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GEOLOGY OF THE SHERRIDON GROUP IN THE VICINITY OF SHERRIDON, MANITOBA

E. Froese and P.A. Goetz

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GEOLOGY OF THE SHERRIDON GROUP IN THE VICINITY OF SHERRIDON, MANITOBA

Abstract

In the vicinity of Sherridon, Manitoba, rocks of the younger Sherridon Group occupy a structural basin surrounded by the older Nokomis Group. The Nokomis Group consists of 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 centre 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 folds, F_1, were isoclinal and transposed the bedding into an axial planar S_1 foliation. Interference of two subsequent fold sets, 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.

Résumé

A proximité de Sherridon (Manitoba), les roches du groupe de Sherridon occupent un bassin structural entouré des roches plus anciennes du groupe de Nokomis. Ce dernier comprend des gneiss quartzofeldspathiques, des migmatites et des gneiss granitoides. Le groupe de Sherridon a été divisé en cinq unités stratigraphiques disposées selon la succession A à E, du bord au centre du bassin.

E. Gneiss supérieur riche en quartz, à minces couches de gneiss à silicates calcaires.

D. Schiste à biotite et grenats.

C. Marbre impur et gneiss à silicates calcaires.

B. Gneiss inférieur riche en quartz, avec couches d'amphibolite, de gneiss pélitique et de gneiss à silicates calcaires et dépôts massifs de sulfures le long de deux horizons stratigraphiques.

A. Gneiss à silicates calcaires.

La minéralisation des sulfures est associée à certains endroits aux roches d'anthophyllite-cordiérite considérées comme des roches métamorphisées altérées hydrothermalement.

Les roches du Sherridon ont subi trois périodes de plissement. La première, F_1, était isocline; les couches ont subi une foliation (S_1) dans un plan axial. L'interférence de deux plissements ultérieurs, F_2 et F_3, a produit un bassin structural en forme de croissant dans lequel les roches du groupe de Sherridon ont été préservées. L'assemblage actuel des minéraux peut s'être amorcé dès la première période de plissement et avoir persisté au cours des seconde et troisième périodes. Le degré de métamorphisme est uniforme et correspond au faciès amphibolite supérieure.

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.

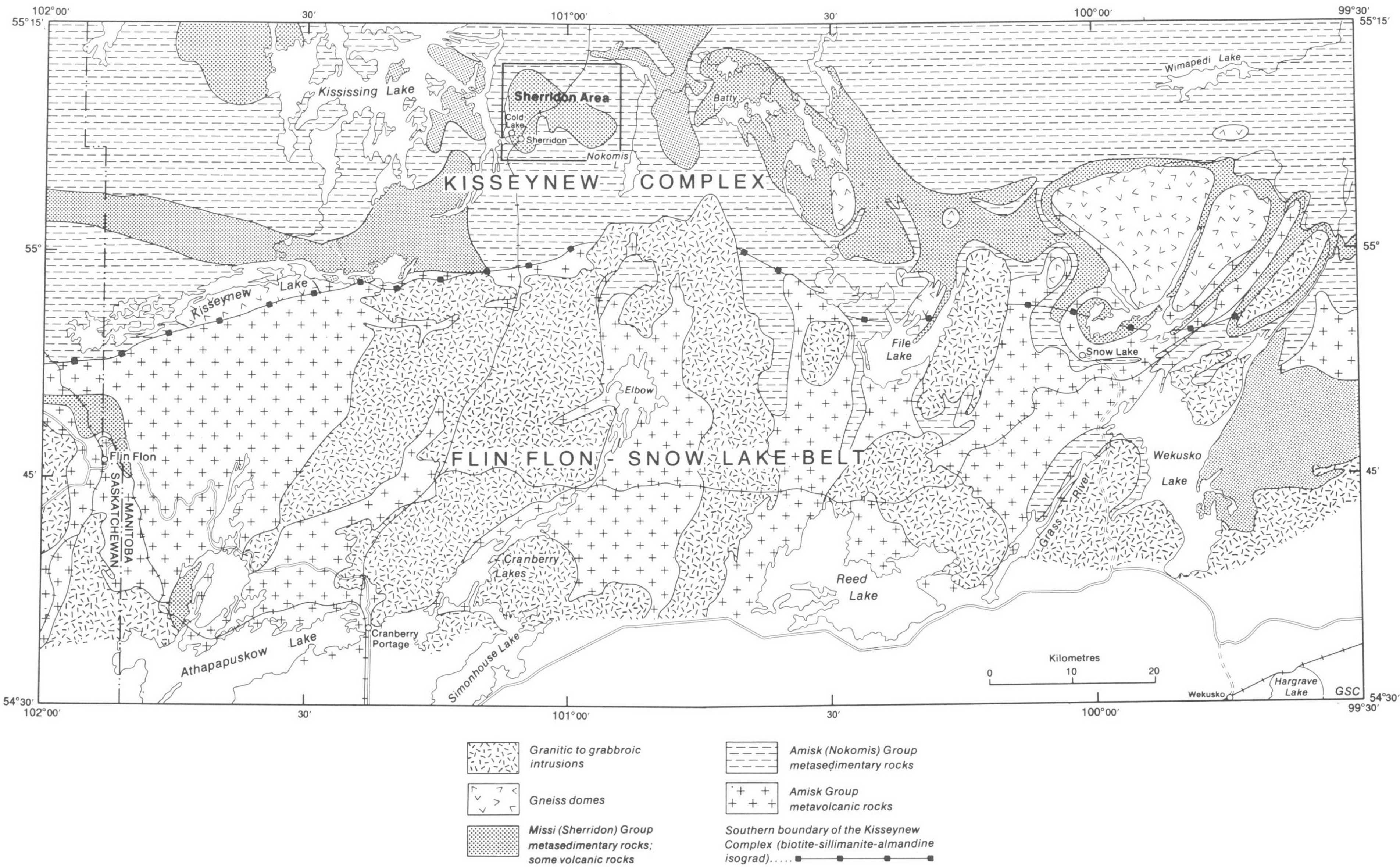


Figure 1. *Location and setting of the Sherridon area.*

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).

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). Wright in particular referred to the transitional contact between Amisk rocks and overlying Kisseynew sedimentary gneisses. However, he included some sediments in the Amisk Group and Wright and Stockwell (1934) specifically assigned the Lower Missi series of Bruce (1918) to the Amisk Group (which they called Wekusko Group). Byers and Dahlstrom (1954) retained this stratigraphic division. 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 led 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, 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, 1980; Froese and Moore, 1980).

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 these 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, 1964; Goetz, 1980), and could be the metamorphic equivalents of cross-bedded arenites of the Missi Group in the

Table 1. Stratigraphic subdivisions of the Flin Flon region

<table>
<tr><th colspan="2">Bruce (1918)</th><th colspan="2">Byers and Dahlstrom (1954)</th><th colspan="2">Bailes (1971)</th></tr>
<tr><th>Flin Flon belt</th><th>Kisseynew Complex</th><th>Flin Flon belt</th><th>Kisseynew Complex</th><th>Flin Flon belt</th><th>Kisseynew Complex</th></tr>
<tr><td>Upper Missi series</td><td rowspan="2"></td><td>Missi Group</td><td rowspan="3">Kisseynew gneisses</td><td>Missi Group</td><td>Sherridon Group</td></tr>
<tr><td>Lower Missi series</td><td rowspan="2">Amisk Group; volcanic and sedimentary rocks</td><td rowspan="2">Amisk Group</td><td rowspan="2">Nokomis Group</td></tr>
<tr><td>Amisk series</td><td>Kisseynew gneisses</td></tr>
</table>

