THE REGIONAL SETTING, PRIMARY MINERALOGY, AND ECONOMIC GEOLOGY OF THE NEMEIBEN LAKE ULTRAMAFIC PLUTON

A Thesis

Submitted to the Faculty of Graduate Studies and Research

in Partial Fulfilment of the Requirements

For the Degree of

Master of Science

in Geology

Department of Geological Sciences

University of Saskatchewan

by

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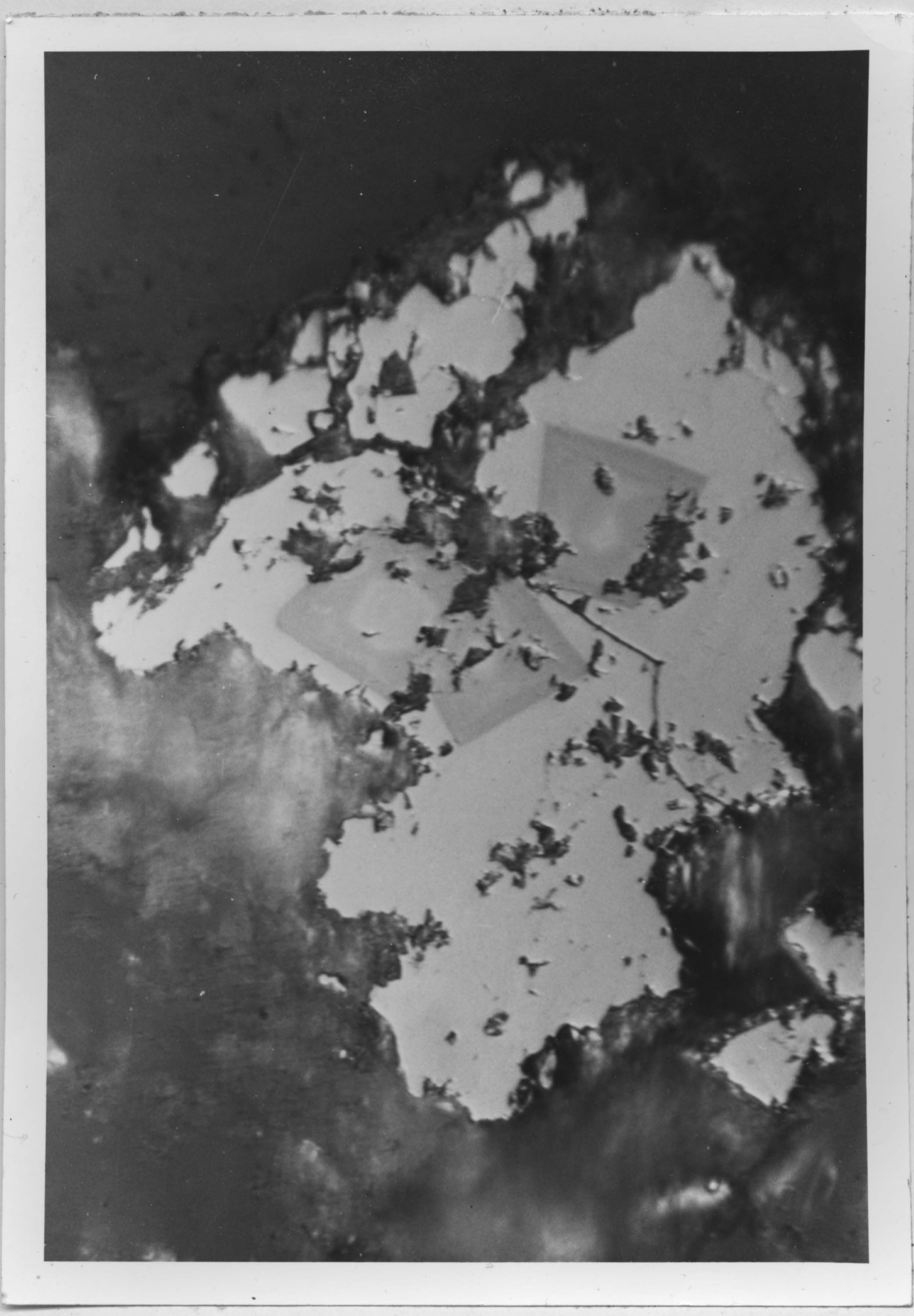
Saskatoon, Saskatchewan

November, 1978



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FRONTISPIECE: MEP2 390. Violarite and bravoite (lighter grey) alteration in pentlandite. Nicols crossed.

ABSTRACT

The Nemeiben Lake ultramafic pluton, in the Churchill Province of the Canadian Shield in central Saskatchewan, is a small 1.6 km circular plug largely composed of high alumina pyroxene cumulates forming a series of grossly concentric layers of clinopyroxenite, websterite, and wehrlite. Minor dunite and gabbro is present in the northwestern reaches of the pluton. Disseminated primary magmatic pyrrhotite, pentlandite, chalcopyrite, magnetite, and chromite occur throughout the body and reach proportions of interest to prospectors in the northern outcrops. A secondary assemblage of fine-grained oxides, sulphides, and native metals occurs in serpentinized and uralitized peridotites and pyroxenites. Primary opaque minerals are largely altered to marcasite, violarite, and haematite. The pluton intruded a supracrustal succession in the Early Aphebian before or in the early stages of the Hudsonian orogenic events. The metamorphic peak during Hudsonian time reached middle to upper amphibolite facies, granitized the country rocks, and contributed to the amphibolization of the ultramafic pluton.

The ultramafic rocks in the "La Ronge-Rottenstone" domain are largely coeval with, and related to, the La Ronge Group volcanics. The Nemeiben Lake pluton may have been part of the feeder system for Early Aphebian volcanics.

It is proposed the La Ronge and Rottenstone domains (Lewry and Sibbald 1977), are parts of the same crustal zone which is progressively exposed to deeper levels as one approaches the Needle Falls shear zone, here interpreted as the westernmost fault zone due to compressional and uplift forces caused by the closure of an ocean previously formed

between fragments of Archean crust.

The Ni-Cu prospect of the Nemeiben Lake pluton is not now economic though standard technology for recovery of sulphide minerals in pyroxenites would probably be adequate. Most base-metal minerals in the altered peridotites belong to the fine-grained secondary assemblage of opaques due to the formation of retrograde hydrous silicates and are probably too fine-grained for standard recovery methods.

ACKNOWLEDGEMENTS

Dr. D. Mossman suggested the area of study and provided some support (N.R.C. grant).

College of Graduate Studies, fellowship for the 1976-77 and 1977-78 winter sessions.

Studer Mines gave permission to work on their ground and use core samples.

Falconbridge Laboratories provided seven whole rock geochemical analyses.

Saskatchewan Research Council Geochemical Laboratory, rock crushing.

Dr. L.C. Coleman, B. Fay, electron microprobe counselling.

E. Hawkins, courteous service, beautifully executed thin, polished thin, and polished sections.

L.H. Forsythe, provided thin sections and their location.

S.L. Fumerton, normative calculations computer program, many stimulating discussions.

B. Pandit, computer debugging (microprobe and normative data), mathematical expertise.

Drs. F.F. Langford and N. Arndt, members of the advisory committee devoted much of their precious time.

Dr. C.F. Gilboy, discussions.

D. Macfarlane, junior assistant in the field, typing, and moral support.

The author takes sole responsibility for ideas and postulates contained herein, though acknowledging input from discussions and personal communications with many colleagues. The hypotheses outlined in this dissertation represent personal opinions and do not necessarily reflect opinions of authors and colleagues referred to.

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INTRODUCTION

a) Location, Form, and Accessibility

The Nemeiben Lake ultramafic pluton is located in the centre of the province of Saskatchewan within the Churchill Province of the Canadian Shield. It is 16 miles north of the town of La Ronge 55° 15' north and 105° 10' west. A pronounced aeromagnetic anomaly 800 gammas above background marks the body (figure I i). Figure I(ii) illustrates the location, accessibility, size and sub-circular form of the pluton. Using drill information and Agarwal's (1970) gravity survey (figure I iii) Cochrane and Richards (1973) infer the body is a lopolith. Dolomage Campbell and Associates (1974) suggest a laccolith.

The largest and best outcrops occur in the northern part of the body on the east shore of Nemeiben Lake. Figure I(iv) indicates the distribution of field rock types in outcrop. A nickel-copper prospect is located at the northern reaches of the pluton (Figure I iii).

b) Physiography

The region consists of low irregular wooded hills and ridges separated by areas of muskeg, swamp, or thin glacial deposits. Maximum local relief is 60 metres. The ultramafic pluton rises to a maximum elevation of thirty metres above Nemeiben Lake and is entirely surrounded by low lying, often muskeg covered ground. The ultramafic-country rock contact is not exposed.

c) Outline and Discussion of Previous Work, Nemeiben Lake Pluton

1) Introduction:

The first known reference to the Nemeiben Lake ultramafic body is by McInnes (1913) of the Geological Survey of Canada. McLarty (1936) mapped the La Ronge West sheet and outlined roughly the ultramafic outcrop area.

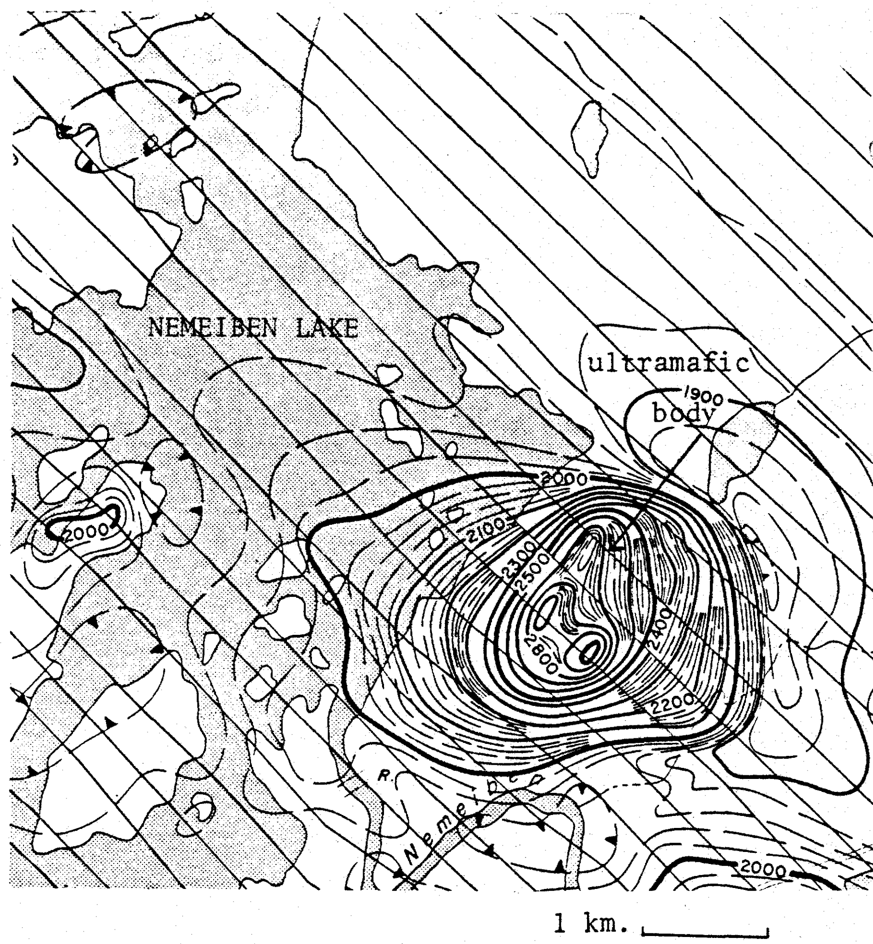
In August of 1944 the original ten COMPLEX claims were staked for Consolidated Mining and Smelting of Canada limited (Cominco). Appendix B is a summary of investigations of the nickel-copper prospect.

2) Petrology

Forsythe (1971) and Peddada (1972) mapped the body and recognized three types of ultramafic rock: pyroxenite, uralitized and serpentinized pyroxenite, and serpentinite (figure I iv) as well as small dykes of dioritic gabbro which cut the northern outcrop.

FIGURE I(i);

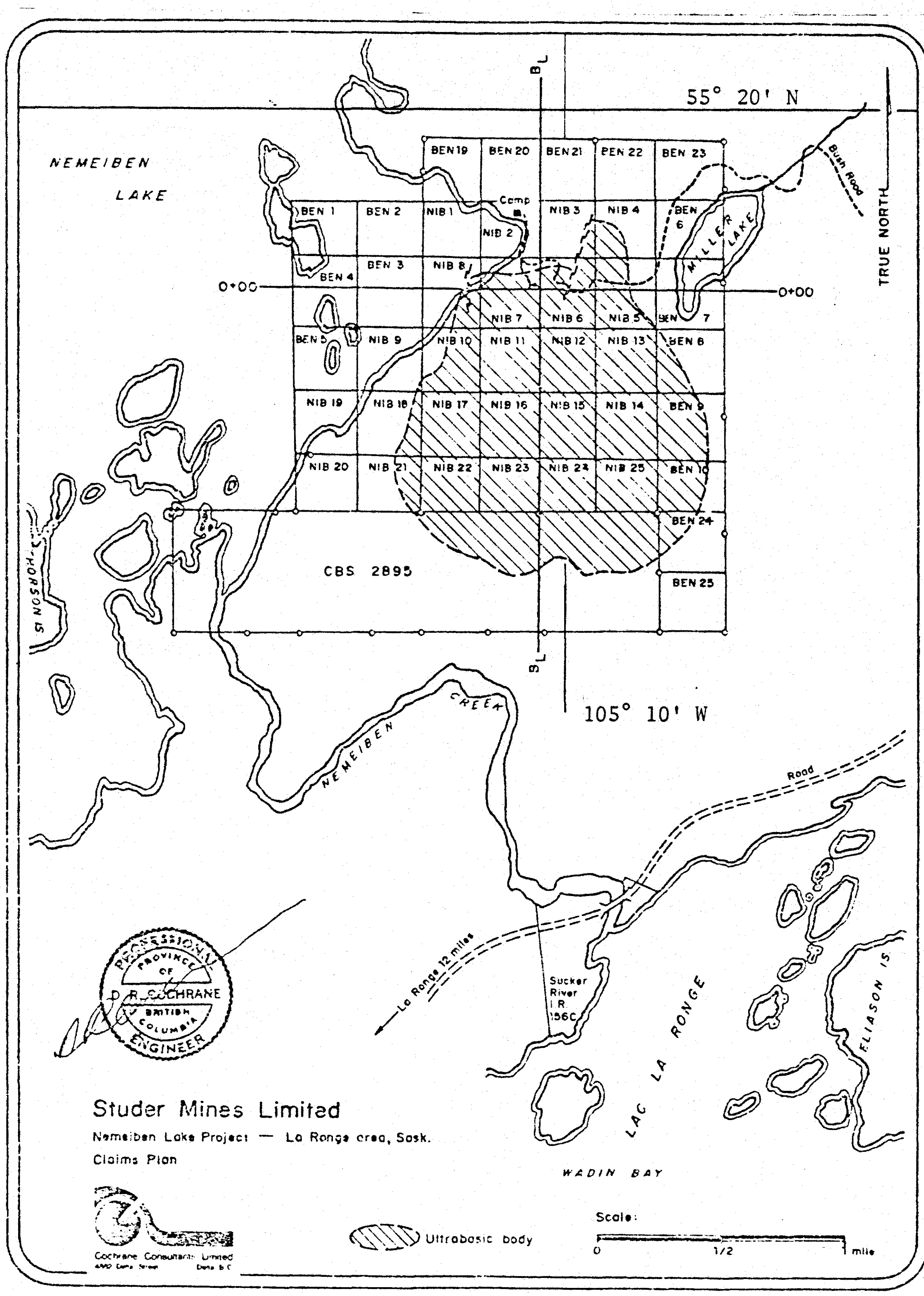
AEROMAGNETIC SIGNATURE, NEMEIBEN LAKE BODY:



From Canadian Aero Services (1953).

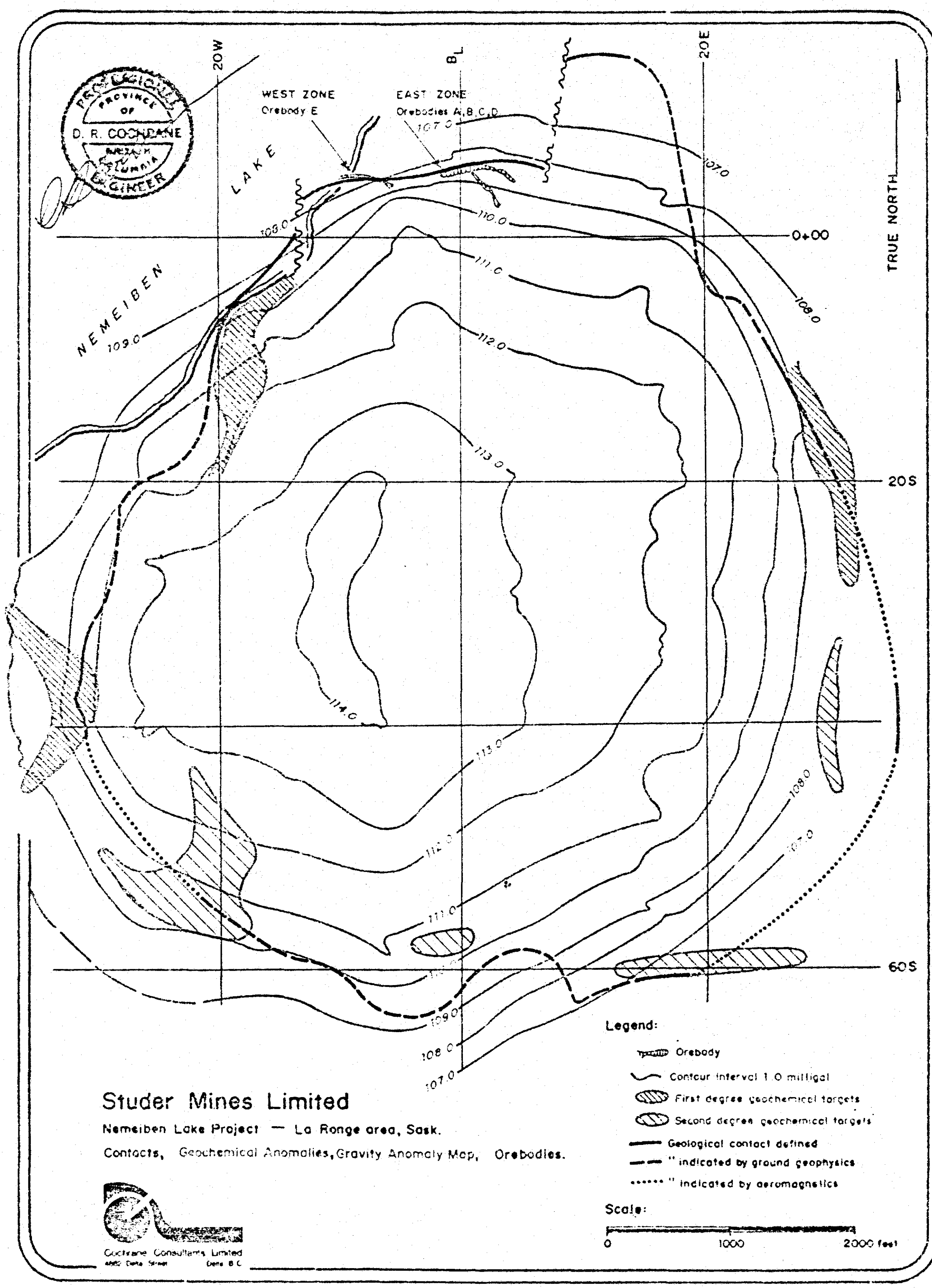
"2000" Gammas

FIGURE I(ii) LOCATION AND FORM, NEMEIBEN LAKE PLUTON



From Cochrane and Richards (1973).

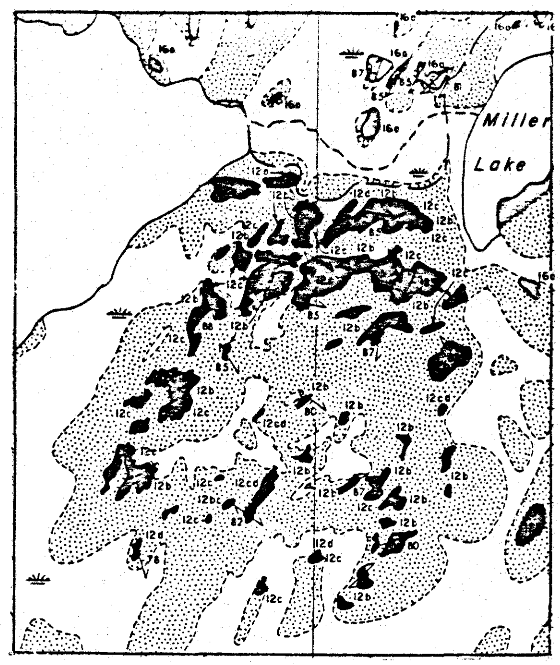
FIGURE I(iii):



Cochrane and Richards (1973).

FIGURE I(iv):

OUTCROP MAP, NEMEIBEN LAKE PLUTON



1 km.

From Forsythe (1971) Map 115E
For more detailed map see Map 115F (Forsythe 1971).

17c	Alaskite.
16a	Light-brown biotite granite.
14a	Dioritic gabbro.
12b	Pyroxenite: diopside, hypersthene, olivine remnants, (rare talc), minor uralite, (anthophyllite), minor serpentine.
12c	Uralitized and serpentinized pyroxenite:- diopside, hypersthene, brown hornblende, actinolite - tremolite uralite, serpentine, (anthophyllite).
12d	Serpentinite:- serpentine, pyroxene remnants, amphibole remnants, olivine remnants, (chrysotile).

A small xenolith of mafic gneiss is reported in the south central part of the body (Pearson 1957, Forsythe 1971).

3) Structure

Most of the rock in the Nemeiben Lake pluton is massive (Pearson 1957, Forsythe 1971, Peddada 1972) but where present faint to moderate foliations tend to trend parallel to the periphery of the body. They dip outward toward the outer edges in the southwest, south and east and inward in the northern part of the body (Pearson 1957, figure I v).

Sporadic mineralogical layering from one to five centimetres wide is reported by Forsythe (1971). Layering of peridotite and pyroxenite is parallel to the contact of the body (Dolomage, Campbell and associates 1974, Peddada 1972).

Pearson (1957) notes two main sets of minor shears, striking in northeasterly and northwesterly directions. Faulting is mostly confined to the two northernmost outcrops (Forsythe 1971, Peddada 1972, Pearson 1957).

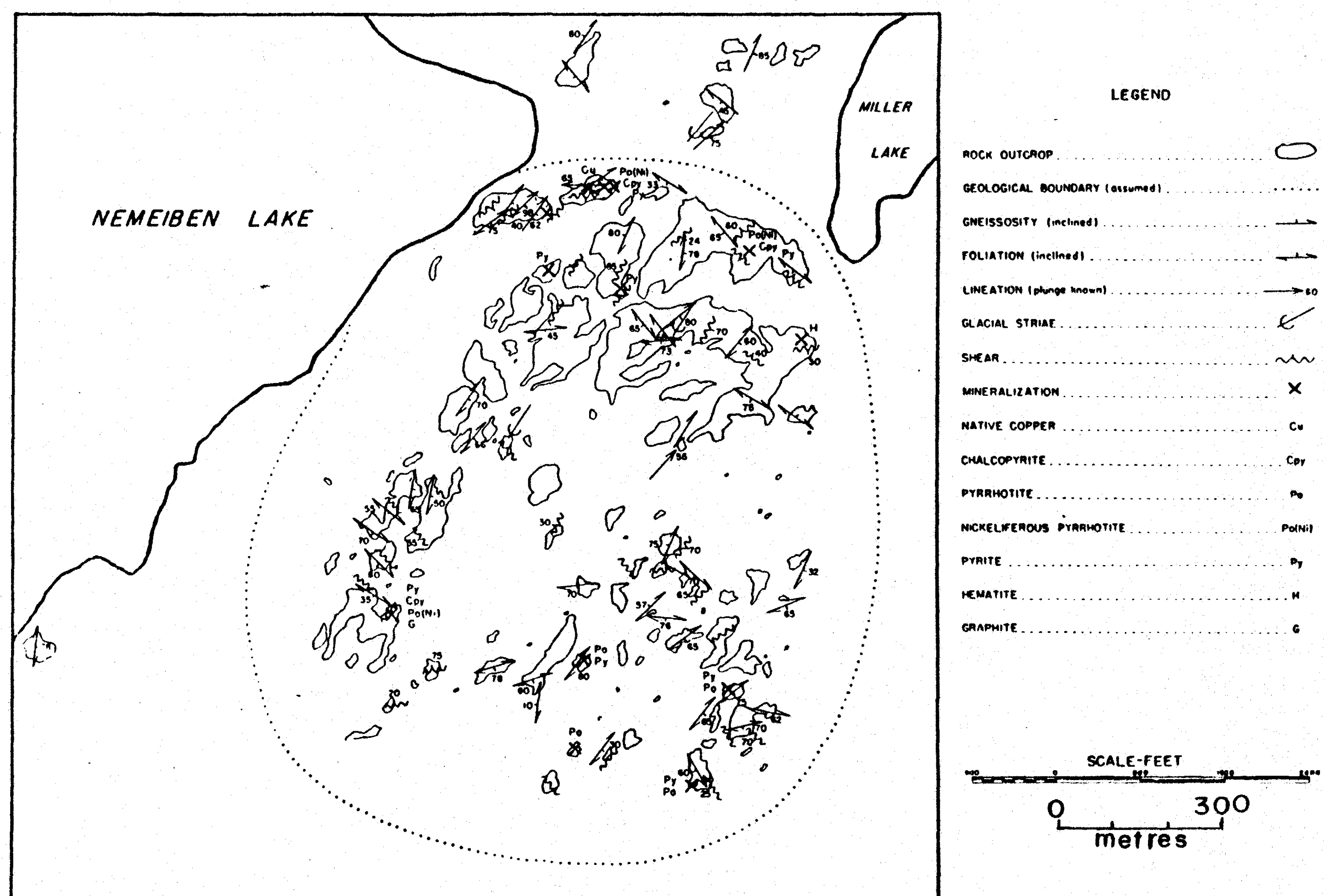
4) Geochemistry

Peddada (1972) used analyses by Hakli (see table B i in Appendix B) for petrogenetic studies. He determined the Nemeiben ultramafic rocks "are similar to olivines in peridotite nodules in basalts and ultramafic intrusives in orogenic belts". The Al_2O_3 content of the orthopyroxenes corresponds to values obtained by Green (1964) in the Lizard area. The relatively high CaO content of the orthopyroxenes indicates a rather high temperature of formation, corresponding to the highest part of the range for orthopyroxenes from intrusive peridotites of ultramafic magma and to the lower part of the range from peridotite inclusions in some basaltic rocks (Peddada 1972).

The clinopyroxenes fall in the higher Al_2O_3 and lower SiO_2 range, in the alkaline field of igneous rocks. The Kd value for the distribution of Mg and Fe between coexisting orthopyroxene and clinopyroxene is comparable to values from peridotite inclusions in basalt. Peddada (1972) estimated a temperature of 1350°C for pyroxene pairs at Nemeiben. The olivine-orthopyroxene pairs plot close to the distribution curve determined experimentally at 900°C and 500 bars pressure (Williams and Eugster 1969). This indicates an equilibrium assemblage. The clinopyroxene

FIGURE I(v):

From Figure 5a, Pearson (1957)



STRUCTURE, ECONOMIC MINERALS

compositions plot at temperatures between $1100^{\circ}C$ and $1200^{\circ}C$ and a pressure range of five to nine kilobars, using O'Hara's (1967) provisional petrogenetic grid (Peddada 1972).

5) Nature of the Country Rocks

The nature of the country rocks and of the contact with the ultramafitites is problematical. The contact does not outcrop. Normally the pyroxenite is fine-grained or chilled near the contact, breccia and interbanding of pyroxenite and granite is common (Cochrane and Richards 1973).

Campbell (1945) and McLarty (1936) consider the pluton intrusive into highly metamorphosed schists and gneisses derived from lavas and sediments. Pearson (1957) describes the country rock as largely granodiorite gneiss, foliated granodiorite, and pegmatite. "No part of the ultramafic body contains any granitic intrusion of any kind, the intrusive is therefore considered to be younger than the surrounding country rock" (Pearson 1957). Beck (1959) called the country rock quartz-biotite schist and gneiss, and garnet schist and gneiss. Agarwal (1970) describes the body as lying within a northeasterly trending lens-shaped band of granitized schists and gneisses surrounded by relatively unmetamorphosed sedimentary and volcanic rocks.

Forsythe (1971) mapped the country rocks as intrusive, light-brown biotite granite and alaskite, containing xenoliths of felsic to mafic schists or gneisses.

Thompson and Brady (1957) drilled two magnetic anomalies east of Sucker River (figure B a) and found some pyroxenite dykes and minor pyrite in the granite gneiss. National Nickel (1966, figure B b), drilled two holes near and west of the Nemeiben Lake ultramafic body. Strongly altered and fractured pink granite was found in one hole, the other hole cut through quartz-biotite gneiss and biotite schist containing sulphide stringers of pyrite and pyrrhotite. A maximum assay of 0.12 percent nickel is reported. Many of the granitoid gneisses and metasedimentary successions in the region contain disseminations of syngenetic sulphide minerals.

6) Economic Geology

Table I (i) is a list of the economic minerals recognized by various workers. Figure I (v) indicates that most occur in the northwesternmost outcrops but some are also megascopically visible in the southern and southwestern reaches of the body.

Two types of ore mineral occurrences are reported. An early assemblage including pyrrhotite, chalcopyrite, pentlandite, magnetite and chromite; and a secondary assemblage including specular haematite, nickeliferous silicates, native copper, marcasite and minor exogene copper minerals at the surface (Campbell 1945). Peddada (1972) recognized minor platinum group metal minerals in chalcopyrite. Needles of millerite have been observed on fracture surfaces (McCormick 1973). Native copper occurs in haematized serpentinites (McCormick 1973, Peddada 1972, Forsythe 1971).

