DEPARTMENT OF ENERGY, MINES AND RESOURCES

Geological Survey of Canada

GEOLOGY OF THE SHERRIDON GROUP

IN THE VICINITY OF SHERRIDON, MANITOBA

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O P E N   F I L E   6 9 2

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Abstract

In the vicinity of Sherridon, Manitoba, rocks of the younger Sherridon Group occupy a structural basin surrounded by rocks of the older Nokomis Group. The Nokomis Group comprises quartzofeldspathic gneisses, migmatites, and granitoid gneisses. The Sherridon Group has been divided into five stratigraphic units, arranged in the sequence A to E from the edge to the center of the basin:

E. Upper quartz-rich gneiss, with thin layers of calc-silicate gneiss.

D. Biotite-garnet schist.

C. Impure marble and calc-silicate gneiss

B. Lower quartz-rich gneiss, with layers of amphibolite, pelitic gneiss, and calc-silicate gneiss, and massive sulphide deposits along two stratigraphic horizons.

A. Calc-silicate gneiss.

The sulphide mineralization is associated, in some localities with cordierite-anthophyllite rocks, which have been interpreted as metamorphosed hydrothermally altered rocks.

Three periods of folding have affected rocks of the Sherridon area. The first event, F_1, was isoclinal and transposed the bedding into an axial planar S_1 foliation. Interference of two subsequent folding events, F_2 and F_3, produced a crescent-shaped structural basin, in which rocks of the Sherridon Group are preserved. The present mineral assemblages may have developed as early as the first period of folding and persisted during the second and third periods. The grade of metamorphism is uniform and corresponds to the upper amphibolite facies.

INTRODUCTION

The Kisseynew Complex consisting mainly of sedimentary gneisses occupies an area north of the Flin Flon-Snow Lake Belt (Fig. 1). The discovery of the Sherritt Gordon orebody at Sherridon led to the first systematic investigation of the Kisseynew gneisses by Wright (1929). Harrison (1951b) summarized the results of subsequent geological work. The Sherridon area straddles two areas mapped on a scale of one mile to one inch (Bateman and Harrison, 1946; Robertson, 1953). In this mapping, the first attempt was made to establish a stratigraphic subdivision of the Kisseynew gneisses. One of the most interesting features of the geology of the Sherridon area is the occurrence of sulphide deposits in metasedimentary gneisses. Robertson (1953) established that the mineralized gneisses belong to the youngest stratigraphic unit (Sherridon Group), generally regarded to be equivalent to the Missi Group of the Flin Flon-Snow Lake belt (Bailes, 1971); however, the Missi Group does not contain massive sulphide deposits.

This study of the Sherridon area was undertaken with a two-fold purpose:

1. To map the Sherridon area at a scale of 1:20 000 and to describe the general geology and metamorphic environment of the Sherridon Group and the enclosed mineral deposits. These aspects are dealt with in this report.

2. To reconstruct the environment of deposition of the Sherridon Group and deduce some constraints for any proposed origin of the sulphide deposits. These aspects are dealt with by P.A. Goetz in a Ph.D. thesis submitted to Carleton University (Goetz, 1980).

FIGURE 1. Location and geological setting of the Sherridon area.

MAP AREAS

A Guay - Wimapedi Lakes (Bailes, 1975)

B File Lake (Bailes, 1980)

C Snow Lake (This Paper)
   (E. Froese and J.M. Moore 1980)

Granitic to grabbroic
intrusions

Gneiss domes

Missi (Sherridon) Group
metasedimentary rocks

Amisk (Nokomis) Group
metasedimentary rocks

Amisk Group
metavolcanic rocks

Southern boundary of the Kisseynew
Complex (biotite-sillimanite-almandine
isograd).......

REGIONAL GEOLOGY

The Flin Flon region, including the southern edge of the Kisseynew Complex was first mapped by Bruce (1918). He recognized the volcanic Amisk series and the sedimentary Missi series, divided into the Lower Missi series composed of quartzite and slate and the upper Missi series composed of arkose and conglomerate. Metamorphic rocks to the north, observed only in contact with Amisk rocks, were termed Kisseynew gneisses (Table 1). Bruce (1918) considered them to be a complex composed of metamorphosed sediments and large volumes of granitic rocks. The sedimentary gneisses appeared to be younger than the Amisk volcanic rocks, the contact being marked by a "gradual transition from the dominantly igneous rock of the Amisk group to the dominantly sedimentary rock of the Kisseynew group" (Bruce, 1918, p. 29). Thus the protoliths of the Kisseynew gneisses were not represented in the Amisk series of the Flin Flon belt; instead, there was a facies change from volcanic rocks in the south to sedimentary rocks in the north, combined with an increase in metamorphic grade.

A subsequent investigation of the Kississing Lake area by Wright (1929) supported the stratigraphic relations established by Bruce (1918). In particular, he refers to the transitional contact between Amisk rocks and overlying Kisseynew sedimentary gneisses. Over a zone, about 1 km in width, he observed alteration of lava flows and sediments. However, Wright (1929) included some sediments in the Amisk Group. Byers and Dahlstrom (1954) assigned the Lower Missi series of Bruce (1918) the Amisk Group, essentially following the practice of Wright and Stockwell (1934).

Table 1

Stratigraphic subdivisions of the Flin Flon region

Bruce (1918)		Byers and Dahlstrom (1954)		Bailes (1971)	
Kisseynew Complex	Kisseynew gneisses	Kisseynew Complex	Kisseynew gneisses	Kisseynew Complex	Sherridon Group
					Nokomis Group
Flin Flon belt	Upper Missi series	Flin Flon belt	Missi Group	Flin Flon belt	Missi Group
	Lower Missi series		Amisk Group; volcanic and sedimentary rocks		Amisk Group
	Amisk series				

Because the Lower Missi series was regarded by them as forming the upper part of the Amisk Group, there were sedimentary rocks in the Flin Flon belt which could be taken as protoliths of the Kisseynew gneisses. Similarly, some of the amphibolites in the Kisseynew gneisses were regarded as metamorphosed Amisk volcanic rocks.

During the 1940's the Geological Survey of Canada carried out an extensive one-mile mapping program. This work lead some of the investigators to question the transitional nature of the Amisk-Kisseynew boundary and to propose a major fault along the contact (Harrison, 1951a and b). However, opinion was not unanimous and Robertson (1951), in a classic paper on the Kisseynew problem, maintained that the boundary is transitional. This view was supported by Byers and Dahlstrom (1954) and by recent studies in the eastern part of the Flin Flon-Snow Lake belt (Bailes, 1975; Bailes and McRitchie, 1978; Froese and Moore, 1979).

The first subdivision of the Kisseynew gneisses was made by Bateman and Harrison (1946) for rocks of the Sherridon area. They recognized three groups: Pre-Sherridon, Sherridon, and Post-Sherridon and showed their strata arranged in a postulated domal structure. Later, Robertson (1953) concluded that in the Batty Lake area, adjacent

to the Sherridon area, the Sherridon rocks occupy synclinal structures
and suggested that the Post-Sherridon Group of Bateman and Harrison
(1946) is, in fact, older than the Sherridon Group. He renamed it
the Nokomis Group. This division was adopted by subsequent
investigators in the Kisseynew Complex (Pollock, 1964, 1965; Kornik,
1968). Bailes (1971) suggested that the Sherridon Group correlates
with the Missi Group of the Flin Flon belt and that the Nokomis Group
correlates with Amisk Group sediments (Table 1). Later, Bailes (1975)
used these terms in preference to Nokomis and Sherridon in an area
of Kisseynew gneisses. However, not all rocks in the Nokomis Group
resemble metamorphosed Amisk sediments. Therefore, the Nokomis
Group may include rocks which have no equivalents in the Amisk Group.
In this paper, we accept the Nokomis and Sherridon Groups as defined
by Robertson (1953). Rocks of the Pre-Sherridon Group of Bateman and
Harrison (1946) are interlayered with typical quartz-rich gneisses
of the Sherridon Group and have been assigned to this group.

The origin of amphibolites in the Kisseynew gneisses has been
a matter of considerable debate. It is very likely that amphibolites
of volcanic and sedimentary derivation are present in both the
Nokomis and Sherridon Groups. In the Sherridon Group, volcaniclastic
rocks give an indication of volcanism and massive amphibolites of
similar composition may be metamorphosed flows. Although the Kisseynew
gneisses are predominantly of sedimentary origin, interlayered volcanic
rocks point to continued igneous activity.

The correlation between Sherridon Group and Missi Group is
based on lithology and, like all such correlations, presents
difficulties. The quartz-rich gneisses have the chemical composition
of lithic arenite or subgreywacke (Pollock, 1965; Goetz, 1980),

and could be the metamorphic equivalents of cross-bedded arenites
of the Missi Group in the Flin Flon area. However, in contrast
to the Missi Group, the Sherridon Group lacks conglomerate. The
Sherridon Group typically includes small layers of calc-silicate
rocks, whereas limy sediments do not occur in the Missi Group.
Furthermore, the Sherridon Group in the vicinity of Sherridon differs
from other localities of Sherridon rocks due to the presence of pelitic
schist, abundant impure limestone (Wright, 1930; 1931b), prominent
layers of volcanic rocks, and sulphide mineralization.

One of the great unresolved problems of the regional geology
is the possibility that remobilized basement gneisses may have been
inadvertently included in the Nokomis Group in the Sherridon area.
Because rocks of the Nokomis Group have been converted in various
degrees to migmatites and granitoid gneisses, they are not easily
distinguished from possibly older rocks. In many localities, the
Nokomis gneisses and migmatites retain some compositional layering and
an overall composition suggesting derivation from a greywacke-shale
succession (Robertson, 1953; Pollock, 1964, 1965; Bailes, 1975). In
contrast to these rocks, Nokomis rocks adjacent to the Sherridon basin
lack psammitic-pelitic compositional layering and might represent older
rocks.