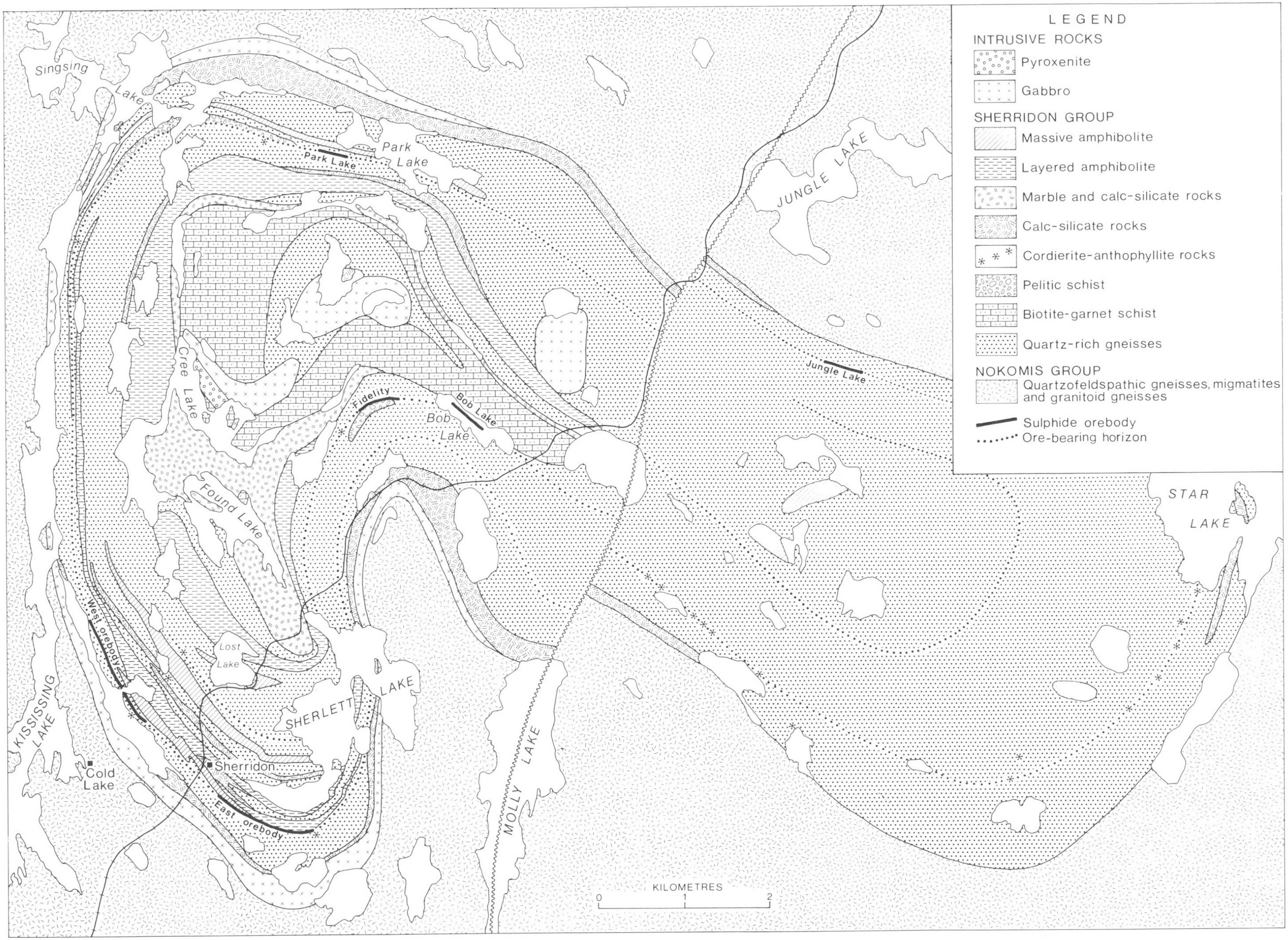


Figure 3. *Geological sketch map of the Sherridon area.*

Flin Flon area. In the Missi Group, volcanic rocks have been reported only in the area east of Wekusko Lake (Frarey, 1950; Shanks and Bailes, 1977) and, in the Sherridon Group, they are generally also of rare occurrence. 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 except in the area east of Wekusko Lake (Bailes, 1976, pers. comm. 1980). 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 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.

Rubidium-strontium isochrons and model lead dates indicate an Aphebian age for rocks of the Flin Flon-Snow Lake belt and for 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 the other from a less pelitic sequence of unknown origin. Much 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 two 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 Figures 2 and 3. In Table 2, average compositions of several lithologic units are listed; individual analyses are available from the authors.

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 predominate in the Nokomis Group. In addition to gneissic structure, the rocks locally have a compositional layering 10 to 100 cm wide, defined by slight variations in biotite content. Mineralogically the gneisses are simple. They consist of quartz, oligoclase-andesine (An_{28-36}), biotite, 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 per cent granitic segregations. Ptygmatic folds are very common in the migmatites.

In some areas a coarsening of grain size and loss of compositional layering indicates gradation of paragneisses 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 into foliated granite (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 the presence of some lime-rich, clinopyroxene-bearing layers.

Sherridon Group

Several lithologies are recognized in the Sherridon Group (Table of Formations). Alternations of rock units are common (see Fig. 2 and 3). No repetition of units by folding was observed and it is assumed, therefore, that the strata become progressively younger from the edge to the centre of the Sherridon structural basin. The Sherridon Group has been subdivided into five stratigraphic units, with age decreasing in the sequence A to E, as shown in the stratigraphic column (Fig. 4). Zoning in the west orebody supports this facing direction. Lithologic units are subparallel to the base of the Sherridon Group. Therefore, the base is thought to be a 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}), K-feldspar, 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 to 30 cm. 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 crossbedding 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, greywacke, and arkose (Fig. 5). It is likely that the precursor of the quartz-rich gneiss was a lithic arenite, similar to the Missi sandstone near Flin Flon, which consists largely of quartz grains and lithic fragments (Mukherjee, 1974; Stauffer, 1974).

A grey, fine grained, biotite-garnet schist (3), having the composition of greywacke (Fig. 5), 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. Unit (3) was mapped as part of the "Pre-Sherridon" Group by Bateman and Harrison (1946); 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 are biotite-rich (about 30 per cent 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 with garnet and anthophyllite crystals up to 10 cm in size. Quartz and biotite are other characteristic constituents, and 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 lower ore-bearing horizon, in a few places below the sulphide layer but more commonly along unmineralized sections of the horizon. The composition of these rocks requires 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 to 10 cm which is accentuated by differential weathering. Their mineralogical composition is variable. Nearly all contain

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 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 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	74.39	62.47	52.07	52.12	44.65
TiO_2	0.21	0.63	0.56	0.64	2.32
Al_2O_3	12.08	16.67	16.09	15.72	15.57
Fe_2O_3	0.36	0.63	1.84	3.08	3.13
FeO	3.10	5.73	9.25	9.33	12.82
MnO	0.09	0.08	0.19	0.21	0.26
MgO	1.62	2.87	5.43	5.37	6.07
CaO	2.50	3.69	8.86	8.95	9.36
Na_2O	1.74	2.47	2.56	1.94	1.75
K_2O	2.34	2.24	0.60	0.47	0.37
P_2O_5	0.08	0.51	0.14	0.15	0.26
CO_2	0.50	0.23	1.17	0.81	1.62
H_2O	1.05	1.13	1.49	1.27	1.60
Standard deviation					
SiO_2	2.16	0.47	1.65	2.33	4.20
TiO_2	0.06	0.12	0.08	0.07	0.73
Al_2O_3	1.13	0.53	1.17	0.65	1.39
Fe_2O_3	0.43	0.33	0.95	0.91	1.23
FeO	0.99	0.12	1.00	0.72	2.46
MnO	0.04	0.01	0.03	0.02	0.05
MgO	0.60	0.12	0.75	0.99	0.54
CaO	0.63	0.39	1.30	0.74	0.82
Na_2O	0.77	0.74	0.93	0.65	0.83
K_2O	0.84	0.14	0.15	0.14	0.05
P_2O_5	0.02	0.13	0.09	0.05	0.06
CO_2	0.33	0.17	0.63	0.84	0.94
H_2O	0.31	0.25	0.36	0.32	0.34
Number of samples	25	3	15	11	6

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. In one sample, chromite, Cr-bearing muscovite, and grossularite have been identified. Cr-bearing grossularite in calc-silicate rocks has been reported previously by Viswanathiah et al. (1979) and Ashton (1979). 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, it displays layering and includes felsic fragments. It is a dark grey, fine- to medium-grained rock with somewhat larger crystals of hornblende and garnet and granoblastic aggregates of quartz, andesine, hornblende, and garnet with a trace of biotite. Cummingtonite is present in some specimens and, more rarely, also anthophyllite. 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 nonvolcanic, 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 composition (Table 2) which probably still reflects the composition of the parent magma. Consequently, chemical analyses have been 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. 6). According to the classification of Pearce (1976), based on discriminant functions, the rocks from unit (7) are island arc low-K tholeiites.

