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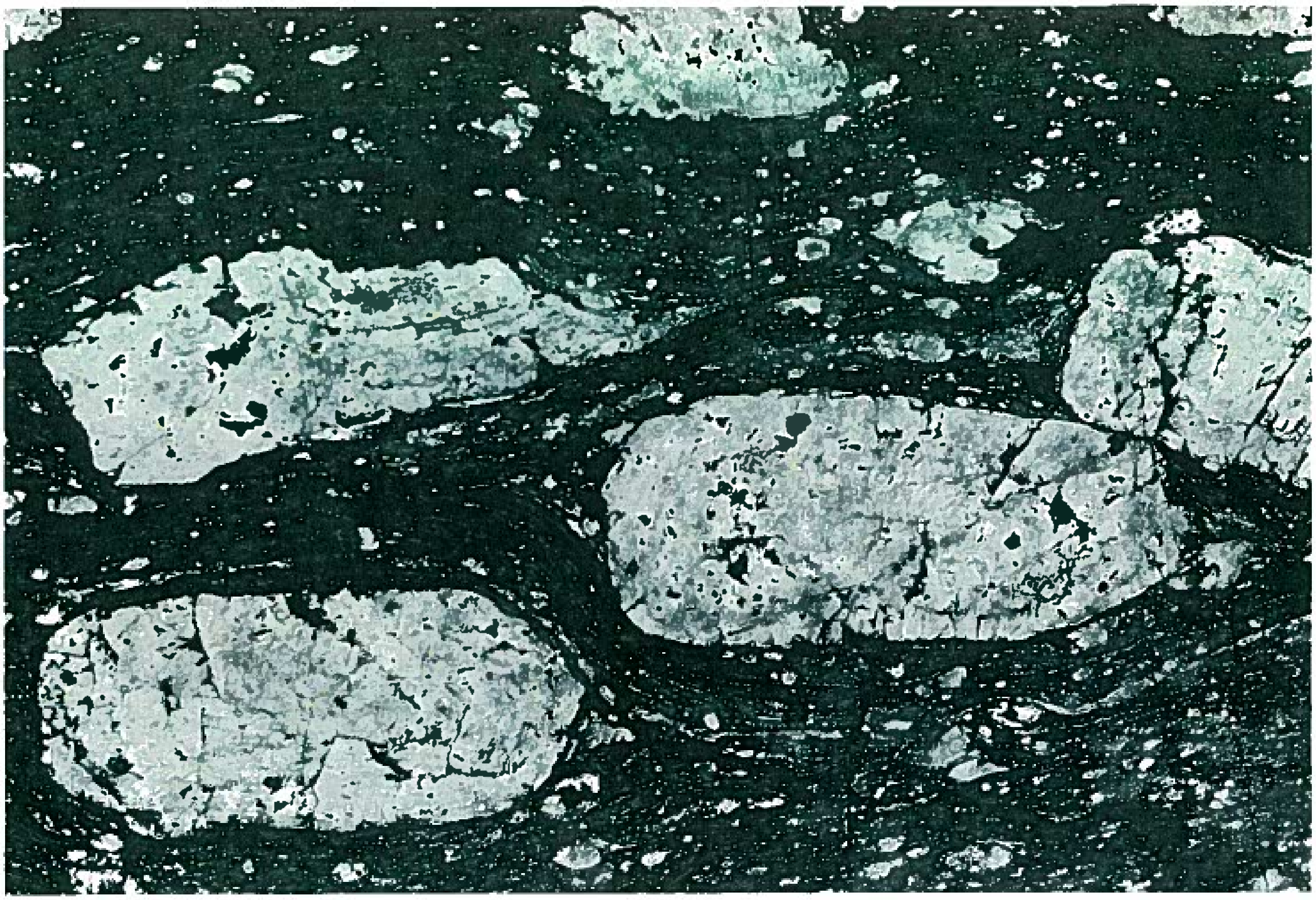
Geology of the
Fitzgerald, Tulip-Mercredi-Charles Lakes district, Alberta

J.D. Godfrey, C.W. Langenberg



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Cover photo: Potassium feldspar porphyroclasts in Recrystallized Mylonitic Rock (223), natural scale.

GEOLOGICAL SURVEY DEPARTMENT, ALBERTA RESEARCH COUNCIL
EDMONTON, ALBERTA, CANADA 1986

Break for lunch on the shore of an inland lake during geological traverses of the Precambrian Shield of northeastern Alberta.

Acknowledgments

In 1975, the field party consisted of Dr. John D. Godfrey, chief geologist; Dr. C. Willem Langenberg and Mervin Rogan, geologists; and Don Macdonald, Ross Nelson, Roger Plouffe, and Kim Wallace, field assistants. Betty (Klewchuk) Macdonald maintained order in the kitchen and fed the crew during the mapping program. The contributions of each member of the field crew are acknowledged and recognized. The support and ready help of Gateway Aviation, Fort Smith, Northwest Territories, and Tracy Leighton, Associated Helicopters Ltd., Edmonton, Alberta, are gratefully acknowledged. Subsequent to the field work, many useful discussions were held with our colleague, Dr. Stephen P. Goff.

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Abstract

The bedrock geology consists of a north-trending belt of Archean granite gneisses in the east that is intruded by an Aphebian granitoid batholithic complex in the west portion of the map area. The migmatitic gneissic belt consists of classic granitic gneisses with minor components of small granitoid bodies, high-grade metasediments, and amphibolite. The granitoid batholith consists of two principal lithologies—the Slave and Arch Lake Granitoids—both of which exhibit a deformed foliation. A major structural feature in the Slave Granitoid body—the Tulip Dome—contains symmetrical screens of narrow high-grade metasedimentary rock bands that define a ghost stratigraphy. Small-scale domal and basinal structures within the north section of the Arch Lake Granitoids suggest proximity to a roofal section and may be related to lateral pressure from an active adjacent Tulip Lake Dome. It appears that the granitoids are ultrametamorphic partial-melt derivatives from the protolithic granite gneisses. The major contact between the granitoids and the gneissic belt is intrusive, with gneissic wall wedges protruding into the granitoids.

The above rocks indicate that the region has undergone a two-cycle polyphase metamorphism. Geochronology and electron microprobe mineral analyses show that an Archean high-pressure granulite facies metamorphism was followed by an Aphebian moderate-pressure granulite facies metamorphism. Mineral assemblages show that the latter retrogressed through amphibolite facies and greenschist facies conditions. From Rb-Sr isochron analyses, the moderate-pressure granulite facies event was dated at 1900 Ma. K-Ar dates on biotite and hornblende reveal that the greenschist facies and closure of the K-Ar system occurred at about 1800 Ma. Those events are coincident with the end of a widespread and severe thermal event (the Hudsonian Orogeny). Regionally, the metamorphic foliation has a northerly trend, but a wide range of variations exists locally, within both the granitoids and the gneissic belt.

The map area is crossed by two north- to northeast-striking, wide regional shear zones. One lies largely within the main granite gneiss belt, and the other forms a complex boundary between the major bodies of Slave and Arch Lake Granitoids. These shear zones are mylonitic and represent a deep-seated environment of ductile shear.

A Pleistocene ice sheet has scoured the region, leaving abundant erosional and depositional evidence of that continental glaciation. The Classical Wisconsin ice sheet flowed almost due west. Its retreat is marked by recessional moraines in the western part of the map area. Aeolian reworking of the typically sandy glacial deposits by southeasterly storm winds resulted in the formation of sand sheets and dunes. Associated wind polish and abrasion can be found on the adjacent bedrock surfaces.

Introduction

This report deals with 1559 km^2 (602 mi^2) of exposed Precambrian Shield in northeastern Alberta. The map area is situated between latitudes 59°45′ and 60°00′N, and longitudes 110°30′ and 111°50′W (figure 1).

The surface of the Precambrian Shield has an overall gentle downslope towards the west. Elevations range from 190 metres (575 ft) at the Slave River up to about 360 metres (1100 ft) eastwards in the interior of the map area. Drainage is predominantly westward to the Slave River lowlands and thence north to the Arctic Ocean. Drainage from Charles Lake is northward through the Thechutheli River which empties into Great Slave Lake and thence north to the Arctic Ocean.

J.B. Tyrrell (1896) made the initial traverse along the north shore of Lake Athabasca in 1892 and 1893, and subsequently F.J. Alcock (1915, 1917) worked in this general area. In 1929 and 1930, A.E. Cameron and H.S. Hicks (Cameron, 1930; Cameron and Hicks, 1931; Hicks, 1930, 1932) conducted reconnaissance surveys of the Shield area north of Lake Athabasca, within Alberta.

After gold was discovered at Goldfields, Saskatchewan, Alcock (1936) returned to map the Precambrian Shield on a scale of 1 inch to 4 miles in the extreme northwest corner of Saskatchewan. Mapping near Fort Smith, Northwest Territories, which adjoins Alberta to the north, was completed in 1938 by J.T. Wilson (1941) on a scale of 1 inch to 4 miles.

In 1954, uranium prospecting activity spread to the Precambrian Shield of Alberta, and G.A. Collins and A.G. Swan (1954) spent several weeks examining mineral prospects at a number of points in the northeastern corner of the province. Low-grade uranium mineralization was found in the course of this prospecting and exploration activity (Ferguson, 1953).

In 1959, the Geological Survey of Canada conducted a reconnaissance geological survey of the Precambrian Shield in Alberta north of Lake Athabasca. The results were published as an uncolored map on a scale of 1 inch to 4 miles, accompanied by notes (Riley, 1960).

In 1960, 1961, 1962, and 1965, the Saskatchewan Department of Mineral Resources (Koster, 1961, 1962, 1963, 1967, and 1971) mapped the northwestern corner of Saskatchewan, adjacent to the eastern boundary of Alberta on a scale of 1 inch to 1 mile.

Uranium exploration activity by Uranerz (Canada) Ltd. in the mid 1970s along a narrow strip of the north shore of Lake Athabasca led to the definition of the Maurice Bay deposit just inside the Saskatchewan boundary. This mining exploration success attracted further geological survey activity in 1978 by C.T. Harper (1978) of the Saskatchewan Geological Survey.

Aeromagnetic surveys conducted by the Geological Survey of Canada were published on a scale of 1 inch to 1 mile and covered the Shield of northeastern Alberta. These maps were later compiled and republished on a scale of 1:250 000 (Geological Survey of Canada, 1964a, 1964b).

Bostock (1982) of the Geological Survey of Canada mapped the Fort Smith area, which adjoins to the north. This information is available in an Open File Report of the Geological Survey of Canada, and includes an uncolored 1:125 000 scale map.

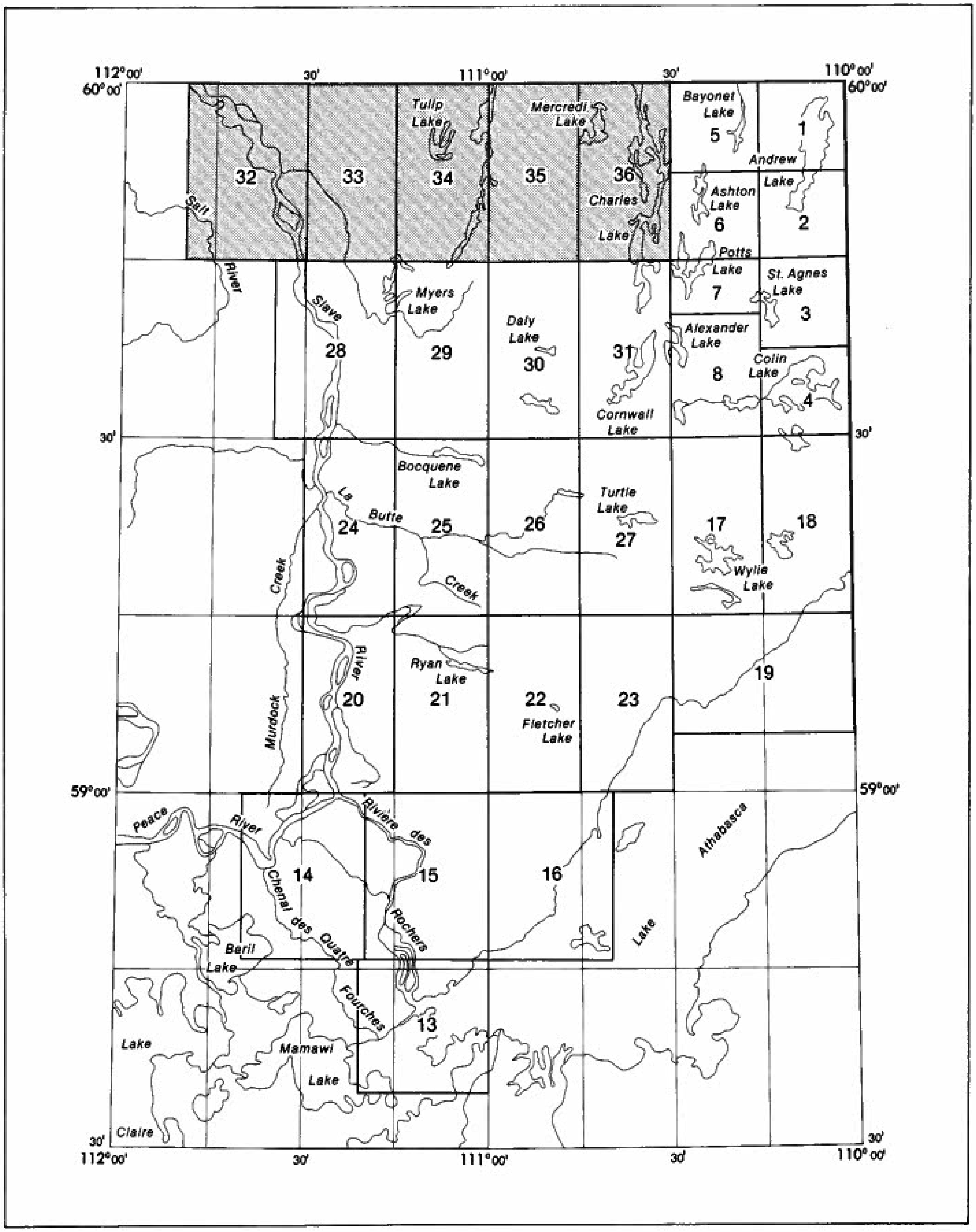


Figure 1. Location of study area, maps 32, 33, 34, 35, 36, the Fitzgerald, Tulip-Mercredi-Charles Lakes district, Alberta, and index to published maps.

In 1957, the Alberta Research Council initiated a Shield mapping program. An air photograph interpretation of geologic structures preceded the field work (Godfrey, 1958a). The Alberta Research Council has subsequently published several district maps and reports in the current series (Godfrey, 1961, 1963, 1966, 1980a, 1980b, 1984, in press; Godfrey and Langenberg, in press; Godfrey and Peikert, 1963, 1964; see figure 1). The field work and publication of district maps and reports are now complete with this publication, the last one in the series.

A number of Alberta Research Council bulletins present syntheses of several aspects of the Shield geology. In particular, the metamorphic history is summarized by Langenberg and Nielsen (1982), and the structural conditions are presented by Langenberg (1983). The geophysical properties of the Alberta Shield have been summarized by Sprenke et al. (in press) whereas the geochemical character and petrogenetic implications are presented by Goff et al. (in press).

Several university theses on various aspects of the bedrock geology have been comleted in the course of the Alberta Research Council's Precambrian Shield program (Piekert, 1961; Watanabe, 1961, 1965; Klewchuk, 1972; Kuo, 1972; Day, 1975; Sprenke, 1985).

Microprobe mineral analyses by Nielsen (1979) and Langenberg and Nielsen (1982) established the metamorphic conditions under which various mineral assemblages have developed and petrogenetic processes have taken place.

A geochronological program with the University of Alberta, under the direction of Dr. H. Baadsgaard, has yielded numerous age dates and allowed identification of significant metamorphic-igneous events in the evolution of the Shield in Alberta. (Godfrey and Baadsgaard, 1962; Baadsgaard et al., 1964, 1967; Baadsgaard and Godfrey, 1967, 1972; Nielsen et al., 1981.)

General geology

The Shield terrain in this map area is a northward continuation of the litho-structural trends and patterns present in the Myers-Daly Lakes district to the south (Godfrey and Langenberg, in press).

The study area is underlain by a Precambrian Shield complex of igneous and metamorphic rocks that lie within the Churchill Structural Province (Davidson, 1972). Two distinct Shield terrains in the map area are the granitoid and granite gneiss terrains (table 1 and figure 2). The map area is dominated by two major plutonic rock masses, composed of the Slave Granitoids and the Arch Lake Granitoids, which together occupy over 85 percent of the map area (table 2). The balance of the map area is made up of granite gneiss, high-grade metasediments, and mylonitic rocks (table 2). The constituent map units within each rock group and the possible genetic relationships are presented in table 3.