The copper-nickel zones are discontinuous lenses and irregular bands at or near the outer contact of the ultramafic body (Cochrane and Richards 1973). The 'ore' zones, diffuse bands of various grades, are characterized by fairly good continuity in width and grade. The ore minerals occur as disseminated blebs or irregular clusters and there is no evidence for a relationship to fractures or shear zones (Dolomage, Campbell and Associates 1974). The best ore concentrations occur at or near embayments or irregularities in the contact and geochemical surveys have indicated there are nickel-copper anomalies around the entire periphery of the body (Dolomage, Campbell and Associates 1974, figure I iii).

Table B(iv) (Appendix B, Peddada 1972), shows the nickel and copper content of the sulphide phase, silicate phase, and whole rock phase of the body. Taking these and the phase relationships into account it is probable that the chalcopyrite and pentlandite exsolved from a Fe-Ni-Cu monosulphide solution to form flames and lamellae of both minerals in pyrrhotite, and round to euhedral grains of chalcopyrite (Peddada 1972).

7) Possible Economic Development

Dunlop (1966) combined Fano's (1956) and his drill information to outline a possible ore body and noted that many mineralized core sections were never assayed. He concluded that a large tonnage of proven and potential copper-nickel ore exists at Nemeiben Lake. The total proven tonnage was 871 750 tons of 0.66 percent nickel and 0.35 percent copper. Assuming 90 percent recovery Dunlop calculated that 11.88 lbs of nickel and 6.31 lbs of copper were recoverable per ton of proven ore. The potential tonnage was calculated to be 2 902 750 tons combined Ni-Cu (Dunlop 1966).

TABLE I (i)
OPAQUE AND ECONOMIC MINERALS IN THE NEMEIBEN LAKE PLUTON

	COMINCO 1945	INCO 1954	PEARSON 1957	McCORMICK 1973	FORSYTHE 1971	PEDDADA 1972
Pyrrhotite (Nickeliferous*)	X(*)	X	X(*)	X	X	X
Pyrite		X	X	X	X	X
Marcasite	X		X			X
Chalcopyrite	x	X	X	X	X	X
Pentlandite				X	(X)	X
Millerite	X			X	X	
Garnierite	X		X			
Annabergite	X					
Violarite-bravoite						X
Copper	X		X	X	X	X
Platinoid Mineral						X
Specular haematite	X	X	X	X	X	X
Iron oxide	X		X			X
Magnetite		X				X
Chromite						X
Bornite-Malachite	(X)		(X)			
Azurite			(X)			

(Minor)

Further drilling (National Nickel 1967-69) outlined two concentrations of ore minerals, a Dunlop West ore body of 796 650 tons grading 0.36 percent nickel and 0.18 percent copper, and a Dunlop East ore body of 3 482 000 tons grading 0.38 percent nickel and 0.18 percent copper (Dunlop 1967).

Dunlop (1967) considered the grades were sufficient to support a 500 t.p.d. mill for nineteen years at a profit. He always added an estimated $1 per ton for the value of contained precious and platinum group minerals although no systematic assays were carried out for these. Assay results on a grab sample ran 0.27 percent copper, 0.41 percent nickel, 0.15 percent cobalt, 0.22 percent chromium and only traces of silver and platinum (Forsythe 1971).

d) Statement of Purpose

The purpose of this dissertation is to provide a description of the Nemeiben Lake ultramafic pluton in terms of its primary mineralogy and regional setting. A petrographic and analytical study of the sulphide minerals and the subsequent metamorphic and structural history of pluton are also outlined. The ultimate goal is to explain the form, time, and location of the intrusion and contained sulphide minerals in terms of a postulated regional tectonic development scheme and the body of knowledge on ultramafic rocks.

e) Outline of Dissertation

Previous work and the goals set for further research are outlined in the introductory chapter. The La Ronge and Rottenstone domains and the ultramafic rocks therein are discussed in chapter II and a scheme for the tectonic development of that part of Saskatchewan's Precambrian shield is proposed. Chapter III is an outline of the petrology, petrography, geological history, and possible petrogenesis of the Nemeiben Lake pluton. The petrography and mineralogy of the opaque minerals including analysis of sulphide phases is the subject matter of chapter IV.

Appendix A is a summary of pertinent information from Saskatchewan Department of Mineral Resources reports covering the La Ronge and Rottenstone domians. Appendix B is a summary of work done on the Nemeiben Lake pluton and its associated ore minerals. Appendix C contains petrographical notes on the sections examined and a list of the samples with their corresponding University of Saskatchewan numbers.

Appendix D contains the electron microprobe analytical results.

f) Method of Investigation

A week was spent in September of 1976 mapping and sampling the pluton. Core was poorly preserved. A few Dunlop Mining core samples were selected for study. Rock samples collected by McCormick and Mineral Evaluation Program core samples were also used in the study. Fourteen thin sections and their location was provided by L.H. Forsythe, Saskatchewan Geological Survey.

The summers of 1976 and 1977 were spent mapping in the Reindeer Lake region of northern Saskatchewan. Ideas concerning the development of the La Ronge and Rottenstone domains were developed from this experience and discussions with Saskatchewan Geological Survey personnel, University of Saskatchewan Department of Geological Sciences teaching staff, and fellow graduate students.

A total of 57 thin sections, 80 polished thin sections, and 4 polished sections were studied. Electron microprobe analyses of 369 sulphide phases in ten polished thin sections were carried out. Seven whole rock major element analyses and the sulphur content of 33 samples were obtained.

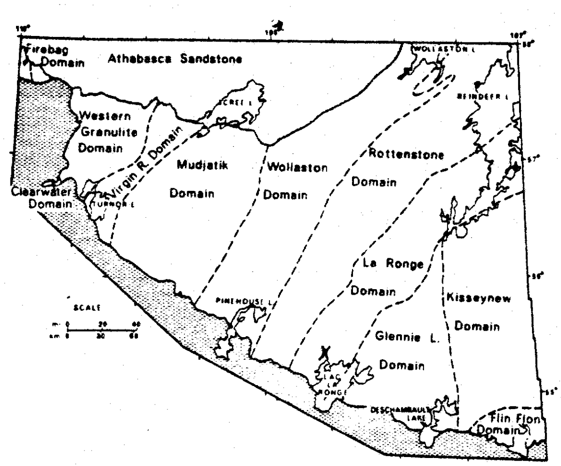
II

REGIONAL SETTING

(a) Introduction:

The Nemeiben Lake ultramafic body is situated in the La Ronge domain of the Churchill Province of the Canadian Shield [Lewry and Sibbald 1977, Figure II(i)]. This domain is composed mostly of intrusive granitoid rocks, granite gneiss, and supracrustal metasedimentary and metavolcanic successions. The Rottenstone domain (Munday 1974, Ray 1974) immediately to the west and northwest is composed largely of intrusive mafic to felsic rocks. Both domains have had essentially the same structural history (Gilboy 1975, pers. comm. 1978). Where they have survived, the supracrustal rocks of the Rottenstone domain are highly migmatized or occur as large rafts and xenoliths in the main intrusive phase.

Figure II(i)



Lithostructural domains of the southern part of the Saskatchewan Shield: stipple indicates extent of Athabasca Sandstone, dash pattern indicates the Phanerozoic cover. x, Nemeiben Lake pluton

Lewry and Sibbald (1977).

Because there are only gradual changes between these two domains in the Reindeer Lake region of northeastern Saskatchewan, any boundary would essentially be arbitrary. In this dissertation it will be argued that the differences are too small for the two regions to be divided into separate lithostructural domains. It is proposed that they belong to one "La Ronge-Rottenstone" domain which is divisible into at least three sub-domains. The position of the Nemeiben Lake ultramafic body will therefore be discussed with regard to its regional setting in the "La Ronge-Rottenstone" domain.

(b) Previous Work in the Lac La Ronge Region:

Richardson (in Franklin 1823) made general geological observations in the Churchill River area between The Pas, Manitoba and Ile-a-la-Crosse, Saskatchewan. in 1892 Tyrrel mapped the geology along the Foster and Churchill Rivers. Lac La Ronge was visited and the geology briefly described by D.B. Dowling (Tyrrel and Dowling 1896, Selwyn 1895).

William McInnes visited the same area briefly in 1908 and more extensively in 1909, as reported in the Geological Survey Summary reports for those years. McInnes (1913) describes the geology of the Nelson and Churchill River basins, which includes Lac La Ronge and Nemeiben Lake (occasionally in the past called Sucker Lake). The first published account of the Nemeiben Lake ultramafic body occurs in the notes and map included with this report.

McInnes (1909) divided the Precambrian rocks of the Lac La Ronge region into the Laurentian, biotite granite gneisses, the Keewatin, chloritic and hornblendic schists, diorites and diabase and the La Ronge series of fine grained biotite gneisses, augen gneisses, quartz schists and limestones. He thought these latter rocks could be of Grenvillian age as "the general lithological resemblance of this set of rocks to the Grenville of eastern Canada is strong" (McInnes 1909). This is the first use of the term Lac La Ronge Series for this group of supracrustal rocks. He later mentions the occurrence of "smaller areas and bosses of pyroxenite, hornblende diorite, and serpentine".

The west half of the Lac La Ronge sheet was mapped at the reconnaissance level by the Geological Survey of Canada in 1935 and a map issued a year later (McLarty 1936).

The oldest rocks recognised by McLarty in the western Lac La Ronge region are volcanic rocks, derived chlorite and hornblende schists, and arenaceous sediments which he termed the Wekusko Group. Intruding the Wekusko Group he found mafic to ultramafic rocks: "diorite, gabbro, pyroxenite, hornblendite, peridotite and basic dykes, are sparingly developed throughout the area invading the volcanic and sedimentary rocks in the form of small irregularly shaped masses and narrow dykes...In places [they] show signs of granitization by later acid intrusive material" (McLarty 1936). The rocks on the east shore of Nemeiben Lake and surrounding the ultramafic body were described as consisting of schists and gneisses "of various compositions and uncertain origin, probably derived from the sediments and volcanics of the Wekusko Group" (McLarty 1936).

Padgham (1966) attempted a regional compilation of the rocks between Lac La Ronge and southern Reindeer Lake. Part of this map is reproduced in Figure II(ii) showing the region of Lac La Ronge and Nemeiben Lake. The Nemeiben Lake ultramafic body is mapped as "late tectonic" and the rocks around it as hornblende-rich volcanic and sedimentary rocks. This writer considers the rocks around the body to be felsic granitoid gneisses; and it will be later argued that the ultramafic body is a pre-tectonic intrusive later affected by the same tectonic, metamorphic, and intrusive events as the general country rocks.

Padgham's (1966) regional synthesis shows the major structures of the Lac La Ronge region [Figure II(iii)]. The Nemeiben Lake area is in his northwest zone analogous to Lewry and Sibbald's (1977) La Ronge domain. Northwest of the Stanley Fault folds are isoclinal; southeast they are larger and more open. The southern area is equivalent to Lewry and Sibbald's (1977) Glennie Lake domain.

There are three belts, each about 25km wide, northwest of the Stanley fault. They differ in fold styles and lithology, and were termed the Northwest Migmatite Zone, the Northwest Zone of Granite Plutons and the Zone of Isoclinal Folds. Padgham (1966) thought these belts may represent different crustal levels, the Northwest Migmatite Zone being closest to the source of granitizing energy.

LEGEND Figure II (ii)

Basic and intermediate igneous rocks, hornblende-quartz diorite, hornblende diorite, gabbro, anorthosite, peridotite

Late tectonic or post-tectonic

Syntectonic, related to syntectonic granodiorites

Pretectonic or early tectonic

Acidic to intermediate igneous rocks
Quartz diorite, quartz-monzonite, granite, sodic granite; granodiorite predominant

Late tectonic or post-tectonic

Syntectonic, mainly gneissic granodiorite

Early tectonic or pretectonic

Migmatite and granitic gneiss

Supracrustal component predominant

Mixed igneous and supracrustal rocks

Igneous component predominant,

Mainly quartz-plagioclase-biotite gneiss and granulite but includes undifferentiated sedimentary rocks and some migmatized sedimentary rocks

Conglomerate, mainly polymictic

Quartzo-feldspathic rocks, generally leucocratic low in mafics. Muscovite abundant locally, as is microcline

Hornblende and calc-silicate gneiss and granulite, includes limestone in a few localities

Staurolite-biotite schist and gneiss and biotite schist with minor conglomerate

Pseudo-conglomerate and pegmatized quartz-plagioclase biotite gneiss

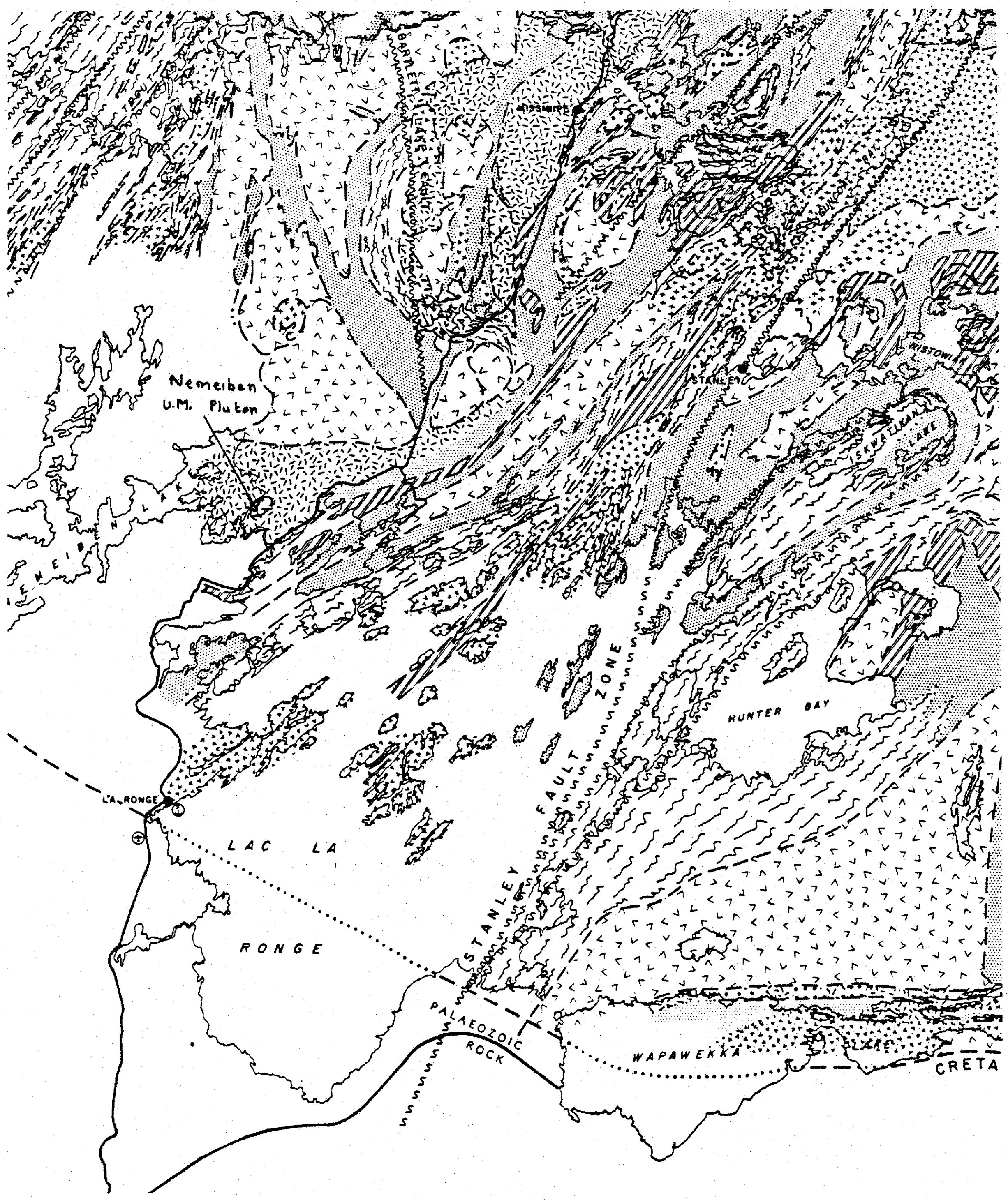
Volcanic and volcanic-sedimentary rocks

Volcanic breccia, agglomerate, amygdaloidal and pillow lavas

Hornblende-rich volcanic and sedimentary rocks. Sheared volcanics, well-layered to laminated, hornblende-rich tuffs and tuffaceous sediments

Quartzo-feldspathic volcanic and sedimentary volcanic rocks

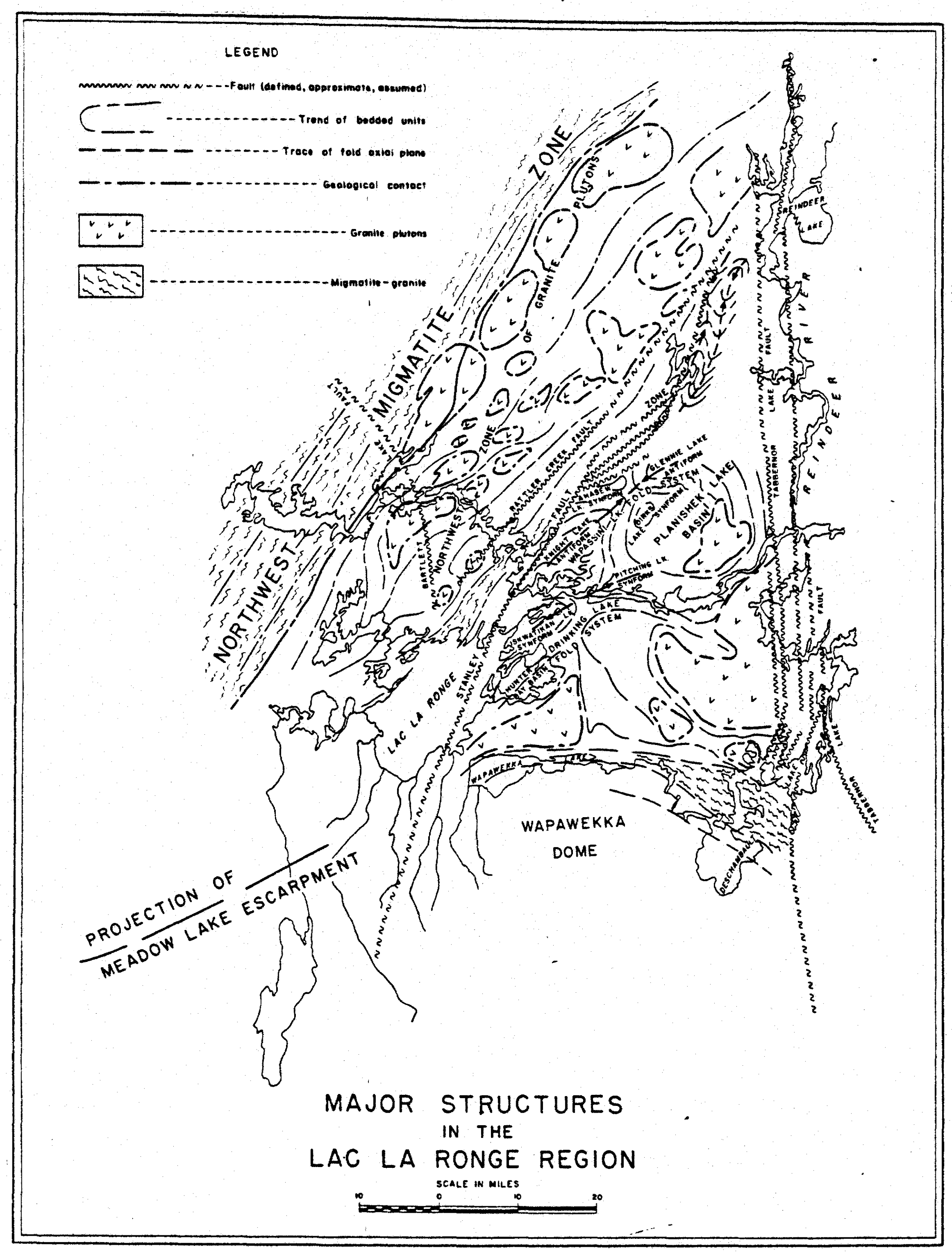
FIGURE II(ii)



REGIONAL GEOLOGICAL COMPILATION, LAC LA RONGE REGION

From Padgham 1966.

FIGURE II (iii)



Padgham 1966.

(c) Mafic to Ultramafic Rocks in the "La Ronge-Rottenstone" domain:

1) Form and Geological Setting

The occurrences of ultramafic to mafic rocks in both the Rottenstone and La Ronge sub-domains are reported in some of the Saskatchewan Department of Mineral Resources reports shown in Figure II(iv). Reference may be made to Appendix A for more detailed documentation.

In the Nemeiben Lake area, small ultrabasic sills and plugs as well as the larger Nemeiben Lake body intrude schists and gneisses or occur in granitic areas. The intrusion of mafic to ultramafic bodies burial of the supracrustal succession, before further intrusion, folding, faulting and metamorphism. Most reports agree that the ultramafic rocks are older than the main granitic events (1). The granitic event(s) are probably Hudsonian (money 1965, Ray 1974, in press, Forsythe 1975).

Padgham (1966) considers the metapyroxenites and metagabbros in the Guncoat Bay area were pre-tectonic. There are some younger ultramafic occurrences elsewhere (Johnston 1969 and Ashton pers. comm. 1977); as well as late diabase dykes which can be pyroxene bearing (Lewry 1975, Shklanka 1961, personal observations 1977). Sibbald (1977) places ultramafic occurrences in the Milton Island area (report no. 153) as post tonalite and Ashton (1978) records an

(1) (Mawdsley and Grout 1951; Forsythe 1968, 1971, 1975; Morris 1960, 1961; Padgham 1960, 1963, 1966; Johnston 1968, 1969, 1970a, 1972, 1973b; Kirkland 1959; Byers 1948; Sibbald 1977; Cheesman 1959).

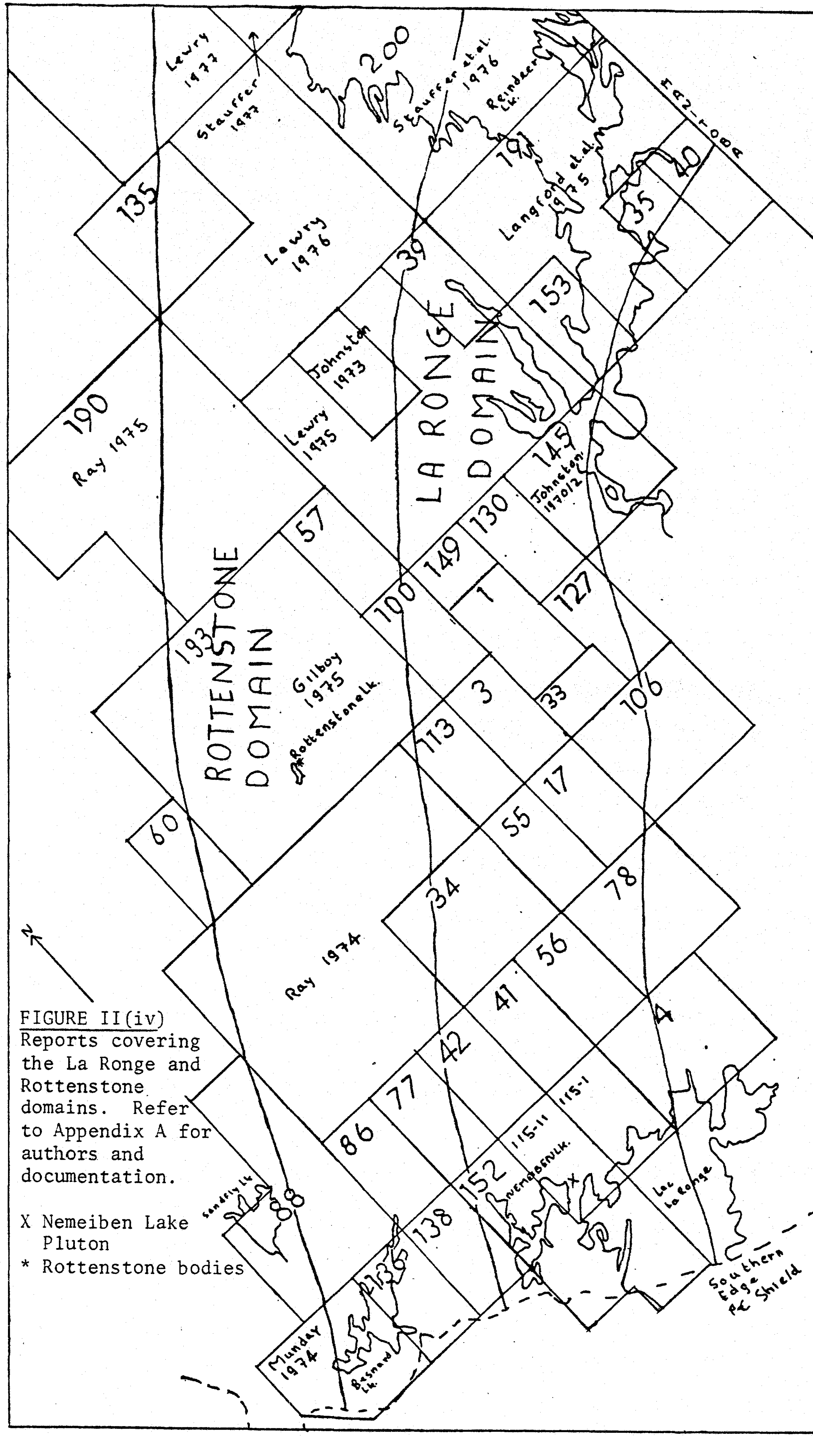


FIGURE II(iv)
Reports covering the La Ronge and Rottenstone domains. Refer to Appendix A for authors and documentation.

X Nemeiben Lake Pluton
* Rottenstone bodies

ultramafic body possibly cutting a tonalite in the southern Reindeer Lake area. The tonalites may be metamorphic rocks.

Many ultramafic occurrences have been described as associated with, grading into, or cut by gabbros (2). Different phases of ultramafic rock are also reported cutting each other. Byers (1948) describes one ultramafic mass as consisting of alternating bands of peridotite and pyroxenite, cut by younger pyroxenite. Minor pyroxenite 'dykes' at an angle to the visible mineralogical layering are present at Nemeiben.

Many ultramafic bodies have been described as dykes (3) cutting the metasedimentary and metavolcanic succession or as sills (4). Some ultramafitites are conformable bodies in a volcanic succession (Padgham 1960, Byers 1948, Cheesman 1959). Gabbros and pyroxene gabbros in the same situation are very common. Padgham (1963) further recognizes the possibility that some of these conformable bodies may represent regionally metamorphosed ultramafic flows. Generally ultramafic rocks seem to cut across some granitoid gneisses (Gracie 1965) or recognizable supracrustals but are cut by later granite.

Johnston (1970a) documents amphibole-titanoaugite pyroxenite roof pendants in granodiorite. The Hall and Tremblay-Olsen showings, Rottenstone Lake, occur in large harzburgitic xenoliths in migmatite-granodiorite (Mawdsley 1946). These remnants are in what is generally interpreted as Hudsonian granitic material (Gilboy in press). Many ultramafic occurrences are cut by these granitic phases (5). Small remnants and inclusions in granites have been described by Forsythe (1971).

(2)(Forsythe 1971, 1972, 1975; Budding 1955; Pearson and Froese 1959; Cheesman 1959; Johnston 1969, 1970a).
(3)(Johnston 1968, 1969, Byers 1948). (4)(Kirkland 1959, Johnston 1969; 1970a, 1973b; Sibbald 1977; Cheesman 1959).
(5)(Johnston 1968, 1969, 1970a, 1973b; Forsythe 1971 ; Morris 1960).

Metasedimentary or metavolcanic xenoliths have been described in ultramafic bodies by Morris (1960) and Forsythe (1971): the Nemeiben Lake ultramafic body contains a small xenolith of mafic schist or gneiss. This xenolith is similar to other gneisses which are intruded by the granitic mass surrounding the ultramafic body.

A special note is made of the boundary intrusions (Stockwell 1946) cutting the Amisk volcanics in the Flin Flon area. They are comprised of three compositionally distinct sequentially emplaced rock groups the first of which is a mafic group including metapyroxenite and meladiorite. The third rock group includes cumulate type wehrlite and olivine gabbro (Syme and Forrester 1977). All the boundary rock types were emplaced before the end of the last deformation episode of the Flin Flon area.

2) Petrology:

Most of the pyroxenites in the "La Ronge-Rottenstone" domain are websteritic, composed of diopside, hypersthene, and amphibole after pyroxene. Minor antigorite, anthophyllite, chrysotile, talc and calcite are often associated with them. The feldspar content in pyroxenites is usually low. Feldspar ranges in composition from An_{50} to An_{60} (i.e. Forsythe 1972). Iron, nickel, and copper sulphide disseminations are quite common.

Some ultramafic rocks are peridotitic in composition, containing olivine or much serpentine after olivine. Harzburgite, dunite, and wehrlite occurrences have been described. Byers (1948) documents both lherzolite and websterite bodies. Some small bodies were termed intrusive hornblendites by authors (Gracie 1965, and Byers 1948).

Many mafic volcanics in the area contain pyroxene (Money 1965; Johnston 1968, 1970a; Sibbald 1977; Cheesman 1959). Olivine and serpentine pseudomorphs after olivine occur in the Reindeer Lake metavolcanics (Ashton pers. comm. 1977).

3) Deformation and Metamorphism:

Many ultramafic bodies are deformed by Hudsonian events. Forsythe (1972) notes a mafic-ultramafic body that has been boudinaged and folded, and small metapyroxenite bodies have been described as folded with the supracrustals by Johnston (1970a, 1973b).

Sibbald (1977) recognized three periods of mineral growth in ultramafitites. A primary igneous generation, a high-grade metamorphic (retrograde) generation, and a late low-grade metamorphic (retrograde) generation. Most of the bodies have been almost completely metamorphosed to retrograde amphibole-serpentine assemblages (6). Forsythe (1968, 1971) considers the metamorphism to have occurred during burial to a depth of ten kilometres. Shearing has also been noted (Padgham 1963, 1966; Pearson and Froese 1959).

Johnston (1970a) has especially noted that mafic to ultramafic rocks have generally been extremely resistant to emplacement of granitic rocks. The harzburgite rafts at Rottenstone Lake are largely unmetamorphosed (Mawdsley 1946).

