuff contains plagioclase phenocrysts (0.6 - 2 mm, 2 - 5%), lenticular, annealed quartz bodies (0.5 - 3 mm, 2 - 5%) and biotite-rich lenticles in a very fine grained (0.02 - 0.1 mm) recrystallized mosaic of quartz, untwinned feldspar, biotite (3 - 15%), white mica (0 - 10%), epidote (1 - 3%) and magnetite (less than 2%). Apatite, sphene, and pyrite are accessories. Mica defines a well developed foliation. Plagioclase phenocrysts include subhedral crystals, glomerocrysts, and crystal fragments; they are commonly recrystallized or contain a ubiquitous sericite-saussurite alteration, and are locally replaced by coarse grained epidote. The quartz bodies are sharply-bounded, lens-shaped aggregates of granoblastic-polygonal subgrains. These are probably recrystallized phenocrysts because, like plagioclase, they comprise a relatively constant percentage of the rock. They do not occur in the polymineralic aggregates that are typically derived from amygdales. Randomly-distributed biotite-rich lenticles (biotite + epidote ± white mica ± magnetite) are up to 1 cm long and a fraction of a millimetre wide, elongate parallel to the foliation. They may represent tectonically flattened lithic or pumice fragments, or flattened, recrystallized mafic phenocrysts.

Basalt sills which intrude the tuff weather grey to black and are grey-black on fresh surfaces. They are fine grained, massive, and aphyric; slight chilling at sill margins was noted locally. The sills have a simple, upper greenschist to lower amphibolite facies mineral assemblage consisting of bluish green hornblende (50 - 60%), untwinned plagioclase (30 - 35%), quartz (5%), magnetite (3%), and epidote (3%). Relict primary textures include pseudomorphs after plagioclase (0.5 - 1.5 mm).

In summary, the following features indicate a pyroclastic (ash flow?) origin for the felsic rocks:

(1) The occurrence of crystals, crystal fragments, layering, and local lamination is consistent with a tuffaceous origin (Anderson, 1970).

(2) The unit has a considerable lateral extent and uniform texture.

(3) The unit is heterolithologic and layered in the distal facies(?) to the northwest, where felsic rocks are interlayered with sedimentary rocks and mafic flows.

(4) The rocks lack any positive flow criteria: flow banding, amygdales and autoclastic breccia are absent.

SILTSTONE AND MAFIC MUDSTONE (9e)

Interlayered siltstone and fine grained mafic mudstone occurs in two separate deposits in the Miskwa Lake supracrustal segment. The larger deposit, south of Miskwa Lake, is lens-shaped, approximately 5 km in length and a maximum of 500 m thick. The smaller deposit may be up to 400 m thick and 2 km in length; it occurs at the margin of the belt, east of Wasekwan Lake. The two deposits are lithologically identical.

If a single southwest-facing top determination in adjacent mafic tuff is correct, the base of unit 9e at Miskwa Lake conformably onlaps a unit of felsic tuff (7e). A thin unit of quartz-rich clastic sediment lies between the felsic tuff and unit 9e; the quartz-rich sediment was probably derived from the siliceous tuff to the northeast, supporting the southwest-facing direction interpreted for this section. Parts of the presumed base of unit 9e are intruded by a concordant tonalite pluton which bisects the volcanic belt. The top is conformably overlain by aphyric basalt flows and intercalated tuff (2a, 2d).

The siltstone-amphibolite deposit east of Wasekwan Lake lies to the east of porphyritic basalt (3a). At Sickle Lake the porphyritic basalt tops to the northeast; assuming a monoclinal sequence, unit 9e overlies unit 3a. A single outcrop of greywacke overlies unit 9e.

Unit 9e is characterized by interlayering of buff- to light-grey-weathering siltstone and dark green-weathering amphibolitic material at a scale of 2 mm - 30 cm. Bedding and lamination are parallel-sided, regular, and continuous. Contacts between beds are sharp, and graded bedding is absent.

The siltstone consists of a fine grained (0.05 - 0.1 mm) recrystallized mosaic of quartz and untwinned plagioclase (60 - 90%), brown biotite (5 - 20%), pleochroic green hornblende (0 - 10%), epidote (2 - 5%), and magnetite (1%). Garnet (1%), partly replaced by chlorite, occurs in one sample from an outcrop adjacent to the concordant tonalite intrusion. A pronounced foliation is defined by biotite and hornblende. Angular plagioclase crystal fragments (0.2 - 0.5 mm) and ovoid quartz grains (0.5 mm) occur in most siltstone beds and comprise 5 - 10 per cent of the sediment.

Siltstone beds commonly display internal laminae defined by variable biotite or amphibole contents. One such siltstone bed displays excellent 1 - 8 mm lamination: light buff laminae are relatively rich in quartz, contain very little biotite, and contain abundant microclasts; light grey laminae with 10 - 15 per cent biotite are finer grained and contain more feldspar. The lamination in some siltstone beds is defined by the presence of acicular amphibole blasts.

Amphibolitic beds are very fine grained (0.05 - 0.2 mm). They are composed of subparallel prisms of pleochroic green hornblende (50 - 70%), untwinned plagioclase + quartz (30 - 40%), and minor magnetite, biotite, and epidote. Some of the thicker amphibolitic beds are internally laminated.

A unit of siliceous siltstone (9d), at most 50 m thick, occurs immediately adjacent to the Sickle Lake felsic tuff (7e). It is not classified as part of unit 9e because amphibolite interlayers are absent; however, it could be considered the basal component of unit 9e at Miskwa Lake. The sediment was almost certainly derived from the felsic tuff; light grey, quartz-rich, resistant beds are sharply interlayered with brownish buff micaceous siltstone or dark brown argillitic laminae. A few quartz microclasts and wispy laminations of amphibole or biotite are the only sedimentary features within the siliceous beds.

PROVENANCE AND ENVIRONMENT OF DEPOSITION

The presence of microclasts and argillitic laminations in the unit 9e siltstone indicate an epiclastic origin. The siltstone may have been derived from the Sickle Lake felsic tuff, and is similar in composition to the siliceous sediment (9d) which directly overlies the tuff. The origin of the amphibolitic beds is unclear. They may be tuffs, precursors to the aphyric basalt (2) directly overlying unit 9e at Miskwa Lake, or a Ca-Fe-Mg-rich mudstone derived from a pre-existing mafic volcanic terrane. The even, delicate nature of primary bedding and the absence of current-related structures suggests a low-energy environment of deposition.

MISKWA LAKE APHYRIC BASALT (2)

Mafic flows, mafic tuff, derived amphibolite and intrusive rocks define a unit 670 m thick extending from an area near Sickle Lake to Wasekwan Lake. The unit is flanked to the northeast by laminated siltstone and mafic tuff (9e) near Miskwa Lake and by intercalated porphyritic and aphyric basalt (3d) in the Wiley Lakes area. Greywacke and siltstone (9c) border the mafic volcanic unit to the southwest. A single top determination, south of Miskwa Lake, defined by grading in a mafic tuff bed, suggests a southwest facing.

The component rock types and their general characteristics are listed in Table 18. The unit represents a metavolcanic-intrusive complex in which remnants of volcanic-textured rock are interspersed with derived metamorphites and locally abundant intrusive rocks. The mafic volcanic rocks have lower amphibolite

TABLE 18: CHARACTERISTICS OF ROCK TYPES COMPRISING THE MAFIC VOLCANIC UNIT (2) IN THE MISKWA LAKE BELT

	MAFIC FLOWS	MAFIC TUFF	MASSIVE AMPHIBOLITE	LAYERED AMPHIBOLITE	DIORITE	QUARTZ DIORITE	TONALITE
WEATHERING COLOUR	Dark green to black	Dark green	Medium to dark green	Dark grey-green	Dark green and white	Buff	Buff
FRESH COLOUR	Medium to dark grey	Medium to dark grey	Medium grey	Medium grey	Dark green and white	Light grey	Light grey
MODE OF OCCURRENCE	Predominate S and W of Miskwa Lake. Locally interlayered with tuff.	Predominate SE of Miskwa Lake.	Strongly recrystallized flows. Commonly intruded by diorite, tonalite.	Recrystallized tuff? Tonalite and quartz diorite *lit*.	Dykes and irregular bodies cm's to m's wide.	Dykes (<10 cm - 1 m) concordant to foliation. Local amphibolite inclusions.	Veins and *lit* (2 mm - 15 cm) concordant to foliation. Anastomosing veins in diorite.
PRIMARY STRUCTURES AND TEXTURES	Massive Aphyric Local amygdales	Bedding (2 mm - 10 cm) Rare grading		Some layering may be primary	Locally densely hornblende (after pyroxene) - phyric	Plagioclase phenocrysts to 3 mm	
GRAIN SIZE	0.1 - 0.2 mm	0.05 - 0.2 mm	0.1 - 0.5 mm	0.2 - 0.5 mm	0.5 - 3 mm	0.5 - 3 mm	0.3 - 1 mm
FABRIC	Granoblastic mosaic. Weak hornblendic foliation.	Foliated aggregate of hornblende, with granoblastic plagioclase, quartz.	Granoblastic inequigranular. Good hornblende foliation.	Granoblastic inequigranular. Layering (5 mm - 5 cm) defined by mafic content, tonalite *lit*.	Equigranular	Equigranular to plagioclase-phyric. Foliated to gneissic.	Equigranular Foliated Xenomorphic
MINERALOGY (%)							
Quartz	5	3	5 - 10	10	5 - 10	20	25 - 30
Plagioclase	20 - 25	15 - 20	45	40	40 - 45	60	65
Hornblende	60	70 - 75	40	40	30 - 40	3 - 5	5
Biotite	5 - 10	—	2	10	2	5	—
Epidote	3	2	2	tr	2	5 - 10	—
Magnetite	1	1	—	tr	—	—	—
Sphene	—	1 - 2	1	—	1	—	—

facies mineral assemblages dominated by green hornblende and andesine (Table 18).

Mafic flows occur south and west of Miskwa Lake. They are fine grained, massive, aphyric, and only locally amygdaloidal. They rarely contain tonalite or quartz diorite veins but are locally cut by quartz or quartz-feldspar stringers. Fine grained flows locally grade to massive amphibolite, generally with an increasing proportion of diorite dykes and quartz diorite veins. Locally there is an abrupt transition defined by an increase in quartz diorite veins, from fine grained basalt to an intrusive complex composed of quartz diorite with rafts and inclusions of amphibolite.

Layered mafic tuff occurs south and southeast of Miskwa Lake. It is locally interlayered with massive, fine grained, mafic flows. Beds in the tuff are 2 mm - 10 cm thick, and consist of alternating dark green hornblendic layers and grey-green hornblende + plagioclase layers. Some beds are graded, with the hornblende-rich portion interpreted as the base of the bed. The layered tuff locally grades to massive tuff.

Finely layered amphibolite occurs in the portion of unit 2 closest to Sickle Lake. Layering (5 mm - 5 cm thick) is defined by variation in the ratio of hornblende to feldspar and by up to 40 per cent tonalite or quartz diorite *lit* (up to 2 cm thick) emplaced parallel to foliation and compositional layering. Some of the thicker *lits* contain amphibolite inclusions. Rare interlayered mafic flows, up to 3 m thick, occur within the layered amphibolite. The primary compositional layering of this rock type suggests that it was derived from bedded mafic tuff.

Hornblende diorite, quartz diorite, and tonalite comprise intrusive bodies ranging from veins and *lits* to irregular small plugs; one lens-shaped, dominantly intrusive mass is over 1 km long. The intrusive rocks are most common in the area southeast of Miskwa Lake and southeast of Wiley Lakes. Cross-cutting relationships between the intrusive phases are consistent throughout the unit, and indicate that the diorite rocks are oldest and the tonalite youngest. The diorites generally occur as larger masses and dykes whereas tonalite commonly occurs as narrow veins and *lits* cutting the volcanic rocks, amphibolites, and earlier diorite and quartz diorite.

The abundance of intrusive veins and dykes within the mafic volcanic unit (2) contrasts with the near-absence of this material in adjacent supracrustal units. Indeed, some parts of unit 2 southeast of Miskwa Lake have the appearance of a contact zone between a volcanic belt and a plutonic terrane. This relationship is consistent with the interpretation of the Miskwa supracrustal belt as a large screen within the dominantly plutonic terrane south of the Cartwright Lake fault zone.

BIOTITE GREYWACKE, SILTSTONE (9c)

Fine grained, thin-bedded greywacke and siltstone occur along the southwest margin of the Miskwa Lake belt. The rocks are exposed as flat, low-weathering outcrops and much of the unit is covered by drift and muskeg. A maximum thickness of 460 m is exposed south of Miskwa Lake, and the unit has an inferred strike length of 9 km. The sedimentary rocks have a sharp, conformable contact with mafic flows and tuffs (2) to the northeast, and have a subconcordant intrusive contact with a post-Sickle(?) tonalite pluton to the southwest. The facing direction of the sedimentary unit is not known; however, mafic tuffs immediately northeast of the sediments display possible southwest-facing graded bedding. If the top direction is correct the sediments overlie the mafic volcanic suite.

The sedimentary rocks weather dull yellowish brown to light grey-brown and fresh surfaces are light to medium grey. A brownish ironstain is locally developed on weathered surfaces. Greywacke and siltstone beds are interlayered with argillitic layers and laminae, resulting in differential weathering of up to 3 mm between adjacent beds. The beds (5 mm - 20 cm thick) are devoid of any sedimentary structures apart from a fine internal biotite lamination; each bed is defined by a characteristic composition and grain size. There is a continuum in grain size between siltstone and greywacke.

Primary clastic texture is well preserved only in the coarser greywacke members of the suite but it is usually not apparent in hand specimen. The greywacke is poorly sorted and seriate-textured with common subangular to subrounded plagioclase crystal fragments (0.1 - 0.3 mm) and sparse subrounded quartz microclasts in a very fine grained (0.5 - 0.1 mm) matrix. Some beds contain rare felsic volcanic rock fragments up to 1 mm long. The fine grained greywackes and siltstones are completely recrystallized and only rare plagioclase microclasts are preserved.

Mineral assemblages developed in the greywacke-siltstone members of the unit are:

(1) quartz + plagioclase + biotite + muscovite ± pyrite;

(2) quartz + plagioclase (An_{33}) + biotite + epidote.

Most rocks are recrystallized to a fine grained (0.1 mm) granoblastic mosaic of quartz and plagioclase, with a prominent preferred orientation of mica. Plate-like muscovite blasts up to 1 mm in diameter occur in some greywackes. Modes of the greywacke and siltstone include 5 - 25 per cent biotite, 70 - 90 per cent quartz + plagioclase (the quartz content is variable), 0 - 10 per cent muscovite, and minor amounts of epidote, pyrite and magnetite. Argillitic laminae and partings consist of 40 - 75 per cent biotite and locally up to 10 per cent magnetite. Poikiloblastic or prismatic hornblende is a minor phase. It occurs only near the top of the sedimentary section, as sporadic blasts or in a few laminae.

The chemical composition of a resistant greywacke bed (analysis 55, Appendix), is distinctly siliceous. The Miskwa greywacke sample contains significantly more SiO_2 and Na_2O, and significantly less Al_2O_3, MgO, and CaO than an average greywacke (cf. Pettijohn, 1975) and Archean greywackes (cf. Henderson, 1972; Goodwin, 1971). The greywacke is, however, very similar in composition to southern belt rhyolites (analyses 42 to 47, Appendix).

Associated lithologies, which comprise a small proportion of the sedimentary sequence, include:

(1) Felsic crystal tuff. The tuff consists of crystal-bearing beds up to 1 m thick, and thin, crystal-free beds. The crystal-bearing beds contain 15 - 20 per cent corroded microcline crystals (1 - 3 mm) and 10 per cent recrystallized, embayed quartz crystals (up to 2 mm) in a very fine grained granoblastic mosaic of plagioclase, quartz, and biotite.

(2) Massive rhyolite. This very fine grained flow or hypabyssal intrusion weathers light buff to light pink; it contains rare 0.5 mm feldspar phenocrysts and locally disseminated pyrite crystals and pyrite fracture fillings.

(3) Reworked mafic tuff. At the top of the sedimentary section there are two exposures of dark green-weathering, fine grained, laminated mafic tuff with concordant *lit* of buff fine grained tonalite.

INTEPRETATION AND PROVENANCE

The Miskwa Lake greywacke-siltstone succession is interpreted as a low-energy deposit derived from dilute density currents and/or weak bottom currents. This interpretation is based on the following observations: (1) the detritus is fine grained, subangular, and poorly sorted, (2) beds are thin, regular, and laminated, and (3) micaceous (± magnetite) partings are present but ripples are absent (indicating the lowest flow regime). The environment of deposition is considered to be within a marine basin, possibly far off-shore, and below storm wave base.

Provenance of the sediment is probably a felsic volcanic terrane, as indicated by the siliceous composition of many greywacke beds, the presence of rare rhyolite rock fragments, and the association with felsic volcanic lithologies.

The arc-shaped belt of Wasekwan Group rocks exposed east of the Keewatin River, between Sickle Lake and Hughes Lake, consists of three major units: intermediate and mafic flows and tuff (4; 2500 m), dacite (6; 790 m), and greywacke-siltstone (9c; 840 m). The structure, inferred to be homoclinal and west-facing, is interpreted from the stratigraphic relationship of the sediments to the dacite. Neither the base nor the top of the sequence is exposed.

KEEWATIN RIVER MAFIC AND INTERMEDIATE VOLCANIC ROCKS (4)

An arc-shaped unit of intermediate and mafic volcanic rocks (4) comprises the majority of the Keewatin River supracrustal belt. Maximum width of the unit is approximately 2500 m south of Hanna Lake; no tops were determined.

The unit consists of three components: (1) mafic and intermediate flows (4a), (2) a wedge-shaped body of mafic lapilli tuff and crystal tuff (4e), and (3) a thin unit of iron formation and mafic tuff (9j, 4e), which occurs between units 4 and 6 (dacite). Greywacke and siltstone (9b) are locally intercalated with the volcanic flows but the relative abundance of sediments in unit 4 is small. The siltstone is characterized by a siliceous composition (analysis 52, Appendix).

MAFIC AND INTERMEDIATE FLOWS (4a)

Mafic and intermediate flows are apparently interlayered throughout much of unit 4 east of the Keewatin River. All of the flows are massive and, apart from rare amygdales, all primary structures have been obliterated. Mafic flows weather dark grey to dark green and are medium grey to dark-green on fresh surfaces. They are aphyric and commonly contain epidote veins and ovoid to irregular epidosite domains. Mafic flows in the southeastern portion of the unit are particularly altered to epidotic assemblages. Intermediate flows weather buff to light grey-green and are medium to dark grey on fresh surfaces; they contain up to 20 per cent plagioclase phenocrysts 1 2 mm in diameter. These rocks too, commonly contain epidote veins and epidosite masses.

The mafic volcanic rocks are characterized by a hornblende-rich mineral assemblage, whereas the intermediate rocks are relatively rich in biotite and contain little or no hornblende (Table 19). Plagioclase phenocrysts are completely recrystallized and replaced by sericite, biotite, and epidote.

MAFIC LAPILLI TUFF AND CRYSTAL TUFF (4e)

A wedge-shaped unit of mafic, lapilli and crystal tuff (4e) occurs in the southeast portion of unit 4. The tuff deposit is a maximum of 335 m thick south of Hanna Lake, where it is truncated by a gabbro pluton, and extends more than 4 km to the northwest before it wedges out.

Dark green weathering mafic lapilli tuff occurs throughout the Hanna Lake deposit but its abundance, fragment size, and bedding thickness is greatest in the southeast portion of the unit. It is commonly characterized by a thick, crude stratification defined by size and abundance of lapilli; bedding contacts are gradational. Locally, the lapilli tuff is interbedded with crystal tuff, with beds (5 mm - 1m thick) defined by fragment size in lapilli tuff and crystal abundance in crystal tuff. Lapilli are lens-shaped, up to 1 by 14 cm in horizontal section (commonly less than 5 cm long), and weather white to light buff. The fragments contain significantly less amphibole than the matrix (5 - 30% *vs.* 50% in the matrix) and are finer grained (0.1 mm *vs.* 0.1 - 0.3 mm in the matrix). Small quartz amygdales occur in some lapilli. Plagioclase crystals comprise less than 5 per cent of the mafic matrix and are up to 1 mm in diameter. The lapilli tuff is matrix-supported; fragment abundance ranges from 10 to 40 per cent.

Crystal tuff weathers dark grey-green and is mafic in composition. Plagioclase crystals and crystal fragments (1 - 3 mm) partly replaced by epidote comprise up to 40 per cent of the tuff. The tuff is bedded (beds 5 mm to 1 m thick) and locally laminated (a delicate alteration of buff feldspar-rich layers and more mafic, plagioclase crystal-bearing layers). Thicker beds are homogeneous in texture and grain size.

The wedge shape of unit 4e, and the coincidence of the largest fragments with the thick southeast portion of the unit, suggests that the southeast portion is a proximal deposit. The proximal tuff grades locally northwest to a more regularly bedded, finer grained, more distal deposit.

IRON FORMATION (9j), MAFIC TUFF (4e), MAFIC FLOWS (4a)

A thin (minimum 10 m, maximum 50 m) unit of magnetite-silicate iron formation, laminated iron-rich mafic tuff, and minor mafic flows and dykes occurs between units 4 and 6 (dacite), east of the Keewatin River. The relationship between the dacite and adjacent sediments (9c) suggests a northwest facing; consequently the heterogenous, iron-rich, tuffaceous unit probably represents the top of unit 4 — the substrate upon which the dacite was deposited.

The magnetite-silicate iron formation weathers greenish-black and is dark grey-green on fresh surface. It contains a delicate lamination defined on outcrop by differential weathering between laminae and by minor siliceous layers. Laminations are defined mineralogically by variable content of magnetite (15 - 60%), amphibole (20 - 70%), and garnet (0 - 20%); garnet is associated with amphibole-rich laminae. Three assemblages, defined by the *abundance* of the constituent minerals, are present

(1) quartz + amphibole + magnetite;
(2) amphibole + magnetite + quartz + garnet;
(3) magnetite + quartz + amphibole.

Amphibole defines an excellent foliation and garnets are flattened, fractured, pulled apart, and partly replaced by chlorite. Chlorite locally replaces much of the amphibole. Feldspar and epidote are absent.

Associated mafic tuff weathers brownish-green and is grey-green on fresh surfaces. It contains a vague 1 - 2 cm layering and local lamination similar to the amphibolitic lamination in the iron formation. The tuff, however, contains up to 40 per cent plagioclase and epidote, small plagioclase crystal fragments, and only 1 - 2 per cent magnetite. Massive mafic flows and dykes comprise a small part of the unit; the iron formation is locally truncated against mafic dykes or sills which cut across layering at a shallow angle.

DACITE (6)

A wedge-shaped deposit of dacite situated 3 km north of Sickle Lake is the sole felsic extrusive centre in the Keewatin River and Miskwa Lake supracrustal segments. The dacite body is a maximum of 790 m thick at the Keewatin River, where it is truncated by a pre-Sickle tonalite pluton. The body pinches out approximately 1300 m northeast of the Keewatin River.

The stratigraphic relationship of the dacite body to adjacent greywackes suggests that the dacite tops west. The body is underlain by a succession of intermediate and mafic flows and tuffs (4), with a few intercalated intermediate to felsic flows similar to flows in the dacite wedge. Two thin (30 - 100 m) units separate unit 4 from unit 6: (1) laminated mafic tuff and magnetite-silicate iron formation, and (2) felsic flows and breccias, which occur immediately adjacent to the dacite. The dacite body is conformably overlain by greywacke and siltstone (9c), some of which is clearly derived from the dacite.

The main dacite body consists of approximately equal proportions of massive plagioclase-phyric flows and crystal-lithic tuff. Mineral assemblages developed in the dacite (below) are representative of the upper greenschist or lower amphibolite facies. Chemical analyses of the flows are similar to an "average" dacite

TABLE 19: MINERALOGY AND FABRIC OF LITHOLOGIES IN THE KEEWATIN RIVER MAFIC TO INTERMEDIATE VOLCANIC SUITE (UNIT 4)

	Mafic flows	Intermediate flows	Mafic tuff	Iron formation
Quartz	5 - 10	5 - 10	5	40
Plagioclase	20 - 45	30 - 55	40 - 50	0
Biotite	0 - 3	20 - 25	5 - 10	0
Chlorite	1	0 - 1	0 - 5	2
Hornblende	40 - 60	0 - 3	25 - 50	30
Epidote	10	5 - 25	1 - 10	0
Magnetite	3	1 - 3	1 - 2	25
Apatite	tr	tr.	tr.	0
Garnet	0	0	0	5
Plagioclase phenocrysts	0 - 5	5 - 20	5 - 40	0
Fabric	Fine grained (0.1 - 0.3 mm) granoblastic — irregular mosaic of plagioclase and quartz, with foliation defined by orientation of biotite flakes and hornblende prisms			Laminated. Excellent hornblende foliation
		biotite-epidote-magnetite lenticles 1 mm - 1 cm long	Locally laminated	

(e.g. LeMaitre, 1976), but contain less Al_2O_3 and more iron (analyses 48 to 50, Appendix).

The dacite flows (6b) weather light grey to buff, and are medium grey on fresh surfaces. They are massive, and have a monotonous, featureless outcrop appearance. Rare quartz amygdales (1 - 3 mm) are the only structures indicative of an extrusive origin. Plagioclase phenocrysts in the flows vary in size (0.5 - 2 mm) and abundance (5 - 20%).

Dacitic tuff (6d) is similar in appearance to the massive flows. It is characterized by vague, metre-scale layering, defined by variable plagioclase crystal content. A fine (5 mm) fragmental texture is apparent locally in outcrop, but is more readily apparent in thin section. Plagioclase occurs as subhedral, slightly corroded crystals and angular crystal fragments. Lithic fragments (commonly less than 5 mm long) include (1) biotite-bearing aphyric andesite or dacite, (2) biotite and hornblende-bearing aphyric andesite or dacite, and (3) plagioclase-phyric rhyolite. Deformation and recrystallization has commonly produced very similar grain size and mineralogy in fragments and matrix.

The following mineral assemblages are developed in the dacite:

(1) plagioclase + quartz + biotite + epidote;
(2) plagioclase + quartz + biotite + epidote + hornblende;
(3) plagioclase + quartz + biotite + epidote + garnet ± hornblende.

Chlorite, magnetite, and apatite are minor components. Plagioclase phenocrysts (0.5 - 2 mm) are euhedral to subhedral and commonly slightly corroded; some phenocrysts display continuous normal zoning. Saussuritization and carbonatization is concentrated at crystal cores; some crystals are completely altered to fine grained pseudomorphs of plagioclase, epidote, sericite, and biotite. The groundmass of the flows, and the matrix of the tuff, consists of a very fine grained (0.05 - 0.1 mm) recrystallized mosaic of untwinned plagioclase, quartz, brown biotite, epidote, and magnetite. Pale green chlorite is a retrograde replacement of biotite. Small garnets, up to 1 mm in diameter, occur as ragged porphyroblasts commonly within or adjacent to plagioclase phenocrysts. Green hornblende blasts occur as rugged stubby prisms or acicular crystals. A typical dacite flow contains 65% plagioclase + quartz (10% plagioclase phenocrysts), 20% biotite, 10% epidote, 2% magnetite, 2% chlorite, and trace apatite.

Tectonite fabrics are well developed. The foliation is defined by orientation of biotite and by trains of epidote grains. Bulk flattening of the rock is indicated by plagioclase crystal pull-aparts, rotation of phenocrysts into the plane of foliation, pressure shadows, and flattening of lithic fragments. Epidote stringers and epidosite segregations oriented parallel to foliation are common.

INTERPRETATION

The main body of dacite flows and tuff is wedge-shaped, and may represent part of a small composite cone. The southwest portion of the edifice has been removed by intrusion of a tonalite pluton. The dacite cone was built up through large-scale interlayering of massive flows and pyroclastic deposits; clastic sediments (see unit 9c below) derived from the cone were deposited on its flank during or after the felsic volcanism. There is no direct evidence to suggest a subaqueous environment of deposition for the dacite; however, the underlying and overlying deposits are clearly water-laid.

GREYWACKE, SILTSTONE (9c)

A lens-shaped deposit of greywacke, siltstone, minor pebble conglomerate, and sporadic mafic flows or sills is exposed northeast of the Keewatin River. Tops were not determined within the unit; however, the composition and texture of the greywacke suggests that the sediments were derived from the adjacent dacite body (6) to the southeast. The sedimentary deposit has a maximum exposed width of 840 m (1050 m inferred from the aeromagnetic signature); the presumed top is truncated by a pre-Sickle tonalite pluton. It is exposed for a strike length of 3.6 km northeast of the Keewatin River.

Greywacke beds (1 - 50 cm thick, commonly less than 20 cm) are massive and poorly sorted; they are defined by variation in the content and size of crystal and lithic fragments, and by interbeds of siltstone. Greywacke commonly has a hiatal texture, characterized by 15 - 30 per cent plagioclase crystals and crystal fragments (0.3 - 1.5 mm) in a fine grained (0.05 - 0.1 mm) matrix. The detrital nature of the plagioclase is indicated by rounding of euhedral crystal margins, fracturing across polysynthetic twin planes, or a combination of both fracturing and rounding. Rock fragments (2 - 10 mm) occur throughout the unit but are most common near the contact with dacite (6); fragment lithologies include subrounded rhyolite or dacite with aphyric or plagioclase-phyric texture, and an intermediate volcanic rock represented by biotite-rich lenticles. The matrix consists of a largely recrystallized mosaic of quartz, untwinned plagioclase, biotite, chlorite (an alteration of biotite), epidote, magnetite, and carbonate. Mafic minerals comprise 20 - 30 per cent of the rocks, and quartz (which occurs only in the fine grained matrix and never in the framework fraction) comprises 10 - 25 per cent.

Siltstone beds (5 mm - 5 cm thick, rarely to 30 cm) are massive to laminated. Laminae are commonly poorly defined and gradational; they are defined by variation in biotite content (5 - 20%), grain size, and quartz content (quartz-rich laminae are coarsest). The siltstone is recrystallized, but the largest detrital grains (quartz) probably represent the coarse fraction of primary grain sizes; these are 0.06 - 0.1 m, and correspond to a corase silt or very fine sand grade*. Near the base of the unit siltstone beds contain 1 - 2 per cent plagioclase and quartz microclasts (0.1 - 0.3 mm). A typical siltstone mode includes: quartz and untwinned plagioclase (70%), biotite and chlorite (25%), epidote (3%), magnetite (1%), and carbonate (1%); garnet (partly replaced by biotite) occurs sporadically. The quartz content is variable; it is most abundant (30 - 40%) in light grey-white, chalky-weathering beds. Biotite defines the foliation.

Associated minor rock types include: (1) pebble conglomerate, with white-weathering felsic volcanic pebbles (up to 5 cm long) supported by a greywacke matrix, occurring near the upper (intruded) contact, and (2) massive, green-weathering mafic flows or sills.

The sediments were largely derived from the adjacent plagioclase-phyric dacite, as indicated by the abundance of detrital plagioclase, the absence of phenocrystic quartz, the composition of rock fragments, and the bulk modal composition of the greywacke. Some of the greywackes may represent reworked dacitic tuff, which forms a significant porportion of unit 6. The sediments overlie successively older volcanic lithologies to the northeast, suggesting that the dacite source was a positive topographic feature, built up on a more extensive, underlying mafic platform.

*Wentworth size class; Pettijohn, 1976.

ZED LAKE-HUGHES RIVER AREA

INTRODUCTION

Fine grained metasedimentary rocks and derived gneisses intruded by gneissoid tonalite and granodiorite occur between Zed Lake and Hughes River; these rocks comprise the southern part of an extensive metasedimentary gneiss terrane which extends from the eastern shore of Reindeer Lake to the northeastern part of Southern Indian Lake (McRitchie, 1976). South of this terrane, volcanic and sedimentary rocks of the Wasekwan Group comprise the Lynn Lake Greenstone Belt; conglomerate of late Wasekwan or Sickle Group age occurs between the northern belt (Wasekwan Group) and the metasedimentary gneiss terrane (Fig. 2). Greywacke and paragneiss of the Zed Lake-Hughes River area (Zed Lake greywacke) have been correlated with rocks of the Burntwood River Metamorphic Suite south of the Lynn Lake Greenstone Belt, which is considered to be approximately equivalent in age to the Wasekwan Group.

A formation of mafic to intermediate volcanic rocks and amphibolite extends along the southeastern margin of the Zed Lake greywacke. The rocks are best preserved west of Gallagher Lake and east of Betty Lake, where the formation is approximately 175 m thick. These rocks, which are commonly strongly foliated and gneissic, include aphyric and porphyritic basalt (with plagioclase and hornblende), andesite, mafic crystal tuff and lapilli tuff, and intermediate volcanic breccia. The formation contains rare, thin (20 cm) siltstone beds and felsitic layers, and is locally intruded by massive gabbro. The volcanic assemblage is typical of the Wasekwan Group, and the formation is interpreted as a section of the Wasekwan which has been isolated from the Lynn Lake greenstone belt by folding or faulting.

GREYWACKE, MIGMATITE, AMPHIBOLITE (1) — ZED LAKE GREYWACKE

BIOTITE ± GARNET-BEARING GREYWACKE, MIGMATITE (1A)

Fine grained sedimentary rocks extend from the southern shore of Zed Lake to the area east of Hughes River, along the northwestern margin of the northern belt. Conglomerate (10a) occurs between these rocks (Zed Lake greywacke) and volcanic and sedimentary rocks of the northern belt to the south. Relationships between these major stratigraphic divisions are not well established, but south-facing graded bedding is preserved in the fine grained sediments (1A) and overlying mafic tuff (4e) east of Hughes River (Cockeram Lake area, NTS 64C-15). The conglomerate (10a) south of this tuff is considered to occupy the core of a syncline, because Wasekwan Group volcanic and sedimentary rocks in the area immediately south of the conglomerate face north to northwest. The minimum width of the Zed Lake greywacke is 4.25 km south of Zed Lake, and 4 km at Hughes Lake; the apparent thickness of the unit is increased by the emplacement of granitoid rocks and probably by repeated folding.

The fine grained sedimentary rocks vary considerably in different parts of the section. In the area to the west (Zed Lake-southern Goldsand Lake) greywacke is interlayered with grey or buff siltstone and minor dark grey or green-grey argillite at a scale of 1 - 15 cm, and locally comprises massive beds up to 60 cm thick. The greywacke is pale to medium grey or blue grey and locally contains detrital quartz, andesine, and rare microcline and micaceous lenticles; embayed quartz in one sample is interpreted as volcanogenic. However, detrital textures are not generally preserved; the rocks are progressively more recrystallized with development of paragneiss towards the margins of the granitoid terrane (19, 21) to the north.

East of Hughes River, greywacke and siltstone are more thinly bedded (0.5 - 7 cm); these rocks have been interpreted as distal turbidites by one of the authors (H.V.Z.). Laminated units (Bouma Division B) are common but the graded division (A) occurred in only 12 out of 30 measured beds and ripple laminations (Bouma Division C) are absent in the uppermost part of the section. Older rocks to the north are locally more thickly layered (20 cm) and the lower parts of beds are graded or massive. East of Hughes River the sedimentary rocks are fine- to medium-grained; siltstone comprises approximately 50 per cent of the section. Immediately west of Hughes River, west of the turbidites, the Zed Lake greywacke is extensively intruded by tonalite and consists of biotite gneiss. The abrupt change in the character of the sedimentary rocks may be related to a major fault at Hughes River.

The sedimentary rocks and derived paragneiss consist largely of plagioclase, quartz and biotite. Rare epidotic pods with garnet-biotite-rich margins occur close to Glad Lake (Lynn Lake area, NTS 64C-14); rare, strata-bound garnet occurs in the same area, locally confined to more siliceous, cream-weathering beds. Accessory pyrite is widespread; finely divided graphite, sphene, apatite and zircon are less common. The strong regional foliation is almost always parallel to bedding. Muscovite occurs locally, parallel to the (biotite) regional foliation or as porphyroblasts. Microcrenulation of the foliation and development of strain-slip cleavage was observed in some argillitic beds, which are locally completely disrupted and deformed in irregular patterns indicative of at least two fold episodes. Granitoid rocks (19, 21) postdate the regional foliation of the Zed Lake greywacke but are followed by later deformation which produced boundinage of the generally concordant intrusions. Rare porphyroblasts of plagioclase, microcline, and tourmaline are interpreted as products of contact metamorphism by the granitoid rocks. Late retrogression produced minor chloritization of biotite, and local prehnite within the mica.

LAYERED AND MASSIVE AMPHIBOLITE (1C)

Minor amphibolite units (1C) up to at least 15 m thick occur within the Zed Lake greywacke in the area between Glad Lake and Merle Lake, and west of Stick Lake. The foliated amphibolite contains up to 15 per cent biotite; one section displays relict ophitic texture in clinopyroxene indicating a magmatic origin. Laminated amphibolite at Merle Lake, however, suggests a tuffaceous or sedimentary derivation.

MOTRIUK LAKE-EAGLE LAKE AREA (NORTHERN BELT)

INTRODUCTION

Volcanic and sedimentary rocks of the Wasekwan Group have been mapped from the area south of Zed Lake northeast to Eagle Lake (northern belt). East of Eagle Lake, the belt continues east and southeast to the southern part of Barrington Lake (Lynn Lake, Cockeram Lake, and Barrington Lake map-areas NTS 64C-14, 15, and 16). The distal part of the volcano-sedimentary belt becomes progressively narrower east of Barrington Lake where it is terminated by granitoid intrusions in the area east of Magrath Lake (Fraser Lake area, NTS 64B-13).

The Wasekwan Group of the northern belt is subdivided into six lithostratigraphic divisions (Figs. 16 and 17). The overall sequence is interpreted as homoclinal and north facing, but local reversals indicate folding particularly in the predominantly sedimentary division (C).

Division A comprises a thick (2400 m) rhyolite lens (Lynn Lake rhyolite) with subordinate intercalations of more mafic volcanics and conglomerate. The rhyolite is apparently overlain by a diverse suite of mafic to felsic volcanic flows and fragmental rocks (division B) and further north, by the predominantly sedimentary division C. The distribution of pyroclastic facies in division B indicates the most proximal rocks occur in the vicinity of Lynn Lake town. Volcanic rocks of division D are predominantly basaltic flows and flow-breccias with subordinate mafic tuff, felsic fragmental units, and iron formation. These rocks are apparently overlain by north-facing mafic tuff and flows, with subordinate volcanic breccia and

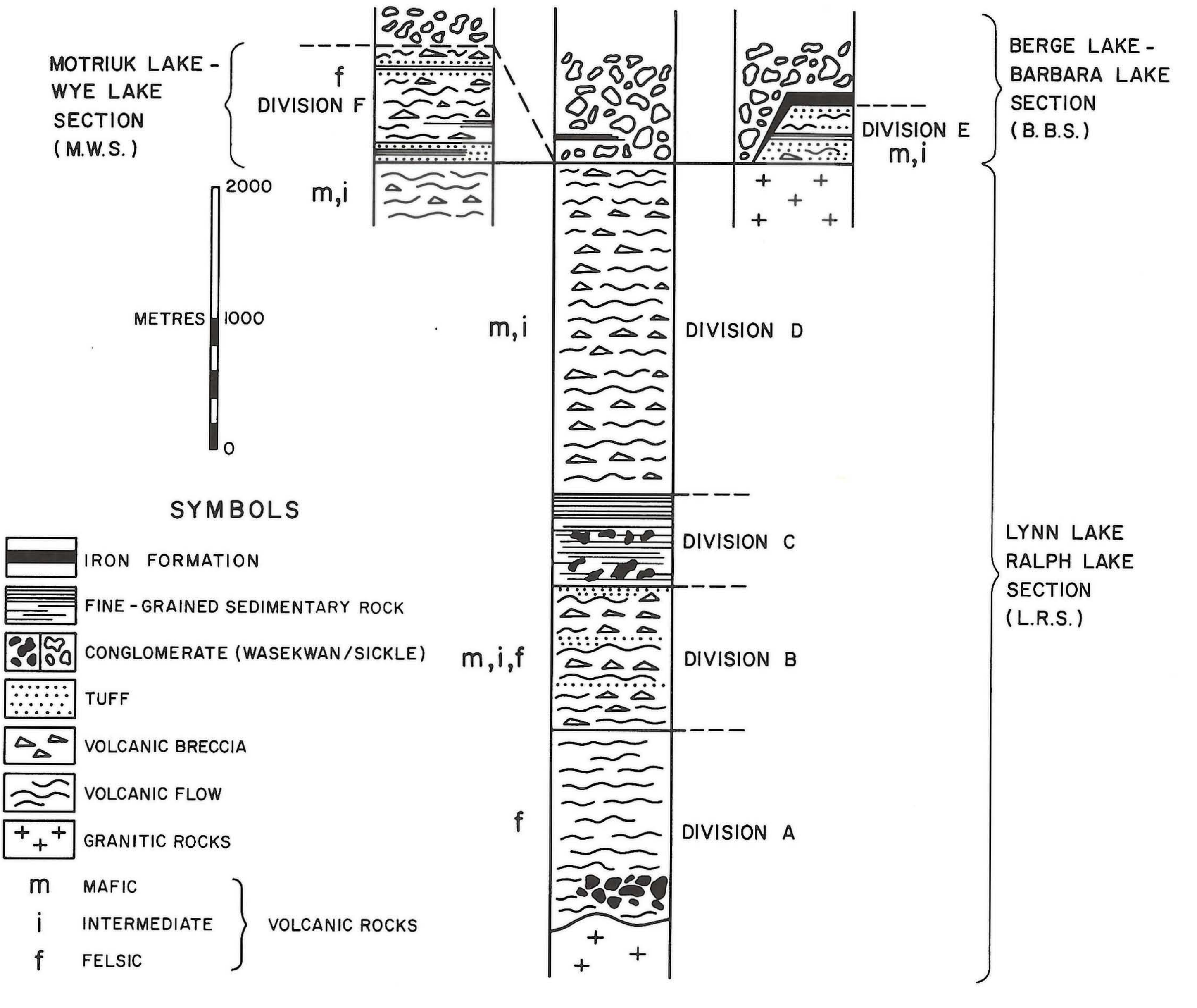


FIGURE 17: Stratigraphic sections in the Lynn Lake area.

greywacke (division E) north of Lynn Lake; further west division D is succeeded by rhyolite flows and breccia and subordinate volcaniclastic rocks of division F (due north of Motriuk Lake). Conglomerate of probable Sickle Group age (10a) extends along the northwestern margin of the northern belt; iron formation up to at least 80 m thick occurs locally between the conglomerate and the uppermost Wasekwan volcanic rocks. The age of the iron formation is unknown; the Sickle/Wasekwan contact at the northern flank of the northern belt is considered to be unconformable on the basis of regional stratigraphic relationships.