Geologic history

The geologic history of this map area is summarized in the form of a stratigraphic column in table 4. The Archean granite gneiss basement complex, comprising 13.5 percent of the map area, is located in the extreme east of the study area. This gneissic complex is intruded by plutonic granitoids which occupy most of the remaining 86.5 percent of the area. The basement granite gneiss complex consists primarily of orthogneisses with subordinate amounts of granitoids, high-grade metasediments, and amphibolites. The formation of these gneisses likely entailed multicycled sedimentation along with polyphase high-grade metamorphism, extensive plutonic intrusion, and deformation. Primary magmatic material was introduced in the form of both granitoid masses and basic dykes, probably during several phases of magmatic activity. Deep-seated events led to major parts of the gneissic belt being migmatized, remobilized, and subsequently mylonitized. Metamorphic mineral assemblages within the high-grade metasediments of the basement gneiss complex contain hypersthene, green spinel, corundum, and sillimanite. The temperature and pressure estimated for this mineral assemblage is 900 ± 100°C and 7.5 ±2 kbar (M_1 of Nielsen et al., 1981). These peak metamorphic conditions, equivalent to moderate-to high-pressure granulite facies metamorphism, existed during development of the ortho-para-gneissic complex.

The Archean age (2.5 Ga) of the Charles Lake Granitoids and gneisses, and their involvement in the Kenoran Orogeny, has been established by a Rb-Sr

Table 1. Principal Precambrian rock groups and the geological terrains (figure 2) in which they occur, Fitzgerald, Tulip-Mercredi-Charles Lakes district, Alberta

Rock Group	Geologic Terrain
granite gneiss mylonitic rocks [high-grade metasediments] [minor granitoids]	A. *Granite gneiss belt* partly migmatitic and mylonitic
Charles Lake Granitoids mylonitic rocks [granite gneiss] [high-grade metasediments]	C. *Charles Lake granitoid belt*
Arch Lake Granitoids [minor granitoids] [high-grade metasediments] [mylonitic rocks]	L. *Arch Lake granitoids*
Slave Granitoids [minor granitoids] [high-grade metasediments] [mylonitic rocks]	S. *Slave granitoid*

[ ] minor component

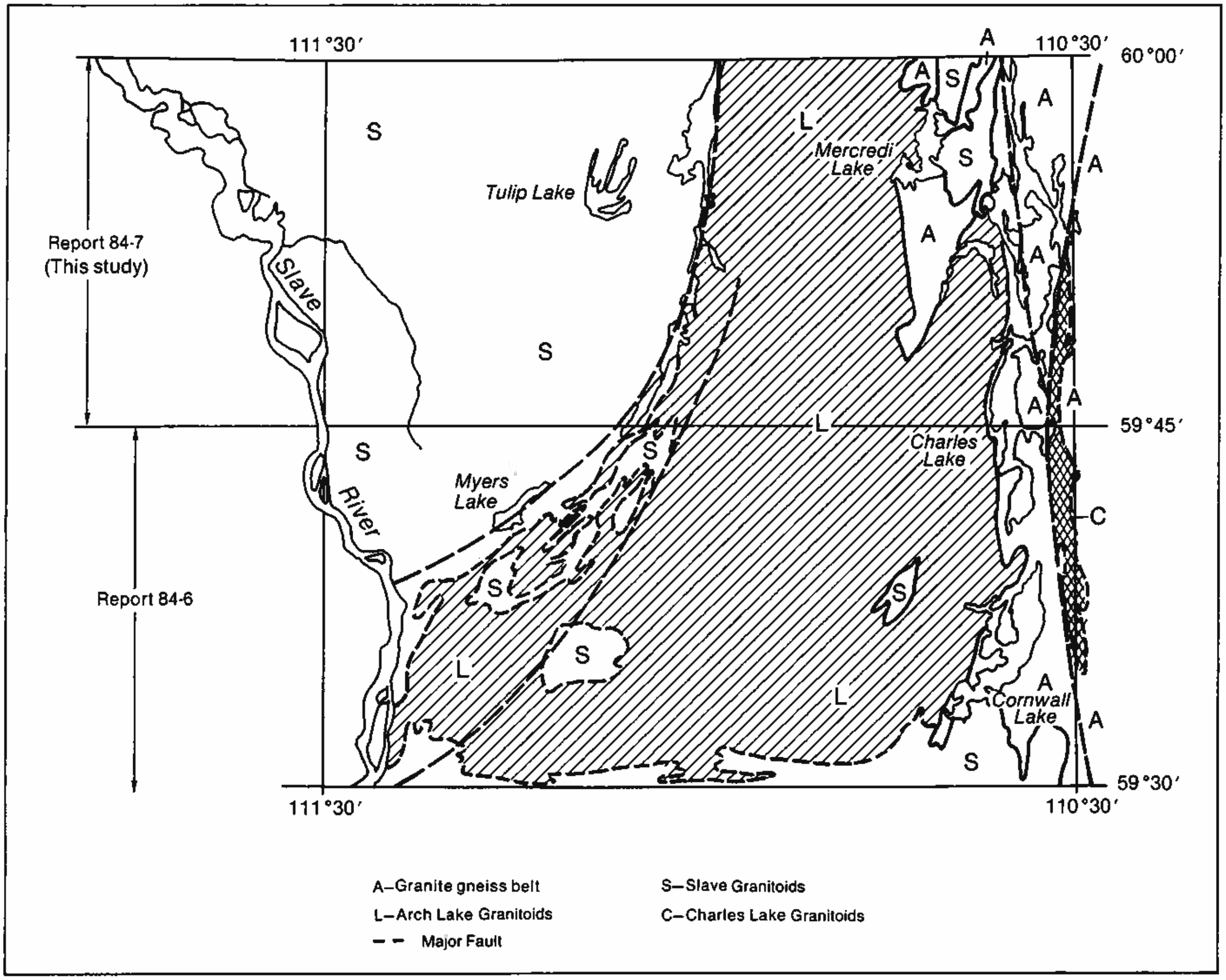


Figure 2. Sketch map of principal geologic terrains

whole-rock isochron on pegmatites cutting the granitoids from the gneissic belt at Charles Lake (Baadsgaard and Godfrey, 1972).

In thin section, cordierite and almandine either enclose or replace the granulite facies mineral assemblage (representing the M_1 event), thereby showing that the rocks were subsequently subjected to lower grade metamorphic conditions (Godfrey and Langenberg, 1978a). Emplacement of the Slave and the Arch Lake Granitoids is associated, and coincident with, prevailing moderate-pressure granulite facies metamorphic conditions ($M_{2.1}$ of Nielsen et al., 1981) during the Hudsonian Orogeny.

Emplacement of the combined Slave-Arch Lake Granitoid masses resulted in a granitoid body that was probably mantled and walled by the basement gneisses. All of the granitoid masses probably originated as remobilized infrastructure materials. The conditions of emplacement are estimated by Nielsen et al. (1981) to have been 740 ±30°C and 5.0 ±0.7 kbar; that is, they were moderate-pressure granulite facies conditions. These conditions are interpreted as a second phase of metamorphism, rather than as retrograde effects of the first metamorphic phase ($M_{2.1}$ of Nielsen et al., 1981). Mineral assemblages in various rocks of the region indicate a retrograde metamorphism through low-pressure amphibolite facies (estimated to be 550 ±55°C and 3.0 ±0.3 kbar; $M_{2.2}$ of Nielsen et al., [1981]), and a greenschist facies ($M_{2.3}$ of Nielsen et al., [1981]).

The moderate-pressure granulite facies conditions ($M_{2.1}$) represent the culmination of the Hudsonian Orogeny and have been dated with Rb-Sr at 1900 Ma

Table 2. Percentage aerial composition of the Fitzgerald, Tulip-Mercredi-Charles Lakes district by rock type and rock group. Covered areas are interpreted on the basis of an aeromagnetic survey

Granite gneiss	9.0
Slave Granitoids	55.5
La Butte Granitoid	trace
Arch Lake Granitoids	29.0
Charles Lake Granitoids	1.0
High-grade metasediments	3.5
Mylonitic rocks	2.0

Table 3. Principal Precambrian rock groups, constituent rock units and their field associations, Fitzgerald, Tulip-Mercredi-Charles Lakes district, Alberta

	Rock Groups				
Mylonitic Rocks	**Granite Gneisses**		**High-Grade Metasedimentary Rocks**		**Granitoid Rocks**
	Amphibolite ↑		Amphibolite ↑		Amphibolite ↑
Derived from all other rock groups	Granite Gneiss	+	Granitic Metasedimentary Rocks Metasedimentary Rocks	→	Arch Lake Granitoids La Butte Granodiorite Charles Lake Granitoids
	[Granite Gneiss]	+	Granitic Metasedimentary Rocks Metasedimentary Rocks	→	Slave Granitoids

↑ intrusive relationship
→ Close field (and possible genetic) relationships
[ ] Less significant component of parent materials

Table 4. Summary of geologic history of the Shield in the Fitzgerald, Tulip-Mercredi-Charles Lakes district, Alberta

Geologic Age	Rock Units/Groups	Predominant Rock Type	Process/Event	
Recent	Fluvial and lacustrine deposits	Sand, silt, mud	Sedimentation	
Pleistocene	Glaciofluvial/lacustrine	Till, sand, silt	Continental glaciation	
Devonian	Elk Point Group and older	Carbonates	Marine sedimentation	
Aphebian			Regional Faults (e.g. Allan Fault) and mylonitization Metamorphism $M_{2.3}$ (greenschist facies)	Hudsonian Event
	La Butte Granodiorite	Granodiorite, (quartz diorite)	Basic dykes Metamorphism $M_{2.1.2}$ (granulite - amph.facies)	
	Arch Lake Granitoids	Granite (granodiorite)	Remobilization	
	Slave Granitoids	Granite (granodiorite)	Migmatization Plutonic intrusion	
Archean	Charles Lake Granitoids	Granite, granodiorite	Basic dykes	Kenoran Event
		Amphibolite	Plutonic intrusion Granitization	
		Metasedimentary Rocks		
		Hornblende Gr. Gneiss	Metamorphism M_1 (granulite facies)	
		Biotite Granite Gneiss	Sedimentation	

(Baadsgaard et al., 1964, 1967; Baadsgaard and Godfrey, 1967, 1972; Nielsen et al., 1981). Generation of the granitoid bodies is linked with intense metamorphism and partial melting of the belt of combined granite gneisses and high-grade metasedimentary rocks. Large masses of the crystal-melt granitic product were mobilized and separated from the granite gneiss-metasedimentary belt to form plutons and batholiths. Small amounts of segregated granitic material remain within the parent migmatitic belt as either dispersed fragments or masses that are large enough to be mapped. An intimate mixture of the parent metamorphic and the derived granitic materials in some places points to an early stage in the segregation process.

The structural and lithological characteristics of the two major granitoid bodies—the Slave and Arch Lake Granitoids—differ markedly. The Slave Granitoids pluton is structurally dominated by the highly elongate, smoothly outlined Tulip Lake Dome that gives rise to a fairly regular northnortheast-trending metamorphic foliation. Bands of high-grade metasedimentary rocks parallel to foliation characterize the otherwise uniform lithology of the Slave Granitoids. Concentric bands of high-grade metasedimentary rock around and within the Tulip Lake Dome suggest residual (protolithic) screens or even ghost stratigraphy. By contrast, the Arch Lake Granitoids in the south (Daly Lake map area) resembles a structurally complex synform, but in the north (Mercredi Lake map area), small-scale domes and basins dominate the structure and completely disrupt any regular orientation of the foliation. Lithologically, only a few minor lenses of high-grade metasediments and granite gneisses are scattered throughout the otherwise uniform granitoids.

The smooth foliation outline and simple structure of the Tulip Lake Dome suggests that it was the last actively inflating (intruding) structural element in the granitoid rock mass. The immediately adjoining structures of the Arch Lake Granitoids (characterized by curved, partly to completely closed foliation of dome and basin structures) suggest that it was laterally compressed by the inflating Tulip Lake Dome, and that this led to secondary mobilization of Arch Lake Granitoids and formation of the small-scale domes and basins.

The southern extent of the small-scale domes and basins of the Arch Lake Granitoids coincides with the southern end of the Mercredi Lake granite gneiss wedge. The latter would appear to form the east abutment of the compression of Arch Lake Granitoids by the inflating Tulip Lake Dome. Adjoining to the east, the major apophysis of Arch Lake Granitoids extending into the Arch Lake region would appear to be the result of a forceful intrusion of viscous (largely solid) Arch Lake Granitoids.

At the eastern edge of the map area, the contact of granite gneiss with Arch Lake and Slave Granitoids (figure 2) is a classical intrusive contact. Several rounded apophyses of granitoids penetrate the mantling gneisses, leaving alternate, angular screens and wedges of granite gneiss projecting into the invading granitoids.

The southern and western contacts of the Arch Lake Granitoids against the Slave Granitoids are a complete contrast in style. In the southern contact, a delicate and complex intertonguing of parallel extensions of each granitoid unit penetrates the adjoining mass. From this boundary it appears that there was interfolding or mixing of two highly viscous media. The western contact lies within the wide Warren Fault Shear Zone, whereas the simpler southern contact appears to be tectonically unaffected. The interpretation is that:

1. The granitoid/granite gneiss contact is a relatively hot/cold body contact. The hot granitoid is intruding upwards into the descending colder, and therefore more rigid, rock mass. This contact is characterized by wedging of the mantling gneisses by the intruding granitoid (solid plus melt phases).
2. The granitoid/granitoid contact is a hot/hot contact. Both of the upward intruding rock masses are heat sources, and therefore their contact displays more plastic-ductile features of deformation, which have an especially complex geometry in the vicinity of the Warren Fault Shear Zone (Tulip Lake and Myers Lake map areas).

Subsequent to the formation of the crystalline basement gneissic complex and Aphebian granitoids, there have been at least four phases of regional sedimentation in the region (the first two phases are not found as outcrops in this particular map area):

1. Aphebian-Proterozoic low-grade, metasedimentary Burntwood Group;
2. Helikian Athabasca Group;
3. Devonion carbonates; and,
4. Pleistocene glacial sediments.

Prolonged uplift and erosion preceded deposition of the Helikian Athabasca Group (Ramaekers, 1979, 1980; Wilson, 1985) sediments. The largely continental Athabasca Group has not been seen in outcrop in the map area. However, as discussed by Godfrey (in press), it is hypothesized that outliers of Athabasca Group sandstone may underlie extensive glacial sandy areas. There is a general decrease in the incidence of extensive glacial sandy deposits with distance away (northward) from Lake Athabasca, where the nearest exposures of the Athabasca Group are found (Godfrey, 1980b, 1984; Wilson, 1985). There is little likelihood of locating Athabasca Group sandstone outliers in the present map area. Sandy areas associated with the glaciofluvial-lacustrine deposits at Charles Lake, and in the Slave River lowlands, are probably not related to underlying Athabasca Group sandstones.

A second extensive period of uplift, resulting in erosional stripping of much of the Athabasca Group rocks, preceded transgression of the Devonian seas. Middle Devonian carbonates unconformably overlie the crystalline basement complex in the extreme western portion of the map area. Exposures of carbonates in the vicinity of the Slave River have flat to gently dipping beds. These Devonian strata thicken to the west where they underlie Wood Buffalo National Park.

A third long period of uplift and erosion preceded the Pleistocene Continental Glaciation. This glaciation has been the most significant recent geological event in the region, and resulted in a generally high proportion of bedrock outcrop and only minor scattered glacial deposits, with the exception of the lowlands along the Slave River, which are dominated by late glacial meltwater deposits and recent alluvium.

Map units

Rock unit classification

Most of the primary structures and textures of sedimentary and igneous origin in the crystalline basement complex have been obscured or lost entirely in the course of polyphase high-grade metamorphism, recrystallization, remobilization, partial melting, intrusion, and polyphase deformation. Mixed rock assemblages, and wide, gradational contact zones, are evident both in outcrop and on the regional scale. This relationship can be seen both in terms of granitoid/granitoid and granitoid/granite gneiss contacts. The principal map units shown in the accompanying colored geological maps depict the predominant rock unit within the given outcrop area. Of necessity, the minor, smaller-scale variations of lithology are largely not represented on the maps.

To permit critical petrological, geochemical, and geophysical comparison, and classification of map units, certain hand specimens are designated as standard reference samples. These standard samples represent as nearly as possible the typical lithology of each map unit observed in the field. Standard samples of granitoid, gneissic, mylonitic, and metasedimentary rock are listed in tables 5 to 14 inclusive (appendix) along with their modal and major element analyses. Field locations of these standard samples are shown on the accompanying geological maps.

Granite Gneisses

The Granite Gneisses are characteristically banded in outcrop. However, the banding ranges widely in quality from distinct to indistinct, and it is locally absent. This metamorphic banding can be planar in geometry, or wavy to contorted, as in migmatitically associated structures. Individual bands can be fairly continuous, or discontinuous to streaky, and either well or poorly defined (as in the case of mafic-poor, felsic orthogneisses). In appropriate cases, by looking at very low angles of incidence along the outcrop surface, it is possible to discern the continuity of an individual band from long, attenuated plastic flow folds where the limbs have come into direct contact. Such folds can extend for a metre or more in length.