4) Economic Geology:

Minor disseminations of syngenetic pyrite, pyrrhotite, chalcopyrite and spinels are common in most of the ultramafic and mafic rocks. Oxide minerals are also common, mainly magnetite and minor chromite (7).

(6) (i.e. Padgham 1963; Forsythe 1968, 1972; Morris 1960, Padgham 1966, Kirkland 1949). (7) (Johnston 1970a, Forsythe 1972, Morris 1960, Sibbald 1977).

Similar disseminations have also been reported in most recognized metavolcanic successions (8).

The Nemeiben Lake ultramafic pluton, a Studer Mines property, and the former Rottenstone mine are the major locales of sulphide minerals in ultramafic rocks of the "La Ronge-Rottenstone" domain. Other prospects and occurrences are known. The Silver Chief Ni-Cu prospect in a pyroxenite-gabbro body at Howard Lake contains veinlets and disseminations of mainly iron and minor nickel and copper sulphides. Locally they constitute up to 20 percent of the rock (Forsythe 1972). Johnston(1968)records a pyroxenite dyke assayed at 0.16 percent nickel. Disseminated chalcopyrite-pyrrhotite in ultramafic rocks are reported to contain little nickel. The nickel present is probably in the silicates rather than the associated sulphides (Johnston 1970a).

Gabbroic rocks similarly contain traces of economic minerals. Pyrite and sparsely disseminated pyrrhotite with traces of chalcopyrite found at several localities (Johnston 1973b) were assayed at 0.1 percent nickel and 0.5 percent copper. Similar occurrences reported by Scott (1970) contain 0.17 percent copper and 0.54 percent nickel. Only trace values of nickel and no nickel minerals (Morris 1960) were seen in a gabbroic plug whose best mineralized core section assayed 0.52 percent copper, 0.31 percent nickel, and 0.01 percent cobalt with traces of gold and silver (Beck 1959). Padgham (1960) records pyrite-pyrrhotite-pentlandite-chalcopyrite minor amounts in a gabbro. A small chalcopyrite showing in gabbro is mentioned by Ray (1974).

(8) [Forsythe 1972, Padgham 1960, 1963; Morris 1961, Johnston 1969, Gracie 1965, Miller 1949].

The gabbro -anorthosite-quartz-diorite McLean Bay complex in Northern Reindeer Lake contains pyrrhotite and pyrite as constant accessory minerals (Shklanka 1962b).

Mineralized lenses of limited tonnage were found in both harzburgite xenoliths at Rottenstone Lake. Only the Hall showing has been mined. The sulphides form 20 to 50 percent of the ore-bearing rock. Pyrrhotite and chalcopyrite are megascopically recognisable. A sample assayed for Mawdsley (1946) ran 2.07 percent copper and 4.29 percent nickel.

Mathieu (1964) provides a mineralogical description of the ores. Pyrrhotite is the most abundant sulphide and is present in relatively large grains. It contains flames of pentlandite and sperrylite. Violarite is abundant, occurring as large grains frequently intergrown with fine sperrylite and pentlandite. It contains sphalerite and cubanite veinlets. These veinlets also occur in pyrrhotite and the silicates. Chalcopyrite is present as small irregular masses and is frequently intergrown with pyrrhotite and violarite. Mathieu and Bruce (1968) record the presence of palladium, rhodium, gold and silver, as well as platinum.

Non metallic economic minerals in the ultramafic bodies of the "La Ronge-Rottenstone" domain are scarce. Amphibole-asbestos is mentioned in one body by Johnston (1973b) and asbestiform serpentine veinlets occur in a highly serpentinized ultrabasic rock intruded into hornblende gneiss (Kirkland 1959).

(d) Radiometric Dates:

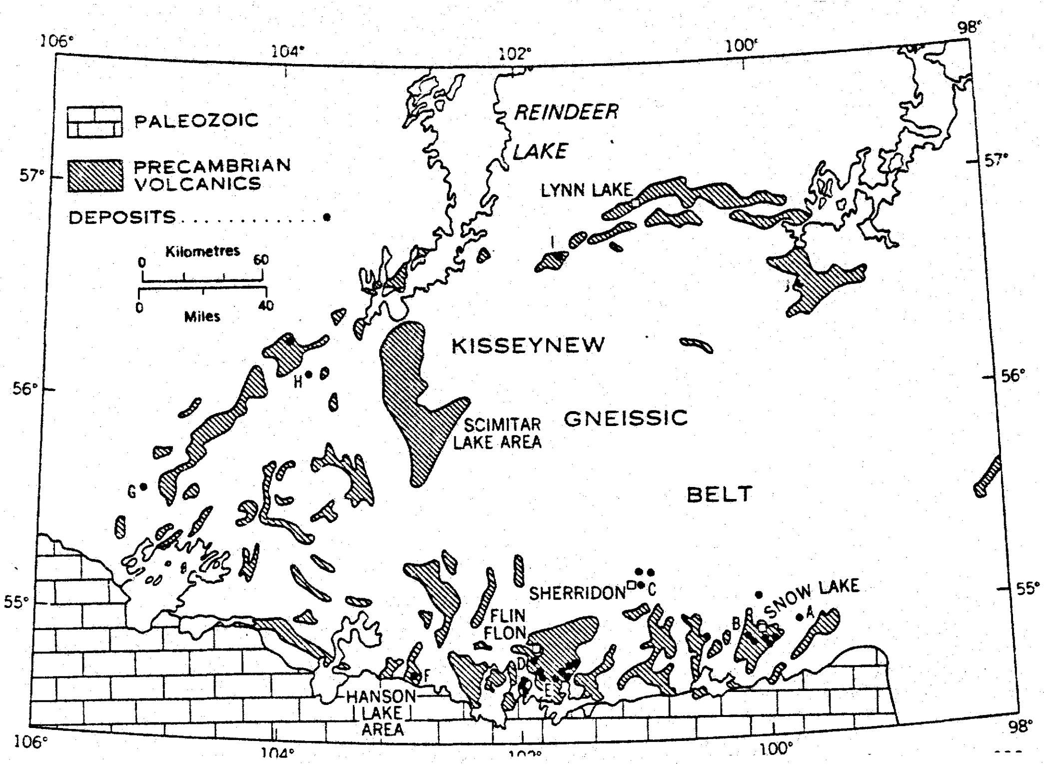
Gilboy (in press) summarised most of the chronological work of interest and most of the references quoted are taken from his work.

Granitoid rocks in the Wollaston domain have yielded radiometric whole rock ages in the range 2000-2750 m.y. (Money 1967, Weber et.al. 1975a, b, Cumming and Scott 1976). Minimum ages are generally accepted to be around 2600 m.y. Younger ages are considered to be the result of up dating during subsequent metamorphic events. The studies of metasedimentary rocks provide ages of 1700-1900 m.y., indicating Hudsonian metamorphism. Cumming and Scott (1976) obtained an older age of 2360 m.y., and suggested this to be a lower age limit for the sediments of the Wollaston Fold Belt.

Radiometric ages of granitoid rocks in the Rottenstone sub-domain are in the range 1.690-1870 m.y. There are some granite gneisses in the Rottenstone which may be equivalent to the Archean basement in the Wollaston Fold Belt (Ray in press, Scott 1970, Money 1965).

The metasediments of the La Ronge and Rottenstone sub-domains are probably of similar age and according to Gilboy (in press) are Aphebian but their exact age is uncertain since correlation is possible with either radiometrically dated Archean or Aphebian rocks (Sibbald 1977). Rb/Sr dating of the Amisk volcanic rocks yielded an isochron of 1775$\pm$89 m.y. (Mukherjee et.al. 1971). An isochron date of slightly higher than 1800 m.y. is obtained from U-Pb in zircons from Amisk rhyolites (Stauffer pers. comm. 1978). The Amisk volcanics are therefore Aphebian and the deformation which affected tham Hudsonian. The general metamorphic and structural history of the Flin Flon region is similar to that of the La Ronge domain, with three metamorphic episodes. Gaskarth (1971) has determined a similar tectonic and metamorphic sequence in the Hanson Lake area. Rb/Sr dating provided ages of 2521$\pm$60 m.y. for Upper Group metavolcanics and 2446$\pm$ 16 m.y. for a syn-third deformation intrusive granite (Coleman 1970). This suggests an Archean

FIGURE II(v)



Location map of some volcanogenic massive sulphide deposits in the circum-Kisseynew volcanic belt.

A = Osborne Lake	F = Hanson Lake
B = Chisel Lake	G = Will
C = Sherridon	H = Brabant Lake
D = Flin Flon	I = Fox Lake
E = Schist Lake	J = Ruttan

From Sangster (1978).

age for the metavolcanics, with the major deformation and intrusive event being Kenoran. Sangster (1978), however, reports that model lead ages from a representative number of deposits in the "circum-Kisseynew volcanic belt", fall between 1700 and 1900 m.y. which supports correlations of the Amisk and La Ronge volcanics (Figure II v).

It is concluded that the La Ronge Group rocks are probably Aphebian and the granitoid rock Hudsonian, apart perhaps for some remobilized basement. This would indicate that most of the mafic to ultramafic pre-granite rocks are early Hudsonian.

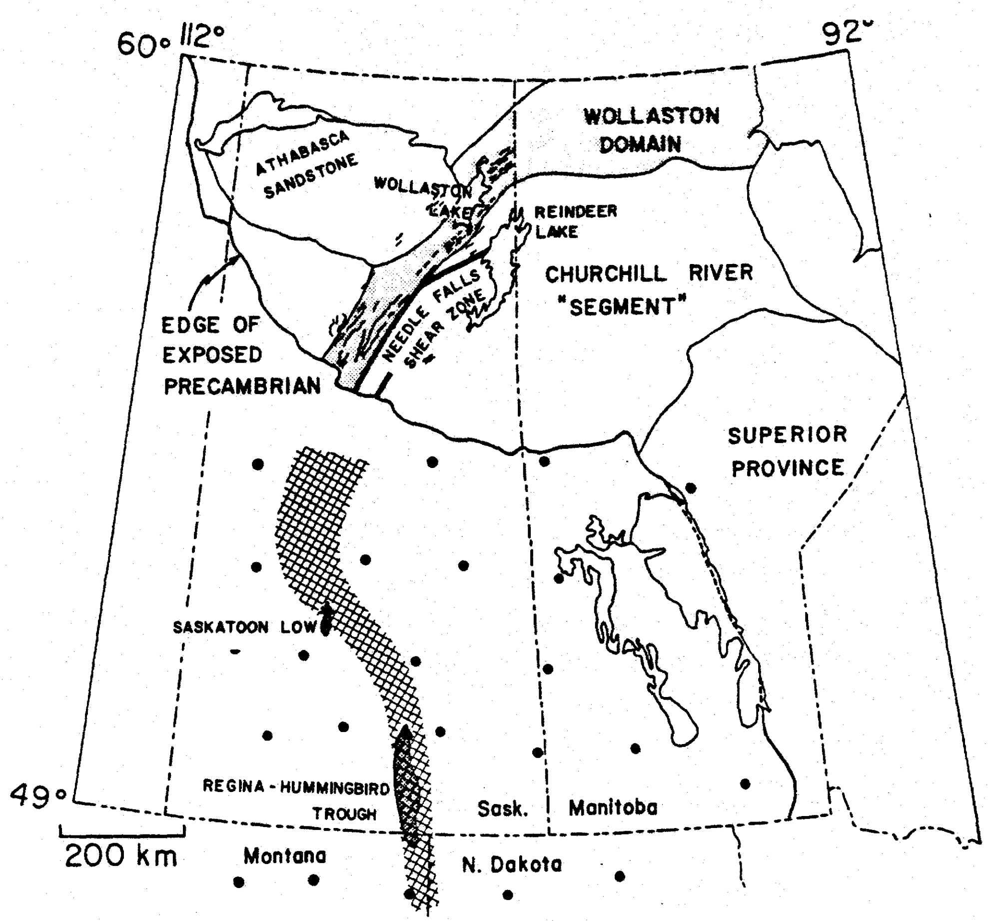
(e) Regional Structural and Metamorphic History, "La Ronge-Rottenstone" Domain :

i) Needle Falls Shear Zone:

The Needle Falls Shear Zone, between the Wollaston and "La Ronge-Rottenstone" domains, is a major crustal break. Some authors interpret it as a Proterozoic plate boundary. Camfield and Gough (1977) trace a long narrow belt of rocks of high electrical conductivity beneath the Paleozoic sediments from southeastern Wyoming to the edge of the Canadian Shield in Saskatchewan (Figure II vi). The extention of this linear belt is the Needle Falls shear zone, and a thesis is made that the electrical conductivity anomaly traces a major lithospheric fracture zone.

Hills et. al. (1975) suggested that there was a Proterozoic subduction zone along this fracture in the southern end of the structure in Wyoming. Camfield and Gough (1977) suggest it is possible that the entire fracture zone is a Proterozoic continental collision zone or geostructure.

FIGURE II(vi)



Geology of the northern part of the conductive body, after Whitaker and Pearson (1972). Trends sketched in the Wollaston Domain join conductors known from airborne electromagnetic surveys. The Venn Low (not shown), a linear solution channel 80 km long in the Prairie evaporite, lies along the conductive body with its mid-point about halfway between Saskatoon and Regina. The Bladworth Low (also not shown) is shorter than the Saskatoon Low and strikes WNW from the edge of the conductive body, west of the Venn Low.

Camfield and Gough (1977).

This must be countered by evidence that the Wollaston domain and Rottenstone sub-domain are believed to have shared a common structural history (Ray 1974). Furthermore, the Needle Falls shear zone lacks the continuity expected of major crustal breaks for it splays and dies out in the Reindeer Lake Region (Fumerton pers. comm. 1977, personal observations 1977, Stauffer et.al. 1977).

(ii) The Rottenstone Sub-domain:

The structural history of the Rottenstone sub-domain and its relationship to other domains in Saskatchewan is poorly understood, due to extreme granitization and migmatization (Ray in press). The lithological and structural pattern is dominated by a northeast to north-northeast trending deformation which is probably Hudsonian. Overprinted Archean remnants may exist, such as in the Combe Lake area (Scott 1970).

Generally, the oldest structure visible in the Rottenstone is a faint east-west foliation, S_1; it is possible but unproven that this may represent a remnant Archean trend. The first period of deformation in the Rottenstone domain may be Archean (Ray in press). In many areas this foliation is found only in supracrustal xenoliths.

The next event in the northwestern part of the Rottenstone was the initiation of the Needle Falls shear zone which rotated the S_1 foliations north-northeasterly in and close to the shear zone. The next phase, accompanied by granitic intrusions produced a generally northeastern S_3 foliation, almost completely overprinting and obliterating the S_1 foliation. Further movement along the Needle Falls shear zone and the Parker Lake gneisses then rotated the S foliation. Some faults developed after the major structural events (Ray in press).

Each of the three structural events was accompanied by metamorphism to the amphibolite metamorphic facies.

The first event resulted in metamorphic segregation into mafic and quartzofeldspathic rich layers, and possibly some extensive anatexix (Ray in press).

The next two structural events were probably continuous and overlapped. They were accompanied by amphibolite facies metamorphism and re-oriented the gneissic foliation, with re-crystallization of biotite and feldspar, local anatexis, and intrusion. The metasediments of the Rottenstone sub-domain contain garnet, sillimanite and rare cordierite at some localities (Ray 1974, Lewry 1975). These minerals grew during this major event which was probably Hudsonian.

(iii) The La Ronge Sub-Domain:

Sibbald (1977) recognized three major episodes of deformation in the La Ronge sub-domain. The first episode resulted in linear and planar structures which in the Milton Island area trend northeast (Report No. 153, Figure II iv). The second and third episodes produced major fold structures that predate and postdate respectively the last major recrystallization of the rocks. Most of these folds plunge northeasterly.

As in the Rottenstone sub-domain, these three structural episodes were accompanied by metamorphic events characterized by preferred crystallographic orientations and mineral growth along foliation planes. The first episode was generally characterized by the growth and preferred orientations of muscovite, biotite, hornblende, and sillimanite (Sibbald 1977, Ray 1975). Granoblastic quartz-feldspar fabrics, metamorphic segregation, and recrystallization of the previous metamorphic minerals with some porphyroblastic growth followed the second episode of deformation. These two episodes reached the amphibolite facies of metamorphism. In the Milton Island area, only localized cataclasis and recrystallization of quartz and feldspar occurred during the third phase of deformation, as well as retrograde metamorphism to the greenschist facies (Sibbald 1977). This third episode is not recognized everywhere in the La Ronge domain. Sibbald (1977) estimates the physical conditions of metamorphism to have been around 5-6 Kb P_{H_2O} and 675-725°C. Gilboy (in press) estimated from metamorphic assemblages that the conditions of the first metamorphic event in the La Ronge sub-domain reached about 640-750°C and 5-6 Kb pressure.

The La Ronge sub-domain has not suffered as severely from anatectic events as the Rottenstone sub-domain. Both sub-domains have shared a common structural history in the "Hudsonian Orogenic Belt" of Ray (1974). Sibbald et.al. (1976) considered the areas from the Wollaston domain northeasterly to the Virgin River Shear Zone part of the Hudsonian mobile belt, the La Ronge and Rottenstone were not. That these areas were involved in some way during Hudsonian events is without question but their precise role is presently unknown.

(f) Discussion and Conclusions:

There is a general concensus that the ultramafic rocks in the "La Ronge-Rottenstone" Domain are older than the main granitic events of the Hudsonian. They are therefore pre-Hudsonian or early Hudsonian. Many ultramafic bodies are websteritic but harzburgitic, lherzolitic and dunitic variants are known. Ultramafic rocks often grade into or are cut by gabbroic rocks, they are obviously somewhat coevial and related. Crosscutting ultramafic rocks are probably due to different phases of the same magmatic event.

Ultramafic and mafic intrusives crosscut "La Ronge Group" Aphebian supracrustal or paragneissic successions and include some metasedimentary and metavolcanic xenoliths. They in turn are cut by or rafted into the Hudsonian granites.

Evidence for in-situ granitization, fusion or partial fusion of metasedimentary rocks, and actual liquid intrusion has been cited. All these processes therefore formed the granitoid rocks of the area. The genesis of granitoid rocks in certain localities is unclear. McLarty (1936)was of the opinion the granitoid rocks on the eastern shore of Nemeiben Lake were probably derived from sedimentary and volcanic rocks.

Forsythe (1971, 1968) considers these of igneous origin, noting the presence of metasedimentary and metavolcanic xenoliths. While describing similar granites in the Stanley area [report 115-1 Figure II(iv)]. Forsythe (1968) states that many inclusions...occur locally, giving the impression these rocks are intrusive. Yet he also uses the word remnant to describe the inclusions stating that "fold trends are outlined by metasedimentary rock remnants in granite" (Forsythe 1971). Part of the granites at least are therefore anatectic products of previously existing metasedimentary successions.

Ultramafitites and gabbros form conformable bodies within the mafic La Ronge Group volcanics which can be pyroxene bearing. The presence of ultrabasic flows has also been postulated. Minor disseminations of syngenetic sulphide or oxide minerals occur in both the intrusive and extrusive rocks The ultramafic rocks may therefore be both parental to and coeval with the extensive La Ronge Group metavolcanics. The volcanics of basaltic composition may be oceanic and derived by partial melting of upper mantle material, represented more directly by the occurrences of ultramafic rocks.

The difference between the La Ronge and Rottenstone sub-domains is one of degree of metamorphism and intrusion. The supracrustal succession has been preserved in the La Ronge sub-domain, but only survived as remnants in the Rottenstone sub-domain. The Rottenstone may simply be closer to the "focus of granitizing energy" (Padgham 1966) or exposed to deeper crustal levels.

Abrupt changes representing different crustal levels on each side of faults are due to appreciable vertical movement of the north-western side. Such faults are used as boundaries between lithostructural domains. Where there are no such disruptive faults, the northwesterly change in degree of granitic intrusion and metamorphism is gradual. In such areas the definition of domain boundaries is very subjective, and the extentions along strike of fault boundaries are used.

The northern intrusive complex, northwest of the Wathaman granite in the northwestern Rottenstone may form a distinct subdivision of the Rottenstone sub-domain (Ray 1975). It is therefore proposed to term this part of the Saskatchewan shield the "La Ronge-Rottenstone" domain, divided up into at least three sub-domains: the La Ronge, the Rottenstone, and the Northern Complex. A better name could be "Churchill River Segment" that used by Weber (in Hajnal and Rose, in press) for the region between the Nelson Front and the Wollaston Domain.

The interpretation of the Needle Falls shear zone and its extensions as a major crustal (plate) boundary is hard to reconcile with the apparent similarities accross this shear zone. The common structural history could be argued to be post and syn-collision events. The Needle Falls shear zone splays and dies out in the Ballentin Island area of the Reindeer Lake region. It could be argued that later igneous and anatectic events sutured and obliterated the northeasterly extension of this crustal break, but one cannot ignore that in its northern reaches the shear zone splays out rather than simply disappearing.

It is therefore unlikely the Needle Falls and related shear zones represent a plate boundary. It may be a large thrust or reverse fault type of structure showing the most displacement near Wyoming and dying out in the Reindeer Lake area of Northern Saskatchewan.

It can therefore be concluded that the majority of ultramafic rock occurrences in the "La Ronge-Rottenstone" domain are Lower Aphebian and pre-to-early orogenic. They may well be comagmatic or parental to both the gabbros and the La Ronge volcanics and due to the same mantle derived magmatic phase(s) but exposed at deeper crustal levels.

(g) <u>Development of the "La Ronge-Rottenstone" Domain</u>:

(i) Discussion of Major Features of the Precambrian Shield of Eastern Saskatchewan and Manitoba.

The Mudjatik and Wollaston domains form the Hudsonian Mobile Belt and the "La Ronge-Rottenstone" domain has been affected by the Hudsonian orogeny. The Needle Falls shear zone is without question a major crustal break but it probably simply marks the northwesternmost reverse or thrust fault zone, whereby the La Ronge-Rottenstone material is wedged against or overides the Wollaston basement.

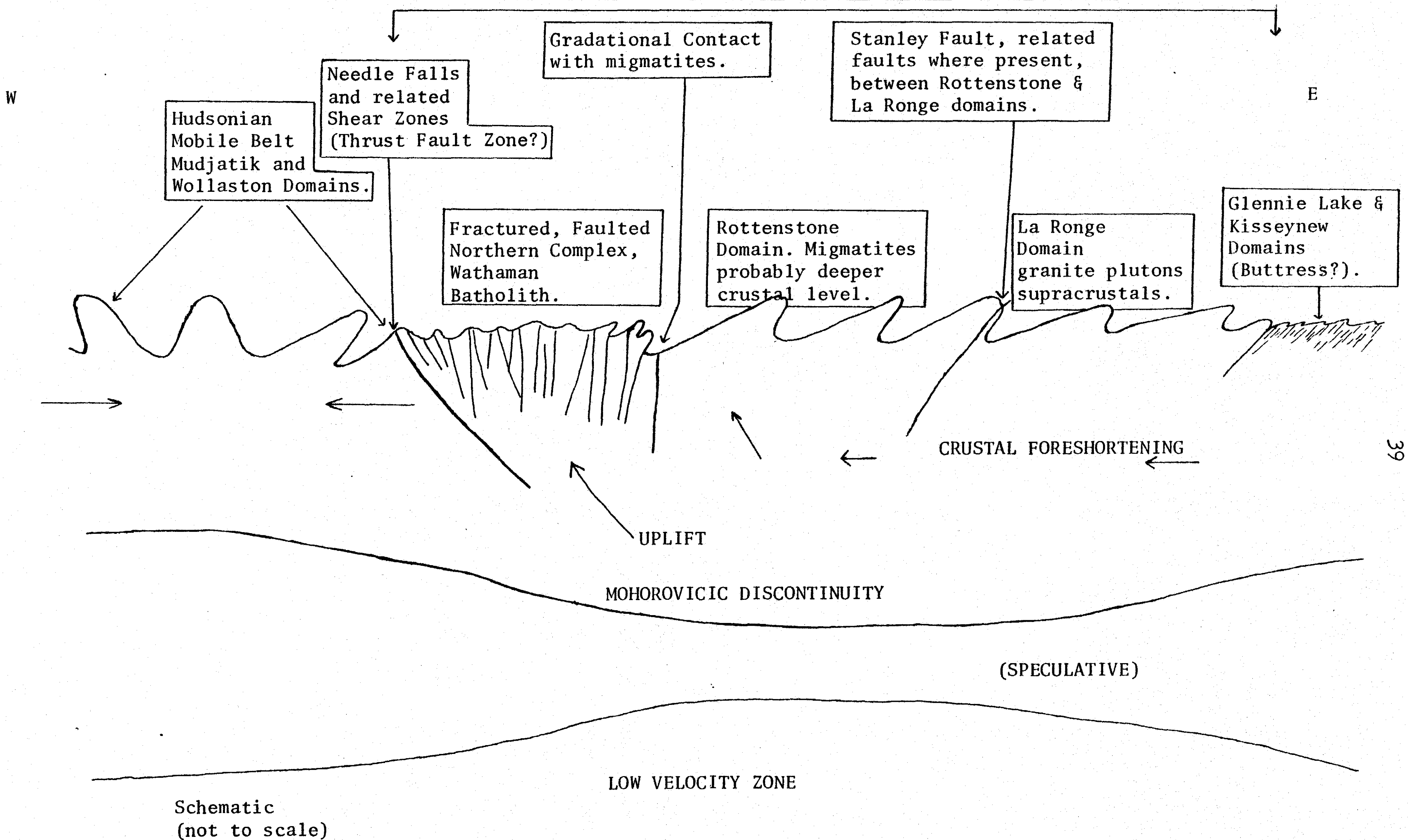
The sub-economic nickel- and copper-sulphide bearing ultramafic rocks in the "La Ronge-Rottenstone" domain may be related to, and a manifestation of the same phenomenon as the Thompson Nickel Belt in the Nelson Front region of Manitoba. Dewy and Burke (1973) have compared the Nelson Front to the Indus structure which as an Alpine suture is characterized by a thickening of the crust. The lack of ophiolitic sequences at the Nelson Front can be explained to be the result of deep level erosion which exposed the assemblages of intrusive ultramafic rock (Hajnal and Rose, in press).

The Churchill River Segment [Figure II (vi)] is formed predominantly of Aphebian volcanics and flyschoid sediments (Weber, in Hajnal and Rose in press). These have low initial strontium isotope ratios indicating direct derivation from the mantle and not reworking of Archean rocks as is the case for the Aphebian materials of the Wollaston Domain. Weber (in Hajnal and Rose, in press) correlates Archean Wollaston to Archean rocks east of the Nelson Front. He therefore postulates that in the Aphebian, part of the Archean Superior plate now represented by the Wollaston domain was ruptured off an original craton. This creates an ocean and a mid oceanic ridge between two continents. Subsequent to this subduction on both sides of the ocean beneath the Superior block and the Wollaston domain developed. Island arc sequences are present in the Churchill River Segment [i.e. the Flin Flon-Amisk Lake volcanics, to which the La Ronge volcanics may be correlative (Sangster 1978)].

Hajnal and Rose (in press) compared the deep structural geophysical signature accross the Nelson Front with data from the Alps and the Peru-Chile trench. They conclude that Weber's hypothesis fits gravity and seismic data better than Dewy and Burke's (1973) Alpine suture model.

West of the Nelson Front, beneath the Churchill River Segment, the mantle occurs at greater depths than beneath the Superior Province in Manitoba. The crust is thick in the wide disturbed belt between the Nelson Front and the possible Archean plate to the west.

FIGURE II(vii) CHURCHILL RIVER SEGMENT, OR "LA RONGE-ROTTENSTONE DOMAIN", CROSS-SECTION



This belt is represented by the Churchill River Segment in Manitoba. The "La Ronge-Rottenstone" domain in Saskatchewan is equivalent to part of the Churchill River Segment. The low velocity tone is probably quite shallow beneath this crustal zone, as shown in Figure II (vii), (Hajnal, oral comm. 1978).

(ii) The Development of the "La Ronge-Rottenstone" Domain: A Hypothesis:

Figure II (vii) which condenses information known concerning the "La Ronge-Rottenstone" domain is now discussed from west to east.

The Mudjatik and Wollaston domains make up the Hudsonian Mobile Belt, in which crustal foreshortening is evident. The Needle Falls shear zone marks a substantial crustal break, interpreted as a major reverse or thrust fault zone. The Northern Complex sub-domain, adjacent to the Wollaston domain, appears to be a series of tectonic slices, mafic to granitic (personal field observations, Fumerton pers. comm. 1977). It also contains an important intrusive igneous component, the Wathaman complex which is the product of crustal melting. The Wathaman complex grades into the migmatites and granites of the southeastern Rottenstone sub-domain which contains few supracrustal remnants, and represents deeper crustal levels than the La Ronge sub-domain. This is due to uplift resulting in deeper levels of erosion. The greatest manifestation of uplift is the Needle Falls shear zone and the interpreted tectonic slices of the northern complex. In this may be an adequate explanation of the observation that the Needle Falls and related shear zones splay and disappear in the northern Reindeer Lake region.

The compressional uplift forces in this region resulted in several en-echelon fault zones rather than in a single zone as seems to be the case further south.

The La Ronge sub-domain was also foreshortened and uplifted by these forces but not to such a great extent. This region therefore represents higher crustal levels than the Rottenstone since it was not eroded to such a depth. The Stanley Fault or related fault zones are taken as the boundary between the La Ronge and Rottenstone sub-domains. They are not manifest everywhere along this boundary. These faults are interpreted as the east side of a large "horst" like structure which was part of the greater uplift in the western part of the La Ronge-Rottenstone domain, developed during Hudsonian orogenic events.

This geological history could be produced by a continent-continent collision, in which case this would be an Alpine type geoctructure, but Weber's hypothesis is preferred. Fumerton (pers. comm. 1977), discards the geosynclinal model as no definite pelagic sediments are known but Weber refers to flysch type sedimentation in the Churchill River Segment.

Plate tectonics as now envisaged is not necessarily involved but whichever model is finally accepted will have to explain the websteritic, lherzolitic, and minor harzburgitic ultramafic occurrences in the region. They are probably pre-tectonic (pre-Hudsonian) and intruded from the bottom of the supracrustal pile. Figure I(vi) shows the speculative positions of the Mohorovicic discontinuity and the low velocity zone below the La Ronge and Rottenstone domains. The geophysical signature defining the low velocity zone can be interpreted as reflecting partial melting in that portion of the upper mantle although not exclusively (Pandit pers. comm.). If such is the case the relatively shallow depth at which the zone occurs under the "La Ronge-Rottenstone" domain is significant. Ultramafic magma could have intruded the crust and in some form reached levels at which they are now observed as intrusives into metasediments, metavolcanics, gneisses or as remnants in younger granitoid rocks. The gabbroic intrusives and mafic volcanics were probably derived from the mantle, and are related to the ultramafics in origin and probably temporarily. The harzburgites are probably representatives of depleted mantle material after the gabbroic phase has separated away from them.