Radiometric methods indicate an Aphebian age of rocks of
the Flin Flon-Snow Lake belt and of the Kisseynew Complex (Sangster,
1978). But to one of us (E.F.) it appears precipitate to discount
the possibility of later up-dating of an Archean Belt.

LITHOLOGY

General Statement

The division of the Kisseynew gneisses into Nokomis Group and
Sherridon Group, first proposed by Robertson (1953), has been

retained in this paper. In the Sherridon area, a structural basin occupied by rocks of the Sherridon Group is surrounded by rocks of the Nokomis Group. The Nokomis Group consists of grey paragneisses and their granitized equivalents - migmatites and granitoid gneisses. In the Batty Lake area, east of Sherridon, the presence of cordierite and sillimanite in some layers suggests pelitic compositions. For this reason, the Nokomis Group has been correlated with the greywacke-shale sequence of the Amisk Group (Bailes, 1971). However, gneisses and migmatites surrounding the Sherridon basin do not possess pelitic layers. It is possible that these rocks represent remobilized basement, although evidence of an unconformity, if it ever existed, has been obliterated. These compositional differences prompted an attempt by Tuckwell (1979) to subdivide the Nokomis Group into two sequences, one derived from greywacke-shale and a less pelitic sequence of unknown origin. A great amount of detailed mapping will be required to test the validity of this subdivision.

The Sherridon Group consists of a succession of siliceous, pelitic, and calc-silicate gneisses with interlayered amphibolites. Sulphide mineralization is present along stratigraphic horizons within the quartz-rich gneisses. The wide variety of rock types in the Sherridon area is not typical of the Sherridon Group elsewhere in the Kisseynew Complex. More commonly the Sherridon Group consists of a monotonous succession of quartz-rich gneisses with some interlayered calc-silicate gneisses, particularly near the base.
                                        (Pollock, 1964, 1965; Bailes, 1971, 1975).
        The lithologic units recognized in the area are listed in the Table of Formations. Their distribution is shown on the map (Fig. 2). In Table 2, average compositions of several lithologic units are listed; the complete analyses are given by Goetz (1980).

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 hornblende.
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 bed 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 are associated with sulphide mineralization.
	(4) Pelitic schists, composed of quartz, plagioclase, biotite, sillimanite, garnet and cordierite; typically rusty weathering, associated with sulphid 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	(1) Quartzofeldspathic gneisses, migmatites, and granitoid gneisses.

Table 2

Average composition of some lithologic units

	Unit 2	Unit 3	Unit 7	Unit 8 low TiO_2	Unit 8 high TiO_2
Mean					
SiO_2	74.43	62.47	52.01	51.73	44.65
TiO_2	0.21	0.63	0.56	0.64	2.32
Al_2O_3	11.77	16.67	16.15	15.47	15.57
Fe_2O_3	0.46	0.63	1.79	2.92	3.13
FeO	3.05	5.73	9.26	9.32	12.82
MnO	0.09	0.08	0.19	0.21	0.25
MgO	1.92	2.87	5.46	6.28	6.07
CaO	2.24	3.69	8.94	9.10	9.36
Na_2O	1.74	2.47	2.57	1.92	1.75
K_2O	2.36	2.24	0.70	0.46	0.37
P_2O_5	0.08	0.51	0.14	0.14	0.26
CO_2	0.52	0.23	1.59	0.83	1.62
H_2O	1.13	1.13	1.39	1.32	1.60
Standard deviation					
SiO_2	2.15	0.47	1.60	2.62	4.20
TiO_2	0.07	0.12	0.09	0.07	0.73
Al_2O_3	1.25	0.53	1.28	0.83	1.39
Fe_2O_3	0.48	0.33	0.92	1.03	1.23
FeO	1.17	0.12	0.94	0.69	2.46
MnO	0.04	0.01	0.03	0.02	0.05
MgO	0.94	0.12	1.30	1.93	0.54
CaO	1.07	0.39	1.76	0.87	0.82
Na_2O	1.07	0.74	1.01	0.62	0.83
K_2O	1.29	0.14	0.48	0.13	0.05
P_2O_5	0.03	0.13	0.09	0.06	0.06
CO_2	0.33	0.17	2.13	0.81	0.94
H_2O	0.43	0.25	0.50	0.35	0.34
Number of samples					
	33	3	17	12	6

Nokomis Group

Rocks of the Nokomis Group were examined only in the vicinity of the contact with the Sherridon Group. Consequently, this study does not deal with problems of regional stratigraphy.

Grey, medium-grained, quartz-plagioclase-biotite gneisses and granitized equivalents are the main rock lithology in the Nokomis Group. In addition to the gneissic structure, the rocks locally have a compositional layering 10-100 cm wide, defined by slight variations in biotite content. Mineralogicall the gneisses are very simple: they consist of quartz, oligoclase-andesine (An 28-36), and minor amounts of almandine. Granitic veinlets are common even in unmigmatized gneisses (1a) and these rocks locally grade into migmatites (1b), composed of 10 to 50% granitic segregations. Ptygmatic folds are very common in these migmatites.

In some areas, the paragneisses grade, by a coarsening of grain size and loss of compositional layering into granitoid gneisses (1c). These rocks are white to light pink, homogeneous, and distinguished by the absence of compositional layering. South of the Sherridon area, the granitoid gneisses grade in turn into foliated granite, presumably derived from highly metamorphosed sediments (Robertson, 1953).

The Nokomis gneisses include layers, from 10 to 100 m thick, of fine to medium grained amphibolite, which typically consists of andesine and hornblende. Robertson (1953) considered these amphibolites to be

of sedimentary origin and this interpretation is supported by their
lime-rich composition. One clinopyroxene-bearing sample contains
15.8% Ca0 (Goetz, 1980).

Sherridon Group

Several lithologies are recognized in the Sherridon Group
(Table of Formations). Interlayering of rock units is common (see
geological map, Fig. 2). No repetition of units by folding was
observed. Therefore, it is assumed that the strata become progressively
younger from the edge to the centre of the Sherridon structural basin,
as shown in the stratigraphic column in Fig. 3. Zoning in the west
orebody supports this facing direction. Lithologic units are sub-
parallel to the base of the Sherridon Group. Therefore, the base is
thought to be s stratigraphic contact and not a fault boundary as
suggested by Tuckwell (1979). It is possible that the Sherridon Group
unconformably overlies the Nokomis Group.

The most abundant rock of the Sherridon Group is a fine to
medium grained, quartz-rich gneiss (2) which consists of quartz,
oligoclase-andesine (An_{25-40}), microcline, biotite, and almandine.
This rock is characterized by quartz ridges on its weathered surface.
Near the base of the Sherridon Group, rocks have a somewhat higher
biotite content and display compositional layering on a scale of
10-30cm. Towards the centre of the basin they become more felsic and
layering becomes indistinct. Locally the grain size is coarser and a
few incipient granitic segregations are present. Quartz-sillimanite
nodules occur in some layers. Very poorly preserved cross-bedding is
present at Singsing Lake. The Na_2O/K_2O ratio of the quartz-rich gneisses
varies greatly causing the composition to fall into the field of
lithic arenite, lithic sandstones, greywacke, and arkose (Fig. 4).

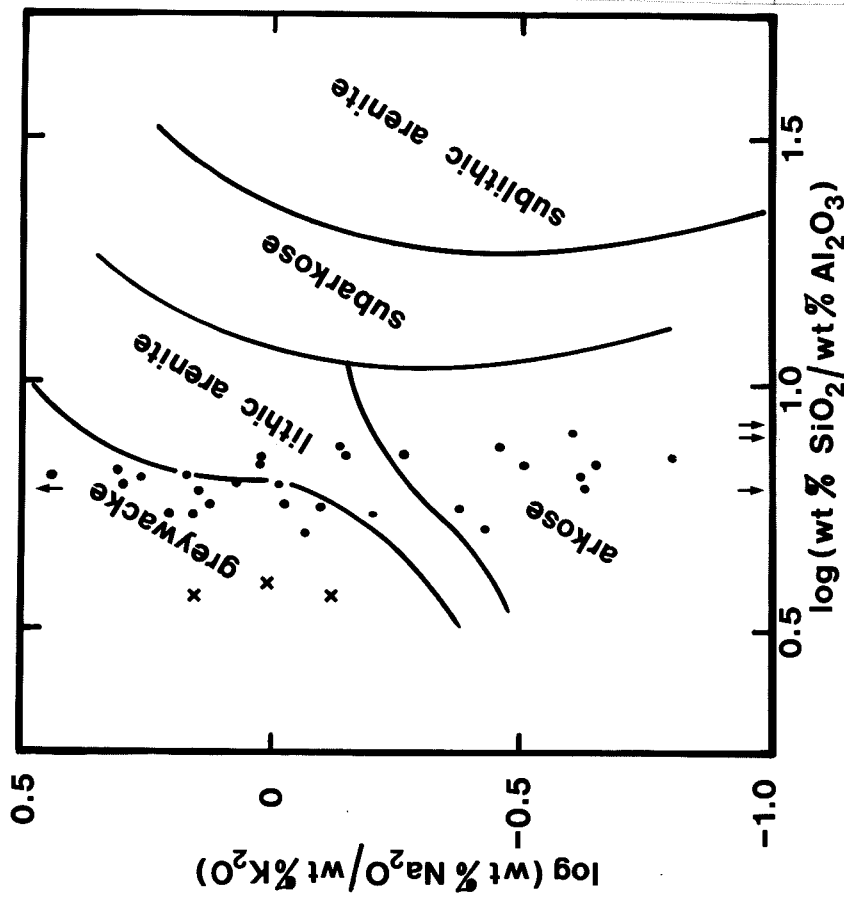|	
2	E. Upper quartz-rich gneiss
3	D. Biotite-garnet schist
6	C. Impure marble and calc-silicate gneiss
5 7 2 8 2 2 5 8 2 7 4 2	B. Lower quartz-rich gneiss
5	A. Calc-silicate gneiss