The granite gneiss terrain typically contains subordinate small granitoid masses. The composition and texture of the small granitoid masses are similar to the principal granitoid rock units of the region (Slave, Arch Lake, and Charles Lake Granitoids). Where the masses are large enough, they are shown as granitoid rocks.

The Granite Gneisses are typically composed of quartz-feldspar layers alternating with mafic-rich layers or foliae, which are usually rich in (chloritic) biotite, and which locally contain hornblende. The gneisses are typically medium grained overall, with the felsic mineral layers being noticeably more abundant and coarser grained than the intervening mafic-rich layers. Chloritization of biotite is usual, and epidote veinlets are present locally. Quartz veins, pods, and pegmatite masses are fairly common. Isolated grains of allanite and concentrations of magnetite in streaks parallel to the foliation have been noted.

Amphibolite and high-grade metasediments are common as minor components of the granite gneiss terrain. Usually they occur as small lenses or bands parallel to foliation.

On a regional scale, the Archean Granite Gneisses are found primarily in two belts and appear to mantle the major granitoid plutons. The east gneissic belt is continuous and has been intruded by the Arch Lake Granitoids. Apophyses of granitoids protrude into the gneissic belt and wedges or pendants of the gneisses extend into the granitoids. Lenses and shreds of gneiss along with high-grade metasedimentary rocks occur in a second belt (at Leland Lakes) that separates the major Slave Granitoids body from the Arch Lake Granitoids.

Major regional shear zones—the Allan and Warren Faults—both cut granite gneiss belts. They both contain very extensive mylonitic zones, primarily affecting the gneisses but also crossing the neighboring granitoids. Minor lenses and patches of granite gneiss are also found within the major granitoid bodies, principally the Arch Lake Granitoids. These gneissic lenses are interpreted as screens which have been dragged along by the granitoid masses as the latter were mobilized from deeper levels.

Biotite Granite Gneiss (11)

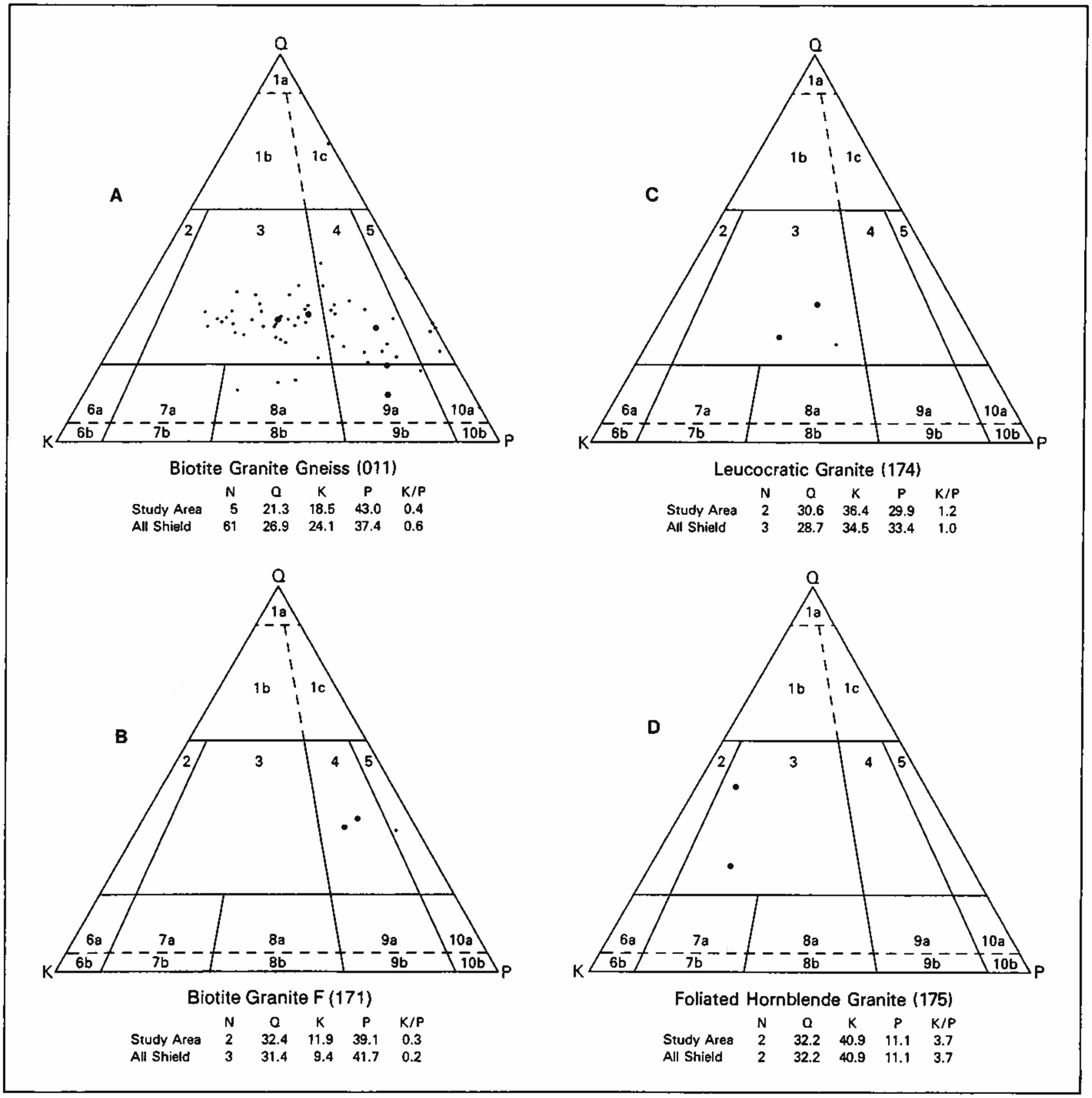
Biotite Granite Gneisses are typically composed of quartz-feldspar layers alternating with biotite-rich mafic layers or foliae that locally contain minor amounts of hornblende. Chemical and modal analyses of five typical samples are presented in table 5 (appendix). The Q-K-P plot in figure 3a shows that the composition ranges largely from granitic to granodioritic.

Hornblende Granite Gneiss (12)

In northeastern Alberta, Hornblende Granite Gneisses are much less abundant than are their biotite counterparts. These two rock units are similar in petrologic and structural character. In the hornblende-bearing gneisses, mafic layers are rarely without some biotite, although the reverse is not necessarily the case for the Biotite Granite Gneisses. Magnetite is more common in the hornblende gneisses than in the biotite gneisses.

Amphibolite (20)

Amphibolite is present in each of the major geologic terrains, rock groups, and a variety of host rocks. They are most abundant in the belt of combined granite gneiss and high-grade metasediments, and notably scarce in the granitoid rocks. The widespread distribution and variety of host rock associations in this igneous-metamorphic terrain suggests that amphibolites were emplaced and/or generated under a range of geologic conditions and times. Major bodies of amphibolite have not been found in the map area. Nowhere do they develop thicknesses indicative of either a volcanic origin or a major plutonic mass. Their origins probably involve both metamorphic and igneous processes. Chilled contacts have not been observed; however, such features could be readily obliterated through a subsequent history of deformation, metamorphism, and recrystallization. Narrow amphibolite lenses and bands are common in the granite gneisses, typically from 0.7 to 3 m thick, and from 2 to over 6 m long. They typically trend parallel to the foliation and are situated within a metamorphic environ-



A: Biotite Granite Gneiss (011)

	N	Q	K	P	K/P
Study Area	5	21.3	18.5	43.0	0.4
All Shield	61	26.9	24.1	37.4	0.6

C: Leucocratic Granite (174)

	N	Q	K	P	K/P
Study Area	2	30.6	36.4	29.9	1.2
All Shield	3	28.7	34.5	33.4	1.0

B: Biotite Granite F (171)

	N	Q	K	P	K/P
Study Area	2	32.4	11.9	39.1	0.3
All Shield	3	31.4	9.4	41.7	0.2

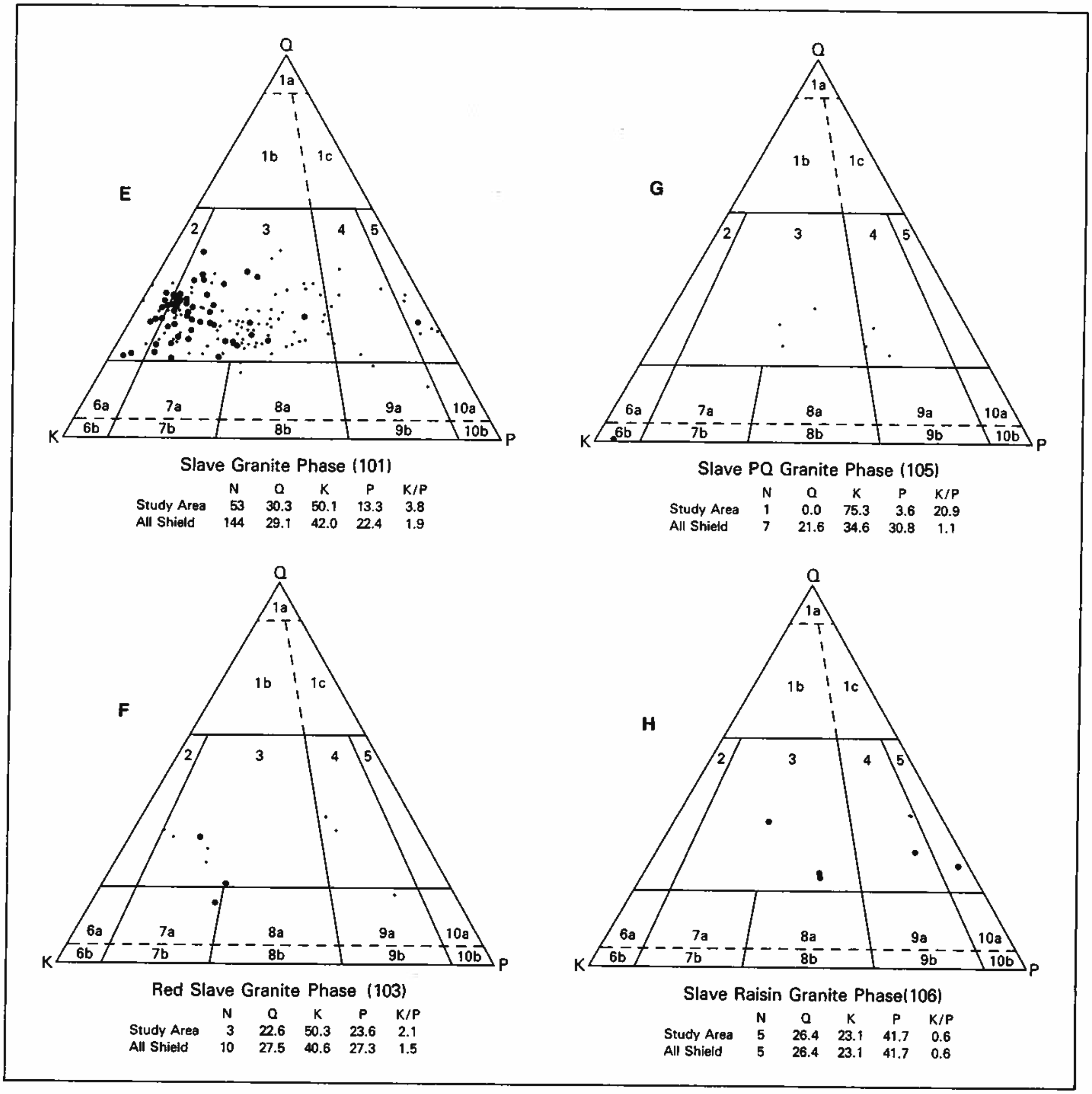
D: Foliated Hornblende Granite (175)

	N	Q	K	P	K/P
Study Area	2	32.2	40.9	11.1	3.7
All Shield	2	32.2	40.9	11.1	3.7

Figure 3. Ternary quartz-potassium feldspar-plagioclase (Q-K-P) plots for granitoids and gneisses in the study area, and for the remainder of the Shield in Alberta

ment of ductile to plastic deformation. Most amphibolite bodies appear to be discontinuous and probably represent either boudinage basic dykes and sills, a fragmented restite accumulation, or an agmatitic pegmatite complex within granite gneiss or metasedimentary rocks.

Massive amphibolites are dark green on a freshly broken surface, and weather to a greenish gray. Gneissic banded varieties weather to alternating green and white to pink layers. Feldspars stand out selectively in high relief on a weathered surface, giving the amphibolite the false appearance of being a much more felsic rock. Hornblende and feldspar are the principal minerals, with minor amounts of biotite and chlorite. Veinlets of epidote and quartz are locally present. As the proportion of hornblende decreases, amphibolite grades to either Hornblende Granite Gneiss (12) or to basic metasedimentary rock. The grain size of amphibolite ranges from fine to coarse, although hornblende crystals greater than 5 mm are relatively uncommon. The texture ranges from massive to foliated to banded, the latter two textures being most common. Many of the banded varieties consist of bands from 10 to 25 mm thick, in which alternating layers differ in



Slave Granite Phase (101)

	N	Q	K	P	K/P
Study Area	53	30.3	50.1	13.3	3.8
All Shield	144	29.1	42.0	22.4	1.9

Slave PQ Granite Phase (105)

	N	Q	K	P	K/P
Study Area	1	0.0	75.3	3.6	20.9
All Shield	7	21.6	34.6	30.8	1.1

Red Slave Granite Phase (103)

	N	Q	K	P	K/P
Study Area	3	22.6	50.3	23.6	2.1
All Shield	10	27.5	40.6	27.3	1.5

Slave Raisin Granite Phase(106)

	N	Q	K	P	K/P
Study Area	5	26.4	23.1	41.7	0.6
All Shield	5	26.4	23.1	41.7	0.6

Figure 3 (continued). Ternary quartz-potassium feldspar-plagioclase (Q-K-P) plots for granitoids and gneisses in the study area, and for the remainder of the Shield in Alberta

their hornblende to feldspar ratio. Chemical and modal analyses of 12 standard samples are given in table 6 (appendix).

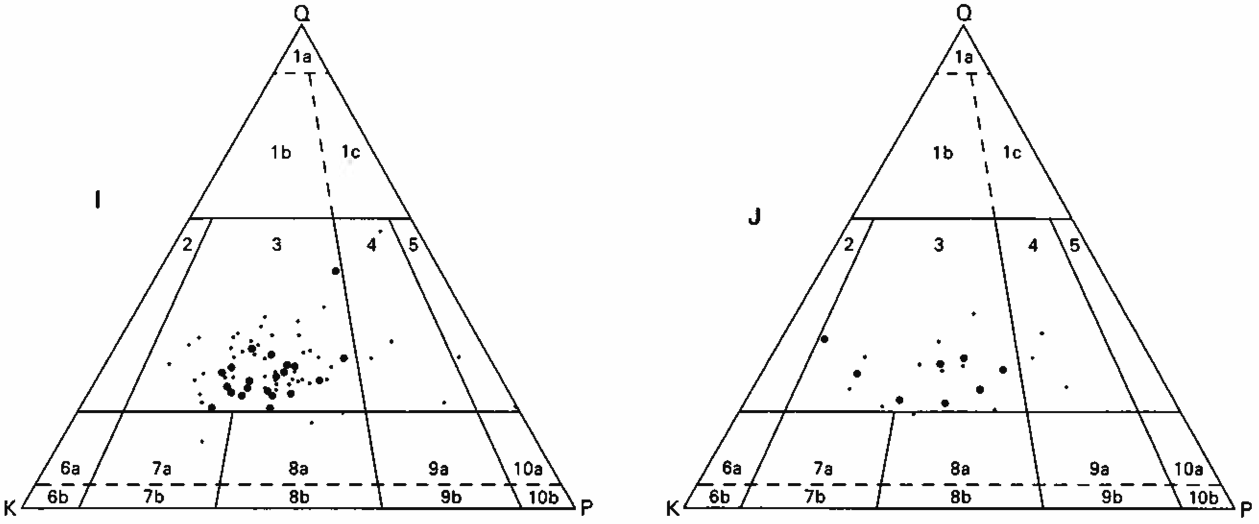
Many of the amphibolites, particularly in the granite gneiss and high-grade metasedimentary rock terrains, have a rusty weathering surface. This phenomenon is probably related in part to small amounts of pyrite.

The less-recrystallized, less-deformed amphibolites, particularly those which have recognizable dyke-like relationships within granitoid host rocks, are probably the youngest igneous rocks in the map area.

High-grade metasedimentary rocks (31)

The high-grade metasedimentary rocks are present as relatively minor lenses and bands within the granite gneiss and granitoid terrains. The largest band lies along the Warren Fault at Leland Lakes.