Lateral facies changes within the northern belt are displayed by a series of stratigraphic columns (Table 5). The western section (Eldon Lake-Barbara Lake) contains a relatively greater diversity of volcanic rocks in division B, with a greater abundance of breccia and felsic volcanics; the latter are insignificant in the sections further east. The sedimentary division (C) in the area to the east (Muskeg Lake) consists of fine grained sedimentary rocks, in contrast to the western section which contains conglomerate and volcanic intercalations. The apparent thickness of division C is significantly greater in the east, but the extent of structural repetition in the division is uncertain. The predominantly mafic volcanic division (D) shows little variation throughout the northern belt; rocks overlying this division include mafic tuffs and flows at Barbara and Payne Lakes, felsic flows and breccia north of Motriuk Lake, and fine grained sedimentary rocks farther to the west (Fig. 16).

The geochemistry of northern belt volcanic rocks is not consistent with the stratigraphic interpretation based on structural field data, which indicate division D overlies division B. The geochemical results indicate that volcanic rocks of division D are magmatically less evolved than those of division B; there is also some evidence for (chemical) gradation between these two divisions, suggesting that rocks of division D may be the precursors of division B rocks in a coherent magmatic series rather than comprising a separate volcanic cycle.*

MAFIC AND INTERMEDIATE VOLCANIC ROCKS (4)

The major part of the Wasekwan Group in the northern belt consists of predominantly mafic volcanic flows and fragmental rocks of unit 4, with subordinate interlayers of intermediate and felsic volcanic rocks (6 and 7) and sedimentary rocks (8 and 9). Mafic volcanic lithologies, which are partly gradational, are intimately interlayered and individual units are generally too small for mapping at the present scale.

MASSIVE AND PILLOWED PORPHYRITIC AND APHYRIC BASALT AND ANDESITE (4a, 4b)

Mafic flows are the most abundant volcanic rocks in divisions B and D, and are common in division E; sporadic flows also occur within the predominantly sedimentary division C (Figs. 16 and 17). The flows include porphyritic and aphyric types interlayered at a scale of 1 - 15 m. The porphyritic rocks with plagioclase and locally hornblende (after pyroxene phenocrysts) are geochemically distinct from other suites in the area; the most distinctive features are relatively high content of Al_2O_3, high total FeO/MgO and low Ni and Cr contents. These features also distinguish porphyritic basalt from aphyric basalt in the northern belt (Table 20). The porphyritic and aphyric volcanics together define a tholeiitic trend of iron enrichment, although half the analyzed samples of division B fall within the calc-alkaline field of the AFM ternary (Irvine and Baragar, 1971).

Individual flows of porphyritic and aphyric basalt are clearly defined with sharp interflow contacts. Aphyric units, which comprise only 10 - 20 per cent of the section, probably include both flows and sills. Interflow contacts within porphyritic basalt sections are not well defined; flow-breccia is preserved at the margins of some massive flows as epidote-rich zones up to 50 cm thick. Vesicles (1 - 5 mm) in trails represented by elongate zones (1 - 3 cm thick) of quartz (or rare carbonate) amygdales locally define the flow direction.

Variolitic, hornblende-phyric pillowed basalt (4b) occurs close to the northern end of Muskeg Lake (NTS 64C-15). Epidotic, ovoid variolites (1 - 5 mm) are scattered in the dark green, hornblenditic, peripheral zone of pillows and coalesce towards a homogeneous pale green core. Euhedral hornblende crystals and crystal aggregates occur throughout the pillows, and locally grow across the margins of the variolites, which probably represent immiscible segregations (Gelinas *et al.*, 1976). The pillowed flow at the north end of Huet Lake is approximately on strike with that close to the northern end of Muskeg Lake. Pillows also occur at the western end of the northern belt (Ralph and Frances Lakes). Ovoid to bun-shaped pillows (20 cm - 1 m long) are rimmed by hornblende or epidote-rich selvages (0.5 - 2 cm thick).

Typical porphyritic basalts contain 15 - 30 per cent andesine

TABLE 20: GEOCHEMICAL CHARACTERISTICS OF BASALT AND ANDESITE IN THE NORTHERN BELT.

Lithology		Number of samples	Division	Al_2O_3 average	Al_2O_3 range	Total FeO/MgO average	Total FeO/MgO range	Ni (ppm.) average	Ni (ppm.) range	Cr (ppm.) average	Cr (ppm.) range
Porphyritic basalt		5	B	17.13	14.23-18.6	3.02	1.65-4.16				
Porphyritic basalt		9	D	18.28	14.56-20.6	2.13	1.58-2.91				
Aphyric basalt		6	B+D	13.79	12.01-15.45	1.40	0.95-1.72				
Andesite: porphyritic	8										
Andesite		10	B+D	18.12	15.56-21.38	2.9	1.61-3.66				
Andesite: aphyric	2										
Basalt ("high"): aphyric	7										
Basalt ("high")		10	B+D					128	37-408	522	142-1660
Basalt ("high"): porphyritic	3										
Porphyritic basalt ("normal")		18	B+D					8	< 1-30	21	8-30

*Results of geochemical investigations will be the subject of a later report.

(locally labradorite) phenocrysts (up to 50%); zones of very sparsely porphyritic basalt with small (1 - 3 mm) sporadic plagioclase (less than 5%) occur within some aphyric flows. Plagioclase occurs as euhedral, corroded phenocrysts and pseudohexagonal to ovoid phenocryst aggregates and is commonly accompanied by hornblende pseudomorphs and rare biotite phenocrysts. The green hornblende is commonly twinned and relict ophitic texture occurs locally. The hornblende pseudomorphs are generally subordinate to plagioclase phenocrysts and comprise 10 - 15 per cent of the rock. The pseudomorphs contain corroded clinopyroxene relicts in some flows north of Arbour Lake, and east of Tulune Lake. Mafic phenocrysts in one flow southwest of Margaret Lake are replaced by ovoid to subhedral biotite pseudomorphs. An isolated flow within fine grained sediments (9b) at Muskeg Lake contains subhedral pyroxene phenocrysts in a matrix of green hornblende, epidote, and minor carbonate; the flow is apparently overlain by related breccia and fine grained sediments to the south.

The composition of the flows is predominantly basaltic, but ranges up to felsic andesite. Andesitic lithologies are common in the flows and volcanic breccias of division B in the vicinity of Lynn Lake town, and in division D south, southeast, and southwest of Lynn Lake airport. Andesite also comprises minor sporadic flows intercalated with basalt in division B and D, and (rarely) in division E. Basaltic flows are generally dark green, in contrast to paler grey-green weathering andesites; some mafic flows are relatively pale, however, as a result of the preservation of a very fine grained feldspathic matrix with random hornblende poikiloblasts. The majority of basalts are recrystallized to fine grained amphibolites (with up to 90% matrix hornblende). The original texture of randomly oriented plagioclase laths is preserved locally but is not common. Flows at the western end of the northern belt are coarsely recrystallized, with poikiloblastic green hornblende, commonly accompanied by cummingtonite and up to 5 per cent accessory magnetite. Some mafic flows immediately east of Tulune Lake are composed largely of clinozoisite and tremolite. Biotite is a common accessory in the matrix, comprising up to 10 per cent of some rocks. At Frances Lake, biotite comprises up to 20 per cent of the matrix of several plagioclase-phyric basalt flows, which are realtively rich in K_2O (e.g. 1.38 wt.%) compared to typical Wasekwan basalts; the micaceous basalts locally intrude felsic volcanic rocks (7) at northern Frances Lake.

The flows probably include both subaerial and subaqueous types; the scarcity of pillowed structure in the northern belt (only five locations) may be an indication that subaqueous volcanism was not widespread. However, some primary structure may have been tectonically destroyed; the widespread development of irregular epidotic bodies and stringers may be the result of deformation and alteration of original pillow selvages. Sedimentary intercalations (greywacke, siltstone, and iron formation) are very scarce within the mafic to intermediate volcanic rocks (4).

VOLCANIC BRECCIA (4c, 4d)

Mafic to intermediate volcanic breccias are intimately interlayered with flows and tuffs of divisions B and D, and to a lesser extent, division E (Figs. 16, 17 and 18). The majority of the fragmental rocks are interpreted as autoclastic but the mode of origin of these rocks is not clear in many cases. The rocks are generally dimictic or polymictic, diagnostic structures are absent or poorly preserved, and the matrix recrystallized and commonly overprinted by green hornblende. A detrital texture is preserved in the matrix of some polymictic volcanic breccia, indicating a hyaloclastic or pyroclastic origin; autoclastic flow-breccias are identified where a magmatic matrix is recognized at a microscopic or mesoscopic scale; elsewhere, breccia type has been inferred from stratigraphic relationships (association with bedded tuffs or flows, respectively). Polymictic breccias which have been interpreted as pyroclastic, hyaloclastic, or reworked breccias have been mapped as polymictic breccia (4d); where the origin can be identified as autoclastic, the rocks have been mapped as autoclastic breccia (4c).

AUTOCLASTIC BRECCIA (4c)

Autoclastic breccia is widely developed in divisions B and D of the northern belt; these rocks are particularly well preserved at the southern part of Ralph Lake, but similar flow-breccias extend throughout the belt to Eagle Lake (and farther east to the Barrington Lake area).

Flow-breccias typically comprise units up to 10 m thick, gradational with intercalated massive flows. Clast types are as follows: pale grey amygdaloidal andesite, dark green plagioclase-phyric basalt and subordinate aphyric basalt; various textural varieties are defined by the size and abundance of quartz amygdales (up to 75%) and plagioclase phenocrysts (up to 50%), and by the presence or absence of hornblende pseudomorphs after pyroxene. The flow-breccias generally contain at least 2 and commonly 3 or 4 clast types; densely plagioclase-phyric basalt is the most common type. Monolithologic flow-breccias are relatively uncommon. One example at southern Ralph Lake contains pale grey, porphyritic, amygdaloidal felsic andesite clasts in a porphyritic basalt matrix; the breccia is locally gradational to massive porphyritic basalt devoid of fragments. Some clasts are zoned with paler rims or increasing quartz-amygdale density toward the cores, or central altered (epidotic) zones. Most extensive alteration results in assemblages of irregular amoeboid bodies of epidosite in a hornblende-rich, basaltic flow matrix. Clasts are angular to ovoid (generally cobble to small boulder size); the local occurrence of sinusoidal and crescentic forms, and zoning of amygdales within some clasts indicate a relatively plastic state was maintained after formation of these clasts. Clasts are matrix supported, generally unsorted but locally oriented with their long axes parallel; this is interpreted as a primary (flow) orientation in areas which display little or no tectonic influence. The scarcity of inter-clast contacts is considered to have a genetic significance for the flow-breccias; (the frequency of inter-clast contacts in unsorted pyroclastic deposits is expected to be greater where clasts are deposited randomly in a fragmental matrix).

The basaltic matrix contains 5 - 20 per cent plagioclase phenocrysts in a very fine grained groundmass of either green hornblende (30 - 90 per cent) and plagioclase, or plagioclase overprinted by medium grained poikiloblastic hornblende. Magnetite euhedra and cummingtonite are common in the vicinity of Ralph Lake, and poikiloblastic green hornblende is widely developed in that area. Plagioclase (andesine or labradorite) occurs as corroded euhedra (1 - 3 mm) and sporadic pseudohexagonal phenocryst aggregates. Green hornblende pseudomorphs after clinopyroxene are common, locally with relict ophitic texture; sporadic biotite phenocrysts occur in the matrix of breccia north of Arbour Lake. Amygdales are composed of fine grained quartz (± plagioclase) in spheroidal to ellipsoidal bodies 1 - 3 cm (up to 1 cm) long. Plagioclase phenocrysts and/or quartz amygdales are locally concentrated in elongate zones (5 mm - 2 cm x 5 - 50 cm) in the matrix. The zones are diffuse and generally clearly distinguished from clasts of similar composition. Some amygdaloidal bodies, however, display poorly defined margins apparently gradational with the matrix. This is interpreted as evidence for derivation of these bodies by immiscible segregation of a vesicular magma which was differentiated shortly before or during extrusion; the vesicularity (resulting from sudden decrease of pressure) and relatively felsic composition of the clasts compared with the matrix would be a consequence of such a process (Roedder, 1978). Other varieties of clasts compositionally equivalent to the matrix are interpreted as incorporated chilled phases of the magma; a wide variety of porphyritic/aphyric textures may be expected in crusts forming at the margins of a mobile magma as a result of variable flow (laminar, turbulent) and consequent concentration or dispersion of phenocrysts.

POLYMICTIC BRECCIA (4d)

Polymictic breccias are best developed in division B in the vicinity of Lynn Lake town, where they are interlayered with a diverse assemblage of tuffs and mafic to intermediate flows (Figs. 16, 17 and 18). These breccias are also widely distributed in the northern belt (divisions B, D and E), but less abundant than the autoclastic types (4c). Coarse breccias are typically 1 - 5 m thick (up to at least 13 m), interlayered with thinner tuff beds (10 cm - 1 m thick). Contacts between breccia and tuff are sharp or gradational; rare grading of lapilli or plagioclase crystals (decreasing size and abundance) occurs in some units. Clasts (angular to ovoid) are generally poorly sorted in the relatively coarse breccias.

Polymictic breccias are heterolithologic, containing both essential and accessory fragments. A typical unit at Lynn Lake contains the following lithologies:

(1) Densely plagioclase-phyric basalt — 75% of total clasts by volume
(2) Porphyritic felsic andesite — 10% of total clasts by volume
(3) Aphyric basalt — 10% of total clasts by volume
(4) Aphyric dacite — 5% of total clasts by volume

Overlying this unit (300 m to the northwest), a coarse breccia deposit contains the largest clasts observed in the area (up to 1.8 m x 25 cm). This breccia, which outcrops in the grounds of Lynn Lake hospital, contains the following lithologies:

(1) Porphyritic felsic andesite (pale grey) — 80% of total clasts by volume
(2) Porphyritic andesite (green) — 10% of total clasts by volume
(3) Densely plagioclase-phyric basalt (dark green) — 10% of total clasts by volume

Felsic andesite and dacite clasts commonly contain up to 50 per cent quartz amygdales and up to 20 per cent plagioclase phenocrysts in a very fine grained quartzo-feldspathic matrix with hornblende (5 - 15%) and/or biotite (0 - 10%), epidote (0 - 20%) and locally pyrite (up to 5%). These clasts are particularly susceptible to epidotic alteration. Mafic fragments consist of fine grained green hornblende (40 - 90%) and plagioclase. Quartz amygdales occur less commonly in mafic clasts, and (rarely) in the tuffaceous matrix of some breccias.

The breccias are generally matrix supported, but some beds are characterized by a densely packed assemblage of lapilli and coarse phenocrysts in a subordinate fine grained matrix. Euhedral to anhedral or broken plagioclase phenocrysts (andesine or less commonly, labradorite) are ubiquituous in the matrix, and hornblende crystals are common. The intermediate to mafic matrix contains predominant hornblende and variable amounts of biotite and locally carbonate; garnet occurs sporadically. The modal composition of the matrix of a typical breccia northwest of Arbour Lake is as follows (visual estimate of thin section): green hornblende (35%), plagioclase (35%), quartz (15%), biotite (10%) and magnetite (3%).

MAFIC AND INTERMEDIATE TUFF (4e, 4f)

Mafic tuff and crystal tuff comprise the major part of division E in the area between Barbara Lake and Burge Lake, and south of Payne Lake (Fig. 16). Similar tuffs are widely distributed but subordinate to flows and related breccias in divisions B and D. Mafic and intermediate tuffs are also locally well developed in the sedimentary division (C) southwest of Margaret Lake, and south and east of Eric Lake; garnetiferous amphibolite, which comprises a distinctive formation within this division, is in part derived from interlayers of mafic tuff. The ratio of tuffs to flows in the southern belt between Wilmot and Eldon Lakes is apparently greater than in the northern belt, but the well developed foliation of the southern belt rocks commonly obscures their primary features and origin. Mafic tuffs are intercalated with mafic flows and subordinate volcanic breccia and fine grained sedimentary rocks in the Barbara Lake-Stick Lake section of the northern belt, where division E is at least 425 m thick, extending along strike for at least 7 km. The division is truncated between Stick Lake and Payne Lake by the Burge Lake granodiorite which is emplaced along a major northeast-trending fold at the northern margin of the northern belt. East of the Burge Lake grandiorite, division E consists largely of intercalated mafic tuffs and flows with rare volcanic breccia. The contact between divisions D and E in that area is arbitrarily placed where the predominance of mafic flows (in division D) apparently gives way to mafic tuffs (in division E) to the north. The volcanic divisions (D and E) are overlain by conglomerate (10a) to the north with apparent unconformity.

Tuffaceous rocks of division E are representative of the various tuffaceous lithologies which occur in the northern belt. These rocks are largely mafic, with 30 - 60 per cent green hornblende, locally accompanied by cummingtonite (needles up to 5 mm), accessory biotite (up to 5%) and opaque minerals (up to 7%). Mafic tuff is gradational with intermediate rocks (with down to 15% hornblende and up to 15% quartz) which comprise less than 10 per cent of the unit. Bedding, distinguished by variable grain size, plagioclase crystal content, or colour (pale or dark green), is locally well developed (e.g. south of Barbara Lake) but is generally not prominent in the tuffs. Fracture cleavage in alternate layers locally defines bedding east of Burge Lake. Some aphyric and crystal tuffs are interlayered in beds 2 cm - 1 m thick (up to 3 m for lapilli-tuff beds). A fine lamination (0.5 - 5 mm) also occurs in some aphyric layers. Graded bedding south of Barbara Lake is defined by the decreasing abundance and size of plagioclase grains towards upper aphyric zones; lapilli occur in the lower parts of some beds. Crystal tuff and aphyric tuff are also gradational laterally, and sporadic clasts of tuff are locally reworked within the section. Rare scoured surfaces and ripples occur in well bedded and graded tuffs just south of Barbara Lake. Rare tabular blocks of mafic tuff have also been incorporated in some basaltic interlayers. Tuffs which are intercalated with volcanic breccia contain sporadic felsic and mafic lapilli and rare bombs of densely plagioclase-phyric basalt. The tuffs are commonly veined by epidote, which also occurs as sporadic ovoid bodies with hornblende-rich margins.

Crystal-tuffs contain euhedral to subhedral crystals and aggregates of calcic andesine (0.5 - 5 mm across). Plagioclase content ranges from 10 - 40 per cent. Some beds contain two distinct grain sizes of plagioclase (0.5 - 1.5 mm and 2 - 5 mm); megacrysts up to 1 cm across occur locally. Medium grained hornblende euhedra occur in some beds but are less widespread than plagioclase; hornblende crystals typically comprise 10 - 20 per cent of the rock (up to 60 per cent). Garnet occurs south of Barbara Lake; biotite, chlorite, carbonate, muscovite and clinozoisite are common accessories. The grain size of the matrix ranges from fine to very fine grained (down to 0.04 mm). Some equigranular tuffs display a clear detrital texture, but generally the rocks are recrystallized, and commonly strongly foliated. These features are important criteria for the distinction of tuffs from flows where the former are not layered.

Mafic and intermediate tuffs are well preserved in the eastern part of the northern belt in the axial zone of the anticline between Pill and Auni Lakes. Northwest of Pill Lake, massive, mafic lapilli crystal tuff is associated with plagioclase-phyric basalt containing amygdales of carbonate or green hornblende. The basalt and tuff are only distinguished microscopically; the latter displays a detrital texture with lithic fragments, euhedral hornblende pseudomorphs after pyroxene, and euhedral to corroded plagioclase crystals and aggregates. Granules of plagioclase-phyric and aphyric basalt, and densely amygdaloidal basalt (with 50 - 80 per cent carbonate microamygdales) are set in a hornblendic matrix. The occurrence of one basaltic clast wrapped around a green hornblende pseudomorph suggests a relatively elevated temperature and subaerial environment of deposition; rapid quenching would preclude this texture in a subaqueous environment. The mafic tuff is on-strike with intermediate lapilli tuff 3 km further east; very fine grained, angular felsic lapilli are loosely strata bound in an intermediate tuff matrix containing both biotite and green hornblende (approximately 10 per cent each).

SEDIMENTARY ROCKS ASSOCIATED WITH MAFIC AND INTERMEDIATE TUFF

Feldspathic greywacke and siltstone (9b, 9c) comprise a minor part (less than 5 per cent) of division E west of the Burge Lake granodiorite where they occur as sporadic interlayers (1 - 3 m thick); these units are more rare in the predominantly mafic volcanic division B and D (less than 1 per cent). A thicker unit (40 - 65 m) has been mapped within the tuffs between Barbara Lake and Burge Lake. The fine grained sedimentary rocks are intermediate to siliceous, with biotite generally predominant over hornblende; weathered surfaces are generally pale to medium grey or beige, or cream. Lamination defined by variable biotite/hornblende ratio and grain size (very fine to fine grained) occurs in some beds, but generally internal lamination is poor or absent. One bed south of Barbara Lake contains approximately 40% quartz and plagioclase, 20% garnet, 15% green hornblende and biotite, and 25% detrital plagioclase and lithic granules; garnet comprises stringers parallel to zones of alteration (chlorite-sericite-saussurite). The composition of the sediments, local occurrence of detrital quartz, and the fine- to medium-grained seriate texture distinguish these rocks from the tuffs.

ENVIRONMENT OF DEPOSITION

The mafic tuffs of division E are considered to include both subaerial and subaqueous types. Poorly bedded or massive sections may have been subaerial; the absence of pillows in basaltic interlayers and the lack of hyaloclastic deposits is consistent with this interpretation. However, tuffs contain minor sedimentary intercalations and locally display good layering, grading, ripples and scour structures which indicate reworking, probably by turbidity currents.

GARNETIFEROUS AMPHIBOLITE (4g)

Garnetiferous amphibolite is a relatively rare lithology within the predominantly volcanic divisions B, D and E, where it is associated with minor sedimentary intercalations in the western part of the northern belt. The most extensive unit comprises part of a heterogeneous formation within the predominantly sedimentary division C. The formation extends from Margaret Lake to Sheila Lake, and is up to 150 m thick and 10 km long; a similar formation is exposed in the area south of Dot Lake. The amphibolite is interlayered with fine grained sediments and conglomerate, mafic tuff, and subordinate felsic lapilli crystal tuff and chert in a zone characterized by widespread garnet and hornblende porphyroblasts and localized shearing, carbonation, and concentration of sulphides. The sedimentary rocks within the formation are very similar to equivalent lithologies elsewhere in division C. A diabase sill intrudes the formation in the Margaret-Sheila Lakes area. The formation is characterized by a ground magnetic anomaly and electromagnetic conductors in the Margaret Lake-Sheila Lake area, and south of Dot Lake, but there are no conductors in the intervening area (Questor Input Surveys map, Lynn Lake area, 1976).

Garnetiferous amphibolite is fine- to coarse-grained; garnets (up to 1.5 cm) are strata bound or in diffuse zones, comprising up to 60 per cent of the rock. The amphibolite, which occurs in layers ranging in thickness from 10 cm - 20 m, is generally gneissic, but locally a fine lamination (0.5 - 5 mm) is defined by variations in grain size and/or hornblende content. The massive amphibolite consists of very fine grained quartz and untwinned feldspar (15 - 20%; average 20%), medium grained poikiloblastic hornblende (20 - 60%; average 45%), garnet (10 - 65%; average 20%), biotite (0 - 10%), cummingtonite (0 - 10%), and accessory pyrite, magnetite, chlorite, and carbonate. Feldspar xenoblasts are rare. Hornblende is green or blue-green and biotite brown, locally green; cummingtonite comprises randomly-oriented needles (up to 5 mm).

Garnetiferous amphibolite is interpreted as the recrystallized product of volcaniclastic rocks or interlayered mafic flows which were partly contaminated by the sediments. Local preservation of fine laminae and intercalation of garnetiferous amphibolite with mafic tuff and plagioclase crystal-tuff south of Dot Lake indicate a volcaniclastic derivation. Emslie and Moore (1961) interpreted the amphibolite as derived from siliceous and carbonate-bearing iron formation, and possible pyroclastic rocks.

TUFFACEOUS AND SEDIMENTARY ROCKS ASSOCIATED WITH GARNETIFEROUS AMPHIBOLITE

Intermediate to felsic crystal and lapilli tuffs (6d, 7e) comprise less than 2 per cent of the heterogeneous, garnetiferous formation in the Margaret Lake-Sheila Lake area, and south of Dot Lake. The tuffaceous beds are similar to fragmental units (6d, 7e) within the mafic and intermediate volcanic section (4) of the northern belt. The very fine grained tuff layers (2 - 20 cm thick) contain detrital plagioclase and quartz, and locally felsic lapilli and relicts of vitreous fragments. Biotite is ubiquitous and porphyroblasts of garnet, green hornblende and rare cummingtonite occur sporadically.

Mafic to intermediate crystal tuff (4e, 4f) occurs as subordinate interlayers (2 - 10 cm thick) within sections of garnetiferous amphibolite and within adjacent greywacke and siltstone. The tuff is similar to analogous rocks south of Barbara Lake (division E); medium grained, subhedral to angular plagioclase occurs in an intermediate to mafic hornblendic matrix. Some beds also contain up to 15 per cent white felsic lapilli (5 - 15 mm x 1 - 2 mm). Minor white chert layers (9h) up to 6 cm thick occur within mafic tuff and garnetiferous amphibolite southwest of Margaret Lake. The very fine grained quartzitic matrix of chert locally displays a delicate lamination defined by fine trails of magnetite or epidote, variations in grain size, and variable content of green hornblende porphyroblasts (5 - 15%) which are randomly distributed. Carbonate and/or magnetite comprise up to 10 per cent of some laminae. Chert is locally gradational to siltstone with increasing contents of biotite and detrital plagioclase and quartz (± quartz ± cummingtonite). A 3 m thick bed of chert is interlayered with mafic tuff and garnetiferous amphibolite south of Dot Lake. The chert contains sporadic pyritohedra and muscovite porphyroblasts, and is locally tectonically brecciated with biotite-filled fractures.

MINERALIZATION AND ALTERATION

Sulphide mineralization occurs in a very fine grained siliceous rock at the eastern shore of Sheila Lake*; the mineralized zone includes a silicified garnetiferous amphibolite layer (1 - 3 m thick) and is intruded by (hornblende) porphyritic diabase. Brecciated massive sulphide (at least 15 cm thick) contains clasts of quartz, talc schist and finely-laminated magnetiferous chert; pyrite-pyrrhotite stringers and disseminations occur in a zone at least 40 m wide. Sulphides comprise up to 10 per cent of a thin (1 m) felsic volcanic unit** at the southeast shore of Margaret Lake which is on strike with the mineralized zone at Sheila Lake.

STRATIGRAPHIC RELATIONSHIPS OF GARNETIFEROUS AMPHIBOLITE

The mineralization at Sheila and Margaret Lakes occurs in rocks indicative of fumarolic activity (chert) and minor volcanism (tuffs) during a period of essentially uninterrupted sedimentation (greywacke, conglomerate). Felsic volcanic rocks are commonly associated with sulphide mineralization, and Goodwin (1962) has suggested a correlation between felsic volcanism and trends of iron enrichment elsewhere, based on the stratigraphic position of iron

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* Assay (%): Cu = 0.03; Ni = 0.06; Zn = 0.53; Pb = 0.02; Mo = tr.

**Assay (%): Cu = 0.03; Ni = 0.02; Zn = 0.1; Pb = tr.

formations. Variation in the composition of the associated volcaniclastic rocks may be partly a result of the volcanism, leading to the development of the coarsely garnetiferous amphibolite.

DACITE AND RHYOLITE (6, 7)

A major body of rhyolite ("Lynn Lake rhyolite")* up to 2400 m thick extends for at least 15 km from the southern end of Frances Lake to the vicinity of the junction between the Lynn and Keewatin Rivers (division A, Fig. 16). The rhyolite consists predominantly of a massive extrusive facies with closely related breccia and intrusive bodies. Sedimentary units within the rhyolite are locally partly incorporated in the volcanic rocks. The felsic body is in contact with younger intrusive rocks to the south; the northern margin is characterized by interlayering of felsic units (7) and mafic volcanic rocks (4) which are part of the volcanic division (B) to the north (Fig. 16). Some mafic units (4) intrude the felsic volcanic rocks, indicating a north-facing sequence; this is supported by evidence of sulphide mineral zonation at several localities within the rhyolite (Gale, pers. comm.). However, graded bedding in the volcanic division (B) to the north of the Lynn Lake rhyolite faces southeast.

Porphyritic rhyolite flows and breccia at least 550 m thick occur north of Motriuk Lake, with several interlayers of intermediate to mafic tuffs and feldspathic greywacke (division F, Figs. 16 and 19). Minor concordant units of felsic volcanic rocks (50 cm - 20 m thick) occur sporadically within the mafic volcanic flows (4) of the northern belt. The most prominent minor felsic units occur southwest of Ralph Lake, northwest of Cockeram Lake, southeast of Arbour Lake and southeast of Eagle Lake. The minor units consist either of a massive porphyritic rock or felsic volcanic breccia; these bodies probably include both extrusive and shallow intrusive units.

MASSIVE APHYRIC AND PORPHYRITIC DACITE AND RHYOLITE (6a, 6b, 7a, 7b)

Massive felsic volcanic rocks are cream to buff or pale grey weathering, very fine grained to aphanitic, and commonly display a brittle, conchoidal fracture. Plagioclase (albite-oligoclase) is ubiquitous in the porphyritic rocks, comprising euhedral to subhedral, corroded phenocrysts 0.5 - 4 mm across; quartz phenocrysts are widespread; these are generally rounded, commonly with embayed margins (rarely euhedral). Microcline phenocrysts were observed at one locality just east of Frances Lake. Contamination of the felsic volcanic rocks in the vicinity of Flag Lake has resulted in irregular pea size bodies and screens of biotite-garnet aggregates, and sericitic pseudomorphs after cordierite or andalusite. Garnet porphyroblasts (0.1 - 2 mm), euhedral magnetite (0.5 - 3 mm), and biotite lenticles (0.5 mm x 1 - 5 mm) are widely distributed in the felsic volcanic rocks. Muscovite porphyroblasts are also common. Dark, diffuse streaks (5 mm - 5 cm x 50 cm - 2 m) are characteristic of the felsic rocks, reflecting slightly more mafic composition and/or finer grain size and/or stronger foliation.

Fragmental structure is common in the southern part of the Lynn Lake rhyolite, and occurs in other felsic volcanic bodies in irregular zones gradational with massive rock. Angular fragments (pebble to small cobble size) are surrounded by a dark grey, biotite-rich matrix, comprising less than 10 per cent of the breccia. This rock grades into zones of massive rhyolite with anastomosing micaceous screens. Some fragmental zones are also gradational with conglomerate (8b) characterized by angular to rounded felsic pebbles in a stiltstone matrix comprising 10 - 60 per cent of the rock. Gradation from massive flow to brecciated rhyolite to conglomerate is well displayed just north of Flag Lake. Fragmental structure consisting of cream-weathering, ovoid felsic clasts within a very pale grey, massive rhyolitic matrix is relatively rare. Breccia of this type with boulders up to 1 m long occurs within massive rhyolite at the northern end of Frances Lake; the brecciation is considered to be autoclastic. Breccia with a biotite-rich matrix is interpreted as a result of autoclastic and/or *in situ* brecciation of cooling, massive flows; fine grained sedimentary material may have been incorporated during extrusion or at a later stage as an in-filling of cooling fractures. The brecciated rhyolite is locally affected by later cataclastic deformation. Microscopic details show quartz and plagioclase grains are dislocated from massive rhyolite into the biotite- or chlorite-rich matrix of the breccia.

PORPHYRITIC DACITE AND RHYOLITE BRECCIA (6c, 7c)

Porphyritic dacite and rhyolite breccia occur as discrete, concordent layers within the predominantly mafic volcanic section (4) of the northern belt; minor units of felsic volcanic breccia and tuff also occur within the predominantly sedimentary division (C) in the vicinity of Margaret and Sheila Lakes, and south of Dot Lake, in association with garnetiferous amphibolite and mafic tuff. The breccia is distinguished from fragmental zones within the massive flows by the common occurrence of more than one fragment type. The breccias generally contain pebble- to small cobble-size fragments in a detrital crystal-tuff matrix. Fragment and matrix compositions range from felsic to intermediate; the matrix is invariably slightly darker than the majority of the clasts. Several clast types are commonly distinguished by aphyric and porphyritic textures. Subordinate ($< 5\%$) porphyritic andesite or basalt clasts occur in some units. The majority of the breccia units are 1 - 20 m thick; the thickest layer occurs approximately 2 km north of Motriuk Lake, where the breccia contains angular to ovoid, felsic cobbles (up to 24 cm x 4 cm) and subordinate mafic fragments in a felsic tuffaceous matrix comprising 50 - 70 per cent of the rock. Contacts with adjacent more mafic tuffs or flows are knife sharp. The tuffaceous breccias are considered to be pyroclastic, reflecting a more explosive type of volcanism than the brecciated rocks within massive felsic volcanic flows.

DACITE AND RHYOLITE TUFF (6d, 7e)

Felsic tuff and crystal-tuff is associated with lapilli tuff and breccia interlayers (6c, 7c) in the predominantly mafic volcanic division (D) and within the sedimentary division (C) extending from Margaret Lake to south of Dot Lake. Felsic tuff is cream to pale green, or pale to medium grey, with brittle, conchoidal fracture. Subhedral, corroded to angular plagioclase (andesine-labradorite) crystals are set in a very fine grained matrix, commonly accompanied by ovoid quartz grains (0.5 - 1 mm). Sporadic felsic lapilli (1 - 5 cm) are aphyric or plagioclase-phyric and locally zoned with chilled selvages and/or slightly more mafic margins. Plagioclase phenocrysts embedded in the margins of some fragments indicate some lapilli were relatively plastic at deposition. Aphanitic, streaky zones in some rocks are interpreted as attenuated, devitrified glass shards. Biotite, garnet, and poikiloblastic green hornblende are common, and cummingtonite and muscovite porphyroblasts have also been observed. Total mafic mineral content is generally 5 - 10 per cent (up to 15 per cent). Felsic crystal-tuff is similar to some fine grained sedimentary rocks (9) in the Margaret-Sheila Lakes area which are probably partly derived from the tuffaceous units. Distinction between felsic tuff and massive flows is uncertain in some cases; the presence of lapilli is the only diagnostic feature of felsic crystal-tuff just west of northern Cockeram Lake, where these rocks are associated with felsic volcanic flows and breccia.

The possible occurrence of felsic crystal-tuff within the Lynn Lake rhyolite was indicated by Emslie and Moore (1961), who also interpreted zones within the felsic body which contain relatively more biotite and garnet as semi-pelite. Earlier mapping (Allan, 1946; Ruttan, 1955) interpreted the entire felsic body as an epiclastic unit. Some poorly layered, porphyritic felsic rocks within the body may represent tuffaceous units derived from the main rhyolite body by a hyaloclastic process described by Dimroth (1977).

*A Rb/Sr isotopic age of 1792 ± 36 Ma has been obtained for the Lynn Lake rhyolite (Clark, 1980).

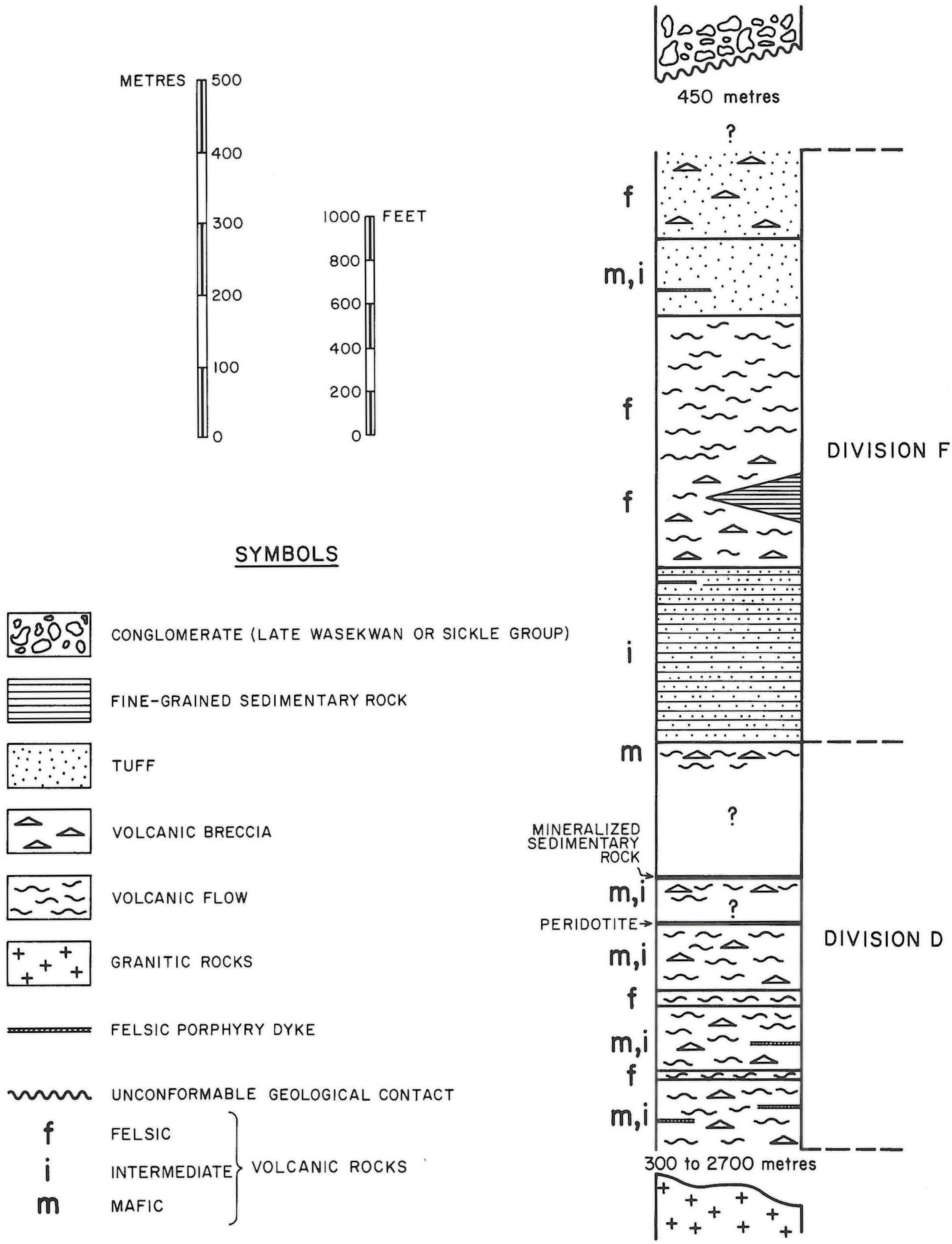

FIGURE 19: Stratigraphic section of the upper part (Divisions D and F) of the Wasekwan Group in the area north of Motriuk Lake.

CONGLOMERATE AND FINE GRAINED SEDIMENTARY ROCKS (8, 9)

Sedimentary rocks in the northern belt occur in a major elongate body extending through Sheila Lake and several smaller lensoid bodies (up to 250 m thick). Sporadic interbeds of greywacke and siltstone (1 - 2 m thick) comprise a very minor part of the volcanic divisions B, D and E (Figs. 16 and 17). The predominantly sedimentary division (C) contains subordinate volcanic units, and the division is laterally discontinuous: the sedimentary rocks wedge out south of Dot Lake, but reappear in a lensoid body south of Minton Lake. Thus division C represents a period of sedimentation during the volcanic activity, which is essentially uninterrupted. Division C consists of greywacke and siltstone, locally interlayered with conglomerate (8b) and subordinate mafic to felsic tuffs, volcanic breccia, and flows. The maximum width of the Sheila Lake body is 700 m, and the maximum estimated stratigraphic thickness is 350 m (assuming a synclinal structure); the lateral extent is approximately 11 km.

Fine grained sediments and conglomerate comprise a sedimentary body (at least 700 m wide) southeast of Arbour Lake. These rocks are probably continuous (beneath glacial drift and muskeg) with greywacke and siltstone at Muskeg Lake and may be stratigraphically equivalent to magnetiferous iron formation at Farley Lake, approximately 20 km east of Arbour Lake (Stanton, 1948). Smaller sedimentary bodies (less than 200 m wide) within the volcanic rocks (4) of the northern belt are located as follows:

(a) between mafic and felsic volcanic rocks (divisions D and F respectively) north of Motriuk Lake (Figs. 16 and 19).
(b) within mafic tuffs at Barbara Lake,
(c) within the Lynn Lake rhyolite,
(d) within mafic volcanic rocks just east of Arbour Lake, and
(e) at the eastern end of Desieyes Lake, at the northern margin of the predominantly mafic volcanic section.

CONGLOMERATE WITH VOLCANIC AND SEDIMENTARY CLASTS (8b)

Pebble/cobble conglomerate beds occur throughout the predominantly sedimentary division (C) of the northern belt, with the exception of the easternmost section (Muskeg Lake area — Table 21, and Fig. 16). Conglomerate is also present within the Lynn Lake rhyolite (division A) and minor conglomerate layers occur within the largely felsic volcanic division (F) north of Motriuk Lake. The most extensive development of Wasekwan Group conglomerate within the northern belt is in the Margaret-Sheila Lake area, where volcanogenic sedimentary rocks are characterized by alternation of feldspathic greywacke, siltstone and conglomerate at a scale of 1 - 5 m. Conglomerate is also associated with mafic and felsic tuff and garnetiferous amphibolite in a formation extending through the southern parts of Margaret and Sheila Lakes. The thickest body of conglomerate mapped (> 135 m < 200 m) occurs at the northern end of Sheila Lake. Clasts are generally pebble to small cobble size; the coarsest conglomerate layers contain clasts up to 40 x 3 cm. Fragments are generally ellipsoidal to strongly flattened but angular to subrounded clasts are locally preserved. Felsic volcanic and fine grained sedimentary lithologies are the predominant clast types; mafic volcanic fragments are subordinate (Table 22). The conglomerate matrix is equivalent to greywacke interlayers within the sequence, and contains biotite or, less commonly, green hornblende as the predominent mafic mineral. The composition is generally intermediate (approximate content of biotite = 10%; hornblende = 0 - 25%; magnetite = 0 - 5%; the remainder of the matrix is largely quartz and plagioclase). Porphyroblasts of green hornblende are widespread especially in the western part of the northern belt (zones 1, 2 and 3, Table 21 and Fig. 16). Minor amphibolitic dykes and veins are also common in this area. Garnet is common accessory in the conglomerate matrix.