3   Lithologic units;see Table of Formations

– – – mineralized horizon

FIGURE 3. Stratigraphic column of the Sherridon Group.
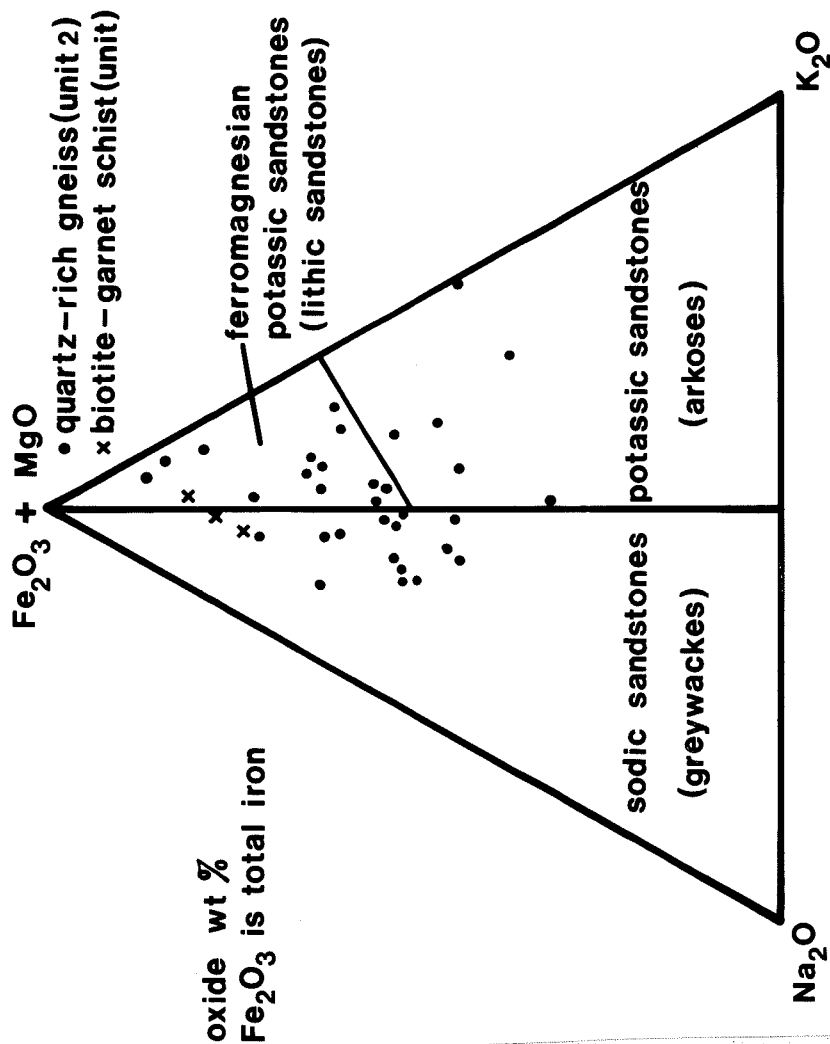
FIGURE 4. Chemical composition of metasedimentary rocks.

A grey, fine-grained biotite-garnet schist(3) is present between Cree Lake and Narrows Lake. This rock is well foliated, lacks compositional layering, and consists of quartz, andesine (An_{30-35}), biotite, and euhedral garnet crystals up to 3 mm in size. The composition of this rock is that of greywacke (Fig. 4). This unit was mapped as part of the "Pre-Sherridon" Group by Bateman and Harrison (1946) and correlated with the Nokomis Group by Robertson (1953). However, this rock is interlayered with quartz-rich gneisses and clearly is part of the Sherridon Group.

Pelitic schists (4) are locally interlayered with quartz-rich gneisses (2). They are fine to medium grained, commonly display rusty weathering, and consist of quartz, oligoclase-andesine An_{25-35}, biotite, almandine, sillimanite, and, locally, cordierite. Some of these rocks are biotite-rich (about 30% biotite). This unit occurs below the Sherridon mine horizon and may represent a short break in the sedimentation of the lithic arenite(2) prior to the deposition of the sulphides.

Cordierite-anthophyllite rocks occur as discontinuous lenses within quartz-rich gneisses. They are coarse-grained rocks with garnet and anthophyllite crystals up to 10 cm in size. Quartz and biotite are other characteristic constituents, but sapphirine was observed in one specimen lacking quartz. These rocks were first recorded in the Sherridon area by Robertson (1953), who commented on their stratigraphic continuity. Most occurrences lie on the Sherridon mine horizon, in a few places below the sulphide layer but more commonly along unmineralized sections of the horizon. The composition of these rocks require a chlorite-rich protolith, probably related to sulphide deposition.

Calc-silicate rocks (5) occur interlayered with quartz-rich gneisses, particularly near the base of the Sherridon succession. They are fine to medium grained, greyish-green, and display prominent layering on a scale of 1-10 cm which is accentuated by differential weathering. Their mineralogical composition is variable. Nearly all rocks contain quartz, andesine-labradorite, and hornblende, and about half of the specimens examined contain K feldspar, biotite, and scapolite. Diopside and calcite are very common; in some layers, calcite constitutes about 50 per cent.

Interlayered impure marble and calc-silicate rocks (6), in beds up to 10 m thick, outcrop near Cree Lake and Found Lake. To the north, the unit thins to 50 m but can be followed through Narrows Lake to north of Bob Lake. The impure marble is mineralogically similar to calc-silicate rocks, except that it has a higher content of calcite. The presence of impure marble was first reported by Wright (1930, 1931b) and further attention was drawn to it by Harrison (1951b) and Robertson (1953).

Amphibolite (7) forms several continuous layers within quartz-rich gneisses (2). In some outcrops, the amphibolite displays layering and includes felsic fragments. It is a dark grey, fine to medium grained rock with somewhat larger crystals of hornblende and garnet. It consists of granoblastic aggregates of quartz, andesine, hornblende, and garnet with a trace of biotite. Bateman and Harrison (1946) noted the fragments and interpreted the amphibolite as a volcanic breccia. Some of the fragments resemble the quartz-rich gneisses. The variety of fragments, some of which may be non-volcanic, suggests a volcaniclastic origin. Between Singsing Lake and Duke Lake, felsic fragments set in a calcite-bearing matrix constitute the bulk of the rock, giving it an overall felsic composition. These rocks have been included in unit (7).

In spite of their fragmental nature, amphibolites sampled to exclude felsic fragments have a rather uniform compostion (Table 2) which probably still reflects the composition of the parent magma. Consequently, chemical analyses are plotted on various diagrams to display their chemical characteristics. According to the classification of Irvine and Baragar (1971), the rocks are subalkaline basalts which fall into the tholeiitic field (Fig. 5). Pearce (1976) used discriminant functions to classify basalts on the basis of modern tectonic setting. The analyses of rocks from unit (7) plot in the island arc low-K tholeiite field (Fig. 6).

Massive, fine grained amphibolite (8), is interlayered with quartz-rich gneisses. It consists of quartz, andesine, hornblende, and garnet. Analyses from this unit are also plotted on classification diagrams (Fig. 5 and 6). The compositions fall into two distinct groups, low-TiO_2 and high-TiO_2 basalts. The low-TiO_2 basalts are very similar in composition to the amphibolites of unit (7). The high-TiO_2 basalts, found in the lower part of the Sherridon sequence, are somewhat alkaline (Fig. 5). Small layers of amphibolite (8) typically occur in the calc-silicate rocks at the base of the Sherridon succession. Locally pillow-like structres, previously described by Bateman and Harrison (1946), have been observed. Bands 1-2 cm wide, characterized by a concentration of hornblende and garnet, outline highly irregular forms. The origin of these structures is unknown but it is doubtful that they are pillows.