Massive, fine- to medium-grained amphibolite (8), is interlayered with quartz-rich gneisses. It consists of quartz, andesine, hornblende, and garnet. 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 (Fig. 6). The high-TiO_2 basalts are found mainly in the lower part of the Sherridon Group. Small layers of amphibolite (8) typically occur in the calc-silicate rocks at the base of the Sherridon succession. Pillow-like structures, previously described by Bateman and Harrison (1946), have been observed locally. Bands 1 to 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.

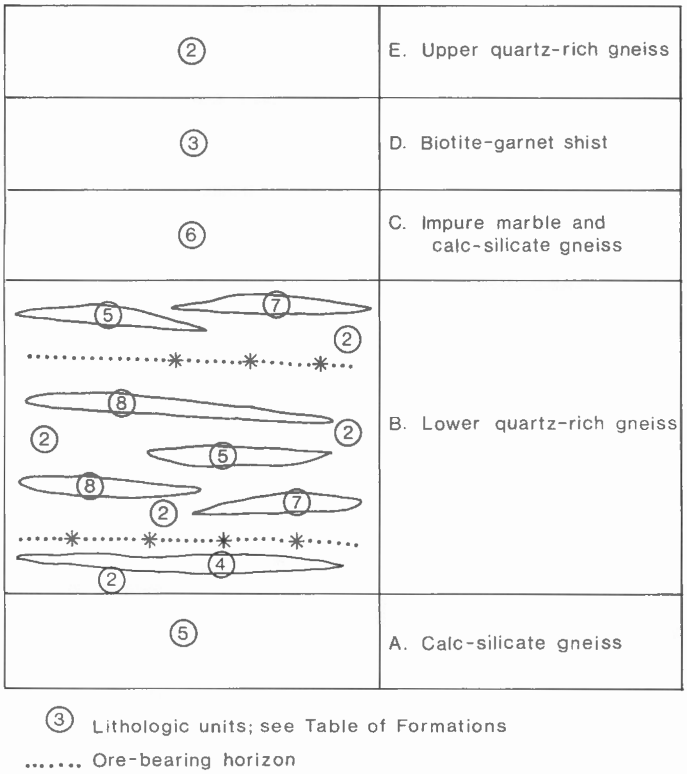


Figure 4. *Stratigraphic column of the Sherridon Group.*

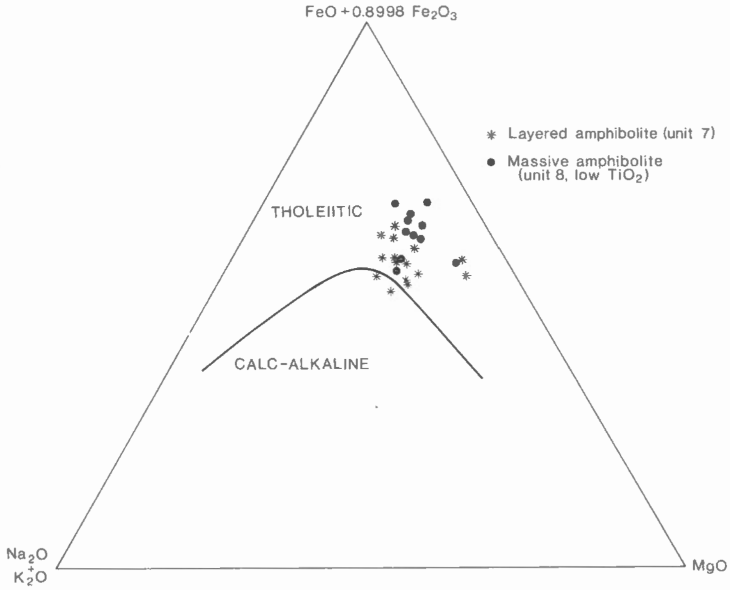


Figure 6. *Chemical classification of metavolcanic rocks.*

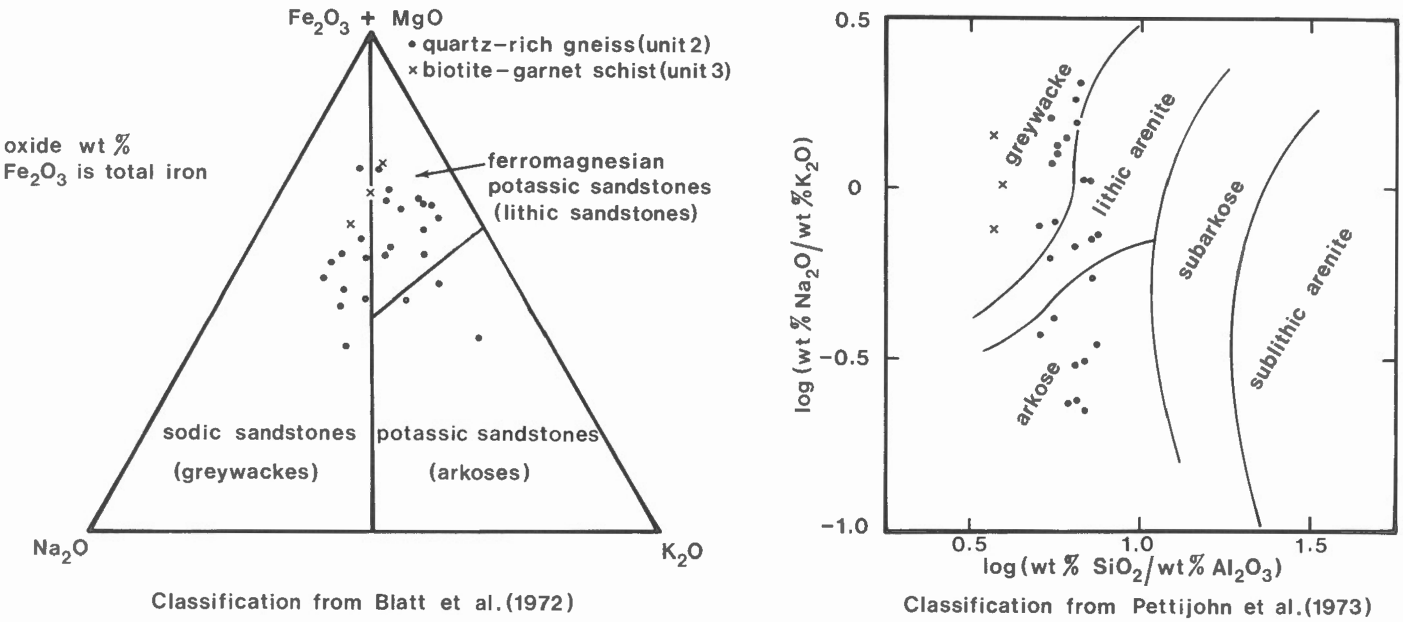


Figure 5. *Chemical classification of metasedimentary rocks.*

Intrusive Rocks

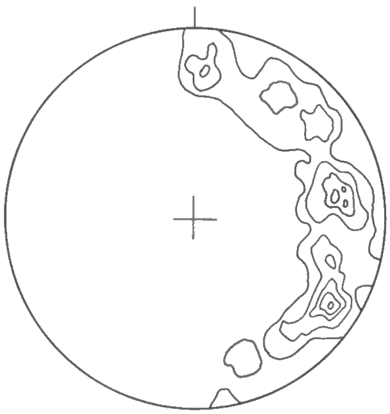
The Sherridon Group was intruded by massive to weakly foliated, medium grained gabbro (9), consisting of labradorite and hornblende, rarely accompanied by small amounts of quartz and garnet. Three small bodies of this gabbro occur in the centre of the Sherridon basin and a prominent sill is present below the base of the Sherridon succession. This sill was mapped as part of the "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 contact with the Nokomis Group 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 to 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.



62 Lineations
Contours 1.6, 4.8, 8.1, 11.3, 14.5% per 1% area

Figure 7. *Lineation in the Sherridon area.*

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 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), as noted by Pearson (1972). 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. The variable attitude of the lineation (Fig. 7) suggests a reorientation of L_2 by F_3. The shallow plunge of lineations indicates gently-plunging F_2 and F_3 folds.

Much previous controversy concerning the structure of the Sherridon area stems from ignoring the variable attitude 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 to be 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 periods 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 kilometre. Highly sheared rocks are exposed where the fault crosses the railway track south of Jungle Lake.