III

THE NEMEIBEN LAKE ULTRAMAFIC PLUTON

(A) Introduction:

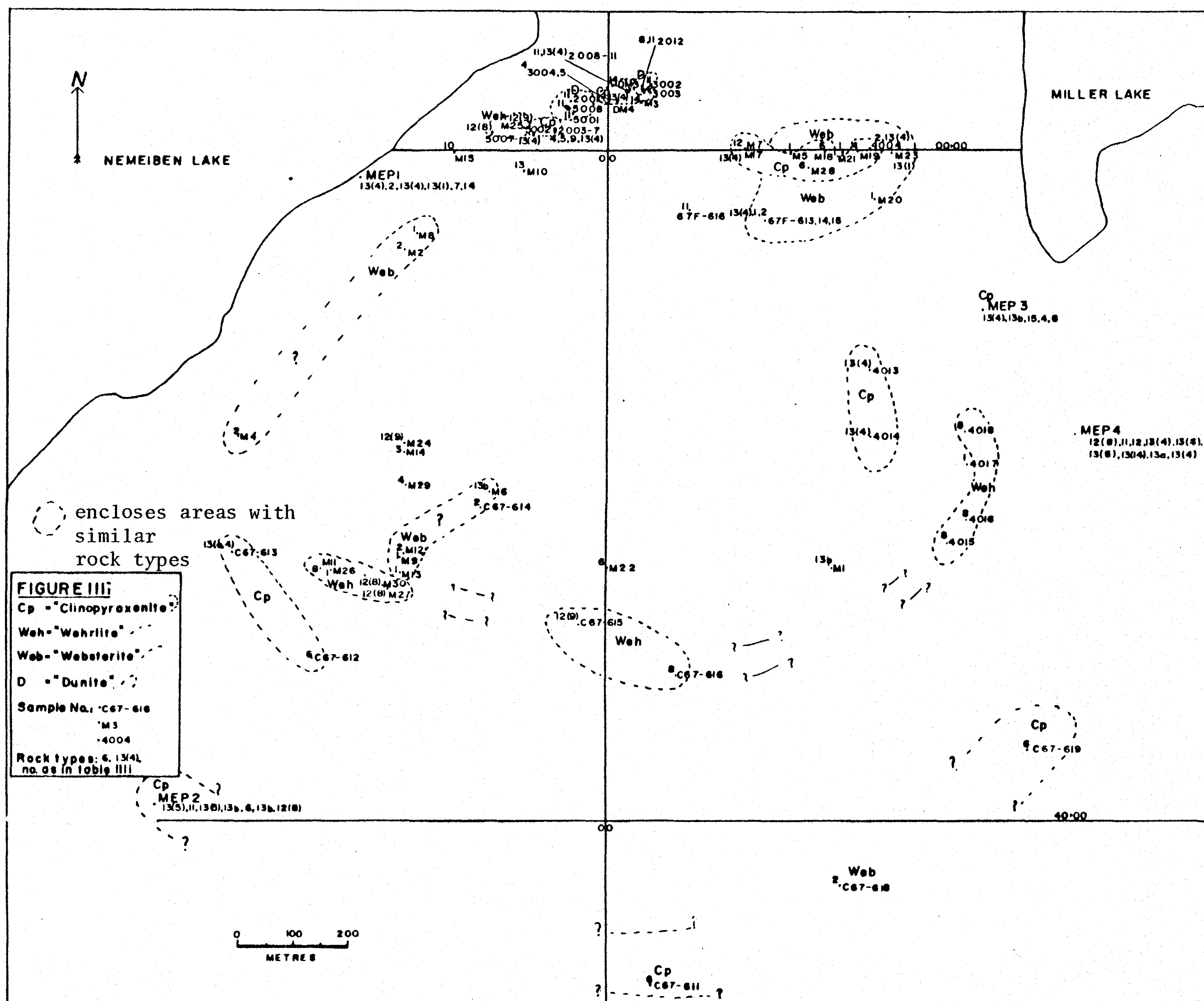
Forsythe (1971) recognized three ultramafic rock units; pyroxenite, uralitized and serpentinized pyroxenite, and serpentinite. The pyroxenite is a websterite, some of which contains olivine. It also includes some clinopyroxenite and olivine clinopyroxenite. The uralitized and serpentinized peridotite unit includes altered websterite, olivine websterite, peridotite and minor lherzolite. The serpentinite unit includes serpentinized dunite, wehrlite, poikilitic wehrlite, lherzolite, uralitized clinopyroxenite, and olivine clinopyroxenite, all of which are highly serpentinized. Separation of poikilitic wehrlite from dunitic and other serpentinite types is possible, but the pyroxenites are virtually indistinguishable in the field. Harzburgite is represented by a large erratic boulder.

Figure III(i) is derived from the thin section study. Areas containing four main rock types divided up by primary mineralogy have been outlined. These are not outcrop areas. Table III(i) lists the rock types recognized with corresponding numbers on Figure III(i). For mapping purposes the rocks have been grouped into clinopyroxenite, wehrlite, websterite, and dunite. Figure I(ii) shows the size and shape of the ultramafic body as determined from geophysical parameters (Cochrane and Richards 1973).

(B) Field Appearance:

(i) Pyroxenite;

Websterite weathers brown to reddish brown or less commonly bluish green. The fresh surface is green, massive, and medium grained.



N
NEMEIBEN LAKE
MILLER LAKE
encloses areas with similar rock types
FIGURE IIIi
Cp = "Clinopyroxenite"
Weh = "Wehrlite"
Web = "Websterite"
D = "Dunite"
Sample No.: C67-616
M3
4004
Rock types: 6, 13(4), no. as in table IIIi
MEP1
MEP2
MEP 3
MEP4
00:00
40:00
0 100 200
METRES

FIGURE III (1)

TABLE III (i)

ROCK TYPES RECOGNIZED IN THIN SECTION

Number On Figure III(i)	Rock Type	Number Recog-nisable	Number of Altered Equivalents (from 12, 13)
1	WEBSTERITE	10	2
2	OLIVINE WEBSTERITE	9	-
3	FELDSPATHIC WEBSTERITE	2	-
4	CLINOPYROXENITE	7	24
5	FELDSPATHIC CLINOPYROXENITE	3	3
6	OLIVINE CLINOPYROXENITE	8	1
7	FELDSPATHIC OLIVINE CLINO-PYROXENITE	1	-
8	WEHRLITE	8	5
9	LHERZOLITE	1	3
10	HARZBURGITE (?)	1	?
11	DUNITE-SERPENTINITE	10	
12	SERPENTINIZED PERIDOTITE	11	
	12 Uralitized & serpen-tinized peridotite	3	
	12(8)*serpentinized & Uralitized wehrlite	5	
	12(9) serpentinized lherzolite	3	
13	AMPHIBOLITE (ultramafic)	40	
	13 a amphibolite		
	13 b serpentine bearing amphibolite	7	
	13(1)*uralitized websterite	2	
	13(4) uralitized (clino)pyrox-enite	24	
	13(5) uralitized feldspathic (clino)pyroxenite clinopy-roxene remnants	3	
	13(6) uralitized & serpentin-ized olivine (clino)pyrox-enite	1	
14	GABBRO	5	1
	14(13) Gabbroic amphibolite	1	
15	GRANITE	4	

* Number in () represents the possible unaltered equivalent.

Weathering alters the rock for about one centimetre. Up to twenty percent amphibole or serpentine is present.

Clinopyroxenite is basically indistinguishable in the field from websterite. It is usually a very hard, green, massive, medium to coarse grained rock with a reddish brown weathered surface. One to five percent disseminated sulphides may occur in the pyroxenites and some sulphide veinlets were also seen. Some weathered surfaces are gossan-like, rich in goethite.

The altered pyroxenitic phases are grey-green to dark grey. They usually have a rusty red weathered surface. They are not just more uralitized and serpentinized versions of the fresh pyroxenites although these do occur. Many are altered peridotites in which the olivine and some of the pyroxene have altered to serpentine and amphibole. Some altered pyroxenites and peridotites are almost totally made up of amphibole. Others contain up to fifty percent serpentine. The grain size is so small that proportions of alteration minerals cannot be determined in hand specimens. Veins of serpentine, calcite, and haematite occur in these rocks. Disseminated oxidized opaques are abundant in uralites, as are veins of pyrrhotite and chalcopyrite. Up to five percent fine-grained sulphide disseminations may occur. These are sometimes completely altered to goethite and limonite.

(ii) <u>Serpentinite</u>:

Dunite and wehrlite are intermingled some at a scale too fine to be mappable. They are only distinguishable on the appearance of their fresh surface. The serpentinized dunites are massive, black and fine-grained with a smooth surface. The serpentinized wehrlites have a rough, blotchy fresh surface or contain large (1 cm) poikilitic altered clinopyroxenite blades with prominant cleavage faces. Some of the serpentinite may have been harzburgitic as no brucite was observed. Minor amounts of green amorphous serpentine, talc, calcite or dolomite, goethite, and haematite occurs in veins and fractures in this rock type.

(iii) Gabbro:

A few gabbro-diorite dykes occur in the northernmost outcrop and the drill holes also intersected plagioclase-rich rock. The gabbro is generally a medium to coarse grained massive mottled light grey to black rock. Contacts with metapyroxenite are sharp where observed at the surface although some in drill core appear gradational over a few centimetres. Plagioclase and large euhedral to subhedral hornblende grains (0.5-1 cm) are megascopically recognisable in most of the gabbros. Chalcopyrite veinlets associated with minor pyrrhotite and pyrite occur in this rock.

(iv) Country Rocks:

The contact between the Nemeiben Pluton and the country rocks is not exposed at the surface, but was intersected in a few of the drill holes. The contact is complex with granite and ultramafitites intermixed in layers 5 to 10 cm thick over a distance of five to ten metres. The ultramafic is fine-grained, and somewhat brecciated. A hybrid quartz dioritic rock though to have formed by contamination of the ultramafic rock is present in places.

The country rocks are pinkish to white granodiorite gneisses cut by aplite dykes. Biotite and quartz range from 2 - 10 percent and 30 - 35 percent respectively. Grain size varies from one to three mm. A few feldspar porphyroblasts, 1 - 2 cm in size, occur in some areas. In places metamorphic segregation has produced alternating 0.5 - 5 cm bands of medium grained (3-5mm) leucocratic material and finer-grained (1-2 mm) more mafic material (10% mafic).

Foliation in the country rock is generally northeasterly but swings around to northwesterly in the area north-northeast of the ultramafic body. This gentle fold may have been caused by the ultramafic body acting as buttress and buckling the granite gneiss. The country rock foliation is roughly conformable to the ultramafic body in its vicinity.

Granite lenses in the ultramafic rock near the contacts as indicated by drill records, indicate that some of the granitic phases are younger than the ultramafic body. In contrast the ultramafitite is fine-grained next to the granite and possibly represents a chilled margin phase as proposed by Cochrane and Richards (1973). This would indicate the ultramafic rock is younger than, and intrusive into, the country rocks. However, the fine-grained nature of the contact could conceivably be due to metamorphism.

(v) Internal Structure:

Relations of various rock types within the pluton appear complex. Serpentinization and uralitization of the pyroxenites and peridotites is patchy; contacts between altered and unaltered phases can either be quite sharp or gradual. Much serpentinite exhibits sharp contacts with pyroxenite or altered pyroxenite but some places have gradational contacts. The nature of the contact between altered ultramafic rocks depends on the original mineralogical composition of the rocks concerned in that olivine and to a lesser extent orthopyroxene altered to serpentine whereas clinopyroxene altered to amphibole. Pyroxenite "dykes" in pyroxenite one to thirty centimetres wide were observed in a few places, only at a slight angle to the fabric of the surrounding rock. These dykes are probably comagmatic with the "intruded" pyroxenite. Such structures are common in ultramafic bodies.

Only minor foliation and mineralogical layering was observed, orientated along the same direction as the nearest contact. No extensive layers of a recognisable rock type was noticed, only lenses and intermingling patches. Wehrlite occurs as discontinuous mega-layers in pyroxenite (Figure III ii) illustrating the structural discontinuity of the igneous fabric.

(vi) Proportions of Rock Types:

Only five percent of the outcrop area is dunitic but the proportion of this rock type may be higher because serpentinite weathers more rapidly than both fresh and altered pyroxenite, as is apparent in the northern outcrops. The southern two thirds of the body is represented by very few scattered outcrops separated by muskeg and forest (Figure I iv). It is possible that a relatively higher proportion of serpentinite than pyroxenite occurs in these areas than in revealed in outcrops.

The remainder of the outcrop area is made up of pyroxenite about half of which is partly serpentinized and uralitized. The altered rocks probably contained more olivine. Most of the rock with two to five percent sulphide disseminations also occurs in the northern part of the body. Megascopically recognisable sulphide disseminations however, can be seen around most of the contact zone in lesser quantities (Figure I v). The petrological pattern of Figure III (i) indicates the body is a circular intrusive plug.

(C) Form of the Intrusion:

Figures III(ii) and III(iii) are interpretation of the form, and distribution of rock types in the pluton. Essentially, it is an intrusive plug with a circular surface plan and gross subcircular mineralogical layering which has intruded a sedimentary and volcanic succession in the Early Aphebian as part of the feeder system to the La Ronge volcanics.

Figure III(ii) is a broad interpretation and extrapolation of the information from Figure III(i), I (iv) and I (v). Wehrlite and clinopyroxenite outline roughly the broad mineralogical layering due to accumulation. Figure III(iii)a shows the possible cross-section in detail and Figure III(iii)b the form of the body at depth. A magma resevoir "at depth" fed the body with new material until crystallization and accumulation due to the lower temperatures and pressures of the sialic crust "plugged up" the channel way. This particular ultramafic body may not have contributed to the La Ronge volcanics as indicated in Figure III(iii) c but was probably coeval with magma that did. The petrogenesis of the pluton and its syngenetic sulphide assemblage is dealt with in more detail in the conclusions of chapters III and IV.

(D) Petrography:

Petrographical notes of the thin sections examined are available in Appendix C(a). Petrographic terminology for fresh ultramafitites or recognisable altered varieties is taken from Streckeisen (1976). In studying thin sections, the rock name assigned was that which best described it without strict adherence to defined percentages of the classification system. This procedure is in accordance with Strekeisen's

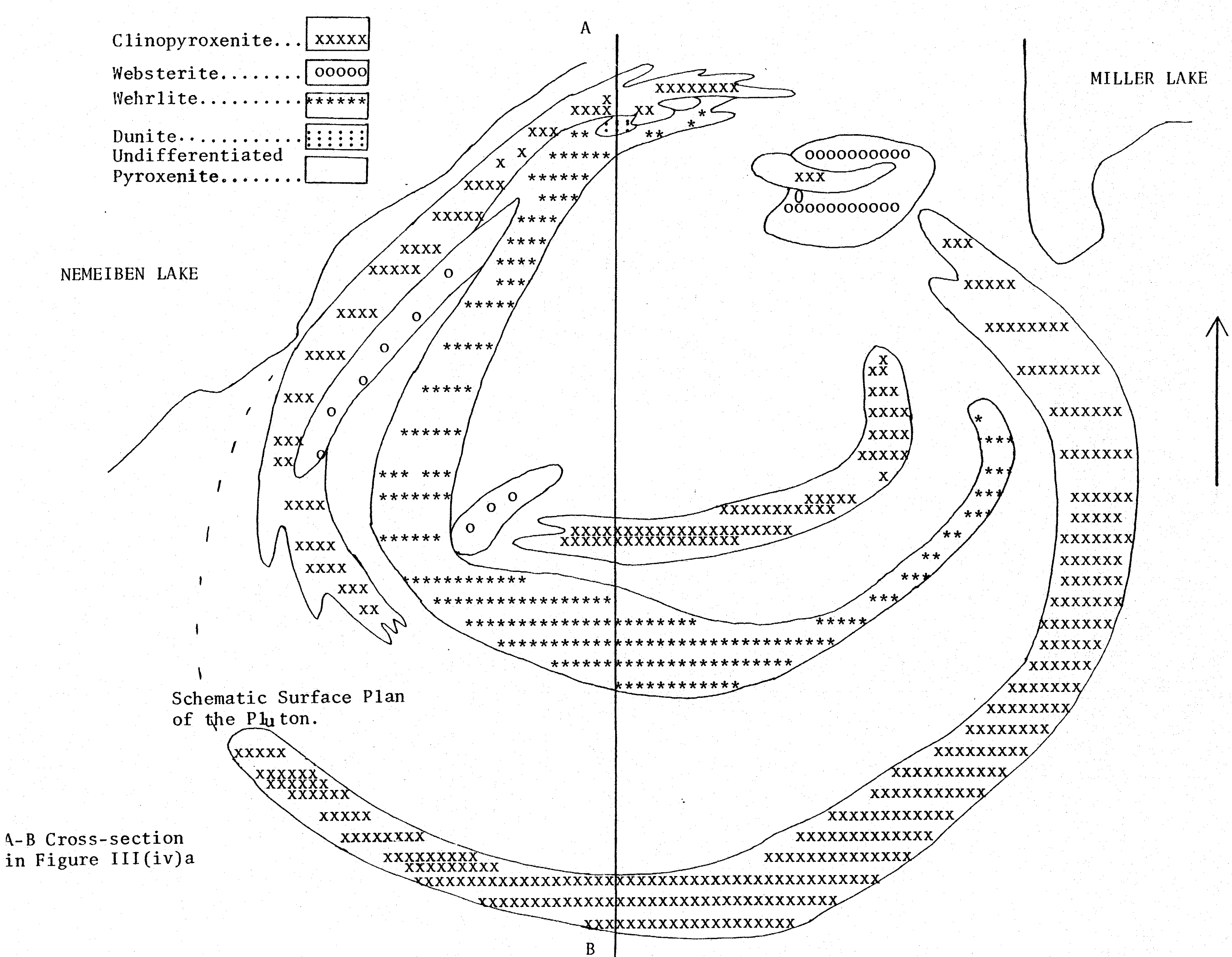
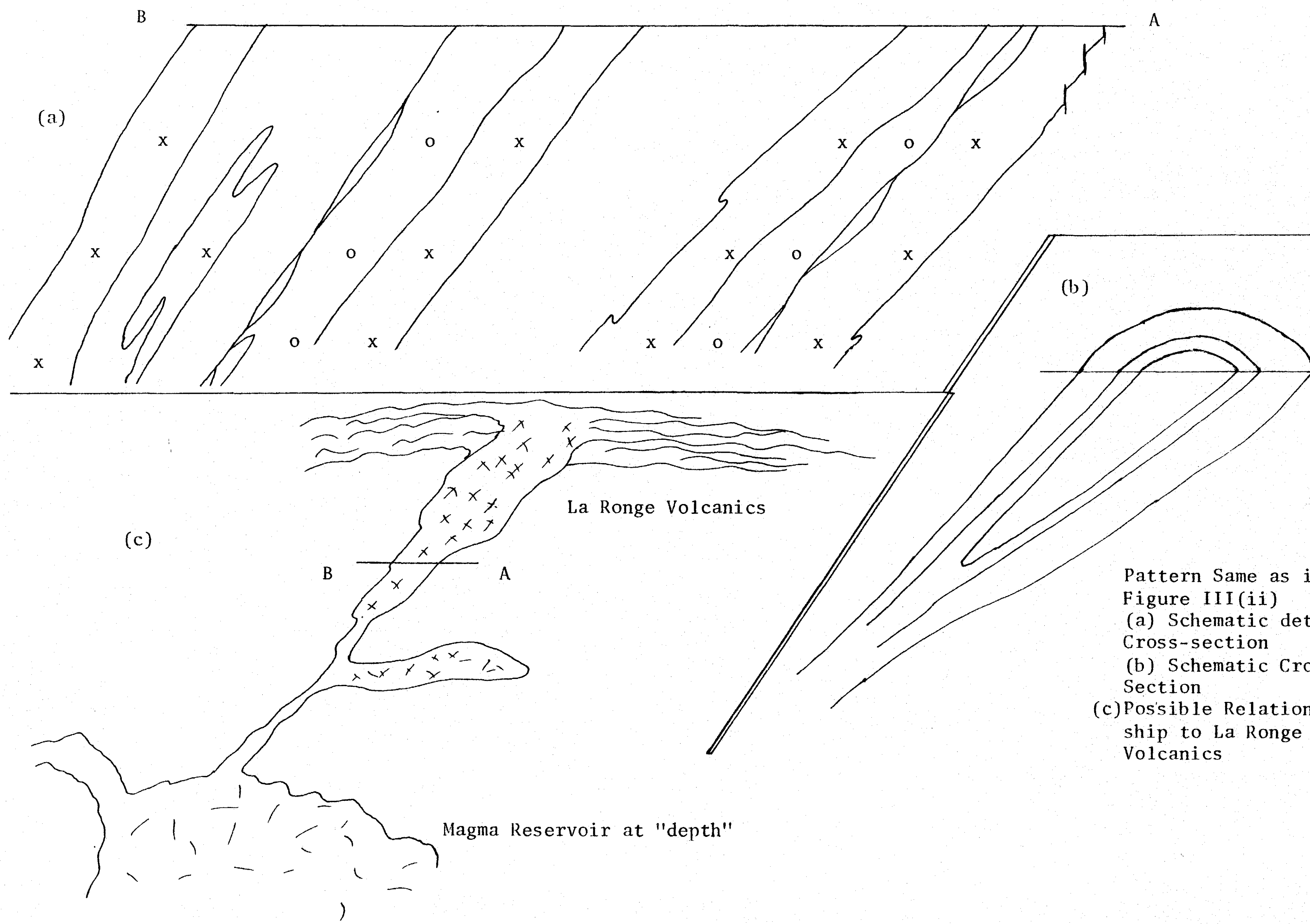


FIGURE III(ii)

FIGURE III(iii)



Pattern Same as in Figure III(ii)
(a) Schematic detailed Cross-section
(b) Schematic Cross-Section
(c) Possible Relationship to La Ronge Volcanics

(1976) own advice. Only visual estimates of mineral abundances were made. Point counting was not carried out since pseudomorphic shapes and appearances of alteration minerals were often used in estimating primary mineralogies.

Gabbro, granite, and thirteen types of ultramafitite were recognized in the thin section study. Table II(i) is a list of the rock types and the number of fresh and altered equivalents of each recognized. They will be discussed according to groups of similar types.

(i) Websterite :

A quarter to a third of the websterites is generally orthopyroxene and in some cases olivine and subordinate plagioclase occurs.

FRESH WEBSTERITE

Opaques	Orthopyroxene	Clinopyroxene	Olivine	Plagioclase	Tremolite
0-5%	10-50%	45-85%	0-30%	0-10%	0-5%
Norm:					
2%	25%	70%	3%	0%	0%

Olivine is often partially to completely serpentinized. Minor talc, serpentine, biotite, brown hornblende, and calcite were also identified.

Grain size is two millimetres on the average. Clinopyroxene crystals are usually two to four mm. Some websterites contain a bimodal distribution of clinopyroxene with size fractions of 0.5mm and 1.5-2.5mm. Orthopyroxene and olivine are usually one to two mm in grain size. A few larger orthopyroxene grains occur, 3-10mm. Tremolite is very fine grained, 0.2-0.5mm long.

Clinopyroxene grains are anhedral with irregular to ragged boundaries. A few to half the clinopyroxenes in websterites are twinned (Plate Ia). Deformation bands, microfractures, and undulose extinction are widespread in some samples. Where deformation features are common in clinopyroxene granoblastic textures often occur.

The orthopyroxenes are subhedral to euhedral. They generally exhibit fewer deformation features than clinopyroxene. A few are highly fractured or strained.

The olivines are spherical and are poikilitically enclosed in clinopyroxene or orthopyroxene (Plate Ib). Some are completely replaced by light green almost isotropic somewhat fibrous serpentine. Light yellow amorphous isotropic serpophite replaces part of some olivines. Mineralogical layering, strings or minor layers of olivine, occur in some websterites with 15-30 percent of this mineral.

Tremolite occurs as small aligned to random patches at the edges of pyroxene grains, or replacing them completely producing topotactic multicrystal pseudomorphs. Brown blastic subhedral hornblende has been observed replacing tremolite. Calcite often occurs intermixed with tremolite. Bastite replacing orthopyroxene has also been recorded.

The disseminated opaques in the websterites are mostly interstitial but some are included by clinopyroxene. The grain size of opaques in websterites containing two to three percent is 0.1-0.3mm. Opaque dusting occurs in serpentine and tremolite meshes.

The minor plagioclase content is interstitial (Plate Ia). Using optical methods its composition was determined to be in the labradorite-andesine range. Pleochroic light brown interstitial primary hornblende is usually closely associated with this plagioclase.

(ii) Clinopyroxenite:

Clinopyroxenite and olivine clinopyroxenite occur; subordinate plagioclase may be present.

FRESH CLINOPYROXENITE COMPOSITION

Orthopyroxene	Clinopyroxene	Olivine	Plagioclase	Opaques	Tremolite
0-8%	55-95%	0-35%	0-7%	1-5%	0-20%
Norm:					
5,2%	85%	2, 10%	0	3%	-

Olivine is often partly to wholly serpentinized. Brown hornblende, calcite, and saussurite also occur.

Grain size is mostly bimodal. Orthopyroxene and olivine grains have sizes between 0.5 and 1 mm and clinopyroxene grains vary between 0.5-1 mm and 2-4 mm. Olivine grains reach 2 mm in size in olivine clinopyroxenites. The larger clinopyroxenes are interstitial and anhedral with ragged edges. In some sections they are poikilitic, enclosing clinopyroxnne, orthopyroxene, and olivine grains. The orthopyroxenes are usually euhedral to subhedral. The olivines are rounded and some round orthopyroxenes occur in olivine clinopyroxenites. A few large orthopyroxenes grew into or included adjacent minerals.

Clinopyroxene grains in some of these samples are completely unaltered and in others they are rimmed by tremolite. Primary or secondary twinning, deformation bands, undulatory extinction, and various degrees of intracrystalline fracturing are present. Tremolite alteration is more usual but some clinopyroxene grains are altered to greyish or green fibrous serpentine. A few large hornblende grains have grown in and replaced tremolite pseudomorphs after clinopyroxene.

Minor calcite or small rectangular haematite masses are included within these grains.

Olivine grains in olivine clinopyroxenites have often collected into cumulative aggregates outlining mineralogical layers. Rhythmic layering of olivine and orthopyroxene is also present. Olivine makes up 60-80 percent of such layers which are 1-2 mm thick and persist for 1-2 cm across thin section contacts with the finer clinopyroxenite are sharp.

Much of the plagioclase is untwinned. The composition of the twinned plagioclase determined optically is An_{44}. Some feldspars are strained and exhibit undulose extinction (Plate IIa). Pleochroic brown hornblende occurs usually closely associated with plagioclase.

The opaques are small (0.5-2 mm) grains or blebs which occur interstitially or as inclusions in the silicate phase. A dusting of very fine-grained opaques occurs in the secondary hydrous minerals and along the crystallographic planes of slightly altered clinopyroxene. Clinopyroxene adjacent to opaque grains is not conspicuously altered.

(iii) Wehrlite:

Most of the olivine in these rocks is partially or completely pseudomorphically replaced by serpentine. The clinopyroxene can be as little as ten percent altered to tremolite but almost complete alteration is common (Plate IIIa).

The virtually ubiquitous occurrence of poikilitic clinopyroxene crystals in these rocks is diagnostic. They form the 1 cm crystal faces which "wink" in the sun in hand specimens.

WEHRLITE COMPOSITION

Olivine or recognisable serpentine pseudomorphs after olivine	Clinopyroxene or recognisable tremolite pseudomorphs after clinopyroxene	Tremolite	Serpentine	Opaques
40-80%	2-55%	0-45%	5-30%	3-5%
Norm:				
40%	35%	10%	10%	3%

Brown serpentine, calcite, and minor chlorite were also observed.

Serpentine pseudomorphs after olivine are usually two to three mm in size. Clinopyroxenes, where intact, reach up to 2 mm and have ragged anhedral outlines except where granoblastic three point junctions are common or when they occur as large poikilitic plates. Wehrlites contain almost no orthopyroxene, a few grains are included in clinopyroxene.

Clinopyroxene usually has altered to a mixture of fine-grained tremolite and minor calcite, sometimes pseudomorphically. Brownish serpentine made up of short thin aligned fibres has replaced clinopyroxene in places. Numerous small remnants of clinopyroxene usually have survived in the tremolite. The large poikilitic grains have largely altered to amphibolite, calcite, and brown serpentine aggregates. Grains in the fresher specimens and the larger remnants in the altered specimens are often twinned to partially twinned, extinguish in an undulatory manner, and are fractured or contain deformation bands.

Greenish fibrous to amorphous isotropic serpentine and calcite occur in veins. Individual blastic calcite grains are often bent and fibres have in places recrystallized to interlocking grains.

Slightly translucent, reddish, isotropic euhedral chromite grains are present. Where chromite is in contact with serpentine a reaction zone containing light green pleochroic chlorite is often present. Minor chlorite also occurs in serpentine not in direct contact with chromite.

Quite a number of the samples exhibit textures interpreted as primary mineralogical layering and cumulate-intercumulate relationships. Linear concentrations of olivine making up to 90 percent of 2-3 mm of rock grade into rock with 50-60 percent olivine and intercumulate clinopyroxene. The cut surface of some of these rocks also show distinct mineralogical layering.

The uralitized and serpentinized wehrlites contain the most opaques because of the addition of dusting due to the growth of low temperature hydrous minerals. Much of the opaque dusting is oxidized giving a reddish colouration to serpentine. These rocks, with various amounts and intensities of fracturing, contain numerous opaque-filled veins and cracks. Two to three percent of these rocks are 0.2-0.3mm primary interstitial opaque grains or blebs.

(iv) Dunite-Serpentinite:

Almost no primary silicate minerals remain in these rocks. Light green, almost isotropic serpentine pseudomorphic after olivine is the major mineral. Brown fibrous serpentine, fine-grained tremolite, and calcite are also present (Plate IVa).