Intrusive Rocks

The Sherridon Group was intruded by massive to weakly foliated, medium grained gabbro (9), consisting of labradorite and hornblende, rarely accompanied by small amounts of quartz and garnet. Three small
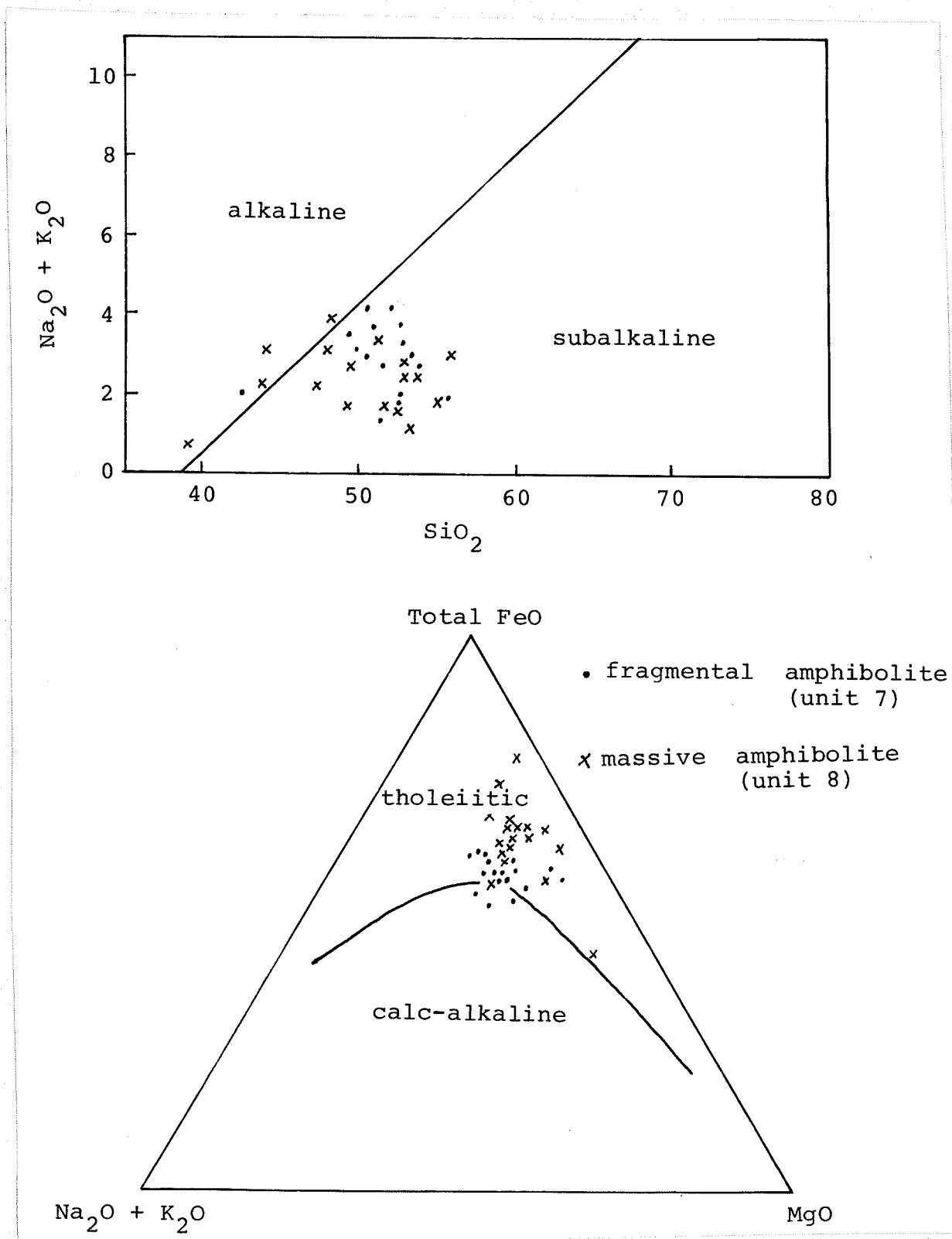
FIGURE 5. Chemical classification of volcanic rocks
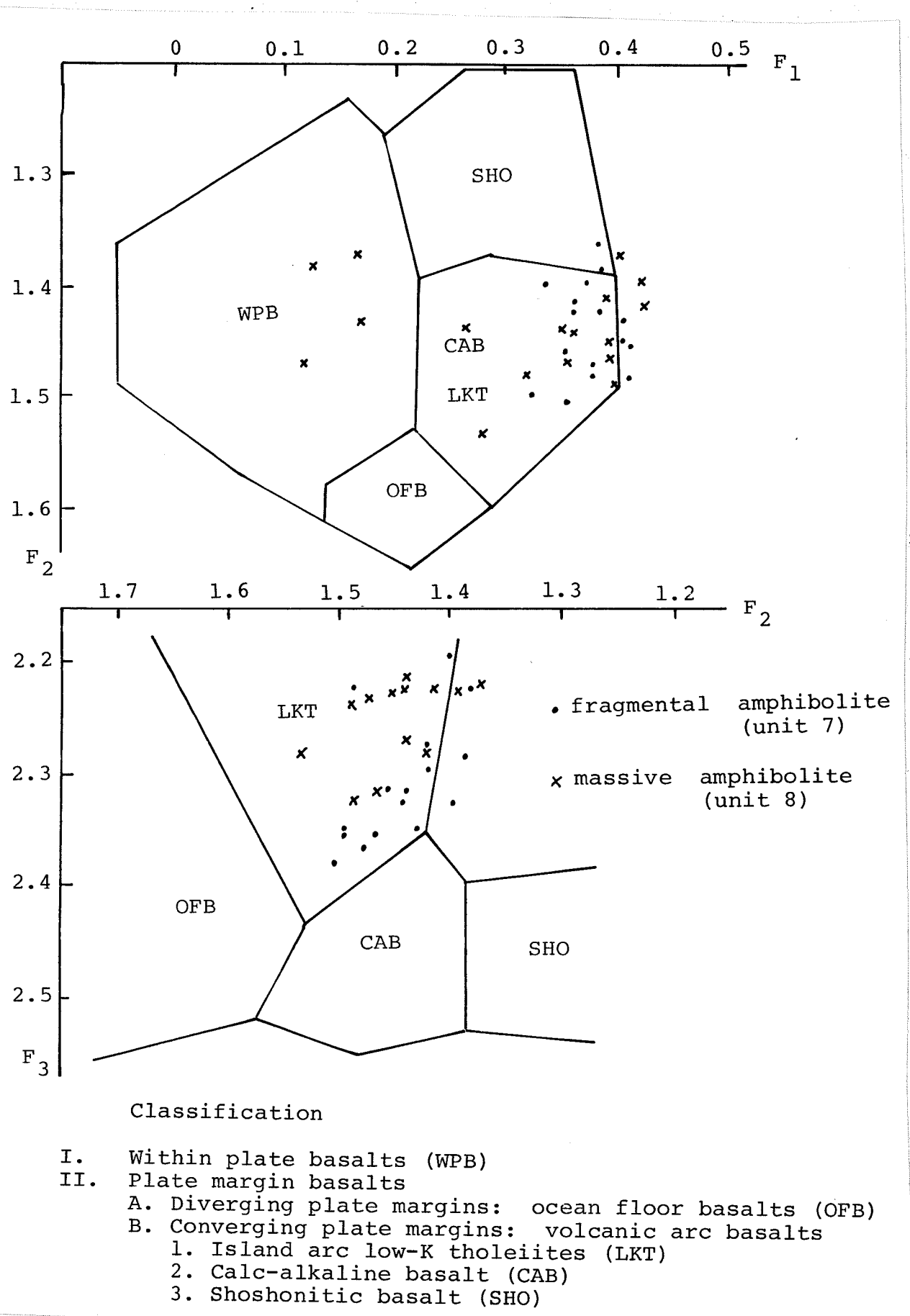(Irvine and Baragar, 1971).

FIGURE 6. Tectonic classification of basalts (Pearce, 1976).

bodies of this gabbro occur in the centre of the Sherridon basin and a prominent sill is present below the base of the Sherridon succession. This sill was mapped as "Post-Sherridon" (i.e. Nokomis) Group by Bateman and Harrison (1946). However, in contrast to Nokomis amphibolites, the gabbro sill is not veined by granitic stringers and the presence of very mafic to ultramafic rocks near the base indicates some differentiation.

At Cree Lake a small body of pyroxenite (10) is associated with the gabbro. This rock is coarse grained and rusty weathering. It consists of hornblende pseudomorphs after pyroxene.

Small bodies of weakly foliated, medium-grained granodiorite (11), consisting of quartz, oligoclase, K-feldspar, and biotite, occur near Found Lake and Sherlett Lake. Masses of felsic pegmatite (12) are present throughout the area.

STRUCTURAL GEOLOGY

Fabric elements displayed by rocks of the Sherridon Group are relatively simple. Compositional layering on a scale of 1 to 100 cm is ubiquitous. Biotite and hornblende impart a foliation parallel to the compositional layering. Fragments are flattened parallel to the layering. This foliation is locally axial planar to folds 10-100 cm in size. The foliation has been folded into open flexures with axes of variable orientation. A lineation is developed in the form of an elongation of mineral aggregates and preferred orientation of hornblende crystals. The lineations lie within a plane (Fig. 7) suggesting reorientation by rotation.

The observed structures indicate three episodes of folding. The first phase F_1 is represented by small isoclinal folds in the foliation plane. This folding probably produced flattening and
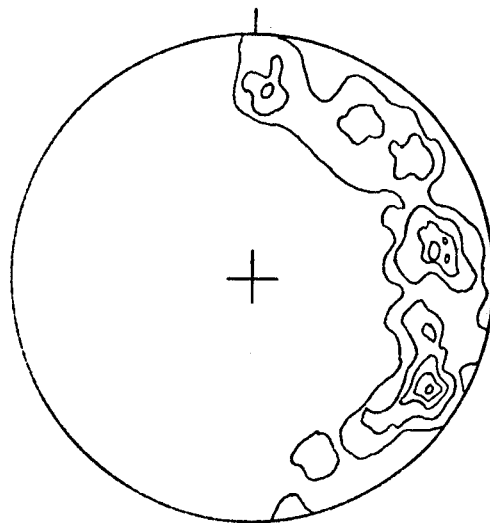
62 Lineations

C.I. - 3.23

M.V. - 14.52

FIGURE 7. Lineations in the
Sherridon area.

transposed the bedding into the foliation plane; thus the present prominent foliation corresponds to S_0 parallel S_1. This surface has been deformed into a crescent-shaped basin, suggesting a type 2 interference pattern (Ramsay, 1967). This pattern is typically developed by refolding recumbent folds. Hence it is suggested that recumbent folding F_2, with axial planes dipping north, was followed by folding F_3 with axial planes trending northwesterly. The F_2 and F_3 episodes did not produce a new axial plane foliation; however, the folded S_0/S_1 surface probably was accentuated by continued mineral growth which could have begun during F_1. Lineation was produced mainly by F_2 and reoriented by F_3.

Much previous controversy concerning the structure of the Sherridon area stems from ignoring the variable plunge of lineations which had been first observed by Bruce (1929). Farley's (1948, 1949) structural interpretation was influenced by the northerly plunge of the west orebody. He noted the reversal in dip of the east orebody, but failed to recognize the easterly plunge, previously noted by Bruce (1933). Apparently he considered both orebodies as part of a northerly-plunging syncline.

Stockwell (1950) determined that the fold at Sheila Lake had an easterly plunge. Kalliokoski (1953) noticed that this was parallel to the plunge of the east orebody. He concluded that this was the plunge of all folds in the area, ignoring previously observed plunges with other orientations. Robertson (1953), in the Batty Lake area, recognized northeasterly-trending lineations which are not parallel to the trend of the major synclines occupied by Sherridon rocks. From this he deduced two period of deformation, corresponding essentially to F_2 and F_3 discussed in this paper.

A prominent fault through Molly Lake has been mapped to Jungle Lake. The offset of lithologic contacts indicates a horizontal left-hand displacement of one km. Very sheared rocks are exposed where the fault crosses the railway track south of Jungle Lake.