Table 3. Tonnage and grade of sulphide deposits (from Davies et al., 1962)

Deposit	Tonnes	%Cu	%Zn	Au g/tonne	Ag g/tonne
Sherritt Gordon*	7 739 506				
East orebody		2.14	5.78	0.65	26.1
West orebody		2.91	2.76	0.62	32.2
West orebody (low grade area)		1.40	0.80	0.41	42.0
Average		2.46	2.84	0.58	33.3
Bob Lake	2 159 098	1.33	1.18		
Jungle Lake	3 356 581	1.42	1.1		
Park Lake	confidential assessment work				
Fidelity	confidential assessment work				

* The grade is not given by Davies et al. (1962); therefore, the grade based on ore reserve calculations is given (Sherritt Gordon Mines Limited, 1930). Farley (1949) mentions an "overall average grade" of 2.45% Cu, 2.97% Zn, 0.62 g/tonne Au, and 19.9 g/tonne Ag, but it is not clear whether this refers to the Sherritt Gordon deposit as a whole or to the east orebody only.

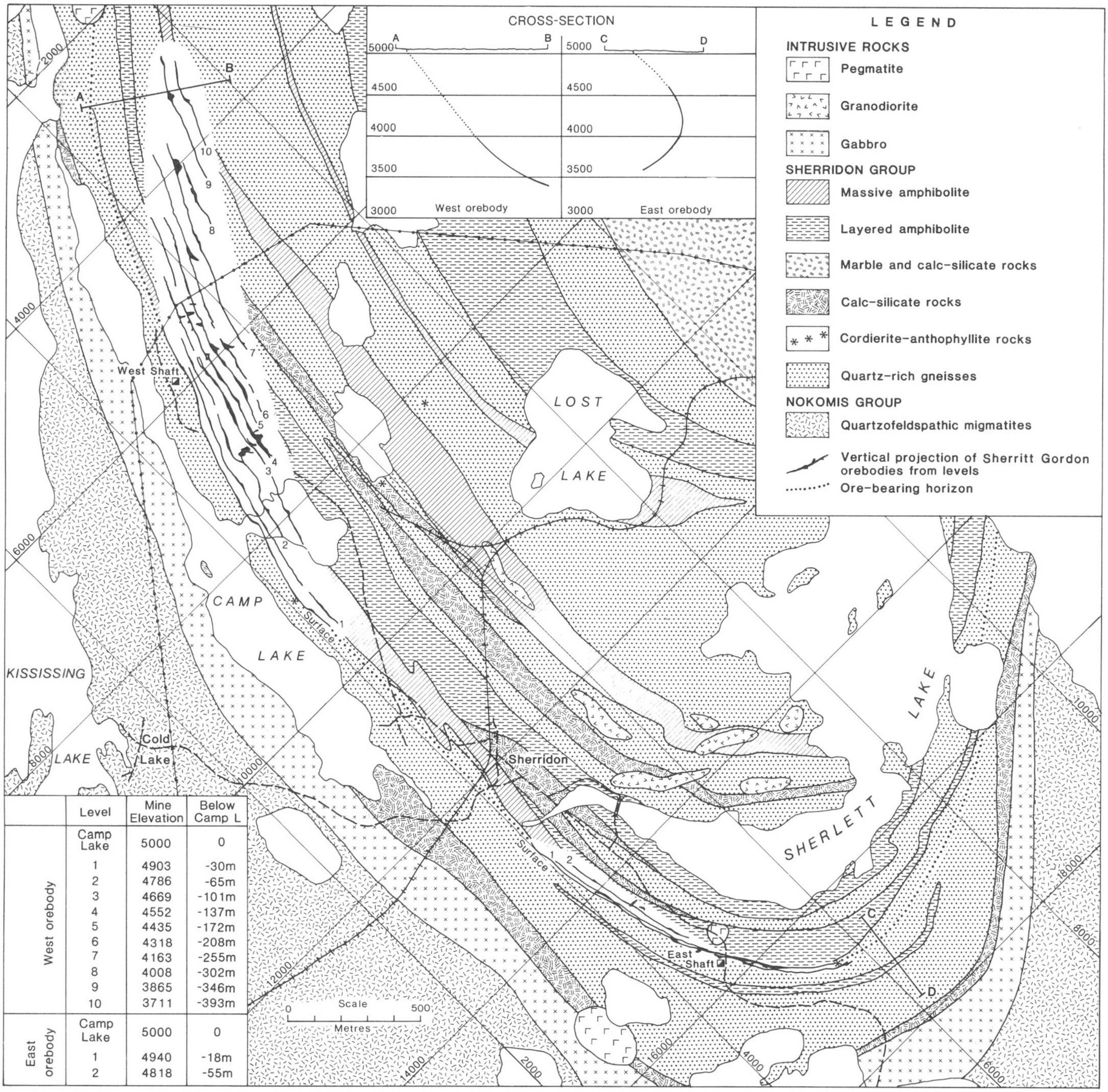


Figure 8. *Surface geology of the Sherritt Gordon deposit. Level plans compiled from unpublished maps of Sherritt Gordon Mines Limited.*

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 led 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 in the calc-silicate layer at the base of the Sherridon Group which 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 (Fig. 2 and 3). These horizons are marked by discontinuous lenses of massive sulphides and intermittent zones of disseminated sulphides.

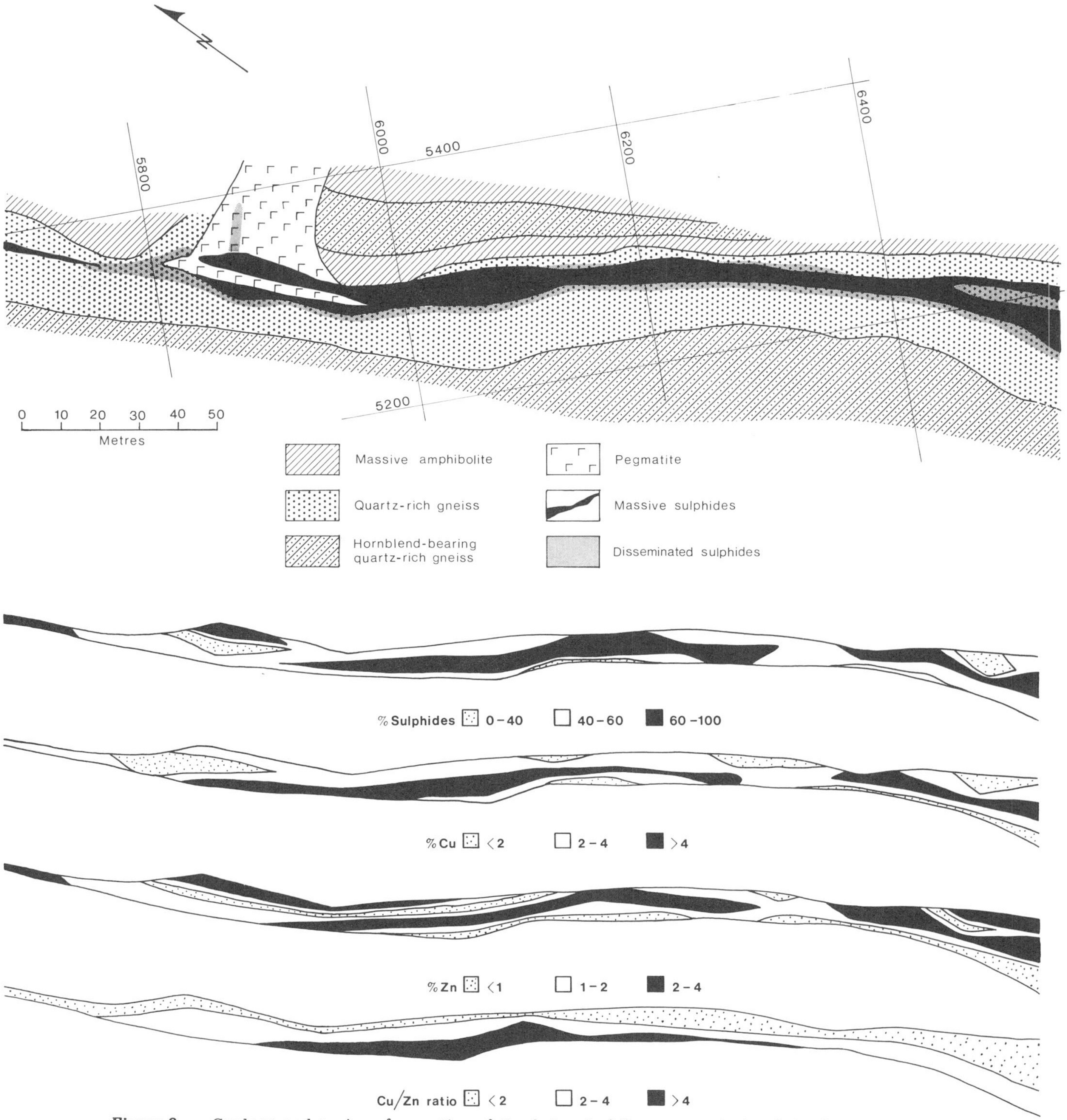


Figure 9. *Geology and zoning of a portion of the 3. level of the west orebody of the Sherritt Gordon deposit. Compiled from unpublished information of Sherritt Gordon Mines Limited.*

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 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 anthophyllite rocks near Elken Lake. Chalcopyrite and sphalerite were reported by Wright (1929) to occur in this showing. The ore horizon presumably 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.