DUNITE-SERPENTINITE COMPOSITION

Serpentine pseudomorphic after olivine	Brown Serpentine	Tremolite	Opaques
85-95%	0-10%	0-2%	3-8%
Norm:			
90%	4%	1%	5%

Clinopyroxene and olivine remnants, dolomite or calcite, and white serpentine occur.

The shape of the serpentine pseudomorphs varies from rounded to pseudohexagonal to rectangular. They average 2-3 mm in size. The interstitial brown serpentine intermixed with minor calcite is after clinopyroxene. Minor bladed to radiating crystals of tremolite also occur in this interstitial material. Many of the small clinopyroxene remnants exhibit strain shadows, undulatory extinction, and some twinning. The olivines in poikilitic clinopyroxene are 0.5 - 1 mm in diameter.

The interstitial opaque mineral grains and blebs average 0.2-0.3 mm in size. Some cubic magnetite grains are cracked and cut by green serpentine veins. Aggregates and elongated vein-like accumulations of small (10-20 microns) secondary opaques occur between serpentine pseudomorphs, in the former radial olivine fractures, and in tension fractures. Composite serpentine, calcite and haematite veins are common.

(v) Uralitized and Serpentinized Peridotite:

Altered peridotites, wehrlites, lherzolites, and one harzburgite were identified.

ALTERED PERIDOTITE COMPOSITION

Green Serpentine	Tremolite	Brown Serpentine	Calcite	Ortho-pyroxene	Opaques
40-80%	0-50%	0-35%	3-15%	0-40%	2-7%
Norm:					
50%	0,35%	0,15%	5%	0,40%	2%

Minor clinopyroxene remnants are common.

Light green serpentine is the most abundant mineral in these rocks. Recognisable rounded to pseudohexagonal pseudomorphs after olivine are common. Brown fibrous serpentine with undulatory extinction is probably after pyroxene as is almost ubiquitous fine-grained colourless tremolite. Calcite occurs intermixed with brown serpentine and tremolite. In wehrlites round serpentine pseudomorphs are closely packed with brown serpentine between them or they "float" in a matrix of long fibrous brown serpentine.

Both orthopyroxene and clinopyroxene remnants occur in brown serpentine and tremolite in altered lherzolitic peridotites. Some of the orthopyroxene remnants are strained.

Veins of amorphous serpentine, tremolite, calcite, and opaques are common in these rocks. Opaque dusting is ubiquitous and was expelled along hydrous silicate boundaries and pseudomorph boundaries or occurs scattered throughout secondary silicates clouding them. Primary opaques vary from 0.2-0.5 mm in size. In the altered lherzolites most interstitial sulphides and oxides occur in regions richest in olivine. Most occur juxtaposed against or between olivines and are interpreted to be primary intercumulus material from textural relationships (Plate IV b).

Harzburgite:

The harzburgite sample is from a boulder in float covering the extreme northeastern part of the body. It indicates harzburgitic phases may occur in the Nemeiben Lake body as no harzburgites are known up ice in the vicinity of the pluton. The sample contains forty percent fractured orthopyroxene altering slightly to serpentine, five percent tremolite with minor clinopyroxene remnants, fifteen percent olivine remnants, and thirty percent light green serpentine probably after olivine.

(vi) Amphibolite (ultramafic):

Forty samples from the pluton are amphibolites some of which contain no remnants of primary igneous silicates. Some have appreciable amounts of serpentine, others contain a few pyroxene remnants and are classed as altered equivalents of websterite, (clino)pyroxenite, feldspathic (clino)pyroxenites, and olivine clinopyroxenite.

ULTRAMAFIC AMPHIBOLITE COMPOSITION

Tremolite	Actinolite	Serpentine (Green)	Serpentine (Brown)	Hornblende	Calcite (dolomite)
0-95%	0-60%	0-20%	0-30%	0-95%	1-10%
Norm:					
75%		5%	10%	2%	3%

Remnants, and up to 5% clinopyroxene can occur. Orthopyroxene remnants are rare. Antigorite, chlorite, and minor feldspar is recorded, 0.5-10% opaques occur in these rocks.

Fine grained colourless tremolite accompanied by opaque dusting and often by calcite is the predominant silicate. It forms pseudomorphs after pyroxene. Some tremolite is granulated. Topotactic replacement by tremolite may reflect former granoblastic textures. Some pseudomorphs reflect former twin planes or undulatory extinction of clinopyroxene.

Green fine grained pleochroic actinolite sometimes occurs devoid of opaque dust and with minor calcite. Calcite is ubiquitous occurring in the alteration amphibole mesh, in veins often in conjunction with opaques and amorphous serpentine, or as rhombohedral to triangular blastic crystals up to 1mm in size (Plate V b).

Subhedral to euhedral pleochroic brown hornblende, up to 2 mm in grain size, occur in many of these rocks. Some brown hornblendes are definitely after clinopyroxene. Fibrous green serpentine replaces some hornblendes and tremolite blades grow into others.

Green serpentine, often clouded by opaque dust, can exhibit ghost fracture patterns reminiscent of olivine. Perfect pseudomorphs after olivine are rare. Some occur including minor primary silicate remnants.

Tremolite grows into and replaces serpentine pseudomorphs after olivine. Up to half the serpentine in some rocks has been altered to tremolite. Some antigorite blades grew at the expense of fine grained cloudy serpentine and are bent.

Brown serpentine occurs as olivine pseudomorphs, as aligned fibres associated with calcite, or in veins. One brown serpentine vein occurs in a fracture and contains many clinopyroxene fragments.

Minor chlorite occurs in the fine grained tremolite of some rocks. Plagioclase is untwinned. Cross-fibrous or amorphous colloform brownish-green isotropic to highly anisotropic serpentine veins are common and some contain calcite filled miarolytic cavities (Plate V a).

Remnant orthopyroxene is rare. It altered to both serpentine and tremolite. Clinopyroxene, often twinned, is more common. In one sample almost all the clinopyroxenes have subparallel extinctions. A few clinopyroxenes contain strain twins. Clinopyroxene alters to brown fibrous serpentine and more commonly to tremolite-actinolite.

Opaque dust occurs throughout most of these rocks in and between all secondary minerals except actinolite. Primary opaques, usually 0.1-0.2mm in grain size, are often cut by tremolite and serpentine and exhibit expansion fractures. Sulphide veins and filaments spread from some blebs, cutting hydrous silicates. Veins of opaques with serpentine and dolomite are common in extensively microfractured rocks.

(vii) Gabbro:

Samples of gabbro or dioritic gabbro and one gabbroic amphibolite were examined. The plagioclase content of the feldspar varies from An_{40} to An_{50}.

GABBRO COMPOSITION

Plagioclase	Hornblende	Clinopyroxene	Tremolite	Actinolite	Serpentine (Brown)
20-70%	0-40%	0-10%	0-35%	0-40%	0-40%
Norm:					
50%	30%	0,10%	10%	0,40%	0,40%
Chlorite, calcite is recorded.					

The common ferromagnesian is a pleochroic green, subhedral hornblende It may be twinned along (100). Fine grained chlorite can occur next to green hornblende. These hornblendes often contain inclusions and dusting of opaques. Tremolite is fine grained and grew into plagioclase. Plagioclase grains exhibit undulatory extinction along polysynthetic twins. The larger grains, two by three mm, are mostly untwinned, cloudy, and show patchy irregular extinction.(1) They often occur in a bimodal interlocking network of plagioclase with granoblastic textures.

The gabbroic amphibolite, composed mainly of actinolite and brown serpentine, is in sharp contact with a slightly feldspathic clinopyroxenite.

(viii) Felsic Phases:

Two granodiorite samples, a quartz vein, and a section across part of the ultramafitite contact were examined. The quartz vein is a network of welded quartz grains, 5mm in size, each containing a very fine network of small interlocking fractures. The quartz exhibits undulose incomplete extinction.

(1) (Plate VI b)

GRANODIORITE COMPOSITION

Ferromagnesians	Quartz	Plagioclase	K Feldspar
4-7%	2 -35%	40%	20-30%

Biotite, chlorite, and hornblende are present.

The granodioritic grab sample of country rock contains four percent biotite, somewhat altered retrogressively to chlorite. Average grain size is 2 mm. The plagioclase is mostly untwinned. The texture is granoblastic. A slight shear, a band recrystallized into small 0.5 mm grains, occurs across the section (Plate VI a).

The granodiorite phase at the contact contains seven percent hornblende biotite, and chlorite, and twenty-five percent 1 mm annealed quartz. The contact zone is a hybrid rock consisting of alternating layers of granodiorite and contaminated ultramafitite. The contact between these two phases is sharp. The granodiorite layers are enriched in mafics near their contacts with the ultramafitite layers. In the hybrid zone the ultramafitite contains plagioclase, minor quartz and alkali feldspar, as well as eighty percent greenish-brown hornblende. This mafic rock is quartz-dioritic, somewhat granulated, and finer grained than the adjacent granodiorite. Some blades of hornblende cut across the contact.

(E) Mineralogy of Primary Igneous Minerals:

Clinopyroxene, orthopyroxene, and olivine are the main primary minerals in the Nemeiben Lake ultramafic pluton. They probably occur in that order of abundance. Minor plagioclase, hornblende, sulphide and oxide minerals also occur. Most mineralogical features have been described in the previous section. An attempt has been made to avoid uneccessary repetition but some is inevitable for the sake of thoroughness.

(i) Clinopyroxene:

Clinopyroxene is the Nemeiben Lake rocks is colourless, diopsidic, and optically positive with a 2V of about 60°. A few pleochroic greenish-brown augites are present. Narrow exsolution lamellae of orthopyroxene in planes parallel to (100) occur in very few clinopyroxenes. Peddada (1972, Table B(i), Appendix B) determined analytically the clinopyroxene to be chromian diopside. The average composition of two analysed grains is $Ca_{42}\ Mg_{53}\ Fe_5$ (Peddada 1972).

Clinopyroxene grains vary in grain size from 0.5–4mm. A bimodal distribution is common, 0.5–1 and 1.5–2 mm. The larger, later intercumulate grains are often poikilitic and include olivine (Plate IIIb) clinopyroxene, orthopyroxene, oxides and sulphides. The smaller grains are cumulate in habit.

Clinopyroxene grains are often twinned to partially twinned. Few multiple twins are present. One grain contains an incoherent twin at a slight angle to (100). Some twins are discontinuous. Most clinopyroxenes are twinned along (100), a few along (001).

Both growth twins and later deformation twins, bands, or shadows are present. Deformation twins at 30° to the c axis and a few irregular deformation bands at 30° to each other about the c axis occur. Undulatory extinction is common, sometimes in visibly bent grains. Intracrystalline fracutring is less common but present as fine-grained reticulate networks of microfractures along cleavage directions. Seldom occurring but recorded are bands of hairline cross fractures crossing at 70° and fine-grained granulation crossing at 45°. In many samples small clinopyroxene grains are more fractured than the larger clinopyroxene grains. In a few samples irregular "wormy" bands of fine grained recrystallized material resembling symplectites occurs in clinopyroxene grains near fractures (Plate II b).

Clinopyroxene grains are usually anhedral and often occur with ragged edges except when three point junctions are common. Clinopyroxene develops this granoblastic texture to a greater degree in strained rocks than the other silicates. Some granulation of clinopyroxene grains to 0.5mm occurs.

Alteration to tremolite is common. Alteration can be complete or partial. Some grains show patchy alteration in the centre or are rimmed by tremolite blades. Magnetite and haematite specks often developed along cleavage planes of incipiently altered clinopyroxenes. In dunites and wehrlites brown serpentine often replaces interstitial clinopyroxene. Light green serpentine can also replace clinopyroxene. Minor calcite is often intermixed in amphibole or serpentine alteration of clinopyroxene.

(ii) Orthopyroxene:

Many orthopyroxene grains in the Nemeiben Lake pluton are colourless and biaxial positive enstatite. Surface traces of the strong (210) cleavage is common and diagnostic together with low birefringence. Some slightly pink biaxial negative pleochroic bronzites are present. Some enstatites are also very pale pink. Orthopyroxene composition is therefore close to Deer et. al.'s (1966) enstatite-bronzite boundary at En_{88}. Peddada (1972)(see table B i Appendix B) reports compositions of $En_{87.5}$ and $En_{90.5}$ or about $Ca_3\ Mg_{86}\ Fe_{11}$ for two analysed orthopyroxene grains.

Most orthopyroxene grains are subhedral to euhedral, 0.5-1.5 mm in size. A few larger, later grains reach 4mm and are often poikiloblastic and idiomorphic. The large grains often contain irregular clinopyroxene exsolutions along (001) (plates Ib, XXIb). In a few, opaque grains are closely associated with these exsolutions. Both exsolutions and inclusions of clinopyroxene can occur in the same grain.

Orthopyroxene grains generally exhibit few deformation features and twins. A coherent growth twin joined along the (101) plane is unique to one slide in this suite. Some strained grains exhibit slightly wavy and undulatory extinction across the c axis. Bent grains also occur. Internal fractures and three point junctions are rare.

Alteration to talc of small orthopyroxene grains included in clinopyroxene is recorded. Serpentine with a bronze schiller (bastite) replaces some orthopyroxene. Direct replacement by tremolite is not common.

(iii) Olivine:

Olivine is colourless, magnesium rich. High relief, high birefringence colours, and a characteristic fracture pattern is diagnostic. The compositions of two grains analysed by electron microprobe are Fo_{87} and Fo_{88} (Peddada 1972) (Table B i in Appendix B).

Many olivines are rounded, 0.5-1 mm in size. Olivine-rich rocks contain 2-4 mm grains, which can be pseudohexagonal to sub-rectangular and aligned. The other igneous silicates have accomodated their growth around olivine which is the earliest cumulate phase. Many small rounded grains are included and often partially ingested by large poikilitic clinopyroxene crystals. These included grains are anhedral and much smaller than other olivine grains and textural relationships indicate some growth of clinopyroxene at the expense of olivine. Inclusions in orthopyroxene occur, usually in the larger later phase. Primary oxides and sulphides often occur closely associated with or in olivine rich layers.

A few olivine grains with undulatory extinction occur. A twinned and cleaved olivine grain is recorded. According to Deer et.al. (1966) such textures are uncommon in olivine. Raleigh (1965) describes slip planes derived experimentally and Spry (1969) mentions twinning in olivines.

Much of the olivine content of these rocks is serpentinized leaving few remnants.

(iv) Plagioclase:

The plagioclase content of the ultramafic rocks occurs as minor allotriomorphic interstitial masses. Many grains are untwinned, or exhibit undulatory extinction and radial strain shadows in places when such is lacking in clinopyroxene. Compositions ranging from An_{44} to An_{50} were determined optically from twinned grains. One grain exhibited two types of twinning: the common polysynthetic albite twins and X-carlsbad twins. Alteration to saussurite is present. Some plagioclase grains include small subhedral clinopyroxene grains.

(v) Hornblende:

A light reddish brown pleochroic hornblende occurs in many rocks containing plagioclase and is closely associated with that phase. It is allotriomorphic and appears interstitial and primary.

The gabbroic phases or dykes from the Nemeiben Lake pluton contain plagioclase determined optically to be in the labradorite-andesine range. The hornblende is pleochroic green, subhedral, twinned along (100) in a few grains, and is probably pargasitic. Chlorite alteration confirms the hornblende phase is magnesium rich. Brown hornblende with magnetite grains along cleavage planes occur in some gabbros. These may be basaltic hornblendes, as defined by Deer et.al. (1966).

(F) Mineralogy and Petrography of Secondary Silicate Minerals:

Tremolite, and various types of serpentine, are the most common secondary hydrous minerals. Actinolite, hornblende, chlorite, saussurite, talc , and calcite also occur. No brucite was identified. Figure III (iv) is a list of the common minerals in the Nemeiben Lake body and their alteration phases with indication of their relative abundance.

(i) Tremolite:

Tremolite, colourless, is generally very fine grained and occurs as 0.2-0.5 mm needles and acicular blades. It grew as randomly orientated masses, epitaxically, or more commonly topotaxically forming multicrystal pseudomorphs after pyroxene (Plate XXb). Pseudomorphic forms after clinopyroxene are the most common, as are clinopyroxene remnants in randomly orientated tremolite meshes. Tremolite also replaces orthopyroxene but seldom pseudomorphically.

Pseudomorphs exhibit higher optical relief than the epitaxial mesh. Aligned tremolite needles in pseudomorphs, 0.4-0.6 mm, are usually longer than in the mesh, 0.2-0.4 mm. Some pseudomorphs are composed of 2-3 mm long tremolite fibres along the whole length of the replaced pyroxene. A dusting of opaques occurs scattered throughout the alteration mineral clouding it, or as aggregates outlining pseudomorphs and between grains (Plate XXa). Opaques often outline former crystallographic planes in pseudomorphs. In many pseudomorphs after clinopyroxene, tremolite mimics former twins and undulatory extinction. In a few rocks multicrystal pseudomorphic growths of tremolite indicates the primary silicate

FIGURE III(iv)

METAMORPHIC MINERALS

Clinopyroxene
- *Actinolite
- Serpentine + calcite + opaque dust
- Tremolite + calcite + opaque dust

Orthopyroxene
- Talc
- Serpentine + opaque dust
  - tremolite
- Tremolite

Olivine
- Serpophite
- Lizardite + opaque dust
  - talc + calcite
  - Tremolite

Lizardite
- Chlorite
- Talc + calcite
- Tremolite
- Antigorite

Tremolite
- Hornblende....fine grained hornblende
- Bladed, acicular tremolite
- Serpentine

Plagioclase ....Saussurite

* Strength of lines indicate relative abundances

minerals were granoblastic. Granular tremolite with three point junctions, 0.2-0.3mm in size, also occurs.

Some acicular blades of tertiary euhedral tremolite up to 2 mm long replaced fine grained tremolite mesh. Some grew as radial masses from a nucleus and exhibit rotating cruciform extinction. Some of these larger tremolite blades are bent. They occur in the same rocks containing antigorite. Some large 3 to 5mm striated tremolite blades occur.

Calcite is ubiquitous in many tremolite rich rocks. Tremolite-calcite-opaque dust are the minerals actually forming the multiphase multicrystal pseudomorphs after clinopyroxene. Tremolite is replaced by blastic brown pleochroic hornblende and replaces serpentine after olivine in a few sections.

Slightly green tremolite is associated with less opaque dust than colourless tremolite. Actinolite occurs in a few sections. This amphibole is virtually devoid of opaque dust. Its structure is richer in iron and accepted the excess ions which are expelled by tremolite.

(ii) Serpentine:

Fine grained lizardite is the main serpentine mineral. It commonly replaces olivine,often retaining the crystal outline and irregular curved fractures of that mineral. It is colourless to light green or slightly brown and is associated with much opaque dust. Some pseudomorphs after olivine are composed of a centre of fibrous brown lizardite rimmed by amorphous brown serpentine. Veins of chrysotile associated with opaques and calcite occur sporadically cutting across primary silicates, opaques, and other secondary silicates. Antigorite blades, often bent, grew in fine-grained lizardite masses in a few samples (Plate Vb). Some yellow isotropic serpentine (serpophite) alters rims or part of some olivine grains.

A brown serpentine (bastite) replaces orthopyroxene, preserving pseudomrophically its schiller and rarely its shape. Long brown fibres of serpentine intimately mixed with calcite and some opaque dust replaces intercumulate clinopyroxene in many dunites and wehrlites. Some poikilitic clinopyroxenes that have altered to this serpentine contain contrasting small 0.5 mm light green pseudomorphs after olivine. Some clinopyroxene alters to a grey serpentine, or to more usual light green somewhat fibrous lizardite. Serpentine after clinopyroxene exhibits lower relief than pseudomorphs after olivine.

Chlorite occurs in very small amounts in serpentine. It is usually associated with antigorite blades or chromite grains. Talc and calcite seldom replace serpentine in olivine pseudomorphs.

(G) Deformation and Metamorphism:

(a) Discussion:

Figure III(v) is an outline of the deformational and metamorphic history of the Nemeiben Lake pluton. Two metamorphic and two deformational episodes are indicated.

Primary mineral growth in the last stages of crystallization took place under some stress or growth constrictions which resulted in three point junctions and in some cases pseudohexagonal equidimentional clinopyroxene grains.

FIGURE III(v)

WEATHERING

Low temperature amorphous serpentine veins in tension fractures. Haematite veins. Supergene alteration of opaque minerals.

METAMORPHISM AND DEFORMATION, 2

Fractures, granulation and granoblastic structures in tremolite. Growth of tremolite and antigorite blades, often bent. Growth of blastic hornblende. Talc and chlorite after serpentine. Minor mobilization and alteration of sulphides.

METAMORPHISM 1a, b

(a) Retrograde: serpentinization of olivine and some orthopyroxene and clinopyroxene.
(b) Followed by the development of tremolite after pyroxene and some serpentine. Production of secondary opaques, alteration of primary sulphides. Expansion fractures in serpentinites, some in uralites.

DEFORMATION 1

Strain shadows, twins, intracrystalline fracturing. Granoblastic structures. Untwinning of plagioclase. Extensive shearing and fracturing at the north end of the body. Mobilization and deformation of some opaques.

INTRUSION

Primary growth twins etc. in clinopyroxene. Primary mineralogical layering, flow foliation. Production of some secondary hornblendes near the contact. Three point junctions in clinopyroxene due to growth under stress at beginning of deformation 1.

DEFORMATIONAL AND METAMORPHIC HISTORY, NEMEIBEN LAKE PLUTON

This was the start of the first deformational stage which resulted in granoblastic textures and the multiple intracrystalline strain features observed. Brittle deformation resulted in some faulting and fracturing which affected the northern contact of the body and a fault which terminates the gabbro dykes. Chalcopyrite and minor pyrrhotite were mobilized from primary blebs into veinlets in microfractures, but some late magmatic veinlets may also have formed at this time.

The formation of retrograde hydrous minerals and associated opaque dust followed. Some haematization of primary opaque minerals as well as the production of additional haematite with magnetite and sulphide veins occurred at this time. Olivine was the first mineral to to be serpentinized, and was followed by the serpentinization of clino-pyroxene and orthopyroxene. Tremolite alteration of pyroxene and some serpentine was partly concurrent and later, and was probably due to metamorphism at slightly higher temperatures. Alteration of the ultramafitites may have been concurrent with and due to the granitization of the country rocks.

The second metamorphic and deformational episode was less extensive. It produced granulation of secondary minerals and the growth of tertiary tremolite, antigorite, chlorite, amphibole, and a few meta-morphic sulphide minerals (i.e. pyrite in marcasite).

Deuteric alteration of pyroxene during intrusion into an interpreted wet supracrustal pile produced some hornblendite phases in parts of the contact region.

(b) Temperatures Reached During Metamorphism:

Alteration of pyroxene to fibrous amphiboles is either ascribed to hydrothermal solutions which may be associated with the late stage crystallization of igneous rocks, or to a post consolidation process associated to regional, thermal, or metasomatic metamorphism (Deer et.al. 1966).

At 400 bars of water pressure tremolite breaks down to pyroxene at 780°C (Boyd 1954). The possible presence of pentlandite exsolutions in opaque dust associated with some tremolite (Chapter IV) indicates that a metamorphic event with temperatures above about 600°C may have contributed to uralitization. Tremolite-actinolite in komatiites of the Eastern Goldfields region of Australia occur in very low (Sub-greenschist) to high grade (upper amphibolite) metamorphic domains (Binns et.al. 1976). No metamorphic olivines were detected in the Nemeiben Lake pluton. In the Eastern Goldfields region these occur at upper amphibolite grades (Binns et.al. 1976). This negative evidence would indicate metamorphism of the Nemeiben Lake pluton reached middle amphibolite grades or temperatures no higher than 550-600°C (Hyndman 1972). Granitic melts form at about 650°C at high P_{H_2O} (Hyndman 1972). Granitization of the country rocks and metamorphism of the ultramafic pluton occurred during the same regional metamorphic and deformational event at the peak of the Hudsonian orogeny in this region.

Serpentine usually forms below 400°C when only water is introduced (Deer et.al. 1966). This is the case at Nemeiben (Peddada 1972). Serpentine breaks down at about 700-800°C (Deer et.al. 1966). Under hydrothermal conditions above 500°C serpentine in contact with olivine breaks down to produce talc (Bowen and Tuttle 1949). Some talc in serpentine pseudomorphs after olivine occurs at Nemeiben Lake.

It can therefore be concluded that serpentinization occurred at relatively low temperatures (400°C) and was followed by formation of tremolite at 600-650°C during metamorphism to the middle and possibly upper amphibolite facies.

(H) Geochemistry:

The major element analyses of five ultramafic rocks, a gabbro, and a granodiorite, are tabulated in table III(ii). Normative calculations were carried out and the results tabulated in table III(iii).

(i) Normative Compositions:

The sample of country rock determined optically to be granodiorite lies close to the tonalite-granodiorite boundary in Strekeisen's classification (1976) in terms of normative composition. The gabbroic sample showed alkaline affinities. It is high in alumina and nepheline, olivine, and clinopyroxene normative. Ilmenite and magnetite are significant normative components. This is reflected by their petrographic presence. The corrected normative plagioclase is An_{66} as compared to the optically determined An_{50}. This confirms the gabbroic rather than dioritic nature of this rock.

The dunitic serpentinite contains 18 percent normative orthopyroxene indicating a harzburgitic nature. It was petrographically determined that most interstitial material in dunites and wehrlites is clinopyroxene. Eight percent normative anorthite is also present. This probably explains the production of clinopyroxene rather than orthopyroxene during crystallization. The clinopyroxenites also contain appreciable amounts of normative orthopyroxene. The normative plagioclase content in these rocks is higher than the petrographically determined amounts and can also account for this. Normative orthopyroxenes calculated first in the program used but was not always formed until the depletion of needed components at Nemeiben as assumed in normative calculations. Not surprisingly the olivine clinopyroxenite contain over twice as much normative olivine content as the

TABLE III (ii)

MAJOR ELEMENT ANALYSES OF SEVEN ROCK SAMPLES

(Courtesy of Falconbridge Metallurgical Laboratories)

Sample No.		Rock Type	SiO_2	Al_2O_3	Fe_2O_3 (1)
1)	M3	Gabbro	45.38	21.19	1.42
2)	1004A	Feldspathic clinopyroxenite	52.97	5.22	3.31
3)	2012B	Serpentinite	38.28	2.42	7.56
4)	MIV	Granodiorite	71.24	16.30	0.42
5)	1006	Uralitized Pyroxenite	52.49	3.62	2.24
6)	M18	Olivine clino-pyroxenite	52.08	3.00	2.29
7)	4004B	Olivine Web-sterite	51.91	4.22	1.75

	FeO (2)	MgO	CaO	Na_2O	K_2O	H_2O- (3)	LOI (4)
1)	7.0	6.86	9.99	2.91	0.35	0.17	1.63
2)	4.9	20.70	11.92	0.75	0.06	0.11	0.76
3)	3.4	35.47	1.09	0.27	<0.02	0.92	12.6
4)	0.6	0.57	3.03	5.58	0.45	0.10	0.53
5)	5.8	22.28	10.68	0.52	0.04	0.15	1.66
6)	3.9	23.28	13.13	0.52	<0.02	0.23	1.32
7)	4.6	20.35	14.16	0.55	0.02	0.11	0.99

CO_2 (5)	P_2O_5	TiO_2	Cr_2O_3	MnO	NiO	Totals (6)
1) 0.10	0.20	1.11	<0.06	0.13	0.05	98.2
2) 0.38	0.16	0.28	0.23	0.16	0.04	101.5
3) 0.47	0.01	0.07	0.72	0.13	0.29	102.3
4) 0.07	0.08	0.24	0.06	0.01	0.03	99.1
5) 0.06	0.04	0.20	0.28	0.16	0.05	100.1
6) 0.67	0.19	0.13	0.39	0.14	0.10	100.4
7) 0.58	0.23	0.18	0.46	0.14	0.07	99.6

NOTES:

(1) FeO calculated to Fe_2O_3 equivalent, which was then subtracted from total iron reported as Fe_2O_3 by XRF, to give figure for iron originally present as Fe_2O_3.

(2) FeO by wet-chemical method.

(3) H_2O - by drying at 105°C. All XRF determinations on samples dried at 105°C.

(4) Percentage weight lost by ignition to 950°C, from samples as received.

(5) Total carbon as Co_2.

(6) Totals use LO1 at 950°C of samples as received; includes loss of CO_2 and H_2O (-105°C).

TABLE III (iii)

Normative Calculations:

Computer program from Irvine and Baragar (1971) as modified by S.L. Fumerton (1978).

Abbreviations:

Q	Quartz	HE	Hedenbergite
C	Corundum	EN	Enstatite
OR	Orthoclase	FS	Ferrosillite
AB	Albite	FO	Forsterite
AN	Anorthite	FA	Fayalite
NE	Nephelene	IL	Ilmenite
DI	Diopside	AP	Apatite

1) M3 Petrographic analysis: Gabbro: (Visual Estimates) Estimated modes:

70% Plagioclase (An50?)
27% Green Hornblende
2% Tremolite
1% Sulphides, oxides.

	Weight %	Cation equivalents		Weight %	Cation equivalents
OR	2.147	2.123	FO	11.597	13.596
AB	24.192	25.377	FA	7.364	5.965
AN	45.355	44.843	MT	2.136	1.522
NE	0.729	0.847	IL	2.187	1.586
DI	2.540	2.581	AP	0.481	0.429
HE	1.277	1.132			

MOL AL_2O_3/K_2O+Na_2O+CaO	0.91
Peralkaline index	0.24
Differentiation index*weight %	27.07
Colour index	27.10
Corrected alkali feldspar	3.2
Corrected anorthite	66.3
Recalculated alkali feldspar	4.5
Recalculated plagioclase	95.5

Rock name: alkali basalt, sodic series.

*Differentiation index is $SiO_2 + FeO + Fe_2O_3 + Na_2O + K_2O + CaO$.

2) 1004A Petrographic Analysis: Feldspathic clinopyroxenite.

7% Plagioclase (An_{44}?)

5% Brown Hornblende

75% Clinopyroxene.

Orthopyroxene, tremolite, olivine, opaques.

