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MINERALOGICAL AND GEOCHEMICAL INVESTIGATION OF THE CORDIERITE-ANTHOPHYLLITE ROCKS AT STAR LAKE, NEAR SHERRIDON, MANITOBA

BY

MARC V. LEROUX, B.Sc.

A thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the degree of

MASTER OF SCIENCE

Department of Geological Sciences
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ABSTRACT

The Sherridon Group, a stratigraphic unit of the Kisseynew gneiss belt, near Sherridon, Manitoba is typically dominated by quartz-rich gneisses. Discontinuous lenses of cordierite-anthophyllite rocks, the focus of the present study, occur within these quartz-biotite gneiss units. These cordierite-anthophyllite gneisses are extremely coarse-grained in places, and are spatially associated with barren (Star Lake) and sulfide-mineralized zones (Sherridon; Elken Lake). The present chemical composition of the Star Lake-Elken Lake gneisses indicates hydrothermal alteration of a basaltic progenitor producing chlorite-rich alteration pipes. This alteration involves a depletion in alkali and alkaline earth elements with an apparent enrichment in Al and Mg as a function of constant summation. These chemical modifications are the result of reactions between heated seawater and basaltic rocks of the crust. A modern analogue of the Sherridon Group environment might be the shelf and slope deposits of modern island arcs.

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Chemical analyses were performed by the University of Ottawa and Bondar-Clegg Laboratories. Mineral analyses were done at the National Museum of Canada - Mineral Sciences Division under the guidance of T.S.Ercit.

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MINERAL ABBREVIATIONS

Alm	Almandine
Als	Aluminosilicate
And	Andalusite
Ath	Anthophyllite
Ap	Apatite
Bt	Biotite
Ccp	Chalcopyrite
Chl	Chlorite
Cld	Chloritoid
Crd	Cordierite
Grt	Garnet
Ged	Gedrite
Hc	Hercynite
Ky	Kyanite
Mag	Magnetite
Mc	Marcasite
Oam	Orthoamphibole
Po	Pyrrhotite
Qtz	Quartz
Sil	Sillimanite
Spl	Spinel
St	Staurolite
Tur	Tourmaline
Wg	Wagnerite
Zrn	Zircon

(I) INTRODUCTION

(i) Statement of Problem

A prominent cordierite-anthophyllite assemblage occurs between Kississing Lake and Star Lake, Manitoba (known as the Sherridon structural basin, Goetz 1980). This structure is underlain by rocks of the Sherridon Group, a stratigraphic unit of the Kisseynew gneiss belt, near Sherridon, Manitoba.

The origin of cordierite-anthophyllite bearing rocks is obscure. They do not have any obvious chemical counterparts among common sedimentary or igneous rocks. Chemically, these rocks range from silica-poor to silica-rich. They are all marked by deficiencies in Ca and alkalies, and relative enrichments in Al, Mg, and Fe. Cordierite- anthophyllite gneisses are almost always associated with Fe -sulfides and base metal mineralization. These rocks have been regarded as allochemical metamorphic products (Eskola 1914), and commonly form in high-grade regional metamorphic terranes, suggesting a common origin for all occurrences.

A detailed mineralogical and chemical study was done in the Star Lake - Elken Lake area of the Sherridon structure (Figures 1 and 2). The objectives of this work are (i) to identify the mineralogical and chemical character of the cordierite-anthophyllite unit; (ii) to compare it to other known occurrences; (iii) to define the processes

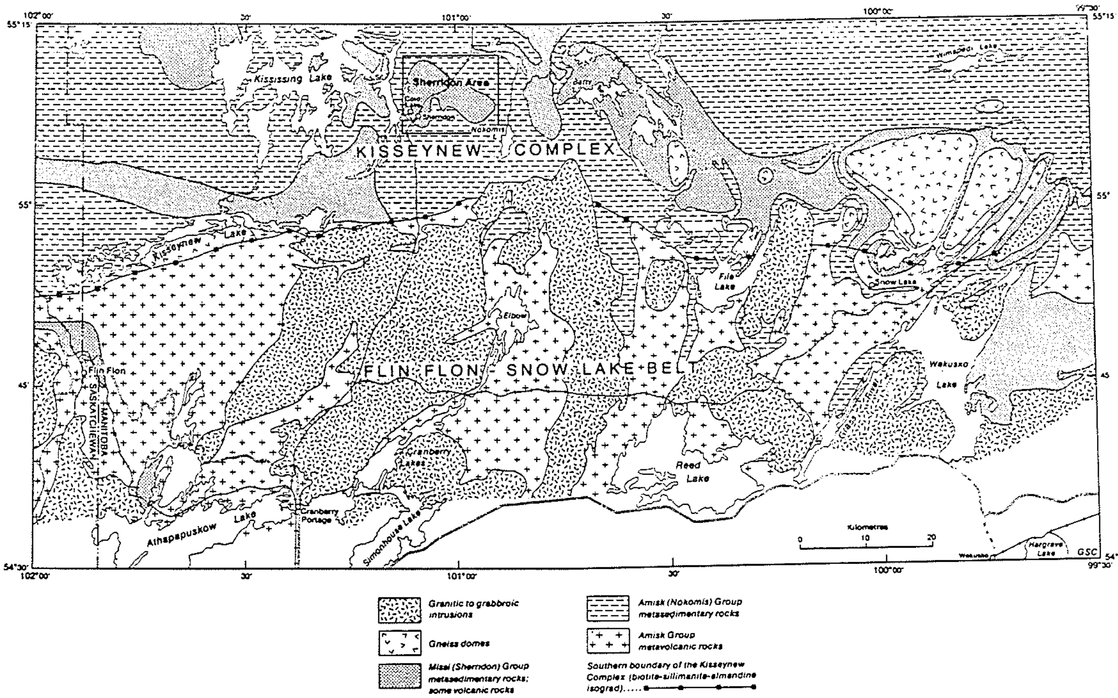


FIGURE 1: Location and setting of the Sherridon area in the Kisseynew Complex (Froese and Goetz, 1981).

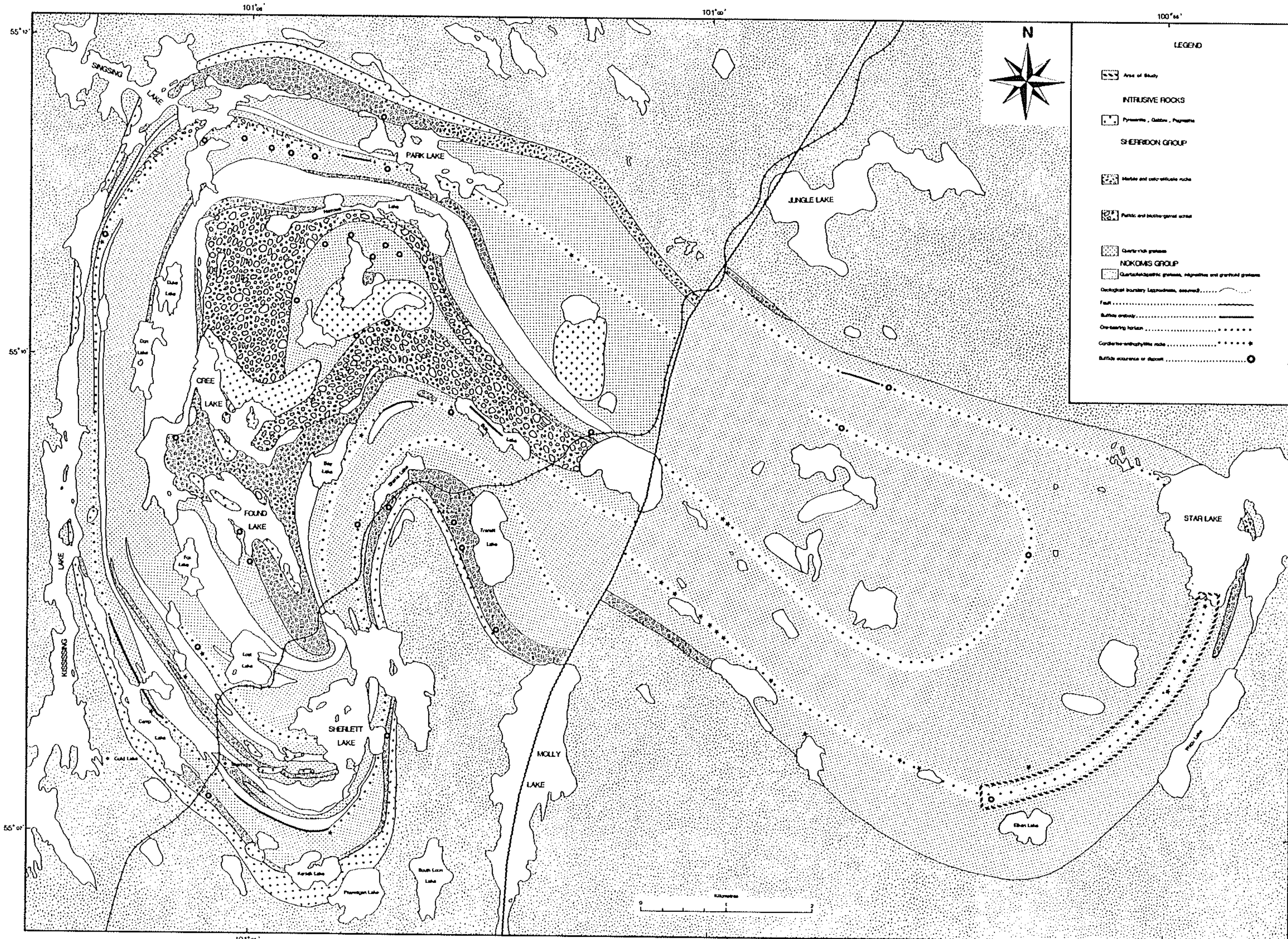


FIGURE 2: Geological sketch map of the Sherridon area with the location of the study area (Froese and Goetz, 1981).

leading to the observed lithologies. The origin and character of the original protolith can then be considered, with a view to establishing chemical and mineralogical parameters that discriminate between the barren assemblage at Star Lake and the sulfide-mineralized zones at Sherridon, Manitoba.

(ii) Previous Work:

Bateman and Harrison (1946) mapped the eastern portion of the Sherridon Structure. These authors primarily mapped west of the Batty Lake area (Figure 1), and discovered the first textural evidence of a volcanic origin for some of the amphibolites near Sherridon. They classified them as volcanic breccias and reported deformed pillow structures.

The anthophyllite-bearing rocks of the Sherridon Group were first recognized by Robertson (1953). In his study of the Batty Lake map-area, which adjoins the Sherridon map-area, he described two main rock types: quartz-rich and hornblende-rich gneisses. These units are associated with thin intercalations of limestone and anthophyllite-rich rocks. The band of anthophyllite-rich rock was traced from east to west in the map-area, and, although not mentioned by Bateman and Harrison (1946), was found at several localities in the Sherridon area (Figure 2). This band contained the characteristic mineral assemblages:

(i)anthophyllite-cummingtonite-biotite

(ii)anthophyllite-biotite-almandine

(iii)anthophyllite-cordierite-biotite

(iv)anthophyllite-cordierite-biotite-almandine

varying in width from 15 to 30 meters and occupying a relatively constant stratigraphic horizon 150 to 250 meters above the base of the Sherridon Group. Robertson (1953) suggested that the mineral assemblages in the anthophyllite band represented the products of iron-magnesium metasomatism of an aluminium-rich sediment or tuff, with the latter option possibly favoured by the wide lateral development and apparent continuity of the band.

Wilkinson (1976) did detailed petrographic work on the anthophyllite-bearing rocks of the Sherridon Group, with emphasis on the Elken Lake area. He noted the similarity of enrichment in Mg, Fe and Al in the Sherridon cordierite-anthophyllite rocks with alteration zones related to massive sulfide deposits, suggesting that the rock type could have been deposited as a chemical sediment on the sea floor.

Other studies of the area include those by Goetz (1980), Froese and Goetz (1981, 1982) and Froese (1985). These authors suggest that the protolith of the cordierite-anthophyllite rocks could have been a chlorite-rich rock representing transported and altered material from an unknown source.

Alteration zones in volcanic rocks are commonly associated with sulfide mineralization, whereas many stratiform lenses of cordierite-anthophyllite rocks in the Sherridon Group occur structurally far removed from sulfide deposits. According to these authors, as most cordierite-anthophyllite rocks lie on the lower ore-bearing horizon (Figure 2), and due to their representative compositions, these rocks required a chlorite -rich protolith, associated with sulfide deposition (Froese and Goetz, 1981; 1982).

This study will, therefore, focus on the mineralogical and chemical character of the cordierite-anthophyllite unit in order to define possible processes leading to the observed lithogies.

(II) GEOLOGICAL SETTING OF THE SHERRIDON AREA

(i) Regional Geology and Stratigraphy

The Flin Flon region, including the southern edge of the Kisseynew Complex, was first mapped by Bruce (1918). The first subdivision of the Kisseynew gneisses, north and east of Flin Flon in northern Manitoba and Saškatchewan, was made by Bateman and Harrison (1946) for the rocks of the Sherridon area. They recognized three groups:

(i) the Pre-Sherridon Group consisting of quartzofeldspathic gneisses in the centre of the Sherridon structure, pre-dating the Sherridon Group in which the orebodies occur;

(ii) the Sherridon Group consisting of a group of distinctive quartzites interbedded with hornblende-plagioclase gneisses that are metamorphosed volcanic flows; these lie in places upon Sherridon gneisses but elsewhere rest on still older sedimentary gneisses;

(iii) and the Post-Sherridon Group; these dark green hornblende-rich gneisses overlie the Sherridon Group quartzites.

Robertson (1953) later suggested that the Pre-Sherridon Group of Bateman and Harrison (1946) is older than the Sherridon Group, ("Sherridon rocks occupy a synclinal structure"), and renamed it the Nokomis Group. Later investigations in the Kisseynew Complex (Bailes, 1971) suggested that the Sherridon Group correlates with the Missi Group of the Flin Flon belt, and that the Nokomis Group correlates with the Amisk Group sediments. The main subdivisions of the Kisseynew Complex thus include Missi Group paragneisses (metasedimentary rocks with some associated volcanic rocks) surrounded by older Amisk Group metasedimentary rocks.

Grey, medium grained, quartz-plagioclase-biotite gneisses and migmatites predominate in the Nokomis Group. In addition to a gneissic fabric, the rocks locally have compositional layering 10 to 100 cm wide, defined by slight variations in biotite content.

The Sherridon Group has been divided into five stratigraphic units (Froese and Goetz, 1981; Figure 4). The lower three units are:

(i) calc-silicate gneisses;

(ii) lower quartz-rich gneisses (with layers of amphibolite, pelitic gneiss, calc-silicate gneisses. Massive sulfide deposits occur along two stratigraphic horizons associated (in some localities) with cordierite-anthophyllite rocks);

(iii) impure marble-calc-silicate gneisses with thin layers of calc-silicate gneisses arranged in a progressively younger sequence from the edge to the centre of the 'Sherridon structural basin', with no repetition of units by folding observed.

The most abundant rock in the Sherridon Group is a fine- to medium-grained quartz-rich gneiss consisting of quartz, oligoclase-andesine, K-feldspar, biotite and fine-grained almandine (Table 1). This unit is characterized by prominent quartz ridges on weathered surfaces, and layers of biotite (compositional layering on a scale of 10 to 30 cm) near the base of the Sherridon Group. Cordierite-anthophyllite rocks occur as discontinuous lenses within these quartz-rich gneisses. They are coarse-grained with garnet and anthophyllite crystals up to 10 cm in size. Most occurrences lie in the lower ore-bearing horizon, in a few

Table of Formations

Group	Lithology
Intrusive Rocks	(12) Felsic pegmatite. (11) Granodiorite, medium grained, composed of quartz, plagioclase, K feldspar, and biotite. (10) Pyroxenite, massive, composed of hornblende pseudomorphs after pyroxene. (9) Gabbro, massive to foliated, composed of plagioclase and ho-nblende.
Sherridon Group	(8) Massive amphibolite composed of plagioclase, hornblende, and garnet. (7) Amphibolite with local layering and presence of felsic clasts; composed of quartz, plagioclase, hornblende, and garnet. Minor amount of felsic fragmental rock. (6) Impure marble and calc-silicate rocks; marble beds distinguished by a high (50%) content of calcite. (5) Calc-silicate rocks, composed of quartz, plagioclase, hornblende, diopside, and calcite. Cordierite-anthophyllite rocks, composed of cordierite, anthophyllite, and garnet, with minor amounts of quartz and biotite; some occurrences associated with sulphide mineralization. (4) Pelitic schists, composed of quartz, plagioclase, biotite, sillimanite, garnet, and cordierite; typically rusty weathering, associated with sulphide mineralization. (3) Biotite-garnet schist, composed of quartz, plagioclase, biotite and garnet; characterized by small euhedral garnet porphyroblasts. (2) Quartz-rich gneisses, composed of quartz, plagioclase, K feldspar, biotite, and garnet. Some interlayered calc-silicate and pelitic gneisses.
Nokomis Group	(1) Quartzofeldspathic gneisses, migmatites, and granitoid gneisses.

TABLE 1: Lithologic units of the Sherridon Group in the vicinity of Sherridon Manitoba (Froese and Goetz, 1981).

places below the sulfide layer, but more commonly along unmineralized sections of the cordierite-anthophyllite horizon - Star Lake, (Figure 2). Calc-silicate rocks are also interlayered with quartz-rich gneisses. These are fine- to medium-grained, greyish-green rocks composed mainly of quartz, andesine-labradorite and hornblende, with sporadic K-feldspar, biotite, scapolite, diopside and calcite. The interlayered impure marble and calc-silicate rocks have a similar mineralogical composition but with higher contents of calcite and the presence of Cr-bearing grossular. The amphibolites form several continuous layers within the quartz-rich gneisses; they are mainly dark grey, fine- to medium-grained rocks of hornblende, garnet, quartz, plagioclase and trace amounts of biotite.

Later investigations of the Kississing Lake map area (Schledewitz, 1988) have resulted in four mappable components for the Kisseynew gneisses. These four components are considered to be sedimentary and/or volcanic derived metamorphic rocks. Two major lithostratigraphic units are the Burntwood River (oldest metamorphic site (Nokomis Group; Robertson, 1953)); an aluminous - graphite - bearing biotite gneiss and the younger Missi metamorphic suite which is predominantly composed of quartzofeldspathic rocks that are variably magnetiferous and hornblende - bearing.

The two remaining lithostratigraphic components have been placed into a category of rocks of uncertain affinity and/or age. These include a suite of amphibolite +/- garnet, calc - silicates and hornblende - biotite - garnet feldspar - quartz gneiss lying discontinuously between the Burntwood and Missi metamorphic suites. It is uncertain whether or not they are part of the Burntwood or Missi suite of rocks. The second is the Sherridon metamorphic suite (Sherridon Group, Bateman and Harrison, 1946; Froese and Goetz, 1981) which is considered to be a highly recrystallized and tectonized varied suite of rocks of uncertain age and affinity.

A new structural interpretation suggests that the Sherridon metamorphic suite may be older than the Missi suite (Zwanzig, 1988). Sherrídon gneisses have been considered to be younger than the surrounding gneisses (Bateman and Harrison, 1946; Froese and Goetz, 1981) but the type section at Sherridon is surrounded by granitoid rocks and has an unknown stratigraphic position. Similar gneisses north and east of Walton Lake lie between two belts of Burntwood River metagreywacke (contact locally gradational). The metagreywacke is stratigraphically overlain by the Missi suite, which suggests that the Sherridon suite lies in the core of an anticline and is equivalent to or older than the Burntwood River suite.

Southwest of Meat Lake, Sherridon - type gneiss is traced laterally into less coarsely recrystallized rocks that appear to represent basaltic, dacitic and intermediate metavolcanic rocks, locally interlayed with greywacke - derived gneiss. This part of the Sherridon suite is tentatively correlated with the Amisk Group (Zwanzig, 1988).

Recent work in the Wildnest Lake area, Saskatchewan has also led to the recognition of a suite of Kisseynew gneisses which are strikingly similar to those of the Sherridon Group in the vicinity of Sherridon, but which have been assigned to the Amisk Group (Ashton et al, 1986; 1987). These geological observations, therefore, cast some doubt on the correlation between the Sherridon Group in the vicinity of Sherridon and the Missi Group. The possibility must be considered that the Sherridon Group, like the Wildnest Lake suite, is largely of volcanic origin and is equivalent to a part of the Amisk Group (Ashton and Froese, 1988).

(ii) Star Lake - Elken Lake: Local Geology and Stratigraphy

The garnet-anthophyllite gneiss zone at Star Lake is considered to be, by some authors, an extention of the cordierite-anthophyllite rocks near Sherridon, Manitoba, where massive sulfide deposits are found along the same stratigraphic horizon. In places, this prominent garnet-anthophyllite gneiss zone is extremely coarse-grained and is underlain by a sillimanite-bearing unit. Within the garnet-anthophyllite rocks, three mappable units have been recognized by Gunter and Yamada (1986). From the structural base upwards, these units contain:

(1) quartz-garnet-anthophyllite-biotite

(2) garnet-anthophyllite +/- cordierite

(3) anthophyllite-cordierite

Unit 1 is characterized by 1 to 2 cm sprays of fine-grained needle-like anthophyllite and platy aggregates of brown to black biotite, both of which tend to concentrate in monomineralic bands parallel to the bedding planes. The garnets are generally 2 to 4 cm in diameter, and occur in a very fine-grained quartz-rich groundmass (photographs 1, 5). Quartz-cordierite aggregates are locally present, and pegmatites intruding the unit tend to develop biotite-rich selvages in contact with euhedral cordierite grains (photographs 2, 3). Euhedral crystals of K-feldspar, quartz, biotite, cordierite and garnet are present. In addition, tourmaline aggregates are also found in the upper part of unit 1 (photograph 4).

Unit 2 is composed mainly of circular to ellipsoidal snowball garnets 5 to 6 cm in diameter, stellate groups of dark brown anthophyllite, 2 to 5 cm in length and locally abundant 2 to 3 cm blue-white weathered quartz-cordierite aggregates (photographs 6, 7, 8). This unit is conspicuously zoned, with a garnet-rich base grading upward into an approximately equal mixture of garnet, anthophyllite and cordierite. Pegmatites intruding this unit do not seem to have reacted with it, as there are no biotite selvages

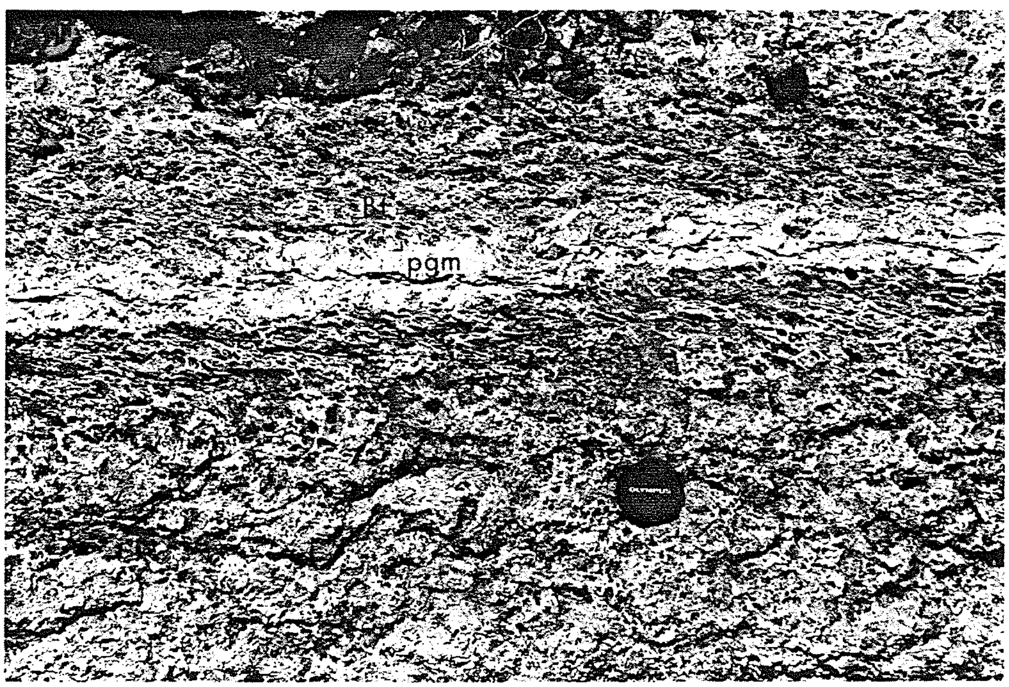
PHOTOGRAPH 1

Unit 1: 1 - 2 cm sprays of fine-grained needle-like anthophyllite, platy aggregates of brown-black biotite and garnets ranging from 2 to 4cm in diameter in a fine-grained quartz-rich cordierite groundmass.

PHOTOGRAPH 2

Unit 1: pegmatite (pgm) intruding unit 1. Note the biotite (Bt) - rich shelvages in contact with euhedral cordierite.


OLYMPUS

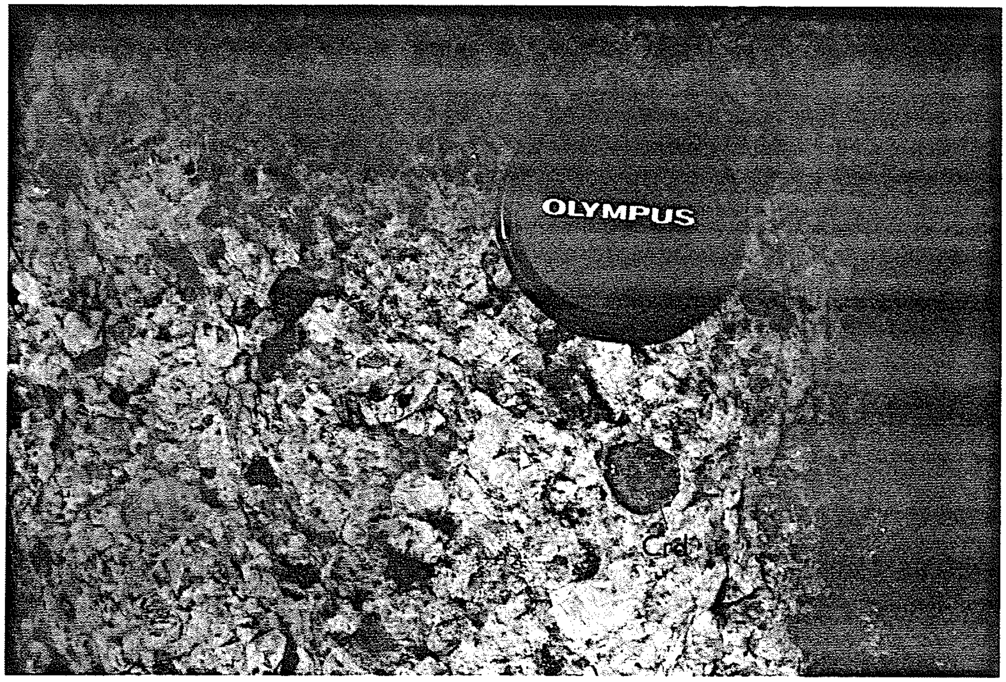

Bt
pgm

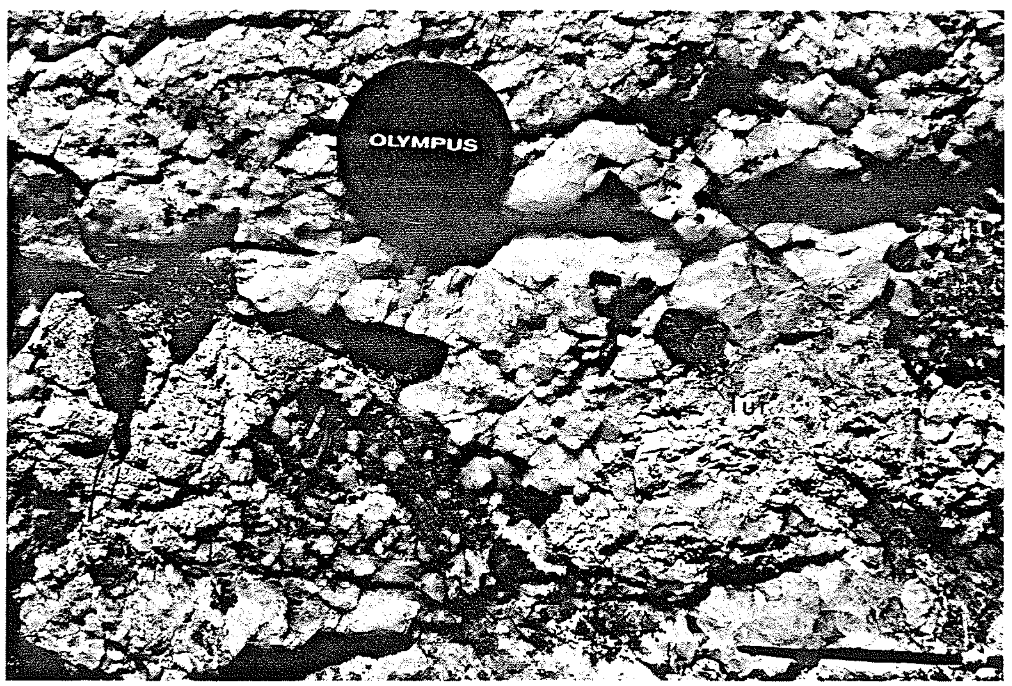
PHOTOGRAPH 3

Unit 1: euhedral cordierite (Crd) in pegmatite intrusion of unit 1.

PHOTOGRAPH 4

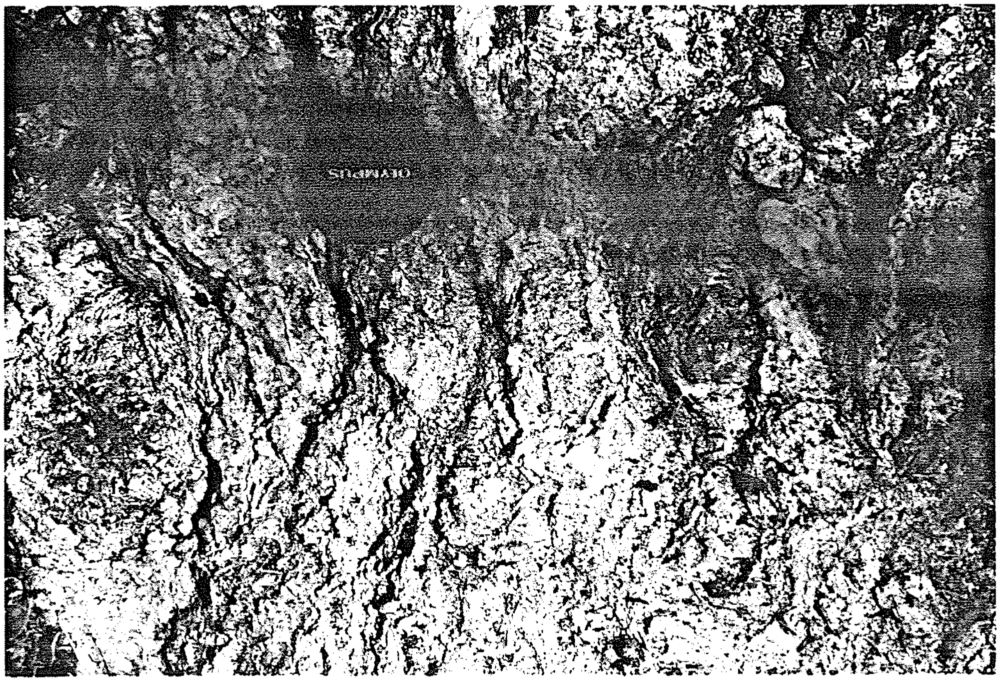
Unit 1: euhedral tourmaline (Tur) found in the upper part of unit 1.


OLYMPUS
Crd


OLYMPUS

PHOTOGRAPH 5
Unit 1: abundant inclusions of quartz in large garnet (Grt) porphyroblast of unit 1.

PHOTOGRAPH 6
Unit 2: circular to ellipsoidal `snowball' garnets, bladed to stellate groups of anthophyllite, and locally abundant blue-white weathered quartz-cordierite aggregates.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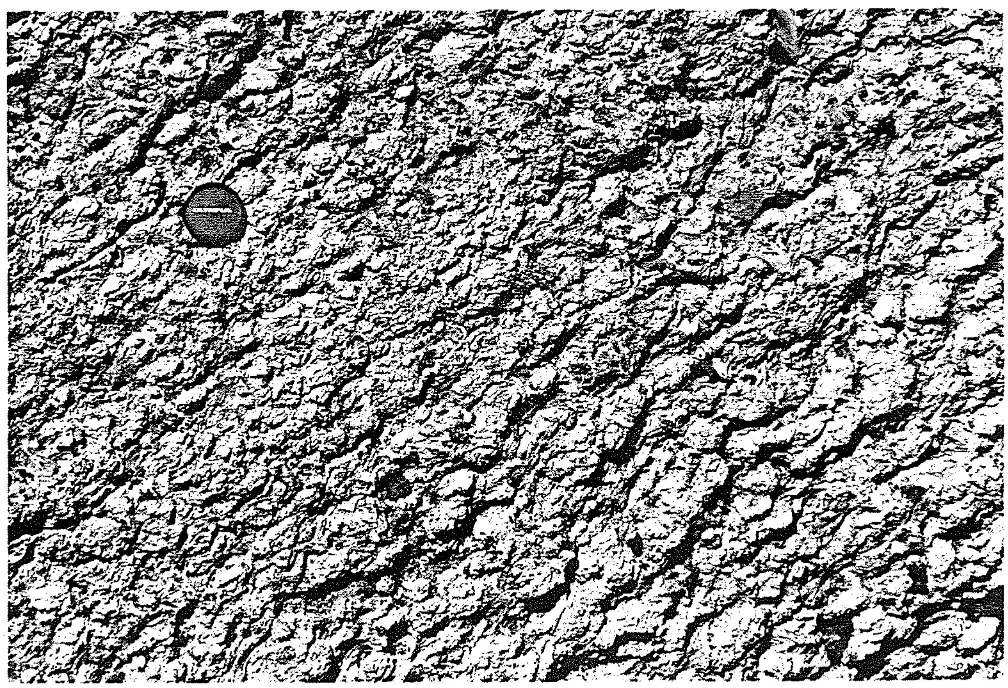
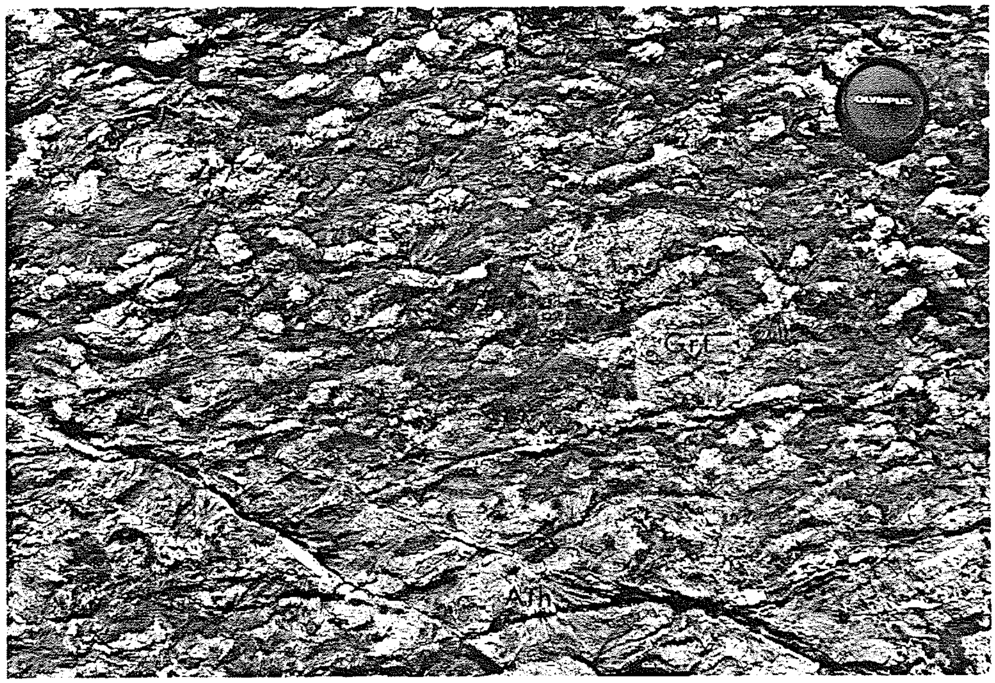
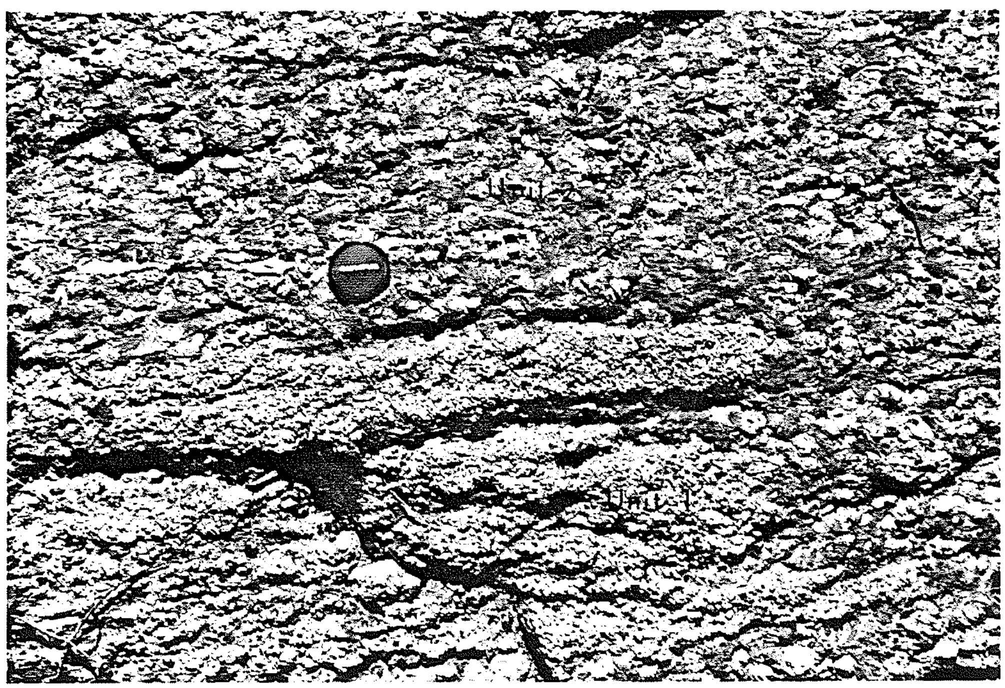


PHOTOGRAPH 7
Unit 2: 5-6 cm `snowball' garnets (Grt), 2-5 cm dark brown groups of anthophyllite (Ath) blades and 2-3 cm quartz-cordierite aggregates.

PHOTOGRAPH 8a
Unit 2: contact of coarser-grained unit 2 (circular to ellipsoidal `snowball' garnets, bladed to stellate groups of anthophyllite and blue-white weathered quartz-cordierite aggregates) with the finer-grained quartz-rich unit 1.


Grt
Ath


Unit 2
Unit 1

found near the contacts (photograph 9). Sillimanite-rich zones occur at contacts between units 1 and 2, and adjoin a finer-grained garnet-rich layer in unit 1 (photographs 10, 11). In the northwest area of Elken Lake (unit 2), there is disseminated pyrrhotite, chalcopyrite and minor pyrite along the same main ore-bearing horizon as the Sherritt Gordon orebodies. However, in this case, the sulfide is thin, stratiform, weakly disseminated and rarely attains a thickness greater than a few meters.

Unit 3 is composed of coarse-grained (5 to 10 cm) elongated to slightly stellate bundles of anthophyllite oriented parallel to bedding (photograph 12). Cordierite occurs as 3 to 5 cm anhedral quartz-cordierite aggregates interstitial to the anthophyllite aggregates (photograph 13). Both the lower and upper contacts of units 2 and 3 are transitional over 1 to 3 m, and are conformable with the flattened garnets and anthophyllite lineations (photographs 14, 15).

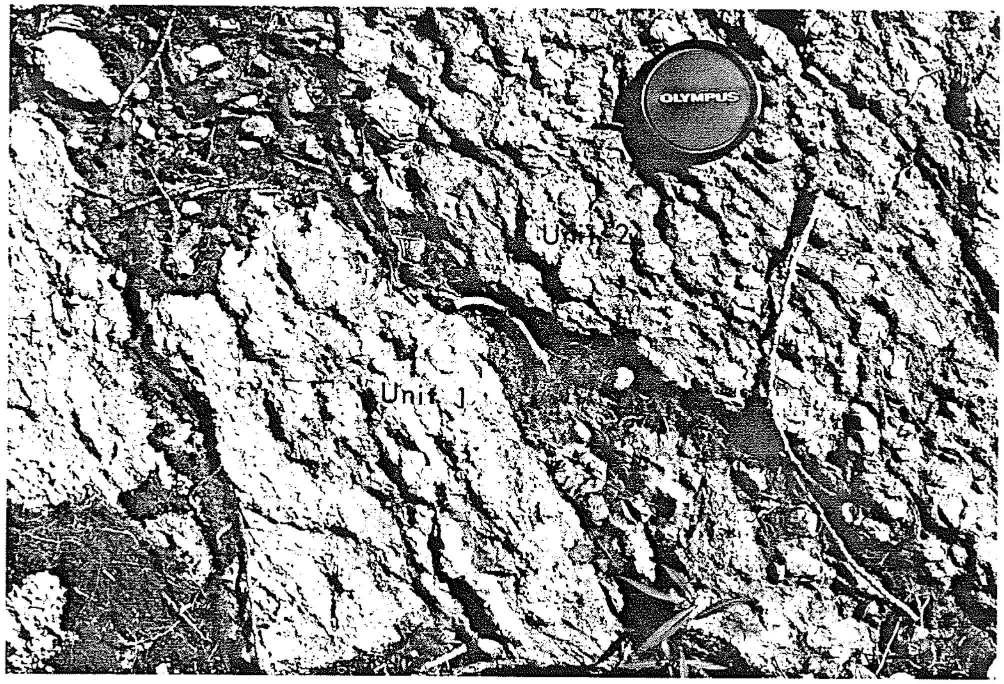
In general, these units contain large, poikiloblastic radiating sheaves of anthophyllite, which may be as much as 10 cm long, poikiloblastic dark-blue to purple cordierite (frequently altered to pinite, and containing quartz inclusions), large poikiloblastic pink garnets, with biotite and quartz making up much of the remainder of the rock. Intergrown in the gneisses are magnetite, green spinel, staurolite and chlorite, with minor

PHOTOGRAPH 8b

Unit 2: contact of coarser-grained unit 2 (circular to ellipsoidal 'snowball' garnets, bladed to stellate groups of anthophyllite and blue-white weathered quartz-cordierite aggregates) with the finer-grained quartz-rich unit 1.

PHOTOGRAPH 9

Unit 2: contact of unit 2 with pegmatite (pgm) intrusion, showing no sign of biotite selvages that are typical of unit 1.


OLYMPUS
Unit 2
Unit 1


Unit 2
bgm
OLYMPUS

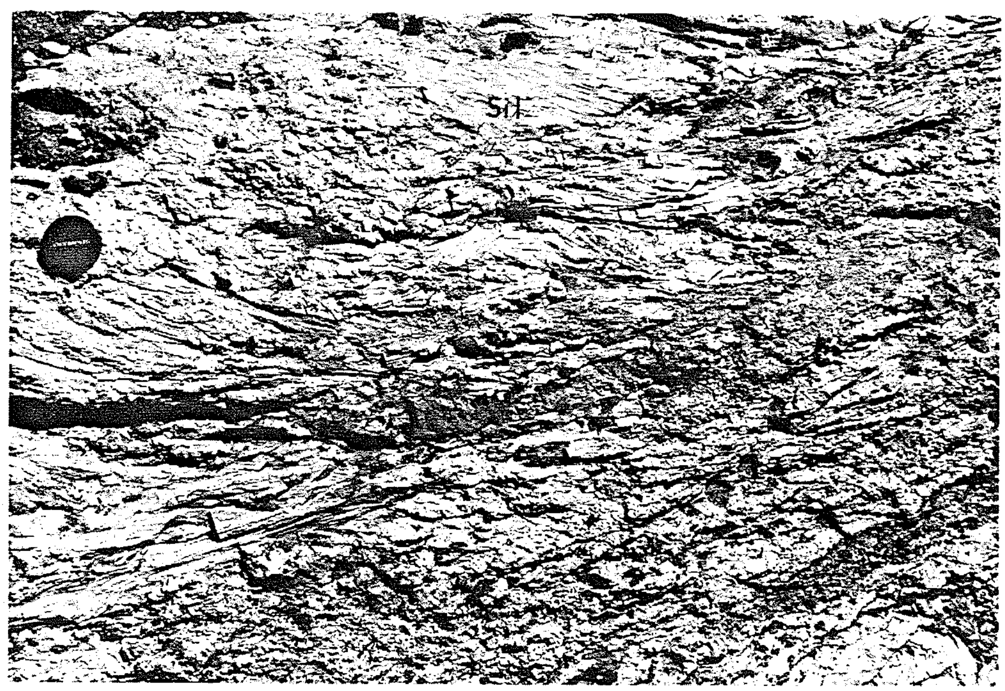
PHOTOGRAPH 10

Sillimanite-rich (Sil) zone located in stratiform tectonic contacts between units 1 and 2, and adjoining a finer-grained garnet-rich layer in unit 1.

PHOTOGRAPH 11

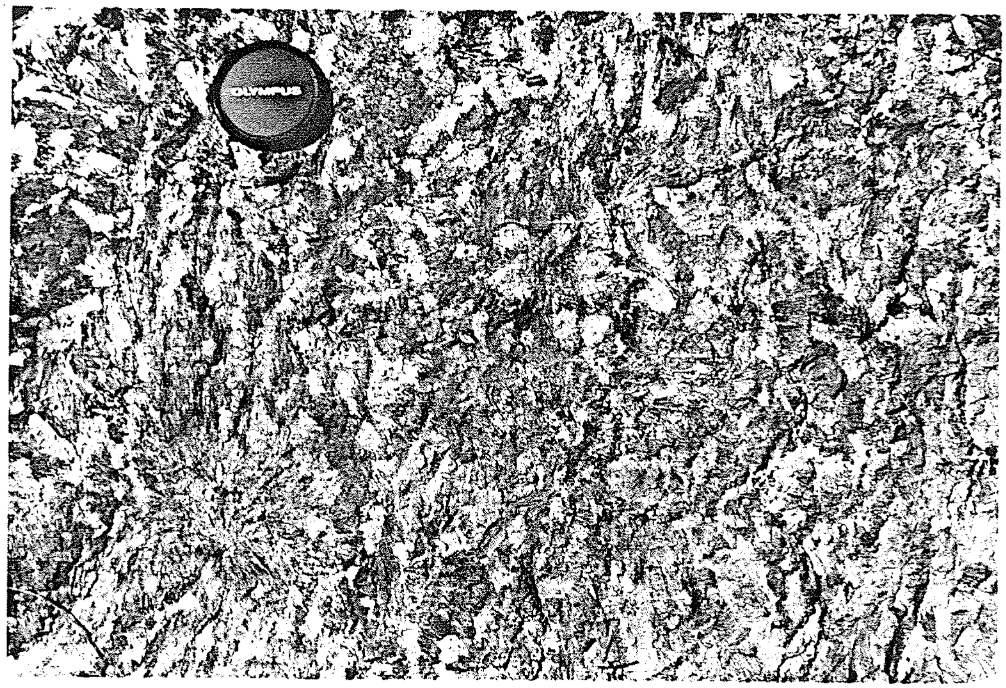
Coarse-grained sillimanite (Sil) from the sillimanite-rich zone.


Sil


Sil

PHOTOGRAPH 12
Unit 3: 5-10 cm elongated to slightly stellate bundles of anthophyllite (Ath) with quartz-cordierite (Crd) aggregates interstitial to the anthophyllite blades.

PHOTOGRAPH 13
Unit 3: 3-5 cm anhedral quartz-cordierite (Crd) aggregates interstitial to the stellate bundles of anthophyllite blades.

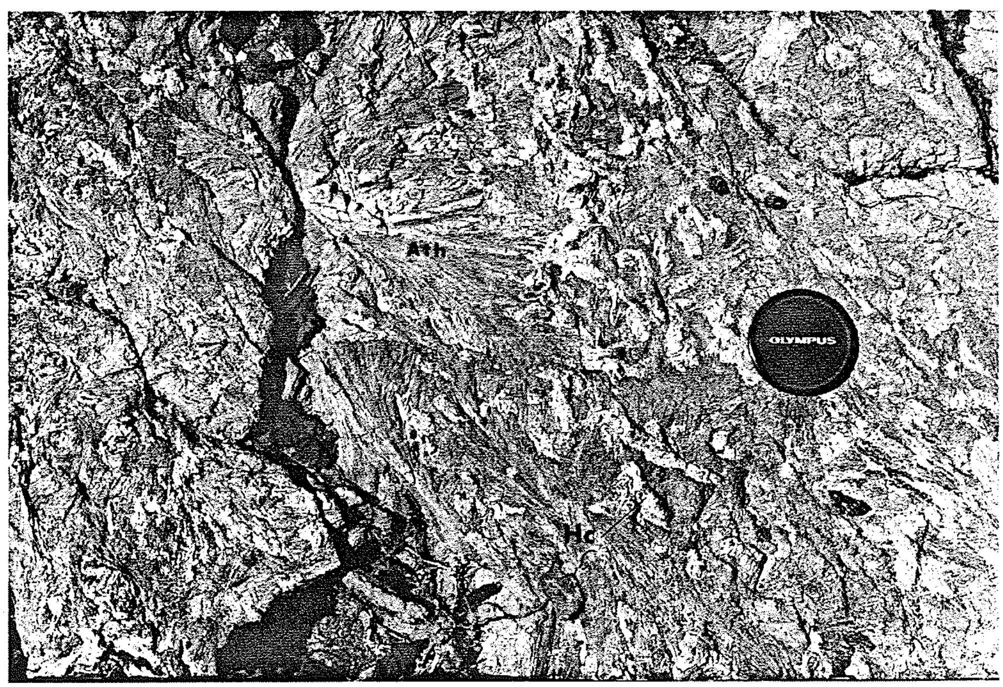

OLYMPUS


OLYMPUS
ATH

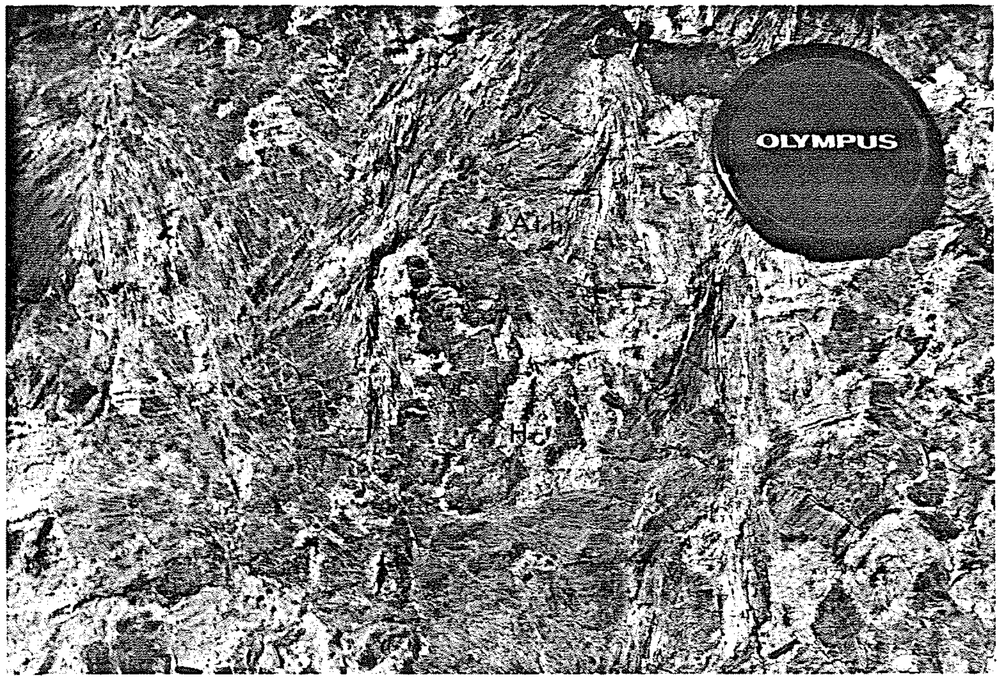
PHOTOGRAPH 14
Unit 3: gradational contact between units 2 and 3; elongate bundles of anthophyllite are oriented parallel to the bedding.