Biotite-bearing conglomerate is more widespread than hornblendic conglomerate; the two types are locally interlayered at a scale of 10 - 50 cm. Discontinuity of hornblende-bearing layers and irregular hornblendic zones within biotite-bearing conglomerate are attributed to metasomatic alteration. Grading from conglomerate to finer grained interlayers is not common; interbed contacts are generally sharp, and the conglomerates are generally unsorted. Several occurrences of displaced lenses (50 cm to 1 m long) of originally semi-consolidated sediment were observed at Sheila Lake.

Intercalations of conglomerate within the Lynn Lake rhyolite (division A, Fig. 16) are characterized by angular felsic pebbles in a micaceous siltstone matrix comprising 60 - 80 per cent of the rock. These units are unsorted and generally less than 5 m thick (up to 30 m). Intercalations of garnet-biotite-chlorite schist occur within conglomerate and rhyolite north of Flag Lake. These are gradational with the conglomerate and probably represent siltstone and mudstone deposits. The close association between the rhyolite and conglomerate, which is locally gradational with brecciated zones of the flows, suggests the sediments were deposited at the margins of a cooling felsic volcanic body which was partly incorporated into the sedimentary rocks.

Massive conglomerate beds up to 3 m thick are intercalated with fine grained, turbiditic sedimentary rocks in the area southeast of Arbour Lake (division C and zone 5, Fig. 16). Graded bedding occurs in both fine grained and conglomeratic layers. Evidence of mass-flow was observed at one place where emplacement of a body of conglomerate has resulted in disruption of the underlying siltstone layer. The conglomerate locally contains ovoid to embayed granules and pebbles of quartz (possibly derived from amygdales) and detrital plagioclase including well preserved euhedral crystals and aggregates similar to those occurring in porphyritic basalt of unit 4a. These features are consistent with a mass-flow origin for these relatively immature deposits.

HORNBLENDE GREYWACKE, BIOTITE GREYWACKE AND PEBBLY GREYWACKE, SILTSTONE (9a, 9b, 9c)

Greywacke and siltstone are the predominant sedimentary lithologies in the northern belt (Table 21); these rocks are locally associated with interbeds of conglomerate (8b), hornblendic mafic mudstone (9e) and rare quartz-rich greywacke (9d), argillite (9g), and chert (9h). The greywackes are predominantly feldspathic, containing prominent grains of plagioclase and subordinate quartz in a fine grained sandstone or siltstone matrix. Lithic granules and sporadic pebbles include (in decreasing order of abundance) felsic volcanics (aphyric and porphyritic), siltstone, and intermediate and mafic volcanics; these are generally subordinate to detrital plagioclase. Potassium feldspar is absent. Greywacke is locally gradational to siltstone; elsewhere these lithologies are well bedded, with sharp contacts. Siliceous siltstone (with 80 - 90 per cent quartz and feldspar) is not uncommon within greywacke/siltstone sequences (e.g. southeast of Arbour Lake — zone 5, Fig. 16); rare argillitic laminae occur at Sheila Lake and in the area between Lynn Lake and Minton Lake (zones 2, 3 and 4).

Greywacke and siltstone range from pale to medium grey to brown, depending on their mafic mineral content. Biotite is almost ubiquitous (generally 10 - 30% of the rocks). Green hornblende is widespread but generally subordinate to biotite, comprising up to 15 per cent of the greywacke. Hornblende-rich greywacke (with 15 - 35% amphibole) occurs sporadically throughout the northern belt, and is most abundant towards the west (zones 1 and 2). Hornblendic greywacke is locally sharply interlayered with biotite-greywacke in this area, and the matrix of conglomerate (8b) locally shows analogous alternation of mafic minerals; however, the contact between hornblendic rocks and equivalent micaceous rocks is more commonly gradational. The hornblende occurs as a fine grained component parallel to the bedding and foliation, or as strata bound, randomly oriented porphyroblasts; it is best developed in zones 2 and 3 (Fig. 16). Hornblende also defines a later foliation discordant to the bedding at a few places in zones 2, 3 and 4.

TABLE 21: STRATIGRAPHY AND STRUCTURE OF METASEDIMENTARY ROCKS (UNITS 8 AND 9) OF THE NORTHERN BELT.

		ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
LITHOLOGIES	CONGLOMERATE	Interlayers (up to 2 m) and scattered pebbles in greywacke	Interlayers and scattered pebbles in greywacke; massive unsorted conglomerate body (200 m maximum thickness) at north end of Sheila Lake	Rare interlayers and scattered pebbles in greywacke	Rare interlayers and scattered pebbles in greywacke	Interlayers in greywacke	Conglomerate absent; rare sporadic pebbles in greywacke and siltstone, which are poorly bedded, generally massive
	GREYWACKE: INTERMEDIATE, MICACEOUS	+	+	Predominant	+	Predominant	+
	GREYWACKE: HORNBLENDIC	+	+	Subordinate	+	Subordinate	+
	GREYWACKE: ARKOSIC		Local occurrences at Sheila Lake				
	GREYWACKE/SILTSTONE RATIO	Greywacke and siltstone both abundant		Siltstone predominant over greywacke			
	ARGILLITE		Local occurrences at Sheila Lake	Rare	Rare	Rare	
	HORNBLENDE-RICH SILTSTONE	+	+	Well developed	Rare		
	CHERT	Rare	Rare		Minor laminae	Absent, but some siltstone laminae relatively siliceous	Rare
	SUBORDINATE VOLCANIC INTERLAYERS	Tuffs, flows and breccias; several flows or sills are intimately admixed with unconsolidated sediment	Tuffs and mafic flows or sills (locally admixed with unconsolidated sediment)	Tuffs, flows and breccias	Minor mafic tuff (south of Dot Lake)		Pyroxene-phyric basalt flow at Muskeg Lake
SEDIMENTARY STRUCTURES	GRADED BEDDING: UPWARD DECREASE IN SIZE AND ABUNDANCE OF SAND-SIZE GRAINS	+	+	+		+	Rare
	GRADED BEDDING: UPWARD DECREASE IN SIZE AND ABUNDANCE OF PEBBLES		+	Rare		Rare	
	SCOUR STRUCTURE		Rare; also rare cross bedding (<10 cm)			Rare	
	RIP-UPS	+	+	+		Dislocation of siltstone substrate by conglomerate	Siltstone reworked into lithic greywacke
	FLAME STRUCTURE			Rare		Rare	
	SEDIMENTARY FOLDING			+			

TABLE 22: CLAST TYPES IN CONGLOMERATE (8b) OF THE NORTHERN BELT

Lithology	Relative abundance	Notes
Felsic volcanic (aphyric/ plagioclase + quartz-phyric)	Locally predominant	White to pale gray weathering. Biotite content = 3 - 10%. Hornblende porphyroblasts common.
Siltstone (intermediate/siliceous)	Locally predominant	Pale to medium beige or medium gray weathering. Biotite content = 10 - 25%.
Feldspathic greywacke	Abundant	
Basalt (porphyritic/aphyric)	Subordinate	Plagioclase-phyric is the most abundant type; hornblende pseudomorphs are not common. Some clasts, containing up to 10% biotite, are similar to mafic flows (unit 4a) at Frances Lake.
Magnetiferous siltstone	Rare	Magnetite content up to 20%.
Graphitic siltstone	Rare occurrences at Sheila Lake	
Mafic, biotite-rich	Rare	
Subporphyritic felsic volcanic	Single occurrence (close to P.R. 391 at Keewatin River)	Provenance interpreted to be a synvolcanic intrusive rock.
Plagioclase aggregates		Aggregates of 2 to 8 euhedral crystals derived from phenocryst aggregates in porphyritic basalt (unit 4a).
Quartz	Minor occurrences southeast of Arbour Lake	Granules and pebbles, ovoid to amoeboid, possibly derived from amygdales in basalt.
Epidote/green hornblende bodies		*In situ* alteration of mafic volcanic clasts or possibly derived from epidosite bodies in mafic flows.

Bedding at a scale of 1 - 20 cm is well defined in greywacke-siltstone sequences; siltstones locally display a fine lamination (0.5 - 1 mm) of mafic mineral trails. Coarser greywacke and conglomeratic beds are typically 20 cm to 1.5 m thick (up to 3 m). Sedimentary structures are more diverse in the western area (zones 1, 2 and 3, Fig. 16) than further east. Graded bedding and rare scoured surfaces in alternating greywacke-siltstone sequences (zones 1, 2, 3 and 5) are probably turbidity current structures. This interpretation is supported by the sporadic occurrence of redeposited siltstone pebbles and tabular blocks up to 30 cm long which are clearly derived by erosion of intraformational beds immediately prior to deposition. The displacement of a 1 m block of conglomerate at Sheila Lake (zone 2) and dislocation of a siltstone bed underlying conglomerate in zone 5 are the probable results of disruption by debris flows. Highly contorted sedimentary folds occur locally in thinly bedded greywacke and siltstone in zone 3; the folding is outlined in some places by garnetiferous laminae. Rare flame structure has been observed in the same section, and also within the turbidites in zone 5. Small scale (less than 10 cm) cross bedding was observed at southern Sheila Lake (zone 2) but ripples and cross bedding (characteristic of Bouma Division C) are generally not developed.

Contemporaneous mafic volcanic flows and mafic to felsic tuffs and minor breccia occur at the western part of zone 1 and the eastern part of zone 3. Intimate admixture of basalt and fine grained sediment at the southwestern part of Margaret Lake (zone 1) is interpreted to indicate contemporaneous deposition, or the injection of basalt into unconsolidated sediment. Similar structures have been observed in the area south of Fraser Lake (southern belt). The variety of primary structure at the western end of the northern belt contrasts with the monotonous sequence of fine grained sedimentary rocks at Muskeg Lake (zone 6, Fig. 2); graded bedding occurs locally in medium- to coarse-grained feldspathic and lithic greywackes in zone 6, but the sequence is composed largely of fine- to very fine-grained greywacke and siltstone devoid of bedding. An isolated flow of porphyritic basalt (unit 4a) with clinopyroxene relicts occurs within these sediments.

The minimum metamorphic grade of the sedimentary rocks at the western end of the northern belt is lower amphibolite. Bedding is commonly reinforced by strata bound garnet, and green hornblende blastesis is extensive especially in zones 1 and 2, locally resulting in reversed (metamorphic) graded bedding (e.g. at Sheila Lake). Cummingtonite commonly accompanies green hornblende, and biotite is locally porphyroblastic in this area. Staurolite and andalusite occur close to the abandoned gold mine in zone 4 (Fig. 16). Garnet and hornblende porphyroblasts occur only sporadically in the area to the east and cummingtonite is absent east of zone 5. Rare chlorite porphyroblasts (zones 1 to 4) probably postdate the amphibolite facies metamorphism and may be related to the development of a weak, hornblendic foliation which overprints both the bedding and earlier regional foliation (biotite, green hornblende) in the western part of the northern belt. Magnetite and pyrite comprise up to 7 per cent of greywacke adjacent to mineralized zones associated with felsic volcanic and/or chert interlayers; finely divided graphite is an accessory in these sediments. Microscopic details of the sediments are given in Table 23.

SILTSTONE AND MAFIC MUDSTONE (9e)

Siltstone and mudstone containing biotite and/or hornblende are commonly interlayered with greywacke (9a, 9b, 9c). Micaceous

TABLE 23: COMPONENTS OF GREYWACKE AND SILTSTONE (UNITS 9b AND 9c)

Quartz:	Subhedral or subrounded to angular, single grains or recrystallized aggregates, coarse- to very fine-grained.
Plagioclase:	Subhedral or subrounded to angular, coarse- to very fine-grained; twinned and untwinned grains both common; oligoclase to labradorite, locally zoned. Some grains contain abundant very fine quartz inclusions (probable metamorphic origin). Locally turbid with sericite or, less commonly, magnetite. Xenoblastic bytownite (An_{73}) occurs close to abandoned gold mine (zone 4). Locally in aggregates of several (2 to 6) crystals (similar to phenocryst aggregates of mafic volcanic flows of unit 4a).
Biotite:	Fine- to very fine-grained, brown to red-brown, defining regional foliation (parallel to bedding); locally porphyroblastic.
Green hornblende:	Fine- to very fine-grained and coarse grained porphyroblastic, sub-parallel to the regional foliation or randomly oriented; porphyroblastic; also defines a later weak foliation (discordant to bedding).
Cummingtonite:	Randomly oriented porphyroblasts, or as colourless zones within (and optically continuous with) green hornblende porphyroblasts.
Garnet:	Dark pink, euhedral to anhedral porphyroblasts or irregular, elongate aggregates (parallel to regional foliation). Commonly pcikiloblastic, and slightly rotated. Some garnets consist of xenoblastic mantles on earlier idioblastic cores.
Staurolite; Andalusite:	Randomly oriented euhedral to anhedral porphyroblasts in magnetiferous siltstone close to abandoned gold mine (zone 4).
Muscovite:	Fine grained, parallel to regional foliation; not widely developed; locally porphyroblastic in arkosic sediments.
Chlorite:	As minor alteration of biotite and rare, randomly oriented porphyroblasts.
Magnetite, pyrite:	Fine grained, disseminated; locally as prominent euhedral grains in sediments (locally with graphite) within zones of mineralization.
Epidote, carbonate:	Minor accessories, mostly in the eastern part of the northern belt.
Lithic granules:	Lithologies are equivalent to clastic components of conglomerate (8b).

TABLE 24: CRITERIA FOR DISTINCTION BETWEEN TUFF AND GREYWACKE AND SILTSTONE

tuff	greywacke & siltstone
(1) Plagioclase euhedral to subhedral or broken	(1) Plagioclase subhedral or angular to subrounded; euhedral crystals rare
(2) Detrital quartz subordinate or absent	(2) Detrital quartz generally subordinate, but locally abundant (quartz-rich greywacke)
(3) Lithic clasts generally volcanic; sedimentary types rare	(3) Volcanic and sedimentary lithic clasts common
(4) Bedding generally poor or absent	(4) Well bedded (alternating greywacke/siltstone or compositional layering intermediate, siliceous or hornblendic)
(5) Mafic tuffs are amphibolitic.	(5) Biotite generally predominant over hornblende except in hornblendic greywacke (9b) and mafic mudstone (9e)
(6) Relatively homogeneous	(6) Greater range of composition
(7) Crystal tuffs display partially hiatal texture (lack of gradation between relatively coarse grained plagioclase crystals and finer grained matrix)	(7) Texture generally seriate (gradation between coarse and finer grained components)

siltstone is more widespread than the hornblendic rocks which are largely confined to the western part of the northern belt, and most abundant in the area north of Lynn Lake (zone 3, Table 21).

Beige or pale grey weathering micaceous siltstone is commonly intercalated with green, amphibolitic mudstone at a scale of 1 - 15 mm. Thicker units of hornblendic mudstone (up to 10 cm) are rare. These rocks are locally interlayered with medium grained greywacke. The sediments are generally moderately well sorted, but detrital felsic granules and plagioclase and quartz grains (0.25 - 1 mm) comprise up to 15 per cent of some siltstone and mudstone laminae. Graded bedding (feldspathic greywacke → micaceous siltstone → hornblendic mudstone) has been observed in narrow zones (5 mm to 1 cm), but interlayer contacts are generally sharp. Green hornblende porphyroblasts are randomly oriented or aligned parallel to the early penetrative foliation (parallel to bedding). A later, weak foliation of biotite (± green hornblende) is discordant to the bedding by 10 - 35 degrees. Garnet is well developed in the sedimentary rocks north of Lynn Lake (zone 3, Table 21) comprising strata bound porphyroblasts and stringers. Medium grained garnetiferous amphibolite members (up to 40 cm thick) within this section are probably derived from mafic mudstone.

The repeated compositional layering (biotite/green hornblende) of these sedimentary rocks* is considered to be related to two concurrent modes of sedimentation. The sequence is interpreted as turbiditic, with a relatively slow accumulation of fine grained (basinal) sedimentary rocks (mafic, hornblende-rich mudstone) interrupted by periodic influxes of turbiditic debris (feldspathic greywacke and micaceous siltstone). Partial sorting of these two facies may reflect the site of deposition within the turbidite basin between proximal and distal environments; alternatively, limited reworking may have occurred if these sediments were deposited close to the limit of wave generated or tidal currents.

PROVENANCE AND ENVIRONMENT OF DEPOSITION OF CONGLOMERATE (8b) AND GREYWACKE, SILTSTONE AND MUDSTONE (9a, 9b, 9c, 9e)

The detrital components of the conglomerate and fine grained sedimentary deposits are largely volcanogenic, with reworked intraformational sedimentary material. These rocks apparently comprise the erosion products of an underlying and/or contemporaneous volcanic sequence. The contact between the volcanic and sedimentary divisions (B and C respectively) is interlayered, and sporadic volcanic formations (4) within the sediments indicate there was no essential break in the volcanism. Some fine grained rocks are of uncertain origin, because these is gradation between tuff (pyroclastic) and derived fine grained sediments (redeposited tuff). However, an overall sequence comprising volcanic fragmental rocks and their derived sedimentary deposits can be recognized. The only feature that can unequivocally identify tuffs is vitroclastic texture, which has not been observed in the Wasekwan Group rocks; the distinction between tuffs and derived sedimentary rocks has necessarily been made on a more comprehensive basis (Table 24).

Interpretation of the environment of deposition of the sedimentary rocks is based upon their primary structures, stratigraphic relationships, and the structure of the sedimentary bodies; sedimentary structures alone are generally not definitive for any single environment. The sedimentary rocks of the northern belt may be interpreted as either shallow-water deposits or the products of turbidity-current flow in deeper water, at least below storm-wave base (resedimented facies of Turner and Walker, 1973). The latter environment is indicated in the northern belt by the following:

(a) graded bedding is locally well developed,
(b) intraformational siltstone clasts are present,
(c) conglomerates are generally thin (< 2 m) and locally graded; imbrication is absent,
(d) cross bedding never exceeds a scale of 10 cm, and
(e) conglomerate is interlayered with greywacke.

A shallow-water origin for the sequence is considered unlikely in view of the rarity of scour and absence of large-scale (> 10 cm) cross-bedded structures which are generally abundant in shallow-water deposits. Repeatedly bedded, locally graded sequences of greywacke and siltstone (e.g. zone 3, Fig. 16) are typical of turbidites. The local disruption of the substrate of some beds is consistent with powerful erosion by high density debris flows. Slump and flame-structures in semi-consolidated sediments (e.g. zones 3 and 5) are commonly associated with rapidly deposited turbiditic sequences.

The turbidites in the northern belt include both proximal and distal deposits (Walker, 1967) but the typical sequence (A to E divisions of Bouma, 1962) is never complete. Cross lamination is

*Average mineral contents are as follows (visual estimates of thin sections) — siltstone: biotite = 20 - 30%, green hornblende = 0 - 10%; mudstone: green hornblende = 20 - 65%, biotite = 0 - 15%; accessories in both lithologies include garnet (0 - 10%) and magnetite (0 - 5%); the remainder of the rocks consists largely of quartz and plagioclase.

conspicuously absent; this deficiency has been noted in proximal turbidites (Walker, op. cit.) but the absence of this feature in the better graded, more distal sequences in the northern belt is enigmatic. The structure may have been eroded, or possibly a relatively high mud/sand ratio in the deposits resulted in a greater cohesion, which precluded reworking into ripple-laminated beds. Greywacke-siltstone sequences with interlayered conglomerate (zones 1 and 2) are more proximal than the turbidites in zones 3 and 4. The latter are more thinly bedded, finer grained, and have a lower sand/mud ratio; well developed graded bedding and abundant mudstone laminae (9e) are also indicative of a relatively more distal environment to the east (Walker, op. cit.). Some sediment transport northeastwards, parallel to the axis of the depositional basin is therefore indicated.

Massive, fine grained sedimentary rocks at Muskeg Lake (zone 6) may have been deposited by a different type of debris flow from that associated with sediments further west. Poorly defined bedding and rare grading in zone 6 suggest a proximal environment, but the sedimentary rocks are finer grained than is typical for proximal deposits. At Farley Lake (15 km east of Muskeg Lake) magnetiferous iron formation is predominant (Stanton, 1948) in sedimentary rocks which may be laterally equivalent to the turbidites. The deposits at Muskeg Lake may therefore represent a transitional environment between the turbidite basin to the west and the cherty sequence to the east. Alternatively, the Muskeg Lake sequence may have a local volcanic derivation. The occurrence of rare detrital clinopyroxene in mafic volcaniclastic rocks at the east shore of the central part of the lake suggests a crystal tuff origin with little or no reworking; the majority of the rocks at Muskeg Lake, however, are fedspathic and lithic greywackes and siltstone.

AGRILLITE, CHERT (9g, 9h)

Chert is a relatively rare lithology in the northern belt. The most prominent occurrences are associated with magnetiferous and/or pyrite-pyrrhotite-bearing iron-formations (9j) and with garnetiferous amphibolite (4g) southwest of Margaret Lake and south of Dot Lake. Thin layers of very fine grained siliceous rocks (1 mm to 2 cm thick) also occur within greywacke-siltstone sequences (9b, 9c), locally associated with argillaceous beds; these horizons commonly contain pyrite, pyrrhotite, magnetite and/or graphite. The opaque minerals are generally very fine grained, commonly defining delicate laminations; sulphides are locally remobilized in discordant veinlets.

Minor siliceous laminae occur in greywacke-siltstone-conglomerate sequences at Sheila Lake, southeast of Arbour Lake, and at Muskeg Lake (zones 2, 5 and 6, Fig. 16). At Sheila Lake siliceous layers are gradational to argillaceous laminae; the very fine grained beds are locally ripped up and incorporated into feldspathic and lithic greywacke layers. Dark grey, argillaceous units contain biotite (up to 65 per cent), quartz, feldspar, and garnet and green hornblende porphyroblasts; cream-weathering siliceous layers contain up to 95 per cent quartz and feldspar, with subordinate biotite and sporadic porphyroblasts of green hornblende or muscovite. Similar cherty and argillaceous laminae occur within feldspathic greywacke southwest of Minton Lake; the chert there contains calcium-rich laminae (with epidote, carbonate and green hornblende) and sulphide minerals which comprise approximately 10 per cent of both chert and argillite.

Sulphide mineralization is associated with a fine grained siliceous rock* 1.5 km north of the northern end of Motriuk Lake. The rock occurs in a frost-heaved zone (8 m wide) within a section of basalt and intermediate to mafic volcanic breccia (see description of unit 15 and Fig. 19). Strata bound pyrite and pyrrhotite comprise up to 40 per cent of thin tourmaline-bearing layers (average thickness = 5 mm to 2 cm; up to 30 cm); sulphides also occur in diffuse zones and stringers. The host rock is considered to be sedimentary; grain size is variable (0.05 - 0.25 mm), possibly reflecting an original detrital texture. The average composition is 45% quartz, 35% plagioclase, 10% pyrite + pyrrhotite, and 5 - 15% biotite.

The siliceous rocks are commonly slightly brecciated with biotite-filled fractures; the biotite predates the foliation in some rocks indicating a relatively early age of brecciation. The very fine grained siliceous and argillaceous rocks which are gradational with feldspathic greywacke and siltstone represent compositional variations within detrital sedimentary sequences. Chert beds associated with garnetiferous amphibolite (4g) and iron formation (9j), which are relatively thicker (up to 3 m), are interpreted as volcanic exhalative deposits.

IRON FORMATION (9j)

Magnetite and/or pyrite-pyrrhotite-bearing iron formation occurs within the Wasekwan Group of the northern belt and in the area southwest of Nail Lake (southern belt); outcrops occur close to P.R. 396 south of Stear Lake and west of Boiley Lake. The formations are commonly associated with electromagnetic and aeromagnetic anomalies (Questor Surveys Limited maps, 1976 and 1977) which have provided valuable indications of the extent and distribution of the iron formations; these have been utilized for stratigraphic correlation in the northern belt (Gilbert, 1977). Local discontinuities in the formation are indicated by the geophysical data, but at a regional scale these rocks are persistent over tens of kilometres. The iron-rich horizons commonly occur between fine grained sedimentary rocks and younger mafic volcanic sequences. Felsic volcanic rocks are associated with several iron formations.

The thickest iron formation in the northern belt consists of a section of magnetiferous chert and greywacke, at least 80 m thick, which extends from Stick Lake to Ralph Lake. Older mafic volcanic flows and fragmental rocks (division E, Figs. 16 and 17) occur southeast of the magnetiferous zone. Medium grained amphibolite and schist derived from gabbro occurs northwest of the iron formation, which is overlain by conglomerate (10a); these younger rocks are very strongly foliated and altered between Barbara and Stick Lakes. The iron formation consists of well bedded magnetiferous chert, siltstone and greywacke. Massive magnetite laminae (1 - 5 mm thick) with up to 50 per cent magnetite and 10 per cent epidote alternate with quartz-rich and muscovite-rich laminae in chert and siltstone beds (2 - 25 cm thick, up to 60 cm). Intermediate greywacke layers (up to 1.5 m thick) with detrital plagioclase, quartz and mafic granules contain up to 7 per cent magnetite, together with biotite and green hornblende (up to 15% each). Magnetite occurs as a very fine grained dissemination and sporadic coarser grains.

Iron formation within the mafic to intermediate volcanic division (D) is poorly exposed. One occurrence south of Dot Lake comprises two beds (30 - 60 cm thick) of a fine- to medium-grained quartzitic rock within aphyric and porphyritic basalt. This rock contains approximately 10 per cent pyrrhotite and subordinate magnetite as a fine, opaque dusting resulting in a pale blue-grey/white mottled surface. The rock is partly brecciated with magnetite-carbonate-hematite-filled fractures. A sparsely porphyritic felsic volcanic unit at least 15 m thick occurs directly on-strike with the iron formation, 1.25 km to the northeast.

Iron formation 1.5 km west of Minton Lake occurs within a section of mafic crystal- and lapilli-tuff (division D, Figs. 16 and 17). The magnetiferous rocks comprise a layer of breccia (3 m thick) containing chert clasts (up to 15 cm across) and partly chloritized, fine grained hornblendite fragments. The white/pale blue-grey mottled chert clasts include both angular and ovoid to amoeboid types, possibly related to the form of the originally gelatinous chert. Magnetite occurs as a very fine grained dissemination and sporadic subhedral grains. The magnetiferous breccia is intruded by a plagioclase-phyric felsic rock containing approximately 8 per cent medium grained euhedral magnetite.

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*Assay: Cu = 0.04%; Ni = 0.03%; Zn = 0.24%; Pb = 0.02%.

The best exposure of iron formation in the northern belt east of Lynn Lake occurs close to the northwestern shore of Arbour Lake. The formation, which extends from the area south of Dot Lake to Arbour Lake, contains at least three iron-rich, amphibolitic members, 3 - 10 m thick interlayered with basalt, felsic volcanic and sedimentary rocks. This formation occurs between a discontinuous sedimentary sequence up to 300 m thick to the south (division C) and mafic volcanic flows and breccias to the north (division D). The sedimentary division (C) is probably contemporaneous with a section (at least 500 m wide) of magnetiferous chert and argillite at Farley Lake, approximately 20 km east of Arbour Lake (Stanton, 1948). One iron-rich member outcrops close to Arbour Lake in the northern (upper) part of a section of fine grained sedimentary rocks at least 100 m thick. These include very felsic siltstone (with up to 95% quartz + feldspar), intermediate siltstone, and garnetiferous greywacke (with 20% combined biotite + hornblende and up to 7% magnetite). Some felsic to intermediate layers within the section are interpreted as crystal tuff or reworked tuff. The magnetiferous horizons are characterized by intercalated layers of hornblendite, plagioclase-phyric basalt, and chert at a scale of 50 cm to 1 m. The very fine- to medium-grained hornblendite (up to 95% green hornblende and up to 15% magnetite) contains thin layers of magnetite and pyrrhotite laminae (1 - 5 cm thick) and chert layers (up to 5 cm thick). Sulphides comprise a mesostasis containing euhedral hornblende, and sporadic aggregates of sphalerite occur intersertal to the amphibole; pyrrhotite stringers and quartz veins truncate the lamination. Pyrite and pyrrhotite are concentrated in very fine grained siliceous layers* elsewhere in this zone. The hornblendite is massive at the northern end of the formation close to Arbour Lake; magnetiferous hornblende-chlorite schist and gneiss occur 1 km to the southwest; these rocks probably underlie the massive hornblendite member. The schist and gneiss are hornblende-phyric and contain aggregates of magnetite, and pyrite + pyrrhotite (up to 3 x 1 mm); minor quartzo-feldspathic zones within the gneiss contain aggregates and stringers of biotite (± muscovite). A frost-heaved, 15 m wide outcrop, 200 m north of the mafic schist and gneiss, contains predominantly felsic volcanic boulders, including massive plagioclase-phyric rhyolite, intermediate and felsic volcanic breccias and streaky dacite or rhyolite with sericite-pyrite-tourmaline laminae.

The iron formations within the Wasekwan Group are typical of the Algoman type (Gross, 1965), which are associated with volcanic and volcanogenic sedimentary rocks. Volcanically-derived iron and silica are precipitated at the sea-floor during fumarolic activity; some silica may be derived by leaching of felsic volcanic rocks which commonly underlie the iron formations (Gross, op. cit.). Differentiation of the felsic volcanic rocks is probably associated with iron enrichment in these sequences (Goodwin, 1962). The origin of hornblendite which occurs in several of the iron formations in the northern belt is uncertain; the mafic to ultramafic rocks may represent tuffs, flows, or possible exhalite deposits.

INTRUSIVE ROCKS

PERIDOTITE (15)

Peridotite outcrops 1.5 km north of the northern end of Motriuk Lake within a section of volcanic breccias, flows and tuffs (Fig. 19). The ultramafic rock occurs approximately 60 m south of a mineralized siliceous sedimentary rock (9h) which is exposed in a frost-heaved zone approximately 8 m wide. The zone is coincident with a three-channel electromagnetic anomaly and corresponding aeromagnetic anomaly (Questor Surveys Limited map, Lynn Lake area, 1976). The latter anomaly is on strike with a strong linear "high" associated with magnetiferous iron formation extending through Barbara and Ralph Lakes. North of Motriuk Lake, this anomaly and associated mineralization occurs at the contact between mafic to intermediate volcanic breccia and subordinate basalt and rhyolite flows to the south, and tuffaceous sediments, felsic flows and fragmentals to the north (Fig. 19).

The peridotite comprises a massive section at least 10 m thick containing a 1 m wide zone of alteration. The pale greenish-grey ultramafic rock is dissected by dark grey, magnetiferous stringers resulting in pillow-like structures (20 cm to 1 m across) which are strongly sheared at the southern margin of the zone. Magnetiferous veinlets and ovoid aggregates of magnetite up to 5 cm across occur in the cores of the ultramafic pods. Alteration products, comprising 50 - 70 per cent of the rock, include serpentine, tremolite, chlorite, and talc. Anastomosing magnetiferous trails dissect coarse olivine crystals (up to 1.5 cm long) and aggregates of pyrrhotite occur within irregular carbonate masses.

The occurrence of the ultramafic rock at the junction between the volcanic section to the south and a predominantly sedimentary unit to the north is considered to reflect a structural control on emplacement of the intrusion; a stratigraphic significance is not recognized. The age of the intrusion is not certain; the ultramafic rock may be coeval with peridotite associated with the Lynn Lake gabbro, which probably postdates at least one phase of deformation and metamorphism of Wasekwan Group rocks (Pinsent, pers. comm.).

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*Assay: Cu = 0.15%; Ni = 0.09%; Zn = 0.39%; Pb = Tr; Au = Tr.

FOX MINE-GEMMEL LAKE AREA

A succession of Wasekwan Group rocks, over 4000 m thick, is exposed in the western part of the Lynn Lake Belt. It comprises five suites of volcanic and sedimentary rocks which are tentatively correlated with units exposed to the northeast:

(1) Fox Lake porphyritic basalt (unit 3) consists of largely mafic autoclastic breccia, flows and related amphibolites. The unit is interpreted as part of the tholeiitic basalt platform exposed in the McVeigh Lake-Cockeram Lake area.

(2) The Snake Lake dacites (units 6 and 7) comprise several separate felsic volcanic bodies overlying the basalt. Massive dacite and altered rocks occur at Snake Lake in the largest body; dacite and rhyolite flows, breccia and tuff occur in thinner horizons interlayered with mafic and intermediate volcanic rocks (Fox Mine succession) south of Dunphy Lakes.

(3) The Fox Mine succession is a heterogeneous assemblage of aphyric basalt (unit 2), porphyritic basalt and andesite (unit 4) and fine grained sedimentary rocks (unit 9). It overlies the larger bodies of Snake Lake dacite and is interlayered with the thinner more felsic bodies. The felsic units are locally overlain by, or strike into fine grained sedimentary rocks including iron formation.

(4) Fox Road turbidite (unit 9) overlies the dacites on the east. It is a 1500 m thick deposit of fine grained and conglomeratic greywacke. The stratigraphic position of the unit and the presence of quartz-pebble conglomerate near the base suggest a correlation with the Fraser Lake-Eldon Lake sedimentary section.

(5) Wilmot Lake volcanic and sedimentary rocks (units 4 and 9) form the youngest unit in the southwestern part of the Lynn Lake Belt. They comprise porphyritic, basaltic and andesitic breccia and tuff similar to the Fraser Lake mafic volcanic body and may be part of the same volcanic pile.

FOX LAKE PORPHYRITIC BASALT (3)

The Fox Lake basalt is a deposit of highly mafic porphyritic flows and breccias that form the lower part of the Wasekwan Group in the southwestern end of the Lynn Lake Greenstone Belt. The deposit lies south and east of Fox Mine, where it is curved around the intrusions at Snake Lake (Fig. 3). The maximum thickness (1200 m) of the Fox Lake basalt occurs between Helen Lake and McWhirter Lake.

The stratigraphic relationship of the Fox Lake basalt is uncertain. The unit is interpreted to occupy an anticline. The closure of the fold, probably located at east-Dunphy Lake, contains Snake Lake dacites apparently deposited on the Fox Lake porphyritic basalt. Isolated bodies of dacite conformably overlie the basalt on the inferred limbs of the anticline. East of Fox Mine the porphyritic basalt is overlain by a mafic to intermediate volcanic succession. At Pyta Lake the basalt is overlain with angular unconformity by Sickle arkose. It is intruded by gabbro and tonalite at Snake Lake.

Fox Lake porphyritic basalt forms a hook-shaped outcrop belt around the northwest side of the Snake Lake intrusions. The belt is about 1.2 km wide east of Fox Mine where it extends 6 km along Highway 396. It extends an equal distance south, from Fox Mine to Pyta Lake where it is 1.5 km wide. The structure of the belt is interpreted to be a northeast plunging anticline, but tops are indicated mainly from overlying rocks. Tops are southeast in the Fox Road turbidite, and northwest in the Fox Mine succession. The closure of the anticline is apparently at east-Dunphy Lake but no units can be traced around the closure within the basalt. The presence of a pair of late folds west of Fox Lake is suggested by changes in the strike of the foliation. The presence of an anticline southwest of DD Lake is implied by a reversal in grading in greywacke (9f).

The porphyritic basalt has been altered to amphibolite in the staurolite-sillimanite zone. Deep green hornblende, pale green amphibole and nearly colourless cummingtonite constitute 40 - 95 per cent of the rock. The rest is recrystallized plagioclase, diopside, up to 10 per cent biotite, epidote, magnetite, calcite and sphene. Primary textures are not preserved but the fine grain size of the matrix is maintained by the secondary minerals, and phenocrysts occur as pseudomorphs.

The main varieties of Fox Lake basalt are:

(1) Dark green, densely porphyritic basaltic flows (3a) and breccia (3c).

(2) Grey-green porphyritic flows (3a), minor pillowed flows (3b).

(3) Grey, amygdaloidal, finely porphyritic and aphyric basalt (3d).

(4) Mafic breccia and amphibolite (3f).

(5) Mafic porphyry (3g).

Fox Lake basalt is probably equivalent to McVeigh Lake porphyritic basalt and possibly Miskwa Lake basalt. The unit has a similar stratigraphic position in the lower part of the Wasekwan Group, and similar petrographic features:

(1) Hornblende occurs in characteristic pseudomorphs after euhedral pyroxene phenocrysts which comprise up to 70 per cent of the rock (average 25%). A range of phenocryst sizes occur in many flows (0.5 - 10 mm, typically up to 5 mm).

(2) Plagioclase phenocrysts are absent or small. They are rarely over 1.5 mm; microphenocrysts, if present, would probably have been destroyed during high-grade metamorphism.

(3) Flows and autoclastic breccias occur in equal proportion.

Some features of the Fox Lake basalt differ from those of the McVeigh Lake basalt:

(1) Coarsely porphyritic rocks commonly grade to sparsely and finely porphyritic rocks, and locally into aphyric basalt.

(2) Amygdales are conspicuous; they comprise up to 80 per cent of some blocks in breccia; locally gas cavities are several centimetres long.

The Fox Lake basalt has a distinctive chemistry characterized by:

(1) High MgO (7.8 - 14.1%, average 11.7%) and low FeO*/MgO (1.08 - 0.8).

(2) Low Al_2O_3 (7.77 - 12.5% average 10.1%).

(3) Relatively high silica (47.3 - 57.9%), possibly due in part to tiny quartz amygdales in analyzed samples.

(4) Variable K_2O/Na_2O (0.03 - 1.4%, average 0.45%) with the highest individual ratio in the most mafic breccia, where biotite occurs as patches of alteration.

(5) Low Ni/Cr (0.03 - 0.7) with Cr contents up to 2764 ppm. Nine analyses (114-122) of grab samples are given in the Appendix.

On the whole, Fox Lake basalt is more mafic than the porphyritic rocks of McVeigh Lake and Miskwa Lake, and MgO/FeO* ratios are higher.

MASSIVE FLOWS (3a), MINOR PILLOWED FLOWS (3b)

Massive flows are interlayered with breccias throughout the Fox Lake basalt and are most abundant in the lower half of the succession south of Oz Lake. Flow thickness ranges from 15 cm to several metres, but contacts between thick flows are generally not exposed.

Hornblende after pyroxene phenocrysts commonly comprises 25 - 40 per cent of the rock. Most flows have seriate textures and the maximum size of phenocrysts varies from one flow to another. There is locally a complete gradation from densely porphyritic to aphyric rock.

Several unusual flows display grading with a densely porphyritic base and a finer grey or green crust. The lower layers contain up to 80 per cent coarse phenocrysts, which have apparently accumulated at the base of the flow. The upper layers are finely porphyritic or aphyric, and generally amygdaloidal.

Internally layered pillows occur 300 m north of the west arm of Pyta Lake. The pillows are 50 cm - 1 m in diameter and have dark green amygdaloidal selvages. The lower part of the pillows comprise dark green basalt crowded, at the base, with 5 mm hornblende after pyroxene phenocrysts which decrease upward in size and abundance. Two-thirds of the way up within the pillows the basalt contains only 2 per cent phenocrysts (1.5 mm) with scattered 2 mm grains of plagioclase in a fine grained groundmass. The upper part of the pillows is grey, weakly banded and contains small hornblende pseudomorphs only. The transition to the upper layer takes place over 3 cm. Available chemical data showing variations in normative clinopyroxene suggest that relatively weak crystal settling of augite took place in the pillows. The considerable difference in colour and texture in the zoned pillows is largely due to an increase in grain size downward. The upper, grey layer crystallized first, producing a thick crust as is indicated in one pillow where this layer is breached by a wedge of autoclastic breccia of grey chips in a darker matrix (Fig. 20). Crystal settling was probably restricted to the dark layer: the plagioclase-porphyritic band at the top of the dark layer is probably the least mafic part of the pillow. A solid crust on a viscous layer of fluid and on a crystal mush provided the conditions that apparently led to the formation of large volumes of autoclastic breccia in the Fox Lake basalt.

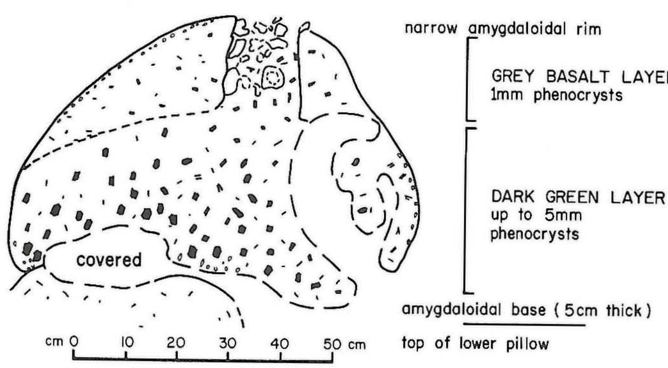

FIGURE 20: Differentiated pillow basalt (unit 3b), north of Pyta Lake. Hornblende pseudomorphs after pyroxene phenocrysts are shown in black.

AUTOCLASTIC BRECCIA (3c)

Nearly half the dark green porphyritic basalt comprises autoclastic breccia and patchy amphibolite interpreted to have been derived largely from breccia. These rocks commonly contain 60 - 80 per cent matrix of dark green or black porphyritic basalt. The fine- to medium-grained groundmass and the phenocrysts are overgrown with green hornblende. Fragments weather green, brown or grey, generally lighter than the matrix. The fragments are oval, angular or irregularly shaped, and up to 30 cm in diameter. Strongly recrystallized blocks which are similar in composition and texture to the matrix have blurred outlines. The best preserved breccias contain a wide variety of fragments commonly enclosed in a darker matrix in which the phenocrysts are larger and more abundant than in the fragments. Variations among fragments include (1) the shape, size and sharpness of outline, (2) the size and abundance of phenocrysts, and (3) the vesicularity (size, abundance and distribution).