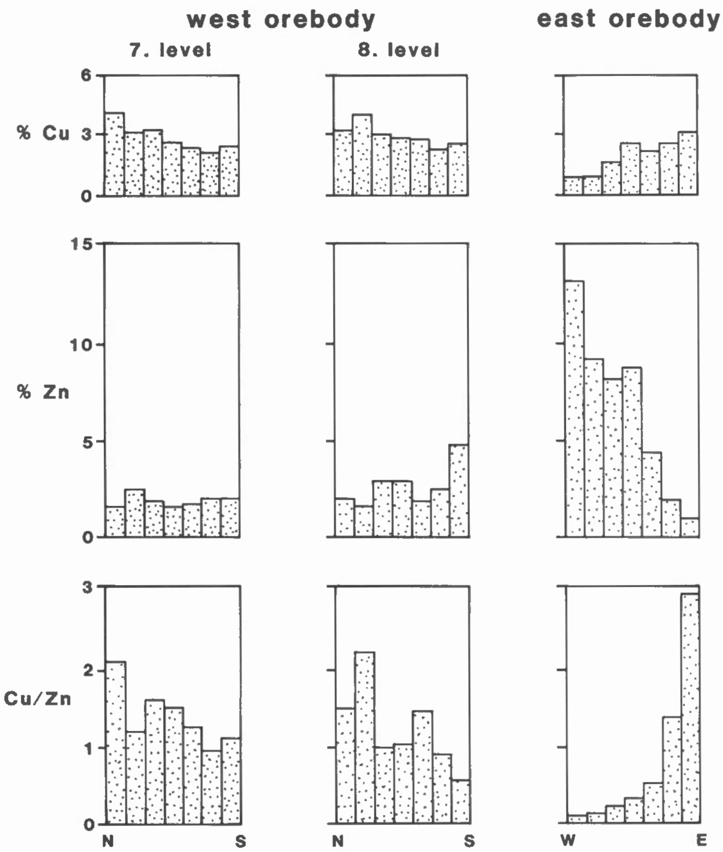


Figure 10. *Lateral zoning of the Sherritt Gordon deposit. Compiled from unpublished ore reserve estimates of Sherritt Gordon Mines Limited.*

The Sherritt Gordon orebodies and host rocks have been described in a paper by the staff of Sherritt Gordon Mines Limited (1930) and by Wright (1929, 1931a), Bruce (1929, 1933), Bruce and Matheson (1930), Derry (1942) and Farley (1948, 1949). The surface geology and the vertical projections of orebodies from mine levels are shown in Figure 8. The orebodies occur as tabular masses of sulphides about 5 m thick and as irregular remobilized masses (offshoot 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 to 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 which is marked by disseminated sulphides. However, level plans commonly show disseminated sulphides on both sides of the orebody (Fig. 9). According to assay plans of one level, the west orebody displays stratigraphic zoning with the Zn/Cu ratio increasing towards the centre of the Sherridon basin (Fig. 9). 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 pronounced lateral zoning in the east orebody, and weak zoning in the west orebody (Fig. 10).

The mineralogy of the ores is simple and consists 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, has 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 main ore horizon is underlain, in part, by pelitic rocks marking a break in coarse clastic sedimentation. In order to account for the formation of a massive sulphide deposit, two methods of transport of metals have been suggested. Metals could be carried dissolved in hot brines (Large, 1977; Turner and Gustafson, 1978; Goetz, 1980) or sulphides could be transported as suspended particles in a gravity flow (Schermerhorn, 1970; Henley and Thornley, 1979). 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). In the Sherridon area, however the altered rocks do not represent channelways but more likely altered material deposited on the seafloor, as suggested by Wilkinson (1976), Schermerhorn (1978) and Warren (1979). The detritus of hydrothermally altered rocks could have been carried either as a suspension in brine (Wilkinson, 1976; Goetz, 1980) or as a sediment gravity flow (Middleton and Hampton, 1976).

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 the first phase of deformation but continued to recrystallize during the second and third phases 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

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

$K = K_2O \cdot Al_2O_3$

$F = FeO - (Fe_2O_3 + TiO_2)$

$M = MgO$

Table 4. Metamorphic mineral assemblages

	qz	pl	kf	bi	si	at	alm	hb	cum	co	cpx
Quartzofeldspathic and pelitic gneiss; amphibolites	x	x		x							
	x	x		x			x				
	x	x		x		x					
	x	x		x	x						
	x	x		x	x		x				
	x	x		x					x		
	x	x		x			x		x		
	x	x		x		x	x	x	x		
	x	x		x				x	x		
	x	x		x			x	x	x		
	x	x		x			x	x			
	x	x		x				x			
	x	x						x			
	x	x					x	x			
	x	x	x	x							
	x	x	x	x				x			
	x	x	x	x			x				
	x	x	x	x			x	x			
	x	x	x	x	x						
Cordierite-anthophyllite rocks	x			x	x		x			x	
	x			x		x	x			x	
	x			x		x				x	
Calc-silicate rocks	x	x		x							x
	x	x		x			x	x			x
	x	x		x			x				x
	x	x						x			x
	x	x					x	x			x
	x	x	x	x			x	x			
	x	x	x								x
	x	x	x					x			x
	x	x	x	x				x			x
	x	x	x	x			x	x			x

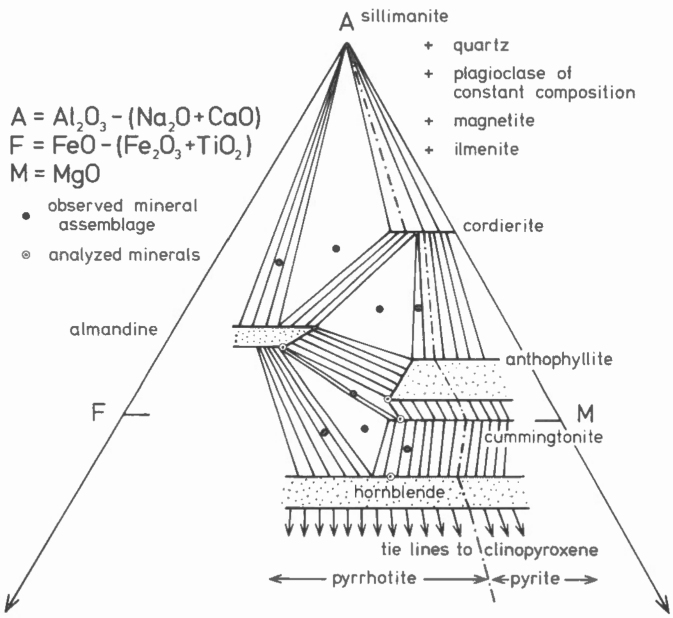


Figure 11. *Mineral assemblages shown on an AFM diagram.*

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 Figure 11. 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. Sapphirine has been reported from other metamorphosed sulphide deposits (Raymond et al., 1980). Gahnite is present in a few ore specimens; analyses of gahnite and coexisting biotite are given in Table 6. Analyses of Cr-bearing minerals from an impure marble are given in Table 7. Coexisting biotite, almandine, cummingtonite, hornblende, and anthophyllite from one specimen have been analyzed (Table 8); these compositions (except that of biotite) are plotted in Figure 11. The AFM diagram has been completed schematically according to observed assemblages. Mineral assemblages in biotite-bearing assemblages are shown in Figure 12.