ECONOMIC GEOLOGY

Following the discovery of the Flin Flon deposit in 1915, prospecting activity was extended to the north and in 1923 the Sherritt Gordon deposit was staked. Economic interest in the area lead to the first mapping by Wright (1929) and later to more detailed mapping (Bateman 1944, Bateman and Harrison, 1946). Several subeconomic deposits have since been found: Bob Lake, Jungle Lake, Park Lake, Fidelity (between Bay Lake and Bob Lake). Tonnage and grade are given in Table 3.

In the Sherridon Group, disseminated pyrrhotite in cherty parts of calc-silicate rocks is very common. Particularly the calc-silicate layer at the base of the Sherridon succession includes many rusty zones. This type of sulphide occurrence characteristically is devoid of copper and zinc.

Copper-zinc sulphides are found along two stratigraphic horizons in quartz-rich gneisses. These horizons are marked by discontinuous lenses of massive sulphides and intermittent zones of disseminated sulphides. Locally sulphide mineralization is associated with cordierite-anthophyllite rocks. The lower horizon includes the Sherritt Gordon orebodies and extends to the north to Singsing Lake. A trench 1 km south of Singsing Lake contains some disseminated chalcopyrite. The ore horizon swings east to include the Park Lake deposit; it then becomes indistinct but apparently continues to the

Table 3

Tonnage and Grade of Sulphide Deposits

(from Davies et al., 1962)

Deposit	Tonnage	%Zn	%Cu
Sherritt Gordon*	8 531 352		
East orebody		5.78	2.14
West orebody		2.76	2.91
West orebody		0.80	1.40
(low grade area)			
Average		2.84	2.46
Bob Lake	2 380 000	1.18	1.33
Jungle Lake	3 700 000	1.1	1.42
Park Lake	confidential assessment work		
Fidelity	confidential assessment work		

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*The grade is not given by Davies et al. (1962); therefore, the grade based on ore reserve calculations is given (Anonymous, 1930). Farley (1949) mentions an "overall average grade" of 2.97% zinc and 2.45% copper, but it is not clear whether this refers to the Sherritt Gordon deposit as a whole or to the east orebody only.

Molly Lake fault and appears again at the Jungle Lake deposit.
The anthophyllite rocks between Molly Lake and Star Lake probably
mark the same stratigraphic horizon. Sulphides occur associated
with the anthophyllite rocks near Elken Lake. Chalcopyrite and
sphalerite were reported to occur in this showing by Wright (1929).
The ore horizon presumable continues from Star Lake westerly to the
Jungle Lake deposit.

The Bob Lake deposit marks the second mineralized horizon.
It extends to the east to include several showings between Bob Lake
and Star Lake. The Fidelity deposit appears to lie on the same
horizon but the continuation of this horizon to the west is not well
defined. It may extend to the north tip of Sherlett Lake and from
there to a trenched area west of Lost Lake.

The Sherritt Gordon orebodies and host rocks have been
described in a paper by the staff of Sherritt Gordon Mines Limited
(Anonymous, 1930) and by Wright (1929, 1931a), Bruce (1929, 1933),
Bruce and Matheson (1930), Derry (1942) and Farley (1948, 1949).
The orebodies occur as tabular masses of sulphides about 5 m thick
and as irregular remobilized masses (offshot orebodies). The ore is
contained in quartz-rich gneiss. Over some distance, the ore follows
closely the contact with amphibolite but even where it is shown as
touching the amphibolite it is generally separated from the amphibolite
by a layer, 1-3 m thick, of quartz-rich gneiss. According to Farley
(1949), the boundaries of the ore are well defined and the hanging
wall contact is relatively sharp in comparison to the footwall contact
marked by disseminated sulphides. Except at the east end of the east
orebody the footwall lies towards the edge of the Sherridon basin.
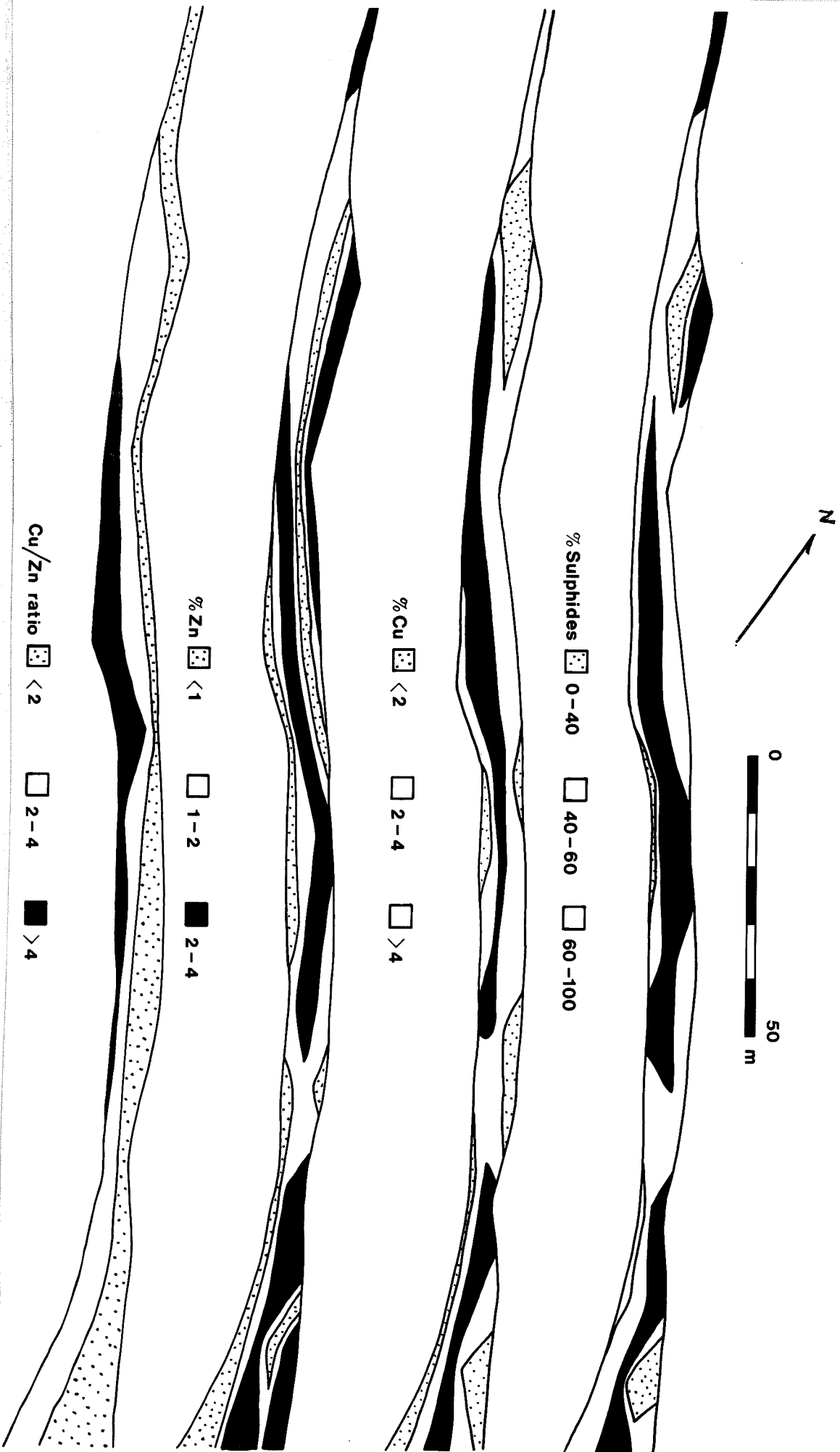According to assay plans of one level (Fig. 8), the west orebody

FIGURE 8. Sulphide distribution and zoning, part of 3. level of the west orebody opposite the west shaft (compiled from company maps).

% Sulphides ⊡ 0-40 ☐ 40-60 ☐ 60-100

% Cu ⊡ <2 ☐ 2-4 ☐ >4

% Zn ⊡ <1 ☐ 1-2 ■ 2-4

Cu/Zn ratio ⊡ <2 ☐ 2-4 ■ >4

N

0   50   m

displays stratigraphic zoning with the Zn/Cu ratio increasing towards the centre of the Sherridon basin. On this particular level, however, disseminated sulphides are present on the hanging wall and footwall of the ore. It is not known whether or not stratigraphic zoning was present in the east orebody. On the basis of unpublished ore reserve estimates, Goetz (1980) deduced lateral zoning in the east orebody, copper-rich in the east and zinc-rich in the west. The west orebody, however, does not display lateral zoning.

The mineralogy of the ores is simple consisting of pyrite, pyrrhotite, sphalerite, and chalcopyrite, and, very rarely, magnetite. Some exsolution blades of cubanite are present in chalcopyrite. Arsenopyrite has been reported as a very rare constituent (Farley, 1949). The gangue minerals are those of the quartz-rich gneisses which form the host rocks: mainly quartz, plagioclase, and biotite, and, more rarely, hornblende, clinopyroxene, scapolite, and calcite. Gahnite was noted in a few samples (Goetz, 1980). The coarse grain size of the ore (1-10 mm), the abundance of pyrrhotite, and the presence of gahnite indicate that the ore, like the enclosing rocks, have been metamorphosed (Sangster and Scott, 1976). Some of the ore has been remobilized into pegmatites; such ore typically is devoid of pyrrhotite (Goetz, 1980).

The sulphides probably are chemical precipitates. The main ore horizon is underlain, in part, by pelitic rocks marking a period of quiescence preceding chemical sedimentation. In order to account for the formation of a massive sulphide deposit, transportation of metals in hot brines is commonly suggested (Large, 1977, Goetz, 1980). The origin of the brines is unknown; a connection with volcanism during the deposition of the Sherridon Group is possible but not obvious.