The high-grade metasedimentary rock bodies are typically elongated, forming bands and lenses in plan view. Their long axes are aligned with the regional structural trend (usually northerly). In outcrop, the metasedimentary rock structures show generally



Arch Lake Granite Phase (161)

	N	Q	K	P	K/P
Study Area	21	25.9	39.4	29.1	1.4
All Shield	70	27.1	36.3	29.5	1.2

Arch Lake Granite Transitional Phase (162)

	N	Q	K	P	K/P
Study Area	8	26.6	41.0	29.1	1.4
All Shield	22	26.6	37.3	30.5	1.2

1a	Quartz rocks
1b	Quartz granite
1c	Quartz granodiorite
2	Alkali granite
3	Granite
4	Granodiorite
5	Quartz-diorite
6a	Quartz-bearing alkali syenite
6b	Alakali syenite
7a	Quartz-bearing syenite
7b	Syenite
8a	Quartz-bearing monzonite
8b	Monzonite
9a	Quartz-bearing monzodiorite
9b	Monzogabbro
10a	Quartz-bearing (diorite, gabbro)
10b	Diorite, gabbro, norite, anorthosite
●	Samples from study area
•	Samples from remainder of shield in Alberta
N	Number of Samples

Figure 3 (continued). Ternary quartz-potassium feldspar-plagioclase (Q-K-P) plots for granitoids and gneisses in the study area, and for the remainder of the Shield in Alberta

steeply dipping isoclinal folds, which are locally crenulated and are particularly intricate and chaotic (due to flow folding) in migmatitic sections. Gneisses and granitoids enclosing the metasediments are commonly much less deformed. Such structural relationships indicate greater deformational mobility (plasticity) of the metasedimentary rocks compared to the host gneisses or granitoids.

The high-grade metasedimentary rocks are dominantly quartzo-feldspathic with subordinate amounts of schist, phyllite, and amphibolite. Mineral assemblages reveal that these rocks have been subjected to conditions of high-grade metamorphism. Almandine is usually observed in outcrop, and hypersthene, green spinel, sillimanite, and cordierite are visible under the microscope. The metasedimentary rocks are commonly pyritic and typically have a rusty, weathered appearance. Locally the rust may be sufficiently extensive to be termed a rusty zone, or in the extreme case, a gossan. Chemical and modal analyses of standard samples appear in table 7 (appendix).

The outstanding structural feature of high-grade metasedimentary rocks in outcrop is the fairly regular relict sedimentary banding. However, this banding becomes more disrupted and therefore less continuous with an increase of metamorphic quartzo-feldspathic material. At the same time, the rock becomes less sedimentary and more granitoid in appearance. Where the granitic component is not prominent, the metasedimentary rocks are typically well foliated, color banded, or both.

Prograde metamorphism of the metasediments to a maximum of granulite facies conditions is indicated by the presence of hypersthene, green spinel, and sillimanite (Godfrey and Langenberg, 1978a; Langenberg and Nielsen, 1982). The development of metamorphic quartzo-feldspathic material (and possibly igneous material) is expressed in a variety of ways:

- isolated feldspar porphyroblasts;
- quartzo-feldspathic concentrations as clusters, pods, and irregular patches;
- pegmatites with either conformable or cross-cutting relationships;
- migmatitic to gneissic phases; and
- minor granitoid bodies, with local biotite-rich schlieren or granitized metasedimentary rock.

The lithologic end products range gradationally from regularly banded metamorphic rocks of obvious sedimentary parentage to rocks that contain a high proportion of metamorphic quartz and feldspar. In outcrop, the latter rocks are termed granitoid-migmatite and granitic pegmatite.

Amphibolite bands, 0.5 to 2 m thick, are fairly common in the metasediments and generally parallel the metamorphic foliation.

Sulfide mineralization is common in the metasedimentary rocks. Pyrite, by far the most abundant sulfide mineral, is associated with rusty zones. Minor copper (chalcopyrite), molybdenite, graphite, and uranium have been noted in adjacent map areas. Such mineralization can be expected to be found here also, if these metasedimentary bands are thoroughly prospected. Narrow, milky white quartz veins and pods, either singly or in groups, are usually barren of sulfide mineralization.

The granitoid rocks

This group of crystalline rocks includes all of the granitoid[1] rock units. Together, granitoids make up 85.5 percent of the map area. There are essentially two broad groupings based on genetic affinities; the Slave and the Arch Lake Granitoids. The individual masses range in size from more than 40 km to less than 1 km across. Most of the granitoids are of Aphebian age, as shown by radiometric dating, with the exception of the Archean Charles Lake Granitoids. The Archean age of these granitoids is indicated by dated pegmatites cutting the granitoids (Baadsgaard and Godfrey, 1972).

Charles Lake Granitoids

The Charles Lake Granitoids form part of the Archean basement gneiss complex. This belt has a unique mix of gneisses and intrusive granitoids not seen elsewhere in the Shield of Alberta. These granitoids include Biotite Granite F, Charles Lake PQ Granite, Gray Hornblende Granite, Leucocratic Granite, and Foliated Hornblende Granite. Minor bodies of Slave and Arch Lake Granitoids also occur in this area. The Charles Lake Granitoids have a diverse character and are grouped together because of their Archean age. Two of these granitoids—Gray Hornblende Granite and Foliated Hornblende Granite—have not been mapped elsewhere in the Shield of Alberta. The north-south linear belt of Archean gneisses has a pronounced northerly foliation which is parallel to, and lies within, the mylonitic regional Allan Fault Shear Zone. The granitoid bodies themselves tend to be markedly elongate and parallel the metamorphic foliation. This helps to emphasize the northerly tectonic fabric of this belt.

Biotite Granite F (171)

Biotite Granite F underlies about 0.5 percent of the map area. It is confined to the granite gneiss belt of the Charles Lake region.

On both fresh and weathered surfaces, Biotite Granite F appears mottled, with large pink to white and gray feldspar megacrysts enclosed in the gray granular matrix. Both texture and composition tend to be homogeneous for this map unit. The subhedral to euhedral potassium feldspar megacrysts range from 2.5 to 12 cm long, averaging about 5 cm. They may be either subparallel or randomly oriented in the coarse-grained massive matrix of quartz, feldspar, and biotite.

Minor quartzo-feldspathic segregations occur as scattered, irregularly shaped aplite and pegmatite masses that are usually too small to be mapped.

A distinctly or consistently well-oriented texture is largely lacking in Biotite Granite F. The matrix may be either massive or poorly foliated, and the feldspar porphyroblasts are either subparallel or randomly arranged in the matrix. The rock composition is in the granodiorite to quartz diorite fields (figure 3H). Two chemical and modal analyses appear in table 8 (appendix).

There is a gradation in texture between Biotite Granite F and Recrystallized Mylonitic Rock (223), and therefore an arbitrary boundary has been established in order to differentiate these two rock units. The massive to poorly foliated matrix of Biotite Granite F grades to the foliated, finer-grained, crushed matrix of Recrystallized Mylonitic Rock (223).

Biotite Granite F does not generally come in direct contact with granite gneiss in the map area. Usually an envelope of high-grade metasediments separates Biotite Granite F from the granite gneisses. Plastic flowage within both the Biotite Granite F and its mylonitic derivative, Recrystallized Mylonitic Rock (223), is especially apparent in the adjoining map area to the south (Godfrey and Langenberg, in press). Folds are indicated within both Biotite Granite F and its mylonitic counterpart. A highly folded contact of the mylonite with granite gneiss appears in the southern section of the map area.

Gray Hornblende Granite (173)

This rock unit is of limited distribution, and generally is locally present as small bodies in close association with Recrystallized Mylonitic Rock (224).

On both fresh and weathered surfaces, Gray Hornblende Granite is buff to gray with small dark specks of mafic mineral. Hornblende porphyroclasts from 2 to 3 mm in size make up from 1 to 4 percent of the rock. They are enclosed in a typically fine- to medium-grained, quartzo-feldspathic matrix. As a rule the matrix is massive, but a slight foliation can be locally present. Uncommon feldspar porphyroclasts range from 6 to 12 mm in size.

Gray Hornblende Granite grades to Recrystallized Mylonitic Rock (224) on a scale visible in outcrop. Though the main bodies of Gray Hornblende Granite are outlined on the maps, there are other bodies within the Recrystallized Mylonitic Rock (224) that are too small to be represented.

Internal structures are either absent or poorly outlined by foliation, and are simple in form. External contacts with either Recrystallized Mylonitic Rock (224) or Hornblende Granite Gneiss (12) are gradational and mostly interlensed.

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[1] The term granitoid is used as a general field term, insofar as the granitoid plutons and rock units collectively, and in some cases individually, represent a range in composition. Some plutons and rock units range from granite to quartz diorite or to granodiorite, whereas others have a more restricted compositional range. See figure 3 and table 3 for details.

Gray Hornblende Granite is apparently the parent material for Recrystallized Mylonitic Rock (224). However, it is possible that some phases of Gray Hornblende Granite could result from an advanced stage of recrystallization of the mylonite. The character of the contacts with other rocks depends on the intrusive history of the Gray Hornblende Granite and the adjacent rock, and the subsequent metamorphic-deformational history.

Leucocratic Granite (174)

Leucocratic Granite is present as dispersed, small bodies within most of the crystalline rock groups of the map area. Most of the Leucocratic Granite masses lie in the regionally north-trending zone centered on Charles Lake. The larger masses are situated west of Charles Lake.

The Leucocratic Granite is light gray to pink to red on both fresh and weathered surfaces. This medium- to coarse-grained massive granite consists of equigranular feldspar and quartz along with about 3 percent mafic minerals. Although the granite is typically massive, lenticular-rodded quartz provides a local foliation-lineation. Minor microgranite and pegmatite phases are present. Two chemical and modal analyses are given in table 8 (appendix), and figure 3 shows that the composition is granitic.

Small patches and bands of granite gneiss, amphibolite and metasedimentary rocks are present in the otherwise uniform Leucocratic Granite. Contacts of the Leucocratic Granite against granite gneiss are generally sharp, although interlensed contact zones are also present. These granitoid/granite gneiss contacts are interpreted as being intrusive.

Although interpretation of the east portion of the map area is based primarily on recent mapping, information from an earlier phase of mapping (Godfrey, 1966), has also been used. Since 1966, a change in classification and terminology has led to one discrepancy in the reclassification of Leucocratic Granite (174). There is good reason to believe that this older established map unit may, in part, be a phase of the currently recognized Slave Granitoids. Detailed radiometric dating is needed to separate the Archean Leucocratic Granite (174) from the Aphebian Slave Granitoids.

Foliated Hornblende Granite (175)

This distinctive rock unit occurs in two masses: a major body in the main peninsula on the east side of Charles Lake, and a small band west of Charles Lake that crosses into the Northwest Territories.

Foliated Hornblende Granite is typically pink on weathered surfaces and pink to gray on fresh surfaces. A weathering characteristic of this rock unit is the relatively well-developed, uniform exfoliation layer, up to 10 to 12 cm thick on glacially smoothed outcrops. This rock is composed of pink feldspar and quartz with streaky patches of hornblende and minor biotite concentrations. These mafic aggregates provide a poorly to well-developed foliation in an equigranular, medium- to coarse-grained texture. Though typically foliated, the mafic mineral aggregates can also be rodlike in shape, imparting a lineation to the granite. Minor, moderately developed banding or gneissosity is related to local shear deformation. Other local textural variations include fine-grained (aplitic) massive phases of pegmatite. The outstanding feature of this rather homogeneous rock is the streaky foliation produced by aligned plates of mafic mineral aggregates that are 2 to 3 cm long. Two chemical and modal analyses are given in table 8 (appendix), and the Q-K-P plot in figure 3J shows that the rock composition is granitic.

Large inclusions of dioritic to amphibolitic composition are present as blocks up to 10 m across. Lenses of amphibolite and granite gneiss are typically elongate and aligned in the foliation of the granite.

The foliation is commonly tightly folded, and such structural complexities are especially evident along the folded contacts with granite gneiss. This rock unit has probably intruded the granite gneiss, with structures reflecting post-intrusion plastic deformation.

Slave Granitoids

The Slave Granitoids dominate the western part of the map area and is the most abundant rock unit in the entire exposed Shield of Alberta. The lithologic and structural characters of the granitoids are relatively simple compared to those of the granite gneiss belt. Nonetheless, the Slave Granitoids contains numerous patches that are possible screens and lithologic gradations to Arch Lake Granitoids and metasedimentary rocks.

The internal structure is dominated by the north-northeasterly elongated Tulip Lake Dome. There are other smaller-scaled domal structures and flexures within the granitoids. Despite the fold structures, the metamorphic foliation varies little from the smooth, regional north-northeasterly trend.

Subordinate masses of Arch Lake Granitoids and high-grade metasedimentary rocks are common in the Slave Granitoids. Derivation of the Slave Granitoids by the partial melting of a granite gneiss/metasediment protolith (possibly dominated by metasediments) seems the most plausible petrogenetic path. This suggestion is based on field observations, stated by Nielsen et al. (1981), and is supported by the geochemical studies of Goff et al. (in press).

Slave Granite Phase (101)

The Slave Granite Phase has a limited textural and compositional range. The overall color is fairly light, typically gray to white, but ranging to pink or mauve pink. The characteristically massive, medium-grained texture locally displays fine- and coarse-grained variations. The typical uniform grain size is locally megacrystic, with 15 to 30 mm long white feldspars comprising up to 15 percent of the rock. The rock is characteristically garnetiferous, with (chloritic) biotite envelopes around garnet cores. These mafic knots (clots) are about 5 mm in diameter and are generally dispersed throughout the rock masses (up to 4 percent in abundance). This rock unit is placed in the granulite facies (Godfrey and Langenberg, 1978a; Langenberg and Nielsen, 1982), based on the presence of microscopic green spinel. (Hypersthene and corundum have also been seen outside of the map area in the Slave Granitoids.) Dispersed small flakes of graphite have been noted locally. Chemical and modal analyses of standard samples are presented in table 9 (appendix). The Slave Granite is predominantly granitic with minor deviations to granodiorite, quartz diorite, and alkali granite (figure 3B).

Red Slave Granite Phase (103)
This rock unit is similar to Slave Granite Phase in mineralogical and textural features, but has a distinct pinkish red appearance. It is gradational between gray, pink, and mauve phases. It may be locally mixed with Slave Granite Phase, making up a minor component of about 10 to 20 percent of an outcrop. Typically leucocratic, garnets in mafic knots make up from 1 to 5 percent abundance; porphyroblastic feldspar from 20 to 30 mm across make up 5 to 20 percent abundance. The matrix is medium- to coarse-grained with a typically weak foliation, though quartz is commonly rodded. Although (chloritic) biotite typically forms less than 1 percent of the rock, higher local concentrations provide a better-defined foliation. Intimate mixtures with aplo-pegmatite are localized. The principal rock composition is granite with minor variations to granodiorite (figure 3). Chemical and modal analyses of this rock unit are presented in table 10 (appendix).

Red Slave Granite generally has gradational and locally intrusive contacts with a number of other rocks, including granitoids, aplites, high-grade metasedimentary rocks, and granite gneiss. Blocks of migmatitic metasedimentary rock and granite gneiss have been seen in the Red Slave Granite. It is possible that Red Slave Granite is a late magmatic phase of the Slave Granitoids. It injected and intruded earlier-formed granitoid phases, and, as a minor (about 20 percent) magmatic component, it may have facilitated massive intrusion of the Slave Granitoids. Its intermediate composition between Slave Granite and Arch Lake Granite, looking similar to Arch Lake Transitional Granite, emphasizes a genetic link between the Slave and Arch Lake Granitoids.

Slave PQ Granite Phase (105)
A member of the Slave Granitoids, Slave PQ Granite is noted primarily for its reddish pink to pink color and the presence of red feldspar megacrysts from 6 to 12 mm across. Biotite, at 3 to 5 percent abundance, contributes to a foliated and even gneissic matrix, although there are also locally massive phases. Small lenses and bands of apparently metasedimentary rock are typical of this rock unit. The predominant rock composition is granite with gradations to granodiorite (figure 3D). One chemical and modal analysis of this rock unit is presented in table 10 (appendix). In the field, Slave PQ Granite exhibits gradational and intrusive contacts with other granitoid rock units, and it contains blocks of other granitoids, such as Arch Lake Granite. Thus, Slave PQ Granite could be a late magmatic phase of the Slave Granitoids. It also shows a tendency to be migmatitic, and even gneissic, to the point where it could be mistaken for a felsic granite gneiss or a migmatitic gneiss in a small outcrop. This latter observation suggests that Slave PQ Granite is the product of partial melting from the parent Archean granite gneisses, and locally shows evidence of its protolithic gneissic origin.

Raisin Granite Phase (106)
This rock unit is confined to the northeast section of the map area, just west of Charles Lake. It is closely associated with Slave Granitoids and appears to be a product of dynamo-metamorphism formed in the environment of the mylonitic Allan Fault Shear Zone.