PHOTOGRAPHS 15a
Unit 3: cordierite (Crd) `pockets' with fine-grained myrmekitic hercynite (Hc) spinel concentrations, surrounded by anthophyllite (Ath) blades.


UNIT 2


Ath
OLYMPUS
Hc

PHOTOGRAPHS 15b
Unit 3: cordierite `pockets' with fine-grained myrmekitic hercynite (Hc) spinel concentrations, surrounded by anthophyllite (Ath) blades.


OLYMPUS
Ath
Hc

pyrite, pyrrhotite, and chalcopyrite.

In the field a rock saw was used to sample the units, providing as continuous a sample as possible. Saw-cut intersections, dimensions and locations are given in Table 2 and Figures 3 and 4.

TABLE 2: STAR LAKE SAW-CUT INTERSECTIONS, DIMENSIONS AND LOCATIONS

SAW CUT #	INTERSECTION OF ROCK UNITS	LENGTH (CM)	LOCATION
SC - 1	UNIT 1 - pegmatite	0 - 120	NW - fig 3
SC - 2a	UNIT 1 - pegmatite - UNIT 1	0 - 146	NW - fig 3
SC - 2b	UNIT 1 - pegmatite - UNIT 1	146 - 257	NW - fig 3
SC - 3a	UNIT 1	0 - 125	N - fig 3
SC - 3b	UNIT 1	164 - 271	N - fig 3
SC - 3c	UNIT 1 - UNIT 2	380 - 561	N - fig 3
SC - 3d	UNIT 2 - UNIT 1 (?)	600 - 677	N - fig 3
SC - 3e	UNIT 2	773 - 870	NE - fig 3
SC - 3f	UNIT 2	870 - 1027	NE - fig 3
SC - 4a	UNIT 3	0 - 100	SE - fig 3
SC - 4b	UNIT 3	100 - 150	SE - fig 3
SC - 5a	UNIT 2	0 - 172	N - fig 4
SC - 5b	UNIT 2 (?)	470 - 685	NE - fig 4
SC - 5c	UNIT 3	762 - 853	NE - fig 4
SC - 5d	UNIT 3	880 - 1022	NE - fig 4
SC - 5e	quartz - biotite gneiss	1230 - 1317	NE - fig 4
SC - 5f	quartz - biotite gneiss	1556 - 1635	NE - fig 4
SC - 6	UNIT 1 (?) - UNIT 2	0 - 76	NW - fig 4
SC - 7	UNIT 1 - sillimanite/quartz	0 - 152	SW - fig 4
SC - 8a	quartz vein - UNIT 3	170 - 476	centre - fig 4
SC - 8b	UNIT 2 - UNIT 3-quartz vein	0 - 96	centre - fig 4

UNIT 1: Quartz - Garnet - Anthophyllite - Biotite

UNIT 2: Garnet - Anthophyllite - Cordierite

UNIT 3: Anthophyllite - Cordierite

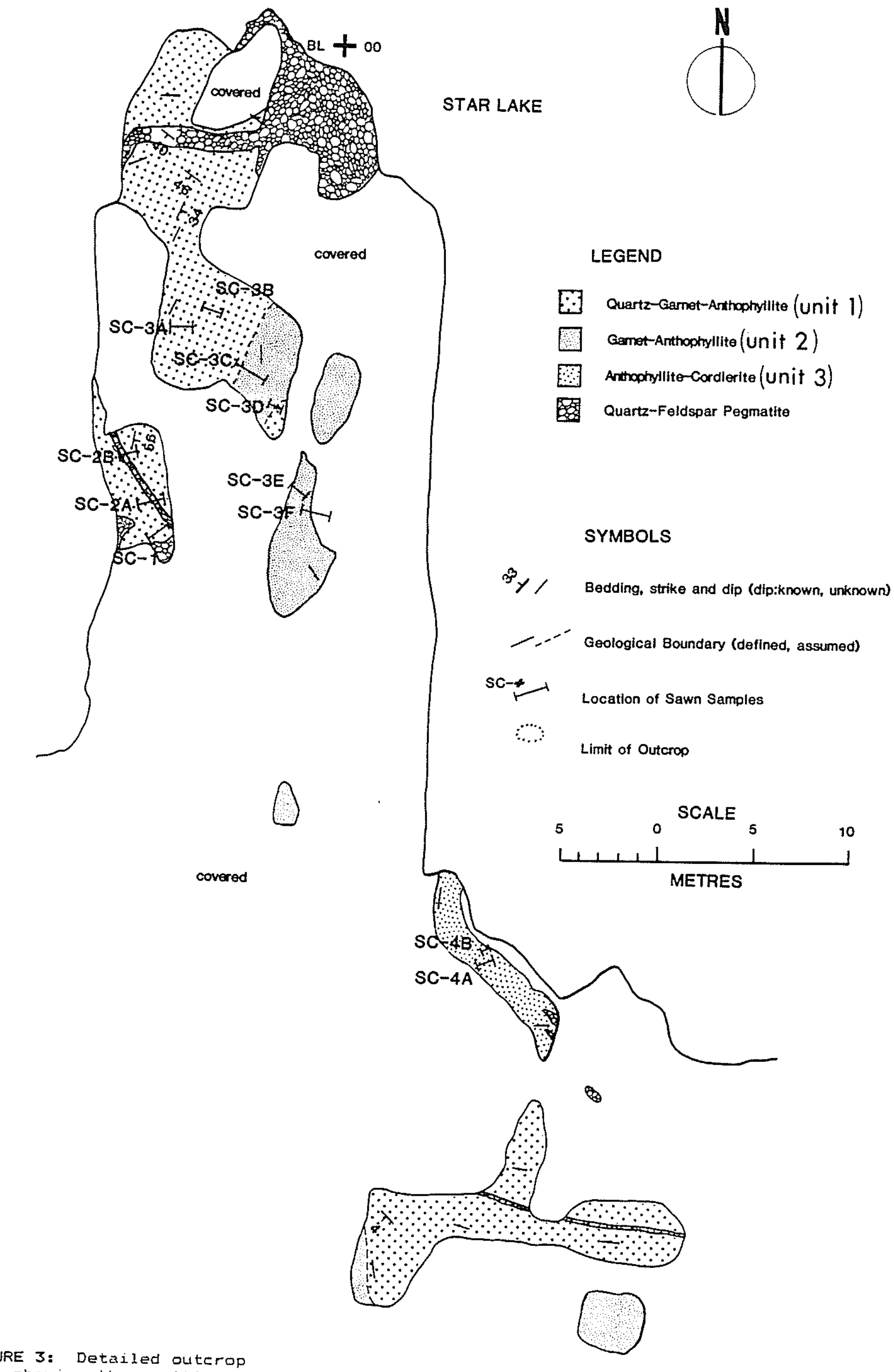


FIGURE 3: Detailed outcrop map showing the position of the various saw cuts (Gunter and Yamada, 1986).

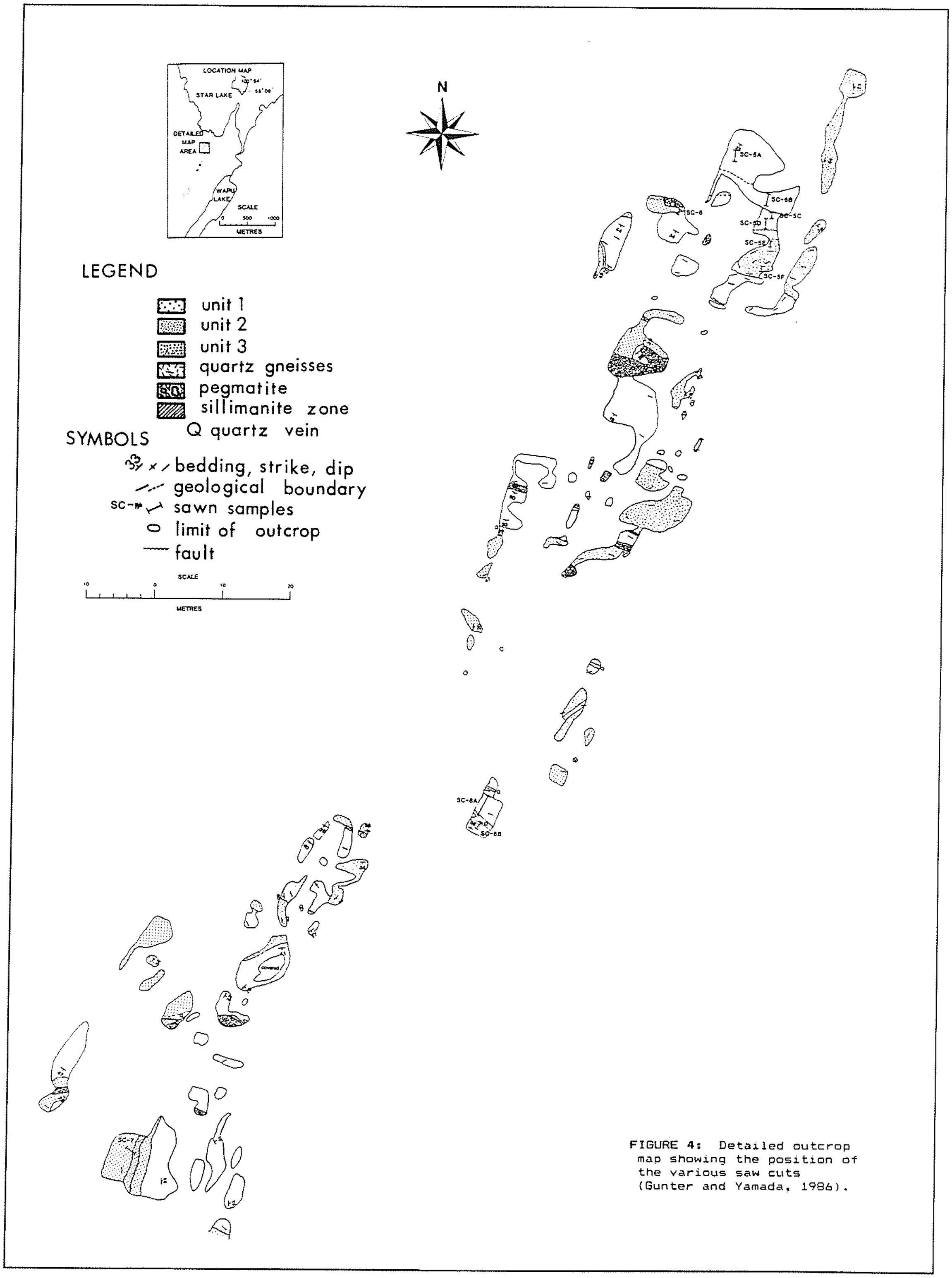


FIGURE 4: Detailed outcrop map showing the position of the various saw cuts (Gunter and Yamada, 1986).

(III) **MINERALOGY AND PETROLOGY:**

The detailed mineral assemblages from the Star Lake - Elken Lake area are summarized in Table 3.

The cordierite-garnet-anthophyllite bearing assemblages occur in a set of well-banded, coarse-grained porphyroblastic rocks which are generally modally dominated by amphibole (over 40-50 %). Schistosity is generally defined by the parallel orientation of long amphibole blades and biotite plates.

Due to the coarse grained nature of the specimens, modal analyses were done on hand specimens in order to give an estimate of bulk rock composition. In practice, a minimum area 100 times the area of the largest grain in the hand specimen (with a minimum of a 1000 point counts in such an area) was used (Jackson and Ross, 1956). Amphibole (where present), garnet, cordierite and quartz are the most abundant minerals, with anthophyllites > garnets > cordierites > quartz (units 2 & 3) (Table 4). Biotite is the next most abundant mineral, followed by sillimanite, hercynite, magnetite, rutile, apatite, staurolite and zircon +/- titanite.

Primary Minerals

(i) Garnet (almandine)

Porphyroblasts of almandine garnet ranging in size from 0.25 mm (broken pieces) to > 25 mm in diameter are very abundant in the gneiss zone. The garnets are usually

TABLE 3: MINERAL ASSEMBLAGES FROM THE STAR LAKE AREA

SAMPLE #	Qtz	Sil	St	Grt	Amp	Crd	Bt	Chl	Hc	Ap	Wg	Mag	Plag
SC													
1-7	o	o		x	o		x					o	
1-14a	o	x		x			x						
2-1	o	o		x		x	x	o	o				o
2-9	o	x		x		x	x						o
3-10	o	x		x	x	x	x						
3-25a	o	o		x	x	x	x						
3-26a	o	x		o	x	x	o	o	o				
3-29	o			x	x	x	x						
3-34	o	o		x	x	x	o	o				o	
3-43	o			x	x	o		o					
3-54a	o	x			x	x	x						
4-2b	o	o		x	x	x	x	x					
4-9	o	x		x	x	x	o	o	x			o	
4-12	o			x	x	x		o	x				
4-13b	o	o			x	x		o		o		o	
5-1	o	x		x	x	x	x	o					
5-9	o	o	x	x	x	o	x	o	o		x	o	
5-12	o		x	x	o		x	o				o	
5-16	o	o		x	x	x	x	o				o	
5-21a	o	o	o	o	x	x	x				x	o	
5-25a	o	o	x	x	x	x	x						
5-35	o	x			x	x	o	o	x			o	
5-39	o	o			x	x	x	o				o	
5-67	o	x					x					o	
6-3	o	o		x		o	x						
6-4	o	o		x		x	x	o				o	
7-1	o	x		x			x	o					
7-4	o	o		x		o	x	o					
7-10	o	x					x	o		x			
8-4	o	o			x	x		x					
8-7	o	x			x	x	x	o				o	
8-11	o	o			o	o	o	x					
8-15	o	x			x	x		o				o	
8-17	o	x			x	x		x				o	
8-28	o	x			o	x		x				o	
ML													
01	o		x	o				o	x				
02	o										x		
08	o		x	o				o				o	
15	o				o		o	o	x				
33	o				o	o	o		x				
37	o		x		o		o						
49	o	x	x	x	x	x		o					
52	o			x	x			o				o	
55	o	o		x	x		x					o	
93	o	x			x	x	x	o	x				

x - analyzed mineral
o - mineral present

TABLE 4: HAND SPECIMEN MODAL ANALYSES OF REPRESENTATIVE SAMPLES

Specimen No.	Unit No.	GARNET	QUARTZ	CORD - IERITE	ANTHO - PHYLLITE	BIOTITE	SILLI - MANITE
SC 1-2	1	2.0	11.8			86.2	
SC 1-14A	1	3.0	27.9			59.6	9.5
SC 2-6	1	29.3	40.4			30.3	
SC 2-11	1	26.8	24.0			49.2	
SC 2-21	1	37.0	22.6			37.0	3.4
SC 2-25	1	32.4	37.3			22.0	8.3
SC 3-8	1	13.2	26.0	5.9	50.0		4.9
SC 3-10	1	9.1	7.7	20.3	52.8		10.1
SC 3-18	1		2.4	21.5	76.1		
SC 3-26	2	19.4	10.4		60.1		10.1
SC 3-28	2	25.5	10.8	11.2	52.5		
SC 3-34	2	28.1	4.7	13.6	53.6		
SC 3-41	2	26.9	3.7	10.3	59.1		
SC 3-44	2	38.1	10.6	5.5	45.8		
SC 3-51	2	44.1	8.1	8.6	38.9		
SC 3-53	2	7.8	5.2	16.7	70.3		
SC 4-5	3	9.5	17.4	11.7	61.4		
SC 4-13	3		32.1	12.7	55.2		
SC 5-2	2	50.2	12.1			37.7	
SC 5-6	2	58.2	1.3		40.5		
SC 5-11	2	56.2	6.4		37.4		
SC 5-18	2	9.8	2.4	29.3	58.5		
SC 5-20	2	28.6	3.0	18.6	49.8		
SC 5-25	2	12.4	13.1	15.1	59.4		
SC 5-29	3		3.0	24.4	72.6		
SC 5-31	3		3.3	34.1	62.6		
SC 5-42	3		2.6	15.5	81.9		
SC 6-1	1		31.9			59.2	8.9
SC 6-4	2	37.0	8.8			41.2	13.0
SC 7-4	1	28.6				13.1	58.3
SC 7-10	1					29.3	70.7
SC 8-4	3			31.0	69.0		
SC 8-6	3		11.2	18.2	70.6		
SC 8-13	3		21.9		78.1		
SC 8-17	3		10.3		89.7		

anhedral to subhedral, and are extensively fractured with chlorite infilling and replacing them (photograph 16). This replacement was possibly caused by a later low-grade metamorphic event. These porphyroblasts contain abundant inclusion trains of quartz, with minor magnetite, staurolite, sillimanite, rutile and hercynite spinel (photograph 17).

Two distinct periods of garnet crystallization can be inferred in these units:

(i) pre-tectonic crystals (photograph 18), with sheaths of biotite along the foliation;

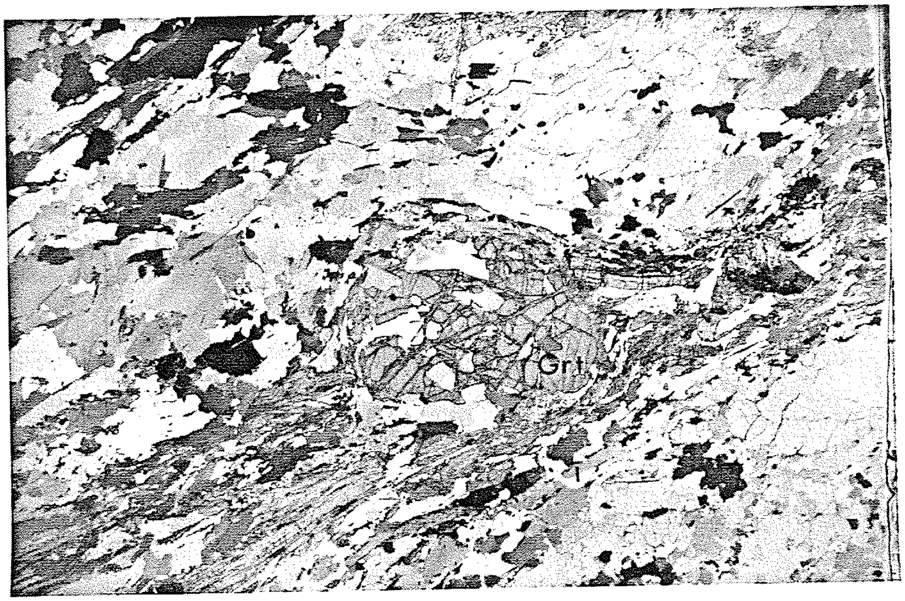
(ii) syntectonic crystals (photograph 19), with 'rotational' features preserved. In general, the garnets show no sign of reaction except in the presence of sillimanite, where they seem to be replaced by cordierite and hercynite spinel (photographs 20 and 21).

(ii) Orthoamphibole (anthophyllite / gedrite)

Orthoamphiboles occur either radially, ranging in length from 0.1 to > 3.0 cm, or in randomly oriented sheath-like groups with individual prisms up to 9 mm long. The blades are dark-brown in hand-specimen and define a schistosity together with intergrown biotite (photograph 22). The sheath-like aggregates have pronounced fractures and prismatic cleavage (photograph 23), both of which are quite characteristic for orthoamphiboles. Cordierite and chlorite reaction rims are found mantling the orthoamphibole

PHOTOGRAPH 16
Extensively fractured garnet (Grt) porphyroblast, with chlorite filling the fractures (ppl - X15).

PHOTOGRAPH 17
Almandine garnets (Grt) with abundant inclusion trains of quartz, and minor magnetite (Mag), rutile, sillimanite (Sil) and staurolite (St) (ppl - X5).


Grt


St
Sil
Mag
Grt

PHOTOGRAPH 18

Pre-tectonic garnet (Grt) with sheaths of biotite (Bt) along the foliation (ppl - X4).

PHOTOGRAPH 19

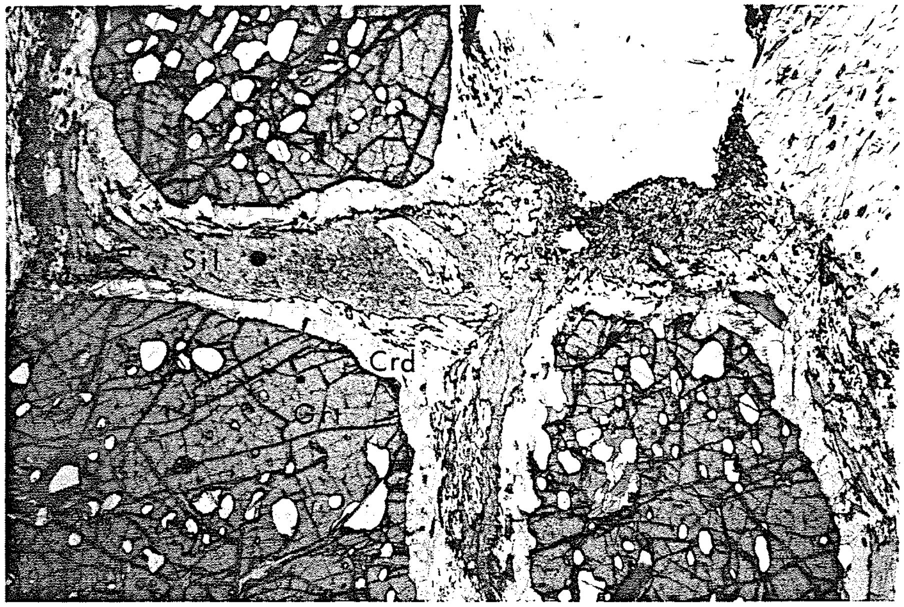
Syntectonic garnet (Grt) with 'rotational' features preserved (crystals contain a set of discontinuous internal S-surface (S1) which are composed of trails of round to elongate blebs of quartz (Qtz) and grains of magnetite) (ppl - X5).

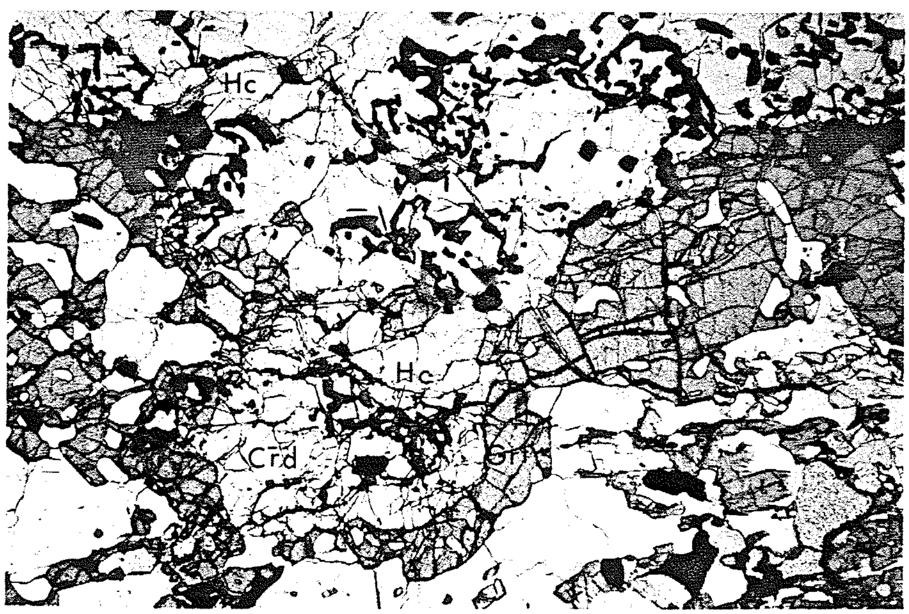

Bt
Grt


Grt
Qtz

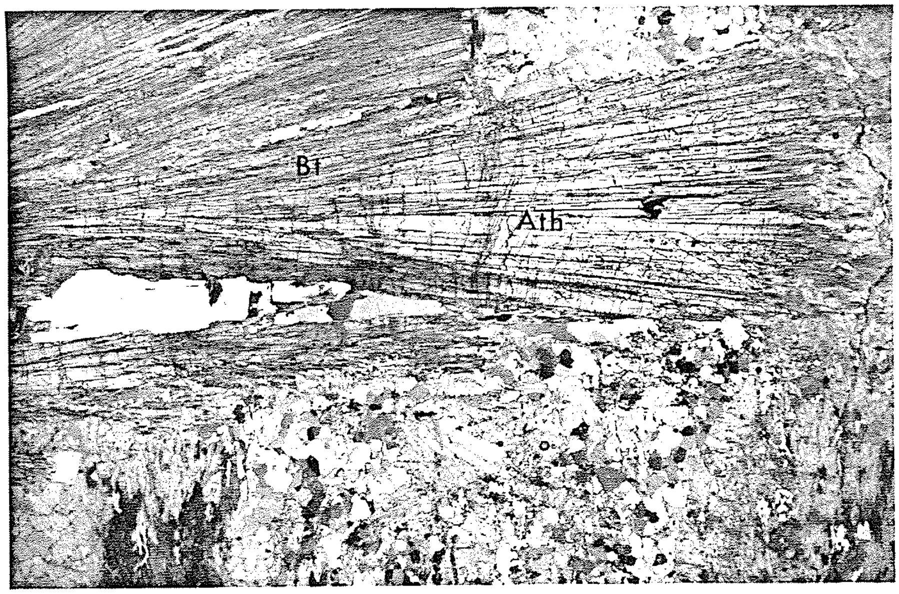
PHOTOGRAPH 20
Garnet (Grt) with cordierite (Crd) rims separating garnet from the surrounding sillimanite (Sil) (ppl - X20).

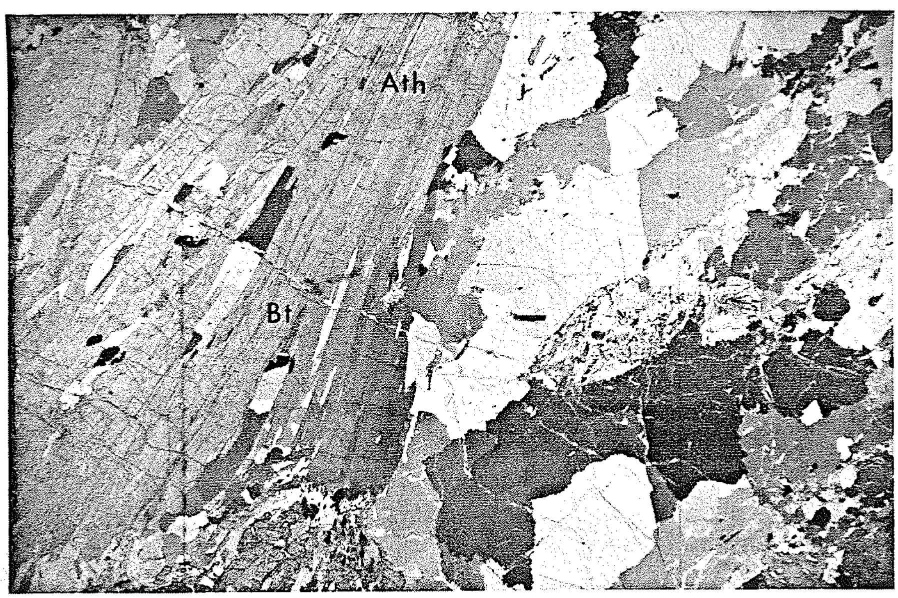
PHOTOGRAPH 21
Garnet (Grt) replaced by cordierite (Crd) and hercynite (Hc) (ppl - X20).


Sil
Crd
Gt


Hc
Hc
Crd
Gt

PHOTOGRAPHS 22a & 22b
Anthophyllite (Ath) blades ranging in length from 0.1->3 cm, and defining a schistosity together with intergrown biotite (Bt) (ppl - X5).


Bt
Ath


Ath
Bt

grains (photograph 24). The orthoamphiboles also show reaction rims of cordierite when in contact with hercynite and sillimanite (photograph 25) revealing their incompatibilities. Textural relationships between staurolites and orthoamphiboles were not found.

(iii) <u>Cordierite</u>

A considerable proportion of the matrix material between amphibole prisms is cordierite; the anhedral grains range from 0.5 to 4 mm in diameter and are purple in hand specimen. Many grains and larger crystals of cordierite are twinned, with both polysynthetic and penetration twins present, and are studded with minute hercynite inclusions. Chlorite is locally found rimming the cordierite, whereas pinite occurs along the fractures. The inclusions give the larger grains a characteristic 'cloudy' appearance, distinguishing them from quartz (photograph 26). Cordierite-quartz-sillimanite aggregates are also commonly found surrounded by amphibole and biotite grains (photograph 25).

(iv) <u>Sillimanite</u>

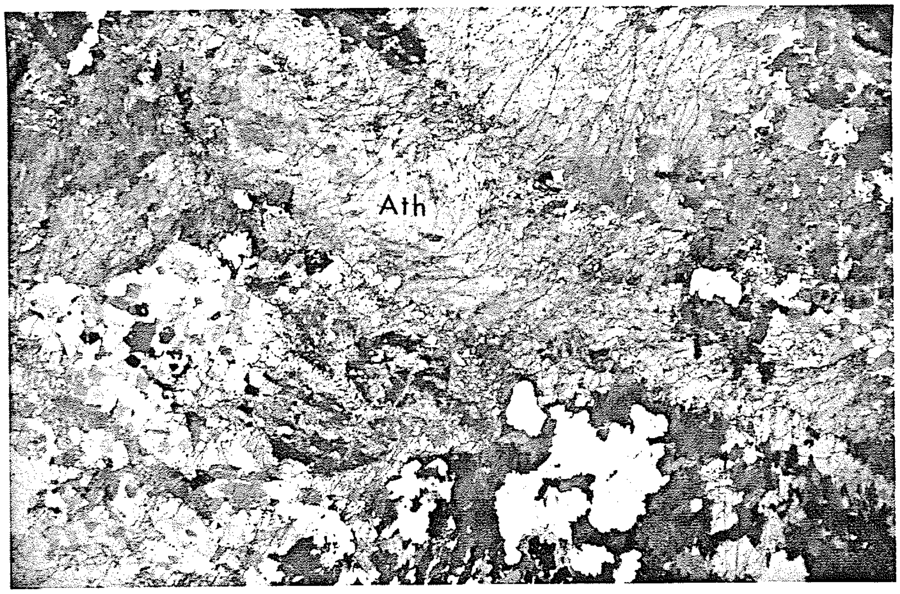
In the gneiss zone, there are two varieties of sillimanite. Fibrolitic sillimanite occurs in elongate to elliptical aggregates of tiny needles oriented parallel to the foliation. They also tend to be associated with other elongate features such as pegmatite and quartz veins. Most aggregates are 0.5 - 10 mm long, and seem to suggest a

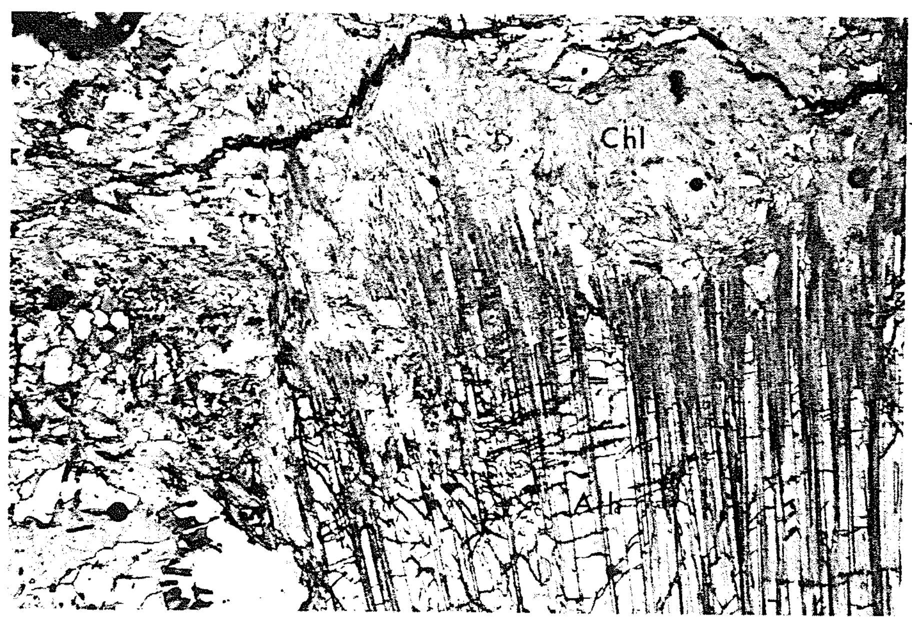
PHOTOGRAPH 23

Anthophyllite (Ath) in sheath-like groups with individual prisms ranging up to 9mm in length: the sheath-like aggregates are randomly oriented and have pronounced fractures and prismatic cleavages (ppl - X5).

PHOTOGRAPH 24

Chlorite (Chl) reaction rims mantling anthophyllite (Ath) blades (ppl - X20).


Ath

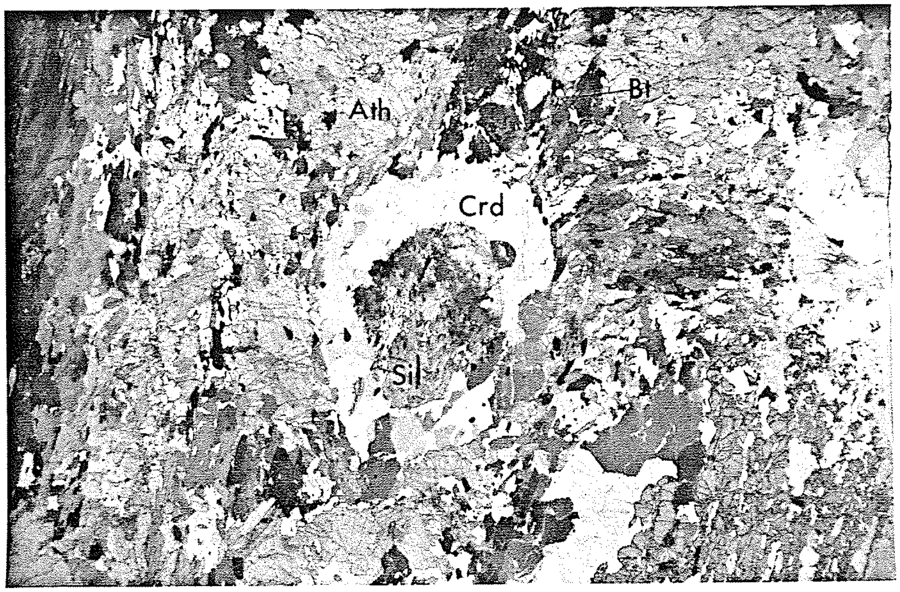

Chl
Ath

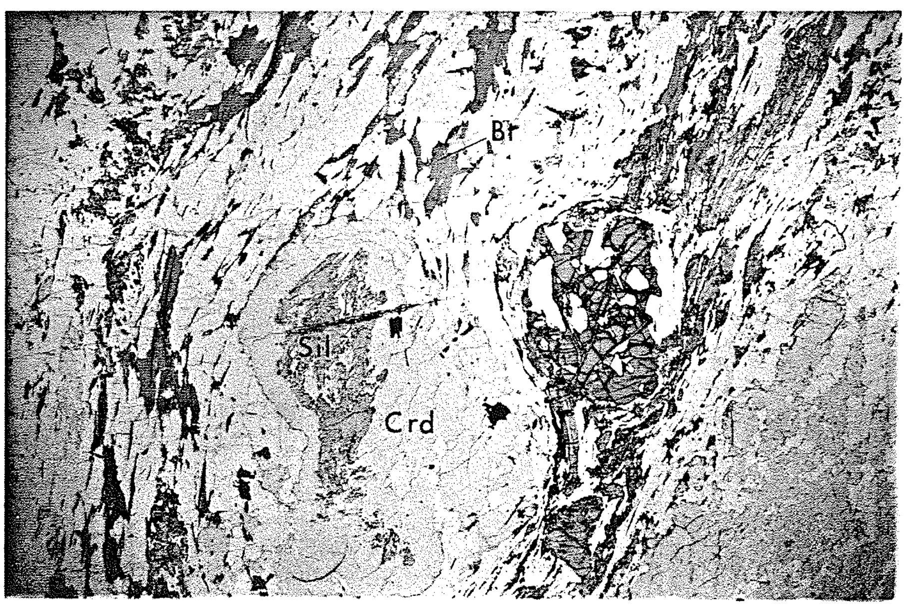
PHOTOGRAPH 25

Quartz-cordierite(Crd)-sillimanite (Sil) pocket surrounded by amphibole (Ath) blades and biotite (Bt) grains (ppl - X5).

PHOTOGRAPH 26

Cordierite(Crd)-sillimanite (Sil) pocket surrounded by biotite (Bt); inclusions give the cordierite a 'cloudy dusting' appearance, distinguishing it from quartz grains (ppl - X4).


Ath
Bt
Crd
Sil


Bt
Sil
Crd

metamorphic reaction process adjacent to the various veins (photographs 27, 28). Coarse prismatic sillimanite crystals are also present. These are randomly oriented in the rock, commonly cross-cutting other minerals and each other (photograph 29). Single prismatic sillimanite crystals are generally 0.1 - 0.2 mm thick and 1.5 - 2 mm long. Aggregates of these crystals are locally as much as 12 cm long and 1 cm in diameter. Some of the sillimanite is replaced and possibly pseudomorphed by hercynite spinel. Sillimanite is found isolated from orthoamphibole by a cordierite mantle indicating their incompatibilities.

(v) Quartz

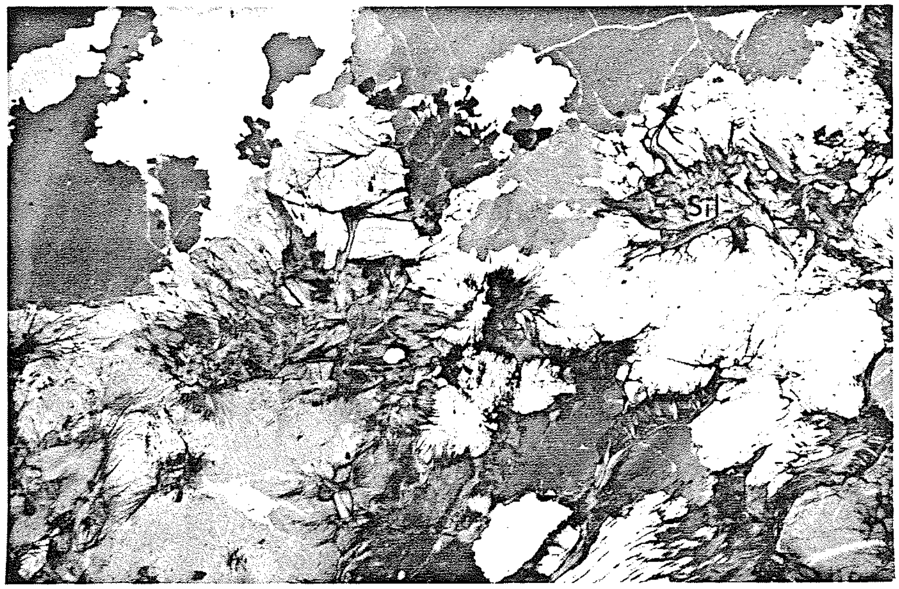
Quartz occurs as fine- to coarse-grained, anhedral and mostly strained aggregates scattered amongst the amphiboles and garnets in the gneiss zone. Quartz is prominent in unit 1; there is no evidence of mylonitic textures, and it is a major constituent of inclusions in the garnet porphyroblasts. Various inclusions of sillimanite, magnetite and rutile occur in the quartz; hercynite spinel inclusions are also found (SC 4-9; SC 4-12) indicating their compatibility.

(vi) Biotite

Most of the biotite in the cordierite-anthophyllite gneiss is light- to dark-brown in thin section. It usually occurs as subhedral to euhedral crystals studded with abundant zircon inclusions which are

PHOTOGRAPHS 27a & 27b

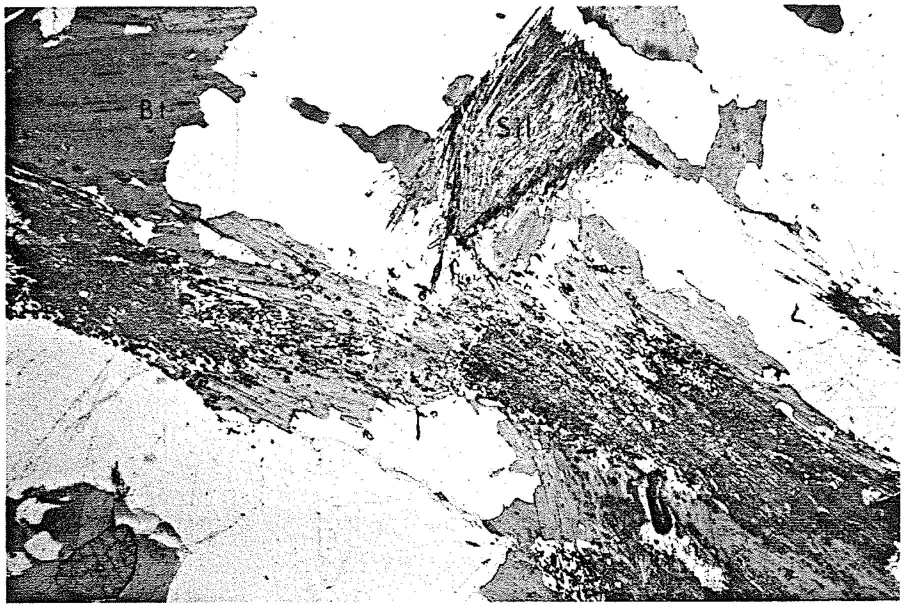
Fibrolitic sillimanite (Sil) aggregates are 0.5–10 mm long and seem to be due to leaching processes adjacent to pegmatite intrusions (ppl – X20).

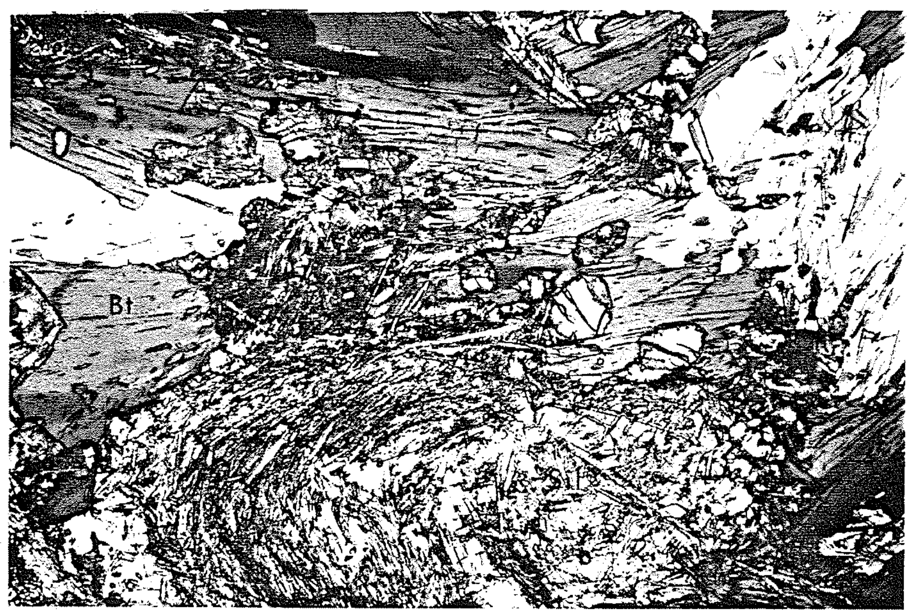

Sil


Sil

PHOTOGRAPH 28
Fibrolitic sillimanite (Sil) in elongate to elliptical aggregates of tiny needles oriented parallel to the foliation (ppl - X20).

PHOTOGRAPH 29
Coarse prismatic sillimanite (Sil) crystals are diversely oriented in the rock and commonly cut other minerals and each other (ppl - X20).


Bt
Sil


Bt
Sil

surrounded by pleochroic haloes (photograph 30). The biotites are 0.5 to 9 mm long and typically define a schistosity associated with anthophyllite. Biotite inclusions occur in amphiboles and garnets with no reaction rims present.

Accessory Minerals

(i) Hercynite spinel

Hercynite is present in all rock units in various amounts, probably dependent upon the extent of reaction between garnet, sillimanite, cordierite and amphibole. The spinel occurs as minute inclusions in cordierite, and as fine- grained myrmekitic intergrowths with cordierite which seem to be the result of pseudomorphing sillimanite sheaths (photographs 31, 32, 33). The mantling relationship between hercynite and cordierite may be explained by the reaction:

sillimanite + garnet = cordierite + hercynite

(ii) Staurolite

Staurolite occurs mainly as anhedral prisms up to 9 mm long, closely associated with amphibole and garnet. In its association with garnet, the grains are usually <1 mm, and occur at the contacts of both. Cordierite rims the staurolite, indicating some reaction (photograph 34), particularly at the contact with anthophyllite. Staurolite frequently replaces almandine garnet. Less commonly, it is itself replaced by hercynite spinel (photograph 35), indicating the compatibilities of the two.

PHOTOGRAPH 30

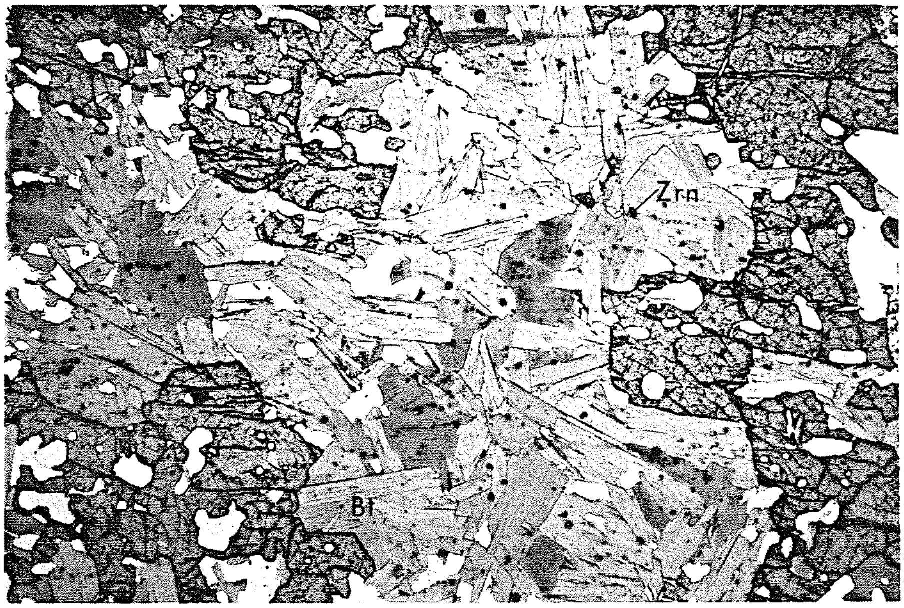
Randomly oriented biotite (Bt) grains studded with abundant zircon (Zrn) inclusions surrounded by pleochroic haloes (ppl - X20).