Cordierite-anthophyllite rocks form intermittent thin layers of
great stratigraphic continuity, particularly along the main ore
horizon. In a few places, cordierite-anthophyllite rocks are found
below the ore zone but they do not form pipe-like alteration zones.
Cordierite-anthophyllite rocks have been interpreted as metamorphosed
hydrothermally altered rocks (Froese, 1969; Whitmore, 1969). But in
the Sherridon area, the altered rocks do not represent channelways
but more likely chlorite and silica sedimented from the brine on the
sea floor, as suggested by Wilkinson (1976) and Schermerhorn (1978).
Feldspars are unstable in chloride solutions; this fact gives rise
to the chloritization of felsic rocks by hydrothermal solutions
(Large, 1977). Thus any rock fragments engulfed in a brine would be
altered to chlorite and silica. It is also possible that chlorite-
rich material from the vent of the hydrothermal solutions is carried
in suspension (Goetz, 1980). It is of some interest to note that
sapphirine was found in one cordierite-anthophyllite rock, because
other occurrences of sapphirine in cordierite-anthophyllite rocks
(Warren, 1979) and in host rocks of sulphide deposits (Raymond and
Leiggi, 1979) have been reported.

METAMORPHISM

Introduction

Metamorphic zones in the Kisseynew gneiss belt are shown
by Bailes and McRitchie (1978). The Sherridon area lies within the
lower part of their zone of high grade metamorphic rocks. Metamorphic
mineral assemblages might have developed during first phase of
deformation but continued to recrystallize during the second and
third periods of deformation. Most Nokomis gneisses have been partially
melted and large parts of them have been converted to migmatites and

granitoid gneisses. In Sherridon Group gneisses, there is evidence for incipient melting. Some rocks, by a coarsening of grain and development of a pinkish cast, resemble granitoid gneisses. But Sherridon gneisses typically have not been converted to migmatites.

Retrograde metamorphism is common. Feldspars are altered to sericite and epidote and ferromagnesian minerals to chlorite and prehnite. In a few rocks, large well-developed crystals of muscovite appear to be products of progressive metamorphism. They probably formed during the initial decrease in temperature causing metamorphic conditions to fall into the muscovite stability field.

The grade of metamorphism is uniform, as in many other areas of the Kisseynew gneisses. The wide variety of rock compositions makes it possible to characterize the metamorphic conditions by a great number of mineral assemblages including sulphide-silicate assemblages.

Mineral Assemblages

In the presence of quartz, plagioclase of constant composition, magnetite, and ilmenite, many mineral assemblages can be represented in the system

$$A = Al_2O_3 - (Na_2O + CaO + K_2O)$$

$$K = K_2O \cdot Al_2O_3$$

$$F = FeO - (Fe_2O_3 + TiO_2)$$

$$M = MgO$$
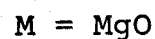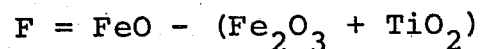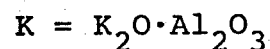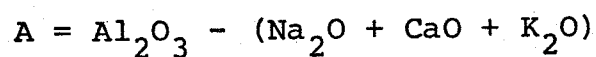
Neglecting the effect of other components, phase relations within this tetrahedron will be determined at fixed values of $P, T,$ and P_{H_2O}. Mineral assemblages that do not include K-bearing minerals can be represented on the AFM face and mineral compatibilities in biotite-bearing assemblages can be portrayed on the biotite composition surface (Froese, 1978).

Compatible mineral assemblages from the Sherridon area
are listed in Table 4 and shown in Fig. 9. A few small staurolite
grains in plagioclase are regarded as armoured relics. Sillimanite
and anthophyllite are present in a few thin section but they are not
found in contact; they apparently are incompatible. Sapphirine was
found in one rock and mineral analyses from this rock are presented
in Table 5. Coexisting biotite, almandine, cummingtonite, hornblende,
and anthophyllite from one specimen have been analyzed (Table 6).
These compositions (except that of biotite) are plotted in Fig. 9.
The AFM diagram has been completed schematically according to observed
assemblages. Mineral assemblages in biotite-bearing assemblages are
shown in Fig. 10.

Metamorphic Conditions

A part of a petrogenetic grid constructed by D.M. Carmichael
is reproduced in Fig. 11. A path of metamorphism in the Sherridon
area is shown reaching a peak at 5 kb and $670^{\circ}C$, a temperature somewhat
above the decomposition curve of muscovite. The pressure was estimated
from the sphalerite geobarometer (Scott, 1973). Sphalerites coexisting
with pyrite and pyrrhotite have a composition of 13±1 mole per cent
FeS (Goetz, 1980), corresponding to a pressure of 6±1 kb. The lower
limit was accepted because pressures indicated by the sphalerite
geobarometer tend to be too high, if sphalerite re-equilibrates during
quenching (Bristol, 1979).

An uncalibrated grid covering the pressure-temperature region
in the vicinity of peak metamorphic conditions (Fig. 12) can be
constructed by combining reactions from Carmichael's grid with reactions
from a grid for granulites (Froese and Jen, 1979). Comparison with
Fig. 10 indicates the most assemblages from the Sherridon area fall into
a pressure-temperature field immediately to the left of the invariant

Table 4
Metamorphic mineral assemblages

|	qz	pl	kf	bi	si	at	alm	hb	cum	co	cpx
	qz	pl		bi							
	qz	pl		bi			alm				
	qz	pl		bi		at					
	qz	pl		bi	si						
	qz	pl		bi	si		alm				
	qz	pl		bi					cum		
	qz	pl		bi			alm		cum		
	qz	pl		bi				hb	cum		
Quartzofeldspathic	qz	pl		bi			alm	hb	cum		
and pelitic gneiss;	qz	pl		bi		at	alm	hb	cum		
amphibolites	qz	pl		bi			alm	hb			
	qz	pl		bi				hb			
	qz	pl						hb			
	qz	pl					alm	hb			
	qz	pl	kf	bi							
	qz	pl	kf	bi				hb			
	qz	pl	kf	bi			alm				
	qz	pl	kf	bi			alm	hb			
	qz	pl	kf	bi	si						
Cordierite-	qz			bi	si		alm			co	
anthophyllite	qz			bi		at	alm			co	
rocks	qz			bi		at				co	
	qz	pl		bi							cpx
	qz	pl		bi			alm	hb			cpx
	qz	pl		bi			alm				cpx
Calc-silicate	qz	pl						hb			cpx
rocks	qz	pl					alm	hb			cpx
	qz	pl	kf	bi			alm	hb			
	qz	pl	kf								cpx
	qz	pl	kf					hb			cpx
	qz	pl	kf	bi				hb			cpx
	qz	pl	kf	bi			alm	hb			cpx
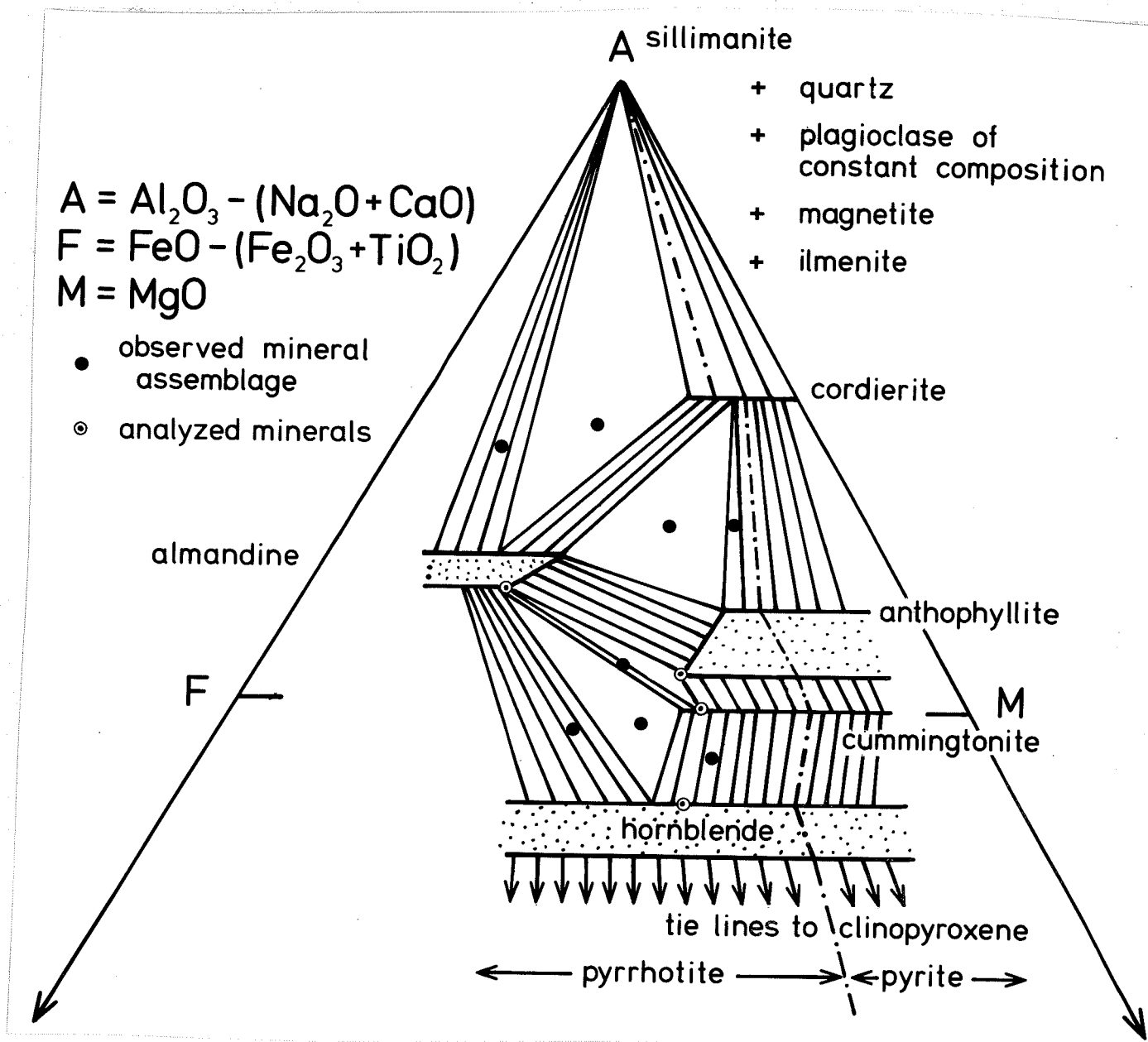
FIGURE 9. Mineral assemblages shown on an AFM diagram.