The breccias appear to be heterolithologic but many are probably derived from single flows. The small, light grey, angular fragments are interpreted as chips of early crust, and larger, angular, weakly porphyritic, amygdaloidal blocks as fragments of a thicker crust. Ovoid, porphyritic fragments and the coarse matrix represent portions of the main body of the flow. One of the breccia units contains polygonal blocks, presumably produced by cooling joints in a sparsely porphyritic crust (Fig. 21). Some ovoid fragments in an underlying breccia were sufficiently plastic to have developed an amygdaloidal core zone. These breccia units are interlayered with flows, identical to the breccia matrix. A 1.5 m layer of matrix contains ghost-like, partly resorbed fragments.

Pyroclastic breccias have not been positively identified, but 600 m west of Helen Lake, amphibolite containing scattered fragments of aphyric basalt is of possible pyroclastic origin. The fragments are 1 - 3 cm long and are round or angular. The matrix may have been a crystal tuff.

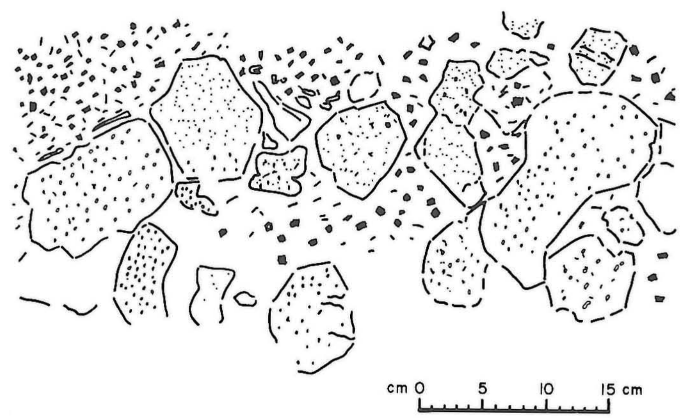

FIGURE 21: Autoclastic breccia (unit 3c), north of Pyta Lake. Mafic phenocrysts are shown in black, amygdales as dots or circles.

GREY-GREEN PORPHYRITIC BASALT (3a, 3b)

Grey-green weathering basalt is nearly identical to the McVeigh Lake basalt. Typical samples contain up to 10 mm phenocrysts of stubby, black hornblende after pyroxene (20%) and 1.5 mm phenocrysts of plagioclase (20%). On average, the basalt comprises amphibole (48%), plagioclase (50%) and biotite (1%). An outcrop on the road near Snake Lake contains massive flows and a few metres of pillowed basalt; the pillows have wide, dark green selvages and grade from amoeboid and sack-shaped bodies to pillow breccia. The porphyritic basalt is overlain at the road by the lowest felsic unit of dacite, and by lapilli tuff belonging to the Fox Mine succession.

FINELY PORPHYRITIC AND APHYRIC FLOWS (3d)

Fine grained varieties of the Fox Lake basalt are light grey weathering, finely porphyritic or aphyric and commonly amygdaloidal. They occur as thin flows, or fragments in a darker matrix of flow breccia. Fine grained basalt constitute most of a 300 m succession overlying more densely porphyritic rocks south of Oz Lake. The grey rocks also occur throughout the Fox Lake porphyritic basalt, as flows or flow tops and as blocks in the flow breccia.

The chemical composition of two analyzed samples is similar to that of the darker basalts. The grey colour results from a slightly higher content of plagioclase and locally from an abundance of nearly colourless cummingtonite. The pale amphibole grows in slender needles with multiple twinning typical of cummingtonite and forms a fine grained interlocking mosaic with feldspar. Amphibole comprises 45 - 95 per cent of the rock. A typical sample contains amphibole (55%), plagioclase (43%) and magnetite (1%). The most mafic rocks consist of a felted mass of pale green or colourless blades of amphibole (less than 0.3 mm long), biotite (5%), and minor plagioclase, chlorite, calcite, and opaque minerals.

Many light coloured basalt flows are aphyric, but the majority are finely porphyritic and contain phenocrysts of: (1) plagioclase, (2) plagioclase + hornblende (after pyroxene), or (3) hornblende (after pyroxene). Plagioclase phenocrysts occur as 0.5 - 4 mm grains (1.5 mm average) in amounts up to 20 per cent of the rock (average 10 - 15%). Hornblende is coarser (2 - 8 mm, 6 mm average) but slightly less common than plagioclase. The grey weathering basalts are conspicuously amygdaloidal, locally scoriaceous. Amygdales contain quartz, or feldspar ± amphibole with a rim of quartz. Oval amygdales are up to 10 mm in diameter; irregular gas cavities are up to several centimetres long.

MAFIC BRECCIA AND AMPHIBOLITE (3f)

About 20 per cent of the Fox Lake basalt is banded and patchy amphibolite derived from mafic breccia, flows, and possibly sills. These rocks form small black or rusty brown ridges. A dark, rough weathering surface is typical where large phenocrysts stand out above the softer biotite-bearing matrix of the basalt. Fine- and medium-grained bands vary from apple green and olive green to black. This variety of amphibolite is common especially in the outcrop belt east of Fox Mine. Other varieties of the unit include breccia, containing altered mafic fragments, and dark green rock with grey, biotite-bearing inclusions.

Generally the amphibolite consists of a felted mass of amphibole with rarely preserved hornblende pseudomorphs after pyroxene phenocryst. The dark green variety contains mainly hornblende (75 - 90%), up to 8 mm long grains, intergrown with plagioclase (up to 15%) biotite (up to 10%), magnetite and retrograde chlorite. In some areas biotite occurs as flat lenses which are several centimetres long on pitted weathering surfaces. The pale green variety of amphibolite and light green patches, bands and fragments in the mixed rock contain either diopside and epidote or variously blades, rosettes, or spiral masses of cummingtonite. A sample taken north of Wolf Lake consists of diopside (60%) forming stubby interlocking grains, hornblende (25%) and interstitial microcline (5%), minor calcite, plagioclase, biotite, sphene and opaque minerals. (The microcline probably formed with amphibole during a metamorphic reaction between biotite and calcite).

The chemical compositions of two samples of the patchy amphibolite are similar to the most densely porphyritic flows and breccia matrix, in that they contain the least amount of Al_2O_3 and Na_2O, and the most CaO, K_2O and Cr of the porphyritic suite (analyses 121, 122; Appendix). The CaO and K_2O contents are highly variable and were probably increased by metasomatism.

The origin of the banded rock is uncertain. Much of the banding is a secondary feature associated with the formation of a strong foliation. At some localities there are bands developed in two intersecting directions — one defining discontinuous layering and the other forming lenses parallel to the foliation. Banded and patchy rocks locally grade into volcanic breccia, and may have formed from breccia and flows.

One variety of patchy amphibolite is interpreted as autoclastic, partly altered mafic breccia. The rock is dominated by matrix (60 - 90%) which is either dark green, bright green or rusty brown. The fragments are generally lighter coloured. They are angular to oval, and up to 20 cm long. The breccia is interlayered with massive amphibolite and banded amphibolite interpreted as mafic flows or gabbro sills.

A second variety of patchy amphibolite contains inclusions and irregular layers of fine grained brownish grey rock. This amphibolite occurs northwest of Snake Lake where the mafic phase is uniform dark green or vaguely banded, and the grey phase consists of fine grained quartz, feldspar and biotite. The latter resembles siltstones but at one locality on Highway 396 ovoid fragments of the grey phase contain quartz-filled amygdales. These amygdales are generally largest in the middle of the fragments, a feature indicating that a felsic magma was present. One layer of amphibolite contains about 40 per cent fragments but a few metres across strike the grey rock predominates and the amphibolite forms the inclusions. The grey phase may have formed as an immiscible felsic liquid in a mafic magma.

MAFIC PORPHYRY (3g)

About 600 m west of Helen Lake a row of black weathering outcrops stand above the glacial sand and cobbles. They are the only exposure of a thick (30 m?) flow or sill of massive mafic porphyry. The rock contains about 80 per cent coarse black hornblende in stubby pseudomorph after pyroxene phenocrysts (up to 10 mm) in a grey or white weathering groundmass composed of fine grained plagioclase, green amphibole, diopside, calcite and sphene. The matrix is confined to angular interstices between phenocrysts. The rock is similar to the basal part of differentiated flows.

SUMMARY AND CONCLUSIONS

The Fox Lake basalt comprises primarily flows and autoclastic breccias. The abundant and early crystallization of pyroxene produced a distinctive seriate porphyritic texture that grades from aphyric to coarsely and densely porphyritic rock. Fine grained, grey weathering, aphyric and finely porphyritic rocks of similar composition are interpreted as rapidly chilled flows. Spectacular flow breccias were formed where the chilled vesicular crust broke up and was incorporated into the densely porphyritic lower portions of the flows. Minor crystal settling took place to produce rare differentiated flows and differentiated pillows at one locality.

The Fox Lake basalt was deposited during an early, exclusively mafic period of volcanism, which preceded felsic volcanism (first dacite, later rhyolite) and associated sedimentation. The presence of large amygdales and rare pillows suggest that the basalt was extruded under shallow marine conditions. The unit has a thickness of about 1200 m and only a moderate extent (10 km); it may represent a small shield volcano. The thickest part of the unit and the most highly amygdaloidal basalt occurs between Helen Lake and McWhirter Lake: possibly a vent existed in the south.

SNAKE LAKE DACITES (6, 7)

Felsic volcanic rocks overlie Fox Lake porphyritic basalt in the triangular area between Fox Mine, east-Dunphy Lake and Pyta Lake. The felsic rocks occur as thick lenses (massive flows) and thin discontinuous layers comprising tuffs and flows. Their composition ranges from dacite to rhyolite, and they are here informally named the Snake Lake dacites. The most remarkable features of the dacites are their extensive alteration and their association with cordierite-anthophyllite schist, cordierite-biotite-sillimanite schist, and possibly with the Fox orebody.

The various felsic bodies lie at the top of the Fox Lake porphyritic basalt, and within the overlying porphyritic and aphyric basalts (Fox Mine succession, units 2, 4; Fig. 3). They are locally directly overlain by sedimentary rocks (9).

The felsic bodies were disrupted by folding, faulting and by the intrusion of gabbro and tonalite. Much of the dacite occurs as screens in the Snake Lake gabbro. Dacite is recrystallized in the sillimanite-staurolite zone to muscovite-biotite- or hornblende-biotite-bearing assemblages, but some primary textures have been preserved.

Locations of the bodies are shown on Figure 22. There appears to be a segmented body at Snake Lake, two folded bodies at east-Dunphy Lake and possibly three bodies south of Fox Mine. Thinner, commonly rhyolitic tuff-bearing layers appear to form horizons connecting the larger bodies. Generally outcrops are widely scattered and details have not been mapped out.

At Snake Lake there are three large screens of dacite enclosed partly within the Snake Lake gabbro (A, B and C in Fig. 22). Linear structures and stratigraphic data indicate that the screens were

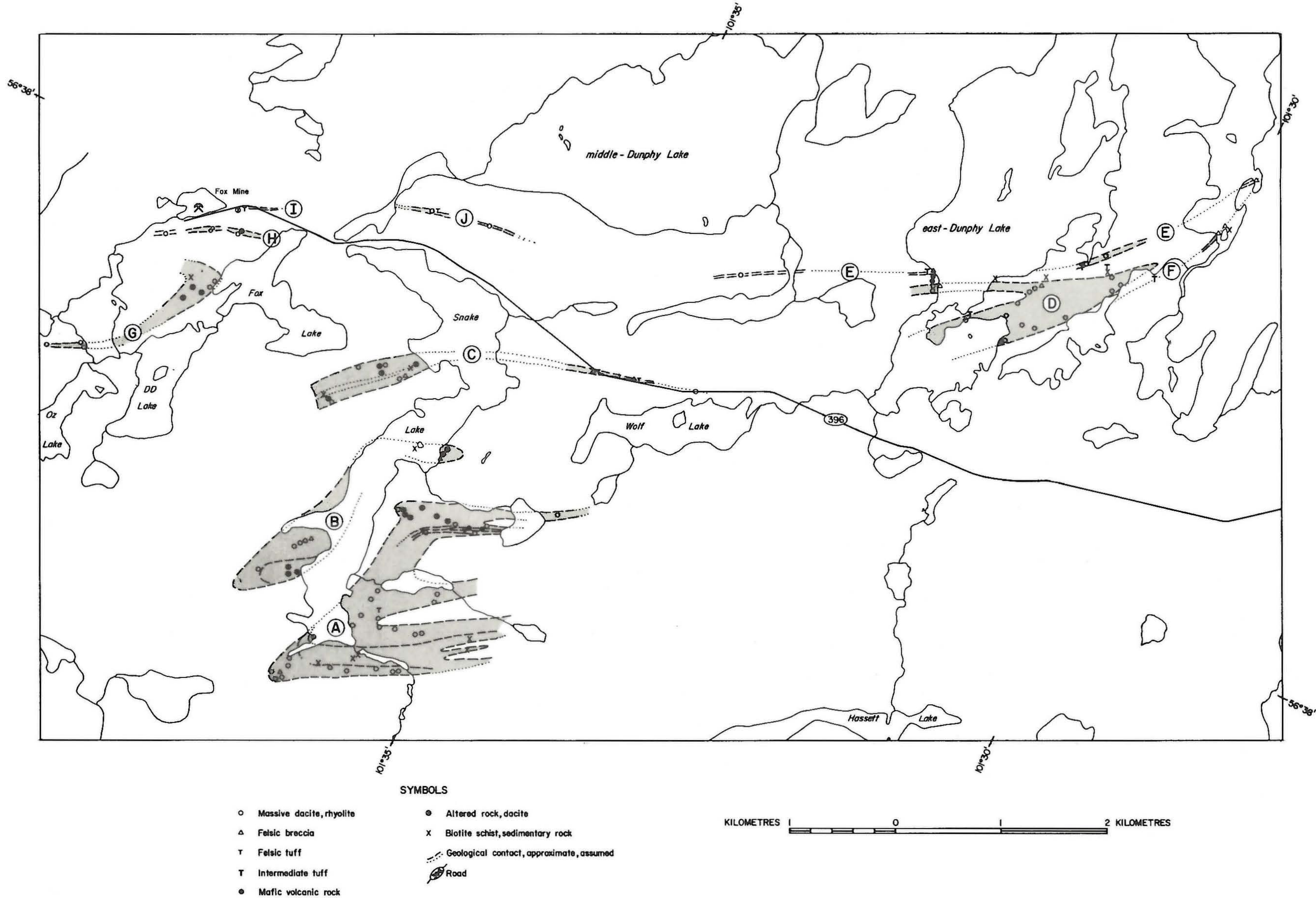

FIGURE 22: Location of Snake Lake dacite bodies (unit 6).

probably derived from a single body, 5 km long and 800 m thick. The southern segment (A) in interpreted to be the closure in the steeply northeast-plunging syncline developed in the Fox Road turbidite (9). Segments B and C lie northwest of the projected trace of the syncline and they probably face southeast but there are no top indicators. The probable base of the dacite at Snake Lake is exposed only northwest of Wolf Lake (body C) where porphyritic basalt is overlain by a thin unit of brownish greywacke and laminated siltstone, which are overlain in turn by a bed of intermediate tuff and by felsic tuff with mafic lapilli. The tuff is overlain by Snake Lake dacitic breccia; flows are exposed along strike. The upper contact of the dacite is intruded by gabbro which is overlain by Fox Road turbidite. Locally, body C is overlain by porphyritic basalt.

The dacite at Snake Lake consists of: (1) a lower division (300 m) of massive and minor brecciated dacite, (2) a central division (200 m) of altered dacite, porphyroblatic schist, argillaceous sedimentary rock and minor porphyritic basalt, and (3) an upper division (300 m) of massive dacite (Fig. 23). Massive dacite grades into altered rocks across strike but lenses of sedimentary and mafic volcanic rocks oriented parallel to the transition zone suggest that the alteration is stratabound. All three divisions are intruded by sheets of gabbro, locally with chilled contacts and with minor alteration of the dacite (oxidation and injection of mafic veinlets).

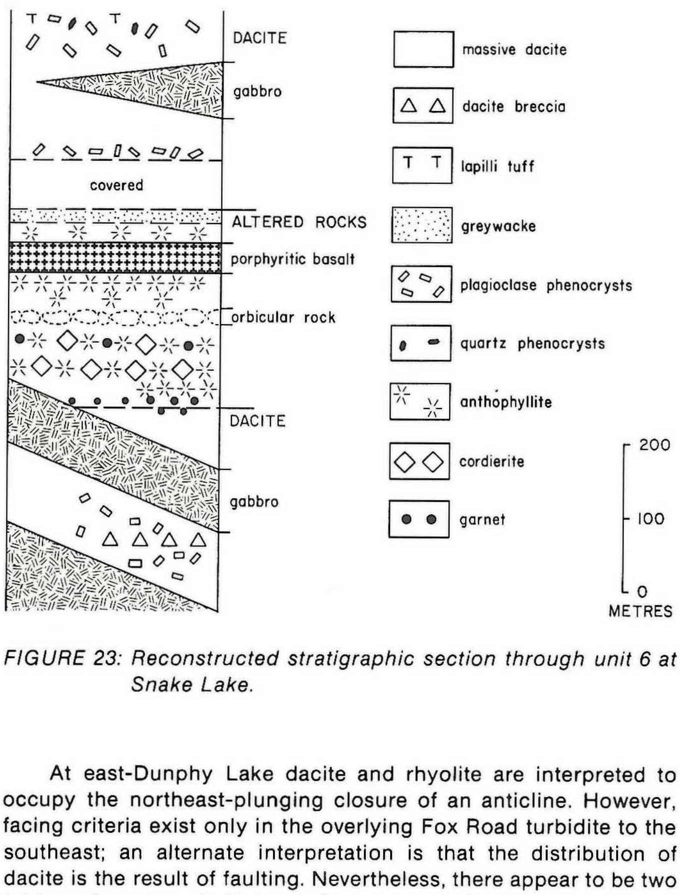

FIGURE 23: Reconstructed stratigraphic section through unit 6 at Snake Lake.

At east-Dunphy Lake dacite and rhyolite are interpreted to occupy the northeast-plunging closure of an anticline. However, facing criteria exist only in the overlying Fox Road turbidite to the southeast; an alternate interpretation is that the distribution of dacite is the result of faulting. Nevertheless, there appear to be two felsic units on each limb of the proposed fold, a lower (inner) predominantly massive unit of dacite and rhyolite (D in Fig. 22) and an upper (outer) predominantly tuffaceous unit (E and F). The thickness of body D ranges from 80 - 400 m whereas body E-F is only a few metres thick and is associated with conglomerate and feldspathic greywacke. The units are separated by and strike into predominantly mafic rocks (Fox Mine succession) including basalt, fine grained sedimentary rocks, tuff and coarsely garnetiferous amphibolite associated with gossan zones and E.M. conductors. The upper units of dacite lies adjacent to granodiorite in the north limb (body E) and it is overlain by Fox Road turbidite in the south limb (body F).

In the area near Fox Mine, felsic rocks are exposed on a dozen small outcrop areas. No detailed work was attempted to correlate between these outcrops. They have been rather arbitrarily grouped into three bodies indicated as G, H. I on Figure 22. All felsic rocks are altered to some degree near the mine, and schists are as voluminous as recognizable rhyolites, dacites, or tuffs. The largest body (G) is over 200 m thick at Fox Lake from where it extends southwest across the tailings pond. It consists of dacite in the south, and schist, greywacke(?) and dacite to the north. The body is enclosed in porphyritic basalt and may be within the Fox Lake volcanic pile. However the foliation within the schist curves north at Fox Lake and suggests that a late fold or fault may be present. The lack of outcrop precludes a reliable interpretation of the structure.

Body H (Fig. 22) is exposed 100 m south of the vent raise. The unit has been mapped as a felsic intrusion (Lustig, 1979) but part of the body resembles the dacite at Snake Lake, and contains autoclastic breccia. The dacite is about 40 m thick and is enclosed in aphyric basalt. On a small exposure 400 m to the southwest, dacite is underlain by porphyritic basalt or andesite.

At the bend in the road, northeast of the mine, altered dacite or rhyolite forms a thin unit that strikes into the Fox orebody. It overlies altered aphyric basalt and andesite of the Fox Mine succession. About 1500 m along strike to the northeast is another thin unit of rhyolite (J in Fig. 22). The overlying thin-bedded burbidites indicate that the succession faces northwest but the structural work of Lustig (1979) suggests that there are several strike faults in the succession.

MASSIVE DACITE (6a, 6b), MINOR RHYOLITE (7a)

Dacite and rhyolite form flat outcrops commonly with a buff weathering surface. The least altered rocks are generally structureless and uniform. The altered rocks are patchy green, often with a stockwork of diffuse veins spotted with dark green mafic minerals. Freshly broken surfaces are grey, with dark green, dark brown, or black mafic lenticles. These mafic aggregates comprise roughly 10 per cent of the rock. They may be deformed pseudomorphs after ferromagnesian phenocrysts replaced by spindle-shaped intergrowths of biotite and chlorite, or biotite and hornblende. Some contain magnetite or calcite. They are generally 2 mm long (maximum 5 mm) and have, in many places, a strong linear fabric. The presence of mafic aggregates is a diagnositc feature for much of the Snake Lake dacite.

A common variety of dacite has small phenocrysts of plagioclase in addition to mafic aggregates. This texture is best seen on slightly weathered, broken surfaces where feldspar is cream coloured. The plagioclase laths are 0.3 - 3.0 mm long and average 1.5 mm. The groundmass consists of very fine, interlocking grains of quartz and feldspar (0.02 - 0.05 mm), and up to 10 per cent fine grained biotite, and lesser muscovite. Some muscovite occurs as late, randomly oriented porphyroblasts. The patchy grey variety of felsic rock contains up to 25 per cent dark green amphibole and small porphyroblasts of pale green amphibole (5%). It generally does not contain biotite clots but locally there are small plagioclase phenocrysts.

The composition of the rocks as indicated by whole rock analyses 131-139 (Appendix) ranges from dacite to rhyolite. Two samples from the largest body at Snake Lake (A) and a sample from Wolf Lake (C) are dacite (67 - 68% SiO_2) and the body (J) north of Snake Lake is rhyolite (72% SiO_2). The body at Dunphy Lake includes dacite and texturally similar rhyolite (67 and 71% SiO_2); the most siliceous rock (73% SiO_2) is at the top of the body. Total alkali content is nearly identical in all these rocks (6.2 - 7.1%). Ratios of K_2O/Na_2O vary over a wide range (0.16 - 2.0) and most samples of dacite are unusually potassic; these features suggest that the suite has undergone variable potash metasomatism. Rhyolitic members are rich in soda compared to potash. They occur as tuffs, are overlain by marine sediments, and may have been altered by sea water.

The majority of the Snake Lake dacite comprises aphyric (6a) or plagioclase-phyric (6b) thick homogeneous flows. The coarsest dacite occurs west of Snake Lake (body B) at the base of the unit. It has a sub-porphyritic texture (with plagioclase up to 5 mm) and may be partly intrusive. The larger body (D) at east-Dunphy Lake contains massive dacite with 1.5 mm plagioclase phenocrysts and small spindle-shaped mafic aggregates similar to the dacite at Snake Lake. The aggregates are composed of biotite near the base of the section but chlorite and hornblende occur higher up, where the rock is patchy and visibly altered. Body D also contains aphyric dacite (6a) and rhyolite (7a) especially in the northwest limb of the proposed anticline and at the top of the southeast limb.

Massive dacite and rhyolite in the Fox Mine area are aphyric or finely plagioclase-phyric.

AUTOCLASTIC BRECCIA (6c)

About 5 m of breccia is exposed west of Snake Lake in the lower part of body B; in contains blocks of porphyritic dacite up to 4 m in diameter, but fragments smaller than 20 cm are most common. The matrix is similar to the fragments and the breccia grades downward (northwest) into massive subporphyritic dacite. The breccia is interpreted as autoclastic and its presence shows that at least part of the relatively coarse grained dacite was extrusive. Other localities with autoclastic breccia are south of Fox Mine (body H) where the matrix is rich in amphibole and garnet (up to 3 cm in diameter). In segment C on Highway 396 coarse breccia with a hornblendic matrix grades laterally into massive dacite. The composition of matrix of the breccia has apparently been altered.

LAYERED BRECCIA (6c), TUFF (6d)

The relatively thinner, northern segment (C) of dacite at Snake Lake contains several beds of layered breccia and lapilli tuff near the top. The deposit is visibly altered and overlies heavily altered massive dacite and coarse grained schist. Commonly, felsic clasts (essential) are enclosed in a darker matrix. One layer has angular fragments up to 15 cm in diameter and there are a few (accidental) mafic lapilli in the matrix of feldspar crystal tuff or altered dacite. The layering in the deposit suggests a pyroclastic origin but primary textures have been obliterated by metamorphism.

The upper (outer) unit of felsic rock at the southwest shore of east-Dunphy Lake (E in Fig. 22) contains patchy garnetiferous dacite with a few light coloured lapilli. Felsic tuff with ovoid and spindle-shaped lapilli in a matrix containing plagioclase crystals and garnet porphyroblasts occur farther northeast along strike. On the east shore of the lake rusty weathering felsic rock with a few rhyolite fragments and calc-silicate lenses occurs in the same unit. On the southeast limb of the proposed anticline (F in Fig. 22) similar rocks are interlayered with polymictic volcanic conglomerate containing abundant clasts of plagioclase-phyric dacite, and greywacke beds rich in plagioclase crystals. These fragmental dacitic rocks are interpreted as pyroclastic, reworked (sorted), and epiclastic (rounded) deposits which lie stratigraphically above the larger body of massive dacite at Dunphy Lakes. They are intercalated with greywacke at the base of the Fox Road turbidite.

ALTERED ROCKS, SCHIST (6e)

Spectacular porphyroblastic schists with exotic mineral assemblages, often including anthophyllite, have replaced large volumes of rock in the Fox Mine-Snake Lake area. Gradational contacts between the magnesian schists and the dacites and local breccia structures preserved in the schist indicate that most of the altered rocks were derived from Snake Lake dacites. The alteration is about 200 m thick in the core of the largest bodies of dacite at Snake Lake. It extends almost the full length of the bodies for a total of 4 km if the segments are restored across gabbro sills. West of Fox Lake (G in Fig. 22) there are 100 m of dacite and altered volcanic rocks overlain by sedimentary rocks. Several thin units of anthophyllite schist occur east of the mine in the succession which is interpreted to underlie the orebody. These schist occur in mafic volcanic rocks a few tens of metres removed from recognizable felsic volcanic rocks.

A common variety of schist contains quartz (30%), plagioclase (10%), cordierite (20%), biotite (30%) and sillimanite (1%). Cordierite (CD) replaces much of the original plagioclase (PG). Chlorite (CL) and possible magnetite (MG), pyrite and ilmenite are minor phases. Other common varieties of schist contain anthophyllite (AT), garnet (GR), staurolite (ST), late chlorite as well as sulphides and magnetite-ilmenite. Common assemblages are:

QZ - PG - CD - BO - SM
QZ - PG - CD - AT - GR - MG - (CL)
QZ - PG - CD - AT - BO - MG - (CL)
QZ - PG - ST - SM - BO - GR

Staurolite also occurs with anthophyllite ± garnet. Anthophyllite forms rosettes of brownish-green blades up to 5 cm long. Garnet reaches 2 cm in size and is often euhedral, and cordierite occurs as large poikiloblasts, often in square, strongly chloritized crystals. Some of the schist has retained fine grained (0.05 mm) quartz and feldspar. Anthophyllite in the schists forms large porphyroblastic blades, often in oval, rosettes elongated parallel to the regional, late-tectonic foliation. The coarse blastesis took place during the main period of regional metamorphism but the chemical alteration took place early in the history of the dacite: the altered metadacites are intruded by apparently unaltered metagabbro.

Some of the altered rocks can be traced into dacite; a good transition is preserved on the east side of Snake Lake where small garnets occur in normal dacite adjacent to layers of dacite alternating with coarse anthophyllite schist. There is a peculiar grey, orbicular rock in which light grey oval masses up to 10 cm long occur in an anthophyllite-bearing matrix. A stratigraphic section is given in Figure 23. In the small enclave of country rock on the east side of the lake, staurolite-garnet-anthophyllite schist has retained the structure of typical felsic breccia. The adjacent schist contains visible pyrite, chalcopyrite and sphalerite.*

Altered rocks interpreted as dacite in the Fox Mine area (body H) retain a finely granular texture of quartz, plagioclase and biotite (10%); ragged needles of pale green amphibole cut across the other minerals. The garnetiferous matrix in the breccias is also interpreted as an alteration product. Northeast of the mine, (body I) in the zone associated with the orebody, there are massive and brecciated, patchy rocks with rust spots and stringers of sulphide and magnetite. They contain up to 10 per cent cummingtonite and locally patches rich in biotite.

SUMMARY AND CONCLUSION

If the top of the porphyritic basalt is taken as a datum, the bodies at Fox Lake (G) and Snake Lake (A, B, C) are the oldest because they lie within porphyritic basalt; the body (H) south of the mine is at the datum, and the large body at D is younger because it lies within aphyric basalt; the thin units (E, F) extending from Dunphy Lakes southwest towards Fox Mine are the youngest. According to this scheme and to limited petrographic and chemical data there was an increase in silica in the felsic volcanism with time. There was also a slight increase in explosive activity, followed by block faulting and protracted sedimentation in the northeast. (See the following section on Fox Road turbidite). Predominantly mafic lava, tentatively correlated with Tod Lake basalt (see following section), erupted in the west during the advanced stages of the felsic volcanism. The Fox orebody is situated within this volcanic pile. It lies on strike with one of the smallest, youngest dacites (I).

*Assay: 0.77% Cu, 0.40% Zn, trace Pb.

Snake Lake dacites first developed as large, relatively uniform bodies, probably domes which may have been intrusive. The enclaves of dacite surrounded by gabbro at Snake Lake can be restored to form a single body which is over 4 km long and has a tapering extension (C) containing probable pyroclastic breccia near the main body, and tuff in the northeast. There are 200 m of altered rocks that form a central unit in the body. The layered structure of these schists suggests that they may have been tuffs and coarser pyroclastic deposits.

The younger, more felsic units are thin flow, pyroclastic and epiclastic deposits associated with zones of gossan and overlain by fine grained graphitic and magnetite-bearing sedimentary rocks. The Fox orebody occurs at the stratigraphic level of one of these minor units.

FOX MINE SUCCESSION (2, 4, 8, 9)

The south wall of the fault along Dunphy Lakes comprises a heterogeneous succession of volcanic and sedimentary rocks containing the Fox orebody. It is informally named the Fox Mine succession and has a thickness of 500 m at the mine. The orebody lies about 300 m above the base of the succession and 200 m south of the fault-contact with Sickle arkose. The rocks extend for 10 km northeast but there are considerable changes along strike. The main components of the outcrop belt are:

(1) aphyric basalt, pillow breccias and flows similar to Tod Lake basalt;
(2) porphyritic basalt;
(3) dacite and rhyolite (described in the section on "Snake Lake dacites");
(4) intermediate volcanic rocks;
(5) polymitic conglomerates; and
(6) greywacke, mudstone and iron formation.

Many of the rocks in the vicinity of the mine are altered and there are anthophyllite schists which occur locally. The succession is intruded by gabbro, diabase and minor felsic rocks.

The succession is interpreted to face north but the only indications for tops are a flow top in underlying porphyritic basalt, a questionable layer of fining-upward pillow breccia within the succession, and a single, but excellent, exposure with graded bedding in interlayered sedimentary rocks.

APHYRIC BASALT FLOWS (2)

The aphyric flows are similar to Tod Lake aphyric basalt in their general appearance, their petrography, chemistry and distribution of volcanic facies. They form relatively large outcrops of dark green or black weathering uniform basalt. The rock has a simple mineral content comprising fine grained green hornblende (up to 0.5 mm long) and plagioclase.

The composition of a thick flow which occurs southeast of middle-Dunphy Lake is nearly identical to the Tod Lake basalt in the north wall of the Dunphy Lake fault (analyses 123, 124; Appendix). The content of MgO (8.3%) and the FeO*/MgO ratio (1.04) are relatively high and TiO_2 (0.45%) relatively low compared to the average composition of Tod Lake basalt southwest of the Tod Lake fault.

Like the Tod Lake basalt, flows are thick and massive in the northeast (up to 20 m) but unlike the Tod Lake basalt they are interlayered with porphyritic basalt. Pillow basalts occur near Fox Mine. At the vent raise, flow units contain such successions as 1 m of massive basalt, 1 to 2 m of pillows and pillow breccia, followed by 30 cm with small fragments in a hyaloclastic matrix. Isolated pillow breccia and amoeboid pillows occur farther south of the vent. Most of the rocks near the mine are altered and some contain conspicuous porphyroblasts of brown garnet or green amphibole. Weathered surfaces are commonly patchy, light and dark grey reflecting variable degrees of alteration.

PORPHYRITIC BASALT FLOWS (4)

Flows with plagioclase and hornblende (after pyroxene) phenocrysts are interlayered with the aphyric basalt. They are most prominent southwest of middle-Dunphy Lake where they are massive and thick. Porphyritic flows occur at the base of the succession near the mine where they resemble Fox Lake basalt.

Porphyritic flows weather dark green or black. They consist of very fine grained hornblende (50 - 65%) and plagioclase, and biotite (up to 8%). They contain up to 30 per cent stubby hornblende pseudomorphs after euhedral pyroxene phenocrysts which are up to 10 mm in diameter (rarely up to 2 cm). Plagioclase phenocrysts (0.5 - 5 mm) are slightly less abundant. Relicts of clinopyroxene are preserved in the core of a few phenocrysts of amphibole which are zoned from pale green near the core to deep green at the margin, possibly reflecting primary zoning in pyroxene.

Although these rocks superficially resemble Fox Lake porphyritic basalt, some of the plagioclase phenocrysts are significantly larger (5 mm). The plagioclase is stubby and contains embayments, a feature not observed in Fox Lake basalt. Moreover, the chemical composition of porphyritic flows (analyses 127, 129, 130; Appendix) is very similar to the interlayered aphyric flows (analyses 123, 124) and to the Tod Lake basalt (analyses 150-174).

Porphyritic flows with plagioclase and hornblende (after pyroxene) occur 500 m south of the Fox Mine shaft. They resemble Fox Lake basalt but chemical work (in progress) suggest that they may be part of the basalt-andesite suite in the Fox Mine succession. The size and abundance of mafic phenocrysts is highly variable in these flows and some flows are differentiated. One layer has a fine grained, highly amygdaloidal contact zone 30 cm wide. The lower part of a second flow contains 25 per cent mafic phenocrysts up to 8 mm in diameter; the phenocrysts become smaller upward and are absent at the flow top. In one place in the flow, the main porphyry has broken through its fine grained crust; a string of epidote patches along the original flow top is pierced by tongues of coarsely porphyritic rock. It should be noted that such a flow would produce an apparently polymictic flow-breccia.

INTERMEDIATE AND MAFIC VOLCANIC ROCKS (4)

Grey weathering aphyric and porphyritic volcanic rocks are abundant in the area surrounding the mine. They include andesite and basalt which are generally indistinguishable in the field. Flows, breccias and minor tuff are present.

Limited chemical data suggest that a relatively high content of SiO_2 (54 - 55%), high FeO*/MgO ration (2.1 - 3.2) and low trace Ni (6 - 14 ppm) is common in the light coloured rocks which are therefore interpreted as andesite (analyses 126, 128; Appendix). However, much of the rock is patchy and visibly altered.

There is more than 50 per cent finely granoblastic plagioclase overgrown with coarser grains of hornblende, and in the patchy rocks, intergrown with fine cummingtonite. An altered intermediate sample at the mine contains plagioclase (60%), hornblende (15%), cummingtonite (15%) and minor quartz, sphene and magnetite. Garnet porphyroblasts occur locally, especially in the matrix of the intermediate breccias.

Grey weathering amygdaloidal, porphyritic flows occur in the lower part of the Fox Mine succession south of the mine. Plagioclase phenocrysts (1 - 2 mm long) comprise 10 - 20 per cent of the rock, mafic phenocrysts are largely restricted to interlayered flows of dark green basalt. The flows are overlain by porphyritic and aphyric breccia including amoeboid pillow breccia and angular autoclastic breccia. Epidote patches are locally abundant, and anthophyllite schist forms a thin layer overlain by several thin flows of andesite(?) and basalt. Local units of intermediate breccia higher in the succession contain angular and irregular-shaped grey blocks in a brownish garnetiferous matrix. They are the coarsest deposits in the area; blocks are up to 50 cm long.

SEDIMENTARY ROCKS (8, 9)

Thin sedimentary units lie stratigraphically above the Fox orebody but they are largely unexposed and known mainly from underground work.

A thin unit of polymictic conglomerate is exposed north of Snake Lake where it overlies altered porphyritic volcanic breccia, minor cummingtonite schist and rhyolite. Greywacke occurs farther north. The conglomerate comprises rounded and angular, largely mafic and felsic volcanic clasts, up to 30 cm long. The greywacke to the north contains hornblende and locally abundant magnetite.

Dark green magnetiferous iron formation with thin cherty layers occurs above the sedimentary layers north of the mine. Garnet amphibolite, associted with tuff and sedimentary rocks on east-Dunphy Lake, may occupy the same stratigraphic position as the iron formation. Similar rock occurs also near Wolf Lake, presumably facing south on the south side of Fox Lake basalt. These rocks generally have a linear magnetic anomaly and are associated with EM conductors. They are probably meta-iron formation.

ORIGIN AND DEPOSITIONAL ENVIRONMENT

The interlayering of various types of volcanic rocks and thin units of fine grained clastic and chemical sedimentary rocks suggests that the Fox Mine succession was deposited distant from main volcanic centres, in a marine environment supplied with only minor sediments. Locally the mafic units are similar in composition and volcanic facies to Tod Lake basalt and the felsic units similar to Snake Lake dacite, suggesting that these units were partly contemporaneous. However they may belong to a separate suite of mafic, intermediate and felsic volcanic rocks.

FOR ROAD TURBIDITE (8, 9)

A 1500 m thick deposit of fine grained and conglomeratic greywacke lies east of the Fox Mine area. The formation consists of quartz-deficient volcaniclastic rocks that display sedimentary structures characteristic of turbidite. It contains clasts of basalt, dacite and rhyolite, some of which resemble the underlying rocks. The formation is informally named "the Fox Road turbidite" for its well preserved primary structures which are best observed on small, clean outcrops in the sand pits along Highway 396. Numerous moss-covered outcrops of the formation lie scattered for about 3 km along strike in the surrounding bush.

The Fox Road turbidite overlies Snake Lake dacite and Fox Lake porphyritic basalt and comformably underlies a suite of younger volcanic rocks which occur north of Wilmot Lake. The turbidite is tentatively correlated with the Fraser Lake-Eldon Lake sedimentary rocks because it is part of a broadly similar stratigraphic succession and because it contains the same distinctive quartz-pebble conglomerate near the base. The Fox Road turbidite is interpreted to represent a thick, high-energy deposit emplaced in a deeper marine environment than the Eldon Lake sediments.

The Fox Road turbidite has an observed strike length of at least 5 km; its maximum extent may be over 20 km northeast but the exposure of the unit is incomplete. North of Hassett Lake the formation occurs in the northeast plunging core of a large syncline; southeast of Dunphy Lakes the formation comprises 1500 m of greywacke and 500 m of gabbro sills, and occupies the southeast-facing limb of the syncline. The trace of the syncline lies 1.5 km north of Hassett Lake, where there is a reversal in facing and a reversal in the relationship between the attitude of the bedding and the foliation. Outcrops are small and lichen-covered in the south and it is not known whether the unit extends towards Wilmot Lake or whether it is truncated along an unconformity or a fault with the Sickle Group to the south.

Hornblende-bearing sedimentary rocks north of Wilmot Lake and south of Motriuk Lake may be a fine grained facies of the Fox Road turbidite but they are intercalated with volcanic rocks and are probably separate lenses of sedimentary rocks.

The metamorphic grade of the turbidite is middle to upper amphibolite facies. Mudstone beds near the base of the succession contain rare knots of fibrolitic sillimanite, whereas north of Wilmot Lake, argillaceous siltstone contains staurolite. The first sillimanite isograd probably passes through the Fox Road turbidite a short distance north of Highway 396 where no diagnostic minerals are present. Porphyroblasts of hornblende and clear grains of microcline are common in an assemblage with quartz and plagioclase ± calcite ± epidote. The minerals were apparently developed in a reaction between biotite and calcite in the middle amphibolite facies.

The Fox Road turbidite consists of five main types of sedimentary rocks listed below in decreasing order of abundance:

Unit 9b: Grey-green and dark green greywacke and buff to light green weathering siltstone containing secondary hornblende; beds are massive or contain graded, parallel laminated, ripple laminated or convoluted units (Bouma divisions A to C).

Unit 9c: Pale buff weathering, fine grained greywacke-siltstone rich in plagioclase, quartz and containing secondary biotite is intercalated with mudstone that was metamorphosed to fine grained biotite-garnet schist; the rocks are thick bedded to laminated and contain few turbidite structures.

Unit 9a: Green and grey paraconglomerate and pebbly greywacke with structures of the resedimented facies (turbidites); they contain angular and subrounded clasts of mafic and felsic volcanic rocks supported by a matrix of hornblende greywacke.

Unit 9f: Dark green mafic mudstone and greywacke, interlayered with light green laminated mudstone.

Unit 8a: Quartz-pebble and polymictic conglomerate; clasts are well sorted and rounded in a matrix of mafic mudstone or greywacke.

The major lithologies are interbedded throughout the Fox Road turbidite but the biotite greywacke-mudstone (9c) is common below the quartz-pebble conglomerate (8a); more mafic greywacke predominates above the conglomerate (Fig. 24).

BIOTITE GREYWACKE-MUDSTONE (9c)

Buff- and grey-weathering greywacke, siltstone and quartz-biotite ± garnet schist form the basal member (100 m thick), possibly a fining-upward succession, exposed only along Highway 396. The rock contains quartz (20 - 30%), plagioclase (40%), biotite (20 - 30%) and garnet (0 - 20%). Some beds contain amphibole, pyrite, minor graphite, calcite, or locally sillimanite. Another member of biotite greywacke (20 m thick) occurs higher in the succession, whereas thinner members and individual beds are interlayered with light green weathering hornblende greywacke throughout the succession. (Hornblende greywacke becomes increasingly important upwards).