The rock is mottled pink to red in a dark background on both weathered and fresh surfaces, but the typical raisin texture is best seen on a weathered surface. The rock name is derived from a distinctive 'raisin-textured' appearance of white to pink to red, rounded to subrounded, equidimensional feldspars that are 2 to 6 mm long. They make up 50 to 70 percent of the rock, and are enclosed in a sheared, foliated, green matrix. The matrix is a mixture of lenticular quartz, biotite, chlorite, sericite, and epidote. The raisin-textured megascopic appearance corresponds to a flaser structure seen under the microscope. Local minor variations include a poor foliation where biotite is unaltered to the exclusion of chlorite, and hornblende and feldspar megacrysts are inconspicuous. The metamorphic foliation tends toward gneissic banding where shearing is particularly evident.

Rare mafic xenoliths, up to 2 m long, and small lenses of impure ferruginous quartzitic metasediment were noted in the Raisin Granite. Xenoliths are aligned in the foliation of the Raisin Granite. Rarely, amphibolite or hornblendite in the contact area with granite gneisses appear to have developed an incipient raisin texture. Small, discontinuous patches and layers of "raisin-type texture" were also noted in the adjacent granite gneiss. Raisin Granite has an interfingering contact with granite gneiss, which is interpreted as intrusive.

The common occurrence of sericite with biotite and chlorite in the matrix, the rounded, granulated feldspars, and the generally sheared, flaser texture of this foliated rock suggest that dynamo-metamorphic effects are widespread but not necessarily uniform throughout much of the mass.

Chemical and modal analyses of standard samples are presented in table 11 (appendix). The ternary plot of figure 3 shows that the Raisin Granite composition is typically granite, but ranges to granodiorite and quartz diorite (figure 3E).

La Butte Granodiorite (140)
This rock unit is characterized by a generally uniform color and texture. The color ranges from a light to medium gray through brownish gray to mauve (resulting from a combination of blue quartz plus pinkish gray feldspar). The texture is typically medium grained with feldspar megacrysts from 8 to 20 mm long and from 0 to 5 percent in abundance. The matrix is typically massive and uncommonly poorly foliated or locally gneissic, consisting principally of feldspar, quartz, and biotite. Rock composition ranges from granite to granodiorite, quartz diorite, and quartz monzodiorite, with a mean composition of granodiorite. Chemical

and modal analyses are presented in Godfrey (in press). La Butte Granodiorite crops out almost exclusively within the Bocquene-Turtle Lakes map area of the Shield in northeastern Alberta (Godfrey, in press). In the present map area, La Butte Granodiorite is principally and intimately associated with the marginal phase of the Slave-Arch Lake Granitoids situated within the Warren Fault Shear Zone. Minor patches of La Butte Granodiorite also occur in the Slave Granitoids that are due east of the confluence of the Dog and Slave Rivers. Outcrops of La Butte Granodiorite commonly show the presence of other minor phases of the Slave Granitoids (for example, 10 percent of the Red Slave Granite), which could be minor magmatic phases that facilitated emplacement of La Butte Granodiorite. Boudins of metasedimentary rock are typical within the La Butte Granodiorite. Hematitic staining, characteristic along fractures within the La Butte Granodiorite, is interpreted as a late-stage alteration feature.

Arch Lake Granitoids

Arch Lake Granitoids are found in a variety of associations: as a major plutonic mass, small irregular patches and lenses within the granite gneiss, and small lenses in the Slave Granitoids in the western granitoid terrain of the map area.

Arch Lake Granite Phase (161)

The Arch Lake Granite Phase is overall reddish in outcrop and is distinctly foliated, both in outcrop and in hand specimen. This penetrative foliation is usually accompanied by a mild granulation. The rock texture is fairly homogeneous and typically medium grained, except where locally coarse. It consists of up to 25 percent feldspar megacrysts which are from 15 to 30 mm long. The megacrysts are commonly aligned in the foliation, giving an augen texture. The matrix consists of pink to red feldspar, biotite, and characteristically blue quartz. Chemical and modal analyses of this rock unit are given in table 12 (appendix). The rock composition is dominantly granite with minor variations into the granodiorite and quartz diorite fields (figure 3F).

Arch Lake Granite Transitional Phase (162)

The Arch Lake Granite Transitional Phase is a subtype of the Arch Lake Granite Phase and it is distinguished by the absence of large (15 to 30 mm long) potassium feldspar megacrysts. However, a smaller size range of potassium feldspar megacrysts, about 15 mm long, constitute up to 5 percent of the rock. Chemical and modal analyses are given in table 13 (appendix). A Q-K-P compositional plot (figure 3G) shows the principal rock type to be granite with minor variations to granodiorite.

Regional Shear Zones

Wide shear zones with mylonitization have affected three regions in the map area. In the east, a belt of granite gneisses and minor granitoids have been affected in the 2 to 3 km wide Allan Fault (Godfrey, 1958a). In the west, Slave and Arch Lake Granitoids, and high-grade metasediments, have been caught up in the Warren Fault Zone, about 1 km wide. A third mylonitic shear zone, about 2 km wide, passes through Mercredi Lake and principally affects granite gneisses with minor granitoids. All these mylonitic shear zones trend northerly and form part of a much larger network of regional shear zones extending easterly into Saskatchewan (Koster, 1961, 1962, 1963, 1967, 1971) and northwards into the Northwest Territories (Bostock, 1982). Although they were probably continuous originally, each of the principal mylonitic shear zones in Alberta have been subsequently reshaped and fragmented by a combination of plastic-ductile deformation, and brittle shear along transverse and longitudinal faults. The south end of the Mercredi Lake mylonitic shear zone is abruptly terminated 19 km south of the Northwest Territories boundary by a subparallel cross-fault.

Within the shear zone, mylonitization has generated deformational products ranging from ultramylonite/mylonite to less-sheared phases of flaser gneiss. All of these sheared rocks have been affected by recrystallization to some extent, resulting in the formation of blastomylonites and the commonly observed porphyroclastic-augen feldspars in a typically streaked or banded matrix.

Mapping indicates that the parent materials for the mylonitic rocks are dominantly gneisses and Arch Lake Granitoids, with lesser amounts of high-grade metasedimentary rocks, Biotite F, Foliated Hornblende Granite, Leucocratic Granite, and Slave Granitoids. The compositional and textural fabric of these mylonitized zones has a planar geometry. The planar form can be seen on scales ranging from hand specimens to outcrops, and to belts several kilometres along strike (as viewed on air photographs).

The regional mylonitic shear zones have been studied by Watanabe (1965), Godfrey (1966, 1980b, 1984, in press), and Langenberg (1983). It is evident that the structures are associated with deep-seated shear zones, and the mylonitic deformation is essentially of a ductile nature. Subsequent to erosional unroofing, further deformation was of a localized but brittle nature, involving brecciation and quartz-vein filling. The age of the major mylonitization has been fixed by K-Ar dating at 1790± 40 Ma ago. These mylonite shear zones are characterized by greenschist facies minerals (Langenberg and Nielsen, 1982).

Rocks of the mylonitic group underlie 2 percent of the map area. All of the three shear zones—the Warren and Allan Fault Zones and the Mercredi Lake Zone—extend beyond the map area farther to the north.

The color and megascopic texture of the mylonites, together with gradational contacts to less-deformed phases of the rocks, were used to develop a field classification of mylonitic rocks that is both descriptive and genetically meaningful in terms of their parental relationships. In a few cases, distinctions between the mylonites have not been clear. The parent materials themselves, at least in the gneissic terrain, are already mixtures of rock types on a fairly detailed scale, and further blending is introduced by mylonitization. An overlap or gradation of geologic character among these mylonites in outcrop or hand specimen is inevitable, but the uncertainty is a very minor one.

The mylonitic group is subdivided on the basis of its protolithic equivalents as follows:

- Mylonitic Rock 221 has largely granite gneiss parent material.
- Mylonitic Rock 222 has largely high-grade metasediment parent material.
- Mylonitic Rock 223 has largely granitoid parent material.
- Mylonitic Rock 224 has largely Gray Hornblende Granite parent material.

Recrystallized Mylonitic Rock (221)

Recrystallized Mylonitic Rock (221) is pale pink to red or dark greenish on both fresh and weathered surfaces. White to pink feldspar porphyroclasts from 6 to 18 mm in size make up to a maximum of about 5 percent of the rock. The augen-shaped porphyroclasts may have trails of smaller feldspar crystals and fragments that are enclosed in a foliated aphanitic, finely banded matrix. Although metamorphic foliation has a generally simple geometry in outcrop, folds can be clearly demonstrated on a regional scale. Five chemical and modal analyses are given in table 14 (appendix).

Small amounts of other rock units from the mylonite group are mixed in this map unit on a scale too fine to be distinguished separately on the present scale of mapping. As the bodies become smaller, distinction between rock types and map units becomes more difficult.

Recrystallized Mylonitic Rock (221) is always enclosed by, and associated with, a rock assemblage typical of the granite gneiss terrain. The contact with rocks of the granite gneiss belt—gneisses, metasedimentary rocks, and amphibolite—is commonly gradational. It is obvious that granite gneiss was the predominant parent material from which Recrystallized Mylonitic Rock 221 was developed.

Recrystallized Mylonitic Rock (222)

This mylonitic rock is present at Mercredi Lake and in both the Warren and Allan Fault Shear Zones.

Fresh and weathered surfaces are dark green to gray to black, and freshly broken surfaces can be vitreous. Minor porphyroclasts of feldspar, and more rarely quartz, are enclosed in a siliceous, banded, massive to foliated, aphanitic to schistose or phyllitic matrix, with chlorite, biotite, and sericite.

Geometrically simple metamorphic foliation structures and gradational crushed and shear contacts follow the pattern described for other mylonites of granite gneiss and granitoid rock associations. It is apparent that quartzo-feldspathic metasedimentary rocks with minor schistose material and basic rocks are the parental materials of the Recrystallized Mylonitic Rock (222).

Recrystallized Mylonitic Rock (223)

Members of this mylonitic rock unit are found in the central Mercredi Lake mylonite band, the Warren Fault Zone in the west and the Allan Fault Zone in the east.

Fresh and weathered surfaces are medium to dark gray. White to gray feldspar augen and euhedral porphyroblasts from 1 to 7 cm in size make up from 5 to 15 percent of the rock. The matrix is typically aphanitic and foliated, and is locally medium-grained and schistose. Minor aplites and pegmatites are present as small bodies which conform somewhat irregularly to the main structural trend. Five chemical and modal analyses are given in table 14 (appendix).

Foliation patterns have a generally simple geometry in outcrop, but on a regional scale they grade from simple forms in the north to distinctly folded and more complex forms in the south. The mylonite contact with quartzo-feldspathic metasedimentary rock is typically interlensed and is gradational both texturally and mineralogically over a short distance. Recrystallized Mylonitic Rock (223) surrounds, and is completely gradational with, uncrushed cores of Biotite Granite F. Granite gneiss in contact with the Recrystallized Mylonitic Rock (223) becomes less contorted and more mylonitic, and the size of feldspar porphyroclasts gradually increases from 1 to 7 cm as the mylonite boundary is approached. Bands of granite gneiss from 0.3 to 3 m wide can be recognized in the contact zone, where felsic and mafic layers of the parent gneiss remain distinct in the mylonitic granite gneiss.

Recrystallized Mylonitic Rock (224)

Recrystallized Mylonitic Rock (224) is confined to the Allan Fault mylonitic band. This rock unit is always closely associated with either Gray Hornblende Granite or Hornblende Granite Gneiss.

Recrystallized Mylonitic Rock (224) weathers to distinctive, large, flaggy, rectangular slabs from 8 to 15 cm thick. Fresh and weathered surfaces are typically grayish green and may possess a delicate pinkish hue in places. The obvious minerals include epidotized hornblende porphyroclasts up to 3 mm in size making up to 7 percent of the rock, and feldspar porphyroclasts from 12 to 18 mm in size making up 5 percent of the rock. The matrix is fine grained, foliated to poorly banded, and comprised of quartz, feldspar, and chloritized biotite. The Recrystallized Mylonitic Rock (224) is distinguished by lack of banding and the characteristic presence of hornblende porphyroclasts. Two chemical and modal analyses are given in table 14 (appendix).

Recrystallized Mylonitic Rock (224) is present as narrow bands oriented in the regional structural trend, proximal to the probable hornblendic parent rocks (Hornblende Granite Gneiss and Gray Hornblende Granite). It is lithologically homogeneous in that xenolithic lenses and masses were not noted in the field. Uncommon, typically medium-grained massive phases of the mylonite generally cover areas that are too small to be represented on the map; nonetheless, they are classified as Gray Hornblende Granite. They are coarser grained than the associated mylonite and appear to result from an advanced stage of recrystallization. Metamorphic foliation and lineation have a simple geometry both in outcrop and on the regional scale. Contacts with Recrystallized Mylonitic Rock (221), Gray Hornblende Granite, and Hornblende

Granite Gneiss are fairly well defined in the field, although they can be gradational over a metre or so.

Devonian carbonate rocks (251)

Middle Devonian and/or earlier-age carbonates rest with profound unconformity on the weathered surface of the Precambrian crystalline basement complex. Carbonate rocks which crop out along the Slave River at the extreme western margin of the map area have been described in detail by both Norris (1963) and Richmond (1965). Very little Paleozoic carbonate was found in this map area. Superior outcrops are available in the adjoining map area to the south (Norris, 1963; Richmond, 1965; Godfrey and Langenberg, in press). One occurrence of carbonate was noted just on the northeast side of the settlement of Fitzgerald, but the section is small and relationships with the underlying Precambrian are not exposed. This carbonate outcrop could belong to the La Loche Formation.

Modal and chemical analyses

Mineralogical and chemical data on the rock units in the map area are presented in tables 5 to 14 (appendix). Representative specimens were chosen from all of the major rock groups—the gneissic, granitoid, mylonitic, and high-grade metasedimentary map units. Selection of standard hand specimens for detailed analyses was based on their representative character as seen in outcrop. The gneissic and granitoid standard samples are represented by individual hand specimens. However, because of the typically wide lithological variations encountered within the metasedimentary rock bands, each standard sample for the high-grade metasedimentary rocks is represented by a combined group of 5 to 10 specimens. Ideally, metasedimentary standard rock samples were collected on traverses approximately perpendicular to the regional strike of the compositional banding (see geology maps in pocket).

Modal analyses for the gneissic and granitoid rock units are plotted on a series of Q-K-P diagrams (figure 3). Modal data from the present study area are distinguished on figure 3 from those of the same rock units from other parts of the exposed Shield of Alberta. Rock type boundaries in these diagrams are plotted according to the recommendations of Streckeisen (1967).

Field work, geochemical (Goff et al., in press), and geochronological studies, all strongly suggest that the Archean basement gneiss complex was the protolithic material from which the younger granitoids were derived. High-grade regional metamorphism of these gneisses led to partial melting. The range in modal composition of granite gneisses and high-grade metasediments does not include the plagioclase-poor to -absent area corresponding to the alkali feldspar granite members of the Slave Granite (101, figure 3e). Hence, complete melting does not appear to be a likely genetic path for the generation of these rock compositions. However, partial melting of the assumed parent materials would be expected to generate end products of potassium-rich composition similar to those of the Slave Granite (Lameyre and Bowden, 1982). Based on the compositional norms for the abundant rock units (for example, granite gneiss, Slave Granitoids, and Arch Lake Granitoids) the Q-K-P diagrams indicate divergent lines of granitoid evolution and segregation from the parent granite gneisses. The intimate field relationship of minor granitoid masses with the granite gneiss/high-grade metasedimentary belt supports the petrogenetic concept of parent gneissic material and derived granitoids. This concept is supported by a geochemical study by Goff et al., in press. The Granitoids probably consisted of a solids-dominated, crystal-melt mush during intrusion. Therefore, much of the restite component produced by the partial melting of the gneiss could form a crystal suspension within the melt. The restite would be represented by calcic plagioclase cores enclosed by mafic-rich zones. Classic intrusive relationships (irregular dykes and screens adjacent to and seemingly enclosing large-scale blocks) have been observed. Although similar in composition, the magmatic components tend to be more leucocratic than the blocks.

Mafic Slave Granite (102) is part of the continuous compositional gradation from Slave Granite to Arch Lake Transitional and Arch Lake Granites. In terms of our present geochemical view of the petrogenesis of the granitoids, this rock unit (102) could contain more of the restite resulting from partial melting of the granite gneisses than does the dominant lithology of the Slave Granitoids. The latter is higher in Si and K. In the Arch Lake Granitoids, the melanocratic Francis Granite is likewise a possible restite-rich component.

The intimate field relationships of the minor leucocratic components (the irregular dykes and patches within the Slave, Mafic Slave, Arch Lake, and Arch Lake Transitional Granitoids) is a product of late-stage leucosome (magmatic) segregation and mobilization. The widespread occurrence of a leucosome phase in each of the granitoid complexes (Slave, Arch Lake, Wylie and Colin; Godfrey and Langenberg, 1978a) points to a common petrogenetic history for these granitoids.

Scattered, small bodies of amphibolite are believed to be derived by metamorphism and structural extension and dislocation of diabase dykes and basic metamorphic segregations.