PHOTOGRAPH 31

Hercynite (Hc) associated with cordierite (Crd) and replacing garnet in the presence of sillimanite and quartz (ppl - X20)

(garnet + sillimanite = hercynite + cordierite + quartz)

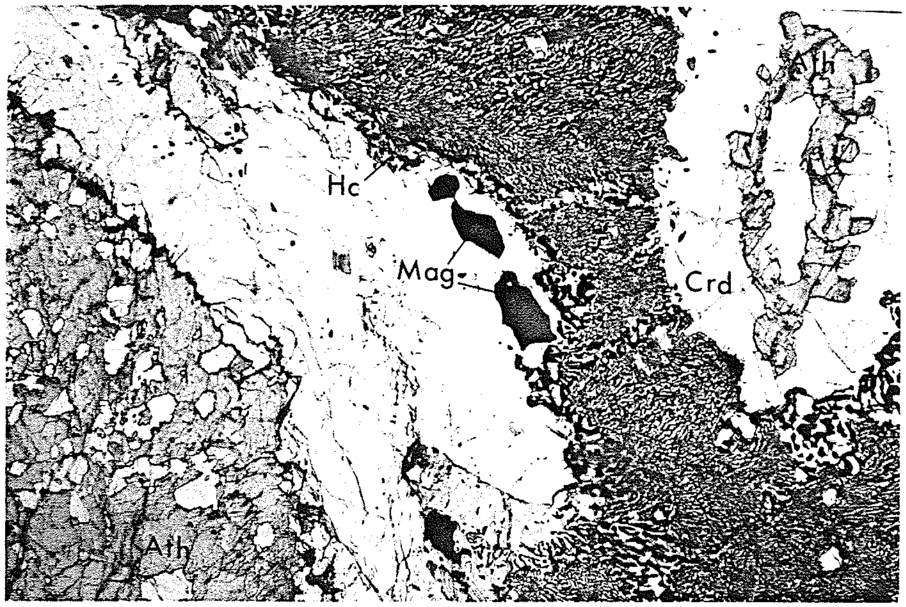
$$0.25(Fe_{1.9}Mg_{1.1})Al_2Si_3O_{12} + 0.5Al_2SiO_5 = 0.65(Fe_{0.7}Mg_{0.3})Al_2O_4 + 0.05\ Fe_{0.4}Mg_{1.6}Al_4Si_5O_{18} + SiO_2$$

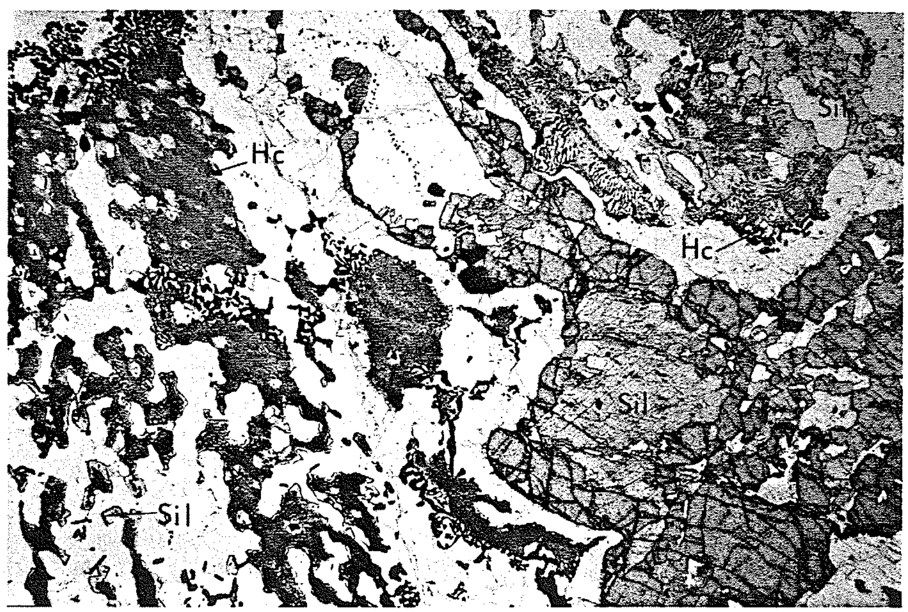

Zrn
Bt


Hc
Crd

PHOTOGRAPH 32
Fine-grained myrmekitic hercynite (Hc) Cordierite (Crd) with minor magnetite (Mag), surrounded by anthophyllite (Ath); a 'ring' structure of anthophyllite is found isolated in a cordierite 'pocket' (ppl - X20).

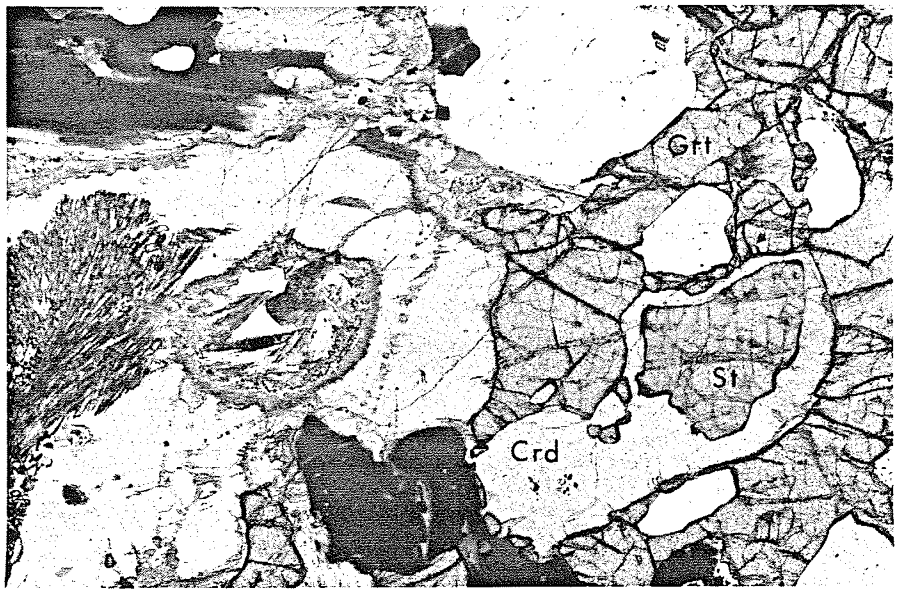
PHOTOGRAPH 33
Fine-grained myrmekitic hercynite (Hc) replacing sillimanite (Sil) and possibly pseudomorphing the sheaths (ppl - X20).

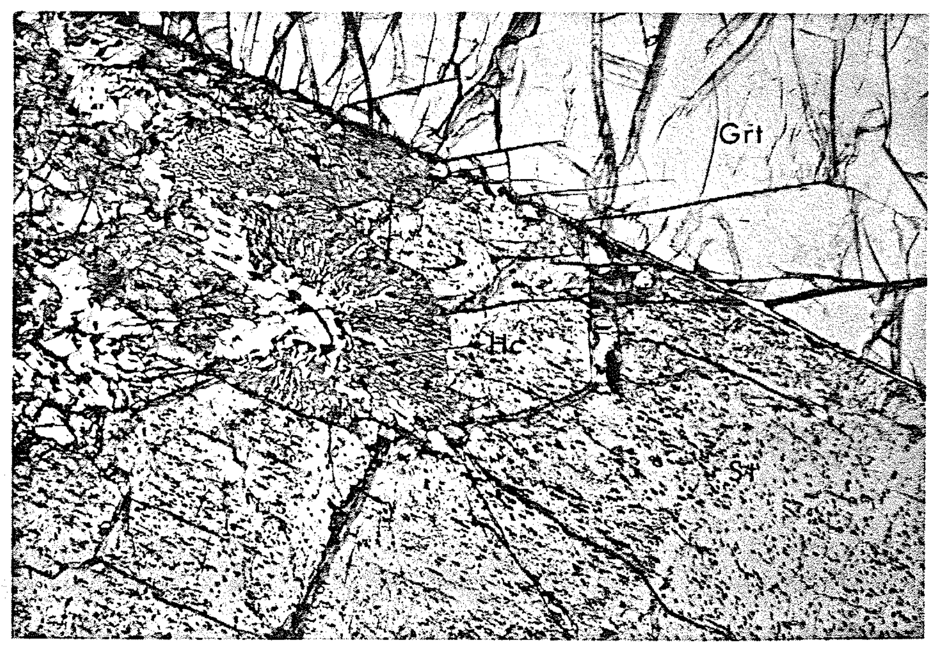

Ath
Hc
Mag
Crd
Ath


Sil
Hc
Hc
Sil
Sil

PHOTOGRAPH 34
Staurolite (St) as an anhedral prism rimmed by cordierite (Crd) and overgrown by garnet (Grt) (ppl - X40) (garnet = staurolite + cordierite).

PHOTOGRAPH 35
Euhedral staurolite (St) grain overgrown garnet (Grt); the Staurolite (St) is itself altered to hercynite (Hc) (ppl - X20).


Grt
St
Crd


Grt
Hc
St

(iii) Phosphates

Two phosphate minerals occur in the cordierite-anthophyllite gneiss zone, apatite and wagnerite. Apatite occurs as individual round to blocky grains, locally prismatic and clear to milky-white in thin-section. This minor phase is present in most sections and is 0.1 to 2 mm in size (photograph 36).

Wagnerite, a Mg-rich phosphate $(Mg, Fe^{2+})_2 PO_4 F$ is orange to red in hand-specimen and yellow in thin-section. It is usually fine-grained, anhedral to subhedral with a vitreous to slightly resinous lustre. Some of the larger grains of wagnerite show cloudy areas at the centre due to minute inclusions of quartz and amphibole (photograph 37). Identification of these tiny inclusions proved impossible by ordinary petrographic methods but was possible by the S.E.M. (scanning electron microscopy) capabilities of the electron microprobe. Both the anthophyllite and quartz inclusions are rimmed by apatite, separating them from the enveloping wagnerite.

(iv) Rutile

Rutile is a characteristic minor constituent of the gneiss zone, ranging from 0.1 to 0.8 percent. It occurs as fine anhedral grains in various sections, with no reaction rims present.

(v) Magnetite

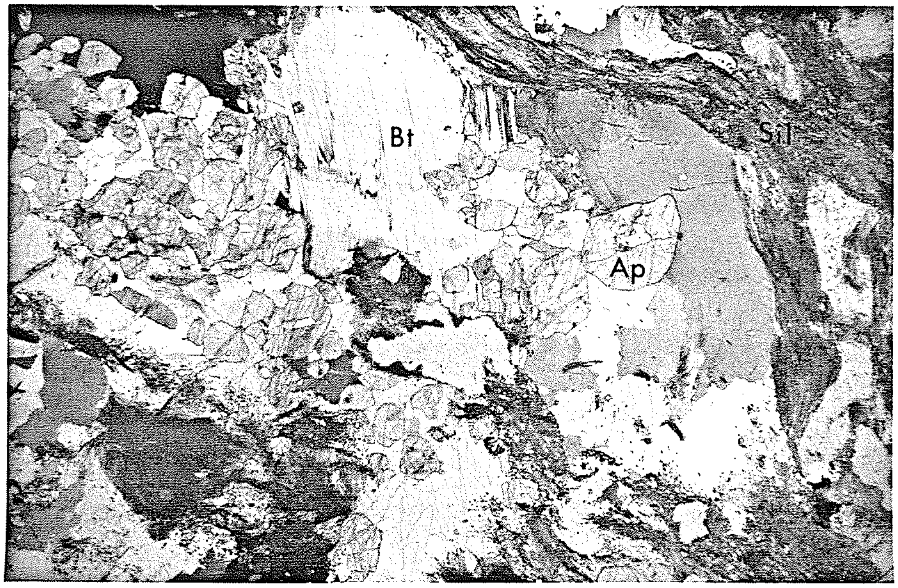
Magnetite shows anhedral outlines, is generally

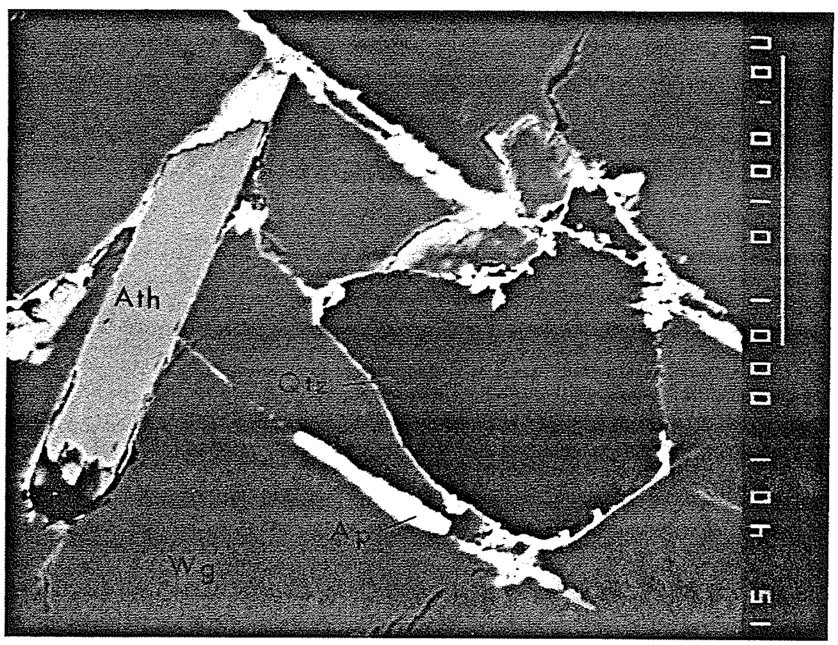
PHOTOGRAPH 36

Rounded to blocky, locally prismatic apatite (Ap) grains are mostly in the sillimanite (Sil) zone; these tend to form a network associated with coarse-grained biotite (Bt) and sillimanite (Sil) (ppl - X5).

PHOTOGRAPH 37

Wagnerite (Wg), a Mg-rich phosphate $(Mg,Fe^{2+})_2PO_4F$), is generally fine-grained, with minute inclusions of quartz (Qtz) and anthophyllite (Ath), both rimmed by apatite (Ap) that separates them from the enveloping wagnerite (Wg) (reflected light).


Bt
Sil
Ap


Ath
Qtz
Ap
Wg

<1 mm in size and present in all rock units. In its association with cordierite, hercynite spinel is present. In some areas, magnetite is altered to hematite, a secondary oxidation process.

(vi) Zircon

Zircon occurs as minute grains with typically euhedral to subhedral habit and characteristic pleochroic haloes. These grains occur exclusively as inclusions in biotite (photograph 30).

(vii) Sericite and Chlorite

Minute shreds' of sericite rim and penetrate cordierite, sillimanite and occasionally anthophyllite (photograph 38).

Reaction rims of chlorite mantle garnet porphyroblasts and cordierite grains, separating them from the surrounding amphiboles. It also occurs as an alteration product after amphibole and/or biotite (photographs 39, 40).

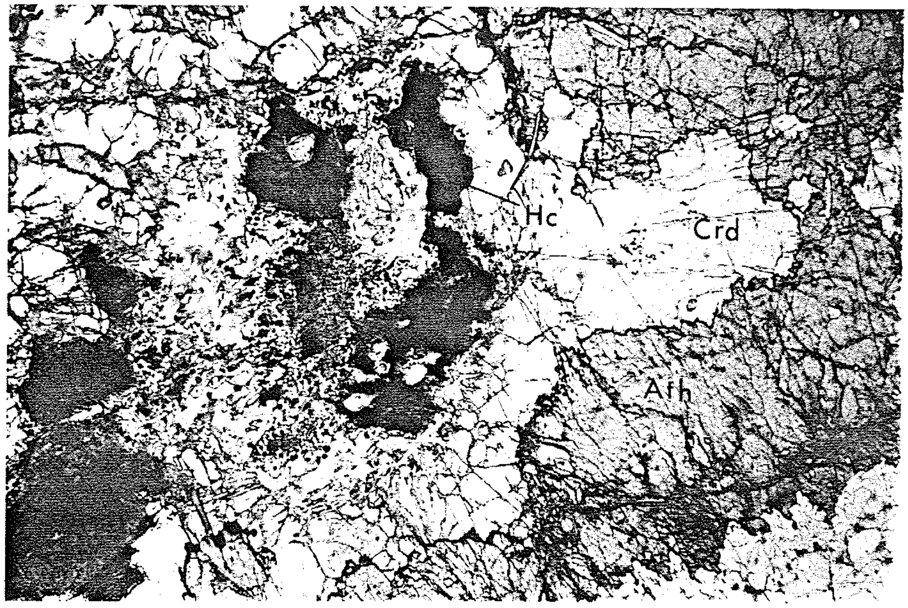
(viii) Sulfides

In the vicinity of Elken Lake, disseminated chalcopyrite, pyrrhotite and marcasite are found in association with the cordierite-anthophyllite gneisses. The small uneconomic sulfide showing occurs in thin stratiform layers that rarely attain a thickness greater than a few metres.

Chalcopyrite forms coarse-grained patches and is usually associated with pyrrhotite, which occurs as blebs in

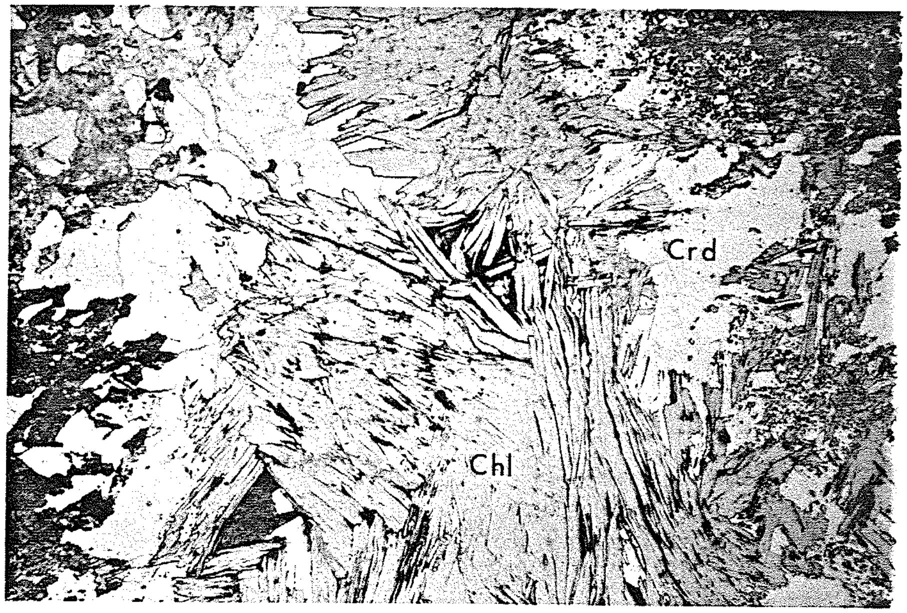
PHOTOGRAPH 38
Minute 'shreds' of Sericite rimming and penetrating cordierite (Crd), Sillimanite (Sil) and anthophyllite (Ath) (ppl - X20).

PHOTOGRAPH 39
Chlorite (Chl) as an alteration product of anthophyllite (Ath) (ppl - X15).


Hc
Crd
Ath

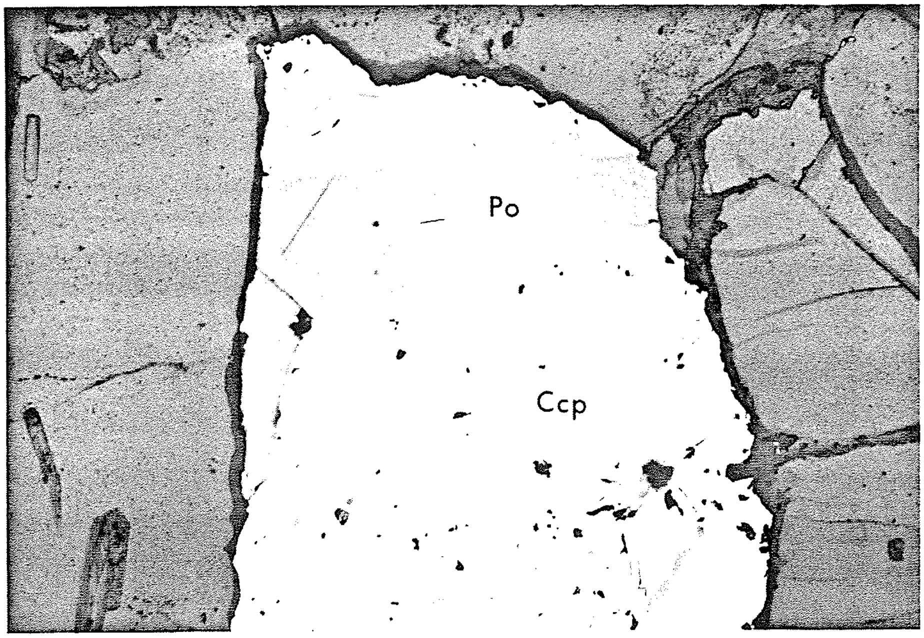

Chl
Ath

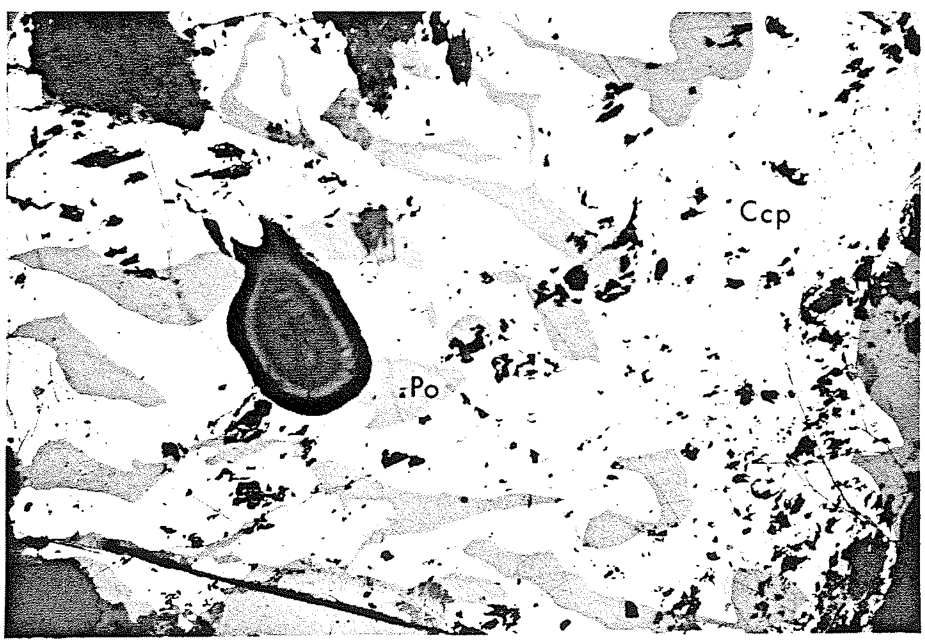
PHOTOGRAPH 40
Chlorite (Chl) as an alteration product of cordierite (Crd) (ppl - X20).


Crd
Chl

the latter (photograph 41). Pyrrhotite itself shows evidence of replacing marcasite (photograph 42). These sulfides form a fine-grained network which infills various fractures in the cordierite-anthophyllite gneiss (photograph 43).

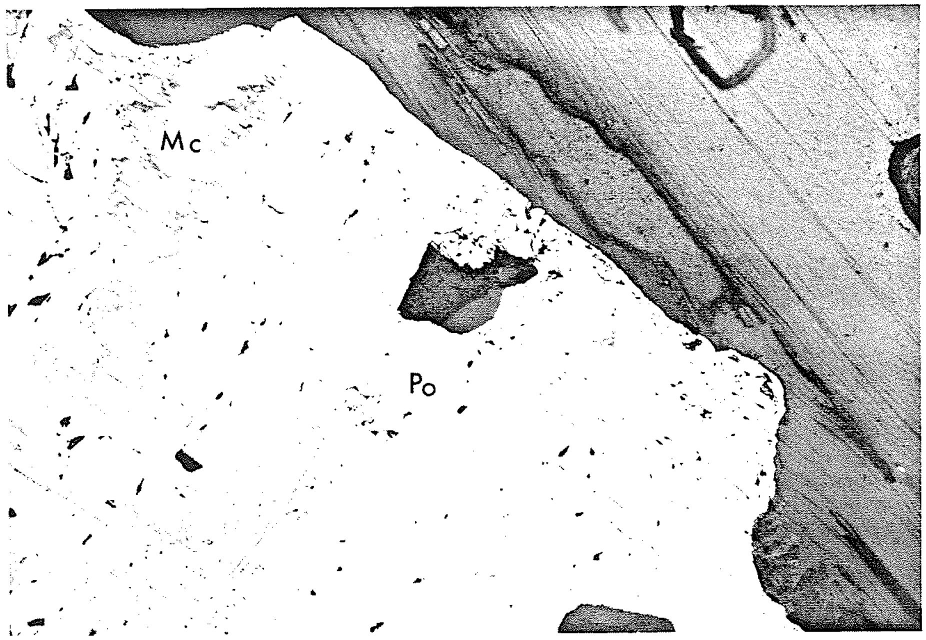
PHOTOGRAPHS 41a & 41b
Coarse-grained patches of Chalcopyrite (Ccp) mainly associated with pyrrhotite (Po) (blebs in the chalcopyrite) (X20).

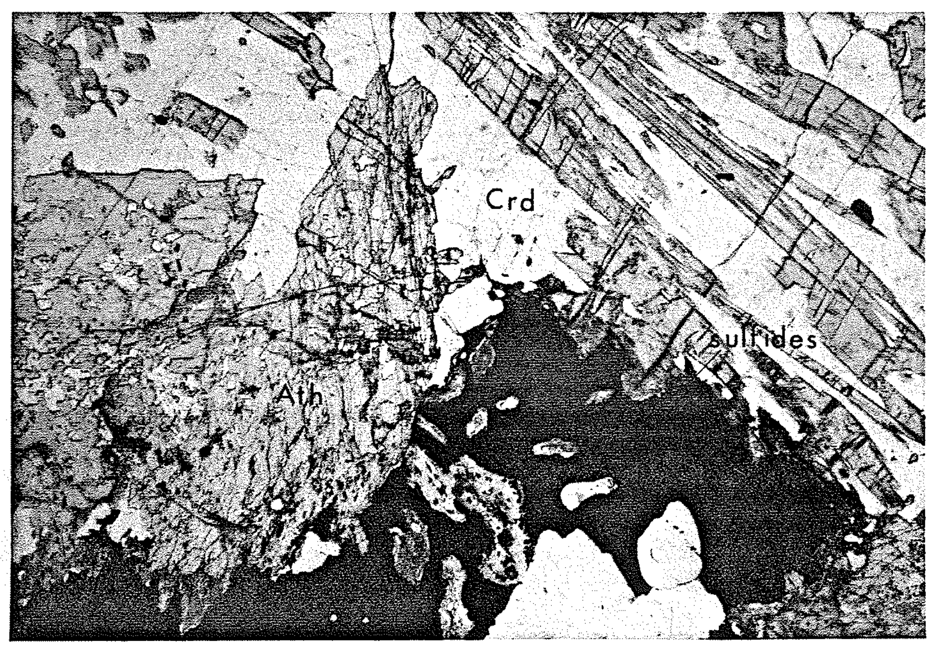

Po
Ccp


Ccp
Po

PHOTOGRAPH 42
Pyrrhotite (Po) replacing marcasite (Mc) (X20).

PHOTOGRAPH 43
Fine-grained network of sulfides infilling fractures in the cordierite (Crd) - anthophyllite (Ath) gneiss (X20).


Mc
Po


Crd
sulfides
Ath

(IV) WHOLE ROCK CHEMISTRY

(i) Chemical Parameters

This section describes the use of chemical parameters to help indicate the origin of the rocks of the Star Lake - Elken Lake area, near Sherridon, Manitoba.

These rocks range from silica-poor (unit 3) to silica-rich (units 1 and 2), as seen in Appendix A. Units 1,2 and 3 typically exhibit low CaO (0.01-1.12 wt%) and alkalies (Na_2O: 0-0.58 wt%; K_2O: 0.02-2.2 wt%) and high amounts of Al_2O_3 (8.0-22.0 wt%), MgO (5.0-15.0 wt%) and FeO (5.0-17.0 wt%). Trace element patterns are fairly constant with some localized anomalies (SC-4-12). REE show characteristic basaltic trends with LREE depleted and HREE enriched values.

Chemical analyses are plotted on different types of diagrams to indicate the chemical fields occupied by igneous and sedimentary rocks, or to distinguish between rocks of igneous and sedimentary origins. The use of these diagrams to indicate the progenitors of the rocks involves the assumption that the metamorphism was essentially isochemical, except for the volatile constituents. The isochemical nature of the metamorphism is suggested by the consistency in chemical composition of the various units.

The rocks from the Star Lake - Elken Lake area have been divided into seven units for easy identification on most diagrams. They are:

(1) " ● " unit 1 (quartz-garnet-anthophyllite),

(2) " □ " unit 2 (garnet-anthophyllite),

(3) " ▲ " unit 3 (anthophyllite-cordierite),

(4) " ✶ " quartz -biotite gneiss,

(5) " ✵ " sillimanite zone,

(6) " ☆ " mineralized unit 2 zone, Elken Lake area

(7) " Δ " unit 2 zone, Sherridon East orebody area

Figures 5 and 6 are after La Roche (1974) and are intended to discriminate between metamorphic, igneous and sedimentary rocks. Figure 5, the` total rock triangle' shows the greater scatter of the two diagrams. Most of the samples from units 1, 2 and 3 plot near the arkose field and felsic termination of the igneous trend, as do the sillimanite and quartz-biotite gneisses. Figure 6, the `silico-aluminate triangle', shows the most consistency for all the data. Samples representing all units plot in the left part of the diagram, the Mg-rich and common-clay regions. The cordierite- anthophyllite gneisses of units 2 and 3 indicate minor Mg enrichment relative to any `normal' igneous rock. Possible basalt/arkose mixture relationships exist which seem to indicate progenetic contamination (discussed in the `Discussion of Geochemistry' section).

Many authors have used Niggli diagrams to show trends and positions of recent igneous and sedimentary rocks in comparison with high-grade metamorphic rocks to help classify them as sedimentary or igneous in character (eg.

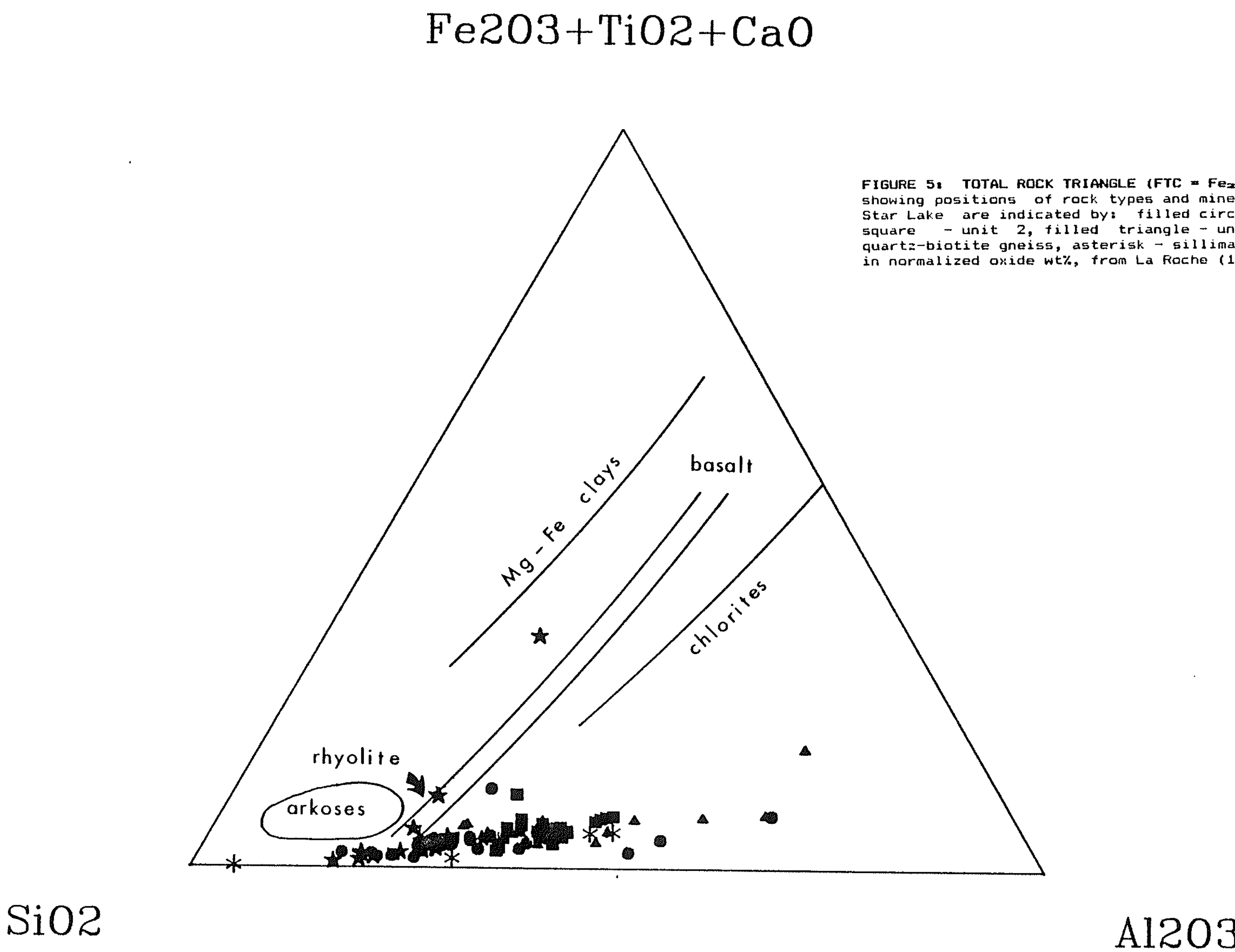


FIGURE 5: TOTAL ROCK TRIANGLE (FTC = Fe_2O_3 + TiO_2 + CaO), showing positions of rock types and minerals. Samples from Star Lake are indicated by: filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone. Diagram in normalized oxide wt%, from La Roche (1974).

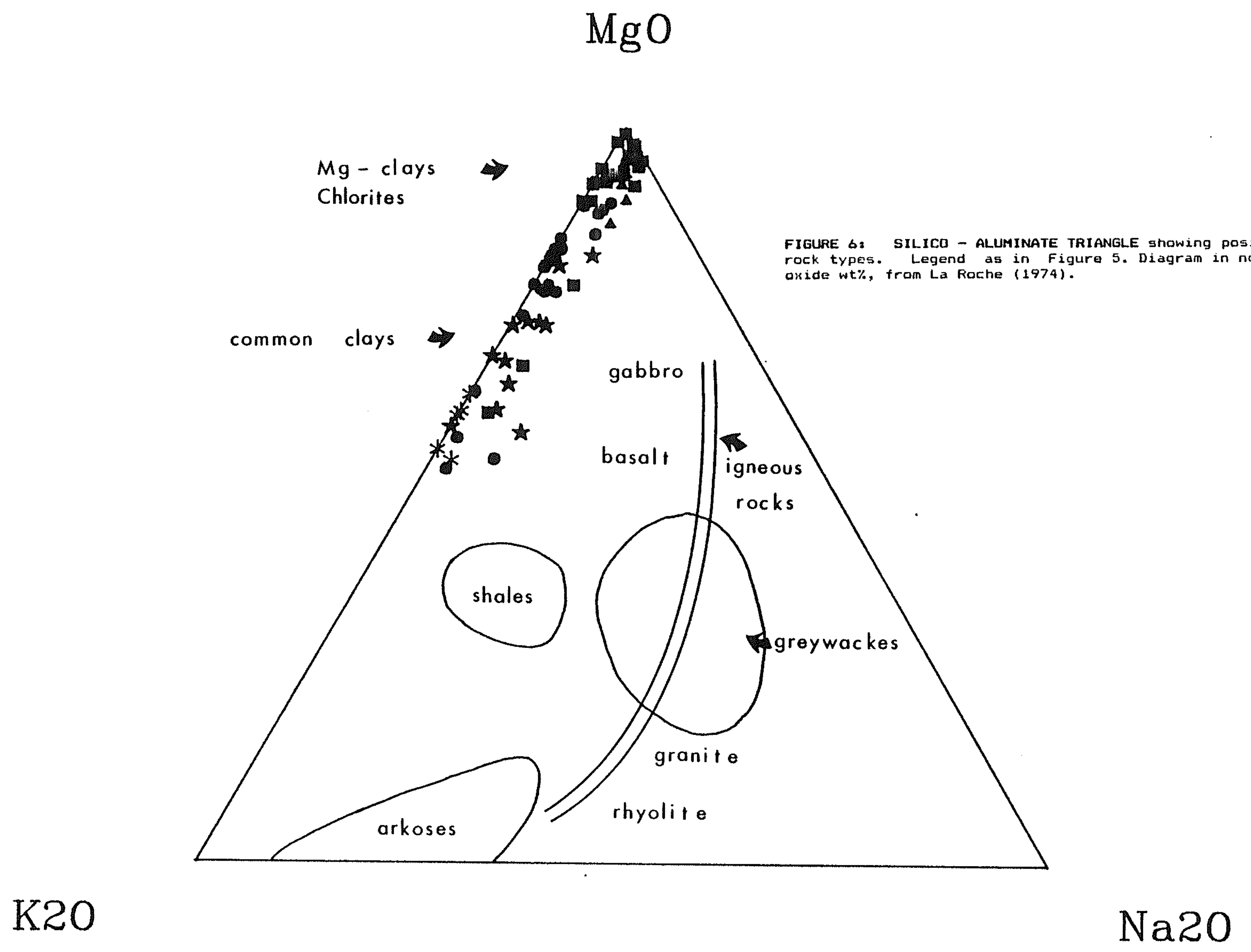


FIGURE 6: SILICO - ALUMINATE TRIANGLE showing positions of rock types. Legend as in Figure 5. Diagram in normalized oxide wt%, from La Roche (1974).

Leake, 1964, 1969; Van de Kamp, 1968, 1969, 1970; Van de Kamp, Leak and Senior, 1976; Stamatelopoulou - Seymour and Maclean, 1977).

Figure 7, a plot of Niggli c vs. Niggli mg., should show a strong trend parallel to the mg ordinate for volcanic rocks, and a large scatter with respect to c for sedimentary rocks. A noticeable parallel trend to the mg ordinate is found for samples of units 2 and 3, suggesting possible development (alteration or weathering) from a volcanic parent. Samples from unit 1 seem to scatter somewhat with respect to the Niggli c axis.

Figure 8 is a plot of (Na_2O+K_2O) vs. ($K_2O/(Na_2O+K_2O))\times100$ (Hughes, 1973) which discriminates relatively unaltered igneous rocks (igneous spectrum) from altered igneous rocks (spilites) and sediments. The rocks interpreted as having been formed from a volcanic parent (Figure 8) all plot outside the igneous spectrum, with the exception of one sample from unit 1 and one quartz-biotite gneiss sample. The occurrence of the data outside the igneous spectrum may be the result of contamination by terrigenous material, (rich in K_2O - as total alkalies increase K_2O becomes dominant) or alteration of a volcanic ash or tuff (derived from felsic to intermediate volcanics or related sedimentary rocks (greywakes or transported tuffs)). This contamination can be substantiated with similar mixtures (basaltic/arkose) in the total rock

FIGURE 7: NIGGLI MG VERSES NIGGLI C for Star Lake rocks. Legend as in Figure 5. From Leake (1964) and Van de Kamp (1968).

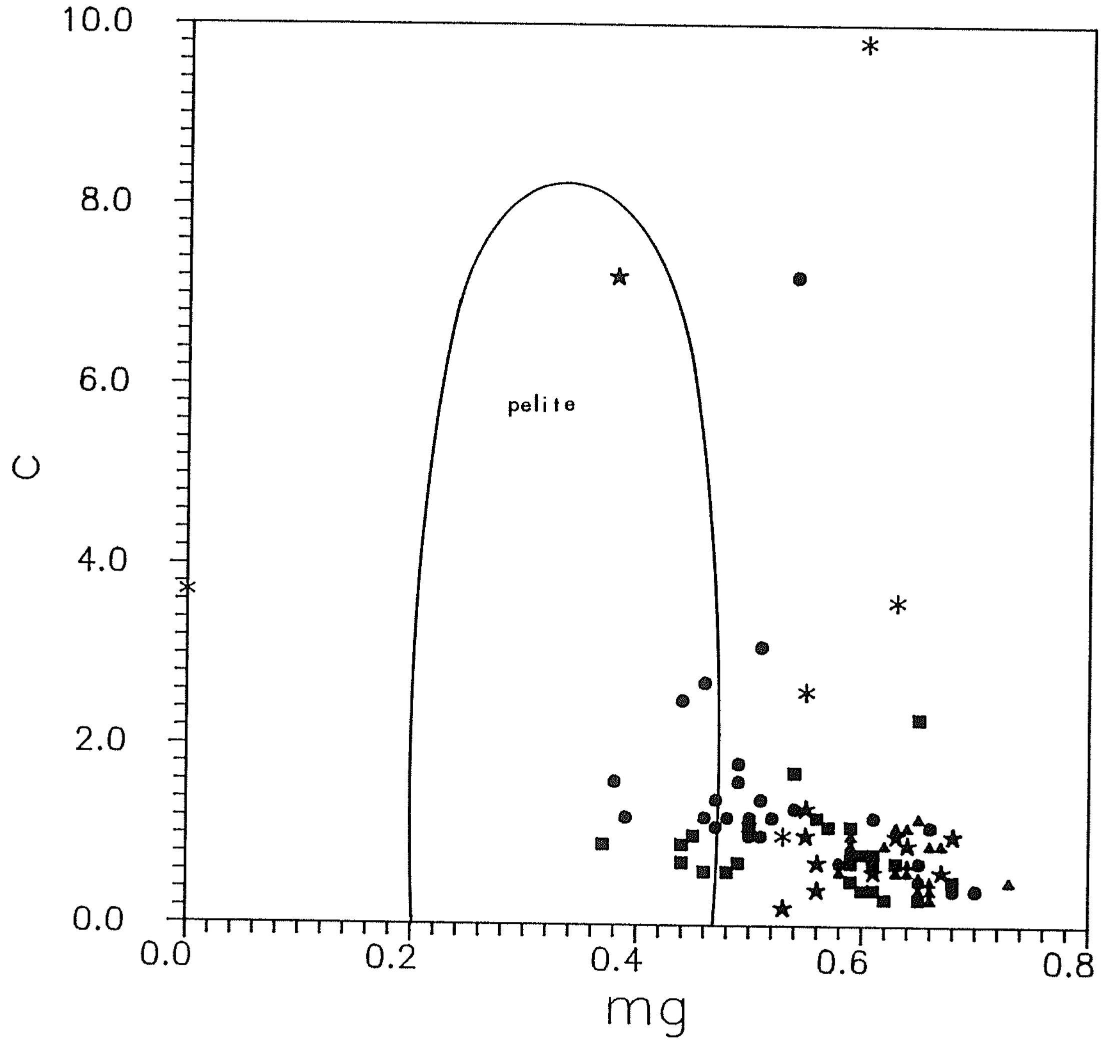
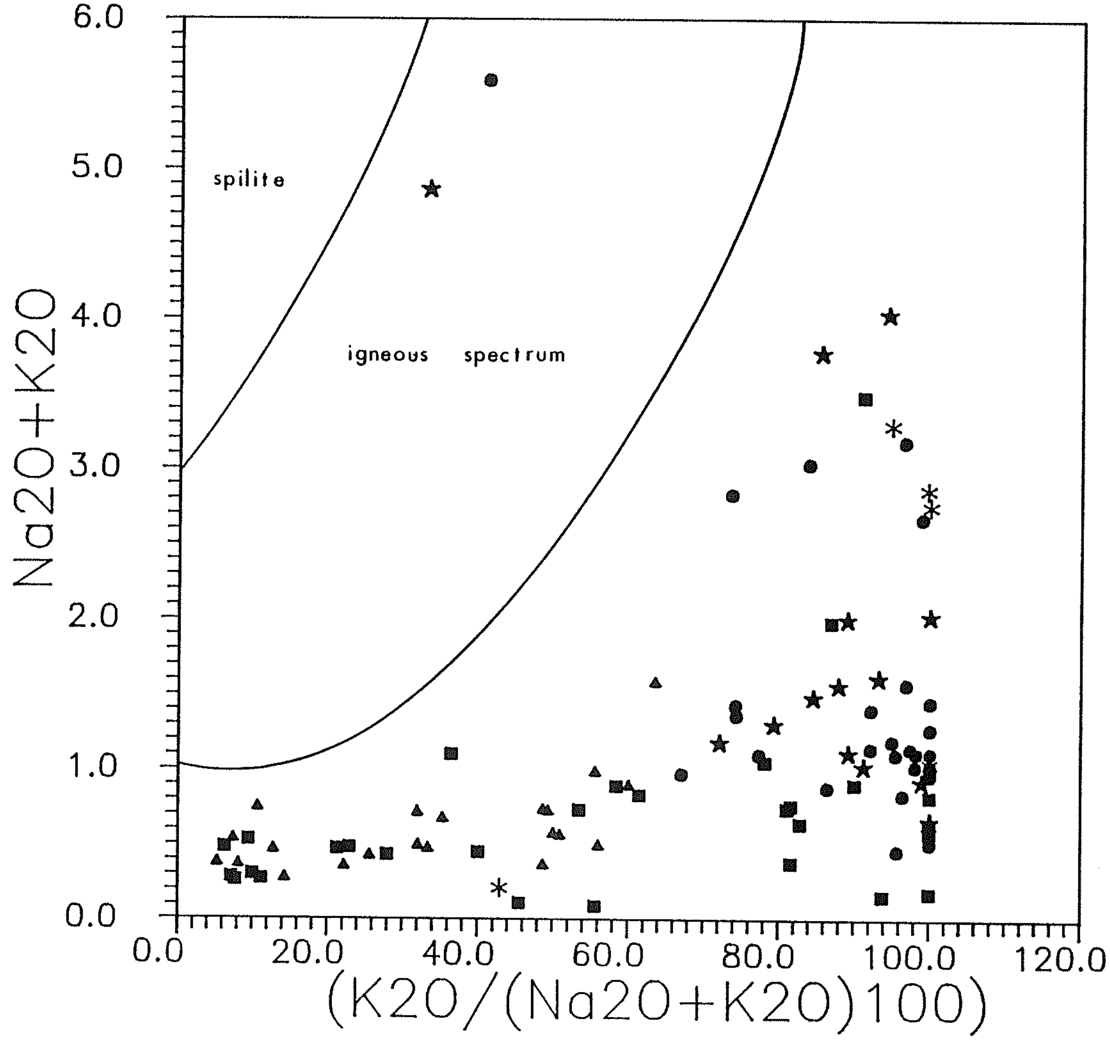


FIGURE 8: Na2O+K2O VERSES (K2O/Na2O+K2O)100 for Star Lake rocks. Legend as in Figure 5. Diagram in wt% oxide. From Hughes (1973).



triangle and silicoaluminate triangle.

Van de Kamp et al. (1976) used a plot of Niggli mg vs. Niggli si to differentiate between sedimentary and igneous precursors for metamorphosed gneisses. Because of the concentration of fine mafic minerals in the high SiO_2 fraction of sands, positive slopes represent sediments, whereas negative slopes represent igneous rocks. Figure 9, a plot of Niggli mg vs. Niggli si, shows a positive distribution for units 1 and 2 and a negative distribution for unit 3. This diagram seems to suggest that initial precursor rocks were formed by mixed sedimentary and igneous processes resulting in variable mafic mineral concentrations.

Leake (1964) used a plot of Niggli k as a function of Niggli mg to distinguish amphibolites of sedimentary origin from those of igneous origin. Goetz (1980) and Gale et al. (1980) showed Sherridon host rocks and unmineralized gneisses to be distributed between the igneous and pelitic fields. Figure 10, a plot of Niggli k vs. Niggli mg, shows similar mixing effects and considerable scatter along the k axis with some slight mg variations. This plot again suggests mixed precursors that were partly sedimentary (greywacke-clay- metasediments) and partly igneous (arkose/basalt mix).

Van de Kamp (1970) and Leake (1969) used a plot of Niggli al-alk against Niggli c to separate metamorphic rocks

FIGURE 9: NIGGLI MG VERSES NIGGLI SI for Star Lake rocks. Legend as in Figure 5. From Van de Kamp et al. (1975).

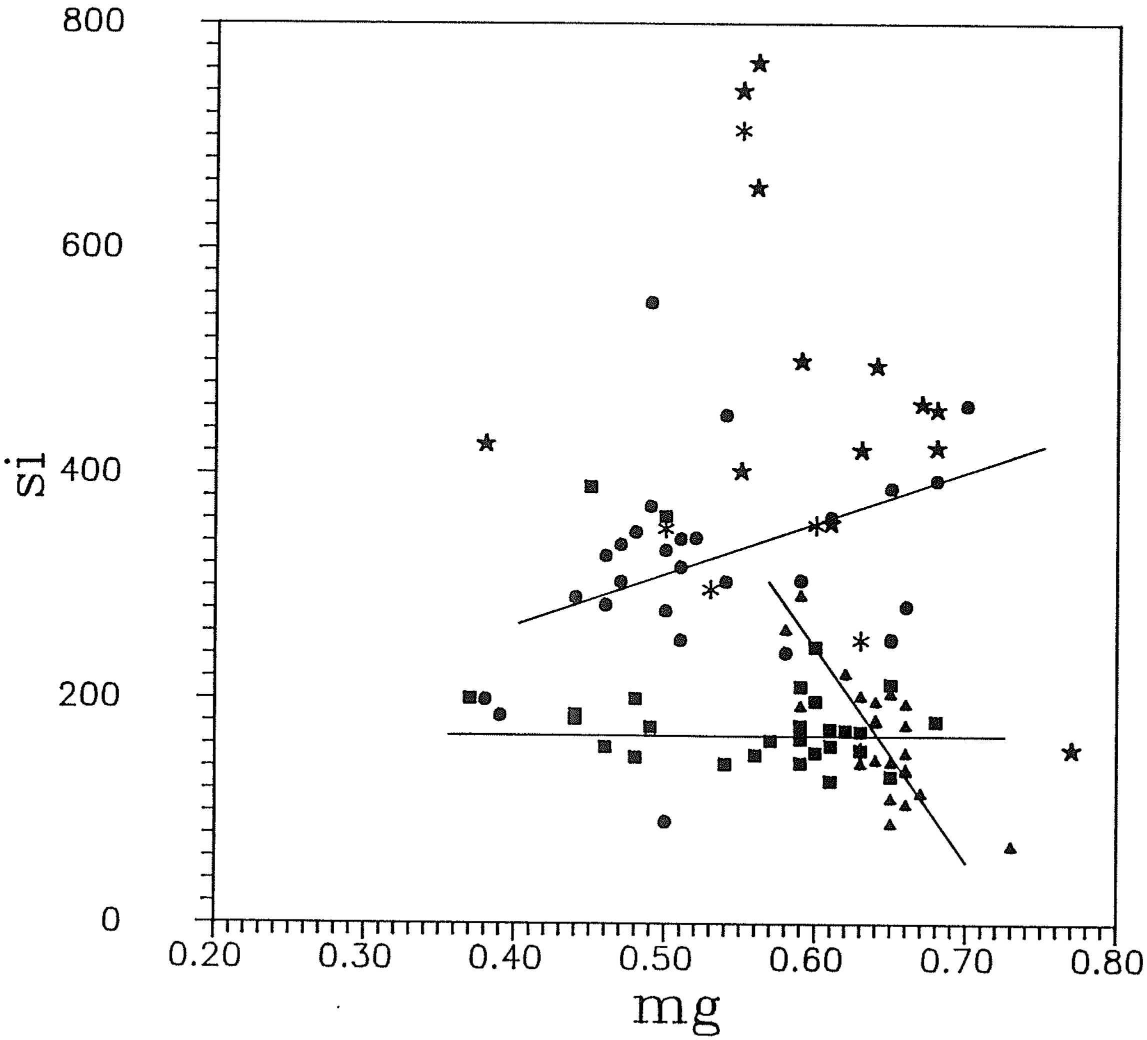
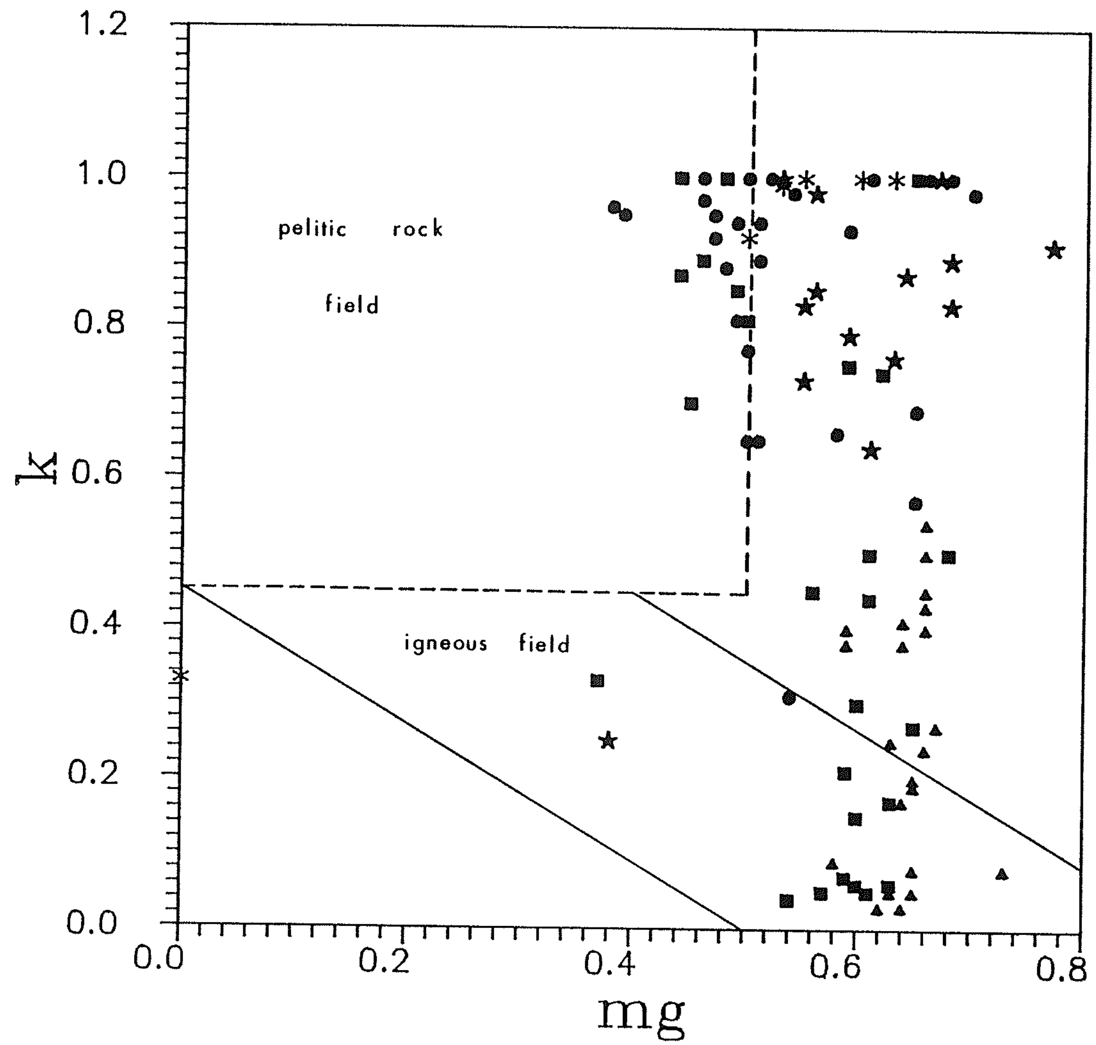


FIGURE 10: NIGGLI K VERSES NIGGLI MG for Star Lake rocks. Legend as in Figure 5. From Leake (1964).



of igneous origin from those of sedimentary origin. The value al-alk indicates available alumina present in excess of that used to produce all micaceous minerals and feldspar. Small variations of al-alk with composition produce a broad igneous field (of positive slope) which overlaps other fields. Figure 11, a plot of Niggli al-alk versus Niggli c, indicates how samples from unit 1 plot mainly in the 'normal clay' region, except for one which plots in the intermediate igneous rock field. Samples from units 2 and 3 lie in the normal clay-greywacke fields. This plot suggests similar precursor characteristics to what can be observed in Figure 10.