Much of the biotite-bearing rock is very fine grained (average 0.05 mm). It ,may have been derived from quartzose mud or fine sand but the texture is granoblastic and devoid of primary features. Graded beds retain grain sizes ranging from 0.03 mm to 1 mm, and rare gritty beds contain a few isolated clasts up to 10 cm across. Some beds contain lens-shaped calc-silicate concretions with epidote, calcite ± pyrite.

The biotite greywacke and siltstone beds are typicall internally massive. They average 40 cm thick but they occur up to 2 m thick, and some of the silt beds are only 2 - 3 cm. The basal biotite greywacke member contains few turbidite structures. Some fine sandstone beds are laminated at the top and a few coarser beds (50 cm thick) have small scale cross bedding (up to 10 cm in amplitude). The top of the basal member has a few graded beds with pelitic tops. These beds have metamorphic (reverse) grading of garnet porphyroblasts and resemble the Burntwood River greywackes. Some pelitic layers at the top of the member contain abundant pyrite.

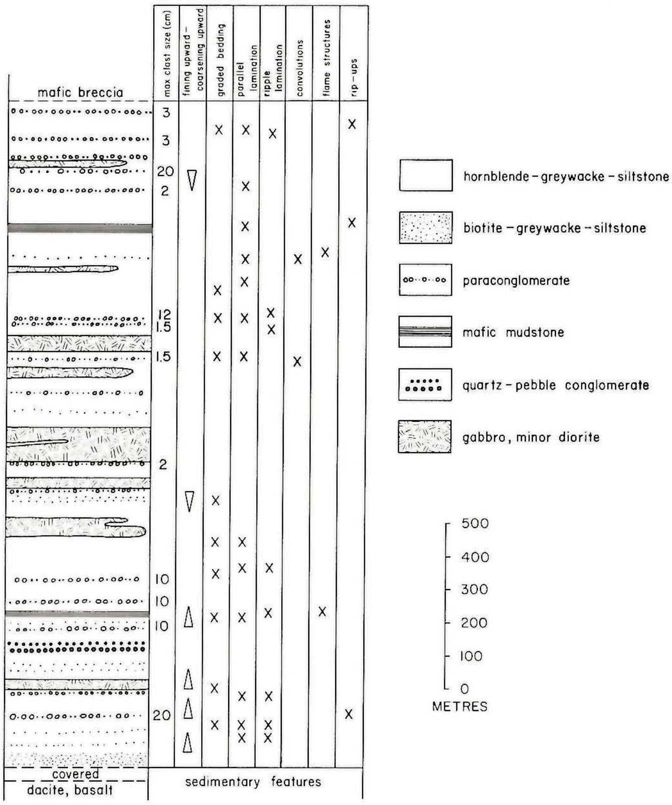

FIGURE 24: Stratigraphic section through Fox Road turbidite (unit 9), showing sedimentary features and maximum clast-size of para-conglomerates.

HORNBLENDE GREYWACKE, SILTSTONE (9b)

Light and dark green weathering greywacke with abundant granoblastic hornblende forms most of the sedimentary succession. It occurs as massive and graded beds ranging in thickness from 2 cm to several metres. The hornblende greywacke is interlayered with the biotite-bearing rocks above the basal member. At about 250 m above the base, nearly all the beds contain hornblende and there are dark green weathering beds containing over 40 per cent hornblende and only 10 - 15 per cent quartz. Typical light green weathering greywacke contains quartz (20%), plagioclase (45%), hornblende (20%) and biotite (10 - 15%). Epidote, calcite, sphene, magnetite and small amounts of microcline are accessories. Quartz and feldspar are very fine grained (0.03 mm) and granoblastic; lithic clasts are commonly up to 2 mm long and consist of mafic and felsic lithologies. A complete transition exists from mudstone to gritty, pebbly and conglomeratic greywacke.

Sedimentary rocks in the fine sand- to mudstone-range of sizes occur as distinct varieties. Pale buff weathering, massive and laminated greywacke-siltstone is most common. It contains small rosette-shaped porphyroblastic aggregates of blue-green amphibole up to 2 mm long. The siltstone contains more plagioclase than quartz, and more biotite than amphibole. Laminated rocks contain biotite (20%) and plagioclase (50%) in white weathering layers, and hornblende (up to 30%), granoblastic microcline (up to 30%) and plagioclase (20%) in dark green layers.

Graded bedding is common in hornblende greywacke. It occurs with parallel laminated tops or ripple laminated tops in beds ranging from 3 - 40 cm thick. Convolutions, rip-ups and flame structures occur locally. Some light coloured graded beds are thicker (up to 2 m) and contain abundant calc-silicate lenses. In the lower part of the Fox Road turbidite several 50 - 60 m thick fining-upward cycles of hornblende greywacke are characterized by a thick bed of paraconglomerate at the base overlain by greywacke and siltstone. In the lower parts of the cycles graded beds are most common, but in the upper parts, parallel laminated and ripple laminated turbidite divisions predominate. In the upper part of the Fox Road turbidite hornblende greywacke and pebbly greywacke occur in well organized turbidite beds 1 cm - 1 m thick. Most beds start with graded divisions but some beds contained all 5 Bouma Divisions. These are interpreted as relatively high-energy turbidite flows, in which rip-ups, scours, flames, and convolutions occur.

MAFIC MUDSTONE, GREYWACKE (9f)

Mafic mudstone is common between 450 m and 600 m above the base of the Fox Road turbidite. The rock displays a well preserved primary layering, but recrystallization has obliterated any detrital textures. Mudstone contains up to 40 per cent hornblende and little quartz.

Mafic mudstone overlies the third fining-upward cycle (Fig. 24). The beds (3 - 10 cm) display delicate parallel laminations but there are also some graded divisions and ripple-laminated divisions. The orientation of flame structures suggests a northerly sediment transport.

PARACONGLOMERATE, PEBBLY GREYWACKE (9a)

About 10 per cent of the Fox Road turbidite consists of exceptionally thick beds of resedimented conglomerate and pebbly greywacke. The conglomerates contain an abundance of matrix which supports pebbles and cobbles of volcanic and sedimentary origin. They are paraconglomerates deposited by high-energy turbidity currents or high-density mass flows. Massive, graded and laminated Bouma divisions are present but thick, weakly graded beds predominate. Paraconglomerates occur most commonly in the lower and upper parts of the Fox Road turbidite. Some of the beds lie at the base of fining-upward cycles or at the top of coarsening-upward cycles.

The lowest bed of paraconglomerates (10 m thick) overlies the basal biotite-bearing greywacke; the bed contains felsic clasts upto 30 cm long except at the top where clasts are smaller. They comprise angular and subrounded blocks of dacite, rhyolite, siltstone, greywacke and tabular rip-ups (2 m long) of laminated, cherty siltstone. The matrix of the bed contains clasts of quartz and abundant plagioclase. The next bed of paraconglomerate lies about 200 m above the base of the greywacke. It is 2 m thick and contains rounded cobbles of rhyolite and a few mafic clasts in a gritty matrix containing abundant subhedral grains of plagioclase. The coarse tail of this bed grades from 10 cm to 1 cm clasts. Similar beds occur directly along strike, overlying dacitic tuff and polymictic breccia on the southeast shore of east-Dunphy Lake. Some of the paraconglomerate was apparently derived from Snake Lake dacite; rounding of some amphibolite clasts indicates erosion from an emergent area. Sedimentary structures indicate mass-flow emplacement.

Higher in the succession there are several 5 - 10 m beds of mafic, pebbly greywacke. The clasts comprise 10 - 20 per cent of the rock and include aphyric basalt, porphyritic basalt, plagioclase-phyric basalt and felsic rocks. Most of the clasts are angular but there are some rounded cobbles of banded amphibolite, similar to a variety of Fox Lake basalt (3f). The mafic matrix contains quartz (10 - 20%), plagioclase (30 - 60%), hornblende (30 - 40%), biotite (up to 15%), and microcline (up to 5%). Microclasts are aphanitic grains and polycrystalline aggregates retaining their primary subangular morphology.

About 350 m above the base of the Fox Road turbidite there is a 5 m paraconglomerate bed with all Bouma divisions present (Fig. 25). Paraconglomerates high in the succession contain only pebbles, except for one coarse bed with rare clasts up to 20 cm.

QUARTZ-PEBBLE AND POLYMICTIC CONGLOMERATE (8a)

Thirteen metres of clast-supported conglomerate occurs at one

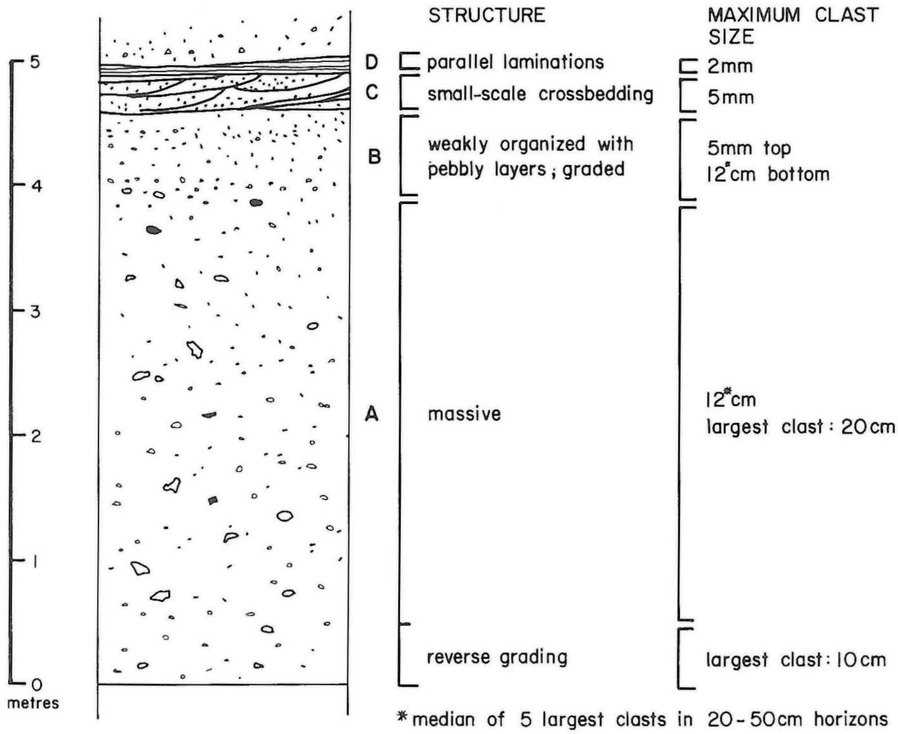

FIGURE 25: 5 metre bed of paraconglomerate, 350 m above the base of the Fox Road turbidite (unit 9), showing Bouma divisions A to D and maximum clast-size.

locality south of Highway 396, about 350 m above the base of the Fox Road turbidite. It overlies coarse grained biotite ± hornblende greywacke and underlies pebbly greywacke. The conglomerate consists of well rounded and sporadic angular cobbles and pebbles of vein quartz and of subordinate aphyric and plagioclase-phyric basalt, dacite and rhyolite. The matrix is generally mafic. Quartz granules and pebbles (0.5 - 2 cm) and a few basaltic clasts are confined to a basal 5 m zone. The rest of the unit is organized into beds, 20 cm - 2 m thick, each bed defined by clast size. Some beds grade upward into mafic greywacke.

Thirty metres above the main conglomerate, there is 1 m of quartz-pebble paraconglomerate. The bed is matrix-supported and grades upwards into pebbly greywacke. It is overlain by a fining-upward cycle of thin bedded greywacke containing gritty layers at the base and garnetiferous pelitic rocks at the top.

PROVENANCE AND DEPOSITIONAL ENVIRONMENT

The Fox Road turbidite is interpreted to occupy a depression which was probably produced by block faulting. The depression acted as a channel along which felsic and mafic debris was transported towards the western end of the Lynn Lake Belt. The 2 km depression was largely filled by volcanic debris before vesicular basaltic flow-breccia was extruded as a cover.

The formation is most mafic in the centre and most felsic at the base indicating that either the source shifted rapidly from a felsic to mafic volcanic terrane or that a thin cover of felsic rocks was eroded to expose a mafic terrane. The basal member was derived partly from dacite similar to the underlying Snake Lake dacite. Tuffaceous beds within the sedimentary section on east-Dunphy Lake suggest a dacitic source there. The provenance of the main part of the succession was probably from the south, beyond the present Sickle unconformity. The structurally restored direction of sediment transport* suggested by flame structures and cross-bedding is northerly but the presence of similar, but finer grained greywacke north of Hatchet Lake and north of Laurie Lake suggests a westerly sediment transport.

The Fox Road turbidite appears to be organized into several fining-upward cycles overlain by coarsening-upward cycles. Each succession contains almost the full size range of the whole formation. The rocks may have been deposits as a turbidite fan. The angular shape of clasts and the turbidite structures indicate that transport was by mass flow rather than fluvial agents. Only the clasts in the quartz-pebble conglomerate were rounded in a stream or on a beach; their presence in distinctive beds within the turbidite sequence suggests that deposition was not far from the landmass.

It can be suggested that deposition took place during block-faulting because 1500 m of greywacke lie on highly vesicular basalt, presumably deposited in shallow water. Considerable subsidence must have taken place during the deposition of the turbidite.

WILMOT LAKE VOLCANIC AND SEDIMENTARY ROCKS

A stratified succession of volcanic and lesser sedimentary rocks occur in the Wilmot Lake area. The rocks are exposed on low outcrops in sand pits along Highway 396, and on widely scattered outcrops at the edge of small ridges in the bush. The succession is interpreted as the youngest in the Wasekwan Group on the west end of the Lynn Lake Belt. It comprises mafic and intermediate porphyritic volcanic breccia and intercalated thin flows and sedimentary rocks. The succession conformably overlies the Fox Road turbidite (9) southeast of Dunphy Lakes, and is unconformably overlain by the Sickle Group at Wilmot Lake; the top is not exposed. If a synclinal structure is assumed, the succession is about 1000 m thick.

The rocks exhibit several characteristics that serve to associate them with unit 4 in the northern Lynn Lake belt and to distinguish

*It is possible that flame structures were reoriented by internal strain which cannot be restored by rotating the plunge and dip of the folded bedding to a horizontal position.

TABLE 25: STRATIGRAPHY OF THE WILMOT LAKE VOLCANIC ROCKS (ASSUMING A SYNCLINAL STRUCTURE)

Lithology	Thickness
mafic breccia and flows, mudstone, siltstone	250 m
polymictic breccia, greywacke, tuff	150 m
mafic and intermediate breccia	200 m
mafic autoclastic breccia, flows, amphibolite	400 m

them from porphyritic basalts of unit 3. The characteristic features include the presence of: (1) abundant basaltic and andesitic breccia, generally plagioclase-phyric and with small pseudomorphs of hornblende after pyroxene phenocrysts, (2) well stratified breccia, some of which is polymictic, and (3) intercalated sedimentary rocks, mafic tuff and minor felsic volcanic rocks.

A crude stratigraphy is developed in which the lowest units comprise uniform mafic breccias and flows with predominantly hornblende megacrysts, whereas the higher levels in the volcanic pile to the northeast contain more diverse rocks (Table 25).

The Wilmot Lake volcanic rocks are interpreted to occupy a syncline which closes north of Hassett Lake in the Fox Road turbidite. The fold may extend northeast towards Gemmell Lake but the location of the axial trace is uncertain. The relationship between the attitude of the layering and the secondary foliation suggests that an axial trace intersects Highway 396 between Mile 20 and Mile 21. The underlying Fox Road turbidite faces southeast along the road, and a graded bed of mafic wacke within the volcanic rocks face northeast near Mile 21. No northwest-facing tops are known, therefore, an alternate interpretation of the structure north of Wilmot Lake is a southeast-facing homocline.

The amphibolites and some mafic breccias at the base of the succession are strongly foliated. Volcanic structures are relatively well preserved in the northeast where middle-amphibolite facies metamorphism is indicated by argillaceous sedimentary rocks which are converted to staurolite schist, and by muscovite-bearing greywackes lacking sillimanite.

The chemistry of the better preserved volcanic rocks gives a range of compositions from basalt to andesite (46.6 - 60.0% SiO_2, 11.7 - 2.3% MgO) (analyses 142-148, Appendix). Most rocks are iron-rich (FeO*/MgO = 2.0 - 3.6) compared to most units in the southern greenstone belt but similar to basalt-andesite occurring south of Hatchet Lake and near Fox Mine. Most of the analysed samples were taken from volcanic breccia and are presumed to be altered. However, the contents of the least mobile elements (Ni and Cr) are low and, therefore, consistent with the basalt-andesite protolith. A sample with 15 per cent MgO (and high Ni and Cr) was taken from one of the most mafic layers in the lower part of the succession (analysis 141); other rare high-Mg rocks occur higher in the pile (analysis 148).

MASSIVE FLOWS, AMPHIBOLITE (4a)

Flows are largely restricted to the lower 400 m of the Wilmot Lake volcanic rocks. Most flows have been metamorphosed to uniform dark green, medium grained (2 mm) amphibolite, locally containing ragged hornblende megacrysts. One of the better preserved flows contains up to 40 per cent hornblende pseudomorphs after 5 mm pyroxene phenocrysts in a matrix of fine grained hornblende and plagioclase. The most mafic rocks contain only hornblende in the matrix.

Minor flows of dark grey, finely porphyritic and aphyric basalt and minor, black Mg-rich basalt occur high in the succession.

AUTOCLASTIC BRECCIA (4c)

Much of the succession consists of autoclastic breccia of basalt and andesite containing phenocrysts of plagioclase and pseudomorphs after pyroxene phenocrysts. The breccias include monolithologic types and others in which there is a variation in the size and abundance of phenocrysts and amygdales.

Foliated, patchy amphibolite in the lower part of the succession is also interpreted as autoclastic breccia. The rock is green or blue-green with lighter coloured, low weathering patches. Its mineral content includes plagioclase (25%) and green hornblende, partly overgrown by diopside; small amounts of cummingtonite, calcite and epidote are commonly present. The largest grains of hornblende are pseudomorphs after pyroxene phenocrysts and porphyroblasts presumably overgrowing and obliterating pyroxene. The amphibolite is locally traced into relatively undeformed breccia containing irregular and small angular fragments with plagioclase and mafic phenocrysts. The breccia matrix comprises on average 70 per cent of the rock. It is coarse grained and contains randomly oriented amphibole porphyroblasts up to 20 mm long.

The most common variety of breccia in the Wilmot Lake volcanic rocks is sparsely porphyritic basalt and andesite containing megacrysts (2 mm) of plagioclase and hornblende in approximately equal abundance (10%). Greenish-grey or dark grey fragments constitute over 50 per cent of the rock and some units are clast-supported. The fragments are up to 50 cm in diameter. Their shape is commonly oval or rounded, locally angular or irregular, and rarely patchy or indistinct. Amygdales are common in the fragments and very local in the matrix; amygdales constitute up to 40 per cent of the fragments in some layers of breccia. In other layers amygdales are concentrated along the margins or in the centre of the fragments.

About 400 m above the base of the succession grey andesitic to basaltic fragments are abundant. They contain up to 40 per cent lath-shaped and equant plagioclase phenocrysts comprising single crystals and metamorphic aggregates. Stubby hornblende porphyroblasts have replaced the mafic phenocrysts. The groundmass consists of hornblende (up to 1 mm long), plagioclase and minor amounts of quartz ± garnet, epidote, calcite and biotite. Amygdales (up to 3 cm in length) contain quartz, or calcite with a rim of quartz.

An autoclastic breccia observed about 500 m above the base of the succession contains medium grey angular blocks with 45 per cent hornblende in a black weathering amygdaloidal matrix (75% hornblende). Some of the blocks are 50 cm in diameter and exhibit bleached margins. The breccia is cut by an auto-intrusive dyke similar to the breccia matrix.

Higher in the succession, northwest of Wilmot Lake, globular basalt, flow-breccia and minor massive flows form a distinctive layered deposit. It consists of more than 60 per cent grey, oval blocks and lapilli in a darker basaltic matrix. Layers (30 cm to 5 m thick) are defined by abrupt changes in the size, shape, grain size and proportion of fragments. The largest fragments (50 cm) are oval and are packed together like pillows. They have protrusions from which smaller oval bodies were apparently produced by budding. The "pillow" basalt contains only very fine phenocrysts: plagioclase laths are less than 0.5 mm long. The pillows and smaller globular bodies have amygdaloidal margins and the matrix may be hyaloclastic. Other layers contain angular fragments and still others contain bent and irregularly-shaped fragments in about 40 per cent matrix. A gradation from the pillowed and globular rock into breccia, and the concomitant increase in the size of phenocrysts suggests that different layers were formed from different batches of similar magma with varying crystallinity and viscosity. An interlayered massive flow is almost aphyric and was apparently the most fluid.

POLYMICTIC BRECCIA (4d)

A moderate proportion of the breccias in the Wilmot Lake volcanic rocks contain mafic to intermediate and, locally, felsic fragments. The polymictic breccias form relatively thin units defined by the size of fragments. They are locally interlayered with greywacke, siltstone and flow breccia.

Well stratified breccia on Highway 396, about 450 m above the Fox Road turbidite contains fragments that have similar compositions but vary considerably with respect to weathering colour, content of phenocrysts and vesicularity. They may have formed as autoclastic breccia from differentiated flows but the weakly to moderately developed sorting suggests a pyroclastic or epiclastic origin. Some beds are interpreted as laharic breccia. They contain a mixture of angular and rounded clasts of basalt, dacite and minor rhyolite. The fragments are unsorted and up to 15 cm long. Thin beds of intercalated greywacke and mafic sandstone indicate a sedimentary environment of deposition.

VOLCANICLASTIC SEDIMENTARY ROCK (9) AND TUFF (4e, 4f, 7e)

Units of layered volcaniclastic rocks are intercalated with the porphyritic breccias. The bedded rocks are abundant in a 100 m thick succession lying 650 m above the Fox Road turbidite. They comprise mainly fine grained amphibolite interpreted as mudstone and tuff, and grey or buff weathering felsic rock interpreted as greywacke and siltstone. These rocks are generally well foliated and locally cut by a network of amphibole-bearing veins. Scattered beds of polymictic pyroclastic breccia or conglomerate and pebbly greywacke are interlayered with the fine grained units.

Mudstone beds are dark green, 2 - 3 cm thick, and alternate with buff weathering siltstone beds (9e). The mafic rocks contain amphibole (25 - 65%) and fine grained (0.05 mm) quartz with minor garnet, calcite, sphene, pyrite and magnetite. Some layers contain small blasts of hornblende overgrowing an unsorted clastic matrix. Other layers have a patchy texture or contain hornblende-rich laminations 2 - 10 mm thick. The siltstone beds are pale brown (biotite-rich) or pale buff (quartz-rich). Many beds contain garnet porphyroblasts; some contain small porphyroblasts of staurolite.

Greywacke (9c, 9d) occurs in 2 - 30 cm thick beds containing lithic clasts and small grains of feldspar. Some beds are quartzose; one bed exposed at the road has a few corroded grains of euhedral volcanic quartz, and beds near Wilmot Lake have euhedral and rounded "quartz eyes" similar to quartz phenocrysts in a small body of rhyolite to the south. The quartzose sedimentary rock is massive, unsorted and was apparently derived from rhyolite with little reworking. It consists of quartz (65%), plagioclase (20%), biotite (12%) and minor chlorite, calcite, muscovite, magnetite and pyrite. Locally the greywacke is rich in biotite and grades into argillite with staurolite porphyroblasts. Delicate sedimentary structures are generally not preserved in the greywacke or siltstone. However, mafic wacke or tuff associated with laharic breccia and greywacke near Mile 21 does contain turbidite structures. Beds are 1 - 50 cm thick (average 3 cm); most are graded and a few have parallel and ripple laminations at the top. The fine grained beds contain much amphibole (40%); the coarser beds contain small angular clasts of plagioclase showing normal grading.

Mafic tuff (4e) occurs with the epiclastic rocks on Highway 396. The tuff contains euhedral and broken mafic crystals (hornblende pseudomorphs after pyroxene) and locally plagioclase phenocrysts (1 mm long). Layers are massive and up to 8 m thick. Fragmental layers (8b) comprise pebbles and cobbles of grey porphyritic and aphyric andesite-basalt, and locally quartz pebbles in a foliated matrix which resembles the crystal tuff. Pebbly greywacke or tuff-breccia near the top of the clastic succession comprises angular fragments of dacite and small fine grained grey chips in a sandy matrix of intermediate composition. One bed of greywacke or intermediate tuff contains scattered clasts of feldspar-phyric basalt up to 8 cm long.

Felsic rocks include a small body of rhyolite (tuff?) north of Wilmot Lake, overlain by texturally and compositionally similar epiclastic beds, and succeeded by isolated beds with rhyolite fragments and by minor felsic greywacke and siltstone interlayered with the otherwise mafic succession at Highway 396.

EVOLUTION, CORRELATION AND ENVIRONMENT OF DEPOSITION

The Wilmot Lake volcanic rocks were probably deposited on the lower slope of a composite volcano in a moderate depth of water where they were intercalated with epiclastic units. Massive flows are rare and autoclastic breccia is commonly stratified. Tuff is locally present, and traces of felsic volcanics are present in the area north of Wilmot Lake.

The volcanism and sedimentation apparently evolved from deposition of (1) mafic breccia and massive flows at the base of the succession to (2) mafic and intermediate breccia, polymictic breccia (locally laharic), minor felsic volcanics and sediments (locally turbiditic) in the middle of the succession, to (3) predominantly mafic breccia and tuff intercalated with muddy and conglomeratic sediments high in the exposed succession.

Broad similarities between the Wilmot Lake volcanic rocks and other successions of unit 4, and the increasing felsic volcanic component towards the northeast suggest that the Wilmot Lake volcanic rocks are part of the same large volcanic pile as the rocks at Gemmell Lake, the Fraser Lake mafic volcanic body and the succession in the northern belt. Several vents or fissures were probably involved: sources of the felsic and intermediate rocks lay in the Lynn Lake-Fraser Lake area, and one of the most mafic sources probably lay farther southeast, closer to Wilmot Lake where the whole succession of lower slope deposits overlies a thick unit of turbidites at the base of the slope.

LAURIE LAKE-DUNPHY LAKES AREA

The southwest margin of the Lynn Lake Belt features extensive turbidite deposits and volcanic rocks which include tuff, basalt and minor ultramafic rock. Adjacent to the greenstone belt volcanic and sedimentary units are interlayered and are considered part of the Wasekwan Group. Farther south, in the Kisseynew Belt, the sedimentary rocks predominate and contain only minor volcanic rocks at the top of a succession which belongs to the Burntwood River Metamorphic Suite. Changes in lithofacies and metamorphic grade take place southwest along strike over a distance of 20 km between Dunphy Lakes and Laurie Lake, and across strike between Laurie Lake and Tod Lake.

Four major lithological suites are recognized in the area: (1) greywacke-siltstone-mudstone (unit 1), generally converted to high-grade gneiss or migmatite (units 1A, 1B) and a thin unit of layered amphibolite (unit 1C) at the top of the succession. (The rocks occur in the Wasekwan Group and the Burntwood River Metamorphic Suite);
(2) conglomeratic greywacke (unit 9a), feldspathic greywacke (unit 9b) and compositionally similar (intermediate) tuff (unit 4f);
(3) Tod Lake aphyric basalt (unit 2): tholeiitic basalt, high-Mg basalt and minor ultramafic rock:
(4) Dunphy Lakes amphibolite: hornblende-bearing greywacke and siltstone (units 9b, 9e), mafic tuff and mudstone (unit 9f), mafic and intermediate flows (unit 4), locally much injected by granitic rock but showing no signs of anatexis.

The three latter lithological suites belong to the Wasekwan Group only. The lowest rocks exposed in the Wasekwan Group on the flank of the greenstone belt are commonly volcanic whereas the oldest rocks in the south are greywacke-mudstone. The Sickle Group or an equivalent gneissic suite overlies all these rocks, generally with a conformable or disconformable contact. However, north of Tod Lake the first evidence for an unconformity exists. A few kilometres to the east, arkose of the Sickle Group overlies Wasekwan Group volcanic rock with highly angular unconformity.

About 2.5 km of quartz-deficient greywacke, mafic to felsic tuff, siltstone, mudstone and minor basalt occur north of Laurie Lake and extend northeast across Dunphy Lakes. The deposit is informally called the Dunphy Lakes amphibolite. Its relationship with the other units in the area is not known at present and the rocks will be treated in a later publication.

The various stratigraphic successions in the Laurie Lake-Dunphy Lakes area occur in separate fault slices and numerous isoclinal folds. The greywacke and basalt occupy anticlines, and metasandstones of the Sickle Group occupy synclines or homoclines truncated at the top along faults. Fault slices occur between Laurie Lake and Tod Lake and south of Dunphy Lakes at the margin of the greenstone belt. They are between 500 m and 3000 m wide and extend along strike for up to 30 km (Fig. 26). The migmatite succession on Laurie Lake and Eager Lake occupies large sheet-like, isoclinal folds. These structures are recumbent folds, refolded into dome-and basin-complexes which contain a core of gneiss derived from the Sickle Group. Belts containing volcanic rocks and other amphibolites become narrower and more contorted towards the south.

GREYWACKE-SILTSTONE-MUDSTONE, MIGMATITE — WASEKWAN GROUP AND BURNTWOOD RIVER METAMORPHIC SUITE

The formation of metagreywacke-mudstone is over 600 m thick and extends from Dunphy Lakes southwest into the Kisseynew Belt. The formation contains three lithologies:
(1) biotite ± garnet-bearing rock (greywacke);
(2) biotite- garnet- sillimanite- cordierite-bearing rock (mudstone); and
(3) microcline-bearing siltstone rich in quartz and feldspar.
Typical features of these lithologies are listed in Table 26.

The formation is overlain and apparently underlain by Tod Lake basalt where it is considered part of the Wasekwan Group, north and west of Tod Lake. Similar greywacke-mudstone is overlain by a thin unit of amphibolite, derived from mafic sedimentary and minor volcanic rocks on Laurie Lake. These units belong to the Burntwood River Metamorphic Suite; they consist largely of turbidite deposited in deep water south of the Lynn Lake Belt.

Stratigraphically equivalent greywacke-gneiss (Zed Lake greywacke) occurs north of the Lynn Lake Belt.

The metagreywacke-mudstone has been identified in four structural subareas in the Laurie Lake-Dunphy Lakes area. A narrow belt of greywacke occurs on both sides of the elongate pluton south of west-Dunphy Lake (I in Fig. 26). The belt includes greywacke, mudstone. siltstone and minor felsic and mafic tuff. The rock is not migmatitic and primary structures are preserved but no definitive turbidite structures or top indicators are present. Consequently the rocks in this belt are only tentatively correlated with the main body of greywacke to the south.

A narrow belt of poorly exposed greywacke at Hatchet Lake lies along strike with the greywacke south of Dunphy Lakes. The belt widens to the southwest where it crossed the Laurie River, and occupies an anticline intruded by granitic rocks on the northeast shore of Laurie Lake (II in Fig. 26).

On the west shore of Tod Lake a succession of greywacke, 400 m thick and 3 km long, is overlain and apparently underlain by Tod Lake basalt (III in Fig. 26). The succession faces southeast and is interfingered with the basalt. It contains minor coarse grained greywacke at the base but is generally fine grained and is tentatively correlated with the greywacke on Laurie Lake.

The predominantly sedimentary gneiss and migmatite south of Laurie Lake is typical of the Burntwood River Metamorphic Suite as it occurs elsewhere in the Kisseynew belt (IV in Fig. 26). It comprises 600 m of graphitic biotite gneiss, sillimanite-garnet-cordierite gneiss and migmatite derived from greywacke-mudstone, overlain by a thin unit of amphibolite derived from mafic mudstone, marlstone, tuff and possible flows. The lower 300 m of the succession locally contain mainly biotite gneiss (1A), derived from greywacke. Locally the more pelitic (upper) gneiss (1B) is identical to greywacke-siltstone-mudstone in the fault block on the northeast shore of Laurie Lake. The greywacke-migmatite occupies sheet-like isoclinal folds which are structurally underlain and overlain by isoclines developed in the Sickle Metamorphic Suite. On Laurie Lake the recumbent folds are refolded in a series of domes, each with a core of Sickle gneiss.

Metamorphic mineral assemblages in the most northerly situated exposures of the greywacke belong to the upper- to middle-amphibolite facies. They are characterized by late muscovite porphyroblasts or by sillimanite knots partly replaced by retrograde muscovite. Large porphyroblasts of staurolite occur in two localities but generally staurolite forms small inclusions armoured with plagioclase or garnet. The inclusions are not part of an equilibrium assemblage but are retained from an incomplete sillimanite-forming reaction. Metamorphic index minerals in the migmatitic paragneiss include (1) sillimanite-garnet-cordierite, and (2) sillimanite-potash feldspar of the upper amphibolite facies; the first granitic veins and patches occur in layers derived from mudstone as a result of feldspar blastesis, probably in the presence of small amounts of melt. The approximate northern limit of anatexis is shown in map 80-1-6. The relative volume of *lits* increases towards the south over the culmination of the dome on South Bay. South of the dome, the network of granitic *lits* comprises an average of 40 per cent of the migmatite and the restite consists of layers of recognizable metagreywacke (psammite) and coarser grained layers of garnet-cordierite or biotite gneiss (pelite). Sillimanite is not abundant in the highest grade rocks but occurs as partly resorbed, flattened *faserkiesel*, as inclusions in plagioclase and cordierite, or as a retrograde phase.

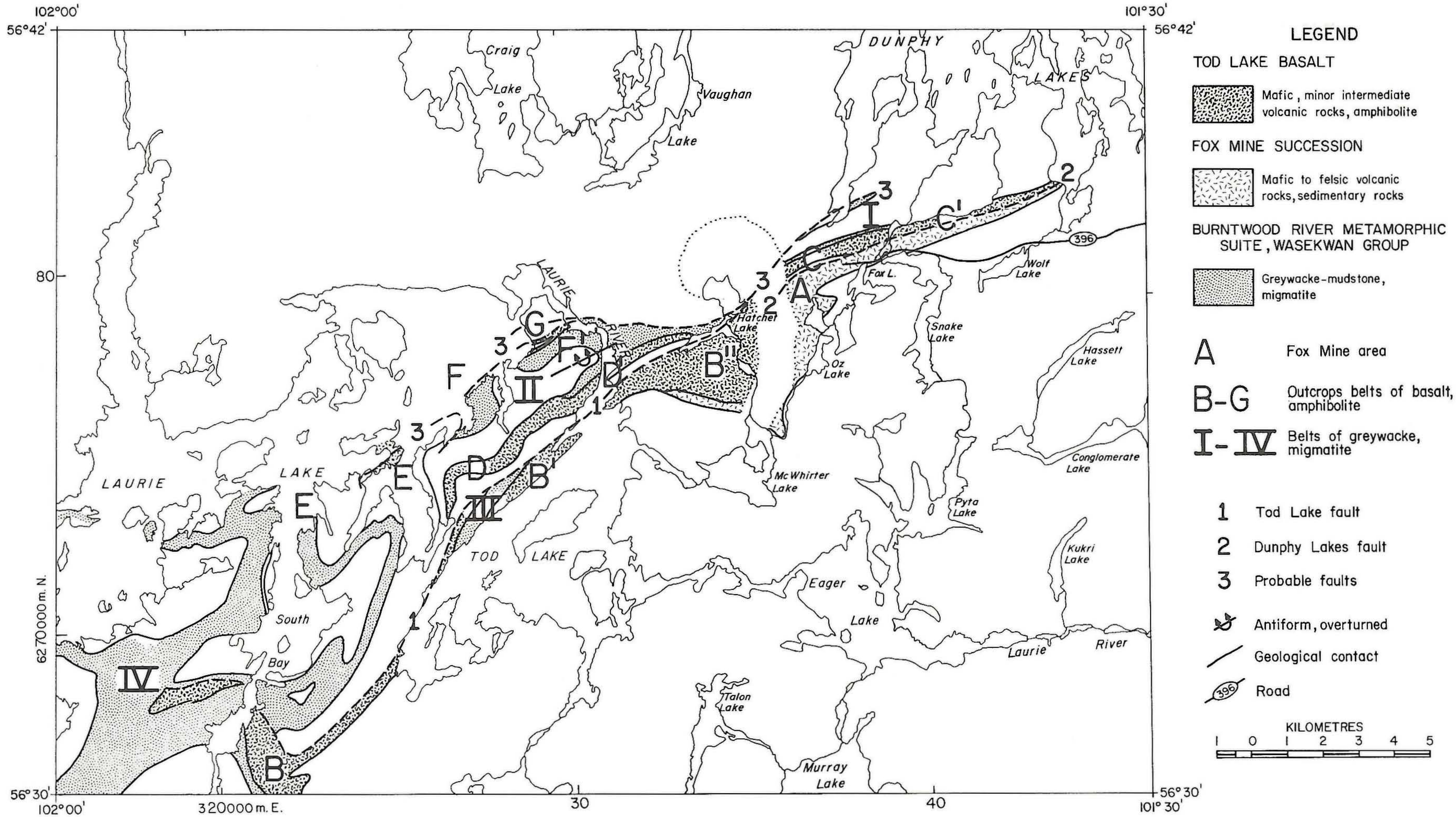

FIGURE 26: Location of fault slices of units 1 and 2 in the Laurie Lake-Dunphy Lakes area.

TABLE 26: MINERAL CONTENT, STRUCTURE AND TEXTURE OF UNIT 1 (NORTHEAST OF LAURIE LAKE ONLY)

	GREYWACKE	MUDSTONE-GREYWACKE	FELSIC SILTSTONE
weathering colour:	medium grey	dark grey, brown	white, buff
average bed thickness	10 - 20 cm	5 - 10 cm	5 cm
internal structure of bed:	graded, massive	graded, laminated	finely laminated
texture:	granoblastic	porphyroblastic	finely granoblastic
MINERAL CONTENT (PER CENT)*			
quartz + feldspar	75	58	80
quartz	40	35	35
plagioclase	35	23	35
microcline			10
biotite	25	30	12
muscovite		1	5
sillimanite		3	±
cordierite		±(8)	
staurolite	±	±	
garnet	±	1	
graphite	trace	0.5	2

*Approximate median value of 9 samples each.

GREYWACKE-SILTSTONE-MUDSTONE (1)

Medium grey weathering beds of metagreywacke (psammite) are the most prominent component of unit 1 especially in the lower part of the succession. The rocks are distinguished by relatively high content of quartz (30 - 60%) and plagioclase (16 - 48%) and the absence or scarcity of garnet (Table 26). They contain small amounts of graphite and locally pyrrhotite. The rock is generally finely granoblastic (0.1 - 0.5 mm); microclasts of quartz or feldspar are commonly less than 1 mm in diameter. On Tod Lake there are some gritty (up to 5 mm) and pebbly (up to 15 mm) beds near the probable base of the greywacke succession. Granoblastic textures are ubiquitous on Laurie Lake but the fine average grain size, lack of coarse clastic grains of quartz and feldspar and thin bedding are indications of fine primary grain size.

Beds of greywacke are massive or graded; grading is visible from an upward increase in biotite and, where garnet is present, from an increase in the size of garnet porphyroblasts upward. Bedding thickness ranges from 2 - 100 cm (average 10 cm). At the base of the unit, as interpreted between Tod Lake and Laurie Lake, beds are locally thicker (average 25 cm) than higher in the succession where the beds average 5 - 8 cm.

Oval lenses of calc-silicate rock up to 30 cm long occur in some of the greywacke beds. They commonly lie in trains several centimetres above the base of the thicker, light coloured beds rich in plagioclase. They are commonly zoned; the core is yellowish green and contains plagioclase, epidote and calcite; the margin is dark green and contains plagioclase, hornblende and commonly garnet. Some of the bodies have overgrown bedding laminations and are interpreted as carbonate concretions that increase in size by localized carbonate metasomatism during the regional metamorphism.

The mudstone portions of the beds are generally a darker shade of grey than the sandy part, but brown weathering biotite schist was derived from the most shaly beds. Pelitic rocks have a moderate content of quartz (30 - 35%) and feldspar (20 - 30%) and more biotite (up to 35%) than the psammite. They are characterized by the presence of porphyroblasts of garnet, cordierite, biotite or muscovite and, locally, knots of fibrolitic sillimanite up to 2 cm long (Table 26). Graphite is abundant and tourmaline, apatite, zircon and armoured inclusions of staurolite are generally present. In some graded beds garnet increase in size upward from 1 mm - 8 mm. Where layers of biotite schist are laminated, garnet occurs in parallel rows. The sillimanite knots commonly occupy only the upper 3 or 5 cm of the more pelitic beds.

Mudstone is common especially in the upper part of the succession on the northern end of Laurie Lake and on Tod Lake. It occurs in 2 - 10 cm, internally laminated beds, interlayered with greywacke. North of Hatchet Lake, biotite-rich rock contains randomly oriented porphyroblasts of muscovite or knots of fibrolitic sillimanite, 3 mm long, with rims of quartz. Small, odd-shaped inclusions of staurolite are common in the plagioclase, and locally there are euhedral staurolite porphyroblast. The rocks are uniform, thin bedded and were apparently derived from weakly sorted greywacke and siltstone.

The fine grained sedimentary rocks southwest of Dunphy Lakes contain abundant biotite and small amounts of sillimanite and graphite. Their mineralogy is similar to the main succession to the southwest but garnet is rare and staurolite is absent in the greywacke. There are interbeds comprising thin layers of amphibolite interpreted as mafic sediments or possibly tuff. Interbeds of buff weathering siltstone contain minor hornblende, magnetite and pyrite. These rocks resemble siltstones from the interior of the greenstone belt. Most of the sedimentary rocks southwest of Dunphy Lakes are very fine grained (0.03 - 0.15 mm) and finely laminated. Graded bedding is rare and other turbidite structures are lacking.

Turbidite structures are best preserved in the greywacke-mudstone on the northeast shore of Laurie Lake. Commonly half the thickness of the bed is laminated and the rest consists of a massive or graded (Bouma A) division. On one outcrop, in the lower part of the succession, the graded divisions average 15 cm in thickness and the laminated divisions average 10 cm. Parallel laminations are common, especially in the upper part of the succession; they are aligned with the foliation on most outcrops and they have been enhanced through blastesis of biotite and garnet in shaly laminae. Ripple laminations are rare and they were blurred during the recrystallization. In the more shaly rocks, the graded divisions and the laminated divisions are generally less than 4 cm thick. Grading is also common in beds containing combined B→E divisions. The beds are parallel sided; rip-ups and scour channels are absent. These features suggest that the turbidity currents were weak and of low density.