The high-grade metasedimentary rocks are typically retrograde quartzitic granulites with compositions corresponding to arkosic graywackes. The chemical composition of the metasedimentary rocks tends to be low in CaO, MgO, and Na_2O, and high in K_20, relative to worldwide averages for graywackes. These differences, at least in part, are probably retained and reflected in the locally high K_2O content of the derived major granitoid masses of Slave and Arch Lake affinity in the Shield of northeastern Alberta.

In summary, it is apparent that the basement gneiss complex has been partially molten, mobilized, segregated, and recrystallized during formation of the suite of Slave and Arch Lake Granitoids.

Metamorphism

The regional metamorphic history is summarized in Godfrey and Langenberg (1978a), Nielsen et al. (1981), and Langenberg and Nielsen (1982).

Metamorphic events in the Shield of northeastern Alberta have been identified and dated with geochronology, using a variety of radioactive systems and isotopes (Godfrey and Baadsgaard, 1962; Baadsgaard et al., 1964; Baadsgaard and Godfrey, 1967, 1972). Two principal metamorphic events have been defined (Langenberg and Nielsen, 1982):

1. An Archean high-pressure granulite facies metamorphism, M_1, is indicated by relic hypersthene, sillimanite, green spinel, and corundum in the Slave Granitoids and high-grade metasediments.
2. An Aphebian moderate-pressure granulite facies metamorphism, M_2, which affected all the Shield rocks of Alberta, coincided with the intrusion of the granitoids.

The Aphebian M_2 Event is associated with an assemblage of almandine, hornblende, cordierite, and andalusite. The moderate-pressure granulite maxima of the M_2 Event has been traced by electron microprobe mineral analysis to retrogress through the amphibolite facies, and ultimately the greenschist facies. The latter is represented by a fairly ubiquitous assemblage of chlorite, muscovite, and epidote. Chlorite is usually seen as an alteration product of biotite, hornblende, or garnet, whereas epidote typically occurs as veinlets.

No remnant of an Archean metamorphism has been found in the Arch Lake Granitoids. Occasional garnet and hornblende indicate that formation of these granitoids was under moderate-pressure granulite conditions. These conditions were probably achieved during the Hudsonian Orogeny and coincided with the emplacement of most of the granitoids in the Shield of northeastern Alberta.

Development of the regional mylonitic shear zones —the Allan and Warren Fault Zones—is related to greenschist facies conditions, presumably a late stage of the Hudsonian Orogeny.

Structural geology

An overview of the structural geology of the Shield in northeastern Alberta has been published by the Alberta Research Council (Langenberg, 1983).

A foliation is developed in all of the igneous-metamorphic rocks of the Alberta Shield: the granitoids, granite gneisses, and high-grade metasediments. Thin sections show that this foliation is formed by the alignment of elongated lenses of platy quartz, micas, and flattened feldspars, indicative of a dynamometamorphic origin. Regional structures are defined by the foliation. One of the most obvious is the Tulip Lake Dome (Langenberg, 1983; Langenberg and Ramsden, 1980). The diapirism of the dome is dated by the age of the Slave Granitoids at about 1900 Ma (Nielsen et al., 1981). Co-existing metamorphic minerals enclosed in high-grade metasediments indicate that the doming occurred under moderate-pressure granulite facies conditions ($P = 5.1 \pm 0.7$ kbar and $T = 750° \pm 30°C$). The Mercredi Lake map area contains the northern continuation of the Hooker Lake Basin in the Arch Lake Granitoids from the Daly Lake map area (Godfrey and Langenberg, in press). A separate structure, the Arch Lake Dome, is outlined partly by the shape of the body of water named Arch Lake. The Mercredi Lake granite gneiss pendant or wall wedge forms a synclinal zone between the Arch Lake Dome and several mild domo/basinal structures west of Arch Lake. All these structures are related to the same phase of deformation.

Doming is a consequence of Archean basement reactivation resulting from heating on a regional scale. The heating also led to partial melting, anatexis, and separation of the S-type Slave, Arch Lake, and La Butte Granitoids. These granitoids were emplaced at higher crustal levels by the process of diapiric doming.

Tight to isoclinal mesoscopic folds in the migmatitic granite gneisses and metasediments are not found in the granitoids. These granite gneiss folds, transected by the intruded granitoids, are assigned to the Archean because dating shows an Archean age for the basement gneiss complex (Baadsgaard and Godfrey, 1972).

Several major mylonitic shear zones are evident in the map area. The Allan Fault Shear Zone is located at Charles Lake in the extreme eastern part of the Mercredi Lake map area. The curved Warren Fault Shear Zone, passing through Leland Lakes, forms the boundary between the Arch Lake and Slave Granitoids masses.

Faulting along the large-scale (regional) shear zones is younger than the domal structures, because some of the shear zones transect or truncate the domes and basins. The regional shear zones are characterized by mylonites with greenschist facies minerals (Langenberg and Nielsen, 1982). K-Ar dating of these minerals shows that the mylonites formed 1790 ± 40 Ma ago. In outcrop, the deformations of the mylonitic rocks are seen as ductile shear phenomena of varied intensity, rather than brittle fracture. These deformations are contained principally, but not exclusively, within the granite gneisses.

Recrystallization has affected all the rocks in the area, and in the mylonitic zones the combination of processes has produced a range of comminuted rocks and textures—mylonites, ultramylonites, blastomylonites, and less-sheared phases such as flaser gneisses. Subsequent minor megabrecciation of the mylonite has produced localized quartz-filled fractures and quartz-lined vugs.

Transverse brittle faults in the map area strike easterly, northwesterly, and southwesterly. They probably formed late, although some of these faults may have originated synchronously with the shear zones, as indicated by their parallelism with the shears. Other faults cut the shear zones and therefore are younger. Other commonly arcuate faults parallel the foliation within the Arch Lake Granitoids.

A series of northeast-striking transverse faults can be seen in Shield rocks in the extreme western part of the map area. Though poorly exposed, these faults appear to have regional significance and probably continue southwestward beneath the Paleozoic cover rocks. They coincide with several major sets of spectacular falls and rapids where they cross the Slave River. The river level falls a cumulative height of about 35 m over the length of the rapids section (25 km), suggesting downthrow to the northwest side of the northeast-striking faults. The location has attracted interest and has been periodically under review as a potential hydroelectric power damsite.

A fairly representative selection of joints is given on the accompanying geological maps. The dominant strike directions are northeast and northwest, with additional minor north and east orientations (Langenberg, 1983). The north and east striking joints are parallel to faults, and they could have formed in the same stress system during the Precambrian. Alternatively, these joints could also have formed as a release in a recent stress field, but controlled in expression by the earliest Precambrian structures. Although the northwest- and northeast-striking joints parallel some faults, they are thought to have originated in a recent regional stress field that had large, unequal, horizontal principal stresses. That stress field is active today, as indicated by breakouts in oilwells, which have deformed and elongated the drillhole cross-sections. The longer axis of the breakouts is aligned northwesterly, that is, parallel to the Rocky Mountain front (Gough and Bell, 1981).

Economic geology

Experience on the Shield of northeastern Alberta has generally shown that metallic minerals are most commonly found in the high-grade metasedimentary rocks. Pyrite, in particular, is widely distributed in amphibolites and metasedimentary rocks, and is less common in the gneisses and granitoids.

Limited areas of secondary uranium mineral stains (confirmed by geiger counter) have been noted in several places within the Slave Granitoids, specifically, 9 km eastnortheast of the confluence of the Dog and Slave Rivers, and 6 km south of Tulip Lake. Scattered minor molybdenite was also noted in the Slave Granitoids 8 km southwest of Tulip Lake, and dispersed minor graphite was found in the Slave Granitoids 5 km north of Tulip Lake.

Confirmed uranium mineral stains were noted within the gneisses east of Charles Lake in the extreme northeast corner of the map area. Confirmed uranium mineral stains were also noted nearby within the high-grade metasedimentary rocks. Graphite was noted in the high-grade metasedimentary rocks in a major band just west of Leland Lakes. In this major band, uranium was also found by prospectors during exploration activity in the late 1950s. The high-grade metasediments have not been explored by the Alberta Research Council; systematic prospecting of these bands could yield additional uranium anomalies.

Other minor occurrences of molybdenite can be expected in the granitoids and high-grade metasediments of this terrain. Its yellow bloom (powellite) could be mistaken for a secondary uranium mineral stain if not checked by a geiger counter or scintillometer. Minor copper (chalcopyrite) showings are also associated with some gossans or rusty zones within the high-grade metasediments. Elsewhere, dispersed magnetite has been noted locally in only low concentrations within the granite gneisses, but is sufficiently abundant to cause problems in the use of a magnetic compass.

Although not observed in the map area, there are minor accumulations of chalcopyrite in the regolith that exists at the unconformity of the basement complex and the overlying Devonian carbonates (Godfrey, 1973).

The economic potential for metallic mineral development in the map area appears to be low. Greatest potential for metallic minerals lies within the high-grade metasedimentary rocks. Faults and shear zones also merit examination in this regard.

Ice-contact fluvial channel deposits in the western part of the map area probably contain gravel and offer the best possibility for granular construction materials in this map area.

The range of textures and colors of granitoids in the map area make this a prospective area for a variety of building stones. The typical local relief of up to 10 to 20 m would make for easy hillside quarry operations. Areas of widely spaced, and orthogonally oriented, joint sets within the granitoids are likely to be found in the course of detailed surficial exploration. A combination of favorable factors could yield some very good prospects for obtaining a range of granitic ornamental building stones.

A keyword index from assessment reports of minerals exploration programs in the area has been compiled and is available from the Alberta Research Council (Poruks and Hamilton, 1976).

Glacial history

A variety of glacial deposits are scattered throughout the map area, and polished, scoured, fluted and striated bedrock surfaces attest to a recent continental glaciation. The direction of the Classical Wisconsin ice advance was from the east. The glacial sediments are dominantly sandy, and occur as both glaciolacustrine and glaciofluvial deposits. The classification, distribution, size, and shape of the glacial deposits are largely based on air photographic interpretation.

A northwesterly aligned system of glaciofluvial channel deposits dotted with interconnected glaciolacustrine deposits (many of the latter showing a stacked series of abandoned beaches) may have developed from ice-marginal meltwater lakes. This entire glacio-fluvial-glacio-lacustrine system, passing 10 km northeast of Fitzgerald, and better developed to the south (Godfrey and Langenberg, in press), may have formed in an ice-contact environment. In a regional context, these linear-shaped glacial deposits may represent a recessional moraine. They appear to converge northwesterly and lose elevation in that direction, suggesting that glaciofluvial transport was also to the northwest.

In general, the phase of stagnant ice-block wasting during late stages of deglaciation results in the formation of kettle holes and depressions in the glaciofluvial-lacustrine deposits. However, due to the absence of large sandy outwash deposits (such as those adjoining the map area to the south), kettle holes and aeolian activity are uncommon in the map area. Redeposited, windblown sand usually takes the form of sheet deposits and dunes, and also polishes and cuts grooves in the bedrock. The orientation of dunes and sand-cut grooves on low, southeast-facing steep outcrop surfaces, indicate that the prevailing storm winds came from the southeast. Wind-polished and -facetted outcrop faces are generally found to the northwest of, and adjacent to, sand sheets.

Athabasca Group sandstone outliers may be the ultimate source of the glacial sands in this map area. The glacial sandy deposits in the La Butte Creek basin to the south (Godfrey, in press), in turn, could be the immediate source of the sediment distributed northwesterly by meltwaters along the ice-contact front. Local reversals of the groundslope along these interconnected meltwater deposits indicate that the pattern of flow direction may not have been entirely simple and unidirectional. These northwesterly trending ice-contact deposits are a late-stage feature of deglaciation as witnessed by the occasional stagnant ice-block related kettle depression. Therefore, although ice topography was probably a contributing factor in the localization of these glaciofluvial-glaciolacustrine deposits, ice cover was probably not sufficiently extensive or continuous to make the deposits supraglacial.

Assuming that the ice-contact deposits drained to the northwest, they would have likely emptied into the contemporaneous Glacial Lake McConnell (Craig, 1965). Several stacked series of abandoned beaches are shown by Bayrock (1972) to the west in Wood Buffalo National Park and these would represent the western limits of Glacial Lake McConnell. The corresponding limits to the east could have been the stacked series of abandoned beaches developed on the northwest trending ice-contact ridge deposits, or even farther east. Abandoned beaches have been recognized to the east, beyond the map area, and on higher ground. The series of beaches on both sides of the river represent a shrinking Glacial Lake McConnell up to the time of unrestricted flow, when the glacial dam was probably breached, and the lakewaters drained northward.

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Appendix

Modal and chemical analyses of standard samples

Table 5. Modal and chemical analyses of standard samples for Biotite Granite Gneiss (11) in percent

Standard sample number	Biotite Granite Gneiss (11) 90	93	119	122	128
Quartz	29.8	8.6	16.4	27.5	24.4
K-Feldspar	24.4	13.7	13.2	30.1	11.2
Plagioclase	36.3	48.4	53.5	29.8	47.0
Biotite	5.4	15.5	7.7	5.2	13.9
Chlorite	0.4	0.0	3.8	1.3	0.2
Hornblende	0.0	3.2	1.9	0.6	0.0
Epidote	2.7	4.1	1.9	3.1	0.9
Muscovite	0.2	0.0	0.0	0.1	0.6
Spinel	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	0.0
Pyroxene	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0
Accessories	0.8	6.5	1.6	2.3	1.8
Number of points	2500	2000	2000	2000	2000

Standard sample number	Biotite Granite Gneiss (11) 90	93	119	122	128
SiO_2	71.06	56.20	62.06	68.25	66.92
TiO_2	0.41	1.48	0.70	0.37	0.47
Al_2O_3	13.75	17.49	16.49	14.56	16.20
Fe_2O_3	2.98	8.47	5.30	3.44	3.92
MgO	0.98	2.18	1.80	1.15	1.36
CaO	2.72	5.86	4.64	2.80	3.62
Na_2O	2.96	3.82	4.33	3.19	3.24
K_2O	3.81	3.21	2.35	4.64	3.00
MnO	0.06	0.17	0.10	0.06	0.07
P_2O_5	0.12	0.68	0.17	0.15	0.16
L.O.I.	0.53	0.47	0.91	0.71	0.65
H_2O	0.00	0.00	0.00	0.00	0.00
Total	99.38	100.03	98.85	99.32	99.61

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 6. Modal and chemical analyses of standard samples for Amphibolite (20) in percent

Standard sample number	Amphibolite (20) 86	89	92	97	118	124	125	126	134	567	581	621
Quartz	1.0	0.0	0.4	0.0	0.4	0.0	0.1	3.9	0.6	9.0	7.4	0.0
K-Feldspar	0.2	0.0	0.1	0.0	0.2	0.0	1.6	0.4	0.2	0.0	0.0	0.0
Plagioclase	39.1	20.6	54.4	1.3	23.1	32.3	17.7	36.9	44.4	44.5	45.7	40.2
Biotite	12.4	1.7	5.5	0.0	0.0	0.0	0.0	11.7	7.5	0.1	2.9	0.1
Chlorite	0.1	18.6	0.1	0.0	0.3	0.0	9.9	6.8	12.0	2.1	0.3	0.5
Hornblende	33.3	55.2	38.4	87.5	69.3	65.1	59.1	38.4	33.1	41.4	42.6	55.0
Epidote	0.1	0.0	0.0	0.0	1.1	0.5	5.7	0.1	1.0	0.0	0.2	0.0
Muscovite	8.7	0.0	0.0	10.9	4.1	0.2	1.2	0.0	0.0	1.6	0.0	3.5
Spinel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accessories	4.6	3.9	1.1	0.3	1.5	1.9	4.7	1.8	1.2	1.3	0.8	0.8
Number of points	2000	2000	2000	2000	2000	2000	2000	2000	2000	1000	1000	1000
SiO_2	53.41	40.66	51.25	46.16	46.36	49.07	44.34	50.06	50.83	53.05	51.80	59.18
TiO_2	2.08	4.10	0.96	1.10	1.34	1.41	1.71	1.37	0.97	2.39	1.61	0.91
Al_2O_3	14.75	16.98	18.91	14.96	14.73	17.51	14.20	17.36	16.18	14.63	14.81	15.37
Fe_2O_3	11.30	15.79	8.53	12.64	12.95	10.69	16.15	10.04	9.43	13.19	12.99	7.26
MgO	5.13	9.00	4.75	10.72	7.53	5.70	6.21	4.39	6.93	3.52	4.32	3.85
CaO	7.85	7.57	9.11	11.72	12.67	12.31	11.14	7.77	8.47	6.67	7.84	6.04
Na_2O	3.72	1.47	4.49	1.25	1.64	1.87	1.18	2.63	2.58	2.62	2.53	2.96
K_2O	1.39	0.96	1.42	0.49	0.84	0.74	1.58	2.05	1.59	1.20	2.68	2.62
MnO	0.22	0.22	0.15	0.20	0.21	0.20	0.41	0.14	0.14	0.14	0.11	0.00
P_2O_5	0.49	0.14	0.17	0.07	0.08	0.09	0.26	0.70	0.37	0.14	0.21	0.15
L.O.I.	0.24	3.03	0.51	1.39	1.89	0.95	1.24	1.98	2.09	1.41	1.08	1.28
H_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.17	0.28
Total	100.58	99.92	100.25	100.70	100.24	100.54	98.42	98.49	99.58	99.08	100.15	99.90