Metamorphic Conditions

In Figure 13, a path of metamorphism for the Sherridon area is shown reaching a peak at 5 kb and 660°C, a temperature somewhat above the decomposition curve of

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	0.30	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	98.44	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 a sulphide ore sample (FQG-O3)

	biotite	gahnite
SiO_2	37.46	0.41
TiO_2	2.30	-
Al_2O_3	16.60	57.33
FeO	14.18	9.37
MnO	0.23	0.19
ZnO	-	30.34
MgO	14.81	2.05
CaO	0.02	-
Na_2O	0.47	-
K_2O	9.30	-
Total	95.37	99.69

Total iron expressed as FeO.

Mineral assemblage: quartz, plagioclase (An_{28-45}), biotite, gahnite, chalcopyrite, pyrrhotite ($Fe_{0.938}S$), sphalerite ($Zn_{0.855}$ $Fe_{0.145}S$).

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

Table 7. Composition of minerals from an impure marble (Specimen FQG-C3)

	grossularite	muscovite	chromite
SiO_2	38.07	45.98	0.81
TiO_2	0.37	0.19	0.08
Al_2O_3	11.37	27.09	9.39
Cr_2O_3	12.24	5.35	50.41
V_2O_3	-	-	5.46
FeO	1.73	1.49	22.00
MnO	0.90	-	0.84
ZnO	-	-	8.84
MgO	0.82	3.80	1.09
CaO	34.36	0.21	0.12
Na_2O	-	0.48	-
K_2O	-	11.18	-
Total	99.86	95.77	99.04

Total iron expressed as FeO.

Mineral assemblage: quartz, plagioclase (An_{22-70}), calcite, tremolite, sphene, apatite, grossularite, muscovite, chromite, pyrrhotite ($Fe_{0.879}S$).

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

Table 8. 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.

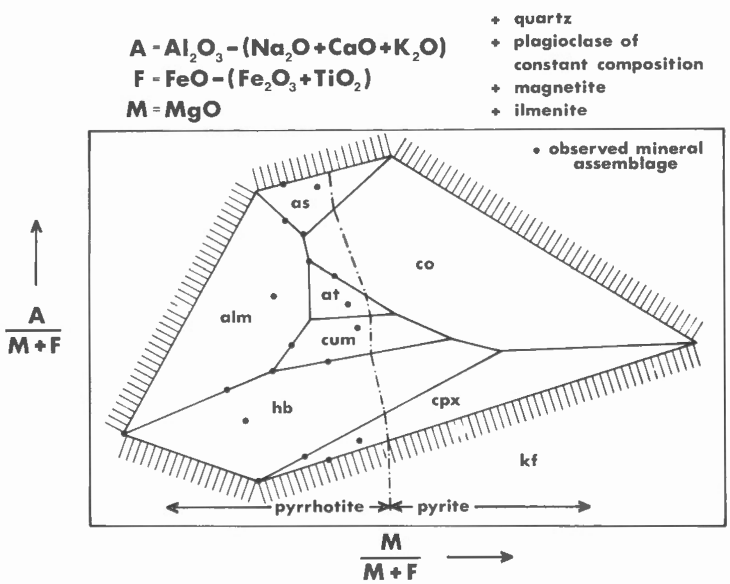


Figure 12. Mineral assemblages shown on the biotite composition surface.

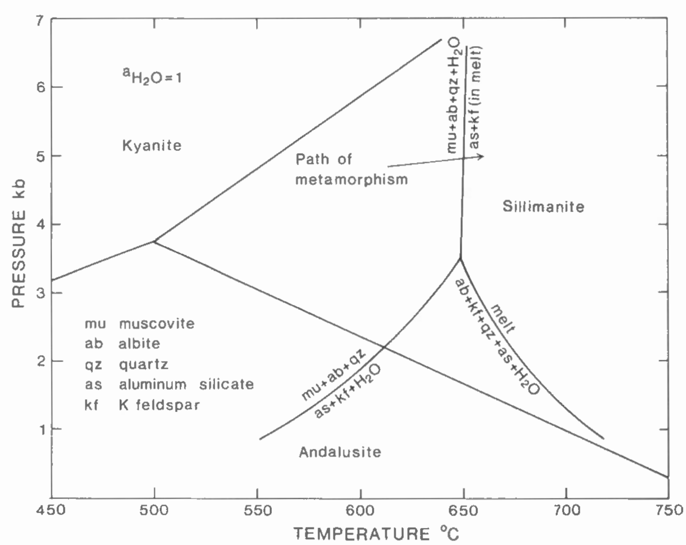


Figure 13. Petrogenetic grid for pelitic rocks.

muscovite in the presence of quartz and albite. The stability fields of the aluminum silicate polymorphs have been taken from Holdaway (1971) and the other reaction curves from Thompson and Algor (1977). 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 sphalerites re-equilibrate during quenching (Bristol, 1979).

An uncalibrated grid covering the pressure-temperature region in the vicinity of peak metamorphic conditions is shown in Figure 14. As indicated, some reactions have been taken from Froese and Jen (1979) and Froese (1980) and others from an unpublished grid constructed by D.M. Carmichael. Reactions not involving muscovite in Carmichael's grid are the same as in a grid published by Korikovskii (1970). Comparison with Figure 12 indicates that most assemblages from the Sherridon area fall into a pressure-temperature field immediately to the left of the invariant point cummingtonite-almandine-hornblende-