Thin beds of light grey and white weathering, fine grained rocks are interbedded with greywacke and mudstone throughout the upper 300 m of the succession. On the northeast end of Laurie Lake and southwest of Eager Lake they form the predominant lithology in the top 50 m. The rock is characterized by its light colour, low content of mafic minerals, and by its fine grain size. It is a siltstone or fine sandstone containing a high proportion of silica and potash, and is interpreted to be derived from rhyolite or rhyolitic ash. It contains variable amounts of microcline (2 - 35%), quartz (10 - 70%) and plagioclase (15 - 70%). The combined volume of quartz and feldspar is generally 80 per cent and there is up to 3 per cent graphite and traces of pyrite (Table 26). Variations in quartz and feldspar occur among beds and among thin laminae. The rock is finely granoblastic (average 0.1 mm) and microclasts are absent. Delicate primary laminations of concentrated graphite occur in the core of some feldspar porphyroblasts. At the top of the succession on the northeast shore of Laurie Lake the siltstone in interlayered with thin beds of sillimanite-bearing mudstone and thin layers of fine grained amphibolite, probably mafic tuff. Rust stains, graphite and pyrrhotite are present at the top, and cherty layers occur locally. The gossan is overlain by the distal, tuffaceous facies of the Tod Lake basalt but the contact is not exposed.

Beds of felsic siltstone (1 - 10 cm thick) are generally parallel sided and weather in high relief. The beds are massive or laminated; some beds show grading from a white feldspar-rich siltstone to a light grey quartz-rich siltstone. Locally beds of greywacke grade upward to white siltstone tops. On Tod Lake a 1 m thick unit of laminated slate and siliceous siltstone occurs within the Tod Lake basalt, and on the south shore of Hatchet Lake a similar rock occurs within the basaltic unit. Southwest of Dunphy Lakes, north of the Tod Lake basalt, white, laminated, felsic siltstone containing traces of graphite and sillimanite are interlayered with pale pink weathering rhyolitic tuff, buff weathering amphibole-bearing siltstone and fine grained amphibolite, similar to siltstone-mudstone successions (9e) in the main parts of the Lynn Lake Belt.

MIGMATITIC GREYWACKE-MUDSTONE (1A, 1B)

Migmatitic greywacke-mudstone is the main unit in the Burntwood River Metamorphic Suite. The succession is a minimum of 600 m thick, the upper half of which contains abundant coarse porphyroblastic schist and granitic veins derived from mudstone (1B). The lower unit consists of thin layers of fine grained grey quartzofeldspathic gneiss (psammite) alternating with narrow veins of white granitic rock (1A). The mafic minerals in both fractions of the migmatite comprise biotite, and, less commonly, small amounts of garnet. Graphite also occurs in both fractions. Sillimanite and cordierite occur locally in veins and in darker layers of gneiss derived from mudstone interbeds. Typical outcrops contain 75 per cent psammitic gneiss, and 25 per cent granitic veins and garnet-sillimanite gneiss.

Some layers of psammite are massive whereas others are internally layered or laminated. Contacts between fine grained grey gneiss and coarse grained more pelitic gneiss represent bedding but are generally parallel to the secondary foliation and to the veins. Lenses of calc-silicate rock are abundant in the psammite.

The granitic veins contain the same minerals as the restite and are predominantly quartz and plagioclase; the proportion of biotite and garnet is commonly much lower (2 - 5%). The texture and grain size varies from fine grained to pegmatitic. Many veins contain quartz in the core and coarsely intergrown quartz and plagioclase on the margins. Similar quartz veins without plagioclase occur north of the migmatites, and more homogeneous granitic veins occur south of South Bay. Some of the restite has selvages of coarse grained biotite, locally with large crystals of garnet along the margin of the veins.

About 150 m below the top of the psammitic unit are isolated outcrops of grey and green banded amphibole-bearing metagreywacke.

The upper half of the greywacke-migmatite succession is exposed around South Bay. It is generally more pelitic and contains more granitic veins than the lower half of the succession. The rocks consist of 3 - 4 cm layers of grey or brown weathering gneiss alternating with white granitic veins. The granite constitutes, on average, 30 per cent of the rock. Most veins are parallel to the layering and foliation but some veins and patches disrupt the layering in a chaotic pattern. Fine grained quartzo-feldspathic gneiss (psammite) constitutes 40 per cent, and porphyroblastic garnet-sillimanite gneiss (pelite) 30 per cent. Very coarse grained cordierite-garnet gneiss is common in an area southwest of South Bay. Biotite and graphite are closely aligned with the foliation, and sillimanite occurs commonly in flattened *faserkiesel* or paper-thin lenses in the foliation. Elongate pods of calc-silicate rock containing plagioclase diopside and hornblende occur in some layers.

The upper part of the unit contains boudins of dark green or black, coarse grained amphibolite composed of mainly amphibole, interpreted as gabbro sills and possible ultramafic bodies.

FELSIC TUFF (7e)

Isolated layers of felsic gneiss on the northeast end of Laurie Lake are interpreted as beds of felsic tuff. The rocks contain crystals of plagioclase up to 6 mm in diameter. The beds are rarely more than 10 mm thick and occur near the top and about 300 m below the top of the succession. A single layer, 30 cm - 1 thick occurs around South Bay about 50 m below the top of the Burntwood River Metamorphic Suite. It is present in both limbs of the isoclinal fold developed in greywacke-migmatite in the South Bay dome and has a remarkable continuity for such a thin unit. The rock has a medium grained granitic texture. It contains rare sillimanite or garnet porphyroblasts.

Fine grained felsic layers southwest of Dunphy Lakes were probably derived from rhyolitic tuff.

INTERPRETATION

The turbidite is interpreted as a fining-upward succession, deposited, under reducing conditions, in the Kisseynew basin from a decreasing supply of epiclastic detritus. Factors that indicate these conditions are:

(1) more mudstone or pelitic gneiss in the upper 300 m than in the lower part of the unit;

(2) thinner bedding with abundant laminated turbidite divisions at the top of the unit;

(3) an abundance of graphite at the top.

Very fine grained rocks lie on the flank of the volcanic belt (south of west-Dunphy Lake) where turbidite structures are not well developed. These rocks suggest onlapping deposition of greywacke from the Kisseynew basin over the flank of the volcanic rocks.

Greywacke and mudstone were probably deposited from relatively low-density, low-energy turbidity flows at a considerable distance from source. The detritus ranged from medium grained sand to mud; beds are commonly thin and include graded divisions and/or abundant laminated divisions. There is an absence of coarse debris, rip-ups, scour channels, and other indicators of high-energy ("proximal") flows.

The detritus of the greywacke was probably derived from a mixed volcanic-sedimentary terrane that included much felsic rock. The high content of biotite, plagioclase and quartz in the greywacke, and high content of quartz, plagioclase and microcline in the tuffaceous siltstone are consistent with a felsic volcanic source; whereas the high content of ferromagnesian minerals including cordierite, garnet and biotite, in schists derived from mudstone, indicates that part of the source terrane had a mafic or intermediate composition. Thin beds of felsic tuffaceous siltstone are massive or finely laminated and may represent water-laid deposits of rhyolitic ash from an active volcano nearby. Felsic volcanism (or an uplifted source area of rhyolite) became increasingly important; therefore siltstone locally dominates the upper part of the succession.

FELDSPATHIC GREYWACKE, TUFF (9, 4f)

A succession comprising feldspathic greywacke (9b), boulder-bearing greywacke (9a), intermediate tuff (4f) and locally intercalated mafic volcanic rocks (4a, 4b) lies on the north and east flank of the dome, on South Bay, where it occupies a Y-shaped structural belt. Cross-bedded arkose of the Sickle Suite (12b) lies to the northeast and hornblende-bearing Sickle gneiss (12d) lies to the southwest. The structural belt is 8 km long, and 500 m wide in the north where it is split by gabbro and quartz diorite. It tapers to 50 m towards the south where the feldspathic greywacke contains a few intercalations of basalt. The greywacke and the overlying unit of Sickle rocks face west and are overturned towards the centre of the dome on South Bay. Tuff predominates south and east of the gabbro, adjacent to Tod Lake basalt but the direction of facing of this part of the succession is not known. If the gabbro lies in the core of an anticline between Laurie Lake and Tod Lake, then much of the tuff faces east and overlies the greywacke.

Apparently the feldspathic greywacke occupies a stratigraphic position above the greywacke-mudstone succession of the Burntwood River Metamorphic Suite. However, the feldspathic greywacke and intermediate crystal tuff are the only plagioclase-rich deposits southwest of Laurie Lake and cannot be correlated with other units in the area. On a small island in Laurie Lake where the unit extends west across the crest of the South Bay dome the feldspathic greywacke is underlain by mafic volcanic breccia and overlain by plagioclase gneiss resembling tuff which is overlain, in turn, by a thin unit of fine grained amphibolite derived from aphyric basalt and possible ultramafic rock, and by felsite derived from rhyolitic tuff. This overlying succession is part of the high-Mg suite of the Tod Lake basalt and is overlain by conglomerate and thin bedded greywacke of the Sickle Metamorphic Suite.

The rocks are metamorphosed to the upper amphibolite facies. Textures are generally granoblastic; clastic textures are preserved only in gritty beds, conglomerates and the coarsest tuffs.

FELDSPATHIC GREYWACKE (9a, 9b)

Thick bedded, uniform, grey, feldspathic greywacke forms the main part of the succession. The unit is 350 m thick where it is truncated by gabbro and faults in the north. Typical greywacke contains biotite (20%), granoblastic plagioclase (55%), quartz (20%), and small amounts of cummingtonite (0 - 10%) or garnet, graphite or magnetite, rare hornblende, tourmaline, apatite and zircon. Some massive light grey beds are extremely rich in plagioclase as are the basal parts of some graded beds. The greywacke has a granoblastic matrix of interlocking grains of twinned plagioclase, averaging 0.15 mm in diameter. The matrix generally occurs alone in massive or graded beds; less commonly the rock contains quartz and feldspar granules, cobbles, or large exotic blocks. The clasts comprise greywacke, aphyric and porphyritic basalt, laminated siltstone, intermediate crystal tuff and rhyolite. They are commonly 10 cm in diameter but some beds contain cobbles larger than 1 mm. The largest clasts are angular slabs of laminated felsic siltstone 8 m long.

Two kilometres south of the thickest part of the succession the greywacke is only 40 m thick. It is interlayered with thin units of mafic volcanic rocks and, in one locality, contains a block (2 m) of intermediate crystal tuff resembling unit 4f. Generally, clasts are less than 30 cm long in the south; they are highly flattened and only a maximum of 3 cm wide. East of South Bay, strong deformation and recrystallization have converted the rock to plagioclase amphibolite in which lens-shaped fragments are locally visible.

A prominent feature of the feldspathic greywacke are large lenses of calc-silicate rock similar to those in the greywacke-mudstone (1A, 1B). They occur in specific layers throughout the succession. Calc-silicate minerals have also replaced large cobbles.

Light grey quartz- and feldspar-rich greywacke and siltstone forms a minor rock type. It contains only 5 - 10 per cent biotite, commonly with minor pale green amphibole. Some beds are finely laminated and contain over 1 per cent graphite. In the crest of the dome on South Bay this rock forms white or buff weathering siltstone in thin beds with hornblende or with 6 mm rusty sillimanite knots.

The feldspathic greywacke shows structures of proximal turbidites and other signs of rapid mass transport. Bedding ranges from massive to very thin. Beds are defined by variations in grain size and composition. They are internally massive, graded or, less commonly, laminated. Beds are up to 6 m thick in the north, but 4 - 30 cm beds are most common. Layers are organized into Bouma divisions nearly everywhere, starting with graded or massive (Bouma A) divisions. Some beds have parallel laminated (B) divisions and a few have ripple laminated (C) divisions. Typical beds contain a 2 m massive division with a gritty base rich in plagioclase and a 3 cm laminated top containing more biotite.

Conglomeratic greywacke beds are also commonly graded; some 2 m beds grade from a maximum clast size of 1 m at the base to that of 15 cm at the top. Small pebbles and granules consist of siltstone, rounded quartz clasts and subhedral plagioclase crystals. Cobbles of greywacke are generally rounded and contain thick alteration haloes accentuated by high-grade metamorphism. Boulders are sub-angular and consist of greywacke or volcanic rock. Widely scattered angular blocks of sedimentary and volcanic rocks occur in massive beds of coarse grained greywacke.

MAFIC ROCKS (4)

Several thin mafic flows (4a) are intercalated with the feldspathic greywacke. Pillowed flows (4b) form interlayers at two localities: one is a thin aphyric flow and the other is a porphyritic flow with large pseudomorphs of hornblende after pyroxene and smaller phenocrysts of plagioclase. In the northern part of the belt of greywacke, numerous basaltic and diabasic dykes (18) occur structurally above the fault contact with the Sickle arkose. They cut the folded greywacke.

INTERMEDIATE TUFF (4f)

Intermediate crystal and lapilli tuff have been recognized on Laurie Lake in a succession 100 m thick, apparently overlying the feldspathic greywacke. Dacitic tuff may be present within the greywacke, high in the succession but it was not positively identified at the local high grade of metamorphism, at which, felsic tuff and greywacke can resemble quartz diorite. The intermediate crystal tuff can be traced for 2 km along strike and lapilli tuff occurs almost 2 km farther to the southwest. The tuff lies adjacent to Sickle arkose, Burntwood River greywacke or Tod Lake basalt, but its base is not exposed.

The structure of the tuff is massive or weakly bedded on a scale of several centimetres. Some beds are graded. They resemble turbidite beds and indicate deposition in a marine environment.

The mineral content of the tuff is dominated by plagioclase (50 - 70%); the lighter coloured variety of tuff contain up to 15 per cent quartz, and the mafic varieties contain up to 10 per cent diopside. The mineral content differs from that of feldspathic greywacke in its greater abundance of green amphibole (20 - 40%); colourless amphibole is present in small amounts. The tuff contains pseudomorphs of plagioclase and rounded to angular clastic grains replaced by single crystals of plagioclase, hornblende or diopside (up to 15 mm in diameter). A few angular fragments of basalt up to 8 cm long occur in some layers. The granoblastic groundmass has an average grain size of 0.1 mm.

Lapilli tuff contains 1.5 cm rounded felsic fragments, long lath-shaped plagioclase crystals, smaller mafic grains and a few quartz eyes. Tuff-breccia consists of 40 per cent grey dacitic blocks in a crystal tuff matrix with mafic crystals up to 10 mm in diameter. Blocks are up to 30 cm in one layer and 10 cm in another. One thin layer, containing small felsic fragments, may be a sedimentary rock.

POLYMICTIC BRECCIA (8d)

Mafic and intermediate breccia occurs locally at the base and near the top of the feldspathic greywacke-tuff succession. It contains lapilli and angular blocks over 1 m long composed of aphyric basalt and porphyritic basalt. Some oval blocks have coarsely amygdaloidal rims. One unit of breccia is interlayered with conglomeratic greywacke and is interpreted as a laharic breccia. It contains fragments of basalt, grey porphyry, and fine grained grey intermediate rock.

SUMMARY AND CONCLUSIONS

The intermediate tuff is an isolated deposit, about 4 km long, of plagioclase-rich andesite to dacite. It is water laid and shows signs of reworking, especially in the south where it is overlain by polymictic volcanic conglomerate. The source was probably in the north where the tuff is most massive. Much of the tuff may overlie feldspathic greywacke as indicated by a structural interpretation. However, the feldspathic greywacke was partly derived from the intermediate tuff; it contains a block of tuff and has a similar plagioclase-rich composition.

The greywacke forms a southerly tapering wedge which is 350 m thick at a fault in the north and extends for 8 km, apparently to a fault in the south. The large size of included blocks suggests that deposition took place at the base of a steep slope from high-energy turbidity currents. The source of plagioclase was probably in the adjacent tuff or similar rocks exposed through erosion in the northeast. Thick massive and graded beds comprising mainly Bouma A divisions and thin B divisions, strongly graded conglomeratic greywacke, and greywacke with boulders up to several metres in diameter, are signs of proximal turbidites and mass flow deposits. The flows apparently had a very high density because some of the boulders are nearly as large as the thickness of the beds in which they were carried. The distribution of clast sizes suggest that sedimentary transport was from the northeast, away from the intermediate tuff or that a channel lay to the northeast. The presence of large, angular, exotic blocks suggests that deposition took place near a submarine fault scarp but the abundance of rounded boulders of basalt and greywacke suggest that a land area acted as the main source. An interlayering of volcanic rocks with the greywacke indicates that the faulting took place during volcanism and may have been related to it. The greywacke and tuff were involved in faulting for a second time after they were buried under a thin unit of Tod Lake basalt, and under a considerable thickness of Sickle sandstone. Apparently, they were thrust over the cross-bedded arkosic shallow-water facies of the Sickle Group, then folded, intruded by gabbro and quartz diorite, and refolded on the flank of the migmatite dome on South Bay.

TOD LAKE APHYRIC BASALT (2)

A platform of aphyric basalt near Fox Mine straddles the boundary between the Lynn Lake Greenstone Belt and the Kisseynew Sedimentary Gneiss Belt. The greatest apparent thickness of basalt (850 m) is at Hatchet Lake from where the unit extends northeast to Dunphy Lakes and southwest to the south tip of Laurie Lake for a strike length of 30 km. A thin unit (0.5 - 50 m) of layered amphibolite (1C) correlated with the Tod Lake basalt continues to the southeast and southwest, far into the Kisseynew Belt. The transition from the basaltic platform to the sedimentary basin is marked by a lateral gradation of volcanic facies from massive and pillowed to pillow breccia, tuff and sedimentary rock. The transition takes place in several steps across major strike faults (Fig. 27).

The Tod Lake basalt overlies different units along, and across strike: it is interpreted to overlie Fox Lake porphyritic basalt (3) and Snake Lake dacite (6) in the Fox Mine area; it overlies greywacke-mudstone (1), feldspathic greywacke (9) and intermediate tuff in the southwest. The Tod Lake basalt is overlain by various units of the Sickle Group: it is uncomformably or disconformably overlain by arkose and conglomerate in the east and it is conformably overlain by fine grained sandstones in the west.

The basalt is folded, faulted and metamorphosed in the upper amphibolite facies.

DISTRIBUTION AND GENERAL DESCRIPTION

The basalt is exposed in northeast-trending outcrop belts which occupy fault slices or lie on the limbs of isoclinal folds. Each belt contains aphyric basalt overlain by arkosic rocks of the Sickle Group. From Fox Mine west, each successive belt exposes a successively thinner, more distal and apparently more Mg-rich facies of aphyric basalt.

In the Fox Mine area (A in Fig. 26) aphyric basalt is very restricted. It is interlayered with intermediate and felsic rocks in the "Fox Mine succession" which overlies porphyritic basalt (3) and dacite (6). This aphyric basalt has not been proved to be equivalent to the main body of the Tod Lake basalt and comprises only a few 10 - 15 m thick layers of pillowed and brecciated flows intercalated with a variety of altered rocks southeast of the mine. It is tentatively correlated with Tod Lake basalt and andesite which occurs to the southwest, along strike near Hatchet Lake.

The largest belt of basalt extends from Hatchet Lake southwest along Tod Lake for almost 20 km to the southern tip of Laurie Lake (B in Fig. 26). The greatest exposed thickness (about 850 m) is south of Hatchet Lake in the north-facing panel of a poorly exposed fold structure. On the west shore of Tod Lake, metagreywacke-mudstone (1) and apparently more volcanic rocks underlie 200 m of basalt.

North of Fox Mine and along Dunphy Lakes (segment C) an outcrop belt of basalt 300 - 600 m wide lies northeast of the main belt. Pillows face north at two localities along Dunphy Lakes but the structure there is not known. The basalt is overlain by Sickle arkose adjacent to the Dunphy Lakes fault on the south. Farther east the basalt may be truncated along the fault.

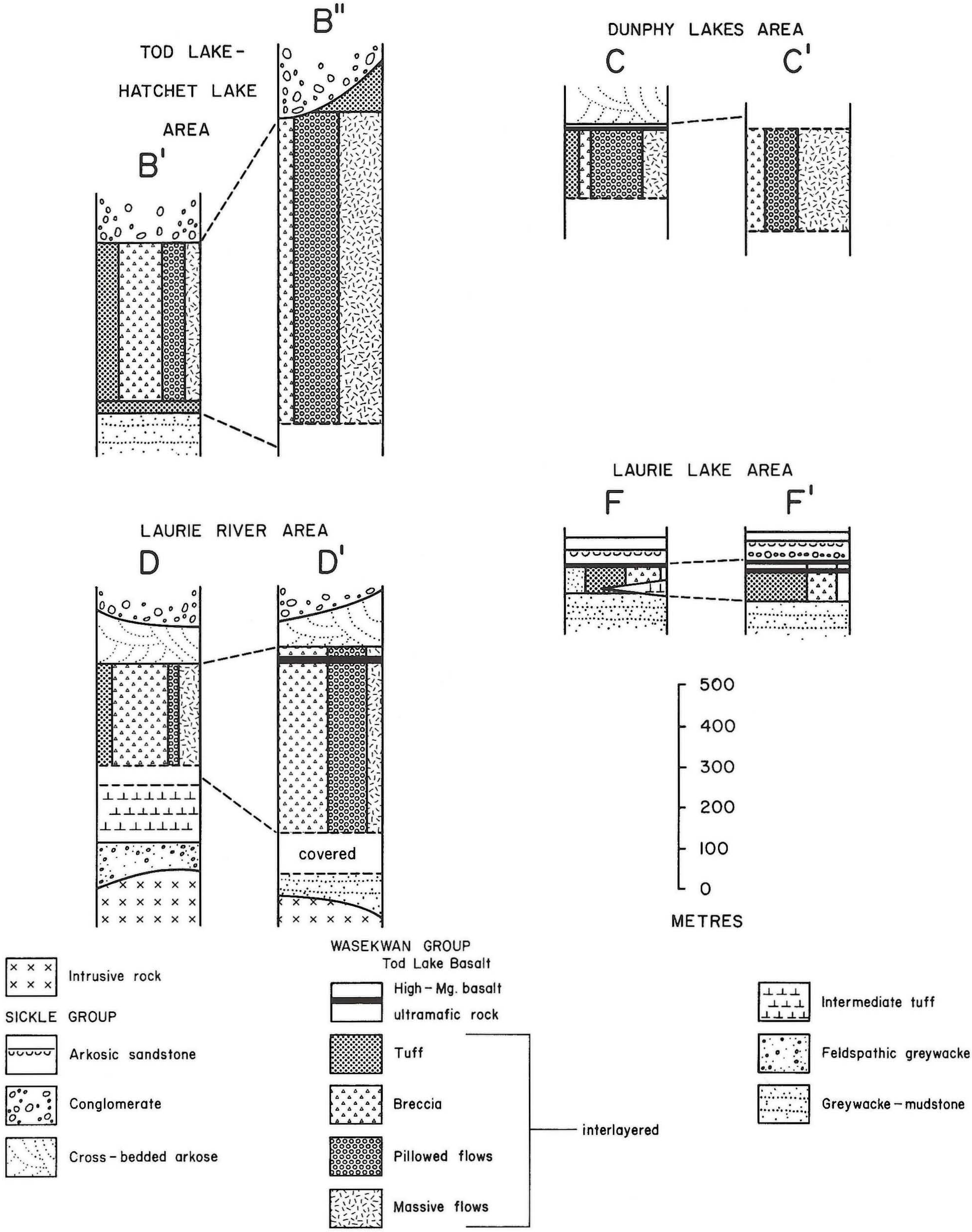

FIGURE 27: Stratigraphic relationships and facies of Tod Lake basalt (unit 2). Location of sections are shown in Figure 26.

The fourth panel of basalt (D in Fig. 26) faces southeast and trends northeast between Laurie Lake and Tod Lake. It is 300 - 600 m thick where it lies south of greywacke and intrusive rocks in the overturned southeast limb of the proposed anticline between Laurie Lake and Tod Lake. It is overlain by Sickle arkose and conglomerate in the northwest wall of the Tod Lake fault. East of Hatchet Lake this belt of basalt may be truncated against the Tod Lake fault. On Laurie Lake the unit is cut by quartz diorite but on the west side of the pluton it continues as a thin sliver of amphibolite (belt E).

The fifth belt of basaltic rock (F in Fig. 26) lies in the northwest-facing limb of the anticline developed in unit 1. The belt can be traced for 5 km from the Laurie River across a peninsula and along the shore of Laurie Lake. This part of the unit is 100 m thick in the northeast and tapers to 40 m in the southwest. It comprises mainly layered tuff of high-Mg basalt. These relatively distal rocks conformably overlie greywacke-mudstone (1). The basalt is conformably overlain by a condensed succession of Sickle conglomerate and arkose in the core of a narrow syncline.

The same high-Mg basaltic tuff is exposed, 50 m to the north where it faces southeast in the other limb of the syncline (G in Fig. 26). This belt of basaltic rock can be traced for 2 km northeast of the Laurie Lake shoreline where it is apparently truncated along another fault.

A layer of hornblende-diopside amphibolite 50 cm - 50 m thick occurs at the top of the Burntwood River Metamorphic Suite overlain by gneisses of the Sickle Metamorphic Suite. The amphibolite may be the distal, largely sedimentary facies of the Tod Lake basalt in the Kisseynew Belt. However, the amphibolite is separated from the basalt by faults.

Generally the basalt forms relatively large outcrops on ridges with moderate relief. Outcrop surfaces of aphyric basalt are smooth and dark green. Varieties with relatively low magnesia contents and probable andesite weather grey; high-Mg basalts are black or apple green. Minor associated ultramafic rocks weather rusty brown. The rock is generally foliated, and pillows and blocks are flattened. In the gneissic terrane on Tod Lake and Laurie Lake, pillows are highly stretched parallel to the steep northeast-plunging amphibole lineation. Pillows are locally rod-shaped (prolate) and appear little deformed in cross-section on horizontal outcrops but on vertical cliff surfaces pillowed basalts and breccias resemble banded gneiss. The tectonite structures indicate that the original stratigraphic thickness was reduced considerably during deformation. The metamorphic grade of basalt ranges from high (sillimanite-staurolite zone) in the northeast to very high (sillimanite-garnet-cordierite zone) in the southwest. The change is reflected in a predominance of epidote in the northeast and diopside in the southwest.

The chemistry of the flows gives a compositional range from high-Mg basalt to basaltic andesite. Preliminary plots show that the unit is a tholeiite. The most mafic varieties are abundant in the distal facies near the top of the succession, whereas the more evolved species are restricted to the thickest part of the pile south of Hatchet Lake and occur in the Fox Mine area. Chemical analyses (150-174) are given in the Appendix.

Typical aphyric basalt consists of hornblende (45%), plagioclase (50 - 55%), biotite (up to 3%), magnetite (0.5 - 2.0%) and rare sphene. A sample of tuff taken from Laurie Lake contains a small amount of quartz. The grey weathering andesite and basalt south of Hatchet Lake contains more plagioclase (58%) and less hornblende (30%). The grey rocks are commonly altered and contain calcite, garnet, pyrite, hematite and rare cummingtonite. An (altered?) intermediate sample at Fox Mine contains plagioclase (60%), green hornblende (15%) and cummingtonite (15%). The rocks have a patchy outcrop surface and the plagioclase is turbid with sericite. More mafic varieties of basalt (containing more than 7% MgO_2) have over 60 per cent hornblende, less than 2 per cent magnetite; biotite is absent. The grain-size varies from 0.02 - 0.05 mm (typical) to 0.02 - 0.5 mm for the more mafic varieties. The fine grained basalts have a weakly foliated granular mosaic texture and the magnesian rocks have a blastic texture with pronounced alignment of hornblende.

MASSIVE FLOWS (2a)

Massive basalt flows are uniformly fine grained to medium grained (0.2 mm). Flows range in thickness to at least 5 m in the northeastern part of the body, and up to 3 m in the southwest. On Laurie Lake there are only a few thin, massive flows. Contacts between flows are defined by subtle changes in grain-size. Amygdaloidal contacts have not been observed, and sedimentary material between flows is scarce.

Much of the massive basalt is interlayered with pillowed basalt and breccia. Locally flows are in sequences such as the one which lies 100 m south of mid-Dunphy Lake. There, 10 m of medium grained massive basalt with an upper chilled zone is overlain by a much thinner (2 m) fine to medium grained flow, followed by 1 m of pillows and 2.5 m of pillow breccia. The pillow fragments apparently fine upwards towards the north.

Massive flows are generally more strongly foliated than pillowed flows, apparently because oriented hornblende grains have replaced and overgrown the coarser of the primary pyroxenes. No primary textures are preserved, but observations at chilled margins indicate that the secondary grain-size mimics the primary size even past the second sillimanite isograd.

Close to Hatchet Lake there is medium grained garnetiferous amphibolite derived from massive flow, highly deformed pillowed flows and/or diabase. Some of the rock is strongly foliated, and garnets attain 1 cm. There are rusty patches in apparently altered basalt.

PILLOWED BASALT (2b) AND BRECCIA (2c)

Approximately half the volume of Tod Lake basalt is pillowed and at least 30 per cent consists of breccia. The latter includes pillow-breccia and autoclastic breccia. Pillow and breccia facies predominate on Tod Lake and Laurie Lake where they are accompanied by an aquagene tuff facies and by mafic sedimentary rocks. The distribution of the massive, pillowed, brecciated and tuffaceous rocks between Dunphy Lake and Laurie Lake indicate a systematic increase of the fragmental facies towards the south and west (Fig. 27).

Incipient pillows have partly resorbed selvages within massive flows. Associated fully developed pillows are 1.5 m long, the largest in the Tod Lake basalt. Pillows have thin (0.8 - 1.0 cm) dark selvages. Some larger pillows are draped over several smaller pillows and assume an irregular shape. The associated massive flows locally have curved primary joints with a selvage-like alteration.

Most of the pillows of the Tod Lake basalt are no more than 1 m long. They are flattened parallel to the foliation and elongated down plunge to a maximum of 5 m. Their original diameter is estimated to be slightly less than 1 m, so that the long dimension on outcrop is a good guide to primary pillow diameter. The upper size-limit ranges from 150 cm south of Dunphy Lake, 80-100 cm near Hatchet Lake, and a maximum length of 65 - 100 cm on Tod Lake where pillows are most flattened. On the more distal part of the basalt body, 20 cm pillows are common; the lower size limit of oval pillows is 8 cm.

Pillows south of Hatchet Lake in the thickest part of the succession are typical sack-shaped light grey bodies with dark brown, green or black selvages, 1 - 1.5 cm thick. Garnet porphyroblasts occur locally within the selvages like beads on a string. In the andesite south of Hatchet Lake, pillow margins are coarsely amygdaloidal. Carbonate veins and traces of pyrite and pink weathering indicate that much of the rock is altered. However, low MgO and Ni, and high SiO_2 and TiO_2 suggest that this was the most evolved part of the pile.

Pillowed flows are interlayered with massive basalt, which is locally garnetiferous. Some pillow basalt contains intercalations of mafic breccia with a carbonate matrix and of thin sedimentary layers bearing biotite and hornblende. Northwest and southeast of Fox Mine chert occurs between some of the pillows.

Small pillows are abundant on Tod Lake on the southwest flank of the body. Pillow breccia becomes increasingly abundant to the west. These small pillows are ellipsoidal and have 1 cm thick, dark green selvages. They are locally separated by fine hyaloclastic material (10 - 15%) which weathers dark green or brown, and has recrystallized to amphibolite with scattered garnet and epidote. Individual flow units are commonly 3 - 10 m thick. Some units start with pillows which are about 1 m long, overlain by smaller, variably sized pillows and pillow breccia. The breccia consists of oval and irregular fragmnts which are light or dark green and may have bleached rims; they are up to 50 cm long but commonly only a few centimetres long. Flow units are commonly overlain by irregular breccia or tuff that weathers patchy or banded light and dark grey. Massive flows are thin and restricted in this environment. Amygdales are present: deposition was in a moderate or shallow depth of water at the margin of the body.

MAFIC TUFF (2d)

The Tod Lake basalt includes massive and laminated basaltic tuff. The thickest deposit (200 m) occurs north of Tod Lake (structural belt B) where it is apparently cut off along the Sickle unconformity. Exposure is poor and there may be interlayered mafic mudstone. Greywacke occurs along strike with tuff at McWhirter Lake. Thinner units of mafic tuff are interlayered with pillowed flows and breccias in belts (B) and (D) (Fig. 26).

The tuff retains no primary textures except layering and a few scattered fragments of basalt. The rock comprises fine grained, foliated amphibolite, often with cummingtonite and/or small garnets, locally with 1 - 3 mm grains of plagioclase and hornblende. The most mafic varieties are rich in cummingtonite or tremolite and commonly schistose. Some varieties have bright green and dark green banding. The lighter coloured varieties on Laurie Lake are interlayered with fine grained biotite schist derived from siltstone. These rocks have graded bedding and laminated bedding of turbidites. They locally overlie mafic polymictic pebbly mudstones at the distal margin of the Tod Lake basalt.

Highly recrystallized varieties may be represented by banded amphibolites with layers (2 cm) rich in diopside or garnet.

HIGH-Mg SUITE (2e, 15)

The upper 10 - 50 m of the Tod Lake basalt forms a separate suite of metamorphic rocks that has a distinctive composition and structure. The succession comprises typical Tod Lake basalt interlayered with high-Mg basalt, lenses of coarse grained ultramafic rock, tuff, and up to three beds of felsic tuff. It contains the most magnesian volcanics with some of the highest Ni content (up to 2,000 ppm) in the Lynn Lake region. The high-Mg suite is developed above the pillowed and breccia facies in the central and western structural segments of the Tod Lake basalt sheet. It forms the top of the condensed volcanic succession, the upper unit of the Burntwood River Metamorphic Suite on the north margin of the Kisseynew Belt. The rocks are conformably or disconformably overlain by Sickle metaconglomerate and metasandstone. They are not generally recognized in the thin amphibolite (1C) but extend into the Kisseynew belt to Russell Lake, 60 km south of Fox Mine where they occur in the core of a nappe-like recumbent fold (Lenton, 1976; McRitchie, 1975). The felsic tuff has been traced 45 km south to Kamuchawie Lake (Zwanzig, 1975).

The medium and fine grained varieties of the mafic rocks (2e) contain hornblende (60 - 90%), plagioclase, and minor rutile. The metamorphic grain size averages 0.1 - 0.5 mm with hornblende up to 3 mm. The coarse grained rocks (15) range in composition from gabbro to what may have been an olivine-websterite. Metamorphic assemblages include green amphibole, olivine, clinopyroxene, orthopyroxene and up to 15 per cent opaque minerals. A body that occurs on the Laurie River where it enters Tod Lake has a basal cumulate layer containing pale green, non-pleochroic amphibole (60%), clinopyroxene (30%), hercynite and magnetite. No primary textures are preserved, but the coarse grain-size and differentiation indicate that some or all of the ultramafic rocks were sills.

Breccia consists of irregular-shaped fragments of pale weathering basalt, up to 1 m long in a darker matrix of high-Mg tuff. Layered tuff is dark green, light green or brown. It commonly contains hornblende pseudomorphs after euhedral pyroxene phenocrysts in a groundmass of intergrown pale green and dark green amphibole. At one locality breccia grades into well layered ash tuff and crystal tuff, composed of high-Mg basalt.

SUMMARY AND CONCLUSIONS

The Tod Lake aphyric basalt is interpreted as part of a platform or shield volcano, built up at the margin of the Kisseynew Sedimentary Belt, adjoining the Lynn Lake Volcanic Belt. The largest volume of pillowed and massive flows occurs south of Hatchet Lake. It contains the most vesicular rocks consisting in part of andesite. They are associated with a unit of tuff probably near a vent or fissure situated southwest of Fox Mine. This locality represents a break between the Fox Lake porphyritic basalt, a type that occurs throughout the volcanic belt, and the Tod Lake aphyric, high-Mg basalt, a type which is restricted to the margin of the (Kisseynew) turbidite basin.

There was a lateral change within the (reconstructed) body of Tod Lake basalt from massive and pillowed facies near Fox Mine to interlayered pillow basalt, pillow breccia and tuff towards the southwest where the unit tapers to 40 m in thickness. The more fragmental rocks overlie the greywacke-mudstone turbidite, locally with a thin unit of conglomerate at the base. Layered mafic gneiss, tentatively correlated with distal basalt, extends far into the Kisseynew Belt. The facies change is gradational along strike within the several structural belts but more abrupt across faults separating these belts. Consequently, there may have been a considerable displacement along the early faults producing a stack of thrust slices and recumbent folds in which the Tod Lake basalt ws transported into the (Kisseynew) turbidite basin, over the greywacke-mudstone.

SUMMARY AND GEOLOGICAL EVOLUTION OF THE LAURIE LAKE-WILMOT LAKE AREA

Deposition of Wasekwan Group rocks in the western part of the Lynn Lake Greenstone Belt proceeded through similar stages (Fig. 28) to that in the McVeigh Lake-Hughes Lake area, with:

(1) development of a mafic platform;
(2) mafic to felsic volcanism and related sedimentation;
(3) sedimentation and block faulting;
(4) mafic, intermediate and minor felsic volcanism, and associated sedimentation.

A stage of calc-alkaline volcanism like that on Hughes Lake was not identified in the west, but instead, a high-Mg basalt with minor ultramafic rocks occurs along the boundary between the Lynn Lake Greenstone Belt and the Kisseynew Sedimentary Gneiss Belt.

Deposition of the sediments and volcanic rocks comprising the Burntwood River Metamorphic Suite was probably contemporaneous with stages (3) and (4) above. However, a younger age cannot be ruled out for the greywacke and overlying basalt. (See section on structure).

Basaltic platform

A body of pyroxene-phyric basaltic flows and autoclastic breccia (Fox Lake basalt, unit 3) can be correlated with the tholeiitic platform consisting of units 2 and 3 at Cockeram Lake, McVeigh Lake and possibly Miskwa Lake. The body at Fox Lake extends for 10 km along strike and is a maximum of 1200 m thick. It was probably part of a small compositionally and texturally distinctive shield volcano; the basalt is characterized by a high MgO content, high Cr content and a low Al_2O_3 content. The presence of large amygdales, local pillow structure and rare intercalated sedimentary rocks suggests that emplacement was in a shallow marine environment. The Fox Lake basalt is interpreted to occupy an anticline that is intruded by gabbro and tonalite at Snake Lake and truncated along the unconformity between the Wasekwan Group and the Sickle Group at Pyta Lake.

Mafic to felsic volcanism and sedimentation

Several felsic extrusive centres were developed on the mafic platform. Large, uniform bodies (Snake Lake dacites, unit 6) were erupted first, probably as partly intrusive domes. Large folded bodies of dacite occur at Snake Lake (800 x 5000 m) and east-Dunphy Lake (400 x 1500 m); smaller bodies occur south of Fox Mine. At Snake Lake, the dacite is locally mineralized and partly altered to cordierite-anthophyllite schist.

Subsequent more siliceous and slightly more explosive eruptions occurred at the same time as a new stage of mafic and intermediate volcanism and local sedimentation. The various rock types were intercalated to produce the Fox Mine succession, which reaches a thickness of more than 500 m at the mine. Mafic porphyritic flows in the lower part of the succession resemble Fox Lake basalt (unit 3) but they have lower MgO and Cr contents, and are similar in composition to the interlayered aphyric flows. This chemistry and the presence of pillows, pillow breccia and hyaloclastite in the

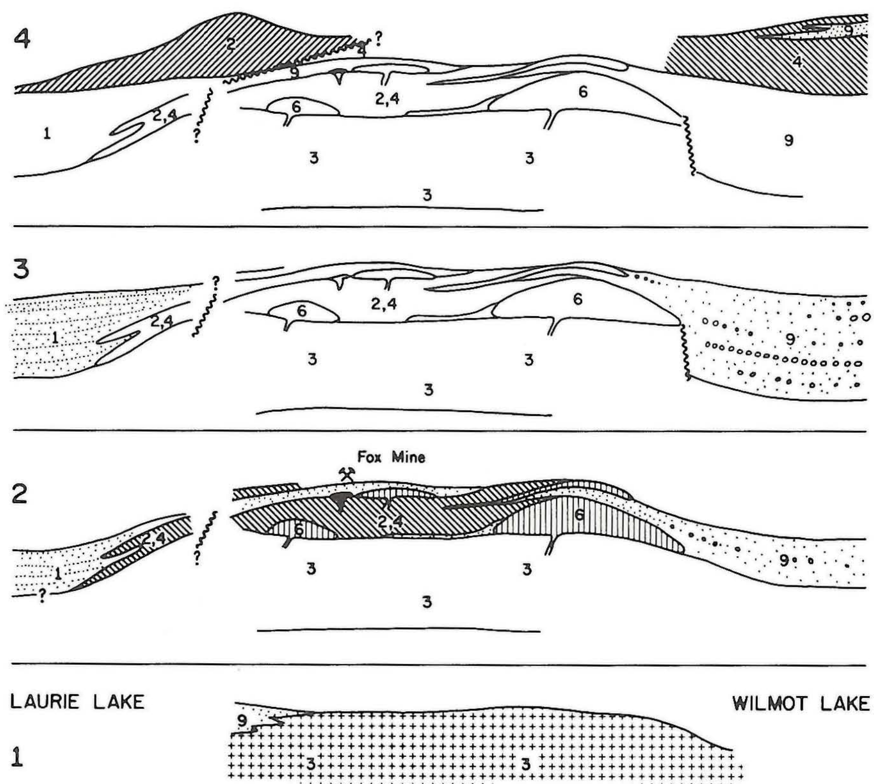

FIGURE 28: Reconstructed stages in the evolution of the southern belt between Laurie Lake and Wilmot Lake.
1. Development of basaltic platform (unit 3), minor tuff and greywacke.
2. Development of felsic centres (unit 6), mafic and intermediate volcanism (units 2, 4), and associated sedimentation (unit 9).
3. Faulting and deposition of coarse (proximal) turbidite (unit 9) and fine (distal) turbidite (unit 1).
4. Mafic volcanism (unit 2), mafic and intermediate volcanism (unit 4) and minor sedimentation (unit 9).

associated aphyric flows suggests a correlation with Tod Lake basalt (unit 2). Grey weathering, strongly recrystallized flows and breccias interpreted as andesites occur mainly near the mine. Thin sedimentary and tuffaceous units, locally with rhyolite at the base, extend from the felsic body on east-Dunphy Lake, southwest into the hanging wall of the Fox orebody.