	Weight %	Cation equivalent		Weight %	Cation equivalent
OR	0.354	0.345	FS	5.873	4.816
AB	6.338	6.537	FO	3.479	4.012
AN	10.688	10.391	FA	0.714	0.568
DI	32.276	32.246	MT	2.578	1.807
HE	5.237	4.567	IL	0.531	0.379
EN	31.561	34.007	AP	0.371	0.325

MOL AL_2O_3/K_2O+Na_2O+CaO	0.23
Peralkaline index	0.25
Differentiation index	6.69
Colour index	82.25
Corrected alkali feldspar	0.6
Corrected anorthite	16.8
Percentage An	63.5
Recalculated alkali feldspar	3.2
Recalculated plagioclase	96.8

3) 2012B. Petrographic Analysis: Serpentinite

90% Green serpentine

6% Brown serpentine

4% Opaques

	Weight %	Cation equivalent		Weight %	Cation equivalent
C	0.026	0.026	FO	59.717	64.517
AB	2.541	2.455	FA	11.328	8.451
AN	6.092	5.547	MT	2.278	1.496
EN	15.238	15.383	IL	0.133	0.089
FS	2.623	2.015	AP	0.023	0.019

MOL Al_2O_3/K_2O+Na_2O+CaO	1.0
Peralkaline index	0.18
Differentiation index	2.54
Colour index	91.32
Corrected anorthite	8.6
Percentage An	70.6

4) MIV Petrographic Analysis: Granodiorite

3-4%	Chlorite and biotite
35%	Quartz
40%	Plagioclase (?untwinned)
20%	K-feldspar (?)

	Weight %	Cation equivalent		Weight %	Cation equivalent
Q	30.233	27.832	EN	1.441	1.588
C	1.338	1.451	FS	0.364	0.305
OR	2.707	2.685	MT	0.618	0.443
AB	47.925	50.548	IL	0.463	0.337
AN	14.728	14.642	AP	0.188	0.169

MOL AL_2O_3/K_2O+Na_2O+CaO	1.07
Peralkaline index	0.59
Differentiation index	80.86
Colour index	2.89
Corrected alkali feldspar	10.1
Corrected anorthite	55.2
Percentage An	26.7
Recalculated quartz	31.6
Recalculated alkali feldspar	10.6
Recalculated plagioclase	57.8

Rock name: calc-alkaline dacite, K-poor series.

5) 1006 Petrographic Analysis: Uralitized (clino)pyroxenite

90% + Tremolite

5% Opaques

1% Calcite

Remnant clinopyroxene, minor serpentine

	Weight %	Cation equivalent		Weight %	Cation equivalent
OR	0.242	0.234	FS	6.072	5.471
AB	4.496	4.617	FO	2.848	3.270
AN	7.589	7.345	FA	0.555	0.440
DI	31.761	31.591	MT	2.519	1.758
HE	4.895	4.250	IL	0.388	0.276
EN	37.911	40.667	AP	0.095	0.083

MOL Al_2O_3/K_2O+Na_2O+CaO	0.18
Peralkaline index	0.25
Differentiation index	4.74
Colour index	87.58
Corrected alkali feldspar	0.4
Corrected anorthite	11.9
Percentage An	63.5
Recalculated alkali feldspar	3.1
Recalculated plagioclase	96.9

6) M18 Petrographic Analysis: Olivine Clinopyroxenite

20%	Olivine or serpentine after olivine
5%	Orthopyroxene
70%	Clinopyroxene
2%	Opaques
	Tremolite, calcite.

	Weight %	Cation equivalent		Weight %	Cation equivalent
AB	4.469	4.556	FO	8.202	9.350
AN	5.944	5.713	FA	1.043	0.821
DI	42.188	41.667	MT	2.4	1.663
HE	4.245	3.660	IL	0.251	0.177
EN	27.622	29.422	AP	0.448	0.388
FS	3.188	2.584			

MOL Al_2O_3/K_2O+Na_2O+CaO	0.12
Peralkaline index	0.29
Differentiation index	4.47
Colour index	89.14
Corrected anorthite	10.4
Percentage An	57.1

7) 4004B Petrographic Analysis: Olivine Websterite

15% Orthopyroxene

75% Clinopyroxene

9% Olivine

1% Opaques

	Weight %	Cation equivalent		Weight %	Cation equivalent
OR	0.121	0.117	FS	3.635	2.977
AB	4.750	4.893	FO	3.498	4.028
AN	9.174	8.907	FA	0.523	0.416
DI	43.039	42.940	MT	2.486	1.740
HE	5.093	4.435	IL	0.349	0.248
EN	26.786	28.882	AP	0.545	0.477

MOL Al_2O_3/K_2O+Na_2O+CaO	0.16
Peralkaline index	0.22
Differentiation index	4.87
Colour index	85.41
Corrected alkali feldspar	0.3
Corrected anorthite	0.3
Percentage An	0.3
Recalculated alkali feldspar	50.0
Recalculated plagioclase	50.0

feldspathic clinopyroxenite. The uralitized pyroxenite has a comparable normative olivine content to the feldspathic clinopyroxenite.

The altered pyroxenite contains more normative orthopyroxene than the clinopyroxenites and even than the websterite. The preponderance of tremolite and the presence of only clinopyroxene remnants had led to the conclusion the rock may have been a clinopyroxenite. The geochemical results indicate a websteritic nature to this rock. This conclusion may apply to many, if not all of the possible uralitized (clino)pyroxenites. Tremolite altered orthopyroxene or hydrous minerals that had previously altered orthopyroxene. Fifteen to twenty percent original orthopyroxene content in this rock is a reasonable guess. Clinopyroxene is still the indicated major primary mineral.

The normative olivine content of the olivine websterite is lower that that determined petrographically. The cut section may be richer in olivine than the rock sample as a whole. This may be an indication of the compositional variability of the Nemeiben Lake rocks over very short distances, or that the rock has gained silica during alteration. The section examined however, is little altered.

The diopsidic nature of the clinopyroxene as determined optically is supported by the normative results. The normative orthopyroxene is enstatitic to bronzitic, also as determined optically (2V). Magnetite is a significant normative mineral in the ultramafic rocks and this is reflected by the presence of primary magnetite in thin section. The feldspathic clinopyroxenite, uralitized (clino)pyroxenite, and olivine websterite contain minor normative orthoclase. Minor normative apatite is contained in all the rocks. The serpentinite contains very minor normative corundum, indicating an excess of alumina relative to K, Na and Ca. Some discrepancies between normative calculations and petrographically determine compositions may be due to alteration. A calcium loss is indicated by numerous calcite veins and sodium probably behaved in a similar manner. Oxidization of orimary oxide phases affect the FeO/Fe_2O_3 ratio and therefore the calculated normative oxide component.

(ii) Discussion:

Figures III(vi) to III(viii) plot component trends against the calculated differentiation index. The index is: $SiO_2 + FeO + Fe_2O_3 + Na_2O + K_2O + CaO$ and is used as a measure of rock composition. SiO_2, CaO, Al_2O_3, and FeO seem to plot with positive slopes. Total iron, Fe_2O_3, and MgO seem to plot with negative slopes. These are essentially three point graphs each cluster representing pyroxenites, gabbro, and dunite. This polarization of plots would probably have occurred even with a more extensive analytical program and indicates the rocks are cumulates.

Ferric iron plots with a positive slope in Figure III(vi) but ferrous iron (Figure III viii) and total iron (Figure III vii), plot with negative slopes. This anomalous trend is similar to that determined for the mafic group of the boundary intrusions in the Flin Flon region. In that case, "successive differentiates become slightly depleted in FeO relative to MgO, while SiO increases rapidly. This differentiation trend can best be explained as the effect of high f_{O_2} and f_{H_2O} during crystallization of a hydrous basaltic magma...If the boundary mafic magma crystallized at relatively high f_{O_2}, as seems likely, then crystallization of some magnetite is likely to have occurred during differentiation" (Syme and Forrester 1977). Figure III (ix) is a plot of SiO_2 against FeO/MgO. It could represent a trend similar to the mafic boundary intrusions. The possible effect of alteration of the body to ferric-ferrous ratio cannot be ignored and could also explain the contrasting slopes. Primary magnetite is ubiquitous in the dunites and wehrlites and is present in most pyroxenites in the Nemeiben Lake pluton. A high f_{O_2} during intrusion is therefore likely. A high f_{H_2O} is unlikely however as very few primary hydrous minerals are present in the pluton apart for minor hornblende in some slightly feldspathic pyroxenites.

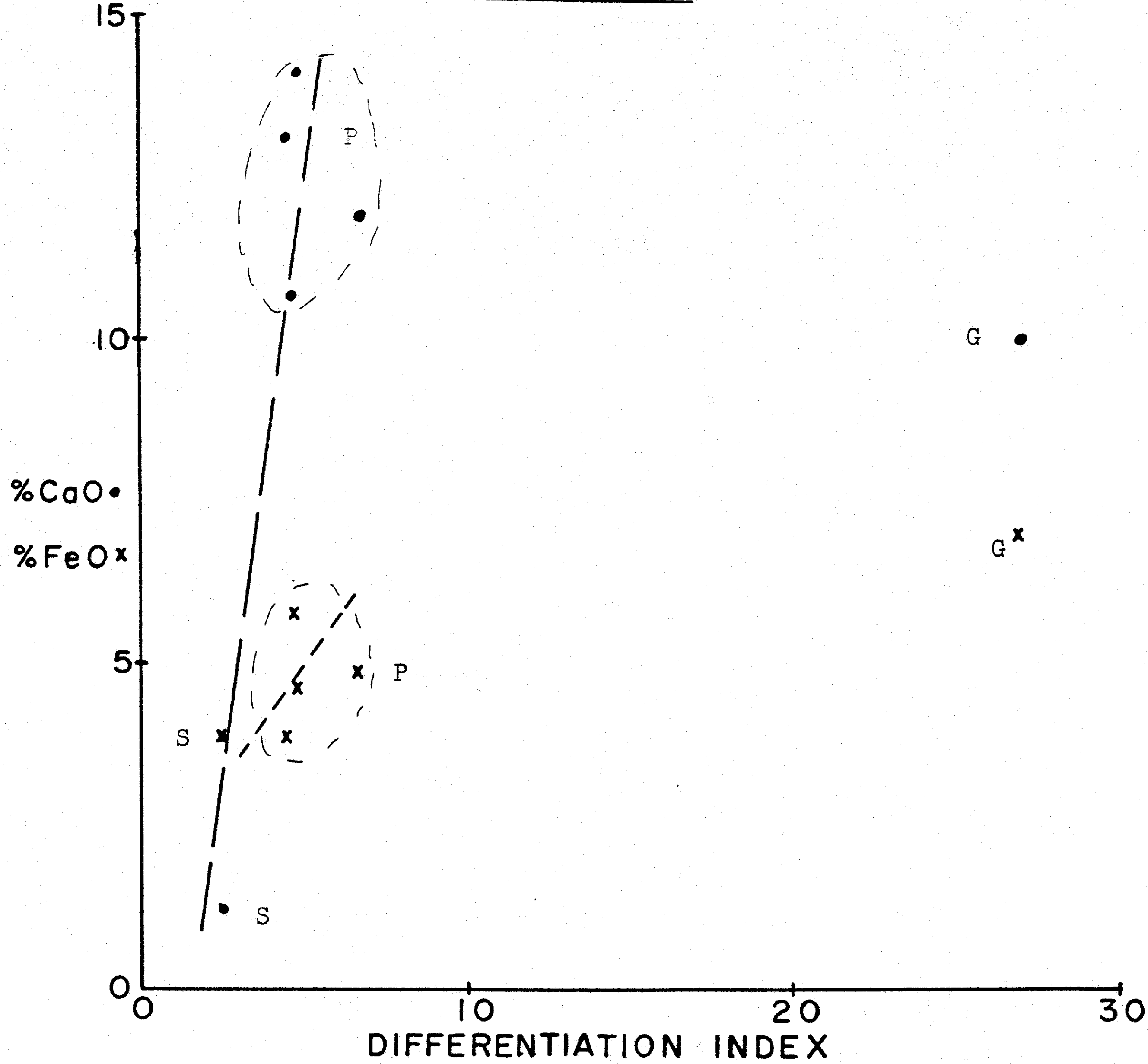
(I) Petrogenesis of the Nemeiben Lake Pluton:

(a) General Features:

Rock types in the Nemeiben Lake ultramafic pluton vary rapidly over short distances. The only sharp contacts are between the dunite-wehrlite unit, and pyroxenitic phases. Narrow pyroxenite layers 5-10 cm wide are present in dunitic rocks and may represent rhythmic layering. Pyroxenite dykes cutting other phases represent younger phases of the some magma intruding already consolidated parts of the body.

Dunitic and wehrlitic rocks form distinct units but they grade into each other over a few centimentres rather than exhibiting sharp contacts. Similarly the olivine pyroxenites, websterites, and clinopyroxenites grade into each other. Most visible contacts in the pyroxenites are metamorphic although some control by primary mineralogy is evident.

FIGURE III(vi)

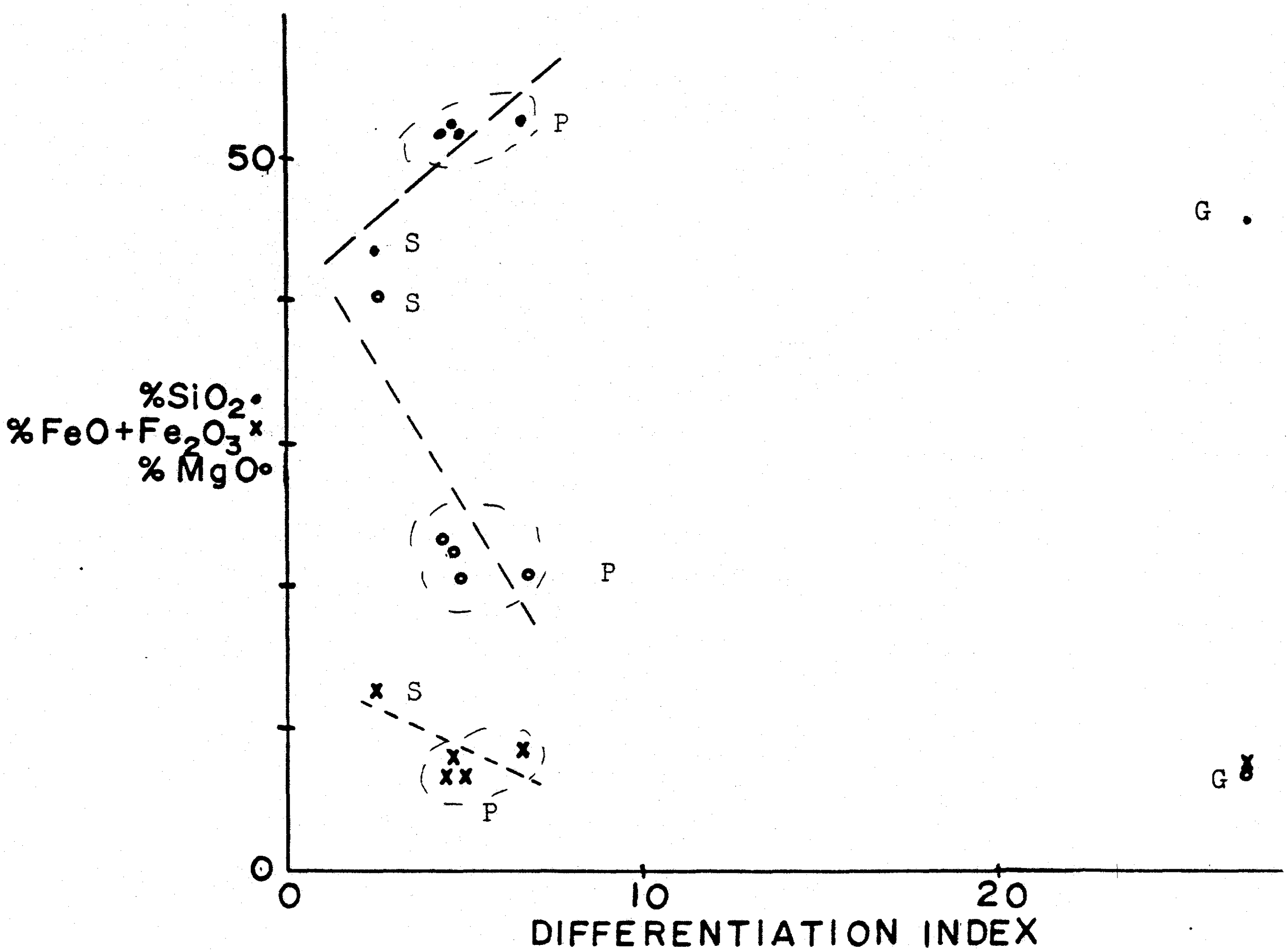


Gabbro and Ultramafic Rocks, From Table III(ii)

For Figures IIIvi to viii,

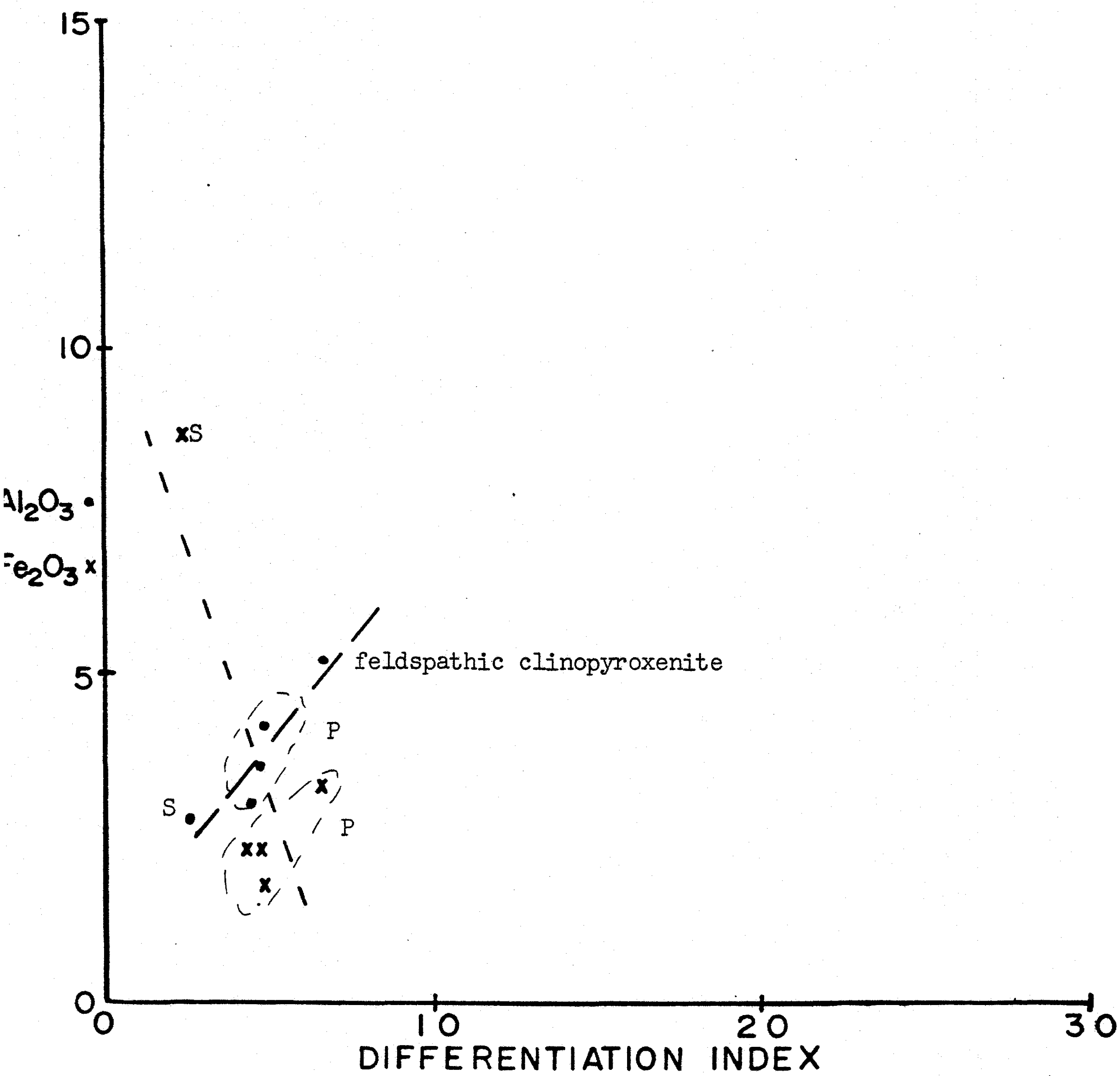
G=Gabbro
S=Serpentinite
P=Pyroxenites

FIGURE III(vii)



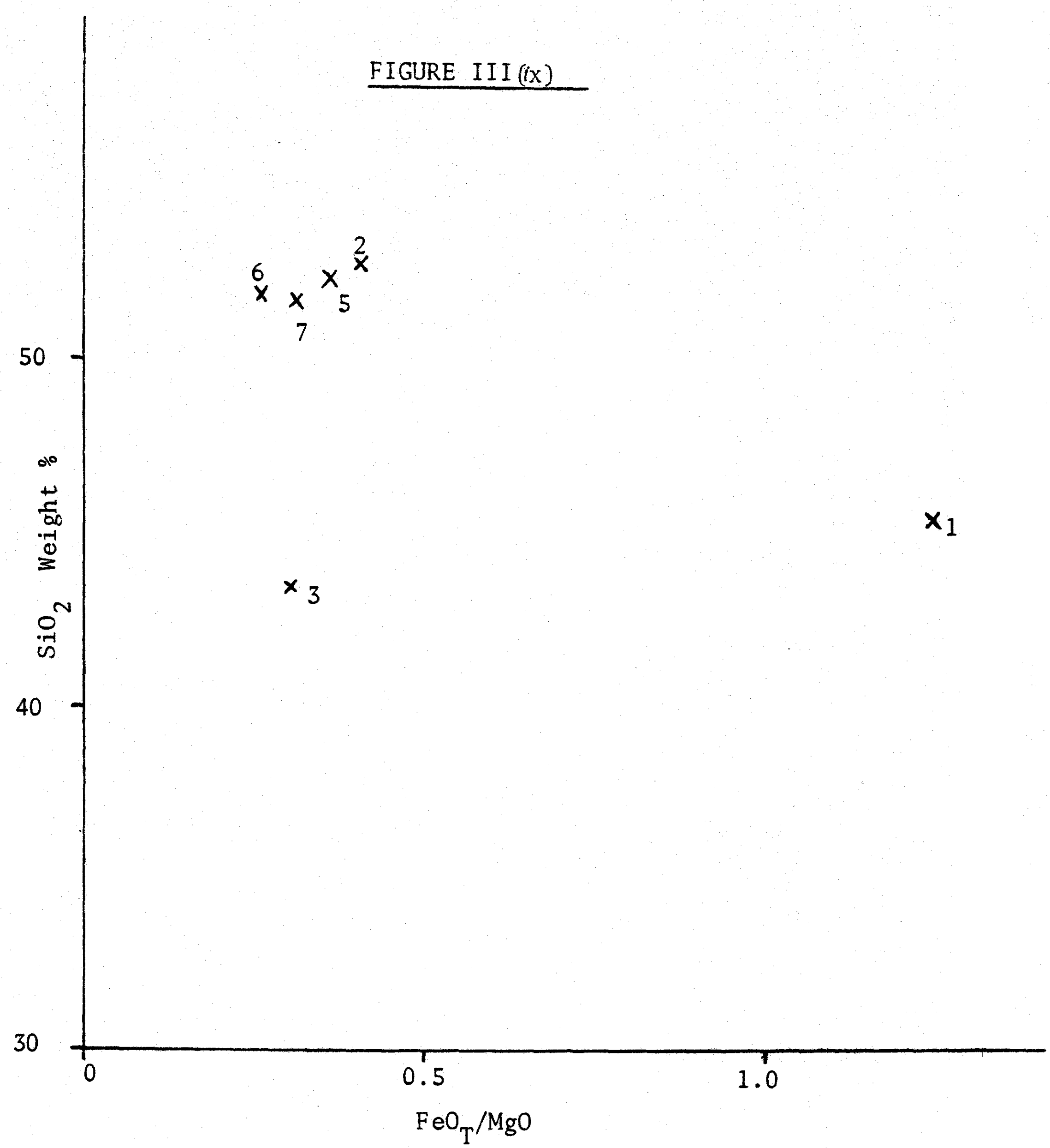
Gabbro and Ultramafic Rocks, From Table III(ii)

FIGURE III(viii)



Gabbro and Ultramafic Rocks, From Table III(ii)

FIGURE III(ix)



1 Gabbro
2 Feldspathic clinopyroxenite
3 Serpentinite (dunite)
5 Uralitized (clino)pyroxenite
6 Olivine clinopyroxenite
7 Olivine websterite

Gabbro and Ultramafic Rocks, From Table III(ii)

Olivine in wehrlites and dunites is cumulus. Clinopyroxene is the common intercumulate phase. Magnetite and chromite also occur as cumulate minerals closely associated with olivine. Sulphide droplets tend to concentrate in olivine rich parts of some rocks. These may be interstitial and cumulate.

The smaller grains of orthopyroxene and olivine in pyroxenites are cumulate. Rhythmic layering as well as simple mineralogical layering of olivine and orthopyroxene in rocks rich in that mineral are cumulate. The common intercumulus or interstitial phase in all ultramafic types at Nemeiben is clinopyroxene. It is often poikilitic, enclosing cumulus minerals. Large poikilitic orthopyroxene plates also occur in a few sections, especially those rich in clinopyroxene.

The first cumulus mineral was olivine, followed by orthopyroxene and then clinopyroxene. Chromite was among the early cumulus minerals as it only occurs in olivine rich rocks. Magnetite precipitated virtually throughout the history of accumulation but in greater quantities at the beginning. Olivine-rich rocks are richest in primary magnetite. The geochemical results also indicate the cumulate nature of the rocks in the Nemeiben Lake pluton.

(b) Composition of Parent Magma:

The equilibration temperature of pyroxene pairs at Nemeiben was calculated to be around 1350°C by Peddada (1972). The olivine grains analysed by Hakli (in Peddada 1972) have the composition Fo_{88}, which indicates that the magma from which they crystallized probably had a high Mg/Fe ratio. The contact region in some places is fine grained tremolite-actinolite, whereas in others it appears to be made up of pargasitic hornblendes formed by deuteric alteration of pyroxenes. These observations indicate that the supposed chill margin, which presumably represents an approximation of the pluton's parent magma, may be magnesium rich and therefore highly mafic or ultramafic.

(c) Formation of the Pluton:

The approximate distribution of rock types (Figures III i, and III ii), in semicircular zones sub-parallel to the subcircular outline of the intrusive plug (Figures I ii, III iii) indicates concurrent accumulation of phenocrysts from a flowing magma. Gravity did not play a part in the accumulation of phenocrysts as olivine rich rocks are not specifically located at the margins of the body. The pluton probably formed by marginal accumulation of crystals carried in a flowing ultramafic or very mafic magma. Differences in composition of the magma or the proportion and type of transported phenocrysts controlled the composition of the cumulate rocks and resulted in the discontinuous layers with contrasting compositions. The gabbro dykes in the northern outcrops may be late differentiates of the same magma. They probably intruded the ultramafic body after the conduit had completely solidified.

IV

THE OPAQUE MINERALS

A) Introduction:

All fresh pyroxenites at Nemeiben contain primary interstitial sulphide blebs and some oxide grains. Pyrrhotite, chalcopyrite, and pentlandite are the main primary phases. Minor primary magnetite occurs. First generation cumulus and second generation interstitial primary oxides occur. Very few first generation sulphides are present. The dunites and wehrlites contain more primary oxides than the pyroxenites, including much magnetite and minor local chromite. One gabbro dyke contains up to 3 % ilmenite and some magnetite. Secondary opaques due to serpentinization and uralitization include magnetite, haematite and some sulphides. Mobilization during the first deformational stage produced chalcopyrite, magnetite, and a few pyrrhotite veins. The uralitized and serpentinized ultramafics contain the most oxidized minerals. Late low temperature haematite veins occur in many serpentinites and some uralites.
Later supergene alteration affected most of the sulphides, and some are completely haematized.

Table IV (i) lists the opaque minerals recognized in polished section. Chalcopyrite, pyrrhotite, marcasite, haematite, and native copper are the most common minerals recognized in hand samples.

B) Opaque Content of Rock Types:

1) Pyroxenites:

The fresh pyroxenites generally contain one to two percent primary opaques, mostly sulphides. Pyrrhotite, chalcopyrite, pentlandite, and minor primary magnetite occur . One olivine clinopyroxenite sample contains minor chromite. Primary opaques generally range in size from

0.2 to 2mm. A few cm-sized masses occur.

2) Altered Pyroxenites:

The altered pyroxenites contain much fine grained (2-20 microns) opaque dust. Magnetite and haematite are the most common constituents of opaque dust in pyroxenites but minor copper, pyrrhotite, chalcopyrite and very rare pentlandite grains occur. Pyrrhotite-chalcopyrite composite grains are common in the sulphide opaque dust but other composite grains occur. Primary opaques in uralites are often haematized.

3) Serpentinites:

The serpentinized dunites and wehrlites contain much opaque dust: magnetite, haematite, sulphides, awaruite, and native copper. Primary magnetite, minor primary chromite, and various monomineralic or composite sulphide blebs occur. Haematite veins are common in the multiple fractures of these rocks. (Plate XIXa).

4) General

Chalcopyrite veins are common in altered rocks at the northern end of the body. Pyrrhotite and marcasite also occur in some veins. Millerite occurs as small radiating needles on the surfaces of some fractures in uralites. The gabbro dykes contain a small percentage of pyrrhotite and pentlandite as well as much chalcopyrite.

TABLE IV(i)

OPAQUE MINERALS RECOGNIZED*

MINERAL	OPTICAL PROPERTIES	NOTES
Pyrrhotite $Fe_{1-x}S$ Often contains Co, (Cu), Ni.	light yellowish brown, cream, to pinkish brown. Weakly to strongly anisotropic Cleavage planes sometimes distinct. Often tarnished to dark reddish brown.	Very common primary opaque. Occurs in secondary assemblage and seldom in veins. Often altered.
Chalcopyrite $CuFeS_2$	Brassy yellow. Weakly anisotropic. Seldom tarnished.	Very common primary opaque. Occurs as veins and in secondary assemblage.
Pentlandite $(Fe, Ni)_9 S_8$ Often contains Co, (Cu)	Light cream. Isotropic.	More common than indicated by previous workers. Minor in secondary assemblage. Often altered.
Magnetite Fe_3O_4	Grey with brownish tint. Isotropic. At times steely blue.	Primary grains, a few euhedral. Opaque dusting. Veins Ubiquitous. Primary grains most common in olivine rich rocks.
Chromite (Fe,Mg) $(Cr,Al,Fe)_2O_4$	Dark grey. Translucent red in many cases. Isotropic.	Minor, in wehrlites, dunites, olivine clinopyroxenite. Anhedral, some euhedral grains.
Ilmenite $FeTiO_3$	Light to dark brown, bireflectant. Anisotropic.	Found mostly in Gabbro.
Haematite Fe_2O_3 Goethite also present	Grey to white. Highly anisotropic. Internal reflections sometimes present.	Occurs as veins, dusting and alteration of other minerals.