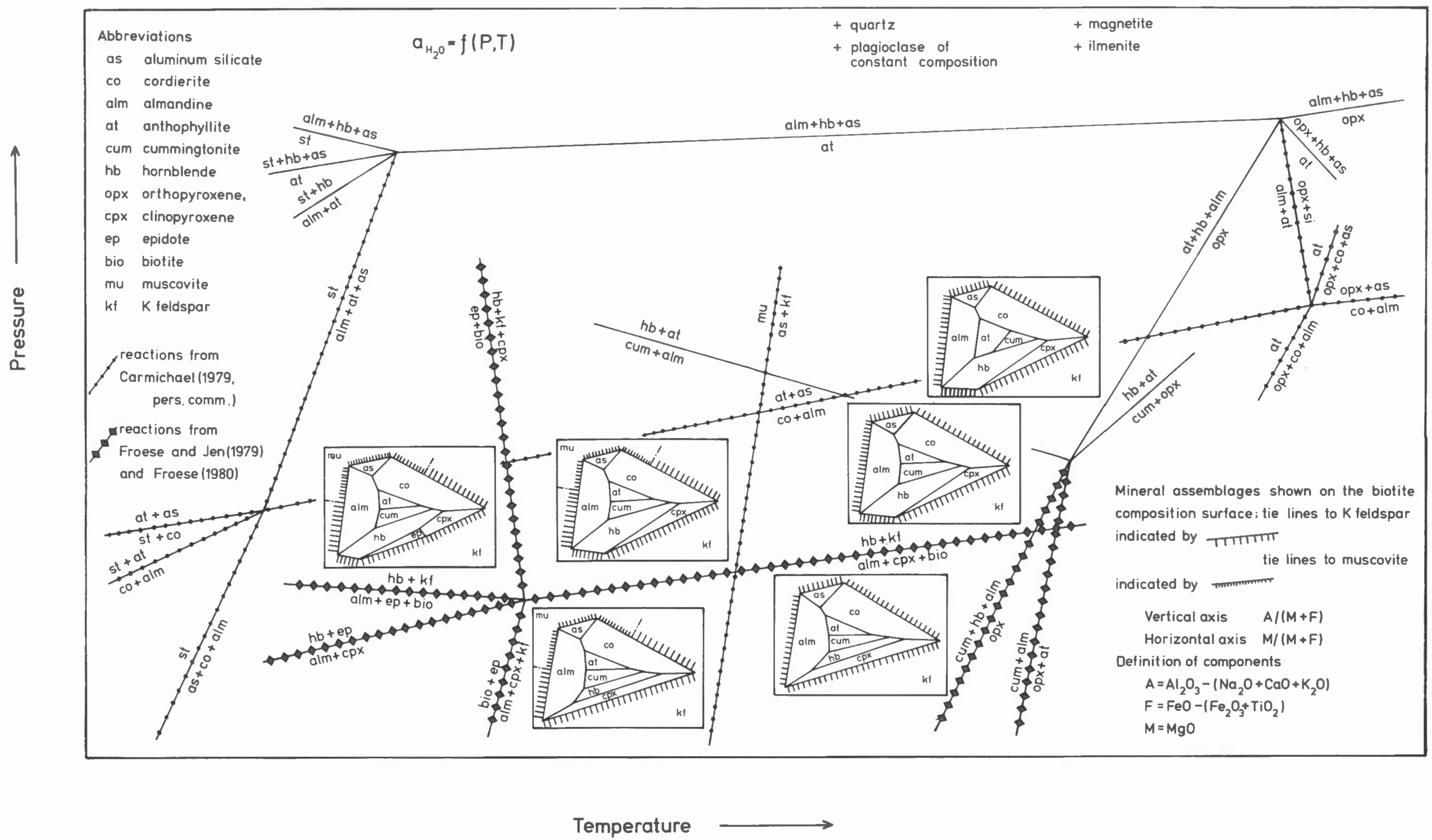


Figure 14. *Petrogenetic grid for pelitic and mafic rocks.*

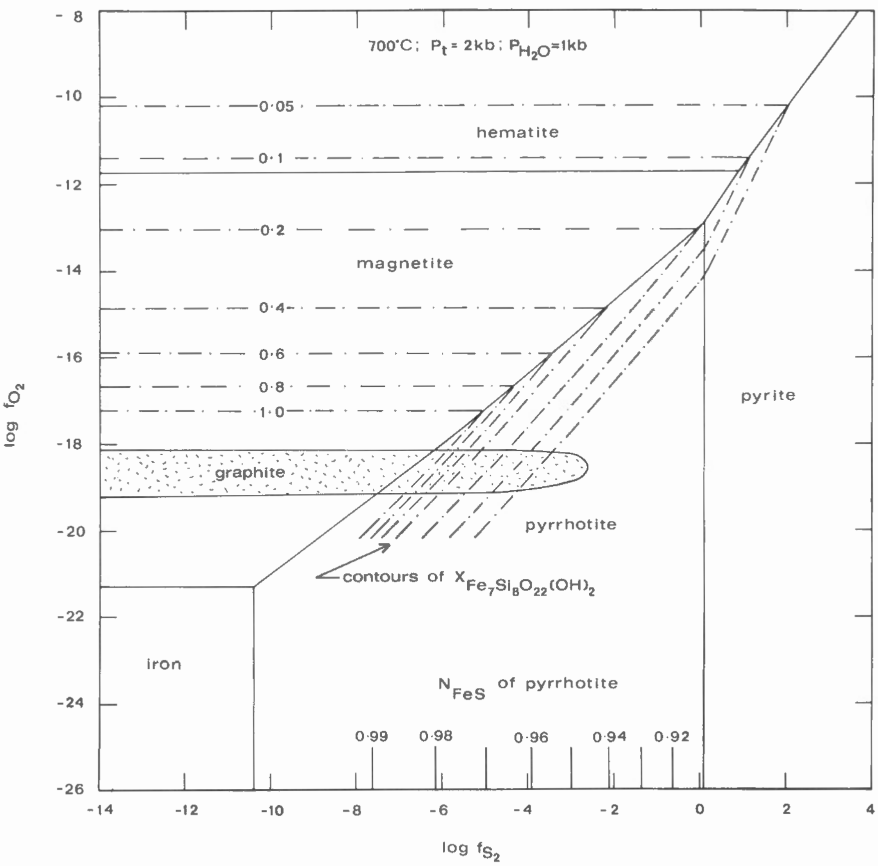


Figure 15. *The stability of iron oxides, iron sulphides, and graphite.*

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

cummingtonite + almandine + plagioclase + H_2O
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
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 fO_2 vs. log fS_2 diagram (Fig. 15). The diagram reproduced in Figure 15 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). Similarly, the biotite composition surface can be divided into two fields (Froese and Moore, 1980). In Figures 11 and 12, the pyrite-pyrrhotite boundary is shown diagrammatically. Magnetite is absent from 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 fO_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 Figure 15, 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 sum 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 Figures 11 and 12. 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 as a retrograde mineral during cooling.

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.

ACKNOWLEDGMENTS

Field work was aided by information and assistance received from Mr. W. Shmon of Sherridon. We are very grateful to Sherritt Gordon Mines Limited and Hudson Bay Exploration and Development Limited for giving us access to their geological information about the Sherridon area. In particular, Sherritt Gordon Mines Limited provided us with maps and assay plans of the former Sherritt Gordon mine in Sherridon. In the field we were ably assisted by D.K. Webster and S.J. Wilkinson in 1975 and by H.E. Jamieson and J.L. Coppelmans in 1976. We benefitted from discussions with A.H. Bailes, D.A. Baldwin, J.M. Franklin, R.K. Herd, J. Langelaar, W.D. McRitchie, J.M. Moore, D.F. Sangster, and H.V. Zwanzig.

REFERENCES

Ashton, K.E.
1979: The geology of the Milton Island map sheet (east half), Saskatchewan; unpublished M.Sc. thesis, University of Saskatchewan, Saskatoon.

Bailes, A.H.
1971: Preliminary compilation of the geology of the Snow Lake – Flin Flon-Sherridon area; Manitoba Mines Branch, Geological Paper 1/71.

1975: Geology of the Guay-Wimapedi Lakes area; Manitoba Mineral Resources Division; Publication 75-2.

1976: Saw Lake area; Manitoba Mineral Resources Division, Report of Field Activities 1976, p. 45-50.

1980: Geology of the File Lake area; Manitoba Mineral Resources Division, Geological Report 78-1.

Bateman, J.D.
1944: Sherritt Gordon mine area, Manitoba; Geological Survey of Canada, Paper 44-4.

Bateman, J.D. and Harrison, J.M.
1946: Sherridon, Manitoba; Geological Survey of Canada, Map 862A.

Blatt, H., Middleton, G.V., and Murray, R.
1972: Origin of sedimentary rocks; Prentice-Hall, Englewood Cliffs.

Bristol, C.C.
1979: Application of sphalerite geobarometry to ores from the Ruttan mine; Economic Geology, v. 74, p. 1496-1503.

Bruce, E.L.
1918: Amisk-Athapapuskow Lake district; Geological Survey of Canada, Memoir 105.

1929: The Sherritt Gordon copper-zinc deposit, northern Manitoba; Economic Geology, v. 24, p. 457-469.

1933: Mineral deposits of the Canadian Shield; The MacMillan Company of Canada Limited, Toronto.

Bruce, E.L. and Matheson, A.F.
1930: The Kisseynew gneiss of northern Manitoba and similar gneisses occurring in northern Saskatchewan; Royal Society of Canada Transactions, v. 24, section 4, p. 119-132.

Byers, A.R. and Dahlstrom, C.D.A.
1954: Geology and mineral deposits of the Amisk-Wildnest Lakes area, Saskatchewan; Saskatchewan Department of Mineral Resources, Report 14.

Davies, J.F., Bannatyne, B.B., Barry, G.S., and McCabe, H.R.
1962: Geology and mineral resources of Manitoba; Manitoba Mines Branch.

Derry, D.R.
1942: The Sherritt-Gordon mine; in Ore deposits as related to structural features, ed. W.H. Newhouse, Princeton University Press, Princeton, p. 15.

Eugster, H.P. and Skippen, G.B.
1967: Igneous and metamorphic reactions involving gas equilibria; in Researches in geochemistry, ed. P.H. Abelson, John Wiley, New York, v. 2, p. 492-520.

Farley, W.J.
1948: Sherritt Gordon mine; in Structural geology of Canadian ore deposits, Canadian Institute of Mining and Metallurgy, Montreal, p. 292-295.

1949: Geology of the Sherritt Gordon orebody; Canadian Mining and Metallurgical Bulletin, v. 42, p. 25-30.

Frarey, M.J.
1950: Crowduck Bay, Manitoba; Geological Survey of Canada, Map 987A.

Froese, E.
1969: Metamorphic rocks of the Coronation mine and surrounding area; Geological Survey of Canada, Paper 68-5, p. 55-77.

1976: Applications of thermodynamics in metamorphic petrology; Geological Survey of Canada, Paper 75-43.

1977: Oxidation and sulphidation reactions; Mineralogical Association of Canada, Short Course Handbook, v. 2, p. 84-98.

1978: The graphical representation of mineral assemblages in biotite-bearing granulites; in Current Research, Part A, Geological Survey of Canada, Paper 78-1A, p. 323-325.

1980: A reaction grid for medium grade mafic rocks; in Current Research, Part A, Geological Survey of Canada, Paper 80-1A, p. 53-55.