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 7. Modal and chemical analyses of standard samples for Metasedimentary Bands (31) in percent

Standard sample number	Metasedimentary Rock Bands (31) 26	57	58	59	60	61	62
Quartz	39.2	30.6	37.5	45.5	34.2	41.9	56.0
K-Feldspar	7.1	8.8	1.5	15.8	20.7	24.2	15.8
Plagioclase	22.9	26.4	33.0	9.7	13.6	10.0	4.4
Biotite	7.2	3.4	14.8	3.3	5.8	5.2	9.1
Chlorite	7.2	1.9	0.4	0.4	0.0	0.7	1.4
Hornblende	3.6	5.8	0.6	0.2	0.0	0.0	0.0
Epidote	0.1	0.1	0.0	0.2	0.0	0.0	0.1
Muscovite	6.5	8.2	9.1	4.3	5.4	2.5	2.2
Spinel	0.0	0.0	0.3	0.9	0.4	0.4	0.0
Garnet	2.7	1.7	0.8	4.1	2.8	3.7	2.4
Pyroxene	1.6	4.3	0.0	0.0	2.5	0.0	0.0
Cordierite	0.0	6.0	1.8	13.0	9.4	10.1	5.1
Andalusite	0.0	0.0	0.0	0.2	0.0	0.1	2.0
Sillimanite	0.2	1.0	0.1	0.3	3.6	0.8	0.3
Accessories	1.7	1.5	0.4	2.6	1.6	0.9	1.3
Number of points	4000	2000	2000	2000	2500	2000	2000
SiO_2	66.17	60.49	67.57	63.35	66.54	70.32	71.57
TiO_2	0.68	0.90	0.65	0.82	0.79	0.82	0.63
Al_2O_3	13.65	17.07	16.50	17.54	16.56	14.96	14.64
Fe_2O_3	5.87	8.45	5.01	8.40	6.23	6.31	6.28
MgO	3.07	3.13	1.14	1.83	1.37	1.29	1.52
CaO	3.49	2.24	2.33	0.65	1.42	0.93	0.46
Na_2O	1.78	1.67	2.09	1.52	1.30	1.34	0.63
K_2O	2.48	3.13	3.44	3.70	4.24	3.48	3.14
MnO	0.10	0.09	0.07	0.15	0.06	0.07	0.05
P_2O_5	0.13	0.10	0.13	0.12	0.13	0.08	0.04
L.O.I.	1.35	1.81	1.10	1.45	0.95	0.70	1.48
H_2O	0.00	0.07	0.05	0.10	0.11	0.06	0.08
Total	98.77	99.15	100.08	99.63	99.70	100.36	100.52

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 8. Modal and chemical analyses of standard samples for Granite F (171), Charles Lake Leucocratic Granite Phase (174), and Foliated Hornblende Granite (175) in percent

Standard sample number	(171) 127	129	(174) 96	123	(175) 87	88
Quartz	30.3	34.5	26.2	35.0	22.5	41.9
K-Feldspar	13.0	10.7	41.8	30.9	44.5	37.3
Plagioclase	27.6	40.6	27.7	32.1	14.7	7.6
Biotite	5.7	11.0	0.0	0.1	3.6	5.3
Chlorite	7.2	3.0	3.4	1.1	0.0	0.0
Hornblende	0.0	0.0	0.0	0.0	14.1	7.4
Epidote	0.0	0.0	0.2	0.2	0.0	0.0
Muscovite	1.8	0.0	0.2	0.2	0.0	0.0
Spinel	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	0.0	0.0
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0
Accessories	4.4	0.2	0.4	0.4	0.6	0.5
Number of points	2500	2500	2000	2000	2000	2500

Standard sample number	(171) 127	129	(174) 96	123	(175) 87	88
SiO_2	67.95	66.96	72.66	71.66	67.55	74.37
TiO_2	0.50	0.45	0.23	0.12	0.42	0.26
Al_2O_3	15.51	15.47	13.95	16.01	13.97	11.42
Fe_2O_3	4.28	3.79	1.67	1.07	6.27	3.98
MgO	1.39	1.77	0.85	0.82	0.41	0.30
CaO	2.30	2.86	0.95	1.82	2.36	1.43
Na_2O	3.05	3.29	3.03	2.70	3.23	2.51
K_2O	2.93	3.51	4.88	4.21	4.75	4.55
MnO	0.07	0.08	0.08	0.03	0.10	0.05
P_2O_5	0.12	0.07	0.18	0.04	0.11	0.00
L.O.I.	1.16	1.15	0.79	0.51	0.19	0.26
H_2O	0.00	0.00	0.00	0.00	0.00	0.00
Total	99.26	99.40	99.27	98.99	99.36	99.13

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 9. Modal and chemical analyses of standard samples for Slave Granite Phase (101) in percent

Standard sample number	Slave Granite Phase (101) 531	532	533	534	535	536	537	538	539	540	541	542	543
Quartz	26.3	35.1	32.2	29.7	33.1	36.4	31.1	38.2	47.0	34.3	29.5	23.8	24.3
K-Feldspar	52.3	52.9	49.3	50.9	51.9	55.3	52.2	41.3	42.0	55.4	4.0	53.5	47.1
Plagioclase	14.0	6.3	9.4	11.1	8.2	4.0	10.6	15.3	7.0	4.5	63.1	14.1	25.0
Biotite	3.0	0.5	0.0	0.9	0.0	1.5	0.6	0.0	0.6	0.9	0.2	1.4	1.7
Chlorite	0.0	0.2	0.5	0.0	3.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epidote	0.7	0.0	0.4	0.2	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Muscovite	2.1	0.1	4.8	2.6	3.4	1.1	0.7	0.6	2.0	2.4	0.6	2.4	0.0
Spinel	0.4	0.4	0.3	0.5	0.0	0.2	0.3	0.6	0.1	0.1	0.4	1.0	0.0
Garnet	0.0	2.1	1.9	1.0	0.0	0.8	3.6	1.4	0.0	0.8	0.0	0.9	1.9
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.6	0.0	1.0	0.0	0.0	0.0	0.3	0.0	0.0	1.5	0.5	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	1.5	0.0	0.1	0.0	0.0	0.0	0.0	0.3	1.5	0.6	1.7	0.0
Accessories	0.9	0.4	1.1	1.4	0.4	0.2	0.5	0.8	0.4	0.0	0.0	0.7	0.0
Number of points	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	1000	2000	1000
SiO_2	74.19	75.02	74.14	73.61	75.87	73.79	73.43	73.72	77.57	76.02	73.99	71.09	72.39
TiO_2	0.18	0.14	0.17	0.20	0.13	0.13	0.20	0.26	0.06	0.04	0.10	0.13	0.19
Al_2O_3	14.51	14.51	14.58	15.03	13.52	15.39	14.23	14.63	13.57	14.11	14.99	16.53	15.17
Fe_2O_3	0.82	0.98	0.90	0.87	0.58	0.58	1.84	1.52	0.32	0.64	0.81	1.11	2.01
MgO	0.28	0.21	0.24	0.21	0.14	0.26	0.38	0.36	0.14	0.12	0.14	0.25	0.65
CaO	0.51	1.25	0.70	0.78	0.35	1.05	0.73	0.64	0.92	0.37	0.60	0.89	0.97
Na_2O	2.55	3.57	2.69	2.84	2.38	3.21	2.50	2.21	2.98	3.84	3.55	3.62	3.39
K_2O	6.56	4.54	6.51	6.40	6.89	5.56	5.82	5.73	3.78	4.14	4.73	5.40	4.40
MnO	0.01	0.03	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.05
P_2O_5	0.10	0.09	0.10	0.11	0.08	0.07	0.07	0.06	0.07	0.19	0.20	0.12	0.12
L.O.I.	0.68	0.34	0.43	0.37	0.34	0.43	0.16	0.44	0.41	0.31	0.40	0.40	0.18
H_2O	0.07	0.07	0.05	0.07	0.06	0.02	0.13	0.11	0.01	0.00	0.18	0.08	0.08
Total	100.46	100.75	100.53	100.50	100.35	100.51	99.50	99.70	99.84	99.80	99.70	99.63	99.60

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 9 (continued). Modal and chemical analyses of standard samples for Slave Granite Phase (101) in percent

Standard sample	**Slave Granite Phase (101)**													
number	**544**	**545**	**547**	**555**	**556**	**557**	**558**	**559**	**562**	**568**	**569**	**570**	**571**	**572**
Quartz	21.6	21.5	25.3	39.2	31.5	31.5	32.1	31.5	31.3	28.2	33.5	40.0	35.7	24.6
K-Feldspar	71.3	64.7	39.3	44.9	52.2	54.3	50.2	53.1	54.8	57.3	50.8	44.1	44.8	54.8
Plagioclase	4.3	9.3	32.6	10.3	7.1	8.1	11.3	8.0	5.1	6.0	6.1	9.5	7.8	12.0
Biotite	2.3	1.4	1.3	0.9	2.6	3.0	0.4	0.9	0.0	0.2	0.0	2.4	7.4	1.0
Chlorite	0.3	0.0	0.9	0.0	0.3	0.0	0.0	0.0	1.3	1.7	0.0	0.0	0.0	0.2
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epidote	0.0	0.1	0.1	0.0	0.5	0.0	0.1	0.0	trace	0.1	0.0	0.4	0.2	1.0
Muscovite	0.0	0.0	0.0	1.4	4.9	2.2	1.1	1.2	0.7	4.8	2.3	0.3	3.5	0.7
Spinel	0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.5	0.3	0.0	1.6	0.0	0.0	0.4
Garnet	0.2	3.1	0.0	0.4	0.3	0.0	1.9	2.0	2.9	0.4	0.1	2.7	0.0	0.9
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	trace	0.0	0.0	0.5	0.0	0.0	2.0	0.3	0.1	0.0	2.0	0.0	0.0	3.5
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	1.0	0.0	0.0	1.3	0.0	0.0	0.0	1.9	3.5	0.0	2.9	0.0	0.0	1.3
Accessories	trace	trace	0.6	0.2	0.2	0.6	0.7	0.6	0.2	0.9	0.9	0.4	0.8	0.2
Number of points	1000	1000	1000	2000	1902	2000	2000	2000	2000	2000	2000	2000	2000	1000
SiO_2	71.19	71.57	68.15	74.79	75.57	76.99	72.01	73.84	73.13	72.83	73.30	73.06	73.47	72.08
TiO_2	0.18	0.22	0.24	0.06	0.18	0.07	0.21	0.13	0.13	0.15	0.15	0.19	0.21	0.19
Al_2O_3	17.13	15.53	16.42	14.84	13.85	13.14	14.84	15.28	15.63	14.74	15.21	15.40	14.85	15.75
Fe_2O_3	1.01	1.66	2.50	0.54	0.89	0.84	1.58	0.86	0.94	1.96	1.26	1.46	1.05	1.68
MgO	0.23	0.37	0.75	0.08	0.23	0.19	0.48	0.20	0.19	0.33	0.25	0.50	0.32	0.29
CaO	0.55	0.74	2.84	0.48	0.51	0.44	0.40	0.66	0.68	0.65	0.48	1.52	0.68	0.68
Na_2O	3.32	3.12	4.16	3.09	2.99	2.39	2.41	2.28	3.09	2.54	2.84	3.97	2.71	2.91
K_2O	5.64	5.76	3.93	5.98	5.19	5.23	6.49	6.07	5.78	6.33	5.40	2.92	5.83	5.32
MnO	0.01	0.02	0.05	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.01	0.01
P_2O_5	0.12	0.16	0.11	0.09	0.06	0.06	0.12	0.08	0.15	0.09	0.11	0.00	0.10	0.11
L.O.I.	0.40	0.34	1.02	0.36	0.48	0.54	0.84	0.32	0.11	0.48	0.44	0.23	0.59	0.25
H_2O	0.05	0.13	0.06	0.01	0.03	0.05	0.13	0.04	0.04	0.09	0.12	0.00	0.01	0.12
Total	99.83	99.62	100.23	100.32	99.99	99.95	99.52	99.77	99.88	100.21	99.58	99.29	99.83	99.39

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 9 (continued). Modal and chemical analyses of standard samples for Slave Granite Phase (101) in percent

Standard sample number	**Slave Granite Phase (101)**												
	573	**574**	**575**	**576**	**577**	**585**	**587**	**588**	**589**	**590**	**591**	**592**	**593**
Quartz	20.4	24.7	23.9	42.0	27.8	39.9	35.8	33.9	28.9	32.0	28.5	30.0	28.9
K-Feldspar	72.4	61.8	46.9	35.2	39.4	32.7	51.6	50.6	58.0	44.3	60.7	45.5	50.5
Plagioclase	3.0	11.7	27.1	19.3	25.2	21.6	7.3	9.3	9.8	15.4	4.7	15.4	15.2
Biotite	0.9	0.4	1.1	3.2	4.0	1.5	0.8	0.0	0.1	2.7	1.1	2.9	1.6
Chlorite	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epidote	0.0	trace	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Muscovite	0.1	0.8	0.0	0.1	0.0	0.6	0.9	4.6	1.2	2.1	0.2	2.5	2.7
Spinel	0.1	0.0	0.0	0.0	0.1	0.3	0.3	0.0	0.0	0.1	0.4	0.9	0.6
Garnet	2.5	0.3	0.9	0.0	0.1	1.5	2.4	1.2	1.8	2.4	2.8	0.8	0.0
Pyroxene	0.0	trace	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.2	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.6	0.0	0.0	0.0	0.2	1.1	0.0	0.0	0.0	1.0	1.1	0.9	1.0
Accesories	0.0	0.2	trace	trace	0.1	0.5	0.4	0.0	0.7	0.0	0.1	0.8	0.0
Number of points	1000	1000	1000	1000	1000	1993	2000	2000	2000	2000	1000	2000	1006
SiO_2	74.02	72.17	72.01	76.68	74.52	70.81	74.54	75.62	74.43	74.24	72.88	72.06	73.63
TiO_2	0.09	0.15	0.18	0.19	0.15	0.10	0.11	0.03	0.03	0.14	0.14	0.15	0.12
Al_2O_3	14.84	15.38	16.41	12.95	14.39	14.48	14.03	14.70	14.80	14.52	15.54	15.63	15.33
Fe_2O_3	0.62	1.71	1.14	1.26	0.99	5.41	1.25	0.61	0.51	0.63	0.96	1.15	0.82
MgO	0.13	0.33	0.37	0.44	0.31	0.38	0.25	0.05	0.09	0.21	0.21	0.26	0.20
CaO	0.41	0.67	0.98	0.77	0.73	0.59	1.60	0.41	0.45	0.64	0.54	0.64	0.70
Na_2O	2.59	2.66	3.48	2.81	3.53	2.82	3.95	2.58	2.92	2.48	3.29	2.83	3.41
K_2O	6.84	6.40	4.77	4.31	4.36	5.52	3.83	5.73	6.68	4.98	5.50	6.14	5.11
MnO	0.01	0.01	0.03	0.01	0.01	0.06	0.01	0.03	0.07	0.01	0.02	0.01	0.03
P_2O_5	0.10	0.08	0.07	0.05	0.11	0.10	0.03	0.11	0.04	0.10	0.13	0.09	0.13
L.O.I.	0.40	0.37	0.10	0.34	0.35	0.22	0.18	0.58	0.11	0.53	0.37	0.46	0.43
H_2O	0.02	0.07	0.02	0.01	0.11	0.01	0.03	0.05	0.08	0.00	0.18	0.10	0.11
Total	100.07	100.00	99.56	99.82	99.56	100.50	99.81	100.50	100.21	98.48	99.76	99.52	100.02

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 9 (continued). Modal and chemical analyses of standard samples for Slave Granite Phase (101) in percent