In order to distinguish between igneous and sedimentary precursors to metamorphic rocks, a discriminant plot of Niggli al+alk versus Niggli c was developed by Van de Kamp (1976). Niggli al+alk decreases and Niggli c increases with an increase in ferromagnesium minerals and calcic plagioclase in going from felsic to more mafic igneous rocks (narrow field with negative slope). A shallow negatively sloping sedimentary field is also present, corresponding to sedimentary rocks of shale and greywacke composition. Figure 12 shows that all Star Lake-Elken Lake samples are low in Ca and have low Niggli al+alk values. This may be due to a process that resulted in alkali depletion, but may be an artifact of dilution by fm related

FIGURE 11: NIGGLI AL-ALK VERSES NIGGLI C for Star Lake rocks. Legend as in Figure 5. From Van de Kamp (1970) and Leake (1969).

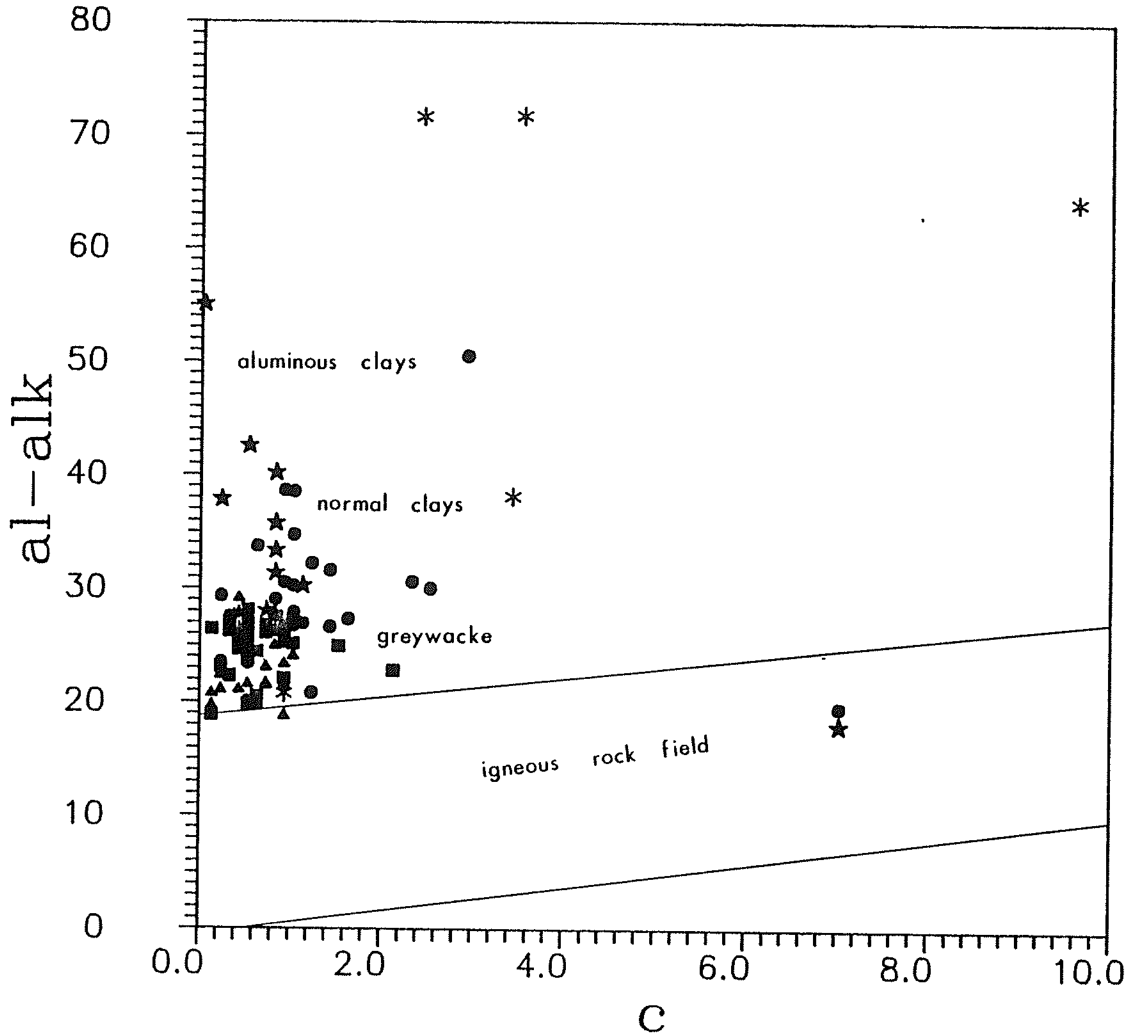
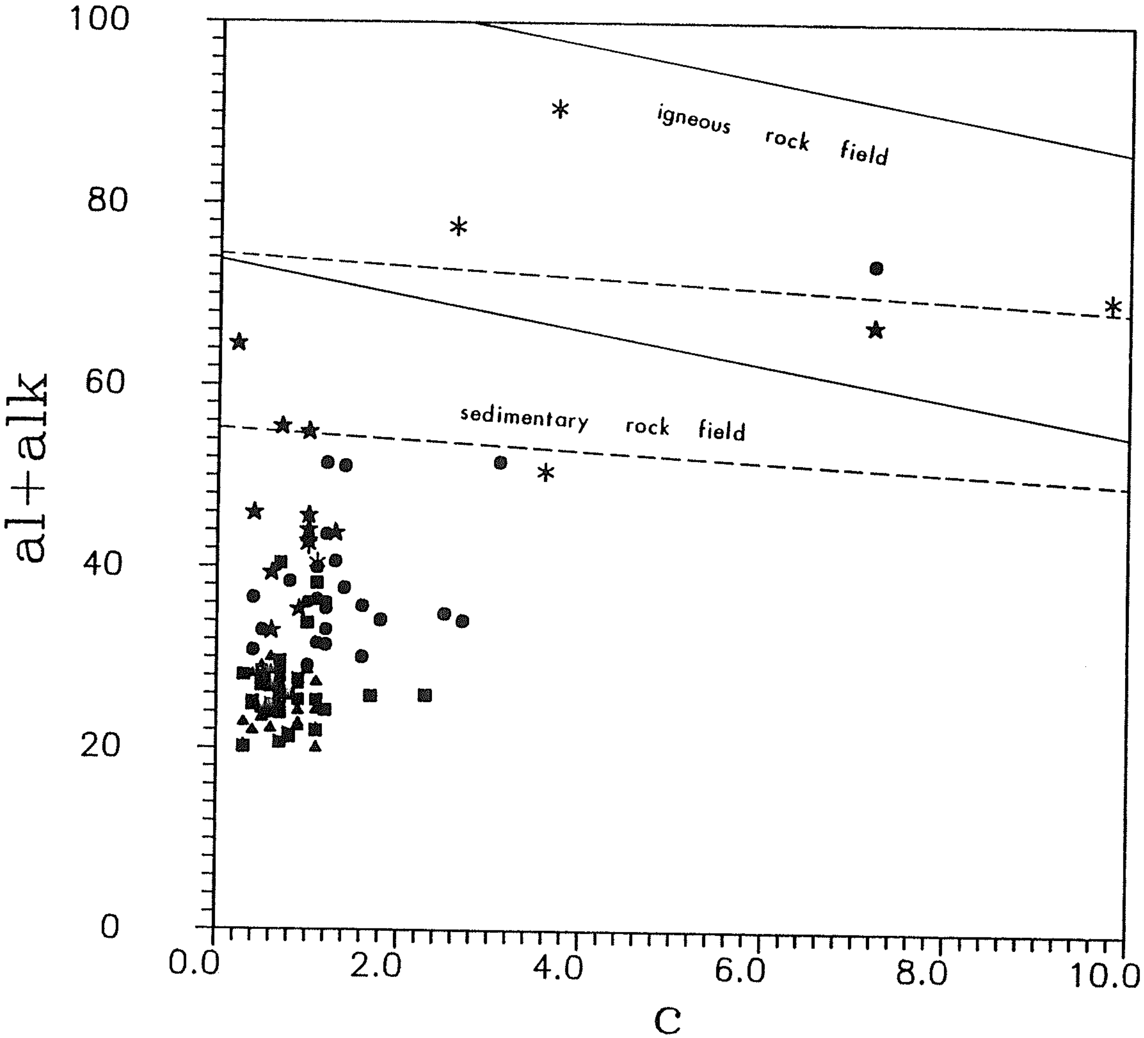


FIGURE 12: NIGGLI AL+ALK VERSES NIGGLI C for Star Lake rocks. Legend as in Figure 5. From Van de Kamp (1970).



to the summation of fm, c, al and alk to 100. Some of the samples also plot in the igneous and sedimentary fields, which again indicates mixture.

The use of a discriminant plot of Niggli ti vs. Niggli al+alk offers some aid in the determination of igneous and to some degree, sedimentary progenitors by virtue of the supposed immobility of titanium (Finlow-Bates and Stumpfl, 1981; Roberts and Reardon, 1978). Niggli al+alk is used along the X-coordinate to produce a broad igneous spectrum with felsic rocks of high al+alk values and mafic rocks of low al +alk values (high fm + c). Figure 13 shows that most samples fall in the low al+alk region, straddling the 'lower limit' of the igneous field. Some of these gneisses also show intermediate-high Niggli ti values, characteristic of chemically weathered basalts. Goetz (1980) has reported such an instance in the Flin Flon area, where high titanium levels occur in a regolith on an old basaltic land surface.

In general, the chemistry of these rocks is variable throughout the stratigraphic horizon at Star Lake - Elken Lake. Many of the discriminant diagrams presented seem to suggest sedimentary and/or volcanic mixed progenitors for these rocks. This will be discussed further in the following section.

Figure 14 shows the range of REE (rare earth elements) found in the Star Lake - Elken Lake gneisses. In

FIGURE 13: NIGGLI AL+ALK VERSES NIGGLI TI for Star Lake rocks. Legend as in Figure 5. From Finlow - Bates and Stumpfl (1981); Roberts and Reardon (1978).

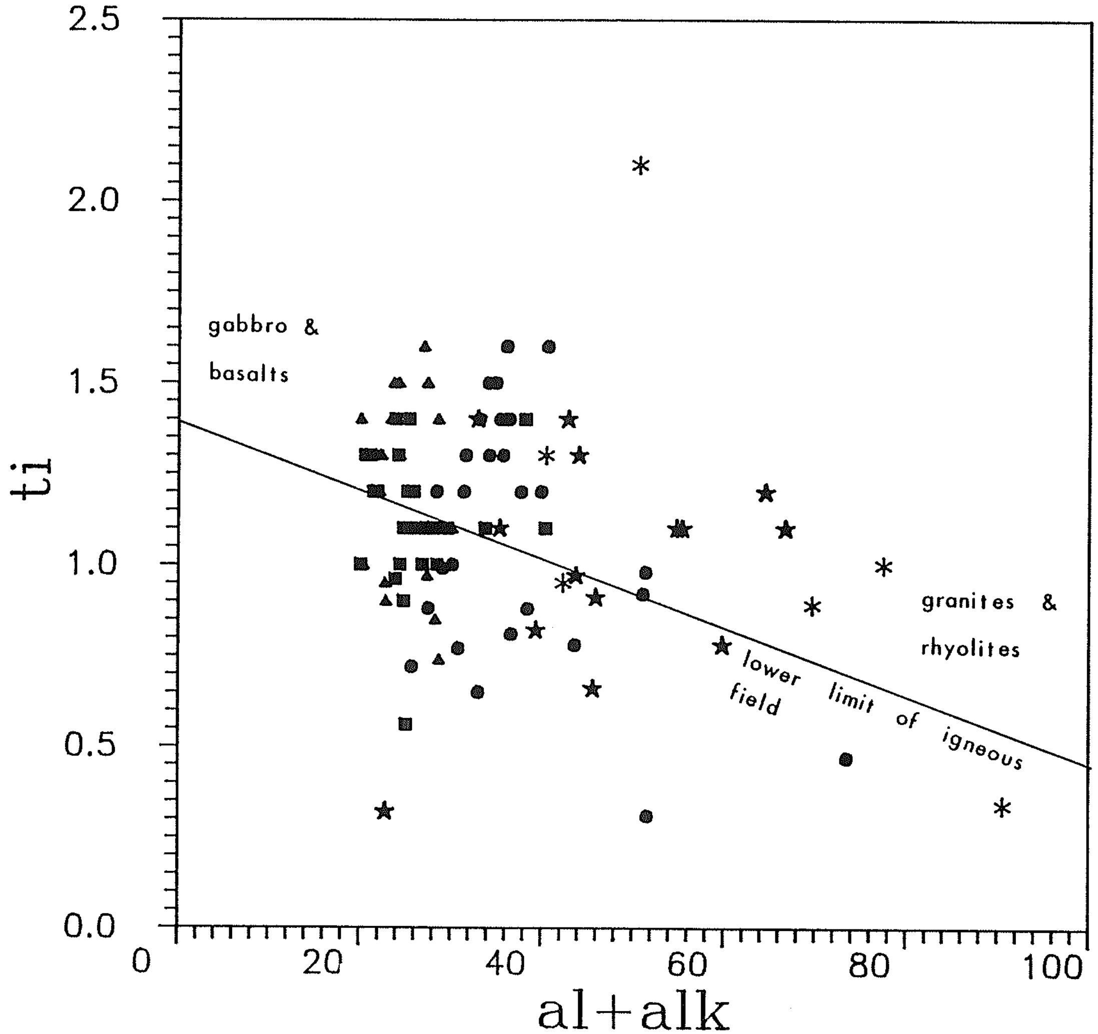
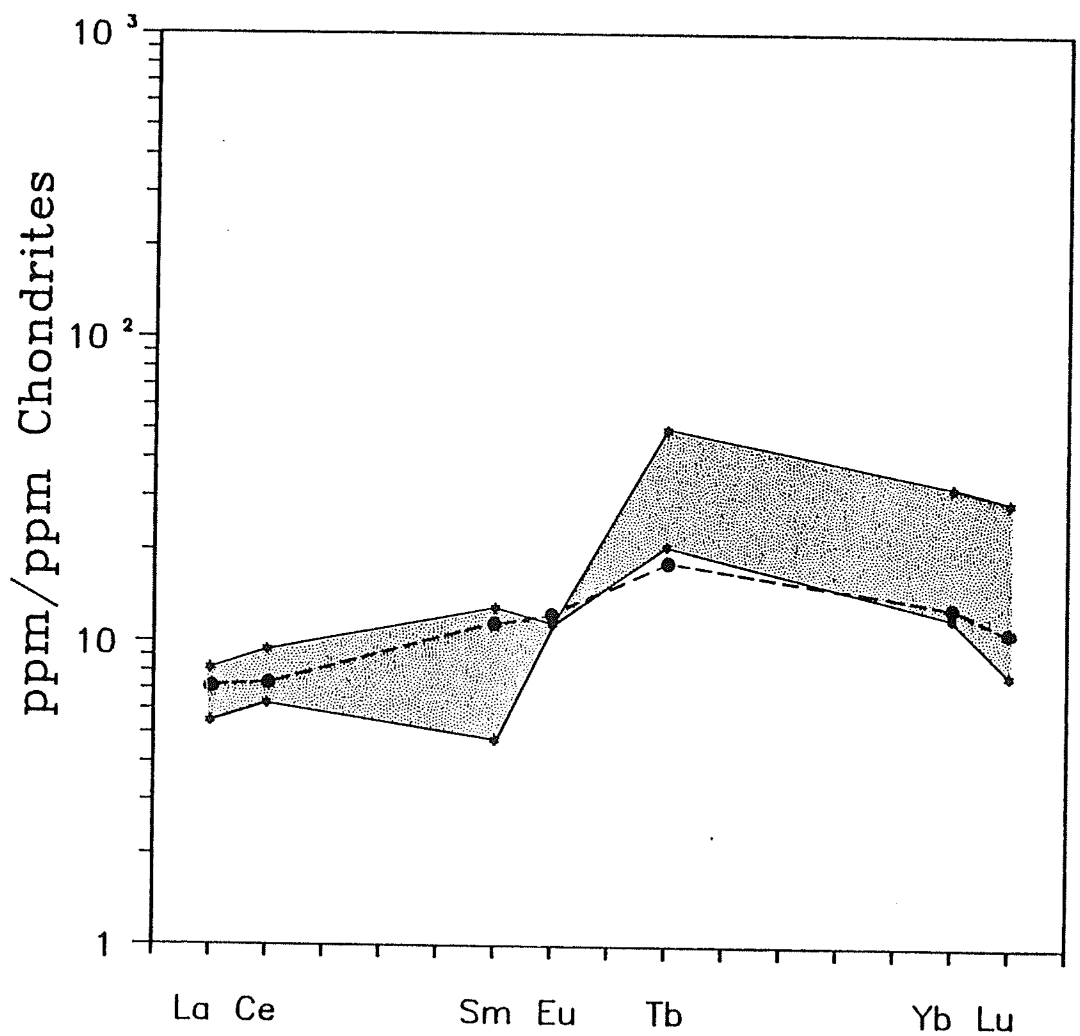


FIGURE 14: The range of REE content found in the Star Lake - Elken Lake gneisses (shaded) containing small negative to positive Eu anomalies. One representative basaltic pattern (dashed line) is also included to illustrate the similarity of REE contents.



all three mappable units and associated quartz-rich gneisses, LREE depletions and HREE enrichments are characteristic. According to Menzies et al. (1979), diagenesis and metamorphism have little relative effect on REE patterns. The REE elements, therefore, seem to be truly immobile. These authors also state that although some fractionation of REE may take place within weathering profiles, there seems to be no selective loss of REE during weathering. If we assume that REE levels were essentially unaffected we can, therefore, associate these trends with an igneous basaltic source (the LREE depleted pattern is indicative of a basaltic source (Taylor and McLennan, 1985)). Menzies et al. (1979) have also found that the most significant feature for metasedimentary rocks from early Proterozoic high-grade terranes (as found in the Star Lake - Elken Lake and surrounding areas) is the wide range in REE patterns ranging from nearly flat trends to LREE depleted trends. These trace element trends, therefore, provide added information in support of a mixed source for these anthophyllite-cordierite rocks.

(ii) <u>Interpretation of Whole-Rock Geochemistry</u>

La Roche's (1974) silico-aluminate and total rock triangle, and some of the plots of Niggli values seem to produce distinct fields for common igneous and sedimentary rocks. Star Lake cordierite-anthophyllite bearing gneisses and sillimanite rocks often plot outside these well-defined fields, and also straddle boundaries between major igneous trends and sedimentary rocks.

All cordierite-anthophyllite rocks at Star Lake - Elken Lake plot near or at the MgO apex of the La Roche (1974) 'silicoaluminate' diagram. This field is also occupied by intensely altered rocks from the cores of the alteration pipes at the Millenbach Mine, Noranda area, Quebec (MacGeehan and MacLean, 1980, Figure 15). Both unit 2 and 3 gneissic rocks plot closer to the MgO apex compared to the unit 1 rocks, possibly indicating increasing alteration from unit 1 to unit 3 respectively. La Roche's (1974) 'total rock triangle' shows similar features, with the quartz-garnet-anthophyllite rocks from unit 1 plotting in the more felsic termination grading into cordierite-anthophyllite rocks of units 2 and 3 towards the Mg clay fields.

Some of the diagrams seem to suggest partly sedimentary and igneous (volcanic) precursors for these cordierite-anthophyllite rocks at Star Lake. Hugh's (1973) plot of (Na_2O+K_2O) vs. $(K_2O/(Na_2O+K_2O))100$ shows that most

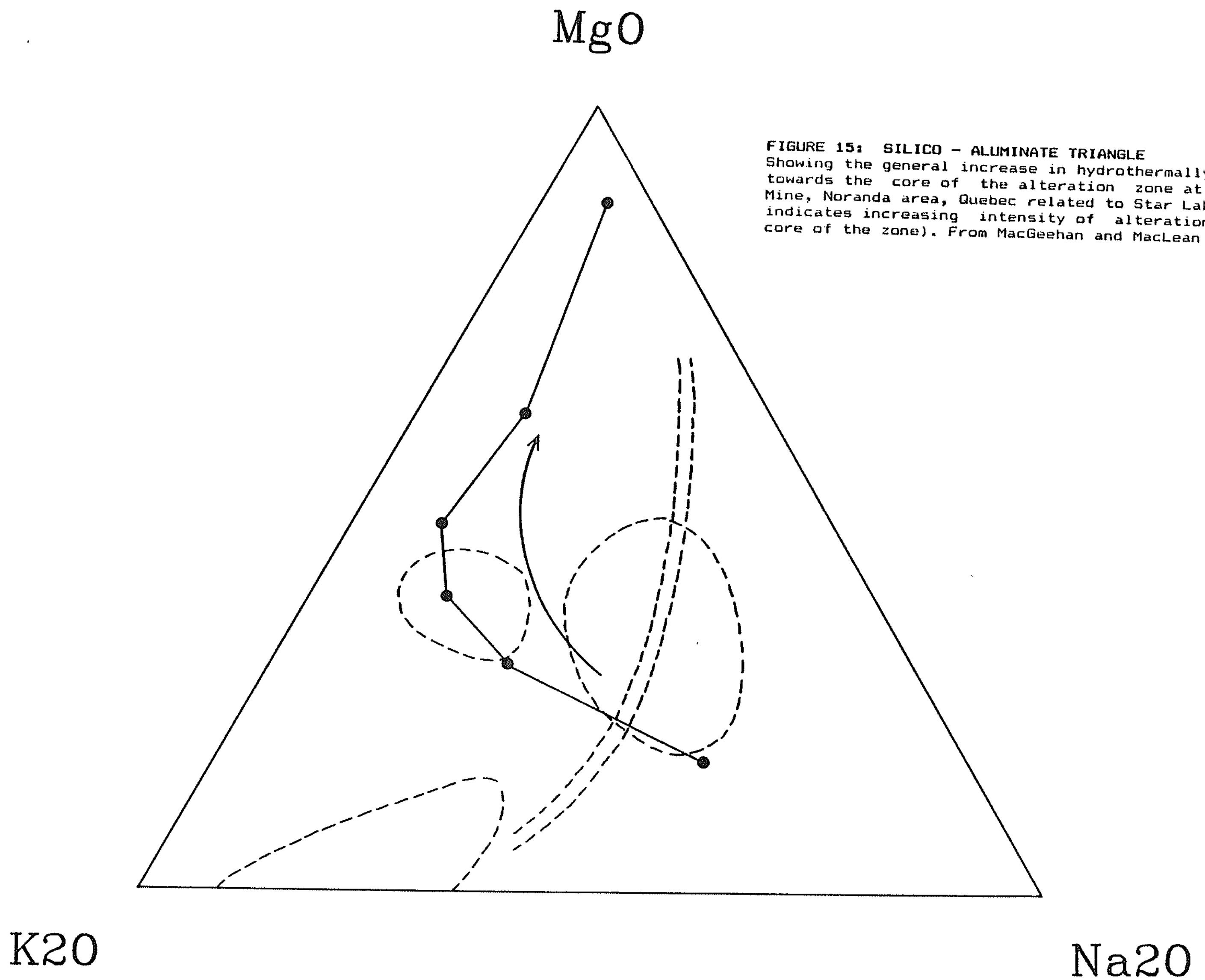
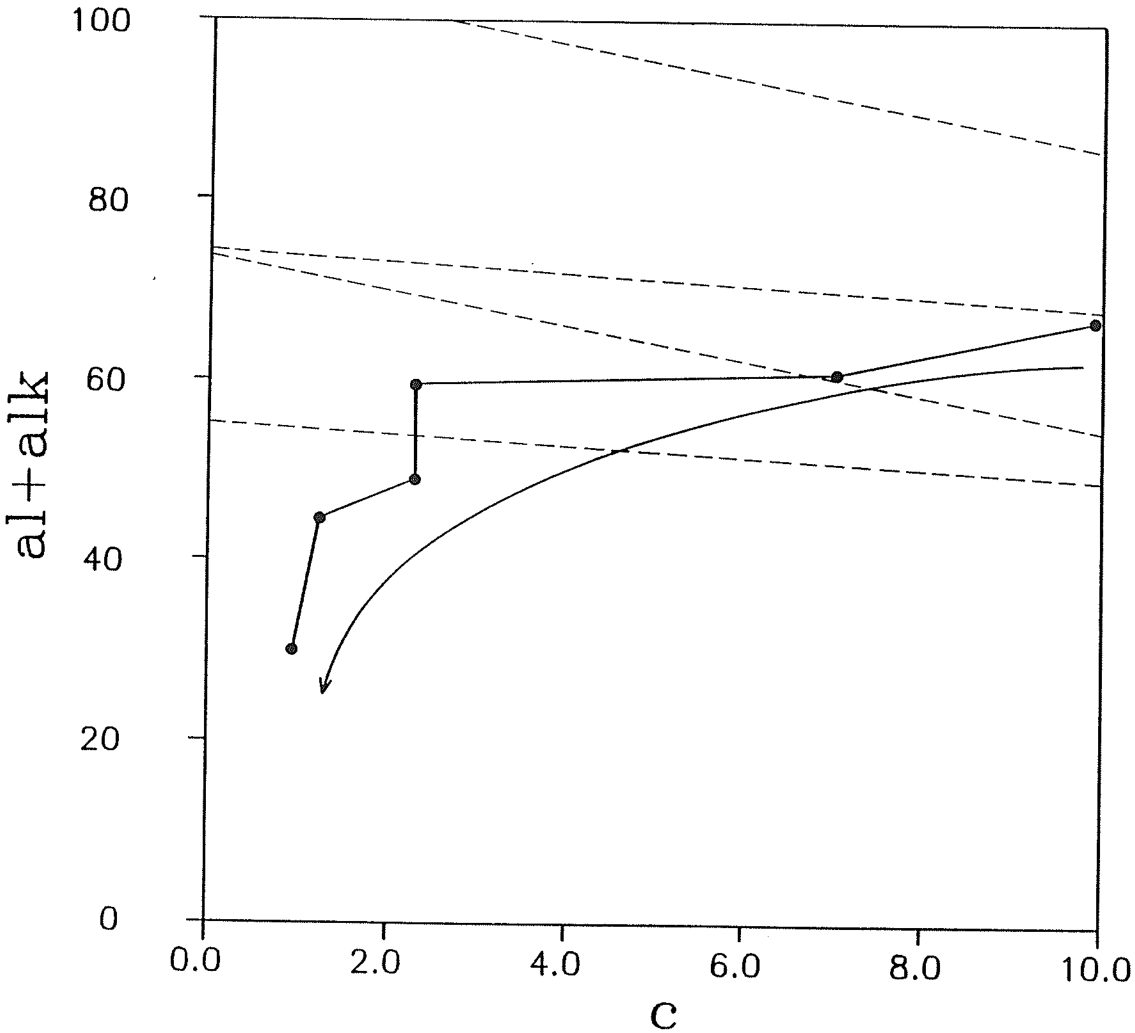


FIGURE 15: SILICO – ALUMINATE TRIANGLE
Showing the general increase in hydrothermally altered rocks towards the core of the alteration zone at the Millenbach Mine, Noranda area, Quebec related to Star Lake rocks (arrow indicates increasing intensity of alteration towards the core of the zone). From MacGeehan and MacLean (1980).

of the samples plot outside the igneous spectrum, possibly resulting from the contamination of volcanic rocks by terrigenous material or alteration process. The plot of Niggli si vs. mg (Van de Kamp et al., 1976) differentiates between sedimentary and igneous precursors for metamorphosed gneisses, due to the concentration of fine mafic minerals in the high SiO_2 fraction of sands ((+) slope for sands, (-) slope for igneous rocks). This diagram also suggests that the process which formed the precursors of the Star Lake gneiss were partly sedimentary and partly igneous (positive and negative slopes present). Leake's (1964) Niggli k vs. mg plot shows that the data straddle both the igneous and pelitic fields, also suggesting precursors that were partly sedimentary and partly igneous (basaltic) in nature.

Due to greater MgO and FeO contents, cordierite-anthophyllite rocks have lower values of al-alk and al+alk than the associated sillimanite-bearing rocks. However, they do have similar low values of Niggli c and, therefore, plot in fields which approach the al-alk and al+alk axes. These fields lie in the subvolcanic to pelitic/greywacke sediment or subvolcanic felsic to intermediate volcanic rock regions, with unit 2 and 3 rocks plotting in the lower al+alk fields. These patterns closely resemble those at the Millenbach Mine, Quebec, with increasing alteration intensity towards the core of the pipe corresponding (by analogy) to rocks from units 2 and 3 (Figure 16).

FIGURE 16: PLOT OF NIGGLI AL+ALK VERSES NIGGLI C
Showing the general increase in hydrothermally altered rocks towards the core of the alteration zone at the Millenbach Mine, Noranda area, Quebec related to Star Lake rocks (arrow indicates increasing intensity of alteration towards the core of the zone). From MacGeehan and MacLean (1980).



Niggli ti values in the cordierite-anthophyllite rocks at all locations have similar values to altered rocks from the cores of the alteration zones at the Millenbach and Mattagami Lake Mines (Figure 17). Most of these gneisses have Niggli ti values and TiO_2 levels (Appendix A & C) below those of the most felsic igneous rocks. If these low titanium levels reflect the original precursor levels and titanium is assumed to be immobile (Finlow-Bates and Stumpfl, 1981; Roberts and Reardon, 1978), then some dilution of original titanium with a low or zero titanium component has occurred. This component may have been added to the gneisses by co-deposition of a possibly altered felsic volcaniclastic or greywacke sedimentary rock or by some post-depositional hydrothermal alteration.

Another characteristic feature of these Ca and Na depleted gneisses is the lack of feldspars (plagioclase and K feldspar) associated with the sillimanite. The absence of plagioclase in these rocks suggests that it was probably not present prior to the metamorphism. The lack of K feldspars could also be explained by a dealkalization reaction followed by a silicate-water reaction;

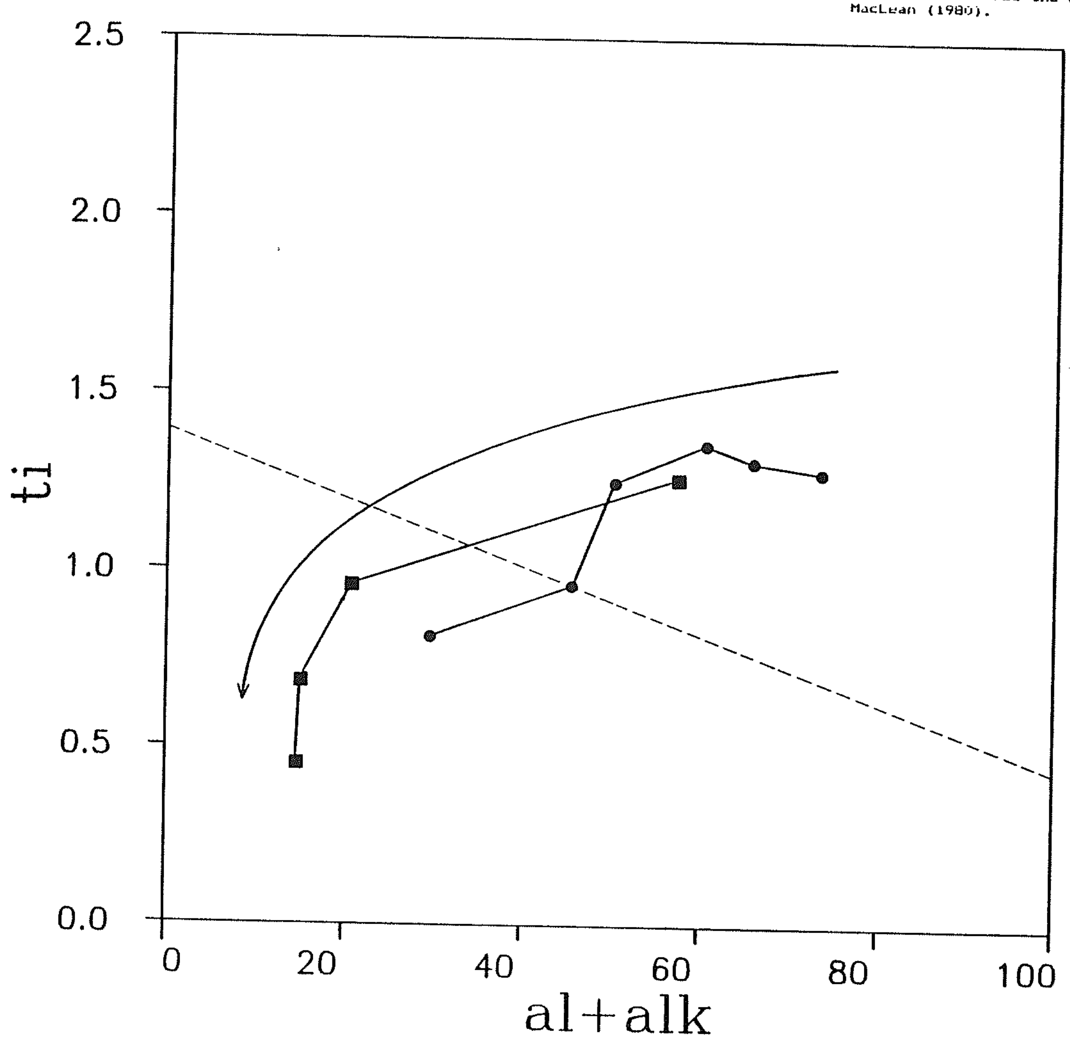
$$3\ KAlSi_3O_8 + 2H^+ = KAl_3Si_3O_{10}(OH)_2 + 6\ SiO_2 + 2K^+$$

K feldspar K mica quartz

$$2\ KAl_3Si_3O_{10}(OH)_2 + 3\ H_2O + 2H^+ = 3\ Al_2Si_2O_5(OH)_4 + 2K^+$$

K mica kaolinite

FIGURE 17: PLOT OF NIGGLI TI VERSES NIGGLI AL+ALK
Showing the general increase in hydrothermally altered rocks towards the core of the alteration zone at the Millenbach Mine, Noranda area, Quebec (circle) and samples representing the Mattagami Lake Mine, Quebec (squares) related to Star Lake rocks (arrow indicates increasing intensity of alteration towards the core of the zone). From MacGeehan and MacLean (1980).



These reactions could possibly explain the production of aluminosilicate layers beneath the more amphibole-rich sections of unit 2. But, as the sillimanite-bearing rocks plot as common felsic to intermediate volcanic rocks or greywackes, these may be the metamorphic equivalents of altered and/or chemically modified versions of these felsic to intermediate volcanics or greywackes.

(V) MINERAL CHEMISTRY

Analyses of coexisting minerals from the cordierite orthoamphibole rocks at Star Lake - Elken Lake are listed in Appendix D.

(i) Orthoamphiboles

Two orthoamphiboles occur in the Star Lake - Elken Lake units, anthophyllite and gedrite.

Variation in the amphibole compositions can be described in terms of end-member anthophyllite [$Mg_7Si_8O_{22}(OH)_2$] and three substitution mechanisms : Fe<=>Mg (Fe - Mg exchange), $Al^{vi}+Al^{iv}$<=>Mg+Si (tschermak exchange) and Na+Al^{iv}<=>Si (edenite exchange); other substitutions such as those involving Mn, Ti, Fe^{3+} or Ca are of minor importance (Spear, 1980). Evaluation of the analyses indicates that the anthophyllite-gedrite series is a solid solution between two end compositions

$R^{2+}{}_2R^{2+}{}_5Si_8O_{22}(OH)_2$ and

$Na_{0.5}R_2{}^{2+}(R_{3.5}{}^{2+}R_{1.5}{}^{3+})Si_6Al_2O_{22}(OH)_2$

where R^{2+}=Mg, Fe^{2+}, Mn^{2+}, Ca

R^{3+}=Al, Fe^{3+}, ($Ti_{1/2}{}^{4+}+Fe_{1/2}{}^{2+}$)

There is apparently complete solid solution in the anthophyllite-gedrite series at high temperature, as shown in specimens from the Star Lake - Elken Lake area. On cooling, members with intermediate Al and Na contents (Figure 18) exsolve to an anthophyllite-gedrite intergrowth. Most intergrowths are optically homogeneous but show strong

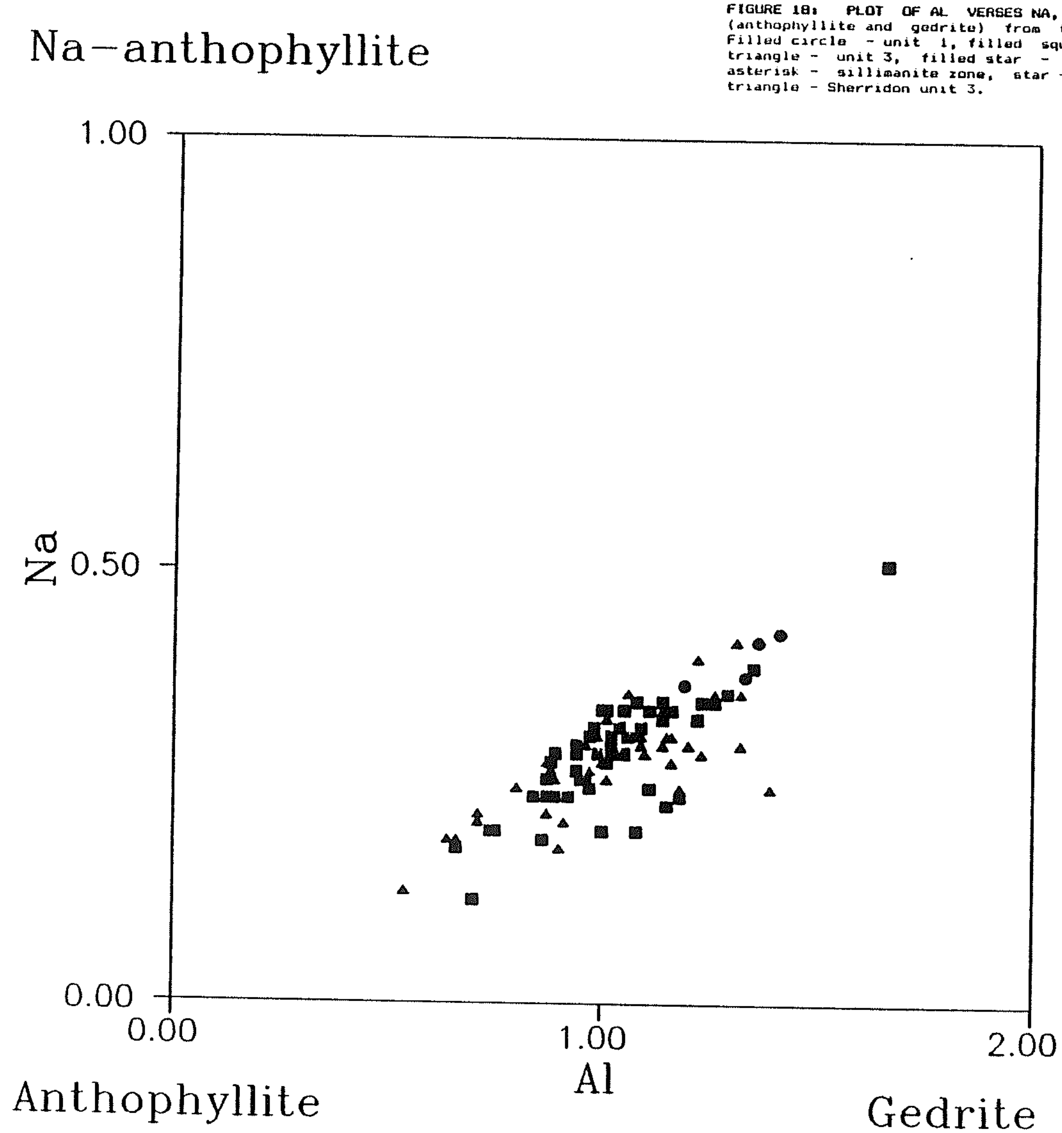


FIGURE 18: PLOT OF AL VERSES NA, showing the amphiboles (anthophyllite and gedrite) from the Star Lake strata. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Sherridon unit 3.

blue, green or yellow schiller effect believed to be due to submicroscopic exsolution.

As shown in Figure 19, amphiboles from unit 3 (associated with cordierite) show a slight Fe^{2+} enrichment compared to those in unit 2, which are mainly associated with garnets. Most of the amphiboles associated with sulfides from Elken Lake have slightly lower Fe^{2+} contents. Figure 20 shows similar Fe^{2+} enrichments and a restricted field of the Star Lake orthoamphiboles. The compositions of the orthoamphiboles generally show enrichment in Mg relative to the host rocks (Figure 21).

(ii) <u>Garnet</u>

In all samples, garnet is essentially almandine - pyrope (Figures 22 and 23). In most cases, garnets are zoned from magnesium cores (+/- calcium) to rims richer in iron (+/- manganese) (Appendix D). This zoning is rather erratic due to later fracturing, possible resorption later in the metamorphic history or due to variation of growth rate in different directions during formation. MnO zoning, although minor, has been related to the marked affinity of Mn for garnet in metamorphosed argillaceous rocks (Harte and Henley, 1966). No apparent correlation exists between the garnet and host rock compositions.

(iii) <u>Cordierite</u>

In most samples, cordierite is associated with

FIGURE 19: FE^{2+} VERSES NA, showing the amphiboles (anthophyllite and gedrite) from the Star Lake strata. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Shorridon unit 3.

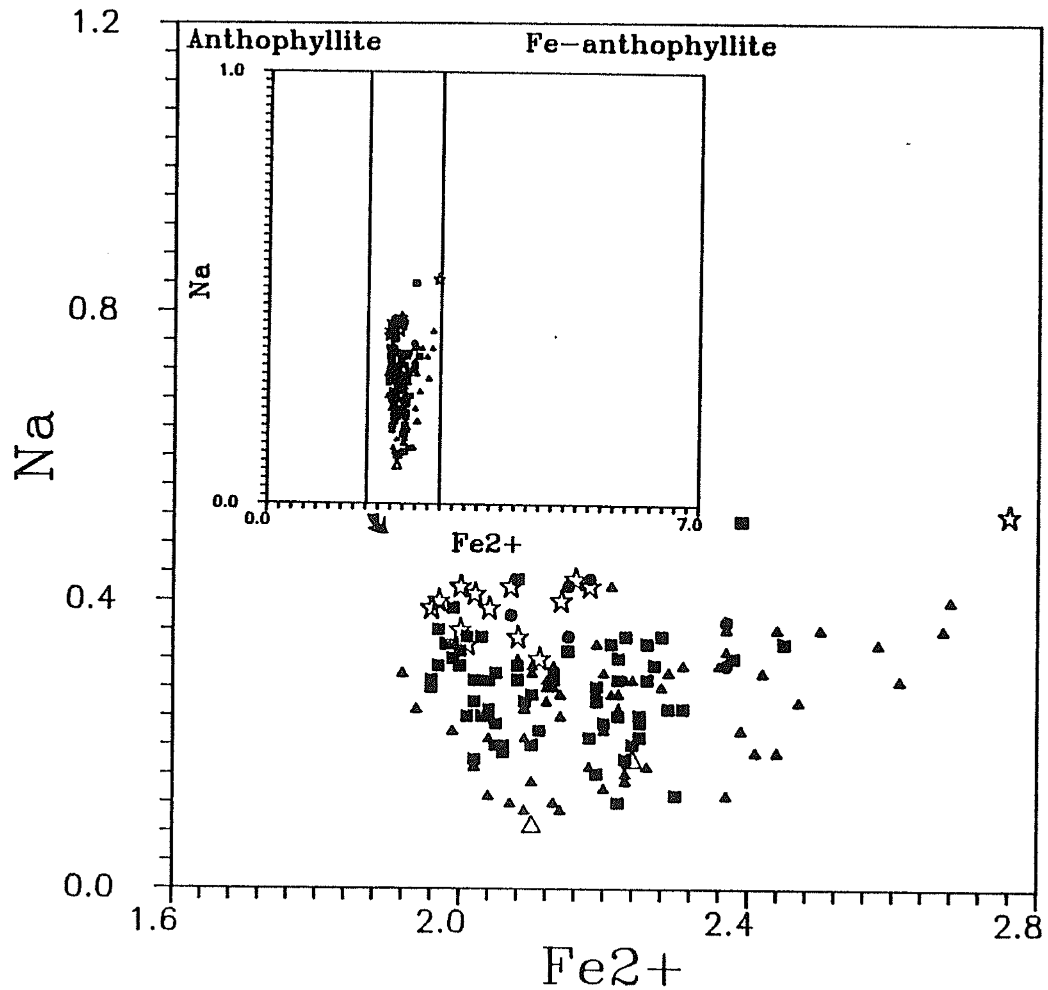


FIGURE 20: Fe^{2+} VERSES Mg, showing the amphiboles (anthophyllite and gedrite) from the Star Lake strata. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Sherridon unit 3.