Froese, E. and Jen, L.S.
1979: A reaction grid for biotite-bearing mafic granulites; in Current Research, Part A, Geological Survey of Canada, Paper 79-1A, p. 83-85.

Froese, E. and Moore, J.M.
1980: Metamorphism in the Snow Lake area, Manitoba; Geological Survey of Canada, Paper 78-27.

Goetz, P.A.
1980: Depositional environment of the Sherridon Group and related mineral deposits near Sherridon, Manitoba; unpublished Ph.D. thesis, Carleton University, Ottawa.

Harrison, J.M.
1951a: Possible major structural control of ore deposits, Flin Flon-Snow Lake mineral belt, Manitoba; Canadian Mining and Metallurgy Institute, Transactions, v. 54, p. 4-8.

1951b: Precambrian correlation and nomenclature, and problems of the Kisseynew gneisses in Manitoba; Geological Survey of Canada, Bulletin 20.

Henley, R.W. and Thornley, P.
1979: Some geothermal aspects of polymetallic massive sulfide formation: Economic Geology, v. 74, p. 1600-1612.

Holdaway, M.J.
1971: Stability of andalusite and the aluminum silicate phase diagram; American Journal of Science, v. 271, p. 97-131.

Irvine, T.N. and Baragar, W.R.A.
1971: A guide to the chemical classification of the common volcanic rocks; Canadian Journal of Earth Sciences, v. 8, p. 523-548.

Kalliokoski, J.
1953: Interpretations of the structural geology of the Sherridon-Flin Flon region, Manitoba; Geological Survey of Canada, Bulletin 25.

Korikovskii, S.P.
1970: The influence of depth on the parageneses of K_2O-undersaturated alumina-rich metapelites; Contributions to Physico-Chemical Petrology, v. 2, p. 59-87, Nauka Press, Moscow. (Translation available in library of Geological Survey of Canada, Ottawa.)

Kornik, L.J.
1968: Geology of the Guay Lake area (west half); Manitoba Mines Branch, Publication 64-6.

Large, R.R.
1977: Chemical evolution and zonation of massive sulfide deposits in volcanic terrains; Economic Geology, v. 72, p. 649-572.

Middleton, G.V. and Hampton, M.A.
1976: Subaqueous sediment transport and deposition by sediment gravity flows; in Marine sediment transport and environmental management, ed. D.J. Stanley and D.J.P. Swift, p. 197-218.

Miyashiro, A.
1964: Oxidation and reduction in the earth's crust with special reference to the role of graphite; Geochimica et Cosmochimica Acta, v. 28, p. 717-729.

Mukherjee, A.C.
1974: Some aspects of sedimentology of the Missi Group and its environment of deposition; Canadian Journal of Earth Sciences, v. 11, p. 1018-1019.

Pearce, J.A.
1976: Statistical analysis of major element patterns in basalt; Journal of Petrology, v. 17, p. 15-43.

Pearson, D.E.
1972: The location and structure of the Precambrian Kisseynew gneiss domain of northern Saskatchewan; Canadian Journal of Earth Sciences, v. 9, p. 1235-1249.

Pettijohn, F.J., Potter, P.E., and Siever, R.
1973: Sand and sandstones; Springer-Verlag, New York.

Pollock, G.D.
1964: Geology of the Duval Lake area; Manitoba Mines Branch, Publication 61-6.

1965: Geology of the Russick Lake area; Manitoba Mines Branch, Publication 63-2.

Popp, R.K., Gilbert, M.C., and Craig, J.R.
1977: Stability of Fe-Mg amphiboles with respect to sulfur fugacity; American Mineralogist, v. 62, p. 13-30.

Ramsay, J.G.
1967: Folding and fracturing of rocks; McGraw-Hill Book Company, New York.

Raymond, W.H., Leiggi, P.A., and Sheridan, D.M.
1980: Sapphirine in Precambrian rocks associated with stratabound sulfide deposits, Custer County, Colorado; United States Geological Survey, Bulletin 1513.

Robertson, D.S.
1951: The Kisseynew lineament, northern Manitoba; The Precambrian, v. 24, p. 8-11, 13, 23.

1953: Batty Lake map-area, Manitoba; Geological Survey of Canada, Memoir 271.

Sangster, D.F.
1978: Isotopic studies of ore-leads of the circum-Kisseynew volcanic belt of Manitoba and Saskatchewan; Canadian Journal of Earth Sciences, v. 15, p. 1112-1121.

Sangster, D.F. and Scott, S.D.
1976: Precambrian, strata-bound, massive Cu-Zn-Pb sulfide ores of North America; in Handbook of Strata-bound and Stratiform Ore Deposits, ed. K.H. Wolf, Elsevier Scientific Publishing Company, Amsterdam, v. 6, p. 129-222.

Schermerhorn, L.J.G.
1970: The deposition of volcanics and pyritite in the Iberian pyrite belt; Mineralium Deposita, v. 5, p. 273-279.

1978: Epigenetic magnesium metasomatism or syngenetic chloritite metamorphism at Falun and Orijarvi; Institution of Mining and Metallurgy, Transactions, section B, v. 87, p. 162-167.

Scott, S.D.
1973: Experimental calibration of the sphalerite geobarometer; Economic Geology, v. 68, p. 466-474.

Shanks, R.J. and Bailes, A.H.
1977: "Missi Group" rocks, Wekusko Lake area; Manitoba Mineral Resources Division, Report of Field Activities 1977, p. 83-87.

Sherritt Gordon Mines Limited
1930: Proposed mining and milling practice at Sherritt Gordon mine; Canadian Mining and Metallurgy, Transactions, v. 33, p. 245-271.

Stauffer, M.R.
1974: Geology of the Flin Flon area: A new look at the Sunless City; Geoscience Canada, v. 1, no. 3, p. 30-35.

Stockwell, C.H.
1950: The use of plunge in the construction of folds; Geological Association of Canada, Proceedings, v. 3, p. 97-121.

Thompson, A.B. and Algor, J.R.
1977: Model systems for anatexis of pelitic rocks. I. Theory of melting reactions in the system $KAlO_2$-$NaAlO_2$-Al_2O_3-SiO_2-H_2O; Contributions to Mineralogy and Petrology, v. 63, p. 247-269.

Tuckwell, K.
1979: Stratigraphy and mineral deposits of the Sherridon area; Manitoba Mineral Resources Division, Report of Field Activities 1979, p. 42-45.

Turner, J.S. and Gustafson, L.B.
1978: The flow of hot saline solutions from vents in the sea floor – some implications for exhalative massive sulfide and other ore deposits; Economic Geology, v. 73, p. 1083-1100.

Viswanathiah, M.N., Shankara, M.A., and Janardhan, A.S.
1979: A note on the origin of chrome grossular garnet (uvarovite) in calc-silicate from Bandihalli, Tumkur district, Karnataka; Journal of the Geological Society of India, v. 20, p. 507-511.

Warren, R.G.
1979: Sapphirine-bearing rocks with sedimentary and volcanogenic protoliths from the Arunta Block; Nature, v. 278, p. 159-161.

Whitmore, D.R.E.
1969: Geology of the Coronation copper deposit; Geological Survey of Canada, Paper 68-5, p. 37-53.

Wilkinson, S.J.
1976: The petrography of the anthophyllite rocks at Sherridon, Manitoba; unpublished B.Sc. thesis, University of Western Ontario, London.

Wright, J.F.
1929: Kississing Lake area, Manitoba; Geological Survey of Canada, Summary Report 1928, part B, p. 73-104.

Wright, J.F. (cont.)
1930: Crystalline limestone in the Kisseynew of northern Manitoba; Canadian Mining Journal, v. 51, p. 762.

1931a: Geology and mineral deposits of a part of northwest Manitoba; Geological Survey of Canada, Summary Report 1930, Part C, p. 1-124.

Wright, J.F. (cont.)
1931b: Prospecting areas of northwest Manitoba; Canadian Institute of Mining and Metallurgy, Transactions, v. 34, p. 83-109.

Wright, J.F. and Stockwell, C.H.
1934: West half of Amisk Lake area, Saskatchewan; Geological Survey of Canada, Summary Report 1933, Part C, p. 12-22.

Note:

Reference concerning the origin of cordierite-anthophyllite rocks added in proof:

MacLean, W.H. and MacGeehan, P.J.
1976: Garon Lake mine, Matagami, Quebec; Mineral Exploration Research Institute, Department of Geological Sciences, McGill University, Montreal, Case History 76-1.