Table 5

Composition of Minerals from a Cordierite-anthophyllite Rock

(Specimen SWO-34)

	cordierite	anthophyllite	biotite	almandine	sapphirine	spinel
SiO_2	49.71	44.32	38.66	39.21	13.33	0.36
TiO_2	0.02	0.29	1.12	0.02	0.03	0.02
Al_2O_3	33.57	18.33	16.44	22.26	61.49	61.90
FeO	2.58	11.20	8.54	25.95	7.33	23.13
MnO	–	0.06	–	0.38	–	0.03
MgO	12.10	21.72	20.59	11.58	17.76	13.41
CaO	–	0.22	0.03	0.91	–	–
Na_2O	0.22	2.29	0.40	0.13	–	–
K_2O	0.04	–	8.93	–	–	–
ZnO	–	–	–	–	–	1.01
Total	98.24	98.43	94.71	100.44	99.94	99.86

Total iron expressed as FeO.
Mineral assemblage: cordierite, anthophyllite, biotite, almandine, sapphirine, spinel, magnetite.

Electron microprobe analyses by M. Bonardi, Mineralogy Section, Geological Survey of Canada.

Table 6

Composition of Minerals from an Amphibolite

(Specimen FQG-166)

	biotite	almandine	cummingtonite	hornblende	anthophyllite
SiO_2	38.01	38.57	52.92	44.39	49.71
TiO_2	1.83	0.06	0.19	0.66	0.23
Al_2O_3	15.68	20.80	3.46	12.56	7.28
FeO	13.84	27.65	20.36	16.31	20.69
MnO	–	1.36	0.46	0.19	0.50
MgO	16.36	7.66	19.03	13.04	18.13
CaO	0.13	4.07	1.58	9.32	0.70
Na_2O	0.13	–	0.38	1.58	0.89
K_2O	9.16	–	–	0.30	–
Total	95.14	100.17	98.38	98.35	98.13

Total iron expressed as FeO.
Mineral assemblage: quartz, plagioclase (An_{52-73}), biotite, almandine, cummingtonite, hornblende, anthophyllite, magnetite.

Electron microprobe analyses by M. Bonardi, Mineralogy Section, Geological Survey of Canada.

A = Al₂O₃ − (Na₂O+CaO+K₂O)

$A = Al_2O_3 - (Na_2O+CaO+K_2O)$
$F = FeO - (Fe_2O_3+TiO_2)$
$M = MgO$

+ quartz
+ plagioclase of constant composition
+ magnetite
+ ilmenite

● observed mineral assemblage

$\frac{A}{M+F}$

$\frac{M}{M+F}$

pyrrhotite ← ✕ → pyrite

co
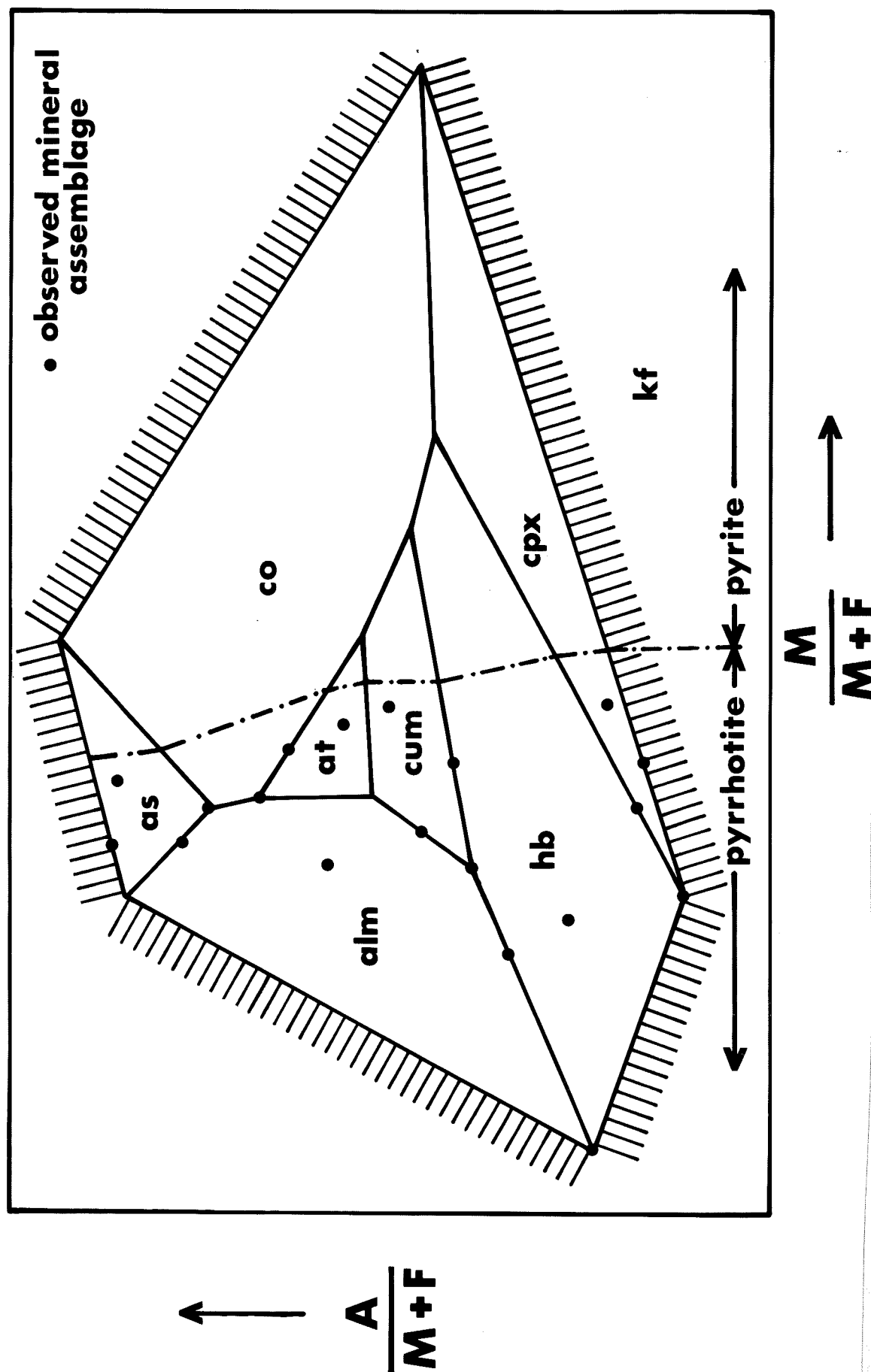
as

alm

at

cum

hb

cpx

kf

FIGURE 10. Mineral assemblages shown on the biotite composition surface.

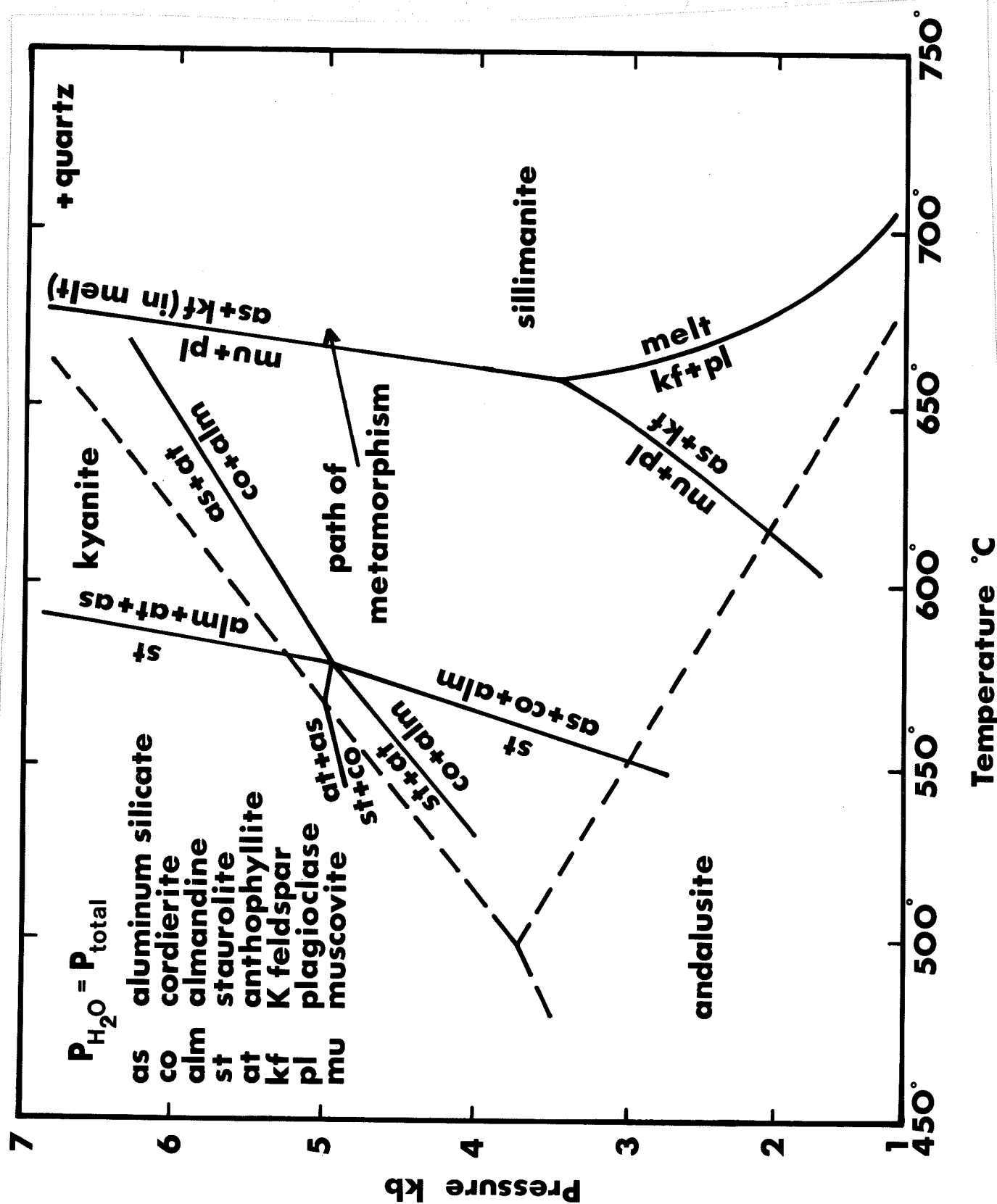FIGURE 11: Petrogenetic grid for pelitic rocks.