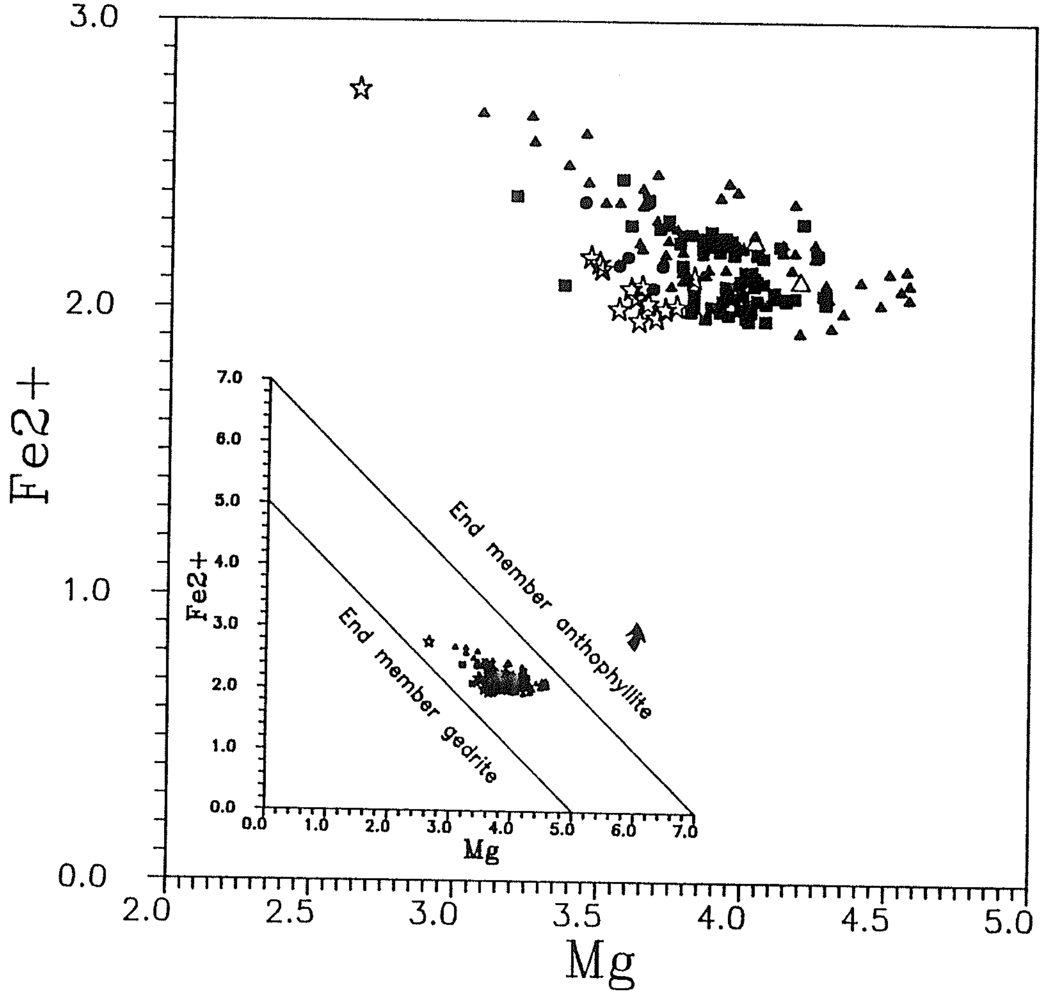
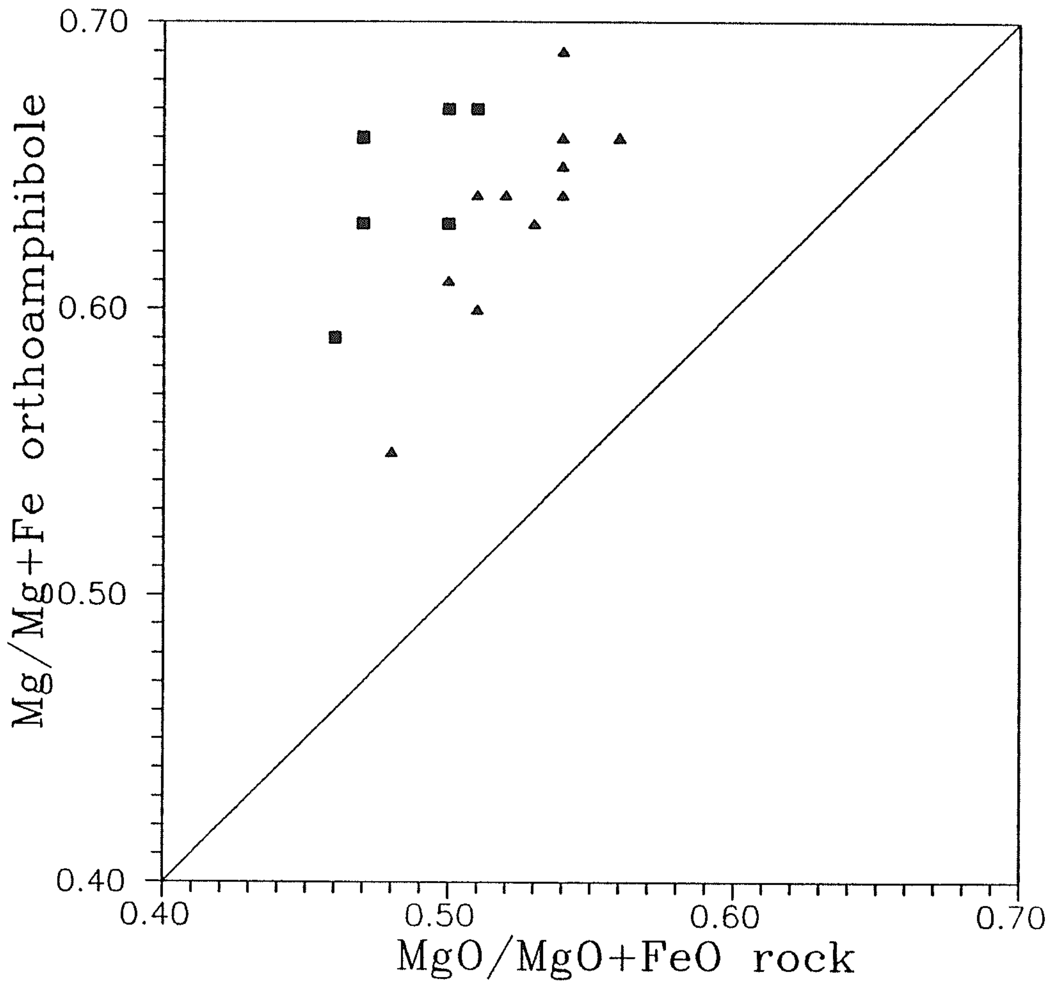


FIGURE 21: MGO/MGO+FEO ROCK VERSES MG/MG+FE ORTHOAMPHIBOLE, showing the amphiboles (anthophyllite and gedrite) from the Star Lake strata, as a function of rock chemistry. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Sherridon unit 3.



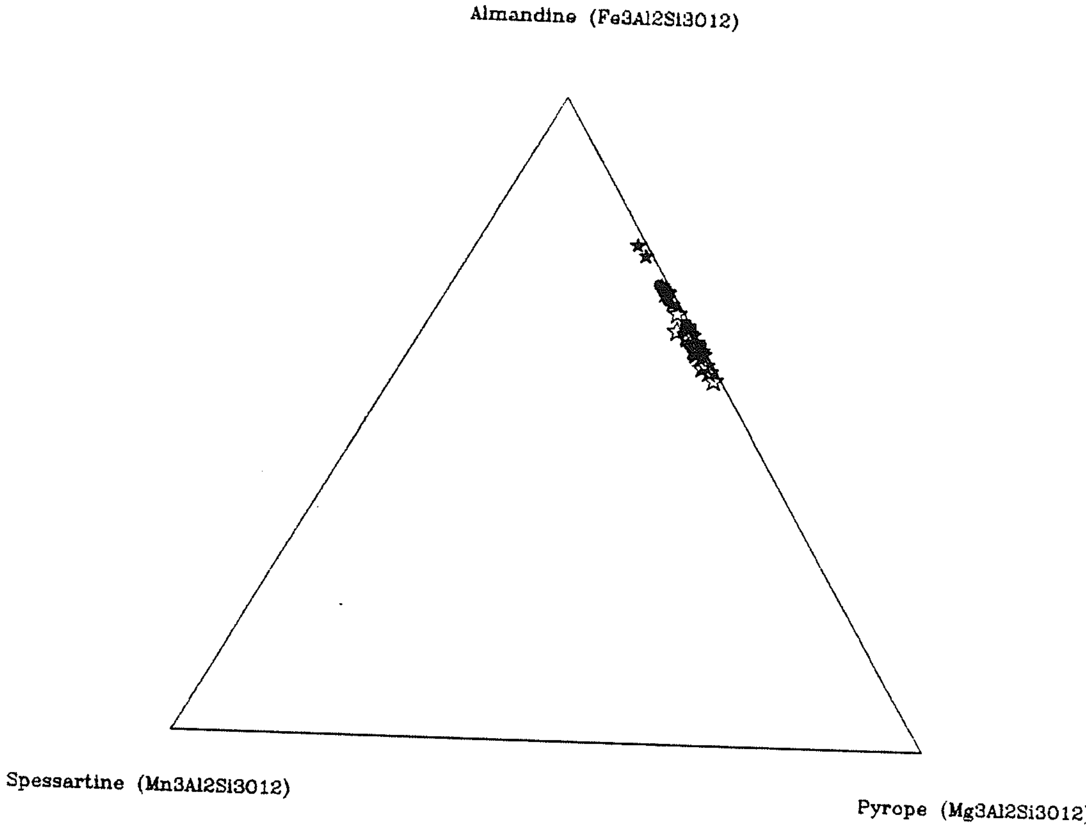


FIGURE 22: ALMANDINE - SPESSARTINE - PYROPE TERNARY PLOT, showing the garnets from the Star Lake strata. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Sherridon unit 3.

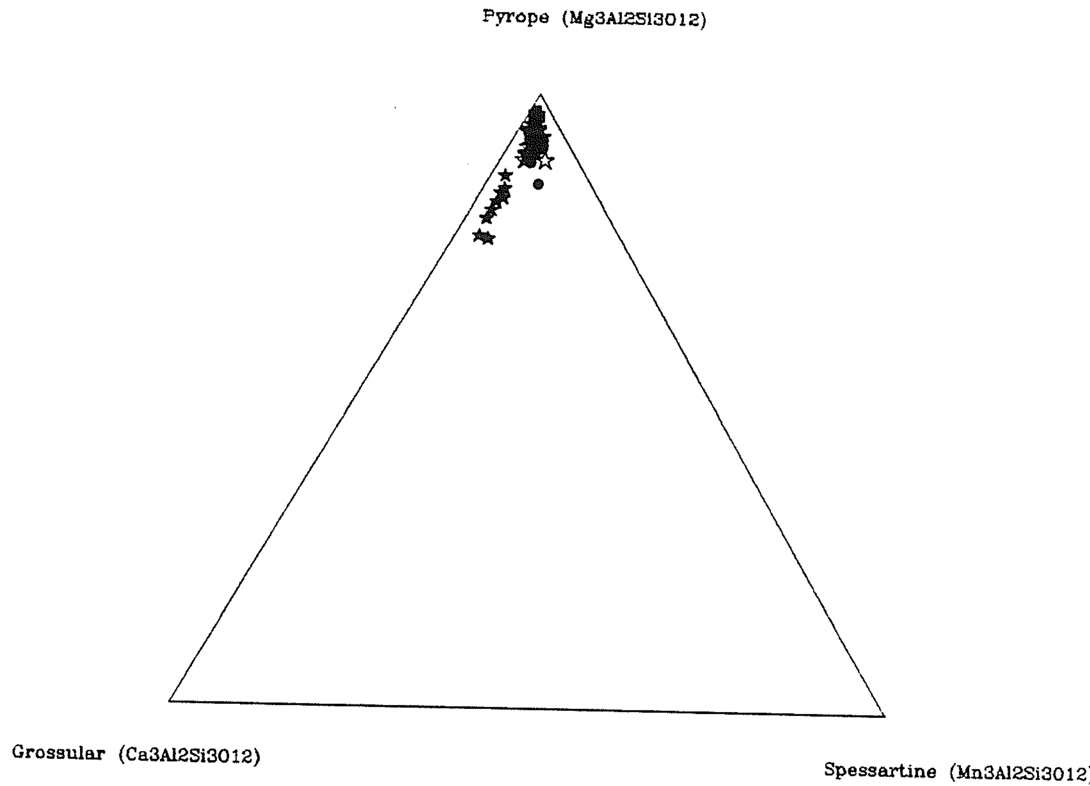


FIGURE 23: PYROPE – GROSSULAR – SPESSARTINE TERNARY PLOT, showing the garnets from the Star Lake strata. Filled circle – unit 1, filled square – unit 2, filled triangle – unit 3, filled star – quartz-biotite gneiss, asterisk – sillimanite zone, star – Elken Lake unit 2, and triangle – Sherridon unit 3.

orthoamphiboles. In any individual specimen of a particular rock unit, the cordierites have fairly constant composition with no evidence of zoning. In general, the magnesium content is greater in unit 2, and the iron content is greater in units 1 and 3. The compositions of cordierite do not follow those of the host rocks but show a marked enrichment of Mg relative to the host rocks.

Cordierite is an important indicator mineral in progressive metamorphism. It has very low density for a ferromagnesian mineral and it is regarded as being characteristic of low-pressure terranes. It often occurs with sillimanite as the characteristic Al_2SiO_5 polymorph.

(iv) Sillimanite

There is no compositional zoning, except for small amounts of Fe^{3+} replacing Al.

(v) Staurolite

Staurolite is a very minor phase in the gneissic rocks from Star Lake. It is fairly uniform, including sample ML49 associated with the Elken Lake mineralization. Sample ML01 shows no indication of zoning of any kind.

(vi) Biotite

Biotite is a minor phase in most samples. Most biotites have moderate TiO_2 (0.5-2.5 wt.%), but some are enriched (TiO_2 reaching 3.5 wt.%, Appendix D). Magnesium-rich biotites occur in unit 3, decreasing in Mg content from unit 2 to unit 1 respectively, probably due to changes in extensive conditions that alter Fe-Mg element partitioning preferences. The H_2O in the biotite analyses are determined by stoichiometry, and may be too high, causing the analyses totals to be somewhat erratic. The composition of biotites generally follow that of the host rocks, with Mg and Al enriched in the biotite relative to the host rock. The poor correlation is a result of the fact that, in addition to rock chemistry, biotite composition is dependent on the physical conditions of crystallization, the coexisting minerals, and the extent of secondary alteration.

(vii) Hercynite

Spinels from Star Lake and the Sherridon anthophyllite-cordierite gneisses are mainly hercynitic (Fe^{2+}) in composition (Figure 24). Zinc contents vary from 0 to 11.78 wt.% in rocks from unit 3 (anthophyllite-cordierite). The increase in Zn is marked by decreases in Fe^{2+} (Figure 25) and Mg (Figure 26). Samples from Sherridon (ML93) show similar patterns for Mg-Zn contents but have evidence of increasing Fe^{2+} with increasing Zn (cordierites associated with these samples have lower Fe^{2+} contents). The Zn-Mg and Zn-Fe relationships are probably due to hercynite/ cordierite partitioning effects. In spinel-bearing rocks the compositions of the spinel reflect bulk composition.

(viii) Phosphates

Two phosphates occur as very minor phases in these

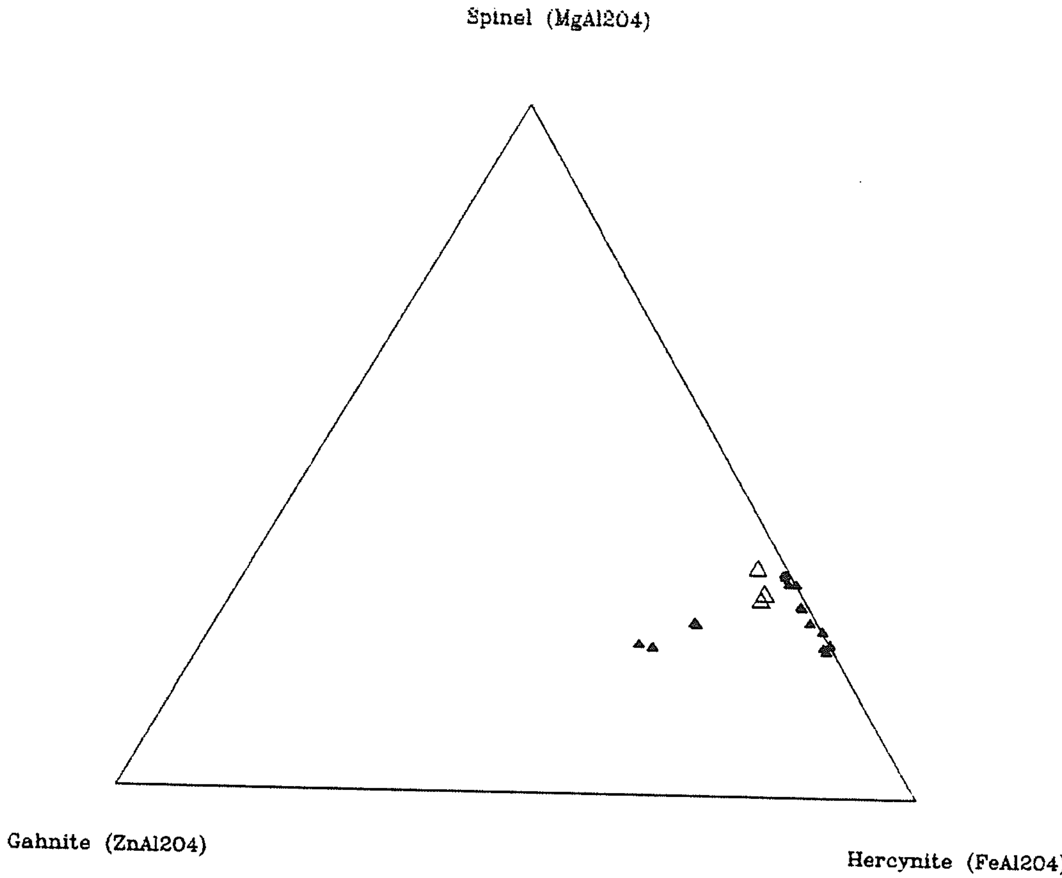


FIGURE 24: SPINEL - GAHNITE - HERCYNITE TERNARY PLOT, showing the hercynite spinels from the Star Lake strata. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Sherridon unit 3.

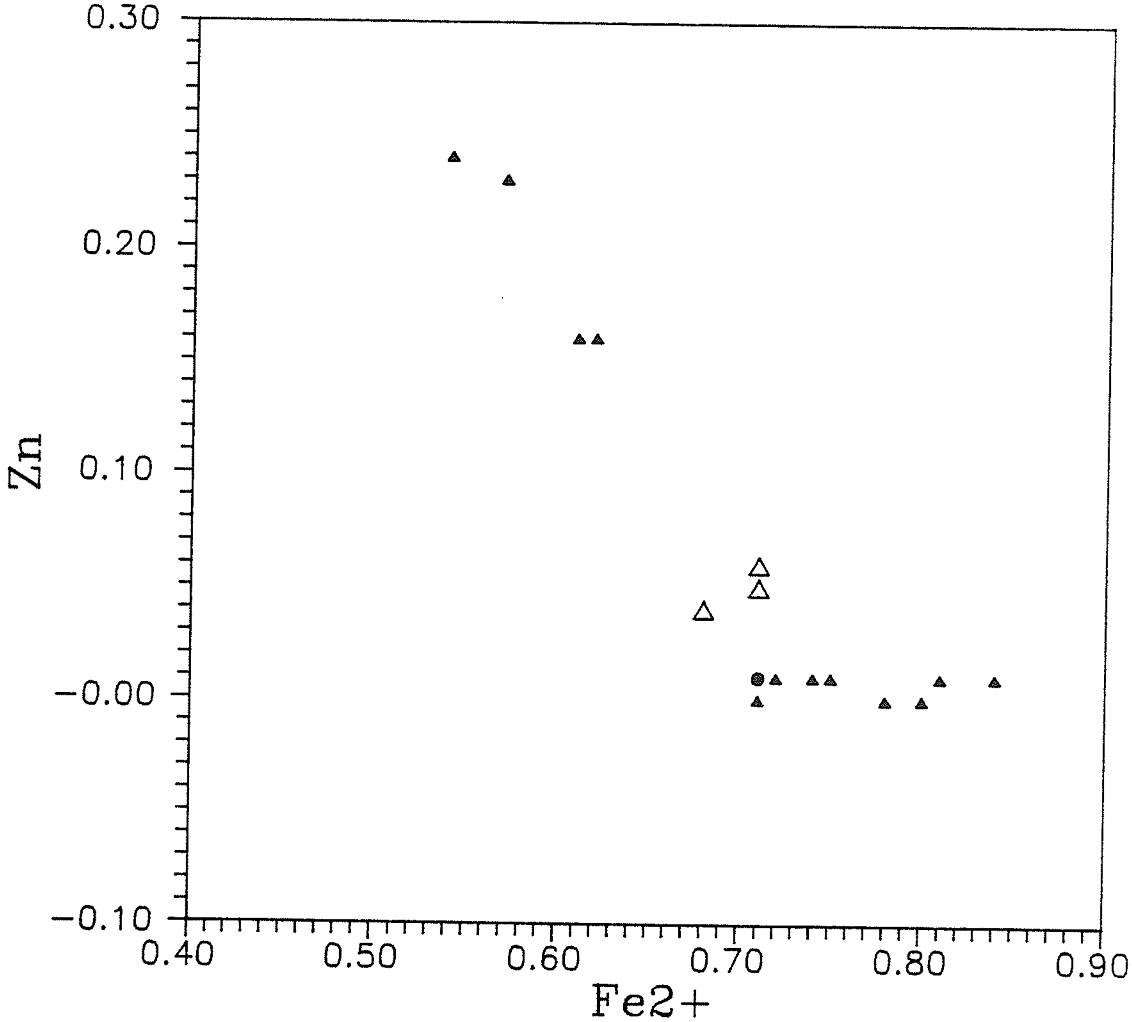


FIGURE 25: Zn VERSES Fe^{2+} in hercynite spinels from the Star Lake strata. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Sherridon unit 3.

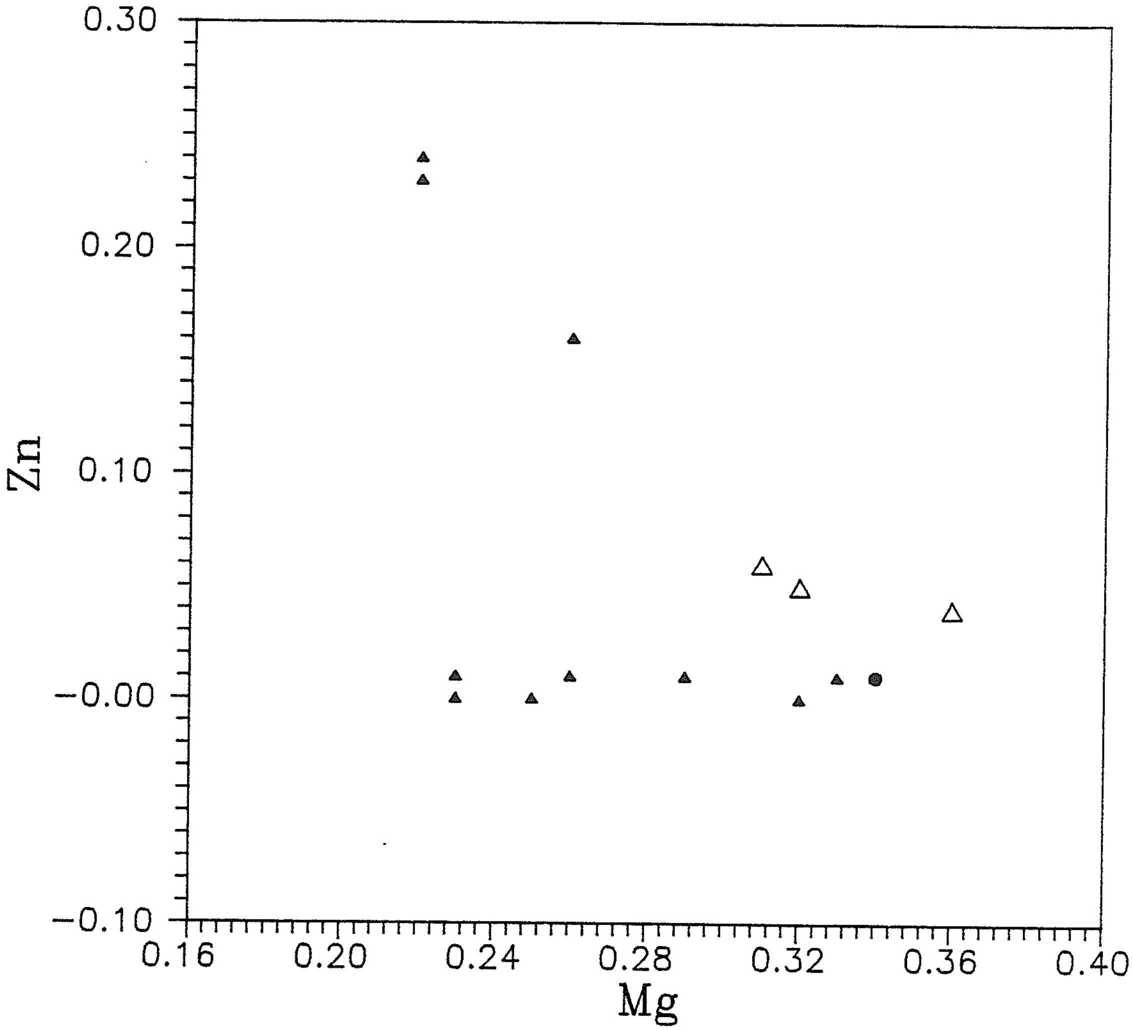


FIGURE 26: Zn VERSES Mg in hercynite spinels from the Star Lake strata. Filled circle - unit 1, filled square - unit 2, filled triangle - unit 3, filled star - quartz-biotite gneiss, asterisk - sillimanite zone, star - Elken Lake unit 2, and triangle - Sherridon unit 3.

gneisses. Apatite is closely associated with the sillimanite zone and is compositionally homogeneous throughout the unit. In areas of extreme calcium depletion and magnesium enrichment, wagnerite ($(Mg,Fe^{2+})_2PO_4F$) is found. This phosphate is fairly constant in composition throughout the samples.

(ix) Chlorite

Chlorite is found in unit 3 samples, showing evidence of later retrograde metamorphism. The composition is fairly consistent throughout all grains (Appendix D).

(VI) MINERAL REACTIONS

Nearly uniform conditions of high-grade metamorphism exist throughout the Kisseynew gneiss belt, decreasing with steep metamorphic gradient into the medium- and low-grade rocks of the adjacent volcanic belts (Bailes and McRitchie, 1978). The rocks of the Star Lake - Elken Lake area contain mineral assemblages characteristic of the amphibolite facies. Retrograde metamorphism is also common, with the presence of chlorite alteration of ferromagnesian minerals.

There is a considerable amount of experimental data pertinent to the system $MgO-FeO-Al_2O_3-SiO_2-H_2O$, some of which is relevant to the present study. A representative petrogenetic grid for quartz-bearing assemblages in this system from Star Lake is shown in Figure 27. Addition of Mg to this system will generally shift invariant points to higher pressures (Fe-Mg partitioning), whereas a decrease in X_{H_2O} will shift them to lower temperatures. Within the constraints of this system, cordierite is limited to low temperatures, whereas orthoamphibole and staurolite both become unstable with increasing temperature. The cordierite - amphibole rocks of unit 3 are stable in a field defined at high temperature by the reaction:

orthoamphibole = garnet + cordierite + quartz

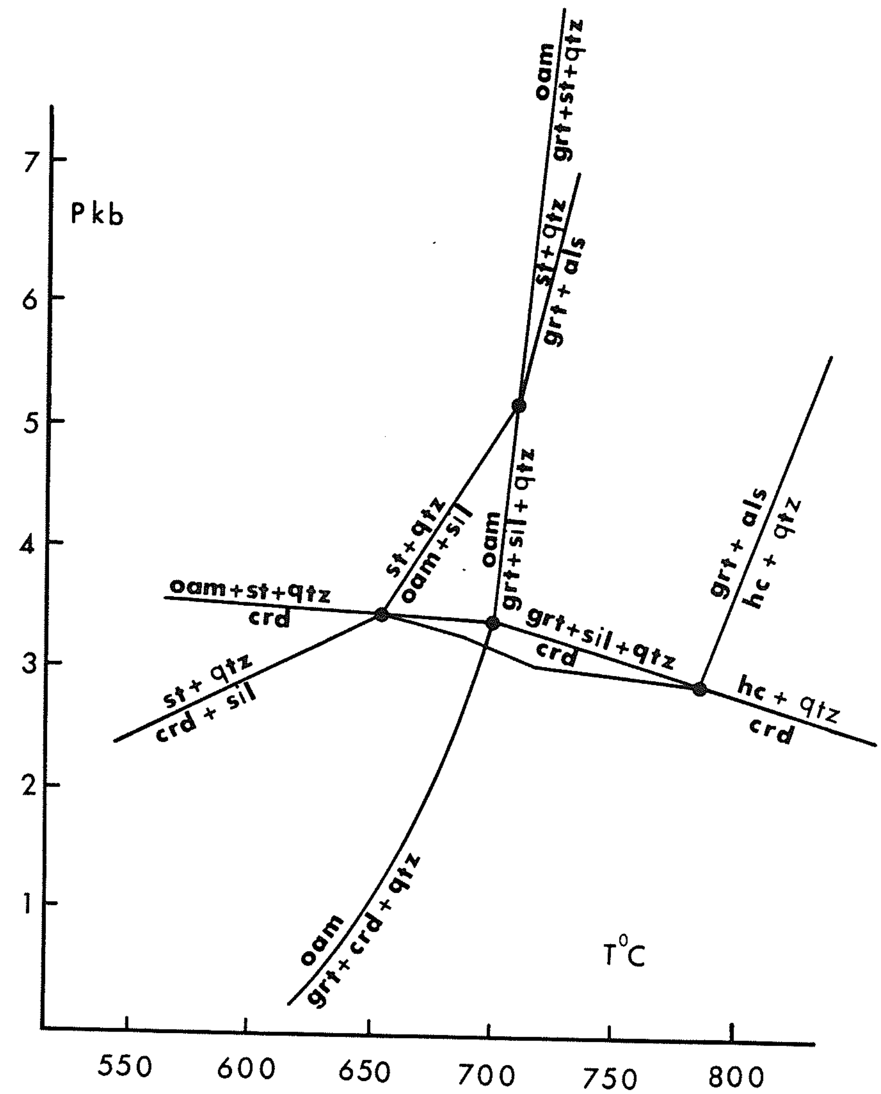


FIGURE 27: Equilibria in the system MgO - FeO - Al_2O_3 - SiO_2 - H_2O; ALS aluminosilicate, CRD cordierite, GRT garnet, HC hercynite, OAM orthoamphibole, QTZ quartz, SIL sillimanite, ST staurolite. From Grieve and Fawcett (1974).

and at high pressure by the reactions:

cordierite = orthoamphibole + staurolite + quartz

cordierite = orthoamphibole + sillimanite + quartz

This petrogenetic grid can only indicate approximate conditions of metamorphism. An attempt to account for the shift in P-T conditions resulting from Fe-Mg partitioning or substitutions may be made with the analytical data on phase compositions.

(i) Geothermometers

(a) Cordierite-garnet

The Fe-Mg partitioning between cordierite and garnet observed both in natural assemblages (Thompson, 1976) and experimental runs (Hensen and Green, 1973; Holdaway and Lee, 1977) has been used for temperature calibration. The equilibrium of the exchange reaction

$$2Mg_3Al_2Si_3O_{12} + 3Fe_2Al_4Si_5O_{18}(OH) = 2Fe_3Al_2Si_3O_{12} + 3Mg_2Al_4Si_5O_{18}(OH)$$

Mg-Grt + Fe-Crd = Fe-Grt + Mg-Crd

is represented by the distribution coefficient

$$K_D^{Grt-Crd} = \frac{(X^{Grt}_{Fe})(X^{crd}_{Mg})}{(X^{grt}_{Mg})(X^{crd}_{Fe})}$$

This coefficient is an exponential function of T, which may be combined with the P-T position of the reaction

$$5Fe_5Al_4Si_6O_{22}(OH)_2 + 3Fe_4Al_{18}Si_8O_{46}(OH)_2$$

orthoamphibole + staurolite

$$= 10.8Fe_2Al_4Si_5O_{18}0.5H_2O + 15.4FeAl_2O_4 + 2.6H_2O$$

cordierite + spinel

This may account for a shift in P-T conditions resulting from Mg-Fe substitution.

$$T = \frac{2725 + 0.0155P}{\ln k_D + 0.896} \quad +/- \ 50\ k$$

(Thompson, 1976)

The equilibrium temperatures for the representative garnet and cordierite rims, obtained for samples SC2-9 (unit 1) and SC4-12 (unit 3) are 658°C and 655°C respectively for 6 Kbar, 661°C and 658°C respectively for 6.5 Kbar and 663°C and 660°C respectively for 7 Kbar.

(b) Biotite-garnet

The Fe-Mg exchange reaction between biotite and garnet is represented by the distribution coefficient:

$$K_D{}^{Grt-Bt} = \frac{(X^{Grt}{}_{Fe})\ (X^{Bt}{}_{Mg})}{(X^{Grt}{}_{Mg})\ (X^{Bt}{}_{Fe})}$$

for the exchange reaction

$$Mg_3Al_2Si_3O_{12} + KFe_3AlSi_3O_{10}(OH)_2$$

garnet + biotite

$$= Fe_3Al_2Si_3O_{12} + KMg_3AlSi_3O_{10}(OH)_2$$

garnet + biotite

For this reaction, Thompson (1976) has shown that the following relationship holds:

$$T = \frac{2740 + 0.0234P}{\ln K + 1.56} \quad +/- \ 50 \text{ K}$$

Equilibrium temperatures for the representative garnet and biotite rims, obtained from sample SC2-1 (unit 1) and SC5-12 (unit 2) are 665°C at 6 Kbar, 669°C at 6.5 Kbar and 673°C at 7 Kbar for both samples. The application of this thermometer is made easier by the lack of zoning in the garnets from both these samples.

Both cordierite-garnet and biotite-garnet derived temperatures show that metamorphic temperatures were fairly constant throughout the Star Lake - Elken Lake area.

(ii) Geobarometers

Despite the variety of their mineral assemblages, cordierite-anthophyllite rocks are not particularly suited to derive pressure estimates from conventional geobarometers, due to the structural and chemical complexities of the orthoamphiboles. Seifert and Schumacher (1986) have shown that the assemblage cordierite-(Mg-Zn-Fe^{2+}) aluminate spinel-quartz can be successful as a geobarometer.

In the system $FeAl_2O_4$-SiO_2, the phases spinel (spl), cordierite (crd) and quartz (qtz) are related by the univariant reaction:

$$Fe_2Al_4Si_5O_{18}(Fe\text{-}crd) = 2\ FeAl_2O_4(Hc) + 5\ SiO_2(qtz)$$

The equilibrium constant for this reaction is

$$K_2 = \frac{(X^{spl}_{Fe})^2\ (X^{qtz}_{SiO2})}{(X^{crd}_{Fe})}$$

Considering quartz as a pure phase and assuming ideality for the spinels

$$K_2 = \frac{(X^{spl}_{Fe})^2}{(X^{crd}_{Fe})^2} \qquad \text{ie. } X^{qtz}_{SiO2}=1$$

Equilibrium pressures for the representative spinels and cordierites from samples SC5-35 (unit 3) and ML33 (unit 3) range from 6.6 Kb at 650°C to 6.8 Kb at 700°C (as shown in Figure 27).

In the system $MgAl_2O_4$-SiO_2, the phases spinel (spl), cordierite (crd) and quartz (qtz) are related by the univariant reaction:

$Mg_2Al_4Si_5O_{18}$ (Mg-crd) = 2 $MgAl_2O_4$ (spl) + 5 SiO_2 (qtz)

$$K_1 = \frac{(X^{spl}_{Mg})_2 \, (X^{qtz}_{SiO2})^5}{(X^{crd}_{Mg})}$$

where $X^{qtz}_{SiO2} = 1$

where $X^{crd}_{Mg} = 1 - X^{crd}_{Fe}$.

Samples SC5-35 and ML33 with equilibrium constant values of K_1 = 0.35 (log K_1 = -0.45) and K_1 = 0.34 (log K_1 = -0.47) respectively, give estimates of equilibrium pressures of 7.1 Kb at 650°C to 7.3 Kb at 700°C (Figure 28). These later estimates may be lower than true values due to the stabilizing effect of H_2O in cordierite, which was not considered in the calculations used to derive K_1. According to Mirwald (1982), hydrous cordierites would plot at +1.5 Kb compared to anhydrous cordierite (Seifert and Schumacher, 1986). The addition of Mg to the system (as occurs at Star Lake) generally shifts invariant points to similar higher pressure regimes (Figure 29). It is therefore obvious that added components (FeO) to the initial dry system MgO-Al_2O_3-SiO_2, reflect variations as a function of pressure, temperature and bulk rock chemistry.

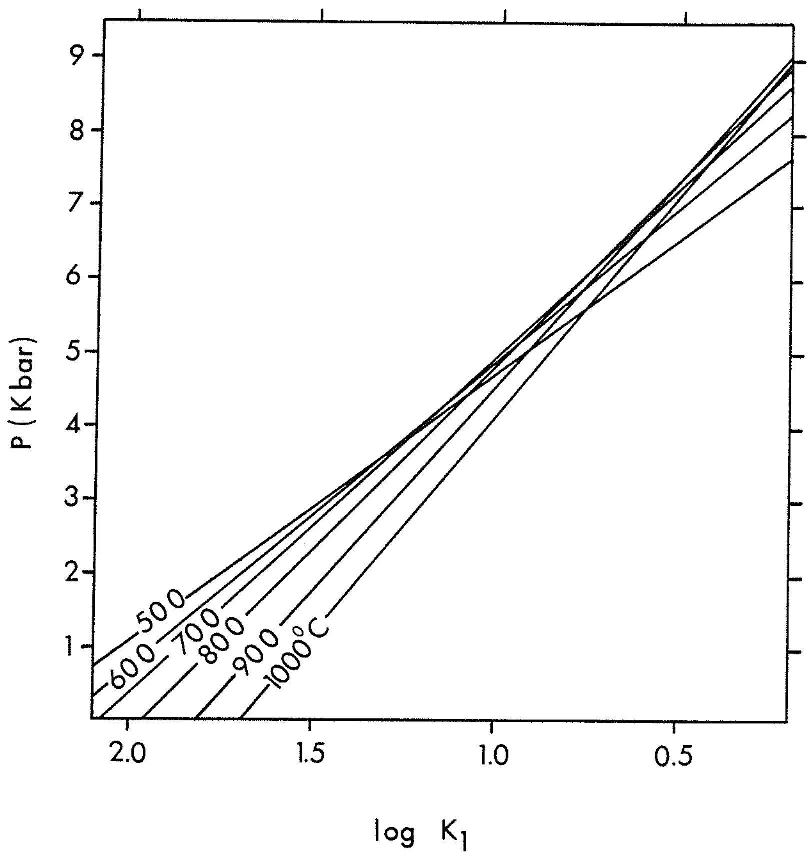


FIGURE 28: Log K_1 for the cordierite - spinel - quartz equilibrium as a function of pressure for different temperatures. From Seifert and Schumacher (1986).

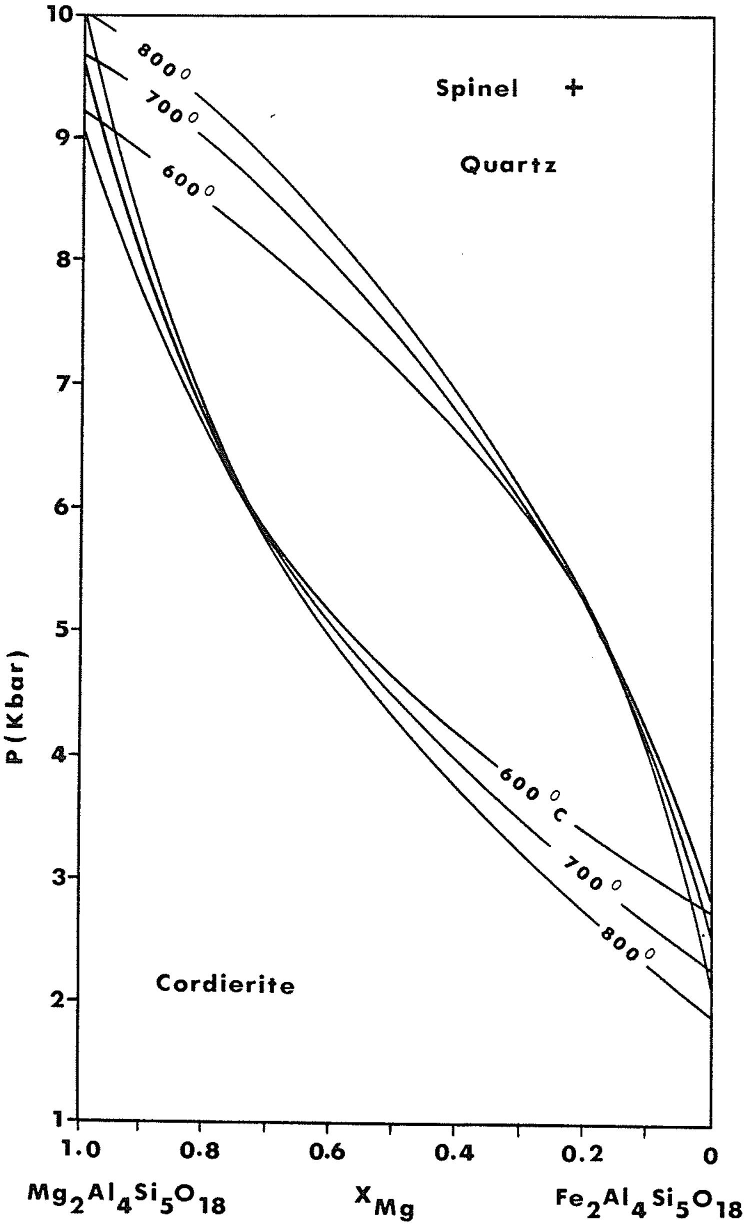


FIGURE 29: Calculated compositions of anhydrous Mg-Fe cordierites in coexistence with quartz and $(Fe,Mg)Al_2O_4$ spinels at three different temperatures. From Seifert and Schumacher (1986).

(VII) DISCUSSION AND CONCLUSION

(i) Possible Cordierite-Anthophyllite Rock Origins

The anthophyllite-bearing rocks of the Sherridon Group form discontinuous layers that have both gradational and sharp contacts with the lithic arenites which enclose them. Hypotheses for the origin of this rock type have been numerous.

The classic study is that of the Orijarvi area (Eskola ,1914). He indicated that the composition of cordierite-anthophyllite bearing rocks does not correspond to that of any sedimentary or igneous rock. For this reason, their origin was attributed to contact metasomatism involving relative enrichment in iron and magnesium and depletion in calcium and alkalis. Later, Wegmann and Kranck (1931) also suggested a metasomatic origin related to regional metamorphism. Tuominen and Mikkola (1950) further suggested that in the Orijarvi area, cordierite-anthophyllite rocks represented isochemically metamorphosed quartz-chlorite rocks.

In the case of the Star Lake - Elken Lake area, Robertson (1953) described an anthophyllite band of wide distribution at a constant stratigraphic horizon. He stated that the character of the mineral assemblage suggests Fe-Mg metasomatism of an aluminum-rich sediment or tuff. Robertson favoured the tuff progenitor because of the wide lateral development and apparent continuity of the band (normal sediments in these types of rocks would probably be less continuous and would not offer such a permeable medium for ascending solutions).

Wilkinson (1976) noted that this assemblage was very similar to the high-temperature assemblages found in metamorphosed volcanic alteration pipes. In alteration pipes, this is the result of the conversion of the original assemblage to one consisting almost exclusively of Fe-Mg chlorite, similar to the Shakami Mine occurrence in Japan (Shirozu, 1974).

Goetz and Froese (1982) proposed that the cordierite-anthophyllite rocks required chloritic rocks as precursors; these could be produced by hydrothermal alteration. "Chloritization is a common proccess in hydrothermal alteration, which involves the selective dissolution and removal of calcium and sodium, producing a rock depleted in these elements and enriched in aluminum. Thus , mafic rocks could acquire the composition of a quartz -chlorite mixture and felsic rocks could become chloritized by a combination of some aluminum with iron and magnesium from the hydrothermal solution." (Goetz and Froese, 1982). They also suggest that the protolith of the cordierite-anthophyllite rocks might have been detritus of hydrothermally altered rocks, transported to their present site either as a fine suspension in a brine (Wilkinson, 1976; Goetz, 1980) or as a sediment gravity flow (Middleton and Hampton, 1976). In the search for chloritic precursors of anthophyllite-bearing rocks, two main processes of chloritization have been considered; hydrothermal alteration related to mineralization (Froese, 1969; Goetz and Froese, 1982) and chloritization as part of the complex alteration leading to the formation of spilites (Vallance, 1967, 1969).

In the case of the cordierite-anthophyllite rocks at the Star Lake - Elken Lake area, the available evidence seems to point to an altered basaltic protolith with mixed injections of sedimentary material. The hydrothermal alteration of basalt by seawater thus forming alteration pipes is the most likely process leading up to the present lithologies. These alteration pipes probably formed due to rapid heating of large volumes of cold undepleted seawater in the vicinity of vent areas. The heated seawater then reacted with the basaltic rocks of the crust, recrystallizing them and modifying the chemistry of both rocks and solution and eventually exiting the rocks as warm or hot springs. In the process, with a very large water to rock volume ratio, chemical components were transferred from the seawater into the altered crust and vice versa. Wolery and Sleep (1976) have suggested that water/rock ratios in submarine hydrothermal systems may be as high as 100 (total mass of water which has passed through the system during its lifetime divided by the mass of rock within the system that has been altered).

In general, upon heating, the cold seawater lost its magnesium very rapidly to form chlorite and smectite mixtures in varying proportions. Seyfried and Mottl (1982) have shown that, with very large water to rock ratios and elevated temperatures, Mg was removed from solution and therefore supplied to the crust whereas Na and Ca had been leached from the basaltic rocks. As sodium is very depleted in these alteration zones, this would reflect the virtual total destruction of feldspars. As the Mg supply exceeds the amount of Mg that the available rock can absorb, the concentration of Mg increases in solution. Under these conditions, the solution becomes acid and rich in heavy metals promoting the formation of sulfides in isolated localities (Elken Lake and Sherridon deposits may be typical examples). The only silicates which could form from basalt and coexist stably with such a solution are quartz, smectite and chlorite. This results from the fact that nearly all the Ca, Na, K, Ba, Mn, Cu and Zn are leached from the altered silicates and reside in the acid solution (Seyfried and Mottl, 1982; Seyfried et al., 1988).

The size and vertical distribution of a chlorite pipe is probably a function of the permeability of the crust. This permeability may have been the result of highly fractured zones associated with major faults or a function of fragmental accumulations being altered. These compositionally variable alteration zones most likely reflect the changing composition of the Star Lake - Elken Lake units, following individual periods of tectonism and metamorphism. Following this accumulation of altered material, high-grade regional metamorphism took place for a long period of time, promoting the growth of coarse crystals of some of the minerals.

It could possibly be inferred that a progressive alteration sequence from unit 1 to unit 3 rocks, from Star Lake, represent a progressive trend towards chlorite rich alteration pipe cores.

(ii) Tectonic and Petrologic History

The Kisseynew meta-sedimentary belt lies between two volcanic belts from which its sediments were derived (Bailes, 1971). Dickinson (1974) stated that a much larger amount of sediments can be derived from a volcanic belt than the amount of volcanic rocks preserved in the belt. This is true of the Kisseynew belt, which contains at least 10 times the amount of sediments as there are volcanics preserved in the Lynn Lake and Flin Flon belts. Due to the volcanic rock and unit size distribution, this setting resembles a modern back-arc basin, suggesting tectonic activity and volcanic alteration. From these relations, it can therefore be inferred that the volcanic and sedimentary belts of central Manitoba and Saskatchewan could have been created by the process of plate tectonics (Karig, 1972).

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APPENDIX A

CHEMICAL ANALYSES OF ROCKS FROM STAR LAKE, NEAR SHERRIDON MANITOBA

Ninety-nine chemical analyses of rocks from the Star Lake - Elken Lake area, near Sherridon, are compiled in this appendix. The analyses are listed by field sample identification number and unit number. Field sample numbers refer to figures 3 - 4 and Table 2; unit numbers refer to the field units:

U-1: unit 1 (quartz-garnet-anthophyllite),

U-2: unit 2 (garnet-anthophyllite),

U-3: unit 3 (anthophyllite-cordierite),

QBG: quartz-biotite gneisses,

SIL: the sillimanite zone,

U-2(M): the mineralized unit 2 (garnet-anthophyllite) of Elken Lake and

U-3(M): unit 3 (anthophyllite-cordierite) near the east orebody at Sherridon Manitoba. (Sherridon unit 3)

A rock saw was used to cut sections within the three mappable Units and adjacent quartz-biotite gneisses in order to provide as continuous a sample as possible for chemical analysis and thin-sectioning. All weathered surfaces were removed, and the sample was sawn in half; one half was saved for making a thin-section, polished thin-section, chemical analyses and hand specimen, and the other half was catalogued at the Manitoba Energy and Mines Bureau.

The sample was then cut for thin-sectioning. Another representative part of the sample was crushed and sent to the University of Ottawa Analytical Geochemistry Section for major oxide analyses, and Bondar - Clegg Geochemical Laboratory for trace element analyses. Methods, lower detection limits and reliability of analyses for each element and reported standards are listed in Table A-1.