Table IV(i) Continued:

MINERAL	OPTICAL PROPERTIES	NOTES
Marcasite FeS_2 often contains Ni,(Co),(Cu).	Light yellowish-white. Highly anisotropic.	Alteration of pyrrhotite. Often with magnetite/ haematite, bird's eye textures.
Millerite NiS	Yellow, bluish anisotropic colours.	In serpentinites, often in turn slightly altered, associated with much haematite.
Bravoite $(Fe,Ni,Cu,Co)S_2$	Greyish brown. Bluish tinges. Isotropic.	Alteration of pentlandite, minor.
Violarite $(Ni,Fe)_3S_4$ May contain Co, Cu	Violet-white. Isotropic to slightly anisotropic.	Major alteration of pent- landite and sometimes nickeliferous pyrrhotite.
Heazlewoodite Ni_3S_2	Creamy yellow, greenish anisotropy.	Tentatively identified in haematite rich serpentinites.
Pyrite FeS_2	Light yellow to white isotropic to very weakly anisotropic.	Veins, minor alteration of pyrrhotite, opaque dust. Minor possible primary grains.
Covellite CuS	Highly bireflectant deep blue, anisotropic.	Alteration of chalcopyrite. Specks in serpentine.
Cubanite $CuFe_2S_3$	Greyish-cream Anisotropic.	Rare, replacement of or intergrowth in pyrrhotite.
Bornite Cu_5FeS_4	Orange-brown, purple tarnish. Weakly anisotropic.	Alteration of chalcopyrite. Minor.

Table IV (i) Continued:

MINERAL	OPTICAL PROPERTIES	NOTES
Copper Cu	Pink, brown tarnish. High reflectance. Isotropic without complete extinction.	Minor specks and veins in serpentinized uralitized and haematized rocks.
Awaruite (Ni,Fe)	White, high reflectance. Light green with yellow tinge occasionally observed. Isotropic.	Specks in opaque dust.
Silver Ag	Creamy white, highly reflectant pinkish tinge isotropic.	One speck identified.
Gold Au	Bright yellow, highly reflectant, isotropic, slight greenish tinge.	One speck identified.

*Optical methods confirmed by electron microprobe.

C) Petrography, Mineralogy:

1) Primary Minerals and their Alteration Products:

(i) Pyrrhotite

Pyrrhotite and chalcopyrite are the most common sulphides at Nemeiben Lake. Pyrrhotite occurs as monomineralic interstitial blebs but also often in composite grains with chlacopyrite, pentlandite, or both (Plates Xb, XVI). Some occur included in clinopyroxene grains. Rounded anhedral shapes are the rule, filling intercrystalline spaces allotriomorphically. Rounded to sausage shaped chalcopyrite inclusions in pyrrhotite are common. Pentlandite can occur in the same fashion (Plate VIIb). Pentlandite flames are less common. Chalcopyrite and pentlandite exsolutions when present often occur along rims of pyrrhotite blebs (Plate IXa). Some pyrrhotite grains are rimmed by chalcopyrite. Pyrrhotite occasionally contains euhedral cubes of pentlandite or chalcopyrite. Rounded blebs of pyrrhotite in turn can occur in pentlandite. Pyrrhotite can occur closely juxtaposed against or within composite grains with magnetite.

A few intimate mixtures of two pyrrhotite phases occur, a light phase and a dark phase. They seem to be hexagonal and monoclinic pyrrhotite respectively as described by Uytenbogaardt and Burke (1971).

Marked (0001) cleavage planes are present in some grains and can be bent. Marcasite alteration along these is common (Plates XIIa, XIVa). Marcasite alteration of pyrrhotite is very common, always accompanied by magnetite or haematite (Plate XIIIb). Bird's eye structures often occur in uralites (Plate XVIIa). Many pyrrhotite grains in altered rocks are completely haematized. Most primary sulphide grains are cut by magnetite, haematite, and some by sulphide veins.

(ii) Chalcopyrite:

Monomineralic chalcopyrite interstitial blebs are very common and the major opaque constituent of some rocks. It is the most common opaque mineral found as inclusions in silicate phases (Plate XXIa). It occurs included in clinopyroxene, plagioclase, and secondary amphiboles. Composite grains with pyrrhotite, pentlandite, or both occur, that with pyrrhotite is the most common interstitial sulphide type. Rounded inclusions in pyrrhotite and occasionally in pentlandite can occur. Chalcopyrite inclusions in pyrrhotite tend to be cubic whereas those in pentlandite tend to be triangular. Exsolution blades of chalcopyrite along cleavage planes of pyrrhotite are rare but rims and exsolution flames at the edges of pyrrhotite grains are common. Unmixing of chalcopyrite at the centre of a pyrrhotite grain and worm-like exsolutions also occur. Exsolution chalcopyrite cuts exsolution pentlandite. A few chalcopyrite-magnetite and chalcopyrite-magnetite-pyrrhotite grains occur. Contacts between pyrrhotite and chalcopyrite are clean and curved (Plate XIa) except in exsolution features where they are less sharp. Chalcopyrite is allotriomorphic.

Chalcopyrite is much less altered than the other primary sulphide phases (Plate XVIIb), but often flowed into microfractures from primary blebs. Some interstitial grains show extensive fracturing as well as flow. Some chalcopyrite grains altered to magnetite,haematite or occasionally to marcasite along edges. Rims of magnetite may be primary or due to replacement of the sulphide phase. Alteration to haematite and goethite is common in altered rocks (Plates XIIIa, XVa).

(iii) Pentlandite:

Pentlandite is much more common than indicated by previous workers. Although it occurs as primary anhedral blebs or euhedral cubic grains, it occurs mostly in composite grains with pyrrhotite of chalcopyrite and pyrrhotite. A few pentlandite-chalcopyrite grains occur. One chalcopyrite-pentlandite composite grain is included in a clinopyroxene. Rounded pentlandite inclusions in pyrrhotite are relatively common. Cubic inclusions in pyrrhotite and chalcopyrite can also occur. One such inclusion in pyrrhotite is hexagonal. Pentlandite in turn includes rounded chalcopyrite (Plate VIIIa) and pyrrhotite blebs. One pentlandite contains a triangular chalcopyrite inclusion . Exsolution flames or rims of pentlandite in pyrrhotite are present.

Pentlandite contacts with chalcopyrite are usually straight, clean, idiomorphic. Contacts with pyrrhotite can be both idiomorphic (Plate XIIa) or curved, less sharp in exsolution features. Feathery pentlandite at the contact of chalcopyrite and pyrrhotite in one grain cuts both phases (Plate IXb).

Pentlandite is very susceptible to alteration to violarite (Plates XIa, XVb). Much violarite occurs along cleavage planes in pentlandite forming a reticulate cubic pattern. Violarite can also form subhedral cubic growths in pentlandite (Frontispiece). Fractured pentlandite can be altered to bravoite along breaks (Plate VIIIa). Some magnetite visibly accompanies violarite alteration of pentlandite (Plate XIIa).

(iv) Oxides:

Two generations of primary magnetite and chromite are apparent. An early assemblage of cumulate, euhedral grains (i.e. Plate XXIb), and a later anhedral interstitial assemblage. The bulk of the first generation opaques occur in wehrlites and serpentinites, and 0.5 to 1.5 mm is the normal grain size of oxide minerals. Some are included by clinopyroxene and orthopyroxene. Small pyrrhotite blebs occur in a few anhedral magnetite grains (Plate IIb). A pyrite cube and a pentlandite cube occur in two grains (i.e. Plate VIIa). Some genuine composite magnetite-sulphide grains occur though many are simply juxtaposed to chalcopyrite or pyrrhotite. Euhedral, subhedral and rounded ilmenite grains occur in the gabbro. Magnetite is commonly altered to haematite (Plate VIIb).

(v) Other Primary Minerals:

A few pyrite cubes showing good cleavage striation and isotropy, 0.2 mm in size, are present in the polished sections examined. Cubanite was identified as inclusions, intergrowths or possibly a replacement in one pyrrhotite grain.

2) Secondary Opaques:

Two generations of secondary opaques occur, the opaque dust produced during alteration of the silicates and that produced by supergene alteration of these and the primary minerals. Some overlap is apparent.

(i) Opaque Dust:

Magnetite and haematite are the most common minerals expelled during the formation of serpentine and tremolite. They form grains 2-20 microns in size in veins, aggregates, or disseminations often outlining pseudomorphs or former cleavage planes of altered pyroxenes.

Most grains are anhedral. A few euhedral magnetite grains occur. Much of the haematite produced during serpentinization localized along fractures forming veins up to three mm wide. Chalcopyrite, minor pyrrhotite, pyrite, marcasite and millerite also localized along fractures forming narrow veins.

Minor sulphide blebs also occur in the opaque dust assemblage. Chalcopyrite, pyrrhotite, marcasite, pyrite and very minor pentlandite monomineralic blebs or euhedral grains 2-15 microns in size and a few composite grains occur. A few of the secondary pyrrhotite blebs in uralite contain pentlandite exsolution flames. Some of the pyrrhotite blebs were determined to be nickeliferous by the electron microprobe. Tiny sulphide specks often occur in metamorphic hornblendes. Millerite often occurs in serpentinized dunites. Minor heazlewoodite was also tentatively identified in haematite rich serpentinites. (Plate Xa).

Native copper and awaruite are also present in the opaque dust.* Copper often occurs in veins or at the centre of haematized former sulphide grains. These native metals mostly occur in serpentine reflecting the higher content of nickel and copper of olivine. Some occur in uralite. One grain each of gold and silver were identified (Plate XVIIIa) These are remnants after the complete haematization of the sulphide phase which contained them. *(Plates XIXb and XIIIa respectively).

(ii) Alteration minerals:

The most notable alteration is that of pyrrhotite to marcasite, magnetite and/or haematite. This often results in bird's eye structures. Complete haematization of primary interstitial sulphide grains is also common. Both alterations are most prevalent in altered rocks, notably in uralites. This may indicate that much sulphide alteration was due to the same epidsode(s)that affected the primary silicates. Sulphide veins are also often haematized. Marcasite occasionally replaces part of some chalcopyrite grains. At times a few idiomorphic pyrite cubes grew in marcasite after pyrrhotite (Plate XIVb).

Violarite is a common alteration mineral after pentlandite. Bravoite is less common but can form a reticulate pattern outlining cubic cleavage and fractures in pentlandite. Violarite forms a more even surface alteration but some cubiform violarite shapes grown in pentlandite occur*. Violarite has also altered some nickeliferous pyrrhotites. Bravoite and violarite grains are also present in the opaque dust. They may have formed directly during serpentinization or by alteration of other such phases. There are indications both processes occurred. Supergene alteration of chalcopyrite produced covellite and bornite. Covellite specks in opaque dust probably after chalcopyrite display bluish haloes. *(Frontispiece, Plate XIIb), (Plate XIb).

Some late low temperature colloform haematite veins closely associated with low temperature amorphous serpentine occur in many dunites.

D) Sulphur Analyses:

Table IV(ii) lists the samples analysed for sulphur according to rock type. There is not much variation among rock types but the clinopyroxenite average is fifty percent higher than the overall average. This may indicate that sulphur concentrated in the later stages of crystallization. Figure IV (i)A is a plot of percent olivine against

TABLE IV(ii)

SULPHUR ANALYSES. (Saskatchewan Research Council)

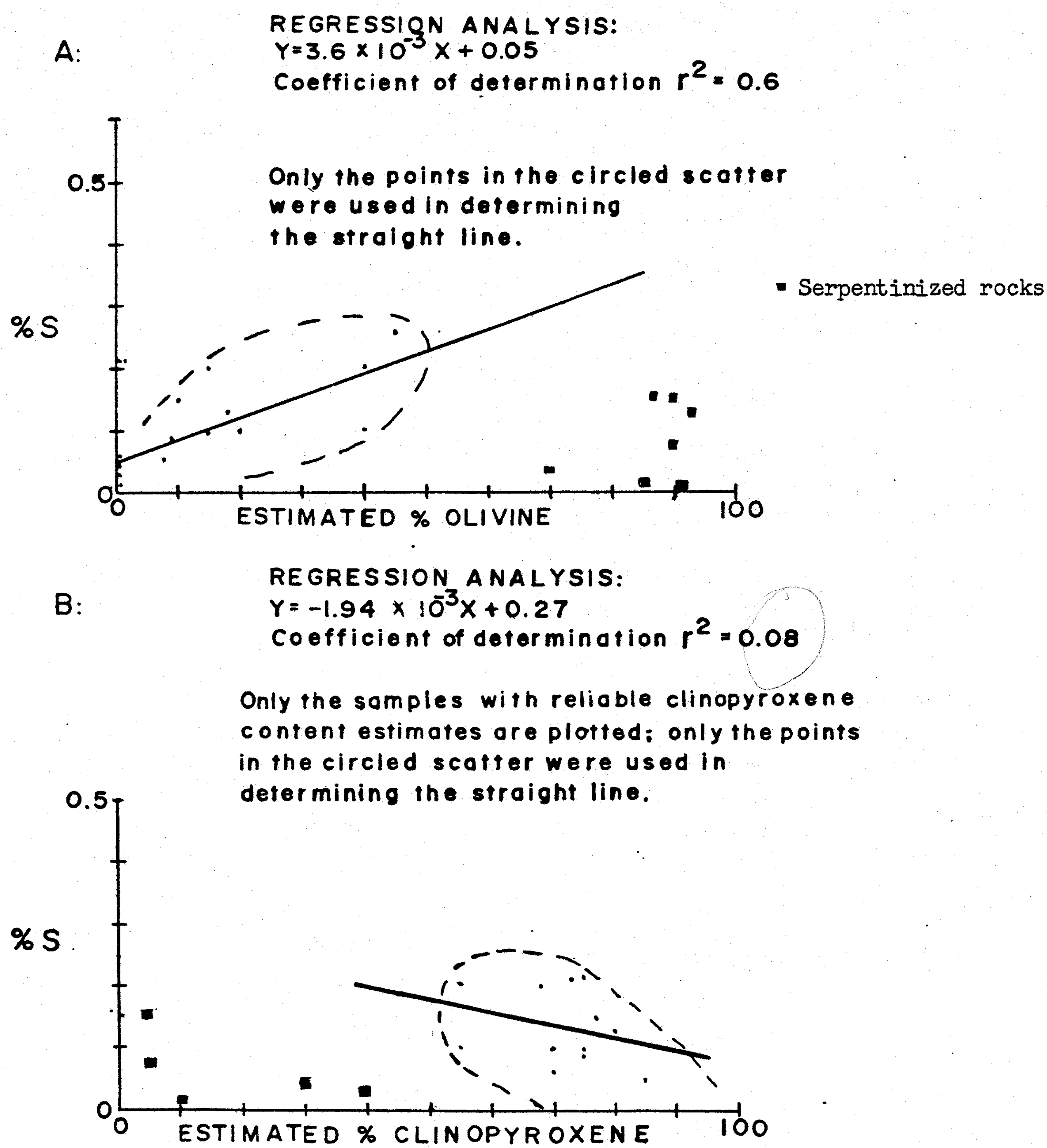
Websterite:	M20		2.39 *	
	4017		.052	
	M26		.059	
ol. web.	MEP1 470.10		.150	
ol. web.	4004B		.087	
feld.web.	M14		.029	
	M8		.211 Av	= .106
Clinopyroxenite:	3005		2.56 *	
feld.ol.clinop.	MEP1 582.7		.204	
ol.clinop.	MEP3 337		.094	
feld. clinop.	1004A		.216	
ol.clinop.	M18		.098	
ol.clinop.	M22		.127	.147
Wehrlite:	4015		.042	
	4018		.205	
	M11		.101	.116
Dunite-Serpentinite:	5008		.152	
	5001		.014	
	3002		.155	
	MEP4 26		.009 *	
	2012B		.131	
	MEP2 195		.075	.105
Serpentinized & Uralitized Peridotite/Pyroxenite:	5007	12(7)	.259	
	3003	13(4)	.061	
	MEP3 134	13(4)	.039	
	MEP4 233	13(4)	.576	
	4013	13(4)	.054	
	M1	13b	.010	
	1006	13(4)	.075	
	MEP2 248.6	13(5)	.005 *	
	M6	13b	.045	
				.133
Gabbro:	MEP1 627.7		.005	
	M3		.368	

1) Average Sulphur without M10 & 3005 = .1108

2) Total sulphur average = .2608

* Left out of averages

FIGURE IV(i)



% Sulphur from Table IV(ii) vs Estimated Percent Olivine, Clinopyroxene.

percent sulphur. A direct positive correlation for unaltered ultramafic types is evident with a reasonable coefficient of determination. Figure IV(i)B plots percent clinopyroxene against percent sulphur. There is no apparent correlation. The computed straight line shows a slight negative slope but the coefficient of correlation is so low as to render the curve meaningless. It can be stated therefore that for pyroxenites there is an increase of sulphur and therefore sulphide content with an increase of olivine.

Most dunitic and wehrlitic rocks contained very little sulphur. They are almost completely serpentinized and uralitized. The alteration process mobilized much of the primary sulphur content.

Figure IV(ii) is a plot of the sulphur contents on the map of the ultramafic body. A sulphur high region occurs over the known concentrations in the northwestern reaches of the body. Spotty highs also occur elsewhere indicating significant amounts of sulphide minerals occur in areas other than the possible delineated ore bodies.

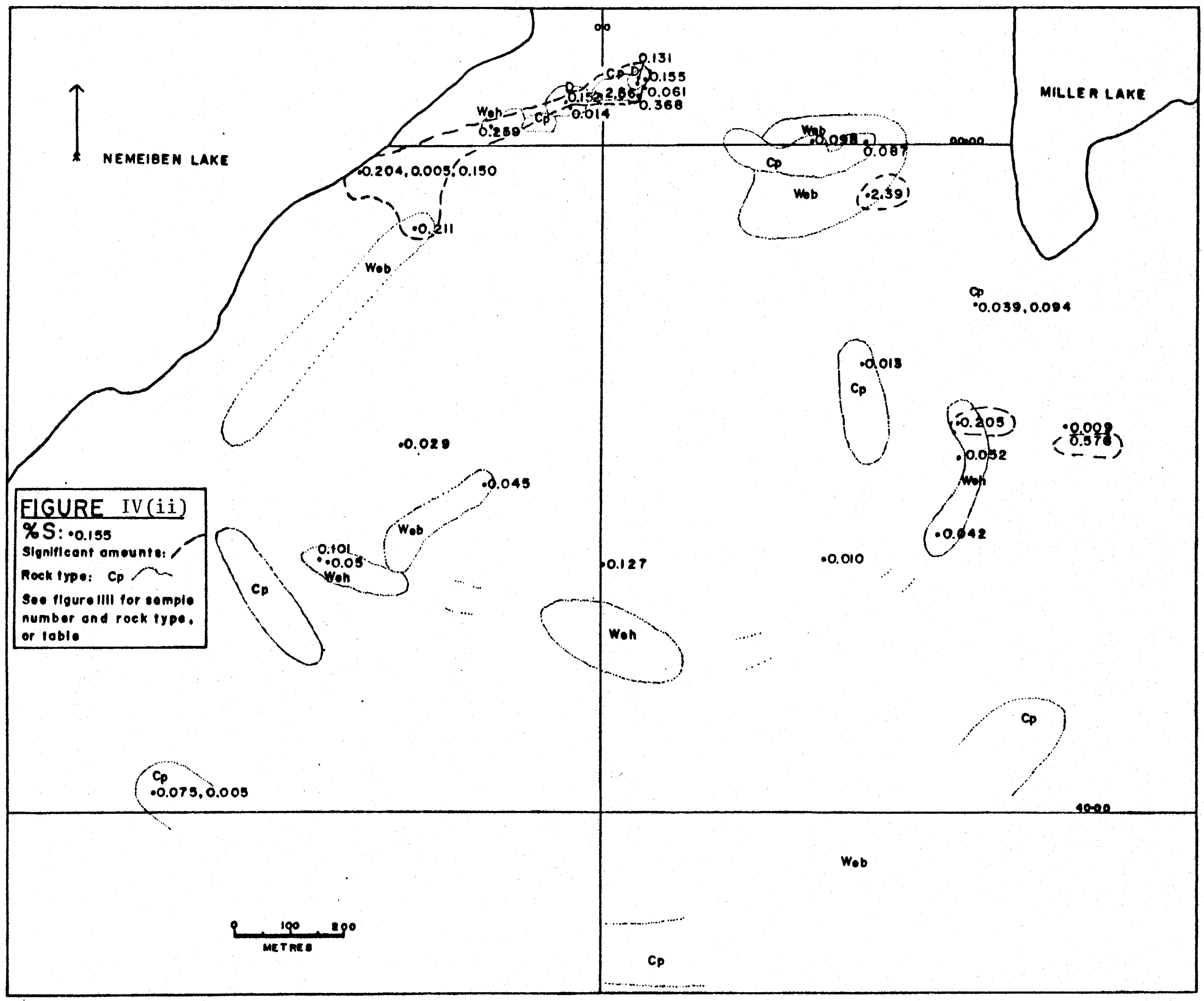
The average crustal abundance of sulphur is 260 ppm (.026 percent) (Mason 1966). This ultramafic body only contains 5 to 10 times more.

E) <u>Discussion of Electron Microprobe Analyses:</u>

Introduction:

Tables IV(iii) to IV(xii) in appendix D are lists of the results of the electron microprobe analyses on sulphide phases in ten rock samples.

Some of the analyses are of poor quality. High totals are probably due to a failure during the econd batch to return to the exact spot previously analysed or may reflect that quantities of some phases are near the detection limits of the procedure followed. Such results may also indicate highly variable compositions over a few microns.


NEMEIBEN LAKE
MILLER LAKE
0.131
0.155
0.061
0.368
2.86
0.152
0.014
0.259
Weh
Cp
0.204, 0.005, 0.150
0.211
Web
Web
0.098
0.087
Cp
Web
2.39
Cp
0.039, 0.094
0.013
Cp
0.205
0.009
0.578
0.052
Weh
0.042
0.029
0.045
Web
0.101
0.05
Weh
Cp
0.127
0.010
Weh
Cp
Cp
0.075, 0.005
Web
Cp
0 100 200
METRES
FIGURE IV(ii)
%S: •0.155
Significant amounts:
Rock type: Cp
See figure IIII for sample number and rock type, or table

The electron beam is two microns in diameter and it can be positioned accurately within a few microns. Many tiny opaque dust grains, especially the probable awaruites, are too small for analysis without contamination from adjacent silicate or sulphide phases.

Results with very low totals are from obviously altered and weathered grains. Oxygen and hydroxyl probably make up the rest of the constituents. The atomic proportions of these grains is still of interest but their oxidized nature must be recognized. Metal contents in alteration phases are usually high and totals are usually low indicating the presence of finely intermixed oxides or hydroxides. Chalcopyrite is the last altered phase. A batch of results was considered reasonable when chalcopyrite analyses provided totals within 2 percent of 100 and stoichiometric proportions.

(i) Fresh Pyrrhotite :

Fourteen relatively fresh pyrrhotite grains were analysed. Only five of the samples, the uralitized websterite, gabbro, uralitized (clino)pyroxenite, feldspathic olivine clinopyroxenite, and the uralitized feldspathic pyroxenite contained these.

Fresh Pyrrhotite Composition

Fe Wt%	Co	Ni	Cu	M*/S
52.91-62.11	0.01-2.59	0.03-6.36	0-6	0.874-.916
Norm:				
60.21	0.09	0.36	0.01	0.90

* Atomic proportions, total metals vs. x S.

Oxidization resulted in a slightly low metal to sulphur ratios in many of these pyrrhotite grains. Pyrrhotite has an incomplete defect structure involving metal atom omissions. "Small amounts of Ni and Co have been reported in pyrrhotite, but careful microscopic examination usually shows that the nickel is present as very fine pentlandite and that the cobalt is within these pentlandite inclusions rather than in the pyrrhotite itself" (Stanton, 1972).

Pyrrhotite, however, may contain some Ni and Co (Uytenbogaardt and Burke 1971), but normally less than one percent in natural occurrences (Ramdohr 1969).

Hexagonal pyrrhotite forms in the composition range 48.1 to 47.5 and monoclinic pyrrhotite from 46.5 to 47.0 atom percent iron (Stanton 1972, Uytenbogaardt and Burke 1971). The atom percent in the analysed pyrrhotites is about 45. This may reflect their slightly oxidized nature. Ramdohr(1969) states that pyrrhotite always occurs "with a deficiency of Fe up to about 1/8 of the stoichiometric quantity". The fresh Nemeiben Lake pyrrhotites are well within that limit of 0.88 metal to 1 sulphur. Hulburt (1971) further states that for $Fe_{1-x}S$, x can vary between 0 and 0.2. Many of the pyrrhotites not included in this discussion could therefore be legitimate "stoichiometric" phases. About 0.85-0.87 metal to 1 sulphur is the ratio for many pyrrhotites with good totals in tables IV (iii) to IV(xii). Over twenty five of the analysed pyrrhotites are therefore unaltered.

Many pyrrhotites contain one percent or more nickel. The grains do not contain visible pentlandite inclusions at x 2000 (oils). This nickel is probably in lattice positions within the pyrrhotite structure. The same can be said about the cobalt content of pyrrhotites. The grains with one percent or more cobalt are also generally nickeliferous. Slight mixing of phase during the high temperature metamorphism of the pluton may explain these observations. Fleischer (1955) reports a maximum of 0.85 percent Co in pyrrhotite was indicated by literature at that time. The limit of isomorphous replacement of iron by cobalt or nickel is not known but is believed to be below one percent (Hegemann in Fleischer 1955) but nickel contents up to 7.5 percent is reported, possibly present as pentlandite exsolutions or inclusions (Fleischer 1955).

The few copper-bearing pyrrhotites pose a problem, as this element is not generally thought to substitute into the pyrrhotite structure at low temperature (Ramdohr 1969). No exsolved chalcopyrite or cubanite is visible. Unmixing from the original monomineralic solid solution may not have occurred. These copper-bearing pyrrhotites are probably metastable. Introduction of copper during metamorphism could also be the cause of these grains. Some of the Cu bearing pyrrhotites are in the opaque dust assemblage, others are larger primary grains. There is the possibility that analyses are not reliable.

(ii) Fresh Chalcopyrite:

Forty-seven chalcopyrites analysed had results with good totals and close to stoichiometric composition. This is an indication of this phase's greater resistance to alteration than pyrrhotite or pentlandite. It is also an indication that the analytical results on most of the other phases are reasonably reliable.

Fresh Chalcopyrite Composition				
Fe wt%	Co	Ni	Cu	M/S
29.16-32.57	0-1.96	0-0.66	31.11-35.77	.95- .07
Norm:				
30.62	0.07	0.08	34.50	$\approx$ 1

The Co and Ni content of most fresh chalcopyrite in the Nemeiben Lake body is low, only traces being detected. Some contain up to 0.6 percent nickel and 2 percent cobalt. According to Hulburt (1971) variations from the ideal percentages of 34.6 Cu and 30.4 Fe are mechanical admixtures of other sulphides. Fleischer (1955) reports that 1000-2000 ppm of Co and Ni was the maximum reported from the literature at that time. Ten times that amount is indicated in some of the chalcopyrites of Nemeiben Lake.

(iii) "Fresh" Pentlandite:

Pentlandite altered very readily to violarite and oxides. Most totals and the metal to sulphur ratios of these grains are low indicating alteration. As a result only 28 grains were fresh enough to be considered in this section.

"Fresh" Pentlandite Composition				
Fe wt%	Co	Ni	Cu	M/8S
10.93-37.36	0-6.36	27.36-51.96	0-3.39(?)	8.49-9.55
Norm:				
29.15	1.57	35.17	0.04	8.91

The ratio of Fe: Ni is usually close to 1 : 1 (Hulburt 1971). This is certainly the case for most pentlandite grains at Nemeiben Lake. A few contain up to 6:1 ratio of Ni to Fe. Ramdohr(1969) states that mixtures of all proportions of Ni, Fe, and Co are described though a (Fe+Co):Ni ratio of about 1:1 is more usual. The occasionally high (1-3%) copper content is problematical. "Chalcopentlandite", with 10-15% Cu, decomposes at 600°C (Pauly 1958). Possibly pentlandites with lesser amounts of copper do not decompose and continue their existance metastably at surface temperatures. Submicroscopic mechanical admixtures could also explain the copper content of some analysed pentlandites. The Fe content of most copper bearing grains is low. Cu^{+2} has an ionic radius of 0.72, Fe^{+2} of 0.74, well within Goldschmidt's rule that substitution is possible if ionic radii are within 15 percent of one another. Sulfides behave as though they were bonded partly by ionic and partly by covalent linkages (Fleischer 1955).

(iv) Alteration Phases of Pyrrhotite:

A marcasite phase and an oxide (haematite, magnetite or goethite) is the common alteration of pyrrhotite at Nemeiben Lake. A low total and a slightly high metal : sulphur ratio for FeS_2 is the general result of analysis of these phases indicating the presence of iron sulphides and oxides. 32 grains were considered typical and included in the table below.

Composition of Alteration Phases of Pyrrhotite

Total %	Fe wt%	Co	Ni	Cu	M/S
76.99-103.9	40.48-53.69	0-2.92	0-4.38	0-.7	.471-.844
Norm:					
95.27	47.17	0.09	1.34	0.09	0.61

Total metal to sulphur averages 0.61. Around 0.55 is a common figure. A total of 95 percent is usual indicating the presence of oxides intermixed with the alteration marcasite. The average oxygen content of altered pyrrhotite is 5 weight percent. A general reaction equation is as follows:

$$Fe_{.85}S_1 \xrightarrow{H_2O} Fe_{.5}S_1 + Fe_{.2}O_{.3} + Fe_{.15}(OH)_{.3}\uparrow$$

100 wt%, .85:1 Fe:S norm	$Fe_{.7} + S_1 = 95$ wt% .30 is equivalent to an added 4.8%	Removed by ground water.