FIGURE 12. Petrogenetic grid for pelitic and mafic rocks.

point cummingtonite-almandine-hornblende-anthophyllite-orthopyroxene.
The assemblage cummingtonite-almandine-hornblende-anthophyllite
indicates that metamorphic conditions just reached those corresponding
to the reaction

cummingtonite + almandine + plagioclase + H_2O

$\leqq$ hornblende + anthophyllite.
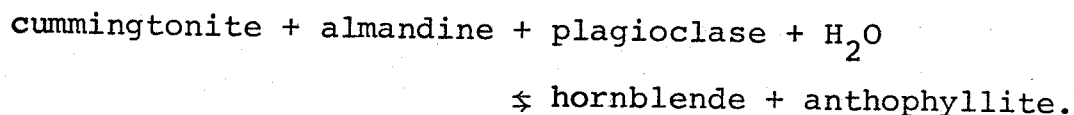
Similarly, the assemblage hornblende - K feldspar - almandine -
clinopyroxene-biotite, observed in a few rocks, suggests metamorphic
conditions corresponding to the reaction

hornblende + K feldspar + plagioclase

$\leqq$ almandine + clinopyroxene + biotite +

H_2O.
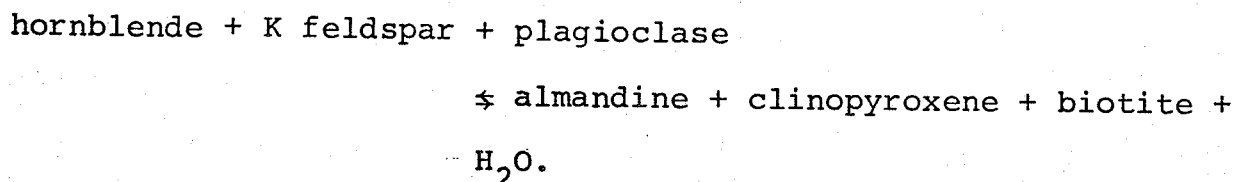
Metamorphism of Sulphide-bearing Rocks

Sulphide-silicate rocks are associated with massive sulphides
of the orebodies. Sulphides also occur as accessories in quartz-rich,
pelitic, and calc-silicate gneisses and in cordierite-anthophyllite
rocks. These rock types make it possible to study the effect of
metamorphism on sulphide-bearing rocks.

It is a common observation that pyrite occurs in magnesium-
rich rocks and that pyrrhotite is associated with iron-rich minerals.
For a single ferromagnesian mineral, e.g. Fe-Mg amphibole, such
relationship is conveniently shown on a $\log f_{O_2}$ vs. $\log f_{S_2}$ diagram
(Fig. 13). The diagram reproduced in Fig. 13 was constructed by
Froese (1977) on the basis of experimental work by Popp et al. (1977).
The invariant point magnetite-pyrite-pyrrhotite is characterized by
a fixed composition of Fe-Mg amphibole. In an AFM diagram, this point
extends into a boundary which divides the diagram into two fields,
marked by the stability of either pyrite or pyrrhotite (Froese, 1976).
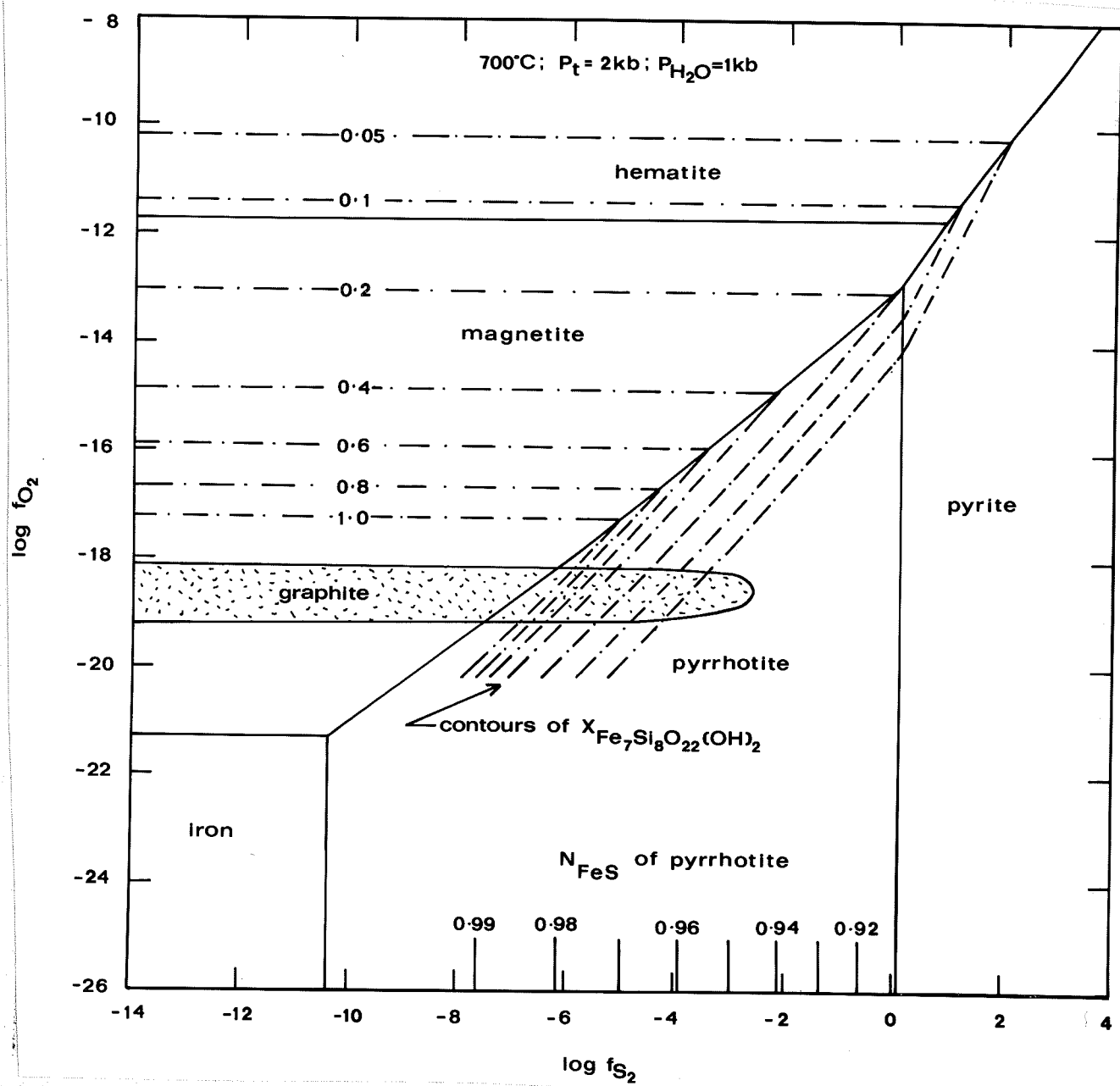
FIGURE 13. The stability of iron oxides, iron sulphides, and graphite.

Similarly, the biotite composition surface can be divided into two fields (Froese and Moore, 1980). In Fig. 9 and 10, the pyrite-pyrrhotite boundary is shown diagrammatically. Magnetite is absent in many rocks, particularly in those containing graphite. In the absence of magnetite, the pyrite-pyrrhotite boundary is shifted toward Mg-richer compositions. The role of graphite deserves further comments. Miyashiro (1964) showed the upper stability of graphite with respect to $\log f_{0_2}$ for a given P_{CO_2}. By carrying out gas equilibria calculations, as discussed by Eugster and Skippen (1967), it is possible to delimit the stability of graphite with respect to all gas species. Thus within the graphite field shown in Fig. 13, the sum of the partial pressures of H_2, CH_4, CO_2, CO, H_2S, and COS is less than 1 kb. Outside this field, this sume would exceed 1 kb and, since P_{H_2O} has been kept at 1 kb, the gas pressure would exceed the total pressure.

Compatible mineral assemblages observed in sulphide-silicate rocks essentially agree with phase relations shown in Fig. 9 and 10. The disseminated sulphide in graphite-bearing calc-silicate and pelitic gneisses typically is pyrrhotite. The chief iron sulphide of disseminated ores in quartz-rich gneisses is pyrrhotite which coexists with relatively iron-rich biotite. However, some pyrite is present as well. Similarly the common disseminated iron sulphide in cordierite-anthophyllite-almandine rocks is pyrrhotite, but again some pyrite has been observed. The occurrence of pyrite in relatively iron-rich rocks, some sufficiently iron-rich to contain almandine is at variance with experimental work on the sulphidation of ferromagnesian silicates. Possibly this discrepancy may be attributed to the formation of pyrite during cooling as a retrograde mineral.

Parts of the Sherritt Gordon orebodies have been remobilized into masses of pegmatite. The iron sulphide in the remobilized ore typically is pyrite. Intrusion of the pegmatite postdates metamorphism and the mineral assemblages do not reflect metamorphic conditions.

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