TABLE A1: GEOCHEMICAL METHODS AND ACCURACY OF ANALYSIS

ELEMENT	LOWER DETEC. LIMIT AND PRECISION (+/- % CONC)	METHOD OF ANALYSIS	ACCURACY OF ANALYSIS (STANDARD DEVIATION)				
			SY - 2	BCC	SC2-12	SC5-14	SC8-17
SiO2	+/- 1.0%	XRF	0.168		0.400	0.950	2.020
TiO2	+/- 1.0%	XRF	0.005		0.021	0.050	0.130
Al2O3	+/- 1.5%	XRF	0.103		0.064	0.014	0.270
Fe2O3 T	+/- 5.0%	XRF	0.036		0.622	0.000	0.520
FeO	0.01%	titrametric			1.263	0.112	0.792
MnO	+/-10.0%	XRF	0.000		0.014	0.020	0.000
MgO	+/- 3.0%	XRF	0.047		0.100	0.640	0.360
CaO	+/- 5.0%	XRF	0.059		0.000	0.000	0.060
Na2O	+/-15.0%	XRF	0.067		0.014	0.000	0.110
K2O	+/- 5.0%	XRF	0.040		0.078	0.020	0.040
P2O5	+/-10.0%	XRF	0.015		0.035	0.010	0.010
Ba	+/-10.0%	XRF	5.170		26.80	7.070	37.50
Cr	+/-50.0%	XRF	8.100		2.830	2.830	2.120
Zr	+/-10.0%	XRF	3.670		3.540	3.540	1.410
Sr	+/-50.0%	XRF	7.150		2.120	0.000	2.830
Rb	+/-50.0%	XRF	3.920		2.120	0.000	0.000
Y	+/-10.0%	XRF	2.530		1.410	1.410	2.120
Ni	+/-50.0%	XRF			0.000	0.000	0.000
Zn	+/-10.0%	XRF	31.66		10.00	24.04	19.09
V	+/-10.0%	XRF			5.660	21.92	17.00
Sc	0.2 PPM	Neutron Act.		0.000	2.620	4.950	2.900
Co	5 PPM	Neutron Act.		1.410	29.70	7.070	1.410
Mo	1 PPM	Neutron Act.		0.420	0.000	0.000	0.000
Cs	0.5 PPM	Neutron Act.		0.495	0.000	0.000	0.000
Cu	1 PPM	Atomic Abs.		0.580	0.577	28.60	0.707
Pb	2 PPM	Atomic Abs.		2.650	1.414	0.707	0.000
F	20 PPM	Specific Ion			31.20	117.0	60.10
S	0.01%	Specific Ion			0.000	0.000	0.000
La	2 PPM	Neutron Act.		4.950	0.000	0.000	0.707
Ce	5 PPM	Neutron Act.		8.490	4.950	0.000	0.000
Sm	0.05 PPM	Neutron Act.		0.707	0.141	0.071	0.212
Eu	1 PPM	Neutron Act.		0.640	0.000	0.000	0.000
Tb	0.5 PPM	Neutron Act.		0.071	0.212	0.000	0.071
Yb	2 PPM	Neutron Act.		0.350	0.000	1.414	0.000
Lu	0.2 PPM	Neutron Act.		0.042	0.071	0.071	0.000

Specimen No.	SC 1-1	SC 1-2	SC 1-7	SC 1-10	SC 1-14a	SC 1-14b	SC 2-1	SC 2-6	SC 2-10	SC 2-12c	SC 2-12d
Unit #	1	1	1	1	SIL	SIL	1	1	1	1	1
Major Oxides	(wt%)										
SiO2	75.55	69.36	69.35	70.02	67.50	71.81	68.86	71.73	72.41	73.21	72.65
TiO2	0.10	0.48	0.47	0.36	0.29	0.35	0.47	0.41	0.37	0.37	0.40
Al2O3	13.10	13.02	12.89	11.19	13.28	10.41	12.92	12.19	10.69	10.81	10.72
Fe2O3	0.27	3.64	0.99	0.88	1.03	1.29	0.52	0.85	0.80	-	0.61
FeO	1.52	6.43	6.44	8.06	6.18	5.93	9.18	7.44	7.95	9.68	7.44
MnO	0.03	0.28	0.09	0.14	0.16	0.14	0.28	0.11	0.16	0.11	0.09
MgO	1.16	4.74	4.77	4.36	4.55	3.97	4.36	4.88	4.86	4.65	4.79
CaO	1.12	0.59	0.30	0.29	0.20	0.22	0.58	0.22	0.22	0.24	0.24
Na2O	3.30	-	0.03	0.11	0.01	0.17	-	0.11	-	0.02	-
K2O	2.29	1.02	2.64	3.07	2.85	3.12	1.02	1.29	0.96	1.00	1.11
P2O5	0.08	0.41	0.15	0.13	0.11	0.16	0.39	0.10	0.22	0.17	0.12
Total	98.52	99.97	98.12	98.61	96.16	97.57	98.58	99.33	98.64	100.3	98.17
Minor Elements	(ppm)										
Ba	186	442	568	360	329	319	392	490	346	374	412
Co	80	86	81	74	67	87	120	100	95	140	98
Cr	28	33	25	30	29	27	29	26	28	29	33
Cs	2	9	5	8	7	8	1	1	1	1	1
Cu	3	1	3	2	2	1	4	12	1	2	3
F	250	1064	765	765	870	814	730	705	500	760	745
Mo	3	4	3	3	3	3	4	3	3	3	3
Ni	-	-	-	-	-	-	-	-	-	-	-
Pb	7	3	4	2	6	5	4	3	3	2	4
Rb	66	5	123	159	155	194	8	8	6	4	7
S	-	-	-	-	-	-	-	-	-	-	-
Sc	5	21	21	24	19	20	32	21	26	22	18
Sr	52	11	11	6	7	-	9	3	6	6	3
V	-	3	-	-	15	-	3	5	-	-	8
Y	33	39	26	28	16	36	36	19	25	21	19
Zn	50	428	98	56	100	120	438	121	39	24	38
Zr	15	57	51	45	39	41	54	48	47	52	47

- not detected

Specimen No.	SC 2-21a	SC 2-21b	SC 2-25a	SC 2-25b	SC 2-26	SC 3-2	SC 3-4	SC 3-8	SC 3-10	SC 3-13c	SC 3-13d
Unit #	1	1	1	1	1	1	1	1	1	1	1
Major Oxides	(wt%)										
SiO2	72.59	72.68	81.29	74.95	74.63	69.04	69.63	68.81	68.32	76.72	78.61
TiO2	0.43	0.41	0.26	0.35	0.38	0.32	0.39	0.42	0.27	0.20	0.18
Al2O3	11.55	12.03	7.52	11.33	10.93	11.48	16.19	11.86	10.73	8.75	9.37
Fe2O3	0.63	0.65	0.44	0.63	0.71	0.75	0.52	0.66	1.17	0.61	0.46
FeO	7.50	7.82	5.23	7.08	5.39	7.63	5.38	7.51	9.40	4.56	3.49
MnO	0.10	0.10	0.12	0.09	0.05	0.05	0.05	0.05	0.14	0.03	0.02
MgO	4.18	4.24	3.06	4.16	5.34	8.48	6.42	8.34	8.03	6.06	5.01
CaO	0.24	0.22	0.24	0.31	0.24	0.18	0.25	0.19	0.18	0.07	0.06
Na2O	0.09	0.06	0.12	0.03	-	0.32	-	0.25	0.35	-	0.02
K2O	1.05	1.13	0.76	0.80	1.45	0.65	0.51	0.85	1.01	1.27	1.09
P2O5	0.13	0.09	0.19	0.21	0.22	0.15	0.23	0.15	0.08	0.10	0.06
Total	98.49	99.43	99.23	99.94	99.34	99.05	99.57	99.09	99.68	98.37	98.37
Minor Elements	(ppm)										
Ba	484	517	320	382	504	233	221	298	348	446	406
Co	130	120	140	140	110	110	120	97	120	130	110
Cr	29	28	34	25	25	29	29	29	31	36	40
Cs	1	1	1	1	1	1	1	1	1	1	1
Cu	1	1	1	1	1	1	1	1	1	1	1
F	655	725	555	600	1125	1000	630	1130	1130	1195	935
Mo	4	3	4	3	3	3	3	2	4	4	3
Ni	-	-	-	-	-	-	-	-	26	-	-
Pb	3	2	2	2	2	2	2	2	2	2	5
Rb	6	10	-	3	8	-	-	5	6	8	6
S	-	-	-	-	-	-	-	-	-	-	-
Sc	20	23	24	19	17	16	13	15	28	17	11
Sr	4	6	5	7	9	5	6	5	3	9	7
V	16	9	-	13	-	-	14	-	28	25	26
Y	20	22	41	24	24	84	23	21	29	22	29
Zn	36	33	12	25	21	43	12	29	30	25	32
Zr	46	50	30	44	42	45	48	47	52	56	59

- not detected

Specimen No.	SC 3-18	SC 3-25a	SC 3-25b	SC 3-29	SC 3-33	SC 3-39	SC 3-42	SC 3-44	SC 3-51a	SC 3-54b	SC 4-2c
Unit #	1	2	2	2	2	1	2	2	2	2	3
Major Oxides	(wt%)										
SiO2	75.09	64.71	61.42	56.71	61.05	70.97	58.67	59.48	57.12	59.35	62.95
TiO2	0.17	0.51	0.64	0.65	0.67	0.27	0.66	0.61	0.64	0.65	0.67
Al2O3	9.76	11.15	13.95	14.35	14.90	13.96	13.21	15.32	15.52	12.78	14.36
Fe2O3	0.45	0.81	1.37	1.00	1.04	0.69	1.52	0.56	0.84	1.13	1.01
FeO	5.01	11.30	11.01	14.00	10.43	6.16	12.86	13.04	14.13	12.32	10.39
MnO	0.05	0.10	0.16	0.27	0.17	0.07	0.25	0.32	0.28	0.14	0.09
MgO	5.57	10.22	10.91	11.97	11.14	5.58	11.98	10.23	10.52	12.69	9.22
CaO	0.09	0.25	0.24	0.39	0.23	0.16	0.30	0.39	0.42	0.26	0.28
Na2O	-	0.48	0.26	0.24	0.27	0.05	0.27	0.24	0.04	0.37	0.19
K2O	0.99	0.05	0.02	0.03	0.03	1.05	0.18	0.02	0.05	0.11	0.18
P2O5	0.08	0.16	0.14	0.62	0.15	0.09	0.20	0.27	0.19	0.15	0.20
Total	97.26	99.74	100.1	100.2	100.1	99.05	100.1	100.5	99.75	99.95	99.54
Minor Elements	(ppm)										
Ba	355	80	93	114	93	411	115	102	92	75	68
Co	110	140	120	130	110	99	91	100	130	110	82
Cr	27	24	20	23	17	33	23	28	21	25	26
Cs	1	1	1	1	1	1	1	1	1	1	1
Cu	1	1	1	1	1	1	5	2	944	4	12
F	960	1125	970	1365	1205	900	1060	810	835	1205	730
Mo	3	3	2	2	2	3	2	1	2	3	3
Ni	-	-	-	-	-	-	-	-	-	-	-
Pb	3	2	2	2	2	2	2	2	2	2	2
Rb	8	-	-	-	-	6	-	-	-	-	-
S	-	-	-	-	-	-	-	-	-	-	-
Sc	18	40	44	66	39	17	63	76	48	32	43
Sr	6	4	1	-	1	6	-	-	4	-	4
V	12	313	349	324	369	42	339	316	346	362	225
Y	32	11	13	22	22	27	30	47	15	15	31
Zn	28	76	91	41	64	44	41	69	80	88	50
Zr	51	24	34	32	31	47	32	32	33	30	37

- not detected

Specimen No.	SC 4-2d	SC 4-5	SC 4-9	SC 4-12	SC 4-13a	SC 4-13b	SC 5-1	SC 5-6	SC 5-10	SC 5-14c	SC 5-14d
Unit #	3	3	3	3	3	3	2	2	2	2	2
Major Oxides	(wt%)										
SiO2	62.86	62.42	65.09	67.15	57.68	66.59	60.98	60.49	63.31	57.77	56.43
TiO2	0.70	0.58	0.56	0.48	0.76	0.61	0.48	0.52	0.48	0.42	0.49
Al2O3	12.87	12.67	12.73	12.03	13.00	11.75	15.10	14.90	13.49	15.28	15.30
Fe2O3	0.71	0.68	0.83	1.87	1.03	1.50	0.87	1.61	0.26	1.27	1.12
FeO	10.53	10.85	9.20	7.47	13.19	8.84	15.26	13.70	13.86	16.51	16.66
MnO	0.05	0.04	0.02	0.01	0.06	0.04	0.18	0.10	0.16	0.27	0.24
MgO	11.15	11.36	10.19	6.99	13.41	9.22	6.95	8.10	7.37	8.31	9.21
CaO	0.24	0.29	0.37	0.13	0.42	0.24	0.28	0.24	0.19	0.21	0.20
Na2O	0.38	0.28	0.25	0.24	0.50	0.36	-	0.09	-	0.01	-
K2O	0.36	0.08	0.02	0.04	0.04	0.02	0.58	0.81	0.82	0.15	0.18
P2O5	0.18	0.13	0.24	0.30	0.12	0.14	0.09	0.04	0.06	0.10	0.08
Total	100.0	99.38	99.50	96.71	100.2	99.31	100.8	100.6	100.0	100.3	99.91
Minor Elements	(ppm)										
Ba	130	98	68	79	72	72	227	299	264	105	95
Co	100	84	130	170	95	110	140	130	150	130	120
Cr	21	19	28	24	28	25	58	64	68	65	69
Cs	1	1	1	1	1	1	1	1	1	1	1
Cu	3	35	29	372	10	90	7	13	24	105	54
F	1095	1160	970	575	975	835	695	975	965	575	780
Mo	2	2	3	4	1	4	1	2	2	1	1
Ni	-	-	-	6	-	-	-	-	-	-	-
Pb	2	2	2	37	2	4	2	2	4	3	2
Rb	-	-	-	-	-	-	-	-	7	-	-
S	-	-	-	-	-	-	-	-	-	-	-
Sc	27	34	17	26	43	29	48	35	42	84	77
Sr	7	8	1	-	1	-	-	1	4	-	-
V	279	253	210	183	298	193	188	233	192	162	193
Y	16	20	7	1642	25	42	12	13	12	29	27
Zn	55	111	616	4746	258	708	74	96	258	101	135
Zr	40	35	31	32	44	34	19	19	20	17	22

- not detected

Specimen No.	SC 5-18	SC 5-19	SC 5-25b	SC 5-31	SC 5-39	SC 5-55	SC 5-60	SC 5-65	SC 5-67	SC 6-1c	SC 6-1d
Unit #	2	2	2	3	3	QBG	QBG	QBG	QBG	1	1
Major Oxides	(wt%)										
SiO2	60.04	66.47	64.52	56.85	56.63	79.71	77.58	82.00	86.46	64.69	69.16
TiO2	0.50	0.43	0.45	0.58	0.50	0.24	0.18	0.15	0.13	0.30	0.25
Al2O3	15.74	10.02	13.87	13.72	14.84	8.47	9.05	8.78	7.74	16.73	14.03
Fe2O3	0.67	0.86	1.05	1.27	0.59	0.55	0.38	0.31	0.26	1.51	1.39
FeO	10.83	9.58	9.74	12.23	12.12	3.58	3.69	3.25	1.32	5.15	4.29
MnO	0.12	0.07	0.11	0.11	0.10	0.03	0.02	0.02	0.01	0.05	0.05
MgO	10.24	10.81	8.64	14.63	13.95	4.41	4.48	2.50	0.96	3.69	3.26
CaO	0.11	0.08	0.14	0.12	0.11	0.13	0.09	0.05	0.01	0.27	0.27
Na2O	0.14	-	0.07	0.34	0.36	0.09	-	0.01	-	0.49	0.75
K2O	0.62	0.64	0.31	0.16	0.54	0.93	2.02	0.91	0.66	2.54	2.08
P2O5	0.09	0.05	0.07	0.10	0.09	0.08	0.06	0.02	-	0.15	0.08
Total	99.10	99.01	98.97	100.1	99.83	98.22	97.55	98.00	97.55	95.57	95.61
Minor Elements	(ppm)										
Ba	188	220	160	82	116	209	269	229	178	541	442
Co	110	86	160	90	76	89	110	100	110	67	68
Cr	57	53	60	68	63	22	24	25	24	27	29
Cs	1	1	1	1	1	1	1	1	1	8	7
Cu	1	1	1	1	1	3	3	85	36	5	3
F	1170	1425	985	1225	1200	650	1110	555	415	730	640
Mo	1	1	2	1	1	2	2	3	2	1	1
Ni	-	4	-	-	-	-	-	-	-	-	-
Pb	3	2	2	2	3	4	4	2	4	5	8
Rb	1	-	-	-	-	1	17	6	1	57	45
S	-	-	-	-	-	-	-	-	-	-	-
Sc	39	22	47	47	43	18	21	21	12	8	6
Sr	1	-	-	-	4	13	6	6	-	9	9
V	225	195	201	257	229	8	4	2	-	34	19
Y	18	10	17	15	14	20	19	36	16	25	25
Zn	38	38	46	42	59	23	16	15	9	63	54
Zr	17	20	17	22	17	39	46	57	47	82	72

- not detected

Specimen No.	SC 6-3	SC 6-4	SC 7-2	SC 7-4	SC 7-10	SC 7-11	SC 8-4	SC 8-7	SC 8-11	SC 8-17c	SC 8-17d
Unit #	2	2	1	1	SIL	SIL	3	3	3	3	3
Major Oxides	(wt%)										
SiO2	73.58	75.99	63.85	58.26	68.80	63.47	57.76	58.05	60.18	51.92	49.07
TiO2	0.39	0.28	0.10	0.33	0.23	0.72	0.63	0.55	0.38	0.56	0.74
Al2O3	10.91	9.97	21.75	21.67	21.92	18.75	14.30	17.64	14.24	16.17	16.55
Fe2O3	0.59	0.30	0.13	0.92	0.27	0.45	0.46	0.67	0.92	1.60	1.08
FeO	6.80	8.07	6.53	11.59	1.69	4.73	12.57	10.23	9.05	11.98	13.10
MnO	0.10	0.10	0.11	0.21	0.01	0.01	0.09	0.08	0.07	0.12	0.12
MgO	4.13	3.84	3.87	4.57	1.61	4.83	13.50	11.87	10.62	15.01	15.52
CaO	0.20	0.19	0.73	0.35	1.78	0.84	0.15	0.19	0.12	0.37	0.46
Na2O	0.26	0.23	0.02	0.05	-	-	0.41	0.44	0.58	0.44	0.29
K2O	1.72	0.82	0.44	1.52	1.04	2.75	0.06	0.55	1.01	0.24	0.29
P2O5	0.16	0.20	0.54	0.14	1.67	0.79	0.10	0.13	0.07	0.09	0.11
Total	98.84	99.99	98.07	99.61	99.02	97.34	100.0	100.4	97.24	98.50	97.33
Minor Elements	(ppm)										
Ba	401	287	182	466	418	998	65	260	202	144	91
Co	91	140	86	81	67	73	81	87	60	63	61
Cr	29	29	45	64	29	32	71	74	57	72	69
Cs	4	1	1	2	1	4	1	1	1	1	1
Cu	4	45	4	1	28	1	4	1	1	1	2
F	730	660	345	610	1230	1600	1065	1330	1215	1170	1255
Mo	4	3	2	1	2	1	1	1	1	1	1
Ni	-	-	-	-	-	-	-	-	-	-	-
Pb	6	2	3	4	6	6	2	2	2	2	2
Rb	25	-	6	29	22	67	-	1	15	1	1
S	-	-	-	-	-	-	-	-	-	-	-
Sc	15	22	18	47	3	10	44	38	36	47	51
Sr	5	7	53	13	72	26	-	6	6	-	4
V	-	-	52	98	26	49	222	232	173	233	257
Y	27	26	16	17	30	13	14	16	13	23	20
Zn	46	44	34	50	41	87	34	45	66	66	93
Zr	50	45	71	35	46	29	23	19	18	25	27

- not detected

Specimen No.	SC 8-21	SC 8-28	ML 05	ML 06	ML 11	ML 12	ML 15	ML 18	ML 23	ML 31	ML 33
Unit #	3	3	SIL	1	SIL	2	3	QBG	2	2	3
Major Oxides	(wt%)										
SiO2	57.37	56.63	81.31	44.13	94.69	63.05	44.54	74.03	53.84	59.06	49.65
TiO2	0.55	0.66	0.13	0.66	0.01	0.47	0.64	0.39	0.33	0.45	0.67
Al2O3	17.92	13.85	14.50	22.19	2.46	13.41	22.01	10.18	16.90	17.81	20.59
Fe2O3	1.22	1.53	0.24	1.39	0.02	3.29	1.73	1.80	2.11	2.01	1.66
FeO	10.15	11.32	0.98	18.57	0.10	14.00	13.07	4.88	12.86	10.38	11.62
MnO	0.09	0.08	0.01	0.41	-	0.47	0.11	0.03	0.07	0.32	0.12
MgO	10.55	12.86	0.82	11.36	-	5.77	15.52	5.60	12.82	5.48	13.77
CaO	0.19	0.22	0.27	0.45	0.06	0.28	0.20	0.10	0.16	0.22	0.23
Na2O	0.32	0.28	-	0.37	0.12	0.06	0.49	0.33	0.37	0.31	0.32
K2O	0.16	0.29	0.64	1.06	0.09	0.05	0.23	0.85	0.52	3.17	0.11
P2O5	0.14	0.11	0.23	0.12	-	0.08	0.33	0.07	0.13	0.14	0.17
Total	98.66	97.83	99.13	100.7	97.55	100.9	98.87	98.26	100.1	99.35	98.91
Minor Elements	(ppm)										
Ba	136	167	228	310	70	64	82	176	199	431	51
Co	63	80	62	84	60	100	66	74	63	58	65
Cr	67	71	23	66	20	56	61	44	37	27	61
Cs	1	1	1	1	1	1	1	1	1	6	1
Cu	2	1	1	1	1	97	28	454	20	2	1
F	1030	1315	480	1055	40	115	1460	1121	1485	960	1320
Mo	1	2	2	1	1	1	1	1	1	1	1
Ni	-	-	-	-	-	-	-	-	-	-	-
Pb	2	2	2	4	2	2	2	6	2	4	2
Rb	-	-	10	7	-	-	-	5	5	122	-
S	-	-	-	-	-	-	-	-	-	-	-
Sc	38	47	2	76	-	59	53	29	18	47	46
Sr	1	3	8	15	5	1	7	8	8	4	8
V	228	235	35	214	-	73	273	146	349	76	247
Y	18	12	7	27	1	18	18	12	20	55	16
Zn	51	70	29	36	-	-	75	101	259	111	75
Zr	21	26	9	24	-	16	27	13	9	82	24

- not detected

Specimen No.	ML 34a	ML 34b	ML 46	ML 47	ML 53	ML 61	ML 65	ML 67	ML 68a	ML 68b	ML 69a
Unit #	QBG	QBG	QBG	2(M)	2(M)	2	QBG	2	QBG	QBG	2
Major Oxides	(wt%)										
SiO2	83.70	83.48	76.36	54.17	55.05	58.76	70.46	62.58	75.72	77.66	59.93
TiO2	0.17	0.17	0.15	0.66	0.60	0.56	0.21	0.44	0.35	0.34	0.49
Al2O3	9.00	8.94	12.38	16.63	16.37	15.52	11.78	13.41	11.52	10.51	16.34
Fe2O3	0.63	0.56	0.88	1.01	1.15	0.92	0.45	0.48	0.53	0.47	1.23
FeO	1.92	2.11	3.44	11.53	14.23	11.86	2.74	9.62	3.32	3.22	10.46
MnO	0.01	0.01	0.03	0.07	0.20	0.14	0.06	0.06	0.02	0.02	0.12
MgO	1.78	1.83	4.02	12.80	10.19	11.04	1.07	11.72	4.49	4.32	9.28
CaO	0.07	0.10	0.14	0.87	0.60	0.28	1.13	0.15	0.14	0.14	0.20
Na2O	0.12	0.27	0.23	0.70	0.45	0.34	3.25	0.32	0.11	0.19	0.14
K2O	0.99	1.03	1.25	0.40	0.03	0.39	1.61	0.51	1.50	1.37	0.60
P2O5	0.02	0.02	0.03	0.42	0.37	0.17	0.09	0.12	0.14	0.10	0.19
Total	98.41	98.52	98.91	99.26	99.24	99.98	92.85	99.41	97.84	98.34	98.98
Minor Elements	(ppm)										
Ba	193	181	203	65	54	186	333	172	439	423	298
Co	74	70	63	85	110	70	57	78	57	74	63
Cr	18	18	22	21	63	52	17	48	22	22	57
Cs	1	1	1	1	1	1	1	1	1	1	1
Cu	21	23	1	2	2780	6	15	1	1	1	1
F	745	700	320	560	665	1760	250	1905	1130	1165	1395
Mo	1	1	1	1	1	1	1	1	3	3	1
Ni	-	-	-	-	-	-	-	-	-	-	-
Pb	2	2	2	2	2	2	2	2	2	2	2
Rb	7	11	11	-	-	-	18	1	15	10	1
S	-	-	-	-	-	-	-	-	-	-	-
Sc	14	13	25	48	68	29	14	21	9	9	55
Sr	29	43	9	13	6	5	85	9	15	10	8
V	4	-	64	288	295	142	7	192	-	-	186
Y	22	23	47	32	17	28	29	10	19	15	17
Zn	17	19	95	140	75	82	55	31	20	10	63
Zr	62	60	99	14	12	27	77	20	57	57	19

- not detected

Specimen No.	ML 69b	ML 70	ML 72	ML 74	ML 78	ML 79	ML 80	ML 81	ML 82	ML 91	ML 104
Unit #	2	QBG	QBG	2	2	1	3	3	3	3(M)	QBG
Major Oxides	(wt%)										
SiO2	59.90	74.47	58.95	68.43	59.08	61.61	64.15	63.98	62.80	70.98	76.71
TiO2	0.49	0.21	0.19	0.40	0.50	0.43	0.64	0.62	0.66	0.23	0.18
Al2O3	15.85	11.44	10.31	11.04	15.89	14.63	12.78	14.15	14.15	10.82	11.20
Fe2O3	1.50	0.96	1.11	0.64	0.94	0.46	0.96	0.95	1.19	1.17	0.14
FeO	10.59	4.62	3.48	9.28	11.88	14.96	9.68	9.05	8.38	7.17	0.65
MnO	0.11	0.06	0.12	0.08	0.09	0.25	0.03	0.04	0.07	0.21	0.07
MgO	9.59	3.73	8.66	8.37	10.33	5.34	10.25	9.46	10.04	6.73	0.66
CaO	0.19	0.23	11.65	0.12	0.18	0.43	0.34	0.34	0.27	0.24	4.17
Na2O	0.11	0.22	0.23	0.37	0.31	0.03	0.36	0.34	0.22	0.37	0.55
K2O	0.53	1.78	3.80	0.10	0.12	1.11	0.02	0.03	0.28	0.36	3.22
P2O5	0.13	0.18	-	0.08	0.11	0.19	0.21	0.22	0.12	0.07	-
Total	98.99	97.90	98.50	98.91	99.43	99.44	99.42	99.18	98.18	98.35	97.55
Minor Elements	(ppm)										
Ba	249	265	647	98	80	614	65	49	119	98	337
Co	64	54	33	81	84	84	65	72	75	69	52
Cr	57	30	20	47	58	57	16	14	20	21	20
Cs	1	5	1	1	1	1	1	1	1	2	1
Cu	1	11	74	7	1	2	34	15	64	280	1
F	1320	870	520	1090	710	770	985	1020	730	730	280
Mo	1	1	1	1	1	1	1	1	1	3	1
Ni	-	-	-	-	-	-	-	-	-	-	-
Pb	2	2	54	2	2	4	2	2	2	2	2
Rb	1	57	31	-	-	10	-	-	-	7	32
S	-	-	-	-	-	-	-	-	-	-	-
Sc	44	20	18	29	35	53	22	16	36	15	11
Sr	6	10	72	4	5	15	4	5	3	6	113
V	193	42	-	151	178	137	223	208	198	-	22
Y	15	21	39	12	18	20	8	40	25	26	23
Zn	50	49	228	36	26	47	465	734	53	98	32
Zr	16	45	59	13	20	22	35	36	36	32	67

- not detected

APPENDIX B

RARE EARTH ELEMENT ANALYSES OF ROCKS FROM STAR LAKE NEAR SHERRIDON MANITOBA

Ninety-nine rare earth element analyses of rocks from the Star Lake - Elken Lake area, near Sherridon, are compiled in this appendix. The analyses are listed by field sample identification number and unit number. Field sample numbers refer to figures 3 - 4 and Table 2; unit numbers refer to the field units:

U-1: unit 1 (quartz-garnet-anthophyllite),

U-2: unit 2 (garnet-anthophyllite),

U-3: unit 3 (anthophyllite-cordierite),

QBG: quartz-biotite gneisses,

SIL: the sillimanite zone,

U-2(M): the mineralized unit 2 (garnet-anthophyllite) of Elken Lake and

U-3(M): unit 3 (anthophyllite-cordierite) near the east orebody at Sherridon Manitoba. (Sherridon unit 3)

Methods, lower detection limits and reliability of analyses for each element and reported standards are listed in Table A-1.

Specimen No.	SC 1-1	SC 1-2	SC 1-7	SC 1-10	SC 1-14a	SC 1-14b	SC 2-1	SC 2-6	SC 2-10	SC 2-12c	SC 2-12d
Unit #	1	1	1	1	SIL	SIL	1	1	1	1	1
La	21	13	6	9	5	14	7	6	8	7	7
Ce	40	31	9	16	10	22	10	16	12	7	14
Sm	4	4	2	3	2	4	3	2	3	2	3
Eu	1	1	1	1	1	1	1	1	1	1	1
Tb	2	2	1	2	1	2	2	2	1	2	1
Yb	3	7	3	4	2	4	4	3	2	2	2
Lu	1	1	-	1	-	1	1	1	1	1	-

Specimen No.	SC 2-21a	SC 2-21b	SC 2-25a	SC 2-25b	SC 2-26	SC 3-2	SC 3-4	SC 3-8	SC 3-10	SC 3-13c	SC 3-13d
Unit #	1	1	1	1	1	1	1	1	1	1	1
La	7	8	4	11	3	3	4	4	3	2	3
Ce	8	10	8	19	5	9	9	9	8	6	5
Sm	3	3	2	4	2	3	2	2	2	1	2
Eu	1	1	1	1	1	1	1	1	1	1	1
Tb	2	2	2	2	2	3	2	1	2	1	2
Yb	2	2	5	3	2	8	2	2	3	3	2
Lu	-	-	1	1	-	1	-	-	1	-	1

Specimen No.	SC 3-18	SC 3-25a	SC 3-25b	SC 3-29	SC 3-33	SC 3-39	SC 3-42	SC 3-44	SC 3-51a	SC 3-54b	SC 4-2c
Unit #	1	2	2	2	2	1	2	2	2	2	3
La	6	4	5	5	5	6	5	5	6	5	6
Ce	12	6	6	7	7	9	7	5	5	8	9
Sm	3	2	2	2	2	2	2	2	3	2	2
Eu	1	1	1	1	1	1	1	1	1	1	1
Tb	2	1	1	2	1	1	1	2	1	1	1
Yb	4	2	2	2	4	2	4	5	2	2	3
Lu	1	-	-	-	1	1	1	1	-	-	1

- not detected

Specimen No.	SC 4-2d	SC 4-5	SC 4-9	SC 4-12	SC 4-13a	SC 4-13b	SC 5-1	SC 5-6	SC 5-10	SC 5-14c	SC 5-14d
Unit #	3	3	3	3	3	3	2	2	2	2	2
La	6	5	6	10	7	3	3	3	2	3	3
Ce	7	7	5	65	13	12	6	5	5	5	5
Sm	2	2	3	48	3	2	1	1	1	1	1
Eu	1	1	1	5	1	1	1	1	1	1	1
Tb	1	1	1	49	1	2	1	1	1	1	1
Yb	2	2	2	150	2	8	2	2	2	5	3
Lu	-	-	-	21	-	1	-	-	-	1	1
Specimen No.	**SC 5-18**	**SC 5-19**	**SC 5-25b**	**SC 5-31**	**SC 5-39**	**SC 5-55**	**SC 5-60**	**SC 5-65**	**SC 5-67**	**SC 6-1c**	**SC 6-1d**
Unit #	2	2	2	3	3	QBG	QBG	QBG	QBG	1	1
La	3	2	4	3	4	6	6	13	5	7	7
Ce	5	5	5	5	5	5	11	26	9	11	12
Sm	2	1	2	1	1	2	2	4	2	2	2
Eu	1	1	1	1	1	1	1	1	1	1	1
Tb	1	1	1	1	1	1	1	2	1	1	1
Yb	2	2	2	2	2	2	3	5	2	3	2
Lu	-	-	-	-	-	-	1	1	-	1	1
Specimen No.	**SC 6-3**	**SC 6-4**	**SC 7-2**	**SC 7-4**	**SC 7-10**	**SC 7-11**	**SC 8-4**	**SC 8-7**	**SC 8-11**	**SC 8-17c**	**SC 8-17d**
Unit #	2	2	1	1	SIL	SIL	3	3	3	3	3
La	8	6	6	2	18	9	4	5	3	3	4
Ce	15	8	8	5	45	18	10	10	5	7	7
Sm	3	2	3	1	8	4	2	2	1	1	2
Eu	1	1	1	1	3	1	1	1	1	1	1
Tb	1	2	1	1	2	1	1	1	1	1	1
Yb	3	3	2	2	2	2	2	2	2	2	2
Lu	1	1	-	-	-	-	-	-	-	-	-

\- not detected

Specimen No.	SC 8-21	SC 8-28	ML 05	ML 06	ML 11	ML 12	ML 15	ML 18	ML 23	ML 31	ML 33
Unit #	3	3	SIL	1	SIL	2	3	QBG	2	2	3
La	3	4	3	5	2	3	2	3	2	21	2
Ce	7	10	5	5	5	5	5	6	5	63	5
Sm	1	2	2	2	-	2	1	2	1	7	1
Eu	1	1	1	1	1	1	1	1	1	1	1
Tb	1	1	1	1	1	1	1	1	1	2	1
Yb	2	2	2	3	2	2	2	2	2	7	2
Lu	-	-	1	1	1	1	1	1	1	1	1
Specimen No.	ML 34a	ML 34b	ML 46	ML 47	ML 53	ML 61	ML 65	ML 67	ML 68a	ML 68b	ML 69a
Unit #	QBG	QBG	QBG	2(M)	2(M)	2	QBG	2	QBG	QBG	2
La	8	8	8	4	3	2	8	2	7	7	3
Ce	25	14	24	12	5	5	29	5	16	15	5
Sm	3	3	5	3	2	2	4	2	3	3	2
Eu	1	1	1	1	1	1	1	1	1	1	1
Tb	1	1	2	1	1	1	1	1	1	1	1
Yb	3	2	7	4	2	3	4	2	2	2	2
Lu	1	1	1	1	1	1	1	1	1	1	1
Specimen No.	ML 69b	ML 70	ML 72	ML 74	ML 78	ML 79	ML 80	ML 81	ML 82	ML 91	ML 104
Unit #	2	QBG	QBG	2	2	1	3	3	3	3(M)	QBG
La	3	5	6	2	3	3	6	3	8	7	8
Ce	5	6	12	5	5	5	9	6	14	16	22
Sm	2	2	4	1	2	2	3	4	3	3	3
Eu	1	1	1	1	1	1	1	1	1	1	1
Tb	1	1	2	1	1	1	1	2	1	1	1
Yb	2	3	5	2	2	2	2	4	4	3	3
Lu	1	1	1	1	1	1	1	1	1	1	1

- not detected

APPENDIX C
NIGGLI NORMS CALCULATED FOR THE ROCKS FROM STAR LAKE NEAR SHERRIDON MANITOBA

Niggli norms were calculated for 99 samples from Appendix A, and are compiled in this appendix. These samples represent samples from the Star Lake - Elken Lake area, near Sherridon. The analyses are listed by field sample identification number and unit number. Field sample numbers refer to figures 3 - 4 and Table 2; unit numbers refer to the field units:

U-1: unit 1 (quartz-garnet-anthophyllite),

U-2: unit 2 (garnet-anthophyllite),

U-3: unit 3 (anthophyllite-cordierite),

QBG: quartz-biotite gneisses,

SIL: the sillimanite zone,

U-2(M): the mineralized unit 2 (garnet-anthophyllite) of Elken Lake and

U-3(M): unit 3 (anthophyllite-cordierite) near the east orebody at Sherridon Manitoba. (Sherridon unit 3)

Specimen No.	SC 1-1	SC 1-2	SC 1-7	SC 1-10	SC 1-14a	SC 1-14b	SC 2-1	SC 2-6	SC 2-10	SC 2-12c	SC 2-12d
Unit #	1	1	1	1	SIL	SIL	1	1	1	1	1
fm	19.3	63.2	58.1	60.9	56.7	58.5	62.6	62.9	67.3	67.4	65.7
alk	27.6	2.7	7.5	9.1	8.0	10.5	2.8	4.2	2.8	3.0	3.4
al	45.9	31.4	33.1	28.6	34.3	29.9	32.1	31.9	28.8	28.4	29.7
c	7.2	2.7	1.3	1.4	1.0	1.1	2.5	1.0	1.1	1.2	1.2
si	451.6	283.3	303.6	303.9	296.9	351.2	290.3	317.4	332.3	327.0	342.9
ti	0.5	1.5	1.6	1.2	1.0	1.3	1.5	1.4	1.3	1.2	1.4
p	0.2	0.7	0.3	0.2	0.2	0.3	0.7	0.2	0.4	0.3	0.2
mg	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5
k	0.3	1.0	1.0	1.0	1.0	0.9	1.0	0.9	1.0	1.0	1.0

Specimen No.	SC 2-21a	SC 2-21b	SC 2-25a	SC 2-25b	SC 2-26	SC 3-2	SC 3-4	SC 3-8	SC 3-10	SC 3-13c	SC 3-13d
Unit #	1	1	1	1	1	1	1	1	1	1	1
fm	62.7	62.5	64.0	62.7	63.4	71.8	59.0	70.9	73.6	68.8	63.0
alk	3.6	3.6	4.1	2.7	4.4	2.7	1.3	2.9	3.5	4.3	4.3
al	32.5	32.8	30.1	33.0	31.0	24.8	38.6	25.5	22.2	26.5	32.3
c	1.2	1.1	1.8	1.6	1.2	0.7	1.1	0.7	0.7	0.4	0.4
si	347.7	336.9	551.7	371.1	360.8	252.2	281.7	252.5	240.6	394.4	460.5
ti	1.6	1.4	1.3	1.3	1.4	0.9	1.2	1.2	0.7	0.8	0.8
p	0.3	0.2	0.5	0.5	0.4	0.2	0.4	0.2	0.1	0.2	0.1
mg	0.5	0.5	0.5	0.5	0.6	0.7	0.7	0.7	0.6	0.7	0.7
k	0.9	0.9	0.8	0.9	1.0	0.6	1.0	0.7	0.7	1.0	1.0

Specimen No.	SC 3-18	SC 3-25a	SC 3-25b	SC 3-29	SC 3-33	SC 3-39	SC 3-42	SC 3-44	SC 3-51a	SC 3-54b	SC 4-2c
Unit #	1	2	2	2	2	1	2	2	2	2	3
fm	66.5	77.7	75.4	77.0	73.9	60.8	78.0	73.6	74.6	78.7	72.1
alk	3.4	1.5	0.7	0.6	0.8	3.0	1.0	0.7	0.2	1.1	0.9
al	29.6	20.0	23.2	21.3	24.6	35.4	20.2	24.6	24.0	19.5	26.1
c	0.5	0.8	0.7	1.1	0.7	0.8	0.8	1.1	1.2	0.7	0.9
si	386.5	197.5	173.2	142.8	171.3	305.4	152.1	162.6	150.1	154.3	194.3
ti	0.7	1.2	1.4	1.2	1.4	0.9	1.3	1.2	1.3	1.3	1.6
p	0.2	0.2	0.2	0.7	0.2	0.2	0.2	0.3	0.2	0.2	0.3
mg	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
k	1.0	0.1	0.1	0.1	0.1	0.9	0.3	0.1	0.5	0.2	0.4

- not detected

Specimen No.	SC 4-2d	SC 4-5	SC 4-9	SC 4-12	SC 4-13a	SC 4-13b	SC 5-1	SC 5-6	SC 5-10	SC 5-14c	SC 5-14d
Unit #	3	3	3	3	3	3	2	2	2	2	2
fm	75.6	76.7	74.4	70.8	78.8	74.9	71.5	72.1	72.6	74.6	75.5
alk	1.7	1.0	0.8	1.0	1.3	1.2	1.1	1.8	1.7	0.3	0.3
al	22.0	21.4	23.6	27.6	18.8	23.0	26.5	25.4	25.1	24.5	23.6
c	0.7	0.9	1.2	0.6	1.1	0.9	0.9	0.7	0.6	0.6	0.6
si	182.4	179.7	204.9	262.0	142.5	222.6	181.9	175.3	200.3	157.3	148.4
ti	1.5	1.3	1.3	1.4	1.4	1.5	1.1	1.1	1.1	0.9	1.0
p	0.2	0.2	0.3	0.5	0.1	0.2	0.1	0.1	0.1	0.1	0.1
mg	0.6	0.6	0.7	0.6	0.6	0.6	0.4	0.5	0.5	0.5	0.5
k	0.4	0.2	0.1	0.1	0.1	-	1.0	0.9	1.0	0.9	1.0

Specimen No.	SC 5-18	SC 5-19	SC 5-25b	SC 5-31	SC 5-39	SC 5-55	SC 5-60	SC 5-65	SC 5-67	SC 6-1c	SC 6-1d
Unit #	2	2	2	3	3	QBG	QBG	QBG	QBG	1	1
fm	71.6	79.6	71.9	79.3	76.8	63.8	60.1	53.7	35.3	47.4	47.5
alk	1.5	1.3	0.9	1.0	1.7	4.3	7.5	4.7	5.4	9.0	10.1
al	26.6	18.8	26.7	19.4	21.2	31.0	31.8	41.2	59.1	42.4	41.0
c	0.3	0.3	0.5	0.3	0.3	0.9	0.6	0.4	0.2	1.2	1.4
si	172.3	212.7	211.4	135.9	138.0	496.1	462.3	654.4	1121.	278.4	342.2
ti	1.1	1.0	1.1	1.0	0.9	1.1	0.8	0.9	1.2	1.0	0.9
p	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	-	0.3	0.2
mg	0.6	0.7	0.6	0.7	0.7	0.6	0.7	0.6	0.5	0.5	0.5
k	0.7	1.0	0.8	0.2	0.5	0.9	1.0	1.0	1.0	0.8	0.7

Specimen No.	SC 6-3	SC 6-4	SC 7-2	SC 7-4	SC 7-10	SC 7-11	SC 8-4	SC 8-7	SC 8-11	SC 8-17c	SC 8-17d
Unit #	2	2	1	1	SIL	SIL	3	3	3	3	3
fm	60.7	65.2	45.3	55.2	20.3	45.8	77.6	70.3	71.3	76.3	76.7
alk	6.6	3.8	1.2	3.2	3.4	6.9	1.1	2.0	3.6	1.3	1.0
al	31.6	30.0	50.4	40.4	66.3	43.7	20.9	27.2	24.7	21.5	21.2
c	1.1	1.0	3.1	1.2	9.8	3.6	0.4	0.5	0.4	0.9	1.1
si	362.1	387.5	252.1	185.1	353.5	251.5	143.7	151.7	176.9	117.2	107.2
ti	1.4	1.1	0.3	0.8	0.9	2.1	1.2	1.1	0.9	1.0	1.2
p	0.3	0.4	0.9	0.2	3.7	1.3	0.1	0.1	0.1	0.1	0.1
mg	0.5	0.4	0.5	0.4	0.6	0.6	0.7	0.7	0.7	0.7	0.7
k	0.8	0.7	0.9	1.0	1.0	1.0	0.1	0.5	0.5	0.3	0.4

- not detected

Specimen No.	SC 8-21	SC 8-28	ML 05	ML 06	ML 11	ML 12	ML 15	ML 18	ML 23	ML 31	ML 33
Unit #	3	3	SIL	1	SIL	2	3	SIL	2	2	3
fm	69.3	77.2	19.9	69.9	5.7	73.8	72.1	66.5	74.5	58.9	71.3
alk	1.1	1.2	3.6	2.1	10.1	0.3	1.2	4.0	1.7	7.4	0.9
al	29.0	21.0	73.9	27.0	80.5	25.0	26.2	28.9	23.4	33.0	27.3
c	0.6	0.6	2.6	1.0	3.7	0.9	0.5	0.6	0.4	0.7	0.6
si	157.3	146.0	705.4	91.0	5295.	200.0	90.1	356.0	127.0	186.0	112.0
ti	1.1	1.3	1.0	1.0	0.3	1.1	1.0	1.4	0.6	1.1	1.1
p	0.2	0.1	0.8	0.1	-	0.1	0.2	0.1	0.1	0.2	0.1
mg	0.6	0.6	0.6	0.5	-	0.4	0.7	0.6	0.6	0.4	0.7
k	0.3	0.4	1.0	0.7	0.3	0.3	0.2	0.6	0.5	0.9	0.2

Specimen No.	ML 34a	ML 34b	ML 46	ML 47	ML 53	ML 61	ML 65	ML 67	ML 68a	ML 68b	ML 69a
Unit #	QBG	QBG	QBG	2(M)	2(M)	2	QBG	2	QBG	QBG	2
fm	43.9	44.2	53.4	71.8	72.5	73.3	26.1	75.1	55.1	56.2	69.7
alk	7.1	8.0	5.6	2.2	1.1	1.4	25.0	1.7	6.0	6.4	1.4
al	48.3	46.8	40.0	23.7	24.7	24.5	41.7	22.7	37.9	36.4	28.2
c	0.7	1.0	1.0	2.3	1.7	0.8	7.2	0.5	1.0	1.0	0.7
si	765.0	740.0	421.0	131.0	142.0	158.0	426.0	180.0	423.0	457.0	176.0
ti	1.1	1.1	0.7	1.2	1.2	1.1	1.1	1.0	1.3	1.4	1.1
p	0.1	0.1	0.1	0.4	0.5	0.2	0.2	0.2	0.3	0.3	0.2
mg	0.6	0.6	0.6	0.7	0.5	0.6	0.4	0.7	0.7	0.7	0.6
k	0.9	0.7	0.8	0.3	-	0.4	0.3	0.5	0.9	0.8	0.8

Specimen No.	ML 69b	ML 70	ML 72	ML 74	ML 78	ML 79	ML 80	ML 81	ML 82	ML 91	ML 104
Unit #	2	QBG	QBG	2	2	1	3	3	3	3(M)	QBG
fm	71.0	55.0	44.4	74.8	72.6	68.3	74.6	71.5	71.7	70.3	11.3
alk	1.4	7.4	6.9	1.5	1.0	2.4	1.1	1.0	1.3	2.5	16.8
al	27.1	36.3	15.9	23.3	25.9	27.7	23.2	26.4	26.1	26.2	43.0
c	0.5	1.3	32.8	0.4	0.5	1.6	1.1	1.1	0.9	1.0	28.9
si	174.0	402.0	155.0	246.0	164.0	199.0	198.0	203.0	196.0	292.0	500.0
ti	1.0	1.0	0.3	1.1	1.0	1.0	1.5	1.5	1.5	0.7	0.8
p	0.2	0.3	-	0.1	0.1	0.2	0.3	0.3	0.2	0.1	-
mg	0.6	0.6	0.8	0.6	0.6	0.4	0.6	0.6	0.7	0.6	0.6
k	0.8	0.8	0.9	0.2	0.2	1.0	-	0.1	0.4	0.4	0.8

- not detected

APPENDIX D
MINERAL CHEMISTRY OF ROCKS FROM STAR LAKE NEAR SHERRIDON MANITOBA

Four hundred, seventy-two mineral analyses from the Star Lake - Elken Lake area, near Sherridon, are compiled in this appendix. The mineral analyses are listed by field sample identification number and unit number. Field sample numbers refer to figures 3 - 4 and Table 2; unit numbers refer to the field units:

U-1: unit 1 (quartz-garnet-anthophyllite),

U-2: unit 2 (garnet-anthophyllites),

U-3: unit 3 (anthophyllite-cordierite),

QBG: quartz-biotite gneisses,

U-2(M): the mineralized unit 2 (garnet-anthophyllite) of Elken Lake and

U-3(M): unit 3 (anthophyllite-cordierite) near the east orebody at Sherridon Manitoba. (Sherridon unit 3)

Analyses of minerals was done with a JEOL 733 electron microprobe with full Tracor Northern automation at the National Museum of Natural Sciences in Ottawa. Standards, spectrometer positions and crystals used are listed in Tables D1 and D2. The ZAF setup table is also listed in Table D3.