Some of the sedimentary rocks are rich in Fe, Mg and S. They were deposited during the last stages of felsic volcanism but mafic magma continued to erupt; the mafic rocks occur north and west of Fox Mine.

Sedimentation and block faulting

Abrupt lateral facies changes take place between thin units of fine grained sedimentary rocks in the Fox Mine succession and thick volcaniclastic deposits in the surrounding areas. Faulting may have contributed to the formation of basins filled with fine grained epiclastic rocks and resedimented conglomerate.

A coarse turbidite and mass flow deposit 1500 m thick (Fox Road turbidite, unit 9) occupies what is interpreted as a tectonic depression presently located east of the mine area. The sediments were apparently derived from more than one source: biotite-bearing greywacke and paraconglomerate at the base of the succession were derived from felsic volcanic rocks whereas well-rounded quartz-pebble conglomerate came from an unidentified terrestrial source. Immature mafic to felsic volcanogenic turbidites and conglomeratic mass flow deposits were probably deposited at the foot of a composite volcano; the volcano later covered the turbidites from the northeast.

A thick succession (2500 m) of fine grained mafic to felsic volcaniclastic rocks and minor flows (Dunphy Lakes amphibolite, unit 9 and unit 4) was deposited in a more distal environment northeast and northwest of Fox Mine. Hornblende-bearing greywacke at the base of the succession northwest of Hatchet Lake may be equivalent to the Fox Road turbidite. The overlying siltstone and mafic mudstone represent lower slope deposits. The fine grained amphibolites on Dunphy Lakes are interpreted as slightly younger tuff, mudstone and flows deposited during unit 4 volcanism. They thicken northeast towards Irene Lake and may have been shed from a composite volcano associated with the northern Lynn Lake belt. Thin units of mafic porphyroblastic schist in the succession are interpreted to be derived from iron formation and magnesian muds.

A unit (350 m thick) of coarse feldspathic greywacke (9a, 9b), minor intermediate tuff (4f) and mafic flows (4a, 4b) located on the flank of the Kisseynew Belt, at Laurie Lake, was probably deposited at the base of a steep slope or scarp. Thick massive and graded beds, some conglomeratic and others containing large angular blocks, suggest that the turbidity currents which deposited these sediments are dense and powerful. This sedimentation and volcanism is tentatively assigned to stages (3) and (4).

Graphitic greywacke-siltstone-mudstone and minor volcanic rocks (Burntwood River Metamorphic Suite) were deposited over a wide area presently occupied by the Kisseynew Sedimentary Gneiss Belt. The present thickness of metagreywacke-migmatite is 600+ m on Laurie Lake and greater to the south. The rocks on Laurie Lake were derived from thin massive, graded and laminated beds laid down by relatively low-energy turbidite flows, probably at a considerable distance from source. The provenance of similar rocks on the south side of the Kisseynew Belt was interpreted to be a largely felsic volcanic terrane (Bailes, 1980); felsic siltstone or reworked rhyolitic tuff and thin layers of rhyolite tuff were deposited near the top of the succession on Laurie Lake, probably during stage (3) or (4). However, the greywacke may be younger than the pre-Sickle deformation of the Wasekwan Group because the Sickle unconformity terminates abruptly at the edge of the Lynn Lake Belt, and because pre-Sickle intrusions have not been identified in the Kisseynew belt.

Mafic and intermediate volcanism, sedimentation

A platform or shield volcano of aphyric basalt (Tod Lake basalt, unit 2) was built up at the boundary between the Lynn Lake Greenstone Belt and the Kisseynew Sedimentary Gneiss Belt where it was subsequently covered by the Sickle Group. Associated basalt and lesser andesite extend into the Fox Mine volcanic succession, whereas high-Mg basalt and minor ultramafic rocks overlie the greywacke-siltstone-mudstone at the margin of the sedimentary belt. Volcanic facies change basinward from predominantly massive and pillowed flows in the northeast to pillows, breccia and tuff on the flank of the sedimentary basin. A thin unit of layered amphibolite, tentatively correlated with the basalt, extends into the centre of the Kisseynew Sedimentary Gneiss Belt. However, a slightly younger age cannot be ruled out for the basin facies because of structural and stratigraphic complications at the basin margin.

Over 1000 m of heterogeneous volcanic strata (Wilmot Lake volcanic rocks, unit 4) were built up within the greenstone belt, on the Fox Road turbidite. The strata comprise mafic porphyritic breccias and flows overlain by mafic and intermediate breccias and tuff intercalated with sedimentary rocks. The Wilmot Lake volcanic rocks resemble the Fraser Lake mafic volcanic body but are more mafic, and contain fewer massive flows. They may have been deposited on the lower slope of a composite volcano situated in the northeast.

APPENDIX: Whole-rock chemical analyses (weight per cent), Ni and Cr (ppm)

	1	2	3	4	5	6	7	8	9	10
SiO_2	52.15	49.55	55.25	52.05	53.60	50.25	51.95	49.15	50.05	48.30
Al_2O_3	14.85	15.87	13.84	14.00	15.39	14.25	14.18	15.60	16.48	15.54
Fe_2O_3	2.64	1.70	2.61	3.18	2.36	4.43	2.48	2.28	2.23	2.44
FeO	8.00	5.94	8.68	9.68	8.74	7.40	9.19	10.04	9.67	8.43
CaO	9.63	14.8	6.89	9.19	7.89	12.8	9.11	10.97	6.76	11.78
MgO	6.95	5.73	5.45	5.03	4.21	3.11	5.98	5.52	5.87	5.81
Na_2O	2.70	1.90	3.54	3.31	4.69	2.69	3.32	3.04	4.06	3.07
K_2O	0.56	0.14	0.53	0.25	0.25	0.22	0.43	0.33	0.35	0.41
TiO_2	0.76	0.59	0.98	1.30	1.21	1.44	0.97	1.13	1.27	1.78
P_2O_5	0.07	0	0.12	0.22	0.22	0.26	0.19	0.30	0.34	0.68
MnO	0.18	0.15	0.22	0.20	0.20	0.23	0.19	0.19	0.20	0.12
H_2O	1.41	1.28	1.42	1.30	0.94	1.24	1.39	1.36	2.40	1.36
S	0.03	0.07	0.28	0.04	0.04	0.08	0.03	0	0	0
CO_2	0.07	2.12	0.12	0.08	0.12	1.12	0.59	0.19	0.10	0.28
Less O ≡ S	0.01	0.03	0.11	0.02	0.02	0.03	0.01			
TOTAL	99.99	99.81	99.82	99.81	99.84	99.49	100.00	99.99	99.78	100.00
Ni	52	146	28	26	11	26	34	74	70	128
Cr	122	230	88	33	10	15	56	80	80	270
FeO*/MgO	1.49	1.30	2.02	2.49	2.58	3.66	1.91	2.19	1.99	1.83

COCKERAM LAKE APHYRIC BASALT (Unit 2; analyses 1 to 7)

1 Pillowed basalt, 1.5 km S of Cockeram Lake (52-6-315-1). Well foliated, primary texture obliterated.

2 Pillowed basalt, SE shore of Cockeram Lake (52-6-346-1). Pillow margin; primary randomly-oriented plagioclase microlite texture preserved. Carbonate and epidote in fractures.

3 Basalt, 2 km N of Moses Lake (52-6-373-2). Primary microlitic texture preserved, a few plagioclase and polymineralic amygdales.

4 Pillowed basalt, 1.5 km NE of Moses Lake (52-6-391-1). Unfoliated, primary randomly-oriented plagioclase microlite texture preserved. 1% plagioclase-filled amygdales.

5 Pillowed basalt, 1.5 km NE of Moses Lake (52-6-416-1). 7% hornblende pseudomorphs after pyroxene phenocrysts (0.1 - 0.7 mm), in a microlitic groundmass. Unfoliated. 3% polymineralic amygdales.

6 Massive basalt, 2 km NE of Moses Lake (52-6-421-1). Unfoliated, randomly-oriented plagioclase microlite texture, 2% quartz and quartz-carbonate amygdales.

7 Fine to medium grained, gneissoid amphibolite, 750 m south of Ace Lake (32-6-83-1). Minor carbonate fracture filling (3%).

HUGHES LAKE APHYRIC BASALT (Unit 2; analyses 8 to 11)

8 Massive basalt, 1.5 km NW of One Island Lake (52-7-1425-1). 40% irregular amphibole aggregates, 5% plagioclase-filled amygdales.

9 Massive basalt, 0.5 km NE of Hill Lakes (52-7-1335-1). Felted mass of fibrous hornblende with very fine grained interstitial plagioclase; a few amphibole aggregates. 5% plagioclase-filled and polymineralic amygdales.

10 Massive basalt, 1.7 km NW of One Island Lake (52-7-1438-2). Primary randomly-oriented plagioclase lath texture preserved. 10% hornblende pseudomorphs after pyroxene phenocrysts (1 - 1.5 mm).

*Total Fe calculated as FeO

	11	12	13	14	15	16	17	18	19	20
SiO_2	48.10	45.75	57.20	49.60	46.80	53.25	47.30	52.30	49.55	47.30
Al_2O_3	15.20	16.83	16.12	15.72	16.09	14.23	13.97	13.80	16.05	16.26
Fe_2O_3	3.14	2.10	2.14	4.44	3.57	2.64	2.92	3.41	1.78	3.21
FeO	7.76	10.96	5.88	5.92	5.66	6.28	9.11	9.89	8.83	7.90
CaO	10.79	12.07	8.07	10.3	12.1	9.19	11.21	8.48	12.76	16.00
MgO	7.00	7.03	4.39	5.93	8.62	6.01	8.81	5.54	5.64	4.61
Na_2O	3.04	1.85	3.44	1.91	1.89	4.39	1.56	2.58	1.57	0.76
K_2O	0.29	0.43	0.82	2.02	1.56	0.48	1.65	0.63	0.32	0.20
TiO_2	0.87	0.89	0.72	1.06	0.74	0.98	1.06	1.36	0.87	0.77
P_2O_5	0.23	0.19	0.14	0.30	0.15	0.29	0.28	0.13	0.08	0.08
MnO	0.17	0.19	0.14	0.18	0.15	0.21	0.23	0.25	0.17	0.29
H_2O	1.94	1.57	1.17	1.70	1.83	0.99	1.83	1.41	1.43	1.58
S	0	0.02	tr	0.01	0.01	0.02	0.01	0.07	tr	tr
CO_2	1.45	0.12	0.14	0.37	0.55	0.66	0.14	0.12	0.71	1.16
Less O ≡ S		0.01				0.01		0.03		
TOTAL	99.98	99.99	100.37	99.46	99.72	99.61	100.08	99.94	99.76	100.12
Ni	66	136	70	30	72	44	65	16	42	18
Cr	270	116	56	178	300	264	362	24	200	144
FeO*/MgO	1.51	1.83	1.78	1.67	1.03	1.44	1.33	2.34	1.85	2.34

11 Massive basalt, SE shore of Hughes Lake (52-7-1241-1). Contains ovoid fragments (up to 2 cm) of pyroxene-phyric and plagioclase-phyric basalt in a microscopically inhomogeneous basaltic matrix.

MISKWA LAKE APHYRIC BASALT (Unit 2; analyses 12 to 13)

12 Mafic tuff, 2.5 km SSE of Miskwa Lake (52-7-1554-1). Layering (5 mm - 10 cm) defined by ratio of hornblende to plagioclase and quartz. Approximately 75-80% hornblende.

13 Amphibolite, 1.5 km S of Miskwa Lake (52-7-1568-1). Fine grained mosaic of subidioblastic, oriented hornblende, equant irregular plagioclase, and blebby quartz. Intruded by diorite and quartz diorite dykes.

McVEIGH LAKE PORPHYRITIC BASALT (Unit 3, analyses 14 to 18)

14 Massive porphyritic basalt, 1 km W of McVeigh Lake (52-6-25-1). 25% hornblende pseudomorphs after primary pyroxene phenocrysts (2 - 10 mm), a few relicts of 1 mm plagioclase phenocrysts. 20% biotite.

15 Massive porphyritic basalt, 0.7 km NW of McVeigh Lake (52-6-876-1). 25% hornblende pseudomorphs after primary pyroxene phenocrysts (to 3 mm), 30% lath-shaped plagioclase phenocrysts (0.5 - 0.7 mm). 5% biotite.

16 Massive porphyritic basalt, 0.6 km W of S end of McVeigh Lake (52-6-126-2). 30% hornblende pseudomorphs after primary pyroxene phenocrysts (to 2 mm), 20% lath-shaped plagioclase phenocrysts (to 2 mm). Unfoliated. 1% biotite.

17 Massive porphyritic basalt, 200 m W of N end of McVeigh Lake (52-6-877-1). 30% hornblende pseudomorphs after pyroxene phenocrysts (2 - 7 mm), indistinct 1 - 2 mm plagioclase phenocrysts. 10% biotite.

18 Massive aphyric basalt apparently intercalated with porphyritic basalt, Elb Lake (52-6-95-1). Recrystallized; remnants of fine-grained (0.5 - 1 mm) diabasic texture.

MISKWA LAKE PORPHYRITIC BASALT (Unit 3; analyses 19 to 23)

19 Porphyritic basalt flow breccia (massive magmatic matrix analysed), 2.6 km SE of Miskwa Lake (52-7-1524-1). 20% hornblende pseudomorphs after pyroxene phenocrysts (1 - 5 mm), 20% subhedral plagioclase phenocrysts (0.5 - 1.5 mm). Relict clinopyroxene and labradorite. 1% quartz amygdales.

20 Porphyritic basalt flow breccia, 4.1 km SE of Miskwa Lake (52-7-1217-1). Porphyritic fragments with quartz amygdales (colour index 40) in a porphyritic matrix (colour index 60). Pyroxene (pseudomorphed by hornblende) and plagioclase phenocrysts.

	21	22	23	24	25	26	27	28	29	30
SiO_2	51.45	54.30	56.60	49.40	54.65	53.25	53.70	49.55	50.90	58.00
Al_2O_3	16.83	14.12	14.55	18.65	15.62	13.92	16.59	16.56	16.78	16.48
Fe_2O_3	3.37	2.97	2.82	3.76	2.35	4.08	3.27	5.11	4.18	1.43
FeO	7.42	10.67	9.47	5.92	8.87	11.80	5.60	5.98	5.92	5.80
CaO	9.87	8.12	8.09	12.23	5.59	7.24	7.76	8.81	6.19	5.69
MgO	5.01	3.81	3.19	4.60	4.44	3.86	5.69	6.25	6.36	4.42
Na_2O	3.24	3.38	3.13	2.49	3.59	1.64	3.38	3.22	4.27	6.32
K_2O	0.26	0.36	0.34	0.27	0.20	0.52	0.55	0.77	0.39	0.30
TiO_2	0.73	0.92	0.72	0.63	1.03	0.67	0.97	1.11	1.23	0.75
P_2O_5	0.04	0.04	0.05	0.11	0.31	0.15	0.34	0.33	0.44	0.20
MnO	0.21	0.16	0.14	0.20	0.28	0.37	0.15	0.14	0.11	0.10
H_2O	1.28	1.22	1.11	1.74	2.81	2.24	1.95	1.83	2.50	0.96
S	0.03	0	0.02	0.01	tr	0.05	0.14	tr	0.04	0.01
CO_2	0.07	0.07	0.07	0.42	0.37	0.07	0.07	0.12	0.10	0.12
Less O ≡ S	0.01		0.01			0.02	0.06		0.02	
TOTAL	99.80	100.14	100.29	100.43	100.11	99.84	100.10	99.78	99.39	100.58
Ni	14	18	10	30	<8	10	80	70	58	58
Cr	40	8	8	40	<6	48	132	231	70	50
FeO*/MgO	2.08	3.50	3.76	2.02	2.48	4.01	1.50	1.86	1.52	1.60

21 Massive plagioclase-phyric basalt, SE end of Wasekwan Lake (52-7-1710-3). 10% recrystallized plagioclase phenocrysts (1 - 3 mm) in a fine grained groundmass.

22 Massive aphyric basalt, 2 km SE of Wasekwan Lake (52-7-1725-1). Rare hornblende aggregates after primary mafic phenocrysts; moderate foliation.

23 Massive aphyric basalt or basaltic andesite, Wiley Lakes (52-7-1730-1). Good hornblendic foliation, no primary texture preserved. 3% ovoid quartz aggregates (0.2 - 0.5 mm); possible amygdales.

KEEWATIN RIVER MAFIC TO INTERMEDIATE VOLCANIC ROCKS (Unit 4; analyses 24 to 26)

24 Massive aphyric basalt, 1.5 km E of N end of Sickle Lake (52-7-1790-1). Fine grained, completely recrystallized, poorly foliated.

25 Massive aphyric basalt, 4 km NE of Sickle Lake (52-7-1157-1). Very fine grained, completely recrystallized, a few quartz-carbonate-plagioclase stringers.

26 Mafic tuff, 3.5 km NNE of Sickle Lake (52-7-1155-1). 10% pseudomorphs after plagioclase phenocrysts (to 1 mm). Good hornblendic foliation.

HUGHES LAKE CALC-ALKALINE SUITE (analyses 27 to 47)

1. **East of Hughes Lake** (analyses 27 to 34), in stratigraphic sequence from base to top.

27 Massive aphyric basalt (Lower Series), 3.5 km NNW of One Island Lake (52-7-1457-1). No primary texture preserved; poorly foliated.

28 Massive aphyric basalt (Lower Series), 1.5 km E of Hughes Lake (52-7-1270-1). No primary texture preserved.

29 Massive aphyric basalt (Lower Series), 0.5 km E of Hughes Lake (52-7-1274-1). 1-2% plagioclase phenocrysts (0.4 mm) in groundmass of plagioclase microlites and very fine grained felted amphibole. 3% quartz-epidote amygdales.

30 Massive porphyritic andesite (Upper Series), 760 m E of Hughes Lake (52-7-1309-1). Small (0.5 mm) plagioclase and hornblende (after pyroxene?) phenocrysts in an inhomogeneous groundmass of plagioclase microlites, locally abundant plagioclase spherulites, and amphibole.

	31	32	33	34	35	36	37	38	39	40
SiO_2	59.60	61.50	57.30	56.85	57.00	57.15	54.85	57.55	62.05	63.40
Al_2O_3	15.57	17.65	16.56	17.62	16.59	16.69	18.10	15.56	16.50	15.01
Fe_2O_3	1.09	2.29	0.69	0.97	2.64	1.75	1.54	1.48	0.89	1.10
FeO	5.72	3.52	5.14	3.57	5.46	5.76	4.44	5.50	3.74	3.75
CaO	7.90	5.71	9.08	10.13	5.16	6.98	8.20	7.72	6.56	5.58
MgO	3.91	2.36	3.98	3.98	4.24	4.17	4.38	4.05	2.38	2.72
Na_2O	3.32	3.99	4.74	5.24	3.42	2.90	5.02	2.98	4.78	3.45
K_2O	0.37	0.70	0.36	0.20	0.82	0.98	0.53	0.99	0.62	1.30
TiO_2	0.82	0.61	0.76	0.74	0.86	0.80	0.70	0.73	0.90	0.69
P_2O_5	0.31	0.21	0.25	0.22	0.17	0.28	0.17	0.25	0.19	0.22
MnO	0.14	0.09	0.09	0.07	0.13	0.15	0.07	0.16	0.07	0.09
H_2O	0.97	1.24	0.77	0.72	3.19	2.27	1.57	1.74	0.95	1.49
S	tr	tr	0	0	0	0.04	0.02	0.22	0.11	0.01
CO_2	0.16	0.10	0.05	0.14	0.41	0.14	0.26	0.54	0.11	0.89
Less O ≡ S						0.02	0.01	0.09	0.04	
TOTAL	99.88	99.97	99.77	100.45	100.09	100.04	99.84	99.38	99.81	99.70
Ni	66	35	66	66	38	66	50	80	24	50
Cr	56	32	82	74	48	82	112	90	72	98
FeO*/MgO	1.71	2.37	1.45	1.11	1.85	1.76	1.33	1.69	1.91	1.74

31 Massive plagioclase-phyric andesite (Upper Series), 2.3 km NW of One Island Lake (52-7-1447-1). 15% corroded plagioclase phenocrysts (0.5 - 1.5 mm) in a groundmass of plagioclase microlites (0.2 - 0.4 mm) and fine grained hornblende.

32 Massive plagioclase-phyric andesite (Upper Series), 670 m E of Hughes Lake (52-7-1326-1). 5-10% subhedral plagioclase phenocrysts (0.5 - 2 mm). Relict pilotaxitic texture locally preserved. Amphibole blastesis (3%).

33 Massive plagioclase-phyric andesite (Upper Series), 2.1 km NW of One Island Lake (52-7-1444-1). 10% euhedral plagioclase phenocrysts (0.5 - 1.5 mm) in a groundmass of felted plagioclase microlites and fine-grained amphibole.

34 Massive porphyritic andesite (Upper Series), 2.1 km NW of One Island Lake (52-7-1439-5). Euhedral phenocrysts of plagioclase (25%, 0.3 - 2 mm) and amphibole after pyroxene (10%, 0.2 - 0.5 mm) in a fine-grained, recrystallized groundmass.

2. **Pole Lake Area** (analyses 35 to 40)

35 Pillowed andesite, 500 m S of Pole Lake (52-6-223-1). Mosaic of epidotized, recrystallized plagioclase crystals (0.2 - 0.8 mm) with interstitial biotite, chlorite, quartz, epidote.

36 Massive porphyritic andesite, 100 m N of Pole Lake (52-6-642-1). Phenocrysts of plagioclase (15-20%, 0.5 - 3 mm) and amphibole after pyroxene (2%, 0.2 - 0.6 mm) in a microlitic, weakly amygdaloidal (2%) groundmass.

37 Aphyric andesite fragment in pyroclastic breccia, 800 m E of Pole Lake (52-6-684-2). Pilotaxitic texture; a few carbonate and polymineralic amygdales.

38 Massive porphyritic andesite, 400 m NE of Pole Lake (52-6-650-1). Phenocrysts of plagioclase (5%), quartz (3%), and amphibole (2%) in a groundmass dominated by felted plagioclase microlites.

39 Massive porphyritic dacite, 1.8 km NE of Pole Lake (52-6-668-1). Phenocrysts of plagioclase (10%, up to 1.5 mm) and quartz (1%, up to 0.7 mm) in a groundmass dominated by felted plagioclase microlites.

40 Massive porphyritic dacite, 400 m NE of Pole Lake (52-6-647-1). Phenocrysts of plagioclase (2%, 1-2 mm) and quartz (2%, 1 mm) in a groundmass dominated by plagioclase microlites. 5% quartz-carbonate amygdales.

	41	42	43	44	45	46	47	48	49	50
SiO_2	65.80	77.30	76.50	76.80	76.30	75.35	74.50	65.85	69.25	61.05
Al_2O_3	15.72	12.86	12.69	11.25	12.62	13.21	13.10	14.84	13.16	14.54
Fe_2O_3	1.86	0.13	0.44	0.76	0.43	0.73	1.09	1.84	1.61	2.52
FeO	3.03	0.42	0.64	0.94	0.86	0.96	1.16	3.87	4.55	5.14
CaO	3.96	0.12	0.70	1.29	1.02	2.15	1.32	4.15	2.90	5.62
MgO	1.16	0.02	0.14	0.30	0.08	0.68	0.64	1.68	0.91	2.41
Na_2O	5.07	4.48	3.82	2.81	4.94	3.55	3.97	3.70	3.84	2.89
K_2O	1.18	3.73	3.73	3.57	2.36	1.55	2.26	1.77	1.47	1.53
TiO_2	0.82	0.07	0.08	0.12	0.06	0.27	0.31	0.58	0.51	0.80
P_2O_5	0.30	0	0	0	0	0.03	0.02	0.14	0.14	0.28
MnO	0.08	0.01	0.03	0.04	0.03	0.03	0.30	0.12	0.12	0.15
H_2O	0.66	0.44	0.60	0.74	0.39	0.82	1.02	1.08	0.93	1.67
S	0.06	0.01	tr	0.03	0	0	0	0.07	0	0.02
CO_2	0.23	0.25	0.55	1.05	0.61	0.34	0.71	0.19	0.38	1.16
Less O ≡ S	0.02			0.01				0.03		0.01
TOTAL	99.91	99.84	99.92	99.69	99.70	99.67	100.40	99.85	99.77	99.77
Ni	<8	<4	10	<4	<6	6	14	10	6	14
Cr	<6	15	<8	<10	<8	<8	<8	8	<8	8
FeO*/MgO	4.06	26.85	7.4	5.4	15.59	2.38	3.35	3.29	6.59	3.07

3. **Dacite**

41 Massive plagioclase-phyric dacite, 500 m E of Hughes Lake (52-7-1257-1). 10% plagioclase phenocrysts (0.7 - 2 mm) in a groundmass dominated by felted plagioclase microlites; a few quartz aggregates (1 mm).

4. **Rhyolite** (analyses 42 to 47)

42 Porphyritic rhyolite, 1.6 km E of Cartwright Lake (52-6-213-1). Phenocrysts of plagioclase (3%, 0.6 - 1.3 mm) and quartz (1%, 0.6 - 1 mm) in a very fine grained matrix of quartz, feldspar, sericite, and minor biotite.

43 Porphyritic rhyolite, 1.6 km E of Cartwright Lake (52-7-1768-2). Phenocrysts of plagioclase (2%, to 2 mm) and quartz (2%, to 1 mm) in a very fine grained groundmass as above. Flow-laminated.

44 Aphyric rholite, 1.5 km E of Pole Lake (52-6-694-1). Very fine grained mosaic of quartz, feldspar, sericite, minor biotite.

45 Aphyric rhyolite, 2.2 km NW of One Island Lake (52-7-1443-1). Plagioclase laths (0.1 - 0.2 mm) are in a very fine grained groundmass of quartz, feldspar, sericite, minor biotite, and minor carbonate.

46 Aphyric rhyolite, 300 m N of Hughes Lake, W of Hughes River (52-7-1629-2). From a massive flow 18 m thick. Rare plagioclase phenocrysts (0.5 mm) in a very fine grained recrystallized groundmass. 5% polymineralic (carbonate-quartz) amygdales.

47 Porphyritic rhyolite, E side of Chepil Lake (52-7-1824-2). 15% plagioclase phenocrysts and glomerocrysts (0.5 - 3 mm) in a very fine grained mosaic of lath-shaped plagioclase (0.1 mm), quartz, feldspar, sericite, and biotite.

KEEWATIN RIVER DACITE (analyses 48 to 50)

48 Porphyritic dacite, E side of Keewatin River, 2 km N of Sickle Lake (52-7-1076-1). 5-10% plagioclase phenocrysts (0.3 - 1 mm) in a very fine grained, foliated groundmass of feldspar, quartz, biotite, epidote, and magnetite. Rare small quartz amygdales.

49 Porphyritic dacite, 4 km N of Sickle Lake (52-7-1084-1). 10-15% plagioclase phenocrysts (0.5-2 mm) is a very fine grained recrystallized ground mass. Good foliation; 1% garnet.

50 Dacitic tuff, 3 km N of Sickle Lake (52-7-1080-1). 10% euhedral plagioclase crystals and angular crystal fragments, aphyric lithic fragments and porphyritic lithic fragments in an intermediate matrix. 3% carbonate.

	51	52	53	54	55	56	57	58	59	60	61
SiO_2	58.50	71.00	63.85	71.90	75.35	50.35	50.70	49.10	48.30	48.45	56.20
Al_2O_3	18.50	13.42	15.32	12.53	11.70	15.48	13.34	15.70	14.97	15.21	15.93
Fe_2O_3	2.75	1.10	1.15	1.47	1.05	2.62	1.95	2.41	2.73	1.69	1.99
FeO	3.75	4.07	6.52	4.05	2.93	8.54	8.12	9.39	10.22	9.91	5.14
CaO	7.70	1.51	6.37	2.98	0.65	10.6	12.0	10.37	9.41	9.08	7.84
MgO	1.76	0.91	1.66	0.98	1.21	7.36	8.17	6.82	7.73	7.67	5.34
Na_2O	3.01	4.81	1.85	3.60	4.31	2.32	2.13	3.14	2.29	2.37	3.47
K_2O	1.60	1.43	0.94	0.78	1.53	0.09	0.21	0.28	0.53	0.72	0.84
TiO_2	0.49	0.40	0.55	0.45	0.20	0.46	0.70	1.09	1.15	1.47	0.63
P_2O_5	0.07	0.09	0.12	0.10	0.01	0.04	0.05	0.28	0.28	0.56	0.21
MnO	0.13	0.10	0.18	0.12	0.04	0.19	0.21	0.17	0.21	0.20	0.13
H_2O	1.30	0.97	1.00	0.76	0.79	1.50	1.45	1.38	2.25	2.15	1.90
S	0.0	0.01	0.02	0.03	0.01	0.02	0.01	0.01	0	0	0
CO_2	0.13	0.10	0.14	0.05	0.08	0.08	0.84	0.17	0.07	0.07	0.22
Less $O \equiv S$			0.01	0.1		0.01					
TOTAL	99.69	99.92	99.66	99.79	99.86	99.64	99.88	100.31	100.14	99.55	99.84
Ni			<6	6	10	80	62	94	86	144	76
Cr			8	<8	<8	192	136	276	228	292	134

SEDIMENTARY ROCKS (analyses 51 to 55)

51 Feldspathic greywacke, 2 km N of Sickle Lake (52-7-1075-1). Intercalated with mafic flows of unit 4. Remnants of clastic texture preserved.

52 Massive homogeneous siltstone, 2.5 km N of Sickle Lake (52-7-1094-1). Very fine grained, 3% plagioclase microclasts (to 0.3 mm).

53 Laminated siltstone, 2.4 km NW of Sickle Lake (52-7-1208-3). From the thin sedimentary formation within unit 3 porphyritic basalt. Lamination defined by amphibole content and ratio of amphibole to biotite. 3% garnet.

54 Laminated siltstone, 4 km NW of Sickle Lake (52-7-1520-1). Same sedimentary formation as above. 2% garnet.

55 Feldspathic greywacke, 1.3 km SW of Miskwa Lake (52-7-1580-1). Very good clastic texture. Poorly sorted, fine to medium sand grade. Rich in plagioclase crystal fragments.

GABBRO (Unit 13, analyses 56 to 60)

56 Porphyritic gabbro, sill, 600 m NW of Foster Lake (52-6-120-2). Finer grained gabbro units (1.5 mm grain size; this analysis) alternate with coarsely porphyritic (5 mm) gabbro; units 6 - 9 m thick.

57 Densely porphyritic gabbro, 1 km S of Cockeram Lake (52-6-298-1). From the gabbro pluton which cores the McVeigh Lake anticline. Blockly hornblende pseudomorphs (1.5 mm) with interstitial plagioclase.

58 Gabbro sill, 1.1 km of One Island Lake (52-7-1651-1). Lath-shaped plagioclase crystals (0.5 - 1 mm), subhedral and interstitial amphibole. Grades to 59, below.

59 Ophitic gabbro, sill, 1.1 km NW of One Island Lake (52-7-1651-2). Hornblende (after pyroxene) oikocrysts to 6 mm diameter enclose lath-shaped plagioclase crystals 0.5 - 1 mm long.

60 Gabbro, pluton, 2.7 km NW of One Island Lake (52-7-1448-1). Lath-shaped plagioclase (0.6 mm), amphibole aggregates after primary pyroxene oikocrysts.

QUARTZ DIORITE (Unit 14)

61 Quartz diorite plug intrusive into the Hughes Lake calc-alkaline suite, Cartwright Lake (52-6-838-1). Fine grained (1 mm), with subhedral plagioclase, anhedral to subhedral amphibole (25%), interstitial quartz, leucoxene, epidote.

	62	63	64	65	66	67	68	69	70	71
SiO_2	50.45	51.45	51.75	52.35	52.45	52.45	52.65	53.35	53.75	54.10
Al_2O	13.09	18.54	18.60	21.38	14.23	18.08	16.22	19.12	19.33	15.56
Fe_2O_3	2.07	2.12	2.66	1.14	2.22	2.37	1.91	1.36	1.73	2.25
FeO	9.44	8.18	8.52	6.78	8.07	9.36	10.67	6.64	7.39	8.92
CaO	10.75	6.66	9.97	10.65	9.23	8.26	5.76	9.49	8.55	8.40
MgO	6.62	3.45	2.62	2.36	6.11	3.18	4.51	3.55	2.99	3.81
Na_2O	3.40	4.74	2.26	2.29	4.23	1.95	3.00	3.18	3.09	2.50
K_2O	0.31	1.77	0.50	0.43	0.39	1.38	1.39	0.24	0.55	0.90
TiO_2	1.69	0.98	1.03	0.90	1.44	1.00	1.23	1.04	0.88	0.79
P_2O_5	0.14	0.35	0.17	0.17	0.26	0.20	0.19	0.24	0.18	0.14
MnO	0.20	0.20	0.25	0.18	0.17	0.19	0.20	0.20	0.17	0.21
H_2O	1.21	1.13	1.00	1.16	1.17	1.49	1.77	0.97	1.23	1.39
S	tr	0.02	0.01	NIL			tr	0.01		0.10
CO_2	0.64	0.15	0.07	0.37	0.11	0.09	0.15	0.18	0.16	0.90
Less O = S		0.01								0.04
TOTAL	100.01	99.73	99.41	100.16	100.08	100.00	99.65	99.57	100.00	99.93
Ni	108	<6	<6	6	84	3	6	10	<1	<6
Cr	350	8	16	8	292	<10	16	40	<10	16
FeO*/MgO	1.71	2.92	4.16	3.31	1.65	3.61	2.75	2.21	2.99	2.87

NORTHERN BELT: DIVISION A (analyses 77 and 78)
: DIVISION B (analyses 62 to 76)

Unit 4; analyses 62 to 74

62 Massive, fine to medium grained, gneissoid amphibolite, 2 km west-southwest of Bob Lake (32-6-779-1).

63 Porphyritic basalt, 2 km southeast of Minton Lake (32-6-975-1). 20% plagioclase phenocrysts in a well foliated matrix of quartz and plagioclase (70%), biotite (15%) and hornblende (15%).

64 Porphyritic basalt, 300 m south of the south end of Margaret Lake (32-6-286-1). 25% plagioclase phenocrysts in a very fine grained amphibolite matrix with minor quartz aggregates (amygdaloidal?).

65 Porphyritic basalt, 1.5 km southwest of the south end of Minton Lake (32-6-651-1). 35% plagioclase phenocrysts in a massive amphibolite matrix of very fine grained quartz and plagioclase with medium grained hornblende porphyroblasts.

66 Pillowed basalt, souther part of Frances Lake (32-6-251-1). 10% plagioclase phenocrysts and 15% hornblende crystals and aggregates in a fine grained amphibolite matrix.

67 Porphyritic basalt, northern part of Frances Lake (32-6-254-1). 20% plagioclase phenocrysts in a slightly foliated amphibolite matrix with 10% biotite and medium grained hornblende porphyroblasts.

68 Sparsely porphyritic basalt, north end of Frances Lake (32-6-257-1). 4% plagioclase phenocrysts in a well foliated quartz-plagioclase matrix with biotite (10%) overprinted by hornblende porphyroblasts (30%).

69 Porphyritic basalt-andesite, 2 km east of Eric Lake (32-6-604-6). 30% plagioclase phenocrysts, 5% hornblende pseudomorphs and 5% quartz amygdales in a well foliated amphibolite matrix.

70 Porphyritic basalt, 1 km southwest of Minton Lake (32-6-650-2). 25% plagioclase phenocrysts in a very fine grained quartz-plagioclase matrix overprinted by porphyroblasts of hornblende (25%) and biotite (7%). Minor quartz aggregates and stringers ($<5\%$).

71 Porphyritic andesite, between Lynn River and West Lynn Lake (32-6-460-1). 15% plagioclase phenocrysts in a very fine grained quartz-plagioclase-biotite matrix with hornblende porphyroblasts and irregular quartz aggregates (5%), possibly amygdaloidal.

	72	73	74	75	76	77	78	79	80	81
SiO_2	58.05	58.05	58.35	60.85	81.85	74.55	75.20	47.10	48.25	48.50
Al_2O_3	19.80	18.05	17.58	16.16	9.98	12.50	12.14	20.60	19.70	20.50
Fe_2O_3	0.85	1.11	2.14	3.25	0.45	0.86	0.26	1.69	1.97	2.17
FeO	5.04	5.92	5.60	4.66	1.06	2.11	1.89	8.55	7.11	8.39
CaO	8.79	8.94	9.07	4.69	0.53	0.57	1.79	11.31	13.80	10.78
MgO	1.97	2.89	2.19	2.07	0.49	0.69	0.79	4.56	4.45	3.55
Na_2O	3.07	2.03	2.89	4.49	4.52	3.16	1.84	2.09	1.48	3.35
K_2O	0.33	0.70	0.36	1.36	0.68	4.83	4.35	0.99	0.31	0.35
TiO_2	0.88	0.84	0.65	0.72	0.14	0.18	0.14	0.77	0.57	0.78
P_2O_5	0.22	0.22	0.16	0.12	0.05	0.05	0.03	0.10	0.06	0.08
MnO	0.12	0.14	0.17	0.12	0.02	0.06	0.05	0.19	0.15	0.16
H_2O	0.74	0.81	0.70	0.76	0.33	0.41	0.48	1.69	1.19	1.10
S				0.01					0.01	
CO_2	0.15	0.08	0.06	0.71	0.07	0.10	0.51	0.10	0.66	0.28
Less O = S										
TOTAL	100.01	99.78	99.92	99.97	100.17	100.07	99.47	99.74	99.71	99.99
Ni	<1	6	3	10	1	<1	<1	6	15	9
Cr	10	24	18	40	<10	14	<10	24	48	14
FeO*/MgO	2.94	2.39	3.46	3.66	2.98	4.17	2.68	2.21	2.00	2.91

72 Felsic andesite, 100 m northeast of Lynn Lake hospital (32-6-498-1). Clast in polymictic breccia, containing 30% plagioclase phenocrysts in a very fine grained matrix overprinted by hornblende porphyroblasts.

73 Aphyric felsic andesite, 2 km east of Eric Lake (32-6-606-2). Very fine grained quartz and plagioclase, with hornblende porphyroblasts (15%), and biotite (10%); minor hornblendic stringers.

74 Felsic andesite, 1.5 km east of Eric Lake (32-6-598-1). 25% plagioclase phenocrysts and 10% hornblende pseudomorphs in a slightly foliated matrix with 5% quartz stringers and aggregates (amygdaloidal?).

Unit 6

75 Porphyritic dacite, at Lynn River, west of West Lynn Lake (32-6-459-1). 20% plagioclase phenocrysts in a very fine grained quartz-plagioclase-biotite matrix with hornblende porphyroblasts, magnetite (8%), and carbonate (4%).

Unit 7; analyses 76 to 78

76 Quartz-rich rhyolite, northern part of Frances Lake (32-6-258-3). Boulder with flow-breccia, containing 15% plagioclase phenocrysts and 2% carbonate.

77 Porphyritic rhyolite, central Frances Lake (32-6-264-1). Plagioclase and quartz phenocrysts (10% each) occur in a well foliated matrix with biotite.

78 Porphyritic rhyolite, south end of West Lynn Lake (32-6-884-1). Very fine grained quartz-plagioclase-biotite-muscovite rock with phenocrysts of quartz and plagioclase, muscovite porphyroblasts, and 3% carbonate. Biotite occurs in very fine fracture fillings and in mafic granules (7%).

NORTHERN BELT: DIVISION D (analyses 79 to 92)
DIVISION E (analyses 93 to 95)

Unit 4; analyses 79 to 90

79 Porphyritic basalt, 5.5 km northeast of Desieyes Lake (32-6-505-1). Phenocrysts of plagioclase (35%) and biotite (5%) and hornblende pseudomorphs after pyroxene (5%) in a well foliated, hornblendic matrix with 5% magnetite.

80 Porphyritic basalt, 1 km north of the northern part of Arbour Lake (32-7-2116-1). 40% plagioclase phenocrysts in a massive hornblende-rich matrix.

81 Porphyritic basalt at the south end of Ralph Lake (32-6-139-3). From massive zone within flow-breccia; contains 40% plagioclase phenocrysts and aggregates in a well foliated amphibolite matrix with medium grained hornblende porphyroblasts and 5% magnetite.

	82	83	84	85	86	87	88	89	90	91
SiO_2	48.80	48.95	49.35	49.50	49.95	51.25	51.80	52.25	53.30	69.15
Al_2O_3	15.45	16.73	14.36	12.63	18.13	15.20	18.65	14.56	18.62	16.25
Fe_2O_3	1.84	2.02	1.45	3.16	2.17	2.55	1.94	1.50	2.08	0.74
FeO	7.81	9.06	8.80	7.39	9.06	7.67	8.96	11.01	7.27	1.97
CaO	11.44	11.63	12.63	15.90	9.60	13.08	7.83	10.18	6.71	3.47
MgO	10.01	6.86	10.17	5.95	5.11	6.15	4.47	6.34	5.68	1.29
Na_2O	1.76	1.79	1.15	0.78	3.16	1.51	3.54	1.23	2.80	4.59
K_2O	0.27	0.30	0.15	0.14	0.19	0.13	0.22	0.28	0.11	1.30
TiO_2	0.46	0.67	0.29	0.98	0.89	0.93	0.87	0.82	0.80	0.28
P_2O_5	0.11	0.06	0.03	0.05	0.15	0.11	0.09	0.10	0.13	0.09
MnO	0.25	0.18	0.20	0.20	0.22	0.20	0.21	0.22	0.18	0.05
H_2O	1.75	1.48	1.60	1.67	0.98	1.27	1.40	1.35	2.54	0.73
S			tr							NIL
CO_2	0.09	0.28	0.14	1.28	0.15	0.07	0.11	0.08	0.15	0.12
Less O = S										
TOTAL	100.04	100.01	100.32	99.63	99.76	100.12	100.09	99.92	100.37	100.03
Ni	156	121	70	88	15	47	<1	37	30	
Cr	490	318	464	757	30	230	10	142	90	
FeO*/MgO	0.95	1.58	0.99	1.72	2.15	1.62	2.39	1.95	1.61	2.04

82 Basalt, at eastern side of Lynn Lake airport (32-6-483-2). 5% medium grained biotite crystals and aggregates in a very fine grained hornblendite matrix.