Standard sample number	Slave Granite Phase (101)												
	594	595	600	601	602	603	604	605	607	609	610	611	612
Quartz	28.8	30.1	28.1	32.5	33.1	32.3	19.9	24.3	28.6	30.2	20.3	22.4	27.1
K-Feldspar	59.5	27.4	47.8	42.3	51.0	55.5	51.0	47.6	49.1	53.4	63.9	61.2	57.0
Plagioclase	5.2	36.9	17.2	11.8	7.5	5.7	23.5	23.9	18.3	13.1	13.8	7.9	8.4
Biotite	1.5	2.2	1.5	9.5	1.1	2.0	1.4	0.4	1.3	0.3	1.1	1.8	0.1
Chlorite	0.1	0.0	1.1	0.0	0.0	0.8	0.0	0.0	0.2	0.1	0.0	0.1	0.3
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epidote	0.0	0.0	0.0	0.3	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Muscovite	1.1	3.0	1.8	2.6	1.5	1.3	1.5	1.3	0.3	1.9	0.0	3.3	6.4
Spinel	1.6	0.0	0.3	0.0	0.0	0.5	0.5	0.3	0.2	0.3	0.1	1.3	0.0
Garnet	0.3	0.3	1.3	0.0	4.6	0.5	1.0	2.0	1.3	0.0	0.6	0.0	0.8
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.2	0.0	0.3	0.2	0.0	0.3	0.0	0.5	0.0	1.0	0.2	0.3	0.9
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	3.1	trace	0.0	0.0	0.0	0.8	1.2	0.3	1.0	0.7	0.6	1.0	0.3
Accessories	0.3	0.2	0.6	0.9	0.4	0.5	0.1	0.0	0.1	0.0	0.0	0.8	trace
Number of points	2034	1000	2000	2000	2000	2002	2000	1007	1003	1010	1000	1979	1013
SiO_2	73.17	74.39	70.26	71.21	74.74	73.96	73.65	72.25	73.45	73.14	71.72	72.59	73.11
TiO_2	0.11	0.19	0.54	0.36	0.13	0.13	0.15	0.14	0.10	0.15	0.13	0.12	0.12
Al_2O_3	15.81	14.53	15.95	15.48	14.26	14.73	14.38	16.15	16.26	15.33	16.31	15.60	15.85
Fe_2O_3	0.81	0.93	1.84	1.97	0.80	0.89	1.69	0.58	0.79	0.96	1.22	0.84	0.84
MgO	0.23	0.31	0.42	0.47	0.22	0.32	0.23	0.17	0.13	0.21	0.23	0.21	0.25
CaO	0.56	0.72	0.83	0.95	0.55	0.45	0.65	0.64	0.57	0.61	0.75	0.62	0.56
Na_2O	3.48	3.58	2.08	2.23	2.62	2.42	2.93	3.39	3.57	3.11	3.48	3.16	3.38
K_2O	5.09	4.17	7.31	5.99	6.05	6.26	5.52	5.76	5.03	5.63	5.31	5.56	4.90
MnO	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.02
P_2O_5	0.25	0.13	0.23	0.09	0.07	0.13	0.14	0.11	0.13	0.13	0.13	0.09	0.17
L.O.I.	0.63	0.31	0.78	0.65	0.28	0.54	0.30	0.39	0.20	0.41	0.46	0.49	0.63
H_2O	0.04	0.19	0.03	0.08	0.07	0.10	0.00	0.17	0.07	0.04	0.05	0.06	0.02
Total	100.19	99.47	100.29	99.49	99.80	99.94	99.65	99.77	100.31	99.72	99.80	99.35	99.85

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 10. Modal and chemical analyses of standard samples for Red Slave Granite Phase (103) and Slave PQ Granite Phase (105) in percent

Standard sample number		(103)		(105)
	546	554	586	606
Quartz	15.4	20.6	31.7	0.0
K-Feldspar	53.4	49.7	48.0	75.3
Plagioclase	27.4	27.8	15.7	3.6
Biotite	1.0	0.2	0.6	15.6
Chlorite	2.7	0.0	0.5	4.5
Hornblende	0.0	0.0	0.0	0.0
Epidote	0.0	0.0	0.0	0.3
Muscovite	0.0	0.2	0.0	0.7
Spinel	0.0	0.3	0.3	0.0
Garnet	0.0	0.3	2.0	0.0
Pyroxene	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.3	0.0
Andalusite	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.6	0.3	0.0
Accessories	0.1	0.4	0.8	0.0
Number of points	1000	1783	2000	1000

Standard sample number		(103)		(105)
	546	554	586	606
SiO_2	70.36	73.26	73.19	56.71
TiO_2	0.25	0.16	0.10	1.25
Al_2O_3	15.34	15.06	14.68	19.72
Fe_2O_3	1.27	1.22	1.12	4.81
MgO	0.81	0.26	0.23	2.10
CaO	1.18	1.05	0.74	0.19
Na_2O	2.94	2.99	3.31	1.15
K_2O	5.99	5.88	5.70	11.77
MnO	0.00	0.03	0.01	0.01
P_2O_5	0.13	0.11	0.11	0.22
L.O.I.	1.05	0.42	0.54	1.06
H_2O	0.05	0.08	0.05	0.09
Total	99.37	100.52	99.78	99.08

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 11. Model and chemical analyses of standard samples for Slave Raisin Granite Phase (106) in percent

Standard sample number	Slave Raisin Granite Phase (106) 84	91	552	553	566
Quartz	25.7	24.4	22.9	22.3	36.9
K-Feldspar	9.2	2.7	32.8	32.6	38.1
Plaioclase	49.8	64.0	37.1	36.9	20.6
Biotite	0.0	2.9	0.1	0.0	2.2
Chlorite	9.3	1.4	2.2	2.1	0.2
Hornblende	0.0	0.0	0.0	0.0	0.0
Epidote	3.2	0.0	3.9	5.4	0.2
Muscovite	2.2	3.6	1.0	0.8	1.8
Spinel	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	0.0
Pyroxene	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0
Accessories	0.6	1.0	0.0	trace	0.0
Number of points	2500	2500	1000	1000	1000

Standard sample number	Slave Raisin Granite Phase (106) 84	91	552	553	566
SiO_2	66.61	68.78	68.39	67.71	72.79
TiO_2	0.61	0.41	0.50	0.55	0.30
Al_2O_3	15.26	15.50	14.90	14.66	13.73
Fe_2O_3	5.09	2.58	3.31	3.41	1.34
MgO	2.01	1.25	0.54	1.08	0.55
CaO	2.30	2.52	1.48	2.38	0.72
Na_2O	3.03	3.71	2.72	3.01	1.96
K_2O	3.12	2.68	6.39	5.41	6.84
MnO	0.03	0.04	0.03	0.03	0.01
P_2O_5	0.12	0.09	0.22	0.04	0.05
L.O.I.	1.86	1.97	0.94	1.09	0.77
H_2O	0.00	0.00	0.00	0.03	0.00
Total	100.04	99.53	99.42	99.40	99.06

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 12. Modal and chemical analyses of standard samples for Arch Lake Granite Phase (161) in percent

Standard sample number	Arch Lake Granite Phase (161) 100	121	131	496	548	549	550	551	564	565
Quartz	21.9	19.4	44.6	24.3	26.9	26.6	22.4	24.3	31.1	27.4
K-Feldspar	45.4	42.2	16.8	31.3	44.5	33.9	40.3	45.5	39.9	34.2
Plagioclase	26.6	32.7	28.9	38.9	21.7	30.0	30.8	27.6	24.0	33.2
Biotite	1.9	3.3	3.6	3.1	3.7	5.1	5.9	0.4	3.1	2.3
Chlorite	1.7	0.9	0.7	0.5	0.5	1.8	0.3	0.5	0.4	0.1
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epidote	0.1	0.3	1.4	0.0	0.5	0.1	0.1	1.3	trace	trace
Muscovite	2.0	0.9	3.5	1.8	0.2	2.5	0.0	0.2	0.2	2.8
Spinel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	1.3	0.0
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accessories	0.4	0.3	0.5	0.1	0.5	0.0	0.2	0.2	trace	0.0
Number of points	2500	2500	2500	1000	2000	1000	1000	1000	1000	1000
SiO_2	71.88	72.09	73.65	74.44	71.97	74.72	71.08	73.10	72.66	73.20
TiO_2	0.27	0.32	0.23	0.25	0.34	0.24	0.34	0.23	0.29	0.22
Al_2O_3	15.26	14.62	13.86	13.14	14.11	12.98	14.91	13.81	14.31	14.21
Fe_2O_3	1.72	1.89	1.48	1.30	1.91	1.35	2.14	1.56	1.60	1.20
MgO	0.71	0.85	0.57	0.64	0.40	0.37	0.36	0.28	0.40	0.26
CaO	1.54	1.60	1.57	0.39	1.20	0.79	1.56	0.79	1.28	0.57
Na_2O	3.00	3.05	2.95	3.07	2.85	2.66	3.11	3.34	3.06	3.10
K_2O	5.08	4.69	4.54	5.19	5.96	5.50	6.42	5.91	5.71	6.27
MnO	0.03	0.04	0.04	0.01	0.02	0.00	0.01	0.00	0.00	0.00
P_2O_5	0.12	0.15	0.08	0.60	0.09	0.08	0.11	0.10	0.10	0.13
L.O.I.	0.71	0.49	0.68	0.70	0.25	0.90	0.37	0.46	0.45	0.49
H_2O	0.00	0.00	0.00	0.11	0.00	0.04	0.00	0.04	0.06	0.03
Total	100.32	99.79	99.65	99.84	99.10	99.63	100.41	99.62	99.92	99.68

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

Table 12 (continued). Modal and chemical analyses of standard samples for Arch Lake Granite Phase (161) in percent

	Arch Lake Granite Phase (161)										
Standard sample number	**578**	**579**	**580**	**582**	**596**	**616**	**617**	**618**	**620**	**623**	**624**
Quartz	22.6	25.7	30.1	22.3	24.2	26.1	24.4	29.8	22.6	19.9	27.0
K-Feldspar	37.5	38.3	36.5	39.5	48.3	37.0	42.8	25.1	47.5	52.4	48.1
Plagioclase	34.9	31.0	27.7	28.7	23.1	31.9	26.3	41.1	24.9	23.0	22.0
Biotite	3.4	4.2	3.3	8.8	3.3	3.9	6.4	2.7	4.1	4.0	1.0
Chlorite	0.1	0.1	0.0	0.0	0.1	1.1	0.8	0.0	0.0	0.3	0.6
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epidote	trace	0.1	trace	0.2	0.0	0.1	0.1	trace	trace	0.0	0.0
Muscovite	1.4	0.2	1.4	0.3	0.2	0.0	0.2	1.3	0.9	0.4	0.0
Spinel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.2	0.9	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.1
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accessories	0.2	0.2	0.1	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.2
Number of points	1000	1000	1000	1000	1000	1000	1010	1001	1000	1000	1000
SiO_2	73.15	73.60	74.50	67.35	73.72	71.80	72.47	71.95	70.99	73.48	74.91
TiO_2	0.32	0.31	0.26	0.86	0.22	0.22	0.33	0.35	0.23	0.24	0.22
Al_2O_3	13.67	14.39	13.63	15.04	14.62	15.48	14.61	15.26	15.48	14.65	14.26
Fe_2O_3	1.46	1.36	1.43	3.97	1.11	1.41	1.62	1.46	1.27	1.18	1.37
MgO	0.48	0.37	0.45	0.90	0.40	0.42	0.48	0.66	0.40	0.44	0.42
CaO	1.35	1.46	0.63	1.94	0.88	1.08	0.75	0.86	1.04	1.16	0.95
Na_2O	2.94	2.83	2.67	2.69	3.01	3.16	2.54	3.18	3.09	2.91	2.94
K_2O	5.61	6.07	5.67	6.13	5.68	5.87	6.20	5.39	6.96	5.86	5.38
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.14	0.02	0.00	0.01
P_2O_5	0.07	0.09	0.10	0.27	0.09	0.10	0.11	0.09	0.09	0.07	0.07
L.O.I.	0.54	0.33	0.66	0.59	0.45	0.40	0.70	0.95	0.27	0.36	0.24
H_2O	0.01	0.01	0.02	0.06	0.05	0.05	0.06	0.11	0.04	0.04	0.03
Total	99.60	100.82	100.02	99.80	100.23	100.11	99.88	100.26	99.88	100.39	100.80

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

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Table 13. Modal and chemical analyses of standard samples for Arch Lake Granite Transitional Phase (162) in percent

	Arch Lake Granite Transitional Phase (162)							
Standard sample number	**480**	**560**	**563**	**583**	**596**	**599**	**615**	**619**
Quartz	26.6	21.0	27.6	24.3	29.3	28.8	20.7	34.6
K-Feldspar	52.8	40.5	27.4	33.6	31.9	37.7	46.7	57.3
Plagioclase	16.8	35.0	42.2	41.3	32.8	30.4	26.1	7.8
Biotite	0.8	1.8	2.3	0.0	4.7	1.0	2.1	0.0
Chlorite	2.5	1.3	0.2	0.0	0.5	1.2	1.0	0.0
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Epidote	0.1	trace	0.0	0.1	trace	trace	0.0	0.0
Muscovite	0.4	0.2	0.0	1.1	0.5	0.9	3.4	0.3
Spinel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accessories	trace	0.2	0.3	0.3	0.0	0.0	0.0	0.0
Number of points	1002	1000	1000	1000	1000	1008	1000	1001
SiO_2	73.11	71.11	74.52	73.65	73.49	75.32	73.43	78.25
TiO_2	0.16	0.30	0.22	0.17	0.21	0.23	0.22	0.10
Al_2O_3	14.91	15.27	14.29	13.52	15.06	13.72	14.84	12.58
Fe_2O_3	1.02	1.82	1.26	2.43	1.15	1.47	1.18	0.40
MgO	0.36	0.61	0.36	0.20	0.44	0.43	0.46	0.22
CaO	0.78	1.28	1.38	0.95	1.16	0.75	0.53	0.63
Na_2O	3.28	2.98	3.27	2.57	3.21	3.08	2.45	2.18
K_2O	5.28	4.74	4.97	6.17	5.18	4.88	5.68	5.81
MnO	0.04	0.02	0.01	0.00	0.00	0.00	0.01	0.00
P_2O_5	0.11	0.10	0.06	0.02	0.10	0.08	0.09	0.07
L.O.I.	0.46	0.67	0.21	0.64	0.25	0.64	0.78	0.28
H_2O	0.07	0.07	0.01	0.02	0.07	0.04	0.03	0.00
Total	99.58	98.97	100.56	100.34	100.32	100.64	99.70	100.52

Chemical analyses by J.R. Nelson, Alberta Research Council Chemistry Laboratory

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problem

Table 14. Modal and chemical analyses of standard samples for Recrystallized Mylonitic Rock (221, 223, 224) in percent

	Recrystallized Mylonitic Rock (221)					**Recrystallized Mylonitic Rock (223)**					**(224)**	
Standard sample number	**85**	**95**	**98**	**597**	**622**	**99**	**130**	**132**	**133**	**584**	**94**	**120**
Quartz	15.0	31.9	29.0	36.9	8.1	23.8	26.0	17.3	27.8	26.8	17.3	15.5
K-Feldspar	15.0	25.8	23.2	61.1	47.6	7.0	5.0	11.1	13.3	20.1	11.6	21.6
Plagioclase	50.0	35.2	37.7	0.0	43.0	52.0	41.9	37.8	40.2	45.2	59.0	47.8
Biotite	1.5	2.7	0.0	0.0	1.0	0.2	20.0	30.3	13.0	7.9	4.4	0.0
Chlorite	0.5	1.0	6.1	1.9	0.0	9.7	3.0	0.9	0.3	trace	1.5	6.2
Hornblende	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4
Epidote	trace	1.7	1.7	0.0	0.2	0.4	3.0	0.8	0.5	trace	4.7	7.2
Muscovite	17.0	1.0	0.6	0.0	0.0	6.0	1.0	1.0	4.0	0.0	0.0	0.1
Spinel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyroxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cordierite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Andalusite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accessories	1.0	0.7	1.7	0.0	0.0	0.9	0.1	0.8	0.9	0.0	1.1	1.2
Number of points	estim.	2500	2500	1000	1000	2500	2500	2500	2500	1000	2500	2500
SiO_2	71.91	71.17	68.35	77.90	72.74	67.74	64.75	65.10	70.01	47.02	66.95	65.74
TiO_2	0.31	0.34	0.42	0.30	0.18	0.51	0.59	0.60	0.42	1.52	0.21	0.24
Al_2O_3	14.40	12.79	14.88	10.99	14.33	15.68	16.17	16.31	14.12	17.86	17.28	17.58
Fe_2O_3	1.91	2.83	3.66	2.06	1.16	3.59	4.56	4.91	3.33	11.11	2.26	2.57
MgO	0.82	0.93	1.77	2.48	0.31	1.97	1.72	1.83	0.98	8.85	1.09	1.34
CaO	1.37	2.16	1.40	0.28	1.10	2.07	2.92	3.70	2.13	6.78	3.84	3.45
Na_2O	2.91	2.84	3.85	4.21	3.54	3.42	2.99	3.22	3.03	2.27	5.09	5.19
K_2O	5.22	4.60	4.01	0.15	6.16	3.25	4.44	3.23	3.90	1.13	2.41	2.83
MnO	0.03	0.03	0.05	0.09	0.00	0.07	0.08	0.08	0.05	0.14	0.08	0.09
P_2O_5	0.13	0.07	0.11	0.08	0.10	0.20	0.20	0.15	0.15	0.07	0.09	0.12
L.O.I.	1.01	0.50	1.09	1.46	0.36	1.61	1.27	0.72	0.64	2.70	0.69	0.91
H_2O	0.00	0.00	0.00	0.07	0.02	0.00	0.00	0.00	0.00	0.09	0.00	0.00
Total	100.02	98.26	99.59	100.07	100.00	100.11	99.69	99.85	98.76	99.54	99.99	100.06

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