TABLE D1: AMPHIBOLE - GARNET ELEMENT TABLE

EL	SPEC	XSTAL	POS	BKG1	BKG2	CF	BASLN	WIND	BIAS	STD
MG	1	TAP	107.735	-2.5	2.5	0.078	0.8	6.0	1750	DIOPSI
SI	1	TAP	77.700	-2.2	2.9	0.206	1.0	5.0	1750	DIOPSI
CA	4	PET	107.580	-2.0	2.0	0.168	2.0	5.0	1750	DIOPSI
FE	3	LIF	134.545	-3.5	2.0	0.149	4.5	5.0	1700	ALMAN2
AL	1	TAP	90.895	-2.5	2.5	0.150	1.0	4.0	1750	GEHLEN
K	4	PET	119.815	-2.0	2.0	0.087	1.5	6.0	1750	SANIDI
CR	3	LIF	159.145	-3.5	2.0	0.439	3.0	6.0	1700	NICHRO
ZN	2	TAP	133.450	-6.0	3.5	0.103	0.8	6.0	1750	BAZNGE
FL	2	TAP	199.555	-4.5	3.5	0.008	0.5	5.0	1780	FLRIEB
NA	2	TAP	129.675	-3.0	2.0	0.050	0.8	6.0	1750	ALBITE
MN	3	LIF	146.085	-3.5	2.0	0.494	3.0	6.0	1700	TEPHRO
TI	4	PET	88.065	-2.0	2.0	0.176	2.0	6.0	1750	TITANI
CL	4	PET	151.370	-2.0	2.0	0.061	1.0	6.0	1750	TUGTUP

TABLE D2: BIOTITE - CHLORITE ELEMENT TABLE

EL	SPEC	XSTAL	POS	BKG1	BKG2	CF	BASLN	WIND	BIAS	STD
AL	1	TAP	90.895	-2.5	2.5	0.059	1.0	5.0	1750	CHLORI
SI	1	TAP	77.690	-2.5	2.5	0.096	1.0	5.0	1750	CHLORI
FE	3	LIF	134.545	-3.5	2.0	0.071	4.5	5.0	1700	BIOTIT
MG	1	TAP	107.735	-2.5	2.5	0.144	0.8	6.0	1750	CHLORI
CA	4	PET	107.575	-2.0	2.0	0.028	2.0	5.0	1750	ALMAN2
CR	3	LIF	159.150	-3.5	2.0	0.348	3.0	6.0	1700	CHROMI
NA	2	TAP	129.675	-3.0	2.0	0.050	0.8	6.0	1750	ALBITE
TI	4	PET	88.065	-2.0	2.0	0.009	2.0	6.0	1750	BIOTIT
MN	3	LIF	146.070	-3.5	2.0	0.035	3.0	6.0	1700	WILL
K	4	PET	119.810	-3.5	2.0	0.073	2.0	6.0	1750	BIOTIT
ZN	2	TAP	133.450	-6.0	3.5	0.102	0.8	6.0	1750	BAZNGE
CL	4	PET	151.355	-2.0	2.0	0.061	1.0	6.0	1750	TUGTUP
FL	2	TAP	199.555	-4.5	3.5	0.008	0.5	5.0	1780	FLRIEB

TABLE D3: ZAF SETUP

Acc. Voltage= 15KV   Take Off Angle= 40.0 Deg

ELEMENT	LINE	
NA20	K	WDS REF: NA
K20	K	WDS REF: K
CAO	K	WDS REF: CA
MGO	K	WDS REF: MG
MNO	K	WDS REF: MN
FEO	K	WDS REF: FE
AL203	K	WDS REF: AL
CR203	K	WDS REF: CR
SI02	K	WDS REF: SI
TI02	K	WDS REF: TI
0	K	BY DIFFERENCE

AMPHIBOLES

AMPHIBOLES

Specimen No.	SC 3-10	SC 3-10	SC 3-10	SC 3-10	SC 3-10	SC 3-10	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-25a
Unit #	1	1	1	1	1	1	2	2	2	2	2
Anth/Ged	ged	ged	ged	ged	ged	ged	anth	anth	anth	ged	anth
SiO2	47.37	47.95	46.00	45.41	46.03	46.77	49.41	49.23	49.13	48.12	49.76
TiO2	0.19	0.20	0.12	0.11	0.13	0.13	0.26	0.29	0.33	0.30	0.31
Al2O3	12.59	10.72	14.26	14.05	13.83	12.91	9.57	9.65	9.52	11.44	9.90
MgO	16.37	17.30	16.92	17.03	17.41	17.58	19.12	19.13	19.19	19.06	19.08
CaO	0.08	0.11	0.09	0.10	0.09	0.11	0.17	0.18	0.17	0.18	0.19
MnO	0.12	0.09	-	0.13	0.12	-	-	-	-	-	-
FeO	20.12	19.94	18.22	18.46	17.50	18.15	18.17	17.58	17.73	17.07	17.93
Na2O	1.34	1.12	1.53	1.56	1.38	1.28	1.09	1.05	0.99	1.23	1.00
F	-	-	-	-	-	-	-	-	-	-	-
O=F	-	-	-	-	-	-	-	-	-	-	-
Total	98.18	97.43	97.14	96.85	96.49	96.93	97.79	97.11	97.06	97.40	98.17
Si *	6.81	6.94	6.64	6.59	6.67	6.75	7.06	7.06	7.06	6.88	7.06
Al	1.19	1.06	1.36	1.41	1.33	1.25	0.94	0.94	0.94	1.22	0.94
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.94	0.77	1.07	1.00	1.03	0.95	0.67	0.69	0.67	0.71	0.72
Ti	0.02	0.02	0.01	0.01	0.01	0.01	0.03	0.03	0.04	0.03	0.03
Mg	3.51	3.73	3.64	3.69	3.76	3.78	4.07	4.09	4.11	4.06	4.04
Ca	0.01	0.02	0.01	0.02	0.01	0.02	0.03	0.03	0.03	0.03	0.03
Mn	0.02	0.01	-	0.02	0.02	-	-	-	-	-	-
Fe	2.42	2.41	2.20	2.24	2.12	2.19	2.17	2.11	2.13	2.04	2.13
Na	0.08	0.04	0.07	0.02	0.05	0.05	0.03	0.05	0.02	0.13	0.05
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.30	0.27	0.36	0.42	0.34	0.31	0.27	0.24	0.26	0.21	0.23
W	0.30	0.27	0.36	0.42	0.34	0.31	0.27	0.24	0.26	0.21	0.23

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES

Specimen No.	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-26a	SC 3-26a	SC 3-26a	SC 3-26a
Unit #	2	2	2	2	2	2	2	2	2	2	2
Anth/Ged	ged	ged	ged	anth	ged	ged	anth	anth	ged	anth	anth
SiO2	48.49	49.35	49.12	49.31	48.47	48.09	49.66	49.87	48.99	49.14	49.76
TiO2	0.26	0.28	0.29	0.32	0.31	0.32	0.35	0.32	0.33	0.28	0.24
Al2O3	11.16	10.42	10.76	10.37	11.57	12.03	8.95	9.48	10.73	9.43	9.45
MgO	19.26	19.57	18.88	19.19	18.94	18.78	18.79	19.48	19.44	19.89	19.81
CaO	0.20	0.16	0.17	0.18	0.20	0.20	0.17	0.18	0.14	0.18	0.16
MnO	-	0.11	-	-	-	0.09	0.11	-	-	0.10	0.12
FeO	16.97	16.79	17.77	17.27	16.97	17.01	18.51	17.88	17.40	17.37	17.31
Na2O	1.17	1.08	1.13	1.08	1.24	1.27	1.01	0.97	1.07	0.93	0.90
F	-	0.39	-	-	-	-	-	0.40	-	-	-
O=F	-	-0.16	-	-	-	-	-	-0.17	-	-	-
Total	97.51	97.99	98.12	97.72	97.70	97.79	97.55	98.41	98.10	97.32	97.75
Si *	6.91	6.98	6.98	7.01	6.89	6.84	7.12	7.05	6.95	7.03	7.08
Al	1.09	1.02	1.02	0.99	1.11	1.16	0.88	0.95	1.05	0.97	0.92
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.79	0.72	0.78	0.75	0.83	0.86	0.63	0.63	0.74	0.62	0.66
Ti	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04	0.03	0.03
Mg	4.09	4.13	4.00	4.07	4.02	3.98	4.02	4.10	4.11	4.24	4.20
Ca	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.02
Mn	-	0.01	-	-	-	0.01	0.01	-	-	0.01	0.01
Fe	2.02	1.99	2.11	2.05	2.02	2.02	2.22	2.11	2.06	2.08	2.06
Na	0.04	0.10	0.05	0.07	0.07	0.07	0.05	0.10	0.03	0.00	0.02
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.28	0.20	0.26	0.23	0.27	0.28	0.23	0.17	0.26	0.26	0.23
W	0.28	0.20	0.26	0.23	0.27	0.28	0.23	0.17	0.26	0.26	0.23

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES

Specimen No.	SC 3-26a	SC 3-29	SC 3-29	SC 3-29	SC 3-29	SC 3-34	SC 3-34	SC 3-34	SC 3-34	SC 3-34	SC 3-34
Unit #	2	2	2	2	2	2	2	2	2	2	2
Anth/Ged	anth	ged	ged	anth	ged	ged	anth	anth	anth	ged	ged
SiO2	50.58	44.32	48.10	48.64	47.26	47.97	49.49	49.42	49.67	48.34	48.17
TiO2	0.28	0.32	0.40	0.32	0.40	0.31	0.26	0.29	0.28	0.25	0.38
Al2O3	9.02	15.40	10.29	9.35	11.07	10.32	8.58	8.84	8.97	9.92	10.65
MgO	19.73	15.23	16.90	18.37	17.50	17.25	19.10	18.76	19.14	18.01	17.98
CaO	0.15	0.19	0.20	0.18	0.21	0.18	0.16	0.19	0.17	0.23	0.20
MnO	-	0.26	0.32	0.23	0.28	0.18	0.12	0.14	0.15	0.16	0.20
FeO	17.45	20.23	20.64	19.12	19.17	20.03	18.50	18.78	18.07	19.10	18.95
Na2O	0.89	1.87	1.22	1.12	1.29	1.16	0.93	1.04	1.05	1.22	1.30
F	-	-	-	-	-	-	-	-	-	-	-
O=F	-	-	-	-	-	-	-	-	-	-	-
Total	98.10	97.82	98.07	97.33	97.18	97.40	97.14	97.46	97.50	97.23	97.83
Si *	7.16	6.44	6.95	7.03	6.86	6.96	7.13	7.11	7.11	6.99	6.92
Al	0.84	1.66	1.05	0.97	1.14	1.04	0.87	0.89	0.89	1.01	1.08
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.66	0.98	0.70	0.62	0.75	0.72	0.59	0.61	0.62	0.68	0.72
Ti	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.04
Mg	4.16	3.30	3.64	3.96	3.79	3.73	4.10	4.02	4.09	3.88	3.85
Ca	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03
Mn	-	0.03	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Fe	2.07	2.46	2.50	2.31	2.33	2.43	2.23	2.26	2.16	2.31	2.28
Na	0.06	0.16	0.05	0.01	0.03	0.04	0.00	0.03	0.05	0.04	0.06
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.18	0.37	0.29	0.30	0.33	0.29	0.26	0.26	0.24	0.30	0.30
W	0.18	0.37	0.29	0.30	0.33	0.29	0.26	0.26	0.24	0.30	0.30

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES

Specimen No.	SC 3-43	SC 3-43	SC 3-43	SC 3-43	SC 3-54a	SC 3-54a	SC 3-54a	SC 3-54a	SC 3-54a	SC 3-54a	SC 3-54a
Unit #	2	2	2	2	2	2	2	2	2	2	2
Anth/Ged	anth	anth	ged	ged	anth	ged	ged	anth	anth	ged	anth
SiO2	49.77	49.56	48.99	47.91	51.71	49.08	47.24	51.47	51.33	49.10	50.30
TiO2	0.29	0.23	0.29	0.32	0.22	0.22	0.29	0.17	0.18	0.24	0.32
Al2O3	8.87	9.79	10.78	11.64	7.25	10.95	12.70	7.54	7.64	10.92	9.11
MgO	18.70	19.44	18.98	18.01	20.42	19.18	18.67	20.51	20.50	19.19	19.95
CaO	0.15	0.15	0.16	0.20	0.15	0.18	0.18	0.13	0.14	0.18	0.14
MnO	0.17	0.17	0.14	0.13	-	-	0.09	-	0.09	-	0.10
FeO	19.09	17.20	17.45	18.31	17.14	16.72	17.25	17.50	17.53	16.84	17.50
Na2O	0.89	0.95	1.08	1.20	0.66	1.03	1.31	0.75	0.75	1.15	0.89
F	-	0.39	-	-	-	-	-	0.47	-	-	-
O=F	-	-0.16	-	-	-	-	-	-0.20	-	-	-
Total	97.93	97.72	97.87	97.72	97.55	97.36	97.73	98.34	98.16	97.62	98.31
Si *	7.13	7.04	6.97	6.86	7.34	6.99	6.74	7.25	7.26	6.98	7.11
Al	0.87	0.96	1.03	1.14	0.66	1.01	1.26	0.75	0.74	1.02	0.89
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.63	0.68	0.78	0.83	0.55	0.83	0.88	0.50	0.53	0.81	0.63
Ti	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.03	0.03
Mg	3.99	4.12	4.03	3.85	4.32	4.07	3.97	4.31	4.32	4.07	4.21
Ca	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.02	0.03	0.02
Mn	0.02	0.02	0.02	0.02	-	-	0.01	-	0.01	-	0.01
Fe	2.29	2.04	2.08	2.19	2.03	1.99	2.06	2.06	2.07	2.00	2.07
Na	0.02	0.09	0.04	0.05	0.06	0.06	0.02	0.09	0.03	0.06	0.03
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.23	0.17	0.26	0.28	0.12	0.22	0.34	0.12	0.18	0.26	0.21
W	0.23	0.17	0.26	0.28	0.12	0.22	0.34	0.12	0.18	0.26	0.21

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES											
Specimen No.	SC 3-54a	SC 3-54a	SC 3-54a	SC 3-54a	SC 3-54a	SC 4-2b	SC 4-2b	SC 4-2b	SC 4-2b	SC 4-2b	SC 4-9
Unit #	2	2	2	2	2	3	3	3	3	3	3
Anth/Ged	ged	ged	ged	ged	ged	ged	ged	ged	ged	ged	ged
SiO2	47.20	48.69	49.54	46.67	47.79	47.31	48.65	48.50	48.19	47.68	48.08
TiO2	0.31	0.34	0.35	0.25	0.30	0.30	0.31	0.30	0.25	0.31	0.31
Al2O3	13.35	10.97	10.61	13.82	12.38	11.73	11.65	11.30	11.59	12.17	11.32
MgO	18.63	19.10	19.30	18.37	18.97	17.52	18.16	18.06	18.08	17.99	17.75
CaO	0.18	0.19	0.17	0.17	0.18	0.16	0.18	0.20	0.20	0.19	0.30
MnO	-	-	-	0.09	-	-	-	-	0.10	0.10	-
FeO	16.97	17.10	17.68	17.13	17.49	18.40	18.23	17.91	17.78	17.83	18.98
Na2O	1.33	1.16	1.12	1.45	1.29	1.22	1.14	1.05	1.09	1.13	1.07
F	-	-	-	-	-	-	-	-	-	-	-
O=F	-	-	-	-	-	-	-	-	-	-	-
Total	97.97	97.55	98.77	97.95	98.40	96.64	98.32	97.32	97.28	97.40	97.81
Si *	6.71	6.94	6.98	6.65	6.77	6.86	6.91	6.95	6.91	6.84	6.90
Al	1.29	1.06	1.02	1.35	1.23	1.14	1.09	1.05	1.09	1.16	1.10
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.95	0.78	0.74	0.97	0.84	0.86	0.86	0.86	0.87	0.90	0.81
Ti	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Mg	3.95	4.06	4.06	3.90	4.01	3.79	3.84	3.86	3.86	3.84	3.80
Ca	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05
Mn	-	-	-	0.01	-	-	-	-	0.01	0.01	-
Fe	2.02	2.04	2.08	2.04	2.07	2.23	2.17	2.15	2.13	2.14	2.28
Na	0.02	0.05	0.05	0.02	0.02	0.06	0.07	0.07	0.07	0.05	0.03
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.35	0.27	0.26	0.38	0.34	0.28	0.24	0.22	0.23	0.26	0.27
W	0.35	0.27	0.26	0.38	0.34	0.28	0.24	0.22	0.23	0.26	0.27

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES											
Specimen No.	SC 4-9	SC 4-9	SC 4-9	SC 4-9	SC 4-12	SC 4-12	SC 4-12	SC 4-12	SC 4-13b	SC 4-13b	SC 4-13b
Unit #	3	3	3	3	3	3	3	3	3	3	3
Anth/Ged	anth	anth	anth	ged	ged	ged	ged	ged	ged	ged	ged
SiO2	49.35	51.76	48.67	48.65	47.98	46.15	47.09	45.45	47.91	47.43	47.62
TiO2	0.21	0.17	0.36	0.30	0.28	0.32	0.30	0.32	0.27	0.35	0.29
Al2O3	10.26	5.27	10.20	11.02	10.13	11.93	12.44	13.14	10.16	10.66	11.62
MgO	18.43	19.59	17.79	18.05	16.14	15.18	15.40	14.39	17.45	17.49	16.88
CaO	0.29	0.24	0.30	0.29	0.31	0.23	0.24	0.28	0.32	0.35	0.34
MnO	-	-	-	-	-	-	-	0.12	-	-	-
FeO	18.65	19.87	19.26	18.75	21.77	22.20	21.73	22.30	19.10	19.15	20.06
Na2O	1.01	0.47	1.01	1.10	1.06	1.31	1.25	1.42	1.08	1.07	1.21
F	-	-	-	-	-	-	-	-	-	-	-
O=F	-	-	-	-	-	-	-	-	-	-	-
Total	98.20	97.37	97.59	98.16	97.67	97.32	98.45	97.42	96.29	96.50	98.02
Si *	7.03	7.46	7.00	6.94	6.99	6.78	6.80	6.68	6.99	6.92	6.86
Al	0.97	0.54	1.00	1.06	1.01	1.22	1.20	1.32	1.01	1.08	1.14
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.75	0.36	0.73	0.79	0.73	0.85	0.92	0.96	0.74	0.75	0.83
Ti	0.02	0.02	0.04	0.03	0.03	0.04	0.03	0.04	0.03	0.04	0.03
Mg	3.91	4.21	3.82	3.84	3.50	3.32	3.32	3.15	3.80	3.80	3.62
Ca	0.04	0.04	0.05	0.04	0.05	0.04	0.04	0.04	0.05	0.06	0.05
Mn	-	-	-	-	-	-	-	0.02	-	-	-
Fe	2.22	2.39	2.32	2.24	2.65	2.73	2.63	2.74	2.33	2.34	2.42
Na	0.06	0.00	0.04	0.06	0.04	0.02	0.06	0.05	0.05	0.01	0.05
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.22	0.13	0.24	0.24	0.26	0.35	0.29	0.36	0.26	0.29	0.29
W	0.22	0.13	0.24	0.24	0.26	0.35	0.29	0.36	0.26	0.29	0.29

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES

Specimen No.	SC 4-13b	SC 4-13b	SC 5-1	SC 5-1	SC 5-9	SC 5-16	SC 5-16	SC 5-21a	SC 5-21a	SC 5-21a	SC 5-21a
Unit #	3	3	2	2	2	2	2	2	2	2	2
Anth/Ged	ged	anth	anth	ged	anth	anth	ged	ged	anth	ged	ged
SiO2	48.31	49.07	48.82	48.83	50.53	49.68	48.53	48.17	51.12	48.95	48.50
TiO2	0.33	0.30	0.34	0.29	0.20	0.26	0.31	0.14	0.12	0.16	0.26
Al2O3	10.29	9.55	9.83	10.14	9.42	10.65	11.38	13.06	7.55	11.68	12.46
MgO	17.16	17.22	18.49	18.37	19.64	19.21	17.90	18.36	19.46	18.87	18.30
CaO	0.29	0.33	0.11	0.13	0.12	0.12	0.11	0.15	0.10	0.12	0.15
MnO	-	-	-	-	-	-	-	-	-	0.11	-
FeO	19.78	20.43	18.80	18.80	17.57	18.04	19.80	17.23	18.75	17.65	17.54
Na2O	1.14	1.09	1.16	1.23	0.69	0.75	0.93	0.90	0.43	0.72	0.83
F	-	-	-	-	-	-	-	-	-	-	0.34
O=F	-	-	-	-	-	-	-	-	-	-	-0.14
Total	97.30	97.99	97.55	97.79	98.17	98.71	98.96	98.07	97.53	98.26	98.24
Si *	7.00	7.07	7.02	7.00	7.14	7.00	6.89	6.82	7.30	6.92	6.85
Al	1.00	0.93	0.98	1.00	0.86	1.00	1.11	1.18	0.70	1.08	1.15
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.76	0.69	0.69	0.71	0.71	0.77	0.80	1.00	0.57	0.87	0.92
Ti	0.04	0.03	0.04	0.03	0.02	0.03	0.03	0.02	0.01	0.02	0.03
Mg	3.70	3.70	3.96	3.93	4.14	4.04	3.79	3.87	4.15	3.98	3.85
Ca	0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mn	-	-	-	-	-	-	-	-	-	0.01	-
Fe	2.40	2.46	2.26	2.25	2.08	2.13	2.35	2.04	2.24	2.09	2.07
Na	0.05	0.07	0.03	0.06	0.03	0.01	0.01	0.05	0.01	0.01	0.11
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.27	0.23	0.29	0.28	0.16	0.20	0.25	0.20	0.11	0.19	0.12
W	0.27	0.23	0.29	0.28	0.16	0.20	0.25	0.20	0.11	0.19	0.12

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES

Specimen No.	SC 5-25a	SC 5-25a	SC 5-25a	SC 5-39	SC 5-39	SC 5-39	SC 5-39	SC 5-35	SC 5-35	SC 5-35	SC 5-35
Unit #	2	2	2	3	3	3	3	3	3	3	3
Anth/Ged	anth	anth	ged	ged	ged	ged	ged	ged	ged	ged	anth
SiO2	49.90	49.69	47.30	47.46	48.32	48.06	48.67	46.66	46.59	46.61	49.38
TiO2	0.26	0.26	0.24	0.28	0.23	0.23	0.19	0.40	0.32	0.63	0.31
Al2O3	9.67	9.76	12.53	12.92	10.23	11.91	10.89	12.82	13.03	12.28	8.32
MgO	18.60	18.31	17.02	17.36	18.56	18.45	18.27	16.77	16.53	16.02	18.43
CaO	0.11	0.15	0.12	0.14	0.14	0.14	0.19	0.17	0.18	0.15	0.13
MnO	0.09	0.10	-	0.16	0.13	0.20	0.12	0.17	0.28	0.19	0.18
FeO	18.96	19.08	19.30	19.01	18.74	18.17	17.87	20.18	20.85	21.16	20.10
Na2O	0.66	0.75	0.91	1.06	0.92	1.04	0.93	1.31	1.33	1.30	0.80
F	-	-	-	-	-	-	-	-	-	-	-
O=F	-	-	-	-	-	-	-	-	-	-	-
Total	98.25	98.10	97.42	98.39	97.27	98.20	97.13	98.48	99.11	98.34	97.65
Si *	7.10	7.09	6.82	6.77	6.97	6.84	6.99	6.71	6.68	6.74	7.13
Al	0.90	0.91	1.18	1.23	1.03	1.16	1.01	1.29	1.32	1.26	0.87
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.72	0.73	0.95	0.94	0.71	0.84	0.83	0.88	0.88	0.83	0.55
Ti	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.04	0.03	0.07	0.03
Mg	3.94	3.89	3.66	3.69	3.99	3.92	3.91	3.59	3.53	3.45	3.97
Ca	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02
Mn	0.01	0.01	-	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
Fe	2.26	2.28	2.33	2.27	2.26	2.16	2.15	2.43	2.50	2.56	2.43
Na	0.02	0.04	0.01	0.03	0.00	0.01	0.04	0.01	0.00	0.05	0.00
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.16	0.17	0.24	0.26	0.26	0.28	0.22	0.36	0.37	0.32	0.22
W	0.16	0.17	0.24	0.26	0.26	0.28	0.22	0.36	0.37	0.32	0.22

* number of ions on the basis of 23 oxygens
\- not detected

AMPHIBOLES											
Specimen No.	SC 5-35	SC 8-4	SC 8-4	SC 8-7	SC 8-7	SC 8-7	SC 8-7	SC 8-15	SC 8-15	SC 8-15	SC 8-17
Unit #	3	3	3	3	3	3	3	3	3	3	3
Anth/Ged	ged	anth	anth	anth	anth	anth	ged	anth	anth	anth	anth
SiO2	47.90	50.15	50.83	50.85	49.90	50.91	46.66	50.56	50.92	49.36	49.91
TiO2	0.35	0.23	0.19	0.19	0.14	0.12	0.33	0.18	0.15	0.37	0.22
Al2O3	11.37	8.83	6.96	6.98	9.95	8.28	12.94	6.39	6.50	8.88	8.89
MgO	17.67	19.15	19.79	20.32	20.27	20.69	17.46	18.44	18.63	17.45	19.15
CaO	0.18	0.16	0.12	0.15	0.14	0.13	0.18	0.31	0.15	0.15	0.16
MnO	0.22	0.16	0.20	0.12	0.12	0.12	0.15	0.16	0.20	0.17	0.22
FeO	19.71	19.00	18.64	17.71	16.56	16.65	18.88	20.38	20.17	20.77	18.12
Na2O	1.14	0.98	0.79	0.78	1.11	0.91	1.56	0.70	0.69	0.95	1.01
F	-	-	-	-	-	-	-	-	-	-	-
O=F	-	-	-	-	-	-	-	-	-	-	-
Total	98.54	98.66	97.52	97.10	98.19	97.81	98.16	97.12	97.41	98.10	97.68
Si *	6.85	7.12	7.29	7.29	7.04	7.20	6.69	7.34	7.36	7.11	7.13
Al	1.15	0.88	0.71	0.71	0.96	0.80	1.31	0.66	0.64	0.89	0.87
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.77	0.60	0.47	0.47	0.70	0.58	0.88	0.43	0.47	0.62	0.63
Ti	0.04	0.03	0.02	0.02	0.02	0.01	0.04	0.02	0.02	0.04	0.02
Mg	3.77	4.05	4.23	4.34	4.26	4.37	3.73	3.99	4.01	3.75	4.08
Ca	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.02	0.02	0.03
Mn	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.03
Fe	2.36	2.26	2.24	2.12	1.95	1.97	2.27	2.48	2.44	2.50	2.17
Na	0.00	0.02	0.00	0.01	0.04	0.04	0.03	0.01	0.02	0.05	0.04
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.32	0.25	0.22	0.21	0.26	0.21	0.40	0.19	0.17	0.22	0.24
W	0.32	0.25	0.22	0.21	0.26	0.21	0.40	0.19	0.17	0.22	0.24

* number of ions on the basis of 23 oxygens
- not detected

AMPHIBOLES

Specimen No.	SC 8-17	SC 8-17	SC 8-17	SC 8-17	ML 55	ML 49	ML 49	ML 49	ML 49	ML 49	ML 49
Unit #	3	3	3	3	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)
Anth/Ged	anth	anth	anth	anth	ged	ged	ged	ged	ged	ged	ged
SiO_2	49.09	51.96	52.42	49.48	40.83	47.03	44.83	45.14	44.67	45.01	46.24
TiO_2	0.19	0.15	0.16	0.22	0.43	0.40	0.32	0.41	0.40	0.31	0.33
Al_2O_3	10.29	6.00	5.35	8.96	17.64	11.99	15.12	15.09	15.40	15.61	14.31
MgO	18.85	20.12	20.09	19.03	12.17	18.06	17.39	17.25	16.65	17.67	17.40
CaO	0.17	0.16	0.13	0.19	0.12	0.19	0.19	0.20	0.20	0.22	0.21
MnO	0.20	0.18	0.22	0.20	0.19	0.11	0.08	-	0.09	0.11	0.07
FeO	17.74	18.45	18.83	18.76	22.65	17.82	17.16	17.33	18.34	16.80	17.73
Na_2O	1.13	0.63	0.56	0.99	1.84	1.15	1.49	1.43	1.59	1.48	1.29
F	-	-	-	-	-	-	-	-	-	-	-
O=F	-	-	-	-	-	-	-	-	-	-	-
Total	97.66	97.65	97.76	97.83	95.87	96.75	96.58	96.85	97.34	97.21	97.58
Si *	7.01	7.42	7.48	7.09	6.15	6.80	6.49	6.51	6.46	6.46	6.62
Al	0.99	0.58	0.52	0.91	1.85	1.20	1.51	1.49	1.54	1.54	1.38
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.74	0.43	0.38	0.60	1.28	0.84	1.07	1.08	1.08	1.10	1.04
Ti	0.02	0.02	0.02	0.02	0.05	0.04	0.04	0.04	0.04	0.03	0.04
Mg	4.01	4.28	4.28	4.07	2.73	3.89	3.75	3.71	3.59	3.78	3.72
Ca	0.03	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Mn	0.02	0.02	0.03	0.02	0.02	0.01	0.01	-	0.01	0.01	0.01
Fe	2.12	2.20	2.25	2.25	2.85	2.15	2.08	2.09	2.22	2.02	2.12
Na	0.06	0.03	0.02	0.01	0.05	0.04	0.02	0.05	0.03	0.03	0.04
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Na	0.25	0.14	0.14	0.27	0.49	0.28	0.40	0.35	0.42	0.38	0.32
W	0.25	0.14	0.14	0.27	0.49	0.28	0.40	0.35	0.42	0.38	0.32

* number of ions on the basis of 23 oxygens
\- not detected

AMPHIBOLES											
Specimen No.	ML 49	ML 49	ML 52	ML 52	ML 52	ML 52	ML 52	ML 93	ML 93		
Unit #	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	3(M)	3(M)		
Anth/Ged	ged	ged	ged	ged	ged	ged	ged	anth	anth		
SiO2	44.96	44.54	44.67	43.81	45.59	45.44	46.61	50.40	48.97		
TiO2	0.49	0.32	0.35	0.42	0.24	0.34	0.24	0.15	0.08		
Al2O3	15.15	16.54	15.69	16.10	14.82	15.51	14.16	7.61	7.56		
MgO	17.17	17.07	16.72	16.42	17.73	17.36	18.10	18.94	18.96		
CaO	0.19	0.20	0.19	0.20	0.19	0.17	0.18	0.25	0.08		
MnO	0.06	0.09	0.16	0.10	0.10	0.09	0.08	0.18	0.12		
FeO	17.58	17.11	18.26	18.47	16.98	16.71	17.27	18.79	16.97		
Na2O	1.55	1.55	1.48	1.52	1.32	1.44	1.26	0.64	0.32		
F	-	-	-	-	-	-	-	-	-		
O=F	-	-	-	-	-	-	-	-	-		
Total	97.15	97.42	97.52	97.04	96.97	97.06	97.90	96.99	93.06		
Si *	6.48	6.39	6.44	6.36	6.56	6.52	6.64	7.27	7.30		
Al	1.52	1.61	1.56	1.64	1.44	1.48	1.36	0.73	0.70		
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00		
Al	1.06	1.19	1.11	1.12	1.07	1.14	1.02	0.56	0.63		
Ti	0.05	0.04	0.04	0.05	0.03	0.04	0.03	0.02	0.01		
Mg	3.69	3.65	3.59	3.55	3.80	3.71	3.84	4.07	4.21		
Ca	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.01		
Mn	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.02		
Fe	2.12	2.05	2.20	2.24	2.04	2.01	2.06	2.27	2.11		
Na	0.04	0.03	0.01	0.00	0.02	0.06	0.01	0.02	0.01		
(x+y)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00		
Na	0.39	0.40	0.40	0.43	0.35	0.34	0.34	0.16	0.08		
W	0.39	0.40	0.40	0.43	0.35	0.34	0.34	0.16	0.08		

* number of ions on the basis of 23 oxygens
- not detected

GARNETS

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Specimen No.	SC 1-7	SC 1-7	SC 1-7	SC 1-7	SC 1-7	SC 1-7	SC 1-14a	SC 2-1	SC 2-1	SC 2-1	SC 2-1
Unit #	1	1	1	1	1	1	SIL	1	1	1	1
SiO2	38.09	38.54	38.42	38.55	38.72	38.20	38.20	38.82	39.33	39.24	38.85
TiO2	-	-	-	-	-	-	-	-	-	-	-
Al2O3	21.18	21.31	21.29	21.13	21.47	21.03	21.10	21.73	21.79	21.83	21.71
MgO	4.18	4.68	4.94	4.05	5.70	4.14	4.23	8.22	8.76	8.04	7.61
CaO	0.44	0.47	0.42	0.50	0.50	0.47	0.58	0.90	0.65	0.64	0.69
MnO	1.54	1.32	1.34	1.58	0.82	1.78	5.11	1.00	1.05	1.14	1.14
FeO	35.59	34.77	34.76	35.46	34.26	35.09	32.00	29.51	29.29	30.46	30.55
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	101.0	101.1	101.2	101.3	101.5	100.7	101.2	100.2	100.9	101.4	100.6
Si *	3.02	3.03	3.02	3.04	3.02	3.03	3.02	3.01	3.02	3.02	3.01
Z	3.02	3.03	3.02	3.04	3.02	3.03	3.02	3.01	3.02	3.02	3.01
Al	1.98	1.98	1.97	1.97	1.97	1.97	1.97	1.99	1.97	1.98	1.96
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.01	0.03	0.02	0.04
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	2.34	2.27	2.26	2.31	2.21	2.30	2.09	1.90	1.85	1.94	1.94
Mg	0.49	0.55	0.58	0.48	0.66	0.49	0.50	0.95	1.00	0.92	0.88
Mn	0.10	0.09	0.09	0.11	0.05	0.12	0.34	0.07	0.07	0.07	0.08
Ca	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.08	0.05	0.05	0.06
X	2.97	2.95	2.97	2.94	2.96	2.95	2.98	3.00	2.97	2.98	2.96

Specimen No.	SC 2-1	SC 2-1	SC 2-1	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 2-9
Unit #	1	1	1	1	1	1	1	1	1	1	1
SiO2	38.93	38.66	39.01	38.62	38.92	39.38	38.91	39.13	39.26	38.96	38.98
TiO2	-	-	-	-	-	-	-	-	-	-	-
Al2O3	21.53	21.60	21.61	21.38	21.51	21.38	21.47	21.84	21.84	22.02	21.47
MgO	7.53	7.04	7.62	8.34	8.99	8.96	7.62	9.20	8.98	8.68	9.09
CaO	0.69	0.88	0.70	0.40	0.32	0.38	0.37	0.41	0.42	0.39	0.44
MnO	1.17	1.29	1.19	0.57	0.53	0.59	0.63	0.48	0.49	0.54	0.49
FeO	30.63	31.03	30.66	30.46	30.01	30.25	31.95	29.88	29.85	30.11	29.48
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	100.5	100.5	100.8	99.77	100.3	100.9	101.0	100.9	100.8	100.7	99.95
Si *	3.02	3.01	3.02	3.01	3.01	3.03	3.02	3.00	3.01	3.00	3.02
Z	3.02	3.01	3.02	3.01	3.01	3.03	3.02	3.00	3.01	3.00	3.02
Al	1.97	1.98	1.97	1.97	1.96	1.94	1.96	1.98	1.98	2.00	1.96
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.03	0.02	0.03	0.03	0.04	0.06	0.04	0.02	0.02	-	0.04
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	1.96	2.00	1.96	1.96	1.90	1.88	2.03	1.90	1.90	1.94	1.87
Mg	0.87	0.82	0.88	0.97	1.04	1.03	0.88	1.05	1.03	1.00	1.05
Mn	0.08	0.09	0.08	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.03
Ca	0.06	0.07	0.06	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.04
X	2.97	2.98	2.98	3.00	3.01	2.98	2.98	3.01	3.00	3.01	2.99

* number of ions on the basis of 12 (O,OH)
- not detected

GARNETS

Specimen No.	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 3-10	SC 3-10	SC 3-10	SC 3-25a	SC 3-25a	SC 3-29	SC 3-29
Unit #	1	1	1	1	1	1	1	2	2	2	2
SiO2	39.62	38.32	39.32	38.18	39.20	39.17	39.06	39.48	38.79	38.92	39.51
TiO2	-	-	-	-	-	-	-	-	-	-	-
Al2O3	21.72	21.11	21.81	21.35	21.81	21.42	21.47	21.83	21.87	21.45	21.66
MgO	9.19	7.01	8.59	5.66	9.51	9.91	8.40	8.58	8.70	8.14	9.63
CaO	0.42	0.44	0.46	0.41	0.46	0.44	0.47	0.59	-	0.55	0.63
MnO	0.52	0.57	0.74	0.94	0.42	0.40	0.47	0.41	0.37	0.92	1.50
FeO	29.71	23.63	29.96	34.40	28.90	28.32	29.88	30.34	29.72	30.03	27.02
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	101.2	91.08	100.9	100.9	100.3	99.66	99.75	101.2	99.45	100.0	99.95
Si *	3.03	3.17	3.02	3.00	3.01	3.02	3.03	3.02	3.02	3.03	3.04
Z	3.03	3.17	3.02	3.00	3.01	3.02	3.03	3.02	3.02	3.03	3.04
Al	1.96	2.06	1.98	1.98	1.98	1.95	1.97	1.97	2.00	1.97	1.96
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.04	-	0.02	0.02	0.02	0.05	0.03	0.03	-	0.03	0.04
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	1.87	1.63	1.91	2.24	1.84	1.78	1.91	1.91	1.93	1.92	1.70
Mg	1.05	0.86	0.98	0.66	1.09	1.14	0.97	0.98	1.01	0.94	1.10
Mn	0.03	0.04	0.05	0.06	0.03	0.03	0.03	0.03	0.02	0.06	0.10
Ca	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05	-	0.05	0.05
X	2.98	2.57	2.98	3.00	3.00	2.99	2.95	2.97	2.96	2.97	2.95

Specimen No.	SC 3-29	SC 3-29	SC 3-29	SC 3-29	SC 3-34	SC 3-34	SC 3-34	SC 3-34	SC 3-34	SC 3-43	SC 3-43
Unit #	2	2	2	2	2	2	2	2	2	2	2
SiO2	39.66	39.85	39.34	38.97	39.96	39.64	39.63	39.31	39.17	39.28	39.30
TiO2	-	-	-	-	-	-	-	-	-	0.08	-
Al2O3	21.72	21.58	21.80	21.48	22.09	21.82	21.82	21.89	21.31	21.17	21.45
MgO	9.69	10.02	9.82	9.46	10.25	9.62	9.82	9.29	8.62	7.43	7.71
CaO	0.55	0.55	0.58	0.55	0.57	0.64	0.59	0.54	0.59	2.06	1.81
MnO	1.67	1.03	1.22	0.87	0.72	1.39	1.00	0.69	0.92	2.43	2.10
FeO	27.07	27.62	27.64	28.32	27.89	27.22	28.03	29.06	29.35	27.78	28.48
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	100.4	100.7	100.4	99.65	101.5	100.3	100.9	100.8	99.96	100.2	100.9
Si *	3.04	3.04	3.01	3.01	3.02	3.03	3.02	3.01	3.04	3.05	3.03
Z	3.04	3.04	3.01	3.01	3.02	3.03	3.02	3.01	3.04	3.05	3.03
Al	1.96	1.94	1.97	1.96	1.97	1.97	1.96	1.98	1.95	1.94	1.95
Ti	-	-	-	-	-	-	-	-	-	0.01	-
Fe	0.04	0.06	0.03	0.04	0.03	0.03	0.04	0.02	0.05	0.05	0.05
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	1.69	1.70	1.74	1.79	1.73	1.71	1.75	1.84	1.85	1.75	1.79
Mg	1.11	1.14	1.12	1.09	1.16	1.10	1.12	1.06	1.00	0.86	0.89
Mn	0.11	0.07	0.08	0.06	0.05	0.09	0.07	0.05	0.06	0.16	0.14
Ca	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.17	0.15
X	2.96	2.96	2.99	2.99	2.99	2.95	2.99	2.99	2.96	2.94	2.97

* number of ions on the basis of 12 (O,OH)
- not detected

GARNETS

Specimen No.	SC 3-43	SC 3-43	SC 3-43	SC 3-43	SC 3-43	SC 3-43	SC 3-43	SC 4-2b	SC 4-2b	SC 4-2b	SC 4-9
Unit #	2	2	2	2	2	2	2	3	3	3	3
SiO2	38.81	39.58	39.66	39.63	39.40	39.90	39.31	39.78	39.23	39.16	38.98
TiO2	-	-	-	-	-	-	-	-	-	-	-
Al2O3	21.34	21.71	21.77	21.61	21.89	21.53	21.83	21.88	21.83	21.50	21.49
MgO	7.53	9.23	9.37	9.32	9.18	9.74	9.47	9.82	9.85	9.11	7.06
CaO	2.06	0.60	0.55	0.51	0.60	0.55	0.53	0.54	0.58	0.56	0.75
MnO	2.27	0.84	0.49	1.15	1.17	0.90	0.48	0.30	0.34	0.34	0.34
FeO	27.32	28.86	28.80	28.45	27.98	28.22	28.70	28.39	28.23	29.08	32.77
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	99.33	100.8	100.6	100.7	100.2	100.8	100.3	100.7	100.1	99.75	101.4
Si *	3.03	3.03	3.03	3.04	3.03	3.04	3.02	3.03	3.01	3.03	3.02
Z	3.03	3.03	3.03	3.04	3.03	3.04	3.02	3.03	3.01	3.03	3.02
Al	1.97	1.96	1.96	1.95	1.98	1.94	1.98	1.97	1.98	1.96	1.96
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.03	0.04	0.04	0.05	0.02	0.06	0.02	0.03	0.02	0.04	0.04
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	1.76	1.81	1.80	1.77	1.78	1.74	1.82	1.78	1.79	1.84	2.08
Mg	0.88	1.05	1.07	1.06	1.05	1.11	1.08	1.12	1.13	1.05	0.82
Mn	0.15	0.05	0.03	0.08	0.08	0.06	0.03	0.02	0.02	0.02	0.02
Ca	0.17	0.05	0.05	0.04	0.05	0.05	0.04	0.04	0.05	0.05	0.06
X	2.96	2.96	2.95	2.95	2.96	2.96	2.97	2.96	2.99	2.96	2.98

Specimen No.	SC 4-9	SC 4-12	SC 4-12	SC 4-12	SC 5-1	SC 5-1	SC 5-1	SC 5-1	SC 5-1	SC 5-1	SC 5-1
Unit #	3	3	3	3	2	2	2	2	2	2	2
SiO2	38.60	38.87	38.68	38.79	39.55	39.45	39.74	39.71	39.51	39.24	39.42
TiO2	-	-	-	-	-	-	-	-	-	-	-
Al2O3	21.34	21.40	21.44	21.25	22.18	21.83	22.09	21.93	22.09	21.59	21.59
MgO	8.04	7.08	7.26	6.77	10.34	9.87	9.67	9.31	9.09	7.94	9.49
CaO	0.84	0.88	0.95	0.98	0.31	0.34	0.35	0.37	0.28	0.24	0.28
MnO	0.34	0.41	0.35	0.33	0.21	0.31	0.43	0.36	0.20	0.15	0.18
FeO	31.35	31.89	32.08	32.70	28.25	28.52	28.19	29.57	30.15	31.72	29.21
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	100.5	100.5	100.8	100.8	100.8	100.3	100.5	101.3	101.3	100.9	100.2
Si *	3.00	3.03	3.01	3.02	3.01	3.02	3.03	3.03	3.01	3.03	3.03
Z	3.00	3.03	3.01	3.02	3.01	3.02	3.03	3.03	3.01	3.03	3.03
Al	1.96	1.96	1.97	1.95	1.99	1.97	1.99	1.97	1.99	1.97	1.96
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.04	0.04	0.03	0.05	0.01	0.03	0.01	0.03	0.01	0.03	0.04
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	2.00	2.04	2.06	2.08	1.79	1.80	1.79	1.85	1.91	2.02	1.84
Mg	0.93	0.82	0.84	0.79	1.17	1.13	1.10	1.06	1.03	0.91	1.09
Mn	0.02	0.03	0.02	0.02	0.01	0.02	0.03	0.02	0.01	0.01	0.01
Ca	0.07	0.07	0.08	0.08	0.03	0.03	0.03	0.03	0.02	0.02	0.02
X	3.02	2.96	3.00	2.97	3.00	2.98	2.95	2.96	2.97	2.96	2.96

* number of ions on the basis of 12 (O,OH)
- not detected

GARNETS

Specimen No.	SC 5-1	SC 5-9	SC 5-9	SC 5-9	SC 5-9	SC 5-12	SC 5-12	SC 5-12	SC 5-12	SC 5-12	SC 5-12
Unit #	2	2	2	2	2	2	2	2	2	2	2
SiO_2	39.36	40.25	39.98	40.18	39.48	40.32	39.98	39.80	39.56	40.26	40.10
TiO_2	-	-	-	-	-	-	-	-	-	-	-
Al_2O_3	21.74	23.02	22.12	22.45	22.10	22.73	22.42	22.46	22.07	22.35	22.45
MgO	9.79	10.82	10.93	11.10	8.64	11.36	10.05	10.59	9.10	10.64	11.31
CaO	0.31	0.33	0.38	0.33	0.31	0.29	0.33	0.36	0.37	0.24	0.34
MnO	0.19	0.22	0.25	0.18	0.36	0.19	0.20	0.36	0.70	0.24	0.45
FeO	29.10	27.90	27.51	27.46	30.83	27.40	29.14	28.37	29.40	28.17	27.24
Na_2O	-	-	-	-	-	-	-	-	-	-	-
Total	100.5	102.5	101.2	101.7	101.7	102.3	102.1	101.9	101.2	101.9	101.9
Si *	3.02	3.00	3.02	3.01	3.01	3.00	3.01	2.99	3.02	3.02	3.00
Z	3.02	3.00	3.02	3.01	3.01	3.00	3.01	2.99	3.02	3.02	3.00
Al	1.96	2.02	1.97	1.98	1.99	2.00	1.99	1.99	1.98	1.98	1.98
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.04	0.00	0.03	0.02	0.01	0.00	0.01	0.01	0.02	0.02	0.02
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	1.83	1.74	1.71	1.70	1.96	1.71	1.82	1.78	1.86	1.75	1.69
Mg	1.12	1.20	1.23	1.24	0.98	1.26	1.13	1.19	1.04	1.19	1.26
Mn	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.05	0.02	0.03
Ca	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.02	0.03
X	2.99	2.98	2.99	2.98	2.99	3.00	2.99	3.02	2.98	2.98	3.01

Specimen No.	SC 5-12	SC 5-16	SC 5-16	SC 5-16	SC 5-16	SC 5-25a	SC 5-25a	SC 5-25a	SC 6-3	SC 6-3	SC 6-3
Unit #	2	2	2	2	2	2	2	2	2	2	2
SiO_2	40.32	39.40	40.33	40.01	39.47	39.78	39.83	38.84	37.85	37.88	37.56
TiO_2	-	-	-	-	-	-	-	-	-	-	-
Al_2O_3	22.71	21.92	22.72	23.00	22.34	22.21	22.11	22.17	21.12	20.88	21.08
MgO	11.35	10.01	10.33	10.25	8.27	9.52	9.64	6.78	3.70	3.72	3.42
CaO	0.33	0.32	0.34	0.39	0.42	0.48	0.49	0.40	0.44	0.43	0.40
MnO	0.34	0.14	0.10	0.12	-	0.33	0.72	0.43	1.03	1.07	1.10
FeO	26.87	29.12	28.73	29.03	31.53	29.01	28.31	32.74	35.31	35.79	36.02
Na_2O	-	-	-	-	-	-	-	-	-	-	-
Total	101.9	100.9	102.6	102.8	102.0	101.3	101.1	101.4	99.45	99.77	99.58
Si *	3.01	3.01	3.01	2.99	3.01	3.02	3.03	3.00	3.04	3.04	3.03
Z	3.01	3.01	3.01	2.99	3.01	3.02	3.03	3.00	3.04	3.04	3.03
Al	2.00	1.97	2.00	2.02	2.01	1.99	1.98	2.02	2.00	1.98	2.00
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.00	0.03	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.02	0.00
Y	2.00	2.00	2.00	2.02	2.01	2.00	2.00	2.02	2.00	2.00	2.00
Fe	1.68	1.83	1.79	1.81	2.01	1.83	1.78	2.12	2.37	2.38	2.43
Mg	1.26	1.14	1.15	1.14	0.94	1.08	1.09	0.78	0.44	0.45	0.41
Mn	0.02	0.01	0.01	0.01	0.00	0.02	0.05	0.03	0.07	0.07	0.08
Ca	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04
X	2.99	3.01	2.98	2.99	2.98	2.97	2.96	2.96	2.92	2.94	2.96

* number of ions on the basis of 12 (O,OH)
- not detected

GARNETS

Specimen No.	SC 6-3	SC 6-3	SC 6-3	SC 6-3	SC 6-4	SC 6-4	SC 6-4	SC 6-4	SC 6-4	SC 6-4	SC 6-4
Unit #	2	2	2	2	2	2	2	2	2	2	2
SiO2	37.57	37.47	37.38	37.17	39.72	39.55	39.70	38.97	38.74	39.38	39.55
TiO2	0.41	-	-	-	-	-	-	-	-	-	-
Al2O3	20.91	21.20	20.68	21.05	22.20	22.07	22.16	21.56	21.79	22.04	22.22
MgO	3.89	3.61	3.60	5.22	9.86	10.07	9.84	7.42	6.44	9.83	9.79
CaO	0.42	0.42	0.44	0.43	0.44	0.48	0.45	0.45	0.44	0.47	0.46
MnO	0.80	0.98	1.05	0.54	0.35	0.38	0.39	0.39	0.50	0.31	0.35
FeO	34.95	35.53	35.25	34.09	27.99	28.23	28.08	31.43	32.75	28.19	28.06
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	98.95	99.21	98.40	98.50	100.6	100.8	100.6	100.2	100.7	100.2	100.4
Si *	3.03	3.02	3.04	3.00	3.03	3.01	3.02	3.03	3.02	3.02	3.02
Z	3.03	3.02	3.04	3.00	3.03	3.01	3.02	3.03	3.02	3.02	3.02
Al	1.99	2.02	1.98	2.00	1.99	1.98	1.99	1.98	2.00	1.99	2.00
Ti	0.03	-	-	-	-	-	-	-	-	-	-
Fe	0.00	0.00	0.02	0.00	0.01	0.02	0.01	0.02	0.00	0.01	0.00
Y	2.02	2.02	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	2.36	2.40	2.38	2.30	1.77	1.78	1.78	2.03	2.14	1.80	1.79
Mg	0.47	0.43	0.44	0.63	1.12	1.14	1.12	0.86	0.75	1.12	1.11
Mn	0.06	0.07	0.07	0.04	0.02	0.03	0.03	0.03	0.03	0.02	0.02
Ca	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
X	2.93	2.94	2.93	3.01	2.95	2.99	2.97	2.96	2.96	2.98	2.96

Specimen No.	SC 6-4	SC 6-4	SC 7-1	SC 7-1	SC 7-1	SC 7-4	SC 7-4	SC 7-4	SC 7-4	SC 7-4	SC 7-4
Unit #	2	2	1	1	1	1	1	1	1	1	1
SiO2	37.74	39.73	38.54	38.73	38.96	38.71	38.68	38.68	39.18	38.62	38.68
TiO2	-	-	-	-	-	-	-	-	-	-	-
Al2O3	21.36	22.09	21.55	21.72	21.77	21.69	21.97	21.51	22.04	21.94	21.67
MgO	6.40	9.71	7.02	7.85	7.60	6.78	7.73	6.31	8.20	6.75	7.11
CaO	0.43	0.48	0.87	0.58	0.61	0.58	0.56	0.77	0.70	0.65	0.60
MnO	0.50	0.32	1.10	1.30	1.40	0.62	0.44	0.59	0.57	0.61	0.64
FeO	32.45	28.43	31.91	30.65	30.93	32.50	31.25	32.60	30.23	32.47	32.01
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	98.88	100.8	101.0	100.8	101.3	100.9	100.6	100.5	100.9	101.0	100.7
Si *	3.00	3.03	3.00	3.00	3.01	3.01	3.00	3.03	3.01	3.00	3.01
Z	3.00	3.03	3.00	3.00	3.01	3.01	3.00	3.03	3.01	3.00	3.01
Al	2.00	1.98	1.98	1.98	1.98	1.99	2.01	1.98	2.00	2.01	1.99
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.00	0.02	0.02	0.02	0.02	0.01	0.00	0.02	0.00	0.00	0.01
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.01	2.00	2.00	2.01	2.00
Fe	2.06	1.79	2.06	1.97	1.98	2.11	2.03	2.11	1.94	2.11	2.07
Mg	0.76	1.10	0.82	0.91	0.88	0.79	0.89	0.74	0.94	0.78	0.83
Mn	0.03	0.02	0.07	0.09	0.09	0.04	0.03	0.04	0.04	0.04	0.04
Ca	0.04	0.04	0.07	0.05	0.05	0.05	0.05	0.07	0.06	0.05	0.05
X	2.89	2.95	3.02	3.02	3.00	2.99	3.00	2.96	2.98	2.98	2.99

* number of ions on the basis of 12 (O,OH)
- not detected

GARNETS

Specimen No.	ML 55	ML 55	ML 55	ML 55	ML 55	ML 49	ML 49	ML 52	ML 52	ML 52	ML 52
Unit #	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)
SiO2	39.18	38.68	39.13	38.88	38.60	38.51	38.87	39.07	39.59	39.21	39.62
TiO2	-	-	-	-	-	-	-	-	-	-	-
Al2O3	21.90	21.54	21.92	21.56	21.93	21.44	21.79	21.98	22.23	22.27	22.25
MgO	9.51	9.57	9.40	9.37	9.00	7.38	9.05	9.49	9.20	9.90	10.44
CaO	1.01	0.93	0.93	1.09	0.81	0.63	0.61	0.55	0.62	0.57	0.65
MnO	0.68	0.68	0.64	0.57	0.57	0.51	0.39	0.38	0.36	0.36	0.45
FeO	27.34	27.62	27.65	27.70	28.80	32.14	29.39	28.95	29.22	28.48	27.62
Na2O	-	-	-	-	-	-	-	-	-	-	-
Total	99.62	99.02	99.67	99.17	99.71	100.6	100.1	100.4	101.2	100.8	101.0
Si *	3.02	3.01	3.02	3.02	2.99	3.00	3.00	3.00	3.02	2.99	3.00
Z	3.02	3.01	3.02	3.02	2.99	3.00	3.00	3.00	3.02	2.99	3.00
Al	1.99	1.97	1.99	1.97	2.00	1.97	1.98	1.99	2.00	2.00	1.99
Ti	-	-	-	-	-	-	-	-	-	-	-
Fe	0.01	0.03	0.01	0.03	0.00	0.03	0.02	0.01	0.00	0.00	0.01
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Fe	1.75	1.77	1.77	1.77	1.87	2.07	1.88	1.85	1.86	1.82	1.75
Mg	1.09	1.11	1.08	1.08	1.04	0.86	1.04	1.09	1.04	1.13	1.18
Mn	0.04	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.03
Ca	0.08	0.08	0.08	0.09	0.07	0.05	0.05	0.05	0.05	0.05	0.05
X	2.96	3.01	2.97	2.98	3.02	3.01	3.00	3.02	2.97	3.02	3.01