Some pyrrhotites are only incipiently altered to marcasite and these analysed phases are mixtures of pyrrhotite, marcasite, and oxide.

The nickel content of these alteration minerals is often 1-2 percent. The removal of iron from the sulphide phase increases the proportion of nickel. Nevertheless these altered pyrrhotites are richer in nickel that the fresh grains. Nickeliferous pyrrhotite is therefore indicated to be more susceptible to alteration at surface temperatures and conditions than pyrrhotite poor in nickel. The cobalt content of marcasite is within accepted limits but again copper generally low, can make up to 1 percent of this phase. It may be in goethite-type oxides and not in marcasite proper.

A few grains interpreted to have been pyrrhotite altered to Cu bearing bravoite and oxide or iron rich violarite and oxide.

v) <u>Alteration Phases of Chalcopyrite:</u>

A few chalcopyrites were slightly altered and some were completely haematized. Ten altered grains provided analyses with totals in the mid eighties to low nineties and high metal: sulphur ratios. They come almost exclusively from the uralitized clinopyroxenite, serpentinized wehrlite and the olivine clinopyroxenite. Nineteen grains have slightly low metal to sulphur ratios and totals in the high nineties to 100+. They come almost exclusively from the gabbro, feldspathic olivine clinopyroxenite, uralitized feldspathic pyroxenite and the olivine clinopyroxenite. This latter rock type is the only sample analysed that contained subequal amounts of both types of alteration.

Composition, Alteration of Chalcopyrite

Total %	Fe	Co	Ni	Cu	M/S
(1)					
66.64-95.64	27.65-38.64	.03-.22	0-1.76	25.05-25.61	1.113-2.44
Norm:					
89.55	31.44	0.08	0.15	30.94	1.23
(2)					
99.81-104.77(?)	29.33-31.44	.01-2.73	0-.11	37.15-36.29	.849-.973
Norm:					
101.66*	30.12	0.12	0.01	34.40	0.94
"Fresh" chalcopyrite:					
≈ 100	30.62	0.07	0.08	34.50	≈ 1

*High but within 2% margin of error: Possible indication of variable composition.

1) In the first case more Fe and considerably less Cu is present than in the fresh chalcopyrites. Sulphur is very low as evidenced by the high M:S ratio. The low total indicates the presence of much oxide or hydroxide ions. The Fe content is probably not lessened unlike that of Cu, because of th- in situ production of haematite and goethite. Sulphur and copper are lost. This may explain the covellite specks observed in some serpentinized and uralitized rock samples.

This type of rock contains many visibly haematized and goethitized primary sulphides.

2) The second type of altered chalcopyrite occur in less altered rocks. The amount of Cu and Fe is not significantly different but slightly lower than in fresh chalcopyrites but the M:S ratio is quite low. Either some oxidation of chalcopyrite took place and the products mobilized away from the site or sulphur was added to the grains. Possibly alteration produced marcasite-digenite type phases in the chalcopyrite, lowering the proportion of metal to sulphur.

vi) Alteration Phases of Pentlandite:

Forty eight grains interpreted to be altered pentlandite phases are considered in this section. Other problematical phases are dealt with in section (vii). Three types were singled out as outlined below.

Composition, some Alteration Phases of Pentlandite

Total%	Fe wt%	Co	Ni	Cu	M/8S
1) 75.33-102	11.61-40.95	0.01-2.02	19.4-44.23	0-3.80	7.25-875
Norm: 92.16	26.90	1.12	30.41	0	7.90
2) 76.98-102+	15.95-47.29	0.07-4.52	20.67-42.2	0-3.62	9.1-14.9
Norm: 90.03	28.93	1.62	31.89	0	10.67
3) 78.71-102+	8.05-35.46	0.08-3.15	9.96-42.23	0-6.71	5.5-7.36
88.17	23.43	1.26	30.12	1.1	6.35
4) 100	29.15	1.57	35.17	0.004	8.91

1) Low totals, low M:S for pentlandite.

2) High M:S for pentlandite.

3) Usually low totals, M:S slightly high for violarite.

4) Fresh Pentlandites, norm.

1) The grains grouped in this category are pentlandite that have been slightly oxidized. This resulted in low totals due to the presence of oxygen and/or hydrogen and to low M:S ratios indicating a loss of metallic ions. Ni is fourteen percent lower per weight on the average than in fresh pentlandite and Fe seven percent lower. More nickel was mobilized than iron. Some of the latter phase stayed in situ as oxides or hydroxides (magnetite, haematite, limonite and/or goethite). Minor violarite was also produced. Pentlandite $\xrightarrow{H_2O,O_2}$ Pentlandite + (violarite) + (oxides + hydroxides). Using the norms a possible reaction is:

$$(Fe_{.52}:Co_{.03}:Ni_{.6})_9(S_1)_8 \xrightarrow{H_2O,O_2} .86\,[Fe_{.52}:Co_{.03}:Ni_{.6})_9(S_1)_8] +$$
$$.23[(Ni_1:Fe_{.32}:Co_{.04})_3S_4] + [(Fe_2)_2(O_2)_3] + [(Ni_{.08} + Fe_{.04} + Co_{.01})(OH)_2] \uparrow$$

2) Little to no loss in Fe, about a nine percent loss of nickel, and a relatively high loss of sulphur resulted in grains with overall low totals and high M:S ratios. This is a process of goethitization with 10 weight percent of the remnant phase oxygen and hydrogen.

3) Violarite is the most common alteration product of pentlandite. A low total indicates the presence of oxides and/or hydroxides and a slightly high M:S ratio for violarite (3:4) confirms this. These oxides or hydroxides are finely intermixed with the other alteration phases. The 2 micron diameter beam therefore analyses the overall alteration products of certain areas. The Ni:Fe ratio in violarite is higher than in pentlandite. It does not approach the ideal 2:1 ratio of the linnaeite structure (Ramdohr 1969) but this is no surprise as it

seldom does (Schouten 1962). A possible reaction resulting in the norm results is shown below ignoring that marcasite and bravoite are sometimes produced along with violarite and the complications of Co and Cu behaviour.

$$(Fe_{.52}:Ni_{.6})_9S_8 \xrightarrow{H_2O,O_2} 2(Ni_{.62}:Fe_{.38})_3S_4 + (Fe_{.02})_2(O_{.02})_3 +$$
$$[2.38(FeOOH) + 1.68\ (NiOOH)]\uparrow$$

vii) Other Analysed Phases:

1) Millerite

Serpentinized rocks often contain much millerite associated with some oxide. Minor heazlewoodite has been identified in these same rocks.

Composition of Grains Containing Millerite

Total%	Fe wt%	Co	Ni	Cu	M/8S
76.59-102	.18-13.98	.28-2.88	43.67-62.14	0.09-2.61	7.42-11.21
Norm: 95.37	6.16	0.77	55.08	0.86	8.58

It is noticed that (Ni+Co)/S is approximately 1.

The high total M and low totals indicate the presence of iron and possibly copper oxides and hydroxides. Millerite usually contains little Co (Ramdhor 1969) but over two percent is indicated in some of these grains. In these cases it may not be in the millerite phase. Millerite at Nemeiben Lake is often allotriomorphic and therefore hard to recognise in the altered serpentinites in which it occurs. Minor amounts of haematite are almost always associated with millerite after pentlandite.

Minorgrains interpreted to be heazlewoodite associated with marcasite and oxide have also been analysed. The results neither confirm nor disprove the identification as these phases are intermixed with other sulphide and oxides.

2) Bravoite:

A few bravoite grains were analysed. Only little alteration of pentlandite to bravoite proper was found. Bravoite contains 2-5 percent copper. Bravoite may contain up to 10 molecular percent copper (Uytenbogaardt and Burke 1971).

3) Ni-Cu-Fe Phase:

Twenty one analysed phases contained various to subequal amounts of Fe, Ni, and Cu.

Composition, Ni-Cu-Fe-Co Sulphide Alteration Phase

Total%	Fe wt%	Co	Ni	Cu	M/8S
75.41-102	8.05-33.54	0.02-6.66	3.23-42.23	6.49-30.83	
Norm: 95.27	24.11	2.23	18.55 very variable	16.22 very variable	7.79

These alteration phases were found in pentlandite, pyrrhotite, and some chalcopyrite. The norm represents a composition of $Fe_{.44}$, $Co_{.04}$, $Ni_{.33}$, $Cu_{.27}$, S_1 or a M:S ratio of 1.08:1. A one to one ratio of metal to sulphur overall and a low total indicating the presence of oxides and/or hydroxides leaves no clue as to the phases making up this alteration material.

The optical properties are not helpful either as the grains are intimate mixtures of indeterminate alteration products. A number of combinations of oxides, hydroxides, and sulphide alteration minerals such as haematite, goethite, limonite, violarite, bravoite, covellite, bornite, digenite, etc. could explain the analytical results.

F) Discussion and Conclusions:

1) Discussion:

The mineralogy, textures, and composition of the primary sulphide phases indicate a high temperature, and magmatic origin. Exsolution lamellae, blebs, and unmixing phenomena in pyrrhotite are due to post crystallization disassociation of high temperature Fe-Ni-Cu-Co monosulphide solid solution phases. Interpreted interfingerings of hexagonal and monoclinic pyrrhotite may also be due to unmixing from higher temperature forms (Ramdohr 1969, Van der Veen 1925).

Much unmixing of sulphide phases took place in the liquid state. Two or three phase composite grains with smooth curved contacts are the result. Rounded blebs of one phase in another are common and are due to the same process. Occasionally euhedral grains of one phase are included in another, commonly pentlandite in pyrrhotite or chalcopyrite, or pyrrhotite in chalcopyrite.

The common occurrence of Ni and Cu in pyrrhotite, Cu in pentlandite, and the sporadic Ni and Co content of chalcopyrite also point to a high temperature magmatic formation. The phase relationship between coexisting Ni, Cu, Fe sulphides and of monosulphide solid solutions outlined by various authors apply and need not be dealt with (i.e. Kullerud and Yund 1962, Kullerud *et.al.* 1969, Shewman and Clark 1970, Naldrett 1969). Peddada (1972) dealt with this subject at length.

Petrographic observations confirm the origin of the primary ores. Some sulphide blebs are included in late and not so late silicate grains. Sulphide grains are commonly allotriomorphic. They occupy interstitial, "intercumulate" spaces and are often concentrated in certain parts of the pluton. The low grade accumulation in the northeastern part of the ultramafic body spatially closely associated with olivine rich rocks illustrates this well.

2) Genesis:

There is therefore no doubt that the primary sulphide and oxide minerals are primary magmatic, "precipitated" grains and immiscible sulphide droplets. Some chalcopyrite and pyrrhotite veins may be late magmatic. Figure IV(ii) and I(v) and geophysical and geochemical surveys (Figure I iii), Appendix B, indicate that sulphides and conductive phases are near the periphery of the body. This is likely a result of the intrusion, flow and "deposition" mechanisms of the ultramafic pluton. Some sulphur could have been contributed to the margins of the body from the country rocks during intrusion. The country rocks contain significant amounts of sulphide (Appendix A, B). Sulphurization may have therefore had a role in the ore genesis and location of the resultant sulphides as once postulated by Naldrett (1966) for occurrences in the Porcupine district of Ontario.

3) Alteration:

Retrograde alteration of primary silicate phases resulted in a secondary assemblage of opaques, namely magnetite, haematite and some sulphides.

These sulphides in the opaque dust assemblage indicate the presence of sulphur during serpentinization and uralitization. The serpentinites contain much haematite. It occurs as numerous veins in expansion fractures and in partially to wholly altered primary sulphide blebs. These haematite rich rocks contain native metals (copper and awaruite were identified) and few remnant sulphide phases. The loss experienced by these rocks probably provided the sulphur for the sulphide opaque dust in the vicinity. Some sulphur may also have been introduced externally in the waters that altered the silicate phase.

Much of the sulphide opaque dust is in uralite and includes pyrrhotite, chalcopyrite and minor pentlandite as well as pyrite, millerite, violarite and other such low temperature phases. A few such pyrrhotite blebs contain what appear to be pentlandite exsolution flames (?). This would indicate that some of the alteration took place at 600°C or more, a metamorphic rather than strictly supergene event. This is also within the stability field of tremolite, which has been determined by Boyd(1954)tc break down at 780°C at 400 bars of water pressure. Mobilization of some sulphide phases produced veins of chalcopyrite, pyrite, marcasite and possibly pyrrhotite.

An ongoing process during and after serpentinization altered the primary and some of the secondary opaque dust and veins. Oxidation and hydration produced marcasite, haematite, pyrite, violarite, bravoite, millerite, goethite and limonite among others. The mixture of phases revealed by the analyses are probably due to the metamorphic event.

G) Economic Considerations:

The mineral assemblage in the pyroxenites would be more amenable to milling and subsequent concentration by floatation than the mineral assemblage in the serpentinized peridotites. The pyroxenites contain 2-5 percent primary sulphide grains ranging from 0.2- 10 mm in grain size, averaging 1 mm. Most of the nickel and copper content is in chalcopyrite and pentlandite much but not all of which occur in composite grains. Pyrrhotite contains few exsolution pentlandite and chalcopyrite phases which pose recovery problems. The grain size of the opaque mineralogy of interest in the altered peridotites is 2-20 microns on the average and recovery from a grinding and floatation process would be low.

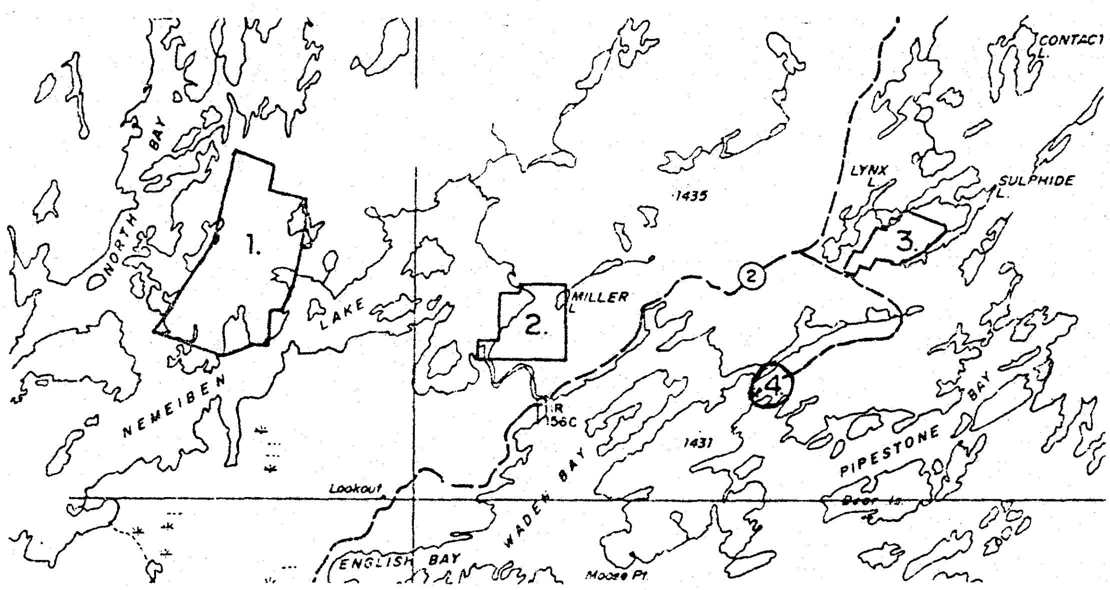


Figure IV(iii)

Location, Nemeiben Lake West Property . From Cochrane and Richards (1973).
1) Nemeiben Lake West Property (Cu).
2) Nemeiben Lake East Property (Ultramafic Body).
3) Sulphide Lake Gold Prospect.
4) Former Anglo Rouyn Mine (mostly Cu).

The primary sulphides in peridotites are almost completely oxidized. The chromite, although of good quality, is insufficient.

Precious metal minerals are rare and cannot significantly increase the value of the deposit. Cobalt occurs in significant amounts in pentlandite, violarite, is present in pyrrhotite and some chalcopyrite.

Tonnage and grades are low and recovery would probably present a problem at the Ni-Cu prospect of the Nemeiben Lake ultramafic pluton. Figure V(i) shows the location of another property, 10 km by water away from this Nemeiben Lake East property. The Nemeiben Lake West property has drill indicated reserves of over 1 000 000 tons grading 1.55 percent copper (Taylor 1970). A combined mining and milling venture if at all possible considering the different natures of the ores, might be the answer to an economically successful venture. Saskatchewan Highway No. 2 passes very close to the ultramafic body. A concentrator would have to be placed at the Nemeiben East property minimizing transportation and development costs and ore from the Nemeiben West property transported to that site, possibly after primary crushing.

V

CONCLUDING STATEMENTS

(A) General Statements:

1. The "La Ronge-Rottenstone" domain consists of three sub-domains: the La Ronge, Rottenstone, and Northern Complex.

2. The Hudsonian Orogeny in the "La Ronge-Rottenstone" domain may have been due to the destruction of an ocean previously created between two Archean plate fragments.

3. The Needle Falls shear zone may represent the westernmost reverse or thrust type fault zone along which "La Ronge-Rottenstone" rocks were wedged against or overode the Archean Wollaston domain.

4. The ultramafic bodies in the "La Ronge-Rottenstone" domain are pre-orogenic and intruded La Ronge Group or related supracrustal successions.

5. Many of the ultramafic occurrences including the Nemeiben Lake pluton were coeval and related to the La Ronge volcanics.

6. The Nemeiben Lake pluton is a pyroxene-rich cumulate-plug which may have been part of the feeder system of the La Ronge volcanics. The parental magma may have been ultramafic.

7. The pluton intruded a supracrustal succession of probably "wet" sediments and volcanics prior to and in the early stages of the Hudsonian orogenic events. Some pyroxene grains near the contact altered to hornblende during the intrusion.

8. Retrograde alteration of olivine and pyroxene to serpentine was followed by a regional metamorphic event which reached the middle to upper amphibolite facies. This metamorphic event resulted in the amphibolization of much of the pyroxene in the pluton and the granitization of the country rocks.

(B) Economic Geology, Nemeiben Lake Pluton:

1. Pyrrhotite, chalcopyrite, and pentlandite are the common primary sulphide minerals in the Nemeiben Lake ultramafic pluton. Magnetite and chromite are also present.

2. The primary ore minerals are magmatic. They include immiscible sulphide droplets occupying intercumulate spaces, a few sulphide-oxide droplets, some oxide droplets, and some cumulate oxide grains.

3. Some late magmatic chalcopyrite and minor pyrrhotite veins are present. The structural and metamorphic event which uralitized the body mobilized some sulphides and produced an opaque dust assemblage including magnetite, haematite, chalcopyrite, pyrrhotite, pentlandite.

4. The haematite rich serpentinites contain both awaruite-(Heazlewoodite)-native copper assemblages and millerite bearing rocks.

The first type of assemblage is due to a reducing type environment with H_2 generation during serpentinization. Millerite bearing rocks contain much calcite-dolomite and altered in an oxidizing medium (Eckstrand 1975).

5. The amphibolite facies metamorphic event mobilized the primary sulphide phases. This probably resulted in some mixing and explains the rare presence of Cu in pyrrhotite and pentlandite and Co-Ni in chalcopyrite. Marcasite, violarite, and haematite replaced much of the primary sulphides.

6. About four million tons of mineralized rock containing 0.55 percent combined Ni-Cu is indicated from industry evaluations and occurs in the northwestern reaches of the body. It is not economic at present demand, prices, and technology.

PLATE I

(a) Dunlop core sample Z, feldspathic websterite: interstitial plagioclase and clinopyroxene. The clinopyroxene grain in the left hand corner is twinned. Nicols crossed.

(b) F C67-614, olivine websterite. Small olivine grain almost included in a large late orthopyroxene with multiple clinopyroxene exsolutions. The clinopyroxene grain to the lower left of the orthopyroxene grain has a strain band. Nicols crossed.

PLATE I

(a)

Scale 1mm.

(b)

Scale 1mm.

PLATE II

(a) 1004 A, feldspathic clinopyroxenite.Interstitial plagioclase and clinopyroxene. Some clinopyroxene grains and feldspar twinned. Nicols crossed.

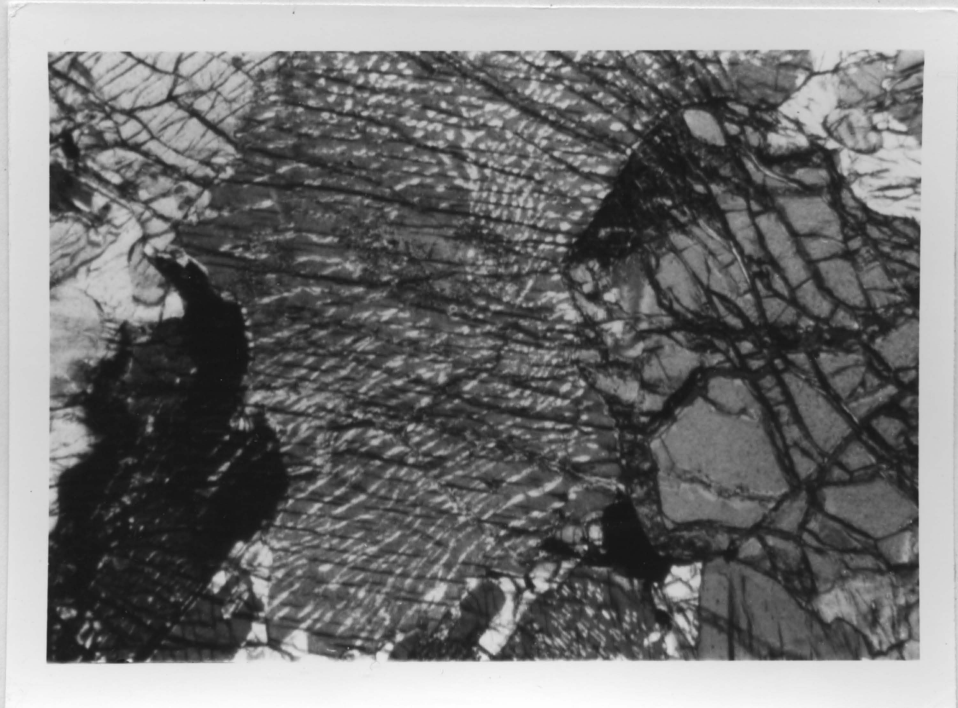
(b) M19, clinopyroxenite. Clinopyroxene grown around an olivine grain (high relief, fractured) in interstitial space. The clinopyroxene grain exhibits an alteration-deformation feature which appears due to granulation. It is only apparent with crossed nicols, has the same relief than clinopyroxene and only occurs near fractures. Nicols crossed.

PLATE II

(a)

Scale 1mm.

(b)



Scale 1mm.

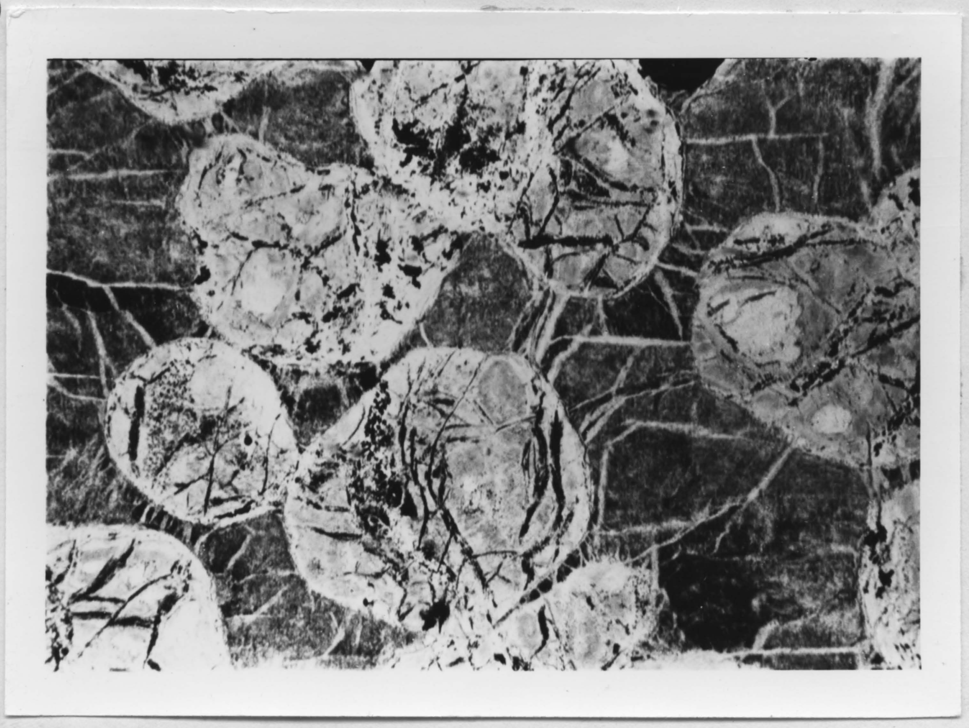
PLATE III

(a) 1001 A, wehrlite. Green serpentine pseudomorphs after olivine and brown serpentine after interstitial clinopyroxene. Magnetite dust. Nicols uncrossed.

(b) F C67-611, olivine clinopyroxenite. Poikilitic clinopyroxene including serpentine pseudomorphs after olivine. On the right hand side of the picture, a larger partially serpentinized olivine grain. Nicols crossed.

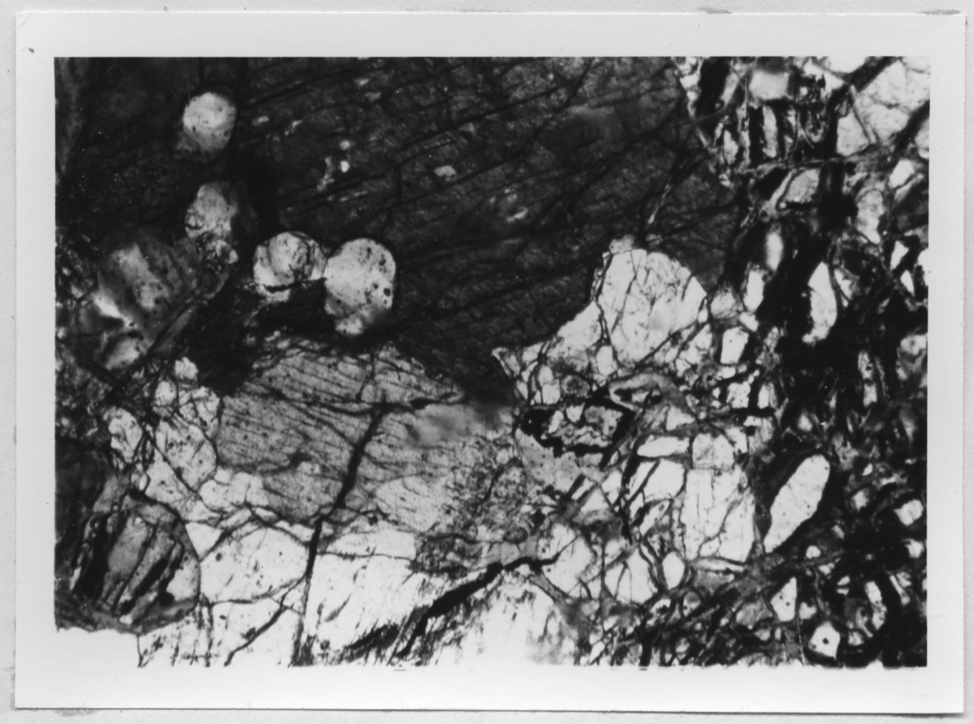
PLATE III

(a)



Scale 1mm.

(b)



Scale 1mm.

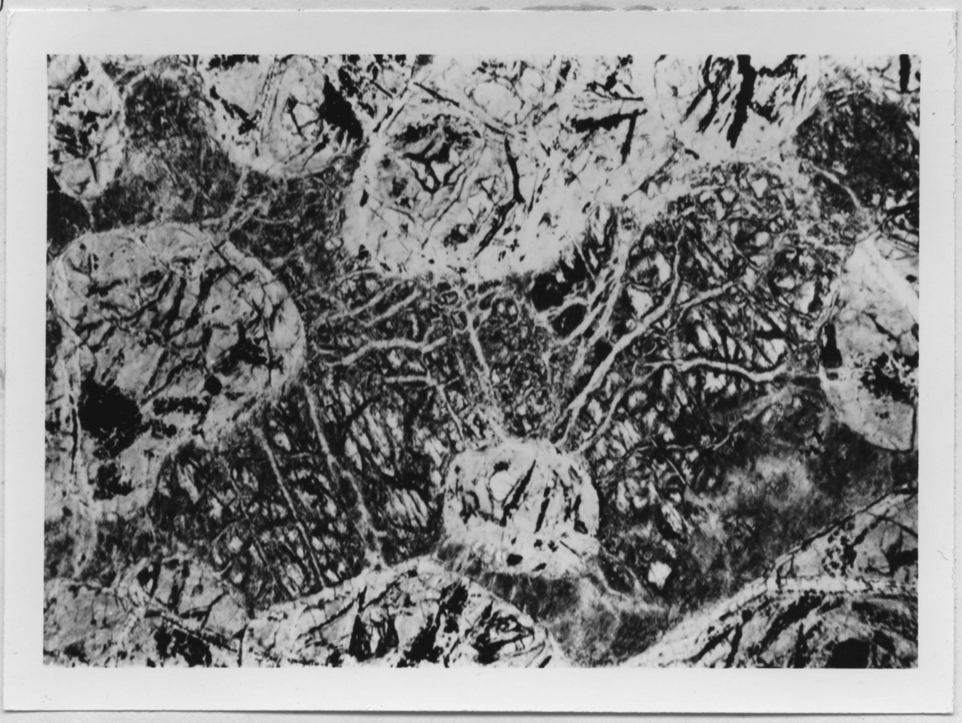
PLATE IV

(a) 5001, dunite. Large, poikilitic clinopyroxene grain, both olivine and clinopyroxene are completely serpentinized. Nicols uncrossed.

(b) 2006, lherzolite. "Intercumulate" opaque material (sulphide and oxide) between serpentine pseudomorphs after olivine in olivine rich "layer". Nicols uncrossed.