83 Porphyritic pillowed basalt, 2 km northeast of the north end of Motriuk Lake (32-6-690-3). 30% plagioclase phenocrysts and 15% hornblende pseudomorphs in a very fine grained hornblende-rich matrix with 5% quartz amygdales.

84 Porphyritic diabase, 1.5 km east of the east end of Desieyes Lake (32-7-2130-1). 30% hornblende pseudomorphs after clinopyroxene in a medium grained amphibolite matrix with 5% ilmenite; relictic ophitic texture.

85 Porphyritic basalt, 4.5 km northeast of Desieyes Lake (32-6-511-1). 25% clinopyroxene phenocrysts (largely altered to hornblende) in a hornblende-epidote matrix with 4% carbonate.

86 Porphyritic basalt, 1 km east of the southern extremity of Ralph Lake (32-6-301-2). 15% plagioclase phenocrysts in a recrystallized matrix with medium grained hornblende porphyroblasts and 5% magnetite.

87 Sparsely porphyritic basalt, 4.5 km northeast of Desieyes Lake (32-6-511-2). Plagioclase phenocrysts (5%) and hornblende pseudomorphs (3%) in a very fine grained hornblende-rich matrix with 10% epidote and 5% quartz stringers and aggregates.

88 Pillowed basalt, at the south end of Ralph Lake (32-6-138-1). 10% plagioclase phenocrysts and quartz amygdales in a recrystallized amphibolite matrix.

89 Porphyritic basalt, 500 m southeast of the eastern end of Desieyes Lake (32-6-528-1). 20% plagioclase phenocrysts and aggregates and 15% hornblende pseudomorphs after clinopyroxene in a slightly foliated hornblendite matrix with 4% ilmenite and minor quartz amygdales.

90 Porphyritic basalt, southern margin of Lynn Lake airport (32-6-475-2). 15% plagioclase phenocrysts, quartz amygdales, and chloritic aggregates in a massive, chlorite-quartz-plagioclase matrix with medium grained hornblende porphyroblasts.

Unit 6

91 Porphyritic dacite, 1.5 km east of the east end of Desieyes Lake (32-7-2131-2). Phenocrysts of plagioclase (25%) and quartz (5%) in a well foliated quartz-plagioclase-biotite matrix.

	92	93	94	95	96	97	98	99	100	101
SiO_2	74.40	50.50	50.65	55.85	48.75	49.90	50.05	50.90	52.90	54.85
Al_2O_3	12.73	19.72	18.91	15.60	12.01	16.96	10.49	22.45	18.65	18.84
Fe_2O_3	1.04	1.89	2.77	2.37	2.40	2.46	1.15	1.26	1.62	1.71
FeO	2.51	7.73	8.33	9.19	9.63	9.23	7.14	6.53	7.85	6.80
CaO	2.15	12.24	11.22	6.51	12.64	9.80	10.80	8.08	8.54	7.75
MgO	0.56	4.02	3.08	3.16	8.42	5.97	14.98	3.33	4.49	2.53
Na_2O	2.97	1.67	1.69	3.66	2.08	2.15	1.04	3.58	3.40	3.69
K_2O	2.21	0.37	0.52	0.19	0.26	0.57	0.20	1.48	0.31	0.58
TiO_2	0.27	0.36	0.94	1.18	1.65	0.49	0.32	0.85	0.58	0.83
P_2O_5	0.05	0.06	0.08	0.23	0.15	0.03	0.21	0.09	0.11	0.17
MnO	0.07	0.18	0.16	0.22	0.20	0.23	0.19	0.13	0.19	0.18
H_2O	0.63	1.13	1.35	1.08	1.57	1.18	2.93	1.27	1.53	1.20
S	NIL		0.01	NIL	0.12	NIL	NIL			tr
CO_2	0.19	0.45	0.08	0.03	0.38	0.23	0.23	0.09	0.09	0.40
Less O = S					0.05					
TOTAL	99.78	100.32	99.79	99.27	100.31	99.20	100.02	100.04	100.26	99.53
Ni		27	4	4	166	20	408	8	14	6
Cr		46	26	<8	520	26	1660	10	30	16
FeO*/MgO	6.14	2.35	3.32	3.57	1.40	1.92	0.55	2.30	2.07	3.29

Unit 7

92 Porphyritic rhyolite, 1.5 km north of the north end of Motriuk Lake (32-7-2067-3). Well foliated quartz-plagioclase-biotite rock with phenocrysts and stringers of quartz and muscovite porphyroblasts.

Unit 4; analyses 93 to 101

93 Porphyritic basalt, 1 km south of Stick Lake (32-6-436-1). 30% plagioclase phenocrysts in a massive amphibolite matrix with 3% carbonate.

94 Porphyritic basalt, 1 km south of Payne Lake (32-8-5126-1). 35% plagioclase phenocrysts in a very fine grained, gneissoid amphibolite matrix.

95 Andesite, 1.25 km south of Payne Lake (32-8-5130-1). Fine grained amphibolite with minor garnet and minor (7%) quartzo-feldspathic aggregates, derived from phenocrysts or amygdales.

Northern belt: unspecified. Includes rocks close to the contact of divisions C and D (analysis 99) and D and E (analysis 98). Analysis 101 is within division C. Analyes 96, 97 and 100 are from the area east of Arbour Lake where volcanic divisions have not been defined.

96 Pillowed basalt, 1 km east of Bob Lake (32-8-5180-1). Hornblende-rich variolites at pillow margins are coalescent toward pillow cores. 15% hornblende pseudomorphs and aggregates (after clinopyroxene) in a massive hornblende-epidote matrix. Primary texture well preserved.

97 Porphyritic basalt, 500 m north of the west end of Raven Lake (32-8-5198-1). 15% plagioclase phenocrysts and 7% pseudomorphic hornblende aggregates in a massive recrystallized matrix of fine-grained quartz and plagioclase with coarser hornblende porphyroblasts.

98 Basalt, 1.75 km south of Payne Lake (32-8-5138-1). Massive, fine- to medium-grained hornblendite with minor quartz aggregates derived from amygdales (3%).

99 Porphyritic basalt, south end of Eric Lake (32-6-497-1). 25% plagioclase phenocrysts (2 - 5 mm) in a very fine grained matrix of plagioclase and quartz overprinted by medium- to coarse-grained hornblende and biotite (15% each).

100 Porphyritic basalt, 1 km northeast of the northern end of Muskeg Lake (32-6-368-1). 20% plagioclase phenocrysts and 3% hornblende crystals in a massive amphibolite matrix.

101 Porphyritic andesite, east shore of Margaret Lake (32-6-288-7). 20% plagioclase phenocrysts in a very fine grained quartz-plagioclase matrix overprinted by hornblende porphyroblasts. Contains ilmenite (5%) and irregular quartz aggregates (7%), possibly derived from amygdales.

	102	103	104	105	106	107	108	109	110	111
SiO_2	46.80	48.70	49.15	49.50	49.90	50.00	50.05	50.40	51.00	52.05
Al_2O_3	16.46	16.63	16.85	14.45	20.47	15.48	18.52	13.15	14.52	17.50
Fe_2O_3	1.57	1.20	1.43	1.55	2.60	2.60	3.00	3.19	1.77	1.48
FeO	10.96	6.97	6.86	7.80	8.05	10.02	8.50	6.91	7.97	8.73
CaO	11.73	12.77	12.10	11.09	10.88	9.01	9.69	10.36	9.07	9.10
MgO	7.03	8.20	8.28	10.27	3.30	6.96	3.31	10.47	8.87	4.43
Na_2O	1.79	1.84	2.07	1.86	2.14	2.10	2.87	2.00	2.66	3.13
K_2O	0.21	0.62	0.62	0.56	0.36	0.82	0.39	0.13	1.37	0.54
TiO_2	1.35	0.68	0.72	0.57	0.85	0.86	0.94	0.69	0.82	1.02
P_2O_5	0.11	0.17	0.18	0.13	0.06	0.05	0.08	0.16	0.20	0.26
MnO	0.21	0.16	0.16	0.17	0.19	0.22	0.21	0.20	0.17	0.19
H_2O	1.61	1.70	1.84	2.02	1.36	1.25	1.61	2.38	1.55	1.35
S	0.04	0.02	0.01	0.01	0.17	0.01	0.02	0.01	0.01	tr
CO_2	0.33	0.44	0.14	0.12	0.11	0.18	0.51	0.29	0.05	0.11
Less O ≡ S	0.02	0.01			0.07		0.01			
TOTAL	100.18	100.09	100.41	100.10	100.37	99.56	99.69	100.34	100.03	99.89
Ni	44	38	44	112	< 4	24	< 4	136	118	4
Cr	92	242	220	430	8	52	< 8	734	460	18
FeO*/MgO	1.76	0.98	0.98	0.89	3.15	1.77	3.38	0.94	1.08	2.27

SOUTHERN BELT: GEMMELL LAKE-McVEIGH LAKE SECTION (analyses 102 to 113)

Unit 4

102 Sparsely porphyritic basalt, 100 m north of Dutton Lake (32-6-90-1). 10% plagioclase phenocrysts in a strongly foliated hornblendite matrix with 8% magnetite and minor quartz stringers.

103 Porphyritic basalt, 500 m southwest of Fraser Lake (32-8-5060-3). 30% hornblende pseudomorphs after pyroxene and minor plagioclase phenocrysts (7%) in a fine grained amphibolite matrix. From a 3 m thick unit with possible pillow selvage remnants, within greywacke sequence.

104 Porphyritic basalt, 600 m southwest of Fraser Lake (32-6-146-2). 25% hornblende pseudomorphs after pyroxene in a fine grained amphibolite matrix. From a 5 m thick extrusive or hypabyssal unit within greywacke sequence.

105 Massive, medium grained amphibolite, 750 m southeast of the east end of Fraser Lake (32-6-193-1). From a 1 m thick sill within mafic volcanic breccia.

106 Densely porphyritic basalt, southwest shore of Louise Lake (32-6-112-1). 45% plagioclase phenocrysts in a hornblende-rich matrix with 15% quartz aggregates, possibly amygdaloidal.

107 Well foliated, fine grained amphibolite, southwest shore of Louise Lake (32-6-110-2).

108 Porphyritic basalt, 1 km north of Pool Lake (32-8-5019-1). 30% plagioclase phenocrysts in a massive matrix of very fine grained quartz and plagioclase magnetite (6%) and hornblende porphyroblasts.

109 Porphyritic basalt, 500 m east-southeast of Dutton Lake (32-6-117-1). 15% hornblende pseudomorphs after pyroxene, partly altered to chlorite, in a strongly foliated hornblende-rich matrix.

110 Porphyritic basalt, 750 m south of Stear Lake (32-8-5082-2). 35% hornblende pseudomorphs after pyroxene in a well foliated matrix of quartz and plagioclase (65%), biotite (20%) and hornblende (15%). From a 5 m thick extrusive or hypabyssal unit associated with feldspathic greywacke.

111 Porphyritic basalt, 250 m south of Nail Lake (32-6-59-1). 15% plagioclase phenocrysts in a well foliated amphibolite of very fine grained quartz and plagioclase with hornblende porphyroblasts (0.5 - 1 mm).

	112	113	114	115	116	117	118	119	120	121
SiO_2	53.85	60.00	56.30	50.55	49.15	49.95	52.70	49.45	57.90	45.15
Al_2O_3	15.33	13.77	12.49	10.33	10.01	7.77	11.22	10.49	10.08	7.21
Fe_2O_3	2.73	2.58	0.29	0.83	0.99	1.04	0.99	1.01	1.28	0.54
FeO	10.91	9.31	9.23	10.20	10.97	10.38	10.27	10.43	7.67	10.83
CaO	7.58	5.33	5.43	9.37	10.45	10.48	8.12	12.45	8.41	19.40
MgO	3.62	2.49	10.13	13.37	13.14	14.05	10.34	11.95	7.97	9.52
Na_2O	2.57	2.89	3.17	1.62	1.32	0.92	2.59	0.42	3.86	0.15
K_2O	0.34	0.46	0.10	0.15	0.23	1.29	0.13	0.22	0.15	0.95
TiO_2	0.79	1.18	0.94	0.84	1.05	0.81	1.09	0.66	0.88	0.54
P_2O_5	0.17	0.12	0.17	0.14	0.13	0.10	0.16	0.11	0.15	0.11
MnO	0.21	0.26	0.19	0.24	0.25	0.26	0.23	0.22	0.24	0.30
H_2O	1.53	1.60	1.31	1.84	1.90	2.08	1.59	1.86	1.16	1.44
S	NIL	0.02	0.02	tr	tr	tr	0.10	0.01	0.08	0.01
CO_2	0.12	0.29	0.22	0.11	0.04	0.11	0.13	0.26	0.15	3.53
Less $O \equiv S$		0.01					0.04		0.03	
TOTAL	99.75	100.29	99.98	99.59	99.63	99.24	99.62	99.54	99.95	99.68
Ni	< 6	< 4	32	232	151	180	124	88	106	108
Cr	< 8	< 8	378	1740	1280	1724	724	824	864	1104
FeO*/MgO	3.69	4.67	0.94	0.82	0.90	0.81	1.08	0.95	1.11	1.19

112 Aphyric basalt, 1.5 km southwest of the south end of Eldon Lake (32-6-10-1). Well foliated fine grained amphibolite with quartz stringers and aggregates.

113 Fine grained, gneissoid, quartz-rich amphibolite, southwest shore of Louise Lake (32-6-110-1). Hornblende content approximately 30%.

FOX MINE-WILMOT LAKE AREA
FOX LAKE PORPHYRITIC BASALT (unit 3; analyses 114 to 122)

114 Finely porphyritic basalt, 300 m west of Helen Lake (12-7-632-3), fine grained (0.02 mm) cummingtonite amphibolite with small quartz-amphibole-filled amygdales; block in coarsely porphyritic breccia matrix.

115 Finely porphyritic basalt, 330 m west of Helen Lake (12-7-6-629-2), cummingtonite amphibolite, flow-top breccia block.

116 Porphyritic basalt flow, 350 m west of Helen Lake (12-7-630-2), 20% hornblende pseudomorphs after pyroxene phenocrysts in a fine amphibolite matrix.

117 Porphyritic pillowed basalt, 1000 m southwest of Helen Lake (12-7-374-C), cumulate base of differentiated pillow, 50% hornblende pseudomorphs after pyroxene phenocrysts in amphibolite groundmass.

118 Porphyritic pillowed basalt, 1000 m southwest of Helen Lake (12-7-374-A), finely porphyritic top of differentiated pillow, 12% mafic phenocrysts, scattered plagioclase-filled amygdales.

119 Porphyritic basalt flow (2 m), 1200 m southwest of Helen Lake (12-7-376-2), patchy hornblende amphibolite with a trace of phlogopite.

120 Porphyritic basalt flow, 600 m north of Wolf Lake (12-7-130-1), 15% hornblende pseudomorphs after pyroxene in a groundmass rich in feathery amphibole.

121 Patchy amphibolite, 400 m northeast of Snake Lake (12-7-53-A), coarse amphibole-diopside amphibolite with biotite-rich "fragments".

	122	123	124	125	126	127	128	129	130	131
SiO_2	47.25	47.60	48.45	60.60	54.80	49.65	53.60	49.90	49.70	67.30
Al_2O_3	7.99	15.30	15.12	14.93	15.72	18.25	16.04	16.72	16.45	14.69
Fe_2O_3	0.81	1.64	1.20	1.72	1.93	1.57	1.67	0.96	1.08	0.93
FeO	10.65	7.45	7.57	5.67	8.97	7.37	8.04	7.77	7.77	3.98
CaO	13.61	12.35	13.79	7.08	8.95	10.41	8.82	10.97	10.34	2.12
MgO	12.97	9.39	8.32	4.69	3.37	6.58	4.65	8.08	8.54	1.64
Na_2O	0.41	2.27	2.12	3.37	2.84	3.35	4.05	2.38	2.37	2.48
K_2O	0.55	0.26	0.22	0.73	0.66	0.45	0.23	0.76	1.17	4.97
TiO_2	0.76	0.48	0.45	0.41	1.01	0.41	0.87	0.52	0.57	0.55
P_2O_5	0.14	0.03	0.03	0.07	0.12	0.06	0.11	0.07	0.08	0.11
MnO	0.23	0.21	0.20	0.14	0.20	0.21	0.25	0.19	0.18	0.26
H_2O	2.00	1.80	1.28	1.08	1.33	1.46	1.09	1.68	1.41	0.78
S	0.01		0.02	tr	0.03	0.01	0	0.01	0.01	tr
CO_2	1.89	0.76	1.36	0.17	0.64	0.23	0.57	0.15	0.11	0.11
Less O ≡ S			0.01		0.01					
TOTAL	99.27	99.59	100.12	100.66	100.57	100.08	99.99	100.16	99.78	99.92
Ni	84	74	76	24	6	32	14	48	52	4
Cr	2764	200	224	146	12	134	47	232	240	10
FeO*/MgO	0.88	0.95	1.04	1.54	3.18	1.33	2.05	1.07	1.02	2.94

122 Porphyritic flow-breccia, 100 m north of Wolf Lake (12-7-48), felted mass of amphibole, biotite (5%).

MAFIC VOLCANIC ROCKS: FOX MINE SUCCESSION, LOWER PART (Unit 2; analyses 123, 124)

123 Aphyric basalt flow, 200 m east of Fox Mine (12-9-334), fine grained amphibolite with minor cummingtonite, diopside and calcite, thin carbonate veins near sample site.

124 Aphyric basalt flow, 1200 m north of Wolf Lake (12-7-149), massive fine grained amphibolite with minor calcite veins.

MAFIC AND INTERMEDIATE VOLCANIC ROCKS: FOX MINE SUCCESSION (Unit 4; analyses 125 to 130)

125 Porphyritic basalt/andesite, 350 m southwest of Fox Mine (12-8-147-3), 15% hornblende megacrysts, 5% plagioclase phenocrysts in a fine grained amphibolite groundmass; altered (?).

126 Porphyritic basalt/andesite breccia, 350 m southwest of Fox Mine (12-8-147-B), 20% hornblende megacrysts, 20% plagioclase phenocrysts in a mafic matrix with fine grained amphibolite fragments; porphyroblasts of garnet and hornblende.

127 Porphyritic basalt flow, 300 m southwest of Fox Mine (12-8-146-5), 20% hornblende megacrysts, 15% plagioclase phenocrysts in a fine grained amphibolite groundmass.

128 Intermediate breccia, 300 m southwest of Fox Mine (12-8-146-2), fine grained felsic fragments in a coarse amphibolite groundmass with garnet and amphibole porphyroblasts.

129 Porphyritic basalt flow, 1200 m north of Wolf Lake (12-7-148-2A), 30% hornblende pseudomorphs after pyroxene phenocrysts, rare pyroxene cores, 15% plagioclase phenocrysts in a fine grained amphibolite matrix: middle of thick flow.

130 Porphyritic basalt flow, 1200 m north of Wolf Lake (12-7-148-2B), as 129: margin of flow.

SNAKE LAKE DACITE/RHYOLITE (Units 6, 7; analyses 131 to 139)

131 Massive dacite, southeast end of Snake Lake (12-7-450), elongate aggregates of hornblende-biotite in a fine grained matrix of plagioclase and quartz.

	132	133	134	135	136	137	138	139	140	141
SiO_2	67.85	66.85	66.90	70.95	73.10	69.90	72.45	71.90	51.00	45.25
Al_2O_3	14.12	15.00	14.93	13.56	15.27	12.52	12.10	13.02	16.02	10.42
Fe_2O_3	0.80	0.77	0.94	0.68	0.15	1.68	0.83	0.48	1.30	2.16
FeO	3.34	4.48	4.54	3.67	0.46	5.32	4.44	3.88	14.38	9.97
CaO	3.60	3.22	3.13	1.73	1.95	2.26	2.87	1.42	3.80	10.92
MgO	1.81	1.32	1.19	0.98	0.13	1.32	1.18	1.47	6.14	15.16
Na_2O	2.45	2.37	2.23	4.12	5.86	2.79	3.51	5.35	1.79	1.57
K_2O	3.74	3.87	4.07	2.53	1.25	2.23	1.09	0.89	1.60	0.17
TiO_2	0.40	0.59	0.59	0.50	0.29	0.63	0.38	0.33	1.48	0.99
P_2O_5	0.04	0.14	0.13	0.12	0.11	0.14	0.07	0.07	0.16	0.11
MnO	0.07	0.08	0.06	0.11	0	0.09	0.11	0.06	0.19	0.21
H_2O	1.00	0.84	1.04	0.61	0.55	1.14	0.85	0.72	1.42	2.42
S	tr	0.01	0.02	0.01	0.09	tr	0.11	0.01	0.07	0.01
CO_2	0.77	0.40	0.11	0.11	0.40	0.15	0.35	0.46	0.15	0.15
Less O ≡ S			0.01		0.04		0.04			
TOTAL	99.99	99.94	99.87	99.68	99.57	100.17	100.30	100.06	99.47	99.51
Ni	8	4	< 2	< 1	< 2	< 2	< 2	< 3	14	392
Cr	24	10	8	< 5	4	4	< 4	6	60	1244
FeO*/MgO	2.24	3.92	4.53	4.37	4.57	5.23	4.47	2.93		0.79

132 Massive porphyritic dacite, 200 m east of Snake Lake (12-7-454), quartz and hornblende aggregates in a granoblastic matrix.

133 Porphyritic dacite (lapilli tuff?), 100 m north of Wolf Lake (12-7-49), quartz phenocrysts and biotite aggregates in a very fine grained matrix of feldspar and quartz, rare felsic lapilli.

134 Massive dacite, east-Dunphy Lake (12-7-100), biotite clots in a fine matrix of quartz, plagioclase, microcline and biotite: probably base of felsic body.

135 Massive porphyritic dacite/rhyolite, east-Dunphy Lake (12-7-78), feldspar-phyric, finely granoblastic: middle of body.

136 Massive porphyritic rhyolite, 600 m east of east-Dunphy Lake (12-7-94), phenocrysts replaced by plagioclase and plagioclase + quartz + muscovite (after potash feldspar?): east margin (top?) of felsic body.

137 Altered(?) dacite/rhyolite, 200 m southeast of Fox Mine (12-9-332-A), fine grained quartz and feldspar with hornblende and garnet porphyroblasts and rare quartz aggregates (phenocrysts?).

138 Altered(?) rhyolite, 300 m southwest of Fox Mine (12-8-146-1B), fine mosaic of quartz and feldspar with hornblende, cummingtonite and biotite blasts.

139 Rhyolite (tuff?), 400 m north of Snake Lake (12-7-62-1), fine grained quartz, feldspar and biotite with hornblende blasts (0.5 mm).

Unit 9

140 Anthophyllite-garnet schist, 300 m north of Snake Lake (12-8-132).

WILMOT LAKE VOLCANIC ROCKS (IN PROBABLE STRATIGRAPHIC ORDER): Unit 4; analyses 141 to 148

141 Mafic-ultramafic schist, 2000 m northeast of Hassett Lake (12-7-261), hornblende blasts (0.5 mm) in fine grained matrix of amphibole.

	142	143	144	145	146	147	148	149	150	151
SiO_2	52.35	51.15	50.25	46.60	55.05	59.95	47.70	75.30	52.70	52.90
Al_2O_3	14.02	15.49	17.56	13.83	16.37	16.29	13.09	11.00	14.21	14.53
Fe_2O_3	2.54	2.34	2.19	2.24	2.14	1.90	2.31	0.18	1.45	1.91
FeO	9.73	10.18	9.51	11.17	8.76	6.46	9.94	1.89	8.71	10.36
CaO	8.88	10.33	9.98	14.70	8.70	7.78	9.54	4.33	10.4	7.43
MgO	5.80	5.14	3.47	5.51	3.72	2.26	11.72	0.25	5.24	4.51
Na_2O	3.41	2.04	2.45	1.32	2.22	2.91	2.39	3.88	3.05	2.75
K_2O	0.35	0.23	0.33	0.41	0.41	0.31	0.14	0.34	0.62	1.04
TiO_2	1.01	1.48	1.52	1.11	1.10	0.95	1.17	0.33	1.08	1.69
P_2O_5	0.09	0.16	0.21	0.12	0.18	0.23	0.19	0.02	0.10	0.26
MnO	0.22	0.21	0.20	0.25	0.20	0.17	0.23	0.12	0.20	0.22
H_2O	1.39	1.27	1.32	1.37	0.99	0.79	1.79	0.45	1.13	2.23
S	0.01	0.01	0.01	0.02	0.01	tr	tr	0.01	0.04	0.12
CO_2	0.17	0.10	0.30	1.38	0.10	0.18	0.10	2.20	1.18	0.44
Less O ≡ S				0.01					0.02	0.05
TOTAL	99.97	100.03	99.30	100.02	99.95	100.18	100.31	100.30	100.09	100.34
Ni	48	28	12	26	6	2	262		32	4
Cr	94	98	25	122	33	16	1050		112	34
FeO*/MgO	2.07	2.39	3.31	2.39	2.87	3.69	1.03	8.23	1.91	2.67

142 Aphyric basalt, 2600 m southwest of Wilmot Lake (12-7-833), fine grained amphibolite.

143 Porphyritic basalt, 2800 m west of Wilmot Lake (12-8-159), 10% hornblende megacrysts and 10% plagioclase phenocrysts, epidote-rich patches near sample.

144 Porphyritic basalt breccia, 2700 m west of Wilmot Lake (12-8-160), 15% plagioclase phenocrysts in fragments and matrix; slightly altered; rare quartz amygdales.

145 Porphyritic basaltic flow breccia matrix, 2700 m west of Wilmot Lake (12-8-160-2), hornblende poikiloblasts (2 mm) in fine grained diopside-bearing amphibolite.

146 Porphyritic basalt/andesite, 2700 m west of Wilmot Lake (12-8-161-1), rare quartz-filled amygdales in fine grained amphibolite with plagioclase (phenocrysts?).

147 Porphyritic basalt/andesite, 2700 m west of Wilmot Lake (12-8-161-3), rare plagioclase phenocrysts in garnet-bearing amphibolite matrix; epidote alteration nearby.

148 Aphyric basalt, 1600 m northwest of Wilmot Lake (12-7-301), felted green amphibole (up to 0.5 mm) with interstitial plagioclase.

Unit 7

149 Rhyolite tuff, 600 m northwest of Wilmot Lake (12-7-725), 10% quartz phenocrysts (up to 1.2 mm) and biotite aggregates (0.4 mm) in a finely granular groundmass of quartz and feldspar.

LAURIE LAKE-DUNPHY LAKES AREA
TOD LAKE APHYRIC BASALT (Unit 2; analyses 150 to 174)

Outcrop belt 'B' (Fig. 26), in stratigraphic order

150 Pillowed basalt, north end of Tod Lake (12-6-629), fine grained foliated amphibolite; epidote alteration nearby.

151 Small-pillow basalt, island on north end of Tod Lake (12-6-631), foliated amphibolite with sericitized plagioclase (55%) and biotite (2%).

	152	153	154	155	156	157	158	159	160	161
SiO_2	51.45	46.80	52.55	55.95	49.70	48.60	50.10	44.15	51.60	49.00
Al_2O_3	14.20	16.96	13.96	12.45	15.07	15.95	14.60	15.29	14.05	13.32
Fe_2O_3	1.39	0.94	1.78	2.41	1.47	1.43	1.83	2.23	1.58	2.09
FeO	8.87	9.31	10.81	11.44	9.05	8.44	8.70	13.00	9.95	10.36
CaO	9.67	10.33	9.06	7.35	11.29	10.63	11.4	8,07	7.32	12.5
MgO	6.50	3.71	5.21	3.73	8.14	9.42	8.15	11.5	8.92	8.54
Na_2O	3.65	4.16	2.72	2.59	2.20	2.11	2.45	2.03	2.83	1.07
K_2O	0.48	0.44	0.18	0.48	0.19	0.16	0.18	0.15	0.25	0.16
TiO_2	1.13	2.56	1.16	1.85	0.92	0.78	0.81	1.20	1.10	1.08
P_2O_5	0.05	0.31	0.12	0.21	0.05	0.04	0.08	0.08	0.09	0.10
MnO	0.22	0.10	0.27	0.25	0.16	0.18	0.18	0.24	0.20	0.20
H_2O	1.65	1.44	1.44	1.29	1.26	1.94	1.43	2.29	1.98	1.67
S	0.02	0.01	0.01	0.01	0.02	0.01	0.03	0.04	0.04	0.01
CO_2	0.86	2.55	0.73	0.17	0.17	0.04	0.15	0.17	0.20	0.15
Less O ≡ S	0.01				0.01		0.01	0.02	0.02	
TOTAL	100.13	99.62	100.00	100.18	99.68	99.73	100.08	100.42	100.09	100.25
Ni	34	14	10	4	146	172	118	133	101	113
Cr	64	16	30	23	416	534	254	290	254	254
FeO*/MgO	1.56	2.74	2.36	3.65	1.27	1.03	1.27	1.31	1.28	1.43

152 Pillowed basalt flow (4 m), island on north end of Tod Lake (12-6-632-5), secondary hornblende up to 0.25 mm long, minor biotite.

Outcrop belt 'B' (Fig. 26)

153 Pillowed basalt, 1400 m southeast of Hatchet Lake (12-7-687), amphibolite with hornblende blast up to 5 mm, 8% calcite.

154 Massive basalt, 1100 m south of Hatchet Lake (12-7-798-1), foliated amphibolite with minor quartz and calcite veins.

155 Pillowed basalt/andesite, 600 m southwest of Hatchet Lake (12-7-807-2), amphibolite with minor garnet porphyroblasts.

Outcrop belt 'C' (Fig. 26)

156 Massive basalt, 500 m north of Fox Mine (12-7-639), fine grained amphibolite with traces of quartz-calcite veins.

157 Massive basalt, 400 m north of Fox Mine (12-7-641-6) amphibolite with hornblende blasts up to 1 mm long, possibly replacing phenocrysts.

Outcrop belt 'D' (Fig. 26), near top of section

158 Pillowed basalt, north end of Tod Lake (12-6-93-1), very fine grained amphibolite, apparently unaltered, jointed sample.

159 Breccia matrix, north end of Tod Lake (12-6-93-3A), foliated amphibolite (tuff-breccia?).

160 Breccia fragments and matrix, north end of Tod Lake (12-6-93-36), amphibolite blasts up to 0.6 mm long.

161 Breccia matrix, north end of Tod Lake (12-6-93-3C), highly foliated amphibolite.

	162	163	164	165	166	167	168	169	170	171
SiO_2	50.30	51.30	49.50	53.20	53.45	50.45	51.95	48.40	48.40	49.45
Al_2O_3	14.31	13.06	14.96	15.15	15.21	17.28	15.16	12.13	9.88	11.39
Fe_2O_3	3.09	2.98	1.53	2.15	2.25	2.08	1.90	2.90	4.20	2.14
FeO	11.24	10.96	10.53	4.86	4.72	5.07	5.53	6.01	5.33	7.05
CaO	9.60	10.7	10.4	10.4	9.91	10.9	8.35	10.4	11.1	11.4
MgO	5.78	5.70	7.82	9.26	8.95	8.38	11.5	14.9	17.1	13.2
Na_2O	2.30	1.68	2.13	2.69	3.04	2.22	2.98	1.66	1.01	1.64
K_2O	0.22	0.20	0.13	0.18	0.17	0.78	0.15	0.42	0.10	0.77
TiO_2	1.58	1.45	1.14	0.41	0.40	0.40	0.33	0.47	0.39	0.72
P_2O_5	0.13	0.14	0.06	0.07	0.07	0.05	0.06	0.07	0.24	0.13
MnO	0.19	0.20	0.19	0.13	0.13	0.15	0.14	0.16	0.19	0.18
H_2O	1.41	1.50	1.56	1.33	1.12	2.00	1.52	2.35	2.19	1.85
S	0.05	0.03	0.06				0	0	0	0.02
CO_2	0.24	0.26	0.15	0.06	0.04	0.49	0.04	0.09	0.04	0.13
Less O ≡ S	0.02	0.01	0.02							0.01
TOTAL	100.42	100.15	100.13	99.89	99.46	100.25	99.61	99.96	100.17	100.06
Ni	53	53	120	196	168	126	148	293	600	276
Cr	12	12	328	584	520	380	732	1080	1196	1083
FeO*/MgO	2.43	2.39	1.69	0.73	0.75	0.83	0.63	0.58	0.53	0.68

162 Massive basalt flow, north end of Tod Lake (12-6-93-7A), foliated hornblende amphibolite.

163 Massive basalt flow, north end of Tod Lake (12-6-93-78), foliated hornblende amphibolite.

164 Massive basalt flow, north end of Tod Lake (12-6-630), foliated hornblende amphibolite.

Outcrop belt 'F' (Fig. 26), in stratigraphic order

165 Massive basaltic rock, northeast end of Laurie Lake (12-6-115-G1), massive fine grained amphibolite with scattered acicular amphibole blasts.

166 Basaltic tuff-breccia, northeast end of Laurie Lake (12-6-115-G2), medium grained amphibolite (may be crystal tuff).

167 Foliated amphibolite, northeast end of Laurie Lake (12-6-115-G3), fine grained; sericite along small fractures.

168 Foliated amphibolite, northeast end of Laurie Lake (12-6-115-G4), 2 mm amphibole needles in a fine amphibolite matrix.

169 Mafic schist, northeast end of Laurie Lake (12-6-115-G5), medium grained amphibolite with minor biotite and plagioclase.

170 Mafic schist, northeast end of Laurie Lake (12-6-115-G6), strongly foliated fine grained amphibolite.

Outcrop belt 'F' (Fig. 26), southwestern part

171 Mafic schist, northeast end of Laurie Lake (12-6-40-G1), medium grained amphibolite with diopside (breccia?).

	172	173	174	175	176	177	178	179	180	181
SiO_2	51.50	49.20	52.20	48.30	49.15	49.20	44.20	42.45	48.15	50.25
Al_2O_3	13.96	11.45	15.30	13.79	14.29	14.12	10.30	10.27	15.15	15.86
Fe_2O_3	1.84	1.48	2.62	2.17	2.39	2.05	3.32	3.72	1.98	1.92
FeO	6.78	7.81	5.03	10.38	10.15	10.07	9.72	9.88	8.24	7.13
CaO	9.75	11.2	10.5	9.08	10.5	10.4	7.77	7.09	10.7	11.7
MgO	10.1	14.1	9.05	10.6	8.07	8.69	19.4	20.7	10.5	7.79
Na_2O	3.17	1.74	2.57	2.11	2.10	2.27	0.62	0.52	2.48	2.93
K_2O	0.35	0.28	0.24	0.19	0.25	0.24	0.07	0.03	0.30	0.36
TiO_2	0.87	0.62	0.47	0.96	1.12	0.94	0.51	0.45	0.65	0.68
P_2O_5	0.13	0.07	0.13	0.09	0.09	0.08	0.06	0.05	0.05	0.04
MnO	0.17	0.18	0.15	0.19	0.20	0.19	0.20	0.18	0.16	0.15
H_2O	1.63	2.05	1.39	1.96	1.89	1.68	3.55	5.11	1.88	1.46
S	0.02	0	0	0.03	0.03	0.04	0.01	0.06	0.01	0.01
CO_2	0.11	0.15	0.07	0.17	0.15	0.07	0.44	0.18	0.18	0.40
Less O ≡ S	0.01			0.01	0.01	0.02		0.02		
TOTAL	100.37	100.33	99.72	100.01	100.37	100.02	100.17	100.67	100.43	100.68
Ni	175	420	146	245	117	140	640	800	210	93
Cr	762	1312	480	196	196	290	220	442	494	384
FeO^*/MgO	0.84	0.65	0.82	1.28	1.16	1.37	0.66	0.64	0.95	1.14

172 Mafic tuff-breccia, northeast end of Laurie Lake (12-6-628-5) medium grained amphibolite matrix and fragments.

173 Mafic/ultramafic rock, northeast end of Laurie Lake (12-6-628-5B), foliated amphibolite (thin unit similar to breccia matrix of 172), probably porphyritic.

174 Mafic tuff(?), northeast end of Laurie Lake (12-6-111-3), feldspar-phyric with a few mafic fragments; medium grained amphibolite.

GABROIC AND ULTRAMAFIC ROCKS (Unit 15, analyses 175 to 181); outcrop belt 'D'

175 Diabase, north end of Tod Lake (12-6-93-4A), base of sill or thick flow; original grain size of 0.7 mm overgrown with amphibole (0.07 - 1.2 mm).

176 Gabbro, north end of Tod Lake (12-6-93-4B), body of sill (175); medium grained amphibolite.

177 Basalt/diabase, north end of Tod Lake (12-6-93-4C), top of sill (175); fine grained, polygonal jointing.

178 Ultramafic rock, north end of Tod Lake (12-6-93-6A), base of differentiated sill, clinopyroxene-, olivine- and spinel-bearing coarse grained amphibolite.

179 Ultramafic rock, north end of Tod Lake (12-6-93-6B), 1 m above base, in olivine-rich layer; sill 178.

180 Gabbro, north end of Tod Lake (12-6-93-6D), body of differentiated sill (178), coarse grained amphibolite.

181 Gabbro, north end of Tod Lake (12-6-93-6E), top of differentiated sill (178), medium grained amphibolite.

	182	183	184	185	186	187	188	189	190	191
SiO_2	77.90	78.15	75.50	57.70	71.20	60.45	55.80	56.90	50.40	48.80
Al_2O_3	11.88	11.59	12.77	14.83	13.57	14.18	18.06	14.16	14.73	15.85
Fe_2O_3	0.51	0.35	0.52	1.85	0.63	1.40	2.30	3.44	2.25	2.05
FeO	1.12	1.08	1.17	9.58	4.20	7.27	6.29	9.50	8.25	9.56
CaO	3.47	3.68	0.76	3.69	1.59	4.10	5.01	5.55	11.53	10.19
MgO	0.22	0.13	0.49	4.38	1.07	5.47	3.05	1.99	7.88	7.94
Na_2O	3.63	3.46	3.49	3.24	4.47	2.96	4.25	5.39	2.05	2.31
K_2O	0.33	0.44	3.93	1.23	1.64	1.52	2.84	0.30	0.40	0.37
TiO_2	0.11	0.10	0.12	1.15	0.46	0.61	0.69	1.17	0.81	0.85
P_2O_5	0.01	0.01	0.02	0.13	0.09	0.09	0.22	0.23	0.13	0.07
MnO	0.05	0.04	0.02	0.10	0.08	0.10	0.15	0.24	0.19	0.19
H_2O	0.35	0.25	0.52	1.70	0.61	1.19	1.06	1.14	1.24	1.39
S	0.02	0.01	0	0.11	0.01	0.06	0.02	0.05	0.05	0.03
CO_2	0.37	0.62	0.18	0.11	0.06	1.10	0.07	0.33	0.15	0.07
Less $O \equiv S$	0.01			0.04		0.02	0.01	0.02	0.02	0.01
TOTAL	99.96	99.91	99.49	99.76	99.68	99.48	99.80	100.37	100.04	99.66
Ni							14	<1	84	84
Cr							544	12	504	176
FeO*/MgO	7.16	10.73							1.30	1.44

FELSIC VOLCANIC ROCKS (Unit 7; analyses 182, 183)

182 Felsic tuff(?), island on east side of Laurie Lake (12-6-217-G), finely granular quartz and feldspar, scattered quartz eyes.

183 Felsic tuff(?), island on east side of Laurie Lake (12-6-217-G2), finely granular quartz and feldspar.

SEDIMENTARY ROCKS, TUFF (analyses 184 to 189)

Unit 1

184 Felsic siltstone, entrance of Laurie River into Tod Lake (12-6-96-G1), very fine mosaic of quartz and feldspar with biotite and muscovite.

Unit 9

185 Greywacke, northeast end of Laurie Lake (12-6-10-G1), compositionally graded bed of hornblende-bearing metagreywacke.

186 Greywacke, northeast end of Laurie Lake (12-6-10-G2), quartz-rich bed.

187 Greywacke, northeast end of Laurie Lake (12-6-13-G2), cummingtonite-bearing hornblendic metagreywacke.

Unit 4; analyses 188, 189

188 Mafic tuff, 300 m east of east-Dunphy Lake (12-7-236), fine grained, cummingtonite-bearing amphibolite.

189 Intermediate tuff, island in the eastern part of Laurie Lake (12-6-214), weakly layered, quartz-bearing amphibolite.

INTROSIVE ROCKS

Gabbro (Unit 12; analyses 190 to 194)

190 Gabbro, 600 m southeast of east-Dunphy Lake (12-7-37-1), recrystallized plagioclase (1 mm laths) with ophitic hornblende aggregates, pseudomorphs after pyroxene.

191 Gabbro, 603 m southeast of east-Dunphy Lake (12-7-37-3), coarse (10 mm) relict grain sizes.

	192	193	194	195
SiO_2	49.40	49.65	47.50	64.35
Al_2O_3	15.07	16.15	16.41	16.00
Fe_2O_3	1.97	1.51	1.86	1.22
FeO	9.22	7.93	9.40	2.79
CaO	10.99	11.77	10.85	3.73
MgO	7.75	7.66	8.57	2.38
Na_2O	2.27	2.22	2.04	4.60
K_2O	0.49	0.33	0.25	2.70
TiO_2	0.86	0.68	0.84	0.45
P_2O_5	0.13	0.09	0.05	0.18
MnO	0.20	0.17	0.20	0.05
H_2O	1.46	1.26	1.35	0.72
S	0.13	0.06	0.01	0.02
CO_2	0.18	0.15	0.29	0.62
Less O ≡ S	100.14**	99.66**	99.62	99.80
Ni	82	76	100	20
Cr	448	368	92	60
FeO*/MgO	1.42	1.21	1.29	1.63

192 Gabbro, 630 m southeast of east-Dunphy Lake (12-7-71-2), relict plagioclase (1 mm) and secondary hornblende.

193 Gabbro, 632 m southeast of east Dunphy Lake (12-7-71-4) scattered, recrystallized plagioclase megacrysts in coarse amphibolite.

194 Gabbro, 1200 m southeast of east-Dunphy Lake (12-7-30-2) relict ophitic texture, plagioclase (1 mm), hornblende after pyroxene.

QUARTZ DIORITE (Unit 16)

195 Hornblende-biotite-quartz diorite, 500 m southeast of east-Dunphy Lake (12-7-40-1), rare plagioclase phenocrysts (up to 1 mm) in a fine grained groundmass of quartz, plagioclase, biotite and hornblende.

**Total includes Cr_2O_3.

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