Specimen No.	ML 52	ML 52	ML 52	ML 52	ML 52	ML 52	ML 52	ML 52	ML 52		
Unit #	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)	2(M)		
SiO2	38.88	39.53	39.34	39.55	39.44	39.93	39.40	39.02	39.48		
TiO2	-	-	-	-	-	-	-	-	-		
Al2O3	21.82	21.94	21.76	22.09	22.06	22.39	22.24	21.97	22.07		
MgO	8.57	9.05	9.46	9.87	10.11	11.01	10.64	8.21	10.40		
CaO	0.63	0.59	0.62	0.58	0.54	0.64	0.65	0.67	0.53		
MnO	1.09	0.56	0.42	0.40	0.37	0.47	0.47	0.42	0.84		
FeO	29.56	29.47	28.88	28.43	28.43	26.56	27.01	30.66	27.59		
Na2O	-	-	-	-	-	-	-	-	0.05		
Total	100.6	101.1	100.5	100.9	101.0	101.0	100.4	101.0	101.0		
Si *	3.00	3.02	3.02	3.01	3.00	3.01	3.00	3.01	3.00		
Z	3.00	3.02	3.02	3.01	3.00	3.01	3.00	3.01	3.00		
Al	1.99	1.98	1.97	1.98	1.98	1.99	2.00	1.99	1.98		
Ti	-	-	-	-	-	-	-	-	-		
Fe	0.01	0.02	0.03	0.02	0.02	0.01	0.00	0.01	0.02		
Y	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00		
Fe	1.90	1.86	1.82	1.79	1.79	1.67	1.72	1.96	1.73		
Mg	0.99	1.03	1.08	1.12	1.15	1.24	1.21	0.94	1.18		
Mn	0.07	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.05		
Ca	0.05	0.05	0.05	0.05	0.04	0.05	0.05	0.06	0.04		
X	3.01	2.98	2.98	2.99	3.00	2.99	3.01	2.99	3.00		

* number of ions on the basis of 12 (O,OH)
\- not detected

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Specimen No.	SC 2-1	SC 2-1	SC 2-1	SC 2-9	SC 2-9	SC 3-10	SC 3-10	SC 3-10	SC 3-10	SC 3-10	SC 3-25a
Unit #	1	1	1	1	1	1	1	1	1	1	2
SiO2	49.27	49.28	49.42	49.14	49.23	49.42	49.23	48.67	49.22	49.05	49.32
Al2O3	33.10	33.24	32.98	33.09	33.12	32.93	33.06	32.81	32.99	32.60	33.05
MgO	10.17	10.22	10.17	10.77	10.49	10.76	10.29	10.25	10.30	10.35	10.95
CaO	-	-	-	-	-	-	-	-	-	-	-
MnO	-	0.11	-	-	-	-	-	-	-	-	-
FeO	5.33	5.31	5.46	4.69	5.22	4.68	5.26	5.41	5.51	5.31	4.33
Na2O	0.16	0.20	0.16	0.22	0.32	0.26	0.25	0.19	0.19	0.27	0.19
Total	98.03	98.36	98.19	97.91	98.38	98.05	98.09	97.33	98.21	97.58	97.84
*											
Si	5.02	5.00	5.03	5.00	5.00	5.02	5.01	5.00	5.01	5.02	5.01
Al	3.97	3.98	3.95	3.97	3.96	3.94	3.97	3.97	3.96	3.93	3.96
B	8.99	8.98	8.98	8.97	8.96	8.96	8.98	8.97	8.97	8.95	8.97
Mg	1.54	1.55	1.54	1.63	1.59	1.63	1.56	1.57	1.56	1.58	1.66
Ca	-	-	-	-	-	-	-	-	-	-	-
Mn	-	0.01	-	-	-	-	-	-	-	-	-
Fe	0.45	0.45	0.46	0.40	0.44	0.40	0.45	0.46	0.47	0.45	0.37
A	1.99	2.01	2.00	2.03	2.03	2.03	2.01	2.03	2.03	2.03	2.03
Na	0.03	0.04	0.03	0.04	0.06	0.05	0.05	0.04	0.04	0.05	0.04
C	0.03	0.04	0.03	0.04	0.06	0.05	0.05	0.04	0.04	0.05	0.04

Specimen No.	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-25a	SC 3-26a	SC 3-26a	SC 3-29	SC 3-29	SC 3-29	SC 3-29	SC 3-34
Unit #	2	2	2	2	2	2	2	2	2	2	2
SiO2	50.31	49.49	49.58	49.82	49.63	50.34	48.07	49.15	48.86	48.84	49.46
Al2O3	33.00	33.33	32.75	33.18	33.76	33.67	32.12	32.97	32.89	32.66	32.85
MgO	11.09	10.73	10.85	10.61	10.85	11.00	9.46	10.58	10.58	10.67	10.72
CaO	-	-	-	-	0.04	-	0.19	-	-	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	4.19	4.79	4.47	4.76	4.36	4.34	4.93	4.68	4.60	4.61	4.57
Na2O	0.22	0.19	0.27	0.20	0.14	0.19	0.20	0.14	0.21	0.19	0.17
Total	98.81	98.53	97.92	98.57	98.78	99.54	94.97	97.52	97.14	96.97	97.77
*											
Si	5.05	5.00	5.04	5.03	4.99	5.02	5.04	5.02	5.01	5.01	5.03
Al	3.91	3.97	3.92	3.95	4.00	3.96	3.97	3.97	3.97	3.95	3.94
B	8.96	8.97	8.96	8.98	8.99	8.98	9.01	8.99	8.98	8.96	8.97
Mg	1.66	1.62	1.64	1.60	1.63	1.64	1.48	1.61	1.62	1.63	1.63
Ca	-	-	-	-	-	-	0.02	-	-	-	-
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	0.35	0.41	0.38	0.40	0.37	0.36	0.43	0.40	0.39	0.40	0.39
A	2.01	2.03	2.02	2.00	2.00	2.00	1.93	2.01	2.01	2.03	2.02
Na	0.04	0.04	0.05	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.03
C	0.04	0.04	0.05	0.04	0.03	0.04	0.04	0.03	0.04	0.04	0.03

* number of ions on the basis of 18 (O,OH)
\- not detected

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Specimen No.	SC 3-34	SC 3-54a	SC 3-54a	SC 3-54a	SC 3-54a	SC 4-2b	SC 4-2b	SC 4-2b	SC 4-9	SC 4-9	SC 4-9
Unit #	2	2	2	2	2	3	3	3	3	3	3
SiO2	48.64	49.66	49.71	49.57	49.90	48.84	50.05	49.11	49.26	49.31	49.09
Al2O3	32.76	33.24	32.89	32.96	33.17	33.01	33.34	33.08	32.77	32.88	32.90
MgO	10.55	11.07	11.06	10.91	10.94	10.23	10.68	10.39	10.56	10.36	10.51
CaO	-	-	-	-	-	0.05	-	-	-	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	4.42	4.22	4.15	4.12	4.01	4.76	4.85	5.11	5.18	5.00	4.77
Na2O	0.22	0.21	0.28	0.19	0.21	0.20	0.22	0.24	0.25	0.21	0.30
Total	96.59	98.40	98.09	97.75	98.23	97.09	99.14	97.93	98.02	97.76	97.57
*											
Si	5.01	5.01	5.03	5.03	5.04	5.01	5.03	5.00	5.02	5.03	5.01
Al	3.98	3.95	3.92	3.94	3.95	3.99	3.95	3.97	3.93	3.95	3.96
B	8.99	8.96	8.95	8.97	8.99	9.00	8.98	8.97	8.95	8.98	8.97
Mg	1.62	1.67	1.67	1.65	1.65	1.56	1.60	1.58	1.60	1.58	1.60
Ca	-	-	-	-	-	0.01	-	-	-	-	-
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	0.38	0.36	0.35	0.35	0.34	0.41	0.41	0.44	0.44	0.43	0.41
A	2.00	2.03	2.02	2.00	1.99	1.98	2.01	2.02	2.04	2.01	2.01
Na	0.04	0.04	0.06	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.06
C	0.04	0.04	0.06	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.06

Specimen No.	SC 4-9	SC 4-12	SC 4-12	SC 4-12	SC 4-12	SC 4-12	SC 4-13b	SC 4-13b	SC 5-1	SC 5-16	SC 5-16
Unit #	3	3	3	3	3	3	3	3	2	2	2
SiO2	48.50	48.90	48.95	49.17	48.89	47.90	49.85	49.92	49.49	49.89	50.17
Al2O3	32.26	33.16	32.78	32.69	32.69	31.82	33.52	33.31	33.22	34.00	33.91
MgO	10.45	9.83	10.09	9.99	9.94	9.98	10.43	10.65	10.64	10.70	10.89
CaO	0.06	-	-	-	-	-	-	-	-	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	4.73	5.79	5.23	5.94	5.78	5.66	4.92	4.83	4.73	4.89	4.60
Na2O	0.29	0.26	0.23	0.26	0.39	0.21	0.26	0.24	0.10	0.12	0.13
Total	96.29	97.94	97.28	98.05	97.69	95.57	98.98	98.95	98.18	99.60	99.70
*											
Si	5.02	5.00	5.02	5.02	5.01	5.02	5.02	5.02	5.02	4.99	5.00
Al	3.94	3.99	3.96	3.94	3.95	3.93	3.98	3.95	3.97	4.01	3.99
B	8.96	8.99	8.98	8.96	8.96	8.95	9.00	8.97	8.99	9.00	8.99
Mg	1.61	1.50	1.54	1.52	1.52	1.56	1.57	1.60	1.61	1.60	1.62
Ca	0.01	-	-	-	-	-	-	-	-	-	-
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	0.41	0.50	0.45	0.51	0.50	0.50	0.41	0.41	0.40	0.41	0.38
A	2.03	2.00	1.99	2.03	2.02	2.06	1.98	2.01	2.01	2.01	2.00
Na	0.06	0.05	0.05	0.05	0.08	0.04	0.05	0.05	0.02	0.02	0.03
C	0.06	0.05	0.05	0.05	0.08	0.04	0.05	0.05	0.02	0.02	0.03

* number of ions on the basis of 18 (O,OH)
\- not detected

CORDIERITES

Specimen No.	SC 5-21a	SC 5-25a	SC 5-35	SC 5-35	SC 5-35	SC 5-35	SC 5-35	SC 5-35	SC 5-39	SC 5-39	SC 6-4
Unit #	2	2	3	3	3	3	3	3	3	3	2
SiO2	50.01	49.90	49.48	49.40	49.51	49.69	49.75	48.65	49.72	49.36	49.19
Al2O3	33.95	33.95	33.23	33.58	33.64	33.21	33.30	33.38	33.90	33.23	33.14
MgO	11.18	10.71	10.58	10.74	10.82	10.45	10.59	10.63	10.60	9.87	9.54
CaO	-	-	-	-	-	-	-	-	-	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	3.98	4.88	4.92	4.76	4.78	5.23	4.91	4.84	4.90	6.03	6.50
Na2O	0.08	0.09	0.15	0.16	0.16	0.07	0.13	0.18	0.19	0.12	0.27
Total	99.20	99.53	98.36	98.64	98.91	98.65	98.68	97.68	99.31	98.61	98.64
*											
Si	5.00	4.99	5.01	4.99	4.99	5.02	5.02	4.97	4.99	5.01	5.01
Al	4.00	4.00	3.97	4.00	3.99	3.96	3.96	4.02	4.01	3.98	3.98
B	9.00	8.99	8.98	8.99	8.98	8.98	8.98	8.99	9.00	8.99	8.99
Mg	1.67	1.60	1.60	1.62	1.62	1.58	1.59	1.62	1.59	1.49	1.45
Ca	-	-	-	-	-	-	-	-	-	-	-
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	0.33	0.41	0.42	0.40	0.40	0.44	0.41	0.41	0.41	0.51	0.55
A	2.00	2.01	2.02	2.02	2.02	2.02	2.00	2.03	2.00	2.00	2.00
Na	0.02	0.02	0.03	0.03	0.03	0.01	0.03	0.04	0.04	0.02	0.05
C	0.02	0.02	0.03	0.03	0.03	0.01	0.03	0.04	0.04	0.02	0.05

Specimen No.	SC 8-4	SC 8-7	SC 8-15	SC 8-15	SC 8-15	SC 8-17	SC 8-17	SC 8-28	ML 49	ML 93	ML 93
Unit #	3	3	3	3	3	3	3	3	2(M)	3(M)	3(M)
SiO2	49.46	50.06	49.47	48.84	49.94	48.71	49.25	49.17	49.41	48.74	48.79
Al2O3	33.41	34.09	32.82	32.49	32.98	32.79	33.09	33.30	33.25	32.62	33.04
MgO	10.21	11.03	9.88	9.89	10.55	10.70	10.99	9.63	10.93	10.59	10.65
CaO	-	-	-	-	-	-	-	-	-	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	5.38	4.47	5.94	6.05	4.97	4.38	4.22	6.51	4.34	4.26	4.21
Na2O	0.20	0.27	0.15	0.20	0.19	0.21	0.18	0.20	0.18	0.27	0.27
Total	98.66	99.92	98.26	97.47	98.63	96.79	97.73	98.81	98.11	96.48	96.96
*											
Si	5.01	4.98	5.04	5.02	5.04	5.00	5.01	5.00	5.01	5.02	5.00
Al	3.98	4.00	3.94	3.94	3.93	3.97	3.96	3.99	3.97	3.96	3.99
B	8.99	8.98	8.98	8.96	8.97	8.97	8.97	8.99	8.98	8.98	8.99
Mg	1.54	1.64	1.50	1.52	1.59	1.64	1.67	1.46	1.65	1.63	1.63
Ca	-	-	-	-	-	-	-	-	-	-	-
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	0.46	0.37	0.51	0.52	0.42	0.38	0.36	0.55	0.37	0.37	0.36
A	2.00	2.01	2.01	2.04	2.01	2.02	2.03	2.01	2.02	2.00	1.99
Na	0.04	0.05	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05
C	0.04	0.05	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05

* number of ions on the basis of 18 (O,OH)
- not detected

BIOTITES

BIOTITES

Specimen No.	SC 1-7	SC 1-7	SC 1-7	SC 1-14a	SC 1-14a	SC 2-1	SC 2-1	SC 2-1	SC 2-1	SC 2-1	SC 2-1
Unit #	1	1	1	SIL	SIL	1	1	1	1	1	1
SiO_2	35.81	35.33	35.48	35.04	34.66	37.64	37.14	36.81	37.40	37.60	37.01
TiO_2	1.03	0.77	0.69	0.67	0.75	2.64	2.59	3.50	2.76	3.18	3.53
Al_2O_3	20.30	20.58	20.61	20.85	20.49	18.07	18.03	18.03	18.50	18.54	18.22
MgO	11.14	11.27	11.25	11.03	11.67	16.18	16.21	14.75	15.48	14.99	14.41
CaO	-	-	0.09	0.07	0.08	-	0.11	0.15	-	-	-
MnO	-	-	-	0.13	0.10	-	-	-	-	-	-
FeO	20.70	20.38	20.44	20.39	19.42	14.29	13.71	15.84	15.20	15.94	16.28
Na_2O	0.45	0.49	0.49	0.51	0.44	0.65	0.61	0.50	0.59	0.61	0.53
K_2O	8.90	8.47	8.93	8.82	9.25	8.64	7.90	8.46	8.40	9.01	8.68
F	-	-	-	-	0.46	0.60	0.78	0.61	0.56	0.54	0.45
H_2O #	4.06	4.03	4.05	4.03	4.02	4.21	4.16	4.17	4.20	4.24	4.18
O=F	-	-	-	-	-0.19	-0.25	-0.33	-0.26	-0.24	-0.23	-0.19
Total	102.4	101.3	102.0	101.5	101.2	102.7	100.9	102.6	102.9	104.4	103.1
Si *	5.28	5.26	5.25	5.22	5.17	5.37	5.35	5.29	5.33	5.32	5.31
Al	2.72	2.74	2.75	2.78	2.83	2.63	2.65	2.71	2.67	2.68	2.69
C	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.81	0.87	0.85	0.88	0.77	0.41	0.41	0.35	0.44	0.41	0.39
Ti	0.11	0.09	0.08	0.08	0.08	0.28	0.28	0.38	0.30	0.34	0.38
Mg	2.45	2.50	2.48	2.45	2.60	3.44	3.48	3.16	3.29	3.16	3.08
Mn	-	-	-	0.02	0.01	-	-	-	-	-	-
Fe	2.55	2.54	2.53	2.54	2.42	1.70	1.65	1.91	1.81	1.88	1.95
B	5.92	6.00	5.94	5.97	5.88	5.83	5.82	5.80	5.84	5.79	5.80
Ca	-	-	0.01	0.01	0.01	-	0.02	0.02	-	-	-
Na	0.13	0.14	0.14	0.15	0.13	0.18	0.17	0.14	0.16	0.17	0.15
K	1.68	1.61	1.69	1.68	1.76	1.57	1.45	1.55	1.53	1.63	1.59
A	1.81	1.75	1.84	1.84	1.90	1.75	1.64	1.71	1.69	1.80	1.74

* number of ions on the basis of 24 (O,OH,F)
\# determined by stoichiometry
\- not detected

BIOTITES

Specimen No.	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 2-9	SC 3-10	SC 3-10	SC 3-10	SC 3-25a	SC 3-29
Unit #	1	1	1	1	1	1	1	1	1	2	2
SiO2	38.13	37.68	37.92	37.14	37.44	37.12	38.10	37.95	37.92	39.27	38.76
TiO2	0.70	2.70	2.03	2.56	2.57	3.38	2.06	2.32	2.98	1.91	1.47
Al2O3	17.37	17.78	18.16	17.75	17.66	17.69	17.39	17.40	17.10	16.94	16.81
MgO	17.92	15.39	16.39	15.47	15.23	14.50	17.48	17.03	16.14	19.21	18.06
CaO	0.13	-	-	-	-	-	-	-	-	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	12.25	15.27	13.94	15.05	12.15	15.41	12.56	12.94	13.64	10.14	13.32
Na2O	0.47	0.68	0.78	0.67	0.59	0.64	0.67	0.71	0.67	0.38	0.37
K2O	7.39	8.79	8.34	8.67	8.54	8.89	8.33	7.67	8.39	8.12	7.04
F	0.54	0.57	0.46	0.43	0.58	-	0.61	0.66	0.61	0.98	0.76
H2O #	4.12	4.19	4.19	4.14	4.08	4.13	4.18	4.17	4.17	4.24	4.19
O=F	-0.23	-0.24	-0.19	-0.18	-0.24	-	-0.26	-0.28	-0.26	-0.41	-0.32
Total	98.79	102.8	102.0	101.7	98.60	101.8	101.1	100.6	101.4	100.8	100.5
Si *	5.55	5.39	5.42	5.38	5.50	5.39	5.46	5.46	5.45	5.55	5.55
Al	2.45	2.61	2.58	2.62	2.50	2.61	2.54	2.54	2.55	2.45	2.45
C	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.53	0.39	0.48	0.41	0.56	0.42	0.40	0.41	0.35	0.37	0.39
Ti	0.08	0.29	0.22	0.28	0.28	0.37	0.22	0.25	0.32	0.20	0.16
Mg	3.89	3.28	3.49	3.34	3.34	3.14	3.73	3.65	3.46	4.05	3.86
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	1.49	1.83	1.67	1.82	1.49	1.87	1.51	1.56	1.64	1.20	1.60
B	5.99	5.79	5.86	5.85	5.67	5.80	5.86	5.87	5.77	5.82	6.01
Ca	0.02	-	-	-	-	-	-	-	-	-	-
Na	0.13	0.19	0.22	0.19	0.17	0.18	0.19	0.20	0.19	0.10	0.10
K	1.37	1.61	1.52	1.60	1.60	1.65	1.52	1.41	1.54	1.47	1.29
A	1.52	1.80	1.74	1.79	1.77	1.83	1.71	1.61	1.73	1.57	1.39

* number of ions on the basis of 24 (O,OH,F)
# determined by stoichiometry
- not detected

BIOTITES

Specimen No.	SC 3-54a	SC 3-54a	SC 4-2b	SC 4-2b	SC 4-2b	SC 5-1	SC 5-1	SC 5-1	SC 5-9	SC 5-9	SC 5-12
Unit #	2	2	3	3	3	2	2	2	2	2	2
SiO_2	38.97	39.00	39.09	38.62	38.82	38.71	38.34	38.56	38.89	38.89	38.44
TiO_2	2.71	2.59	1.73	1.22	2.32	2.76	2.67	2.23	1.90	2.32	2.67
Al_2O_3	17.01	17.20	17.97	17.90	17.40	17.20	17.60	17.75	17.30	17.37	18.00
MgO	18.77	18.88	19.32	20.26	18.45	17.34	17.40	18.03	18.21	18.63	17.50
CaO	-	-	-	0.18	-	-	0.06	-	0.08	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	10.67	10.66	10.98	10.65	12.11	13.60	13.40	13.35	12.32	11.33	11.97
Na_2O	0.54	0.51	0.37	0.33	0.54	0.65	0.61	0.58	0.54	0.56	0.59
K_2O	8.28	8.64	8.35	7.71	8.02	8.38	7.92	8.44	8.29	8.58	8.17
F	1.13	1.13	0.58	0.89	0.52	0.96	0.73	0.73	1.01	0.88	0.69
H_2O #	4.27	4.28	4.28	4.27	4.25	4.27	4.25	4.28	4.26	4.27	4.24
O=F	-0.48	-0.48	-0.24	-0.37	-0.22	-0.40	-0.31	-0.31	-0.43	-0.37	-0.29
Total	101.9	102.4	102.4	101.7	102.2	103.5	102.7	103.6	102.4	102.5	102.0
Si *	5.48	5.46	5.47	5.42	5.48	5.44	5.41	5.40	5.48	5.46	5.43
Al	2.52	2.54	2.53	2.58	2.52	2.56	2.59	2.60	2.52	2.54	2.57
C	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.30	0.30	0.44	0.38	0.37	0.29	0.34	0.33	0.35	0.34	0.43
Ti	0.29	0.27	0.18	0.13	0.25	0.29	0.28	0.24	0.20	0.25	0.28
Mg	3.93	3.94	4.03	4.24	3.88	3.63	3.66	3.77	3.83	3.90	3.69
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	1.25	1.25	1.29	1.25	1.43	1.60	1.58	1.56	1.45	1.33	1.41
B	5.77	5.76	5.94	6.00	5.93	5.81	5.86	5.90	5.83	5.82	5.81
Ca	-	-	-	0.03	-	-	0.01	-	0.01	-	-
Na	0.15	0.14	0.10	0.09	0.15	0.18	0.17	0.16	0.15	0.15	0.16
K	1.48	1.54	1.49	1.38	1.44	1.50	1.43	1.51	1.49	1.54	1.47
A	1.63	1.68	1.59	1.47	1.59	1.68	1.60	1.67	1.64	1.69	1.63

* number of ions on the basis of 24 (O,OH,F)
# determined by stoichiometry
- not detected

BIOTITES

Specimen No.	SC 5-12	SC 5-16	SC 5-21a	SC 5-21a	SC 5-21a	SC 5-21a	SC 5-25a	SC 5-39	SC 5-67	SC 5-67	SC 6-3
Unit #	2	2	2	2	2	2	2	3	QBG	QBG	2
SiO_2	38.74	39.37	38.82	38.94	38.85	41.24	38.14	37.81	36.76	35.70	35.63
TiO_2	1.63	3.18	1.81	2.43	2.29	2.42	3.11	2.38	2.00	2.11	1.86
Al_2O_3	17.81	16.58	17.21	16.61	16.57	17.76	17.08	17.82	20.12	19.55	19.54
MgO	18.30	18.24	18.56	17.93	18.36	17.92	16.26	17.56	13.61	13.63	11.29
CaO	-	0.05	-	-	0.08	-	-	-	-	0.06	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	11.73	12.08	11.76	11.65	11.44	12.50	13.78	13.59	15.43	15.68	20.63
Na_2O	0.46	0.43	0.37	0.47	0.40	-	0.37	0.34	0.49	0.65	0.58
K_2O	9.03	8.92	8.81	8.43	8.37	2.43	8.24	8.82	8.77	8.66	8.59
F	0.50	0.90	0.89	0.70	1.01	0.86	0.50	0.70	0.78	0.47	-
H_2O #	4.24	4.30	4.24	4.21	4.22	4.30	4.18	4.23	4.16	4.08	4.05
O=F	-0.21	-0.38	-0.37	-0.29	-0.43	-0.36	-0.21	-0.29	-0.33	-0.20	-
Total	102.2	103.7	102.1	101.1	101.2	99.10	101.5	103.0	101.8	100.4	102.2
Si *	5.48	5.49	5.49	5.55	5.52	5.76	5.47	5.36	5.30	5.25	5.27
Al	2.52	2.51	2.51	2.45	2.48	2.24	2.53	2.64	2.70	2.75	2.73
C	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.45	0.22	0.36	0.34	0.30	0.68	0.36	0.34	0.72	0.64	0.68
Ti	0.17	0.33	0.19	0.26	0.25	0.25	0.34	0.25	0.22	0.23	0.21
Mg	3.86	3.79	3.91	3.81	3.89	3.73	3.48	3.71	2.93	2.99	2.49
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	1.39	1.41	1.39	1.39	1.36	1.46	1.65	1.61	1.86	1.93	2.55
B	5.87	5.75	5.85	5.80	5.80	6.12	5.83	5.91	5.73	5.79	5.93
Ca	-	0.01	-	-	0.01	-	-	-	-	0.01	-
Na	0.13	0.12	0.10	0.13	0.11	-	0.10	0.09	0.14	0.19	0.17
K	1.63	1.59	1.59	1.53	1.52	0.43	1.51	1.59	1.61	1.63	1.62
A	1.73	1.72	1.69	1.66	1.64	0.43	1.61	1.68	1.75	1.83	1.79

* number of ions on the basis of 24 (O,OH,F)
# determined by stoichiometry
- not detected

BIOTITES											
Specimen No.	SC 6-3	SC 6-3	SC 6-3	SC 6-4	SC 6-4	SC 7-1	SC 7-4	SC 7-4	SC 7-10	SC 7-10	SC 7-10
Unit #	2	2	2	2	2	1	1	1	SIL	SIL	SIL
SiO2	36.10	36.00	36.26	37.79	37.55	35.86	35.93	36.37	36.52	36.57	36.60
TiO2	2.00	0.48	0.45	1.07	1.21	2.35	1.66	1.17	2.49	2.65	2.51
Al2O3	19.13	20.75	20.81	18.96	19.36	19.70	19.83	19.85	19.74	20.06	20.03
MgO	11.30	11.89	11.81	16.56	16.58	12.82	14.29	14.77	14.43	14.40	14.47
CaO	0.13	-	-	-	-	-	-	-	-	-	-
MnO	-	-	-	-	-	-	-	-	-	-	-
FeO	19.90	18.82	19.30	14.69	13.93	17.87	16.56	15.99	14.91	15.06	14.65
Na2O	0.54	0.40	0.48	0.84	0.77	0.25	0.25	0.30	0.30	0.45	0.32
K2O	7.70	8.73	8.10	8.03	7.49	9.21	9.34	9.00	9.47	8.97	9.42
F	0.47	-	-	0.60	0.51	0.44	0.47	0.62	-	0.46	0.55
H2O #	4.06	4.06	4.07	4.21	4.19	4.11	4.13	4.14	4.14	4.18	4.18
O=F	-0.20	-	-	-0.25	-0.21	-0.19	-0.20	-0.26	-	-0.19	-0.23
Total	101.1	101.1	101.3	102.5	101.4	102.4	102.3	102.0	102.0	102.6	102.5
Si *	5.34	5.32	5.34	5.38	5.37	5.23	5.22	5.26	5.29	5.24	5.25
Al	2.66	2.68	2.66	2.62	2.63	2.77	2.78	2.74	2.71	2.76	2.75
C	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.67	0.94	0.95	0.56	0.63	0.61	0.61	0.65	0.66	0.63	0.64
Ti	0.22	0.05	0.05	0.12	0.13	0.26	0.18	0.13	0.27	0.29	0.27
Mg	2.49	2.62	2.59	3.51	3.54	2.79	3.09	3.19	3.11	3.08	3.09
Mn	-	-	-	-	-	-	-	-	-	-	-
Fe	2.46	2.33	2.38	1.75	1.67	2.18	2.01	1.94	1.81	1.81	1.76
B	5.84	5.94	5.97	5.94	5.97	5.84	5.89	5.91	5.85	5.81	5.76
Ca	0.02	-	-	-	-	-	-	-	-	-	-
Na	0.16	0.12	0.14	0.23	0.21	0.07	0.07	0.08	0.08	0.13	0.09
K	1.45	1.65	1.52	1.46	1.37	1.71	1.73	1.66	1.75	1.64	1.72
A	1.63	1.77	1.66	1.69	1.58	1.78	1.80	1.74	1.83	1.77	1.81

* number of ions on the basis of 24 (O,OH,F)
# determined by stoichiometry
- not detected

BIOTITES

Specimen No.	SC 8-7	SC 8-7	ML 55	ML 55	ML 55	ML 93	ML 93	ML 93	ML 93	ML 93
Unit #	3	3	2(M)	2(M)	2(M)	3(M)	3(M)	3(M)	3(M)	3(M)
SiO_2	38.02	37.73	33.94	36.50	36.53	37.14	38.16	38.45	37.43	38.59
TiO_2	3.37	1.84	3.46	3.23	3.45	1.02	1.13	1.18	1.31	1.18
Al_2O_3	17.26	17.79	18.80	18.17	18.19	16.63	17.85	17.80	18.23	17.73
MgO	17.85	18.11	12.02	13.45	13.47	16.97	17.00	17.15	17.65	17.15
CaO	-	-	1.25	0.05	0.04	-	-	-	-	0.15
MnO	-	-	-	-	-	-	-	-	-	-
FeO	12.09	12.48	17.81	17.45	16.50	12.05	13.42	13.56	13.90	13.38
Na_2O	0.91	0.58	0.25	0.52	0.39	0.17	0.21	0.30	0.19	0.41
K_2O	8.42	8.09	6.53	8.65	8.73	9.19	9.08	8.96	7.71	8.50
F	0.53	0.80	0.48	0.54	0.59	0.52	0.58	0.35	0.47	0.47
H_2O #	4.24	4.20	3.97	4.13	4.12	4.02	4.17	4.19	4.17	4.19
O=F	-0.22	-0.34	-0.20	-0.23	-0.25	-0.22	-0.24	-0.15	-0.20	-0.20
Total	102.5	101.3	98.31	102.5	101.8	97.49	101.4	101.8	100.9	101.6
Si *	5.38	5.39	5.13	5.30	5.32	5.54	5.49	5.51	5.39	5.52
Al	2.62	2.61	2.87	2.70	2.68	2.46	2.51	2.49	2.61	2.48
C	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	0.26	0.38	0.48	0.41	0.44	0.46	0.51	0.51	0.48	0.51
Ti	0.36	0.20	0.39	0.35	0.38	0.11	0.12	0.13	0.14	0.13
Mg	3.77	3.86	2.71	2.91	2.92	3.78	3.64	3.66	3.79	3.66
Mn	-	-	-	-	-	-	-	-	-	-
Fe	1.43	1.49	2.25	2.12	2.01	1.50	1.61	1.62	1.67	1.60
B	5.82	5.93	5.83	5.79	5.75	5.85	5.88	5.92	6.08	5.90
Ca	-	-	0.20	0.01	0.01	-	-	-	-	0.02
Na	0.25	0.16	0.07	0.15	0.11	0.05	0.06	0.08	0.05	0.11
K	1.52	1.47	1.26	1.60	1.62	1.75	1.67	1.64	1.42	1.55
A	1.77	1.63	1.53	1.76	1.74	1.80	1.73	1.72	1.47	1.68

* number of ions on the basis of 24 (O,OH,F)
# determined by stoichiometry
- not detected

CHLORITES

CHLORITES

Specimen No.	SC 4-2b	SC 4-2b	SC 8-4	SC 8-11	SC 8-11	SC 8-17	SC 8-17	SC 8-17	SC 8-28	SC 8-28	SC 8-28
Unit #	3	3	3	3	3	3	3	3	3	3	3
SiO_2	26.18	28.19	26.22	25.69	25.23	26.42	25.70	31.51	24.87	25.13	25.45
TiO_2	0.07	0.09	0.13	0.08	0.09	-	-	-	0.07	-	0.11
Al_2O_3	23.15	21.91	23.28	23.23	23.76	22.64	22.46	21.41	23.22	23.25	23.38
MgO	21.91	21.30	23.44	20.73	21.29	21.97	20.99	20.25	21.07	20.48	21.56
CaO	-	-	-	-	-	0.09	0.06	-	-	0.07	-
MnO	-	-	-	0.10	-	-	0.09	-	-	-	-
FeO	18.71	19.22	16.54	20.33	19.20	17.60	18.37	16.36	19.28	19.86	19.07
Na_2O	-	0.10	-	-	-	-	-	-	-	-	-
K_2O	-	-	-	-	-	-	0.05	-	-	-	-
H_2O #	12.21	12.25	12.30	12.13	12.12	12.07	11.88	12.07	11.97	11.96	12.13
Total	102.2	103.1	101.9	102.3	101.7	100.8	99.60	101.6	100.5	100.8	101.7
Si *	5.14	5.52	5.12	5.08	4.99	5.25	5.19	6.26	4.98	5.04	5.03
Al	2.86	2.48	2.88	2.92	3.01	2.75	2.81	1.74	3.02	2.96	2.97
B	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al	2.50	2.58	2.47	2.50	2.53	2.55	2.54	3.28	2.46	2.53	2.47
Ti	0.01	0.01	0.02	0.01	0.01	-	-	-	0.01	-	0.02
Mg	6.42	6.22	6.82	6.11	6.28	6.51	6.32	6.00	6.29	6.12	6.35
Ca	-	-	-	-	-	0.02	0.01	-	-	0.02	-
Mn	-	-	-	0.02	-	-	0.02	-	-	-	-
Fe	3.07	3.15	2.70	3.36	3.18	2.92	3.10	2.72	3.23	3.33	3.15
Na	-	0.04	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	0.01	-	-	-	-
A	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00

* number of ions on the basis of 20 cations
# determined by stoichiometry
\- not detected

SILLIMANITES

SILLIMANITES

Specimen No.	SC 1-14a	SC 1-14a	SC 2-9	SC 2-9	SC 3-10	SC 3-10	SC 3-10	SC 3-10	SC 3-26a	SC 3-26a	SC 3-26a
Unit #	SIL	SIL	1	1	1	1	1	1	2	2	2
SiO_2	37.33	37.04	36.97	37.15	37.19	36.52	37.03	37.02	37.48	36.87	37.61
Al_2O_3	59.36	57.02	60.40	59.77	60.25	58.91	59.41	59.98	59.92	59.94	60.86
MgO	0.16	0.16	-	0.13	-	0.17	-	-	-	0.15	0.05
Fe_2O_3	0.46	0.49	0.29	0.38	0.34	0.46	0.32	0.25	0.25	0.36	0.29
ZnO	-	-	-	-	-	0.23	-	-	-	-	-
K_2O	0.10	0.33	-	-	-	-	-	-	-	-	-
Total	97.41	95.15	97.66	97.43	97.78	96.29	96.76	97.30	97.65	97.32	98.81
* Si	1.04	1.05	1.02	1.03	1.03	1.03	1.03	1.03	1.04	1.02	1.03
B	1.04	1.05	1.02	1.03	1.03	1.03	1.03	1.03	1.04	1.02	1.03
Al	1.94	1.91	1.97	1.95	1.96	1.95	1.95	1.96	1.95	1.96	1.96
Mg	0.01	0.01	-	0.01	-	0.01	-	-	-	0.01	-
Fe^{3+}	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	-	-	-	-	-	0.01	-	-	-	-	-
K	-	0.01	-	-	-	-	-	-	-	-	-
A	1.96	1.94	1.98	1.97	1.97	1.98	1.96	1.97	1.96	1.98	1.97

Specimen No.	SC 3-54a	SC 3-54a	SC 3-54a	SC 4-9	SC 4-9	SC 5-1	SC 5-1	SC 5-1	SC 5-35	SC 5-35	SC 5-35
Unit #	2	2	2	3	3	2	2	2	3	3	3
SiO_2	37.12	37.36	37.12	36.56	37.03	37.16	37.38	37.41	37.25	37.23	37.06
Al_2O_3	59.49	59.76	59.47	58.73	60.04	61.03	60.63	61.18	60.80	60.68	60.60
MgO	0.23	0.08	-	-	-	-	-	0.07	-	-	-
Fe_2O_3	0.41	0.27	0.20	0.32	0.29	0.24	0.26	0.25	0.32	0.31	0.31
ZnO	-	-	-	-	-	-	-	-	-	-	-
K_2O	-	-	-	-	-	-	-	-	-	-	-
Total	97.25	97.47	96.79	95.61	97.36	98.43	98.27	98.91	98.37	98.22	97.97
* Si	1.03	1.03	1.03	1.03	1.03	1.02	1.03	1.02	1.02	1.02	1.02
B	1.03	1.03	1.03	1.03	1.03	1.02	1.03	1.02	1.02	1.02	1.02
Al	1.95	1.95	1.95	1.95	1.96	1.97	1.96	1.97	1.97	1.97	1.97
Mg	0.01	-	-	-	-	-	-	-	-	-	-
Fe^{3+}	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	-	-	-	-	-	-	-	-	-	-	-
K	-	-	-	-	-	-	-	-	-	-	-
A	1.97	1.96	1.96	1.96	1.97	1.98	1.97	1.98	1.98	1.98	1.98

* number of ions on the basis of 5 (O,OH)
- not detected

SILLIMANITES

Specimen No.	SC 5-67	SC 7-1	SC 7-10	SC 7-10	SC 8-7	SC 8-15	SC 8-15	SC 8-17	SC 8-17	SC 8-28	ML 49
Unit #	QBG	1	SIL	SIL	3	3	3	3	3	3	2(M)
SiO_2	38.55	36.91	37.23	36.72	37.63	37.10	36.92	37.13	36.93	36.91	36.62
Al_2O_3	55.53	60.47	61.02	60.36	61.22	59.59	59.40	59.38	60.01	60.59	61.42
MgO	0.43	-	-	-	-	-	-	0.06	-	-	-
Fe_2O_3	0.48	0.25	0.19	0.21	0.31	0.27	0.28	0.28	0.24	0.34	0.24
ZnO	-	-	-	-	-	-	-	-	-	-	-
K_2O	0.08	-	-	-	-	-	-	-	-	-	-
Total	95.26	97.63	98.44	97.29	99.16	96.96	96.60	96.85	97.18	97.84	98.28
Si *	1.09	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.02	1.01
B	1.09	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.02	1.01
Al	1.85	1.97	1.97	1.97	1.96	1.95	1.96	1.95	1.96	1.97	1.99
Mg	0.02	-	-	-	-	-	-	0.00	-	-	-
Fe^{3+}	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	-	-	-	-	-	-	-	-	-	-	-
K	0.00	-	-	-	-	-	-	-	-	-	-
A	1.88	1.97	1.97	1.98	1.97	1.96	1.97	1.96	1.97	1.98	2.00

Specimen No.	ML 93										
Unit #	3(M)										
SiO_2	38.23										
Al_2O_3	60.25										
MgO	1.21										
Fe_2O_3	1.21										
ZnO	-										
K_2O	-										
Total	100.9										
Si *	1.03										
B	1.03										
Al	1.91										
Mg	0.05										
Fe^{3+}	0.03										
Zn	-										
K	-										
A	1.99										

* number of ions on the basis of 5 (O,OH)
- not detected

STAUROLITES

STAUROLITES

Specimen No.	SC 5-9	SC 5-12	SC 5-25	ML 01	ML 01	ML 01	ML 01	ML 01	ML 01	ML 01	ML 01
Unit #	2	2	2	1	1	1	1	1	1	1	1
SiO_2	27.10	27.39	27.45	27.60	27.98	27.37	27.55	27.37	27.31	27.41	27.45
TiO_2	1.11	0.84	0.99	0.71	0.72	0.64	0.70	0.62	0.70	0.76	0.78
Al_2O_3	54.42	54.46	52.92	53.20	53.64	53.32	53.58	53.71	53.59	53.25	53.53
MgO	3.74	3.95	3.25	3.31	3.36	3.51	3.52	3.58	3.53	3.54	3.47
MnO	-	-	-	0.11	0.07	0.09	0.12	0.12	0.09	0.09	0.10
FeO	9.91	10.25	12.06	13.32	13.35	13.44	13.44	13.39	13.23	13.34	13.29
ZnO	1.51	0.30	-	-	-	-	-	-	-	0.14	-
Na_2O	-	-	-	-	-	-	-	-	-	-	-
Total	97.79	97.19	96.67	98.25	99.12	98.42	98.91	98.79	98.45	98.53	98.62
Si *	3.73	3.77	3.83	3.81	3.83	3.78	3.78	3.76	3.77	3.78	3.78
Al	0.27	0.23	0.17	0.19	0.17	0.22	0.22	0.24	0.23	0.22	0.22
C	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Al	8.56	8.61	8.53	8.47	8.48	8.46	8.45	8.47	8.48	8.44	8.47
Ti	0.12	0.09	0.10	0.07	0.07	0.07	0.07	0.06	0.07	0.08	0.08
B	8.68	8.70	8.63	8.54	8.55	8.53	8.52	8.53	8.55	8.52	8.55
Mg	0.77	0.81	0.68	0.68	0.69	0.72	0.72	0.73	0.73	0.73	0.71
Mn	-	-	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fe	1.14	1.18	1.41	1.54	1.53	1.55	1.54	1.54	1.53	1.54	1.53
Zn	0.15	0.03	-	-	-	-	-	-	-	0.01	-
A	2.06	2.02	2.09	2.23	2.23	2.28	2.27	2.28	2.27	2.29	2.25

Specimen No.	ML 01	ML 01	ML 01	ML 08	ML 37	ML 37	ML 49				
Unit #	1	1	1	1	2	2	2(M)				
SiO_2	27.19	27.67	27.40	26.55	27.09	27.36	26.78				
TiO_2	0.65	0.63	0.66	1.03	0.89	1.03	0.79				
Al_2O_3	54.49	53.08	53.50	53.53	54.77	53.32	53.72				
MgO	3.38	3.60	3.41	1.89	3.46	3.88	4.13				
MnO	0.09	0.11	0.13	0.10	-	0.06	0.07				
FeO	13.40	13.19	13.33	11.74	11.54	11.52	11.09				
ZnO	-	-	-	1.36	-	-	0.14				
Na_2O	-	-	-	-	-	-	-				
Total	99.20	98.28	98.43	96.20	97.75	97.17	96.72				
Si *	3.72	3.82	3.78	3.75	3.73	3.79	3.73				
Al	0.28	0.18	0.22	0.25	0.27	0.21	0.27				
C	4.00	4.00	4.00	4.00	4.00	4.00	4.00				
Al	8.51	8.46	8.48	8.65	8.61	8.50	8.54				
Ti	0.07	0.07	0.07	0.11	0.09	0.11	0.08				
B	8.58	8.53	8.55	8.76	8.70	8.61	8.62				
Mg	0.69	0.74	0.70	0.40	0.71	0.80	0.86				
Mn	0.01	0.01	0.02	0.01	-	0.01	0.01				
Fe	1.53	1.52	1.54	1.39	1.33	1.34	1.29				
Zn	-	-	-	0.14	-	-	0.01				
A	2.23	2.27	2.26	1.94	2.04	2.15	2.17				

* number of ions on the basis of 23 oxygens
\- not detected

SPINELS

HERCYNITE SPINELS

Specimen No.	SC 4-9	SC 4-9	SC 4-12	SC 4-12	SC 4-12	SC 5-35	SC 5-35	ML 15	ML 15	ML 15	ML 01
Unit #	3	3	3	3	3	3	3	3	3	3	1
SiO2	0.16	0.19	0.15	0.20	0.23	0.26	0.20	-	0.18	-	-
TiO2	-	-	-	-	-	-	-	0.05	0.17	-	-
Al2O3	58.48	59.11	59.18	59.05	59.99	60.54	59.96	59.35	55.70	59.15	59.54
Cr2O3	-	-	-	-	-	0.11	-	-	-	-	-
V2O3	0.67	0.76	0.26	0.24	0.23	0.17	0.17	0.15	0.17	0.14	-
MgO	6.22	6.26	5.26	5.27	5.16	6.25	7.14	6.06	5.15	5.37	8.07
MnO	-	-	-	-	-	-	0.10	-	0.11	-	0.10
FeO	25.72	26.55	23.98	24.18	23.10	32.27	32.95	33.07	34.27	33.82	30.63
ZnO	7.45	7.82	11.19	10.90	11.78	0.49	0.45	0.17	0.51	-	0.71
Total	98.70	100.7	100.0	99.84	100.5	100.1	99.97	98.85	96.26	98.48	99.05
Si *	0.01	0.01	0.00	0.01	0.01	0.01	0.01	-	0.01	-	-
Al	1.96	1.95	1.97	1.97	1.99	1.97	1.96	1.97	1.93	1.98	1.96
Cr	-	-	-	-	-	0.00	-	-	-	-	-
V	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	-
Ti	-	-	-	-	-	-	-	0.00	0.00	-	-
B	1.99	1.98	1.98	1.99	2.00	1.98	1.97	1.97	1.94	1.98	1.96
Mg	0.26	0.26	0.22	0.22	0.22	0.26	0.30	0.26	0.23	0.23	0.34
Mn	-	-	-	-	-	-	0.00	-	0.00	-	0.00
Fe	0.61	0.62	0.57	0.57	0.54	0.75	0.74	0.78	0.84	0.80	0.71
Zn	0.16	0.16	0.23	0.23	0.24	0.01	0.01	0.00	0.01	-	0.02
A	1.03	1.04	1.02	1.02	1.00	1.02	1.05	1.04	1.08	1.03	1.07

* number of ions on the basis of 4 oxygens
- not detected

HERCYNITE SPINELS

Specimen No.	ML 33	ML 33	ML 93	ML 93	ML 93	ML 33	ML 33				
Unit #	3	3	3(M)	3(M)	3(M)	3	3				
SiO_2	-	-	-	-	-	-	0.08				
TiO_2	-	-	-	-	-	-	-				
Al_2O_3	61.18	59.58	58.43	58.74	58.72	58.92	58.64				
Cr_2O_3	-	-	-	-	-	-	-				
V_2O_3	0.11	0.12	-	-	-	0.20	0.15				
MgO	7.97	7.82	7.38	7.69	8.53	6.92	5.57				
MnO	0.11	0.09	0.09	0.08	0.08	0.08	0.11				
FeO	30.98	31.03	29.98	29.99	28.99	31.97	34.49				
ZnO	0.16	0.26	2.83	2.17	2.15	0.37	0.45				
Total	100.5	98.90	98.71	98.67	98.47	98.46	99.49				
Si *	-	-	-	-	-	-	-				
Al	1.97	1.96	1.95	1.95	1.94	1.96	1.95				
Cr	-	-	-	-	-	-	-				
V	-	-	-	-	-	0.01	-				
Ti	-	-	-	-	-	-	-				
B	1.97	1.96	1.95	1.95	1.94	1.97	1.95				
Mg	0.33	0.33	0.31	0.32	0.36	0.29	0.24				
Mn	-	-	-	-	-	-	-				
Fe	0.71	0.72	0.71	0.71	0.68	0.75	0.82				
Zn	-	0.01	0.06	0.05	0.05	0.01	0.01				
A	1.04	1.06	1.08	1.08	1.09	1.05	1.07				

* number of ions on the basis of 4 oxygens
- not detected

APATITES

APATITES											
Specimen No.	SC 7-10	SC 7-10	SC 7-10	SC 7-10							
Unit #	SIL	SIL	SIL	SIL							
SiO2	-	0.07	-	0.06							
MgO	0.33	0.42	0.33	0.24							
CaO	52.33	51.84	55.18	55.55							
MnO	0.13	0.11	-	0.18							
FeO	0.81	0.98	1.02	0.86							
Na2O	0.10	0.09	0.08	0.09							
P2O5	43.61	43.19	43.72	43.33							
F	5.10	4.95	4.72	5.17							
O=F	-2.15	-2.08	-1.99	-2.18							
Total	100.3	99.57	103.1	103.3							
P *	3.04	3.04	3.00	2.97							
B	3.04	3.04	3.00	2.97							
Si	-	0.01	-	0.01							
Mg	0.04	0.05	0.04	0.03							
Ca	4.62	4.61	4.79	4.81							
Mn	0.01	0.01	-	0.01							
Fe	0.06	0.07	0.07	0.06							
Na	0.02	0.01	0.01	0.01							
A	4.73	4.76	4.91	4.93							

* number of ions on the basis of 13 oxygens
- not detected

WAGNERITES

WAGNERITES											
Specimen No.	SC 5-9	SC 5-9	SC 5-21	SC 5-21	ML 02	ML 02	ML 02				
Unit #	2	2	2	2	2	2	2				
SiO2	-	-	-	0.09	-	-	-				
TiO2	2.00	2.06	1.34	1.25	0.91	0.76	0.61				
MgO	42.82	42.83	42.60	42.28	43.76	43.70	44.46				
CaO	0.17	0.12	0.09	0.15	0.06	0.05	0.05				
MnO	-	-	-	-	0.10	0.09	0.09				
FeO	7.11	6.90	7.96	7.22	7.14	7.11	7.05				
Na2O	-	-	-	0.24	-	-	-				
P2O5	44.09	43.56	43.38	42.41	42.60	43.06	42.68				
F	9.11	9.30	9.59	8.72	8.05	8.22	8.28				
O=F	-3.84	-3.92	-4.04	-3.67	-3.39	-3.46	-3.49				
Total	101.5	100.9	100.9	98.69	99.23	99.53	99.73				
P *	1.03	1.03	1.02	1.03	1.03	1.03	1.02				
B	1.03	1.03	1.02	1.03	1.03	1.03	1.02				
Si	-	-	-	-	-	-	-				
Ti	0.04	0.04	0.03	0.03	0.02	0.02	0.01				
Mg	1.77	1.78	1.77	1.80	1.86	1.85	1.88				
Ca	0.01	-	-	0.01	-	-	-				
Mn	-	-	-	-	-	-	-				
Fe	0.17	0.16	0.19	0.17	0.17	0.17	0.17				
Na	-	-	-	0.01	-	-	-				
A	1.99	1.98	1.99	2.02	2.05	2.04	2.06				

* number of ions on the basis of 5 oxygens
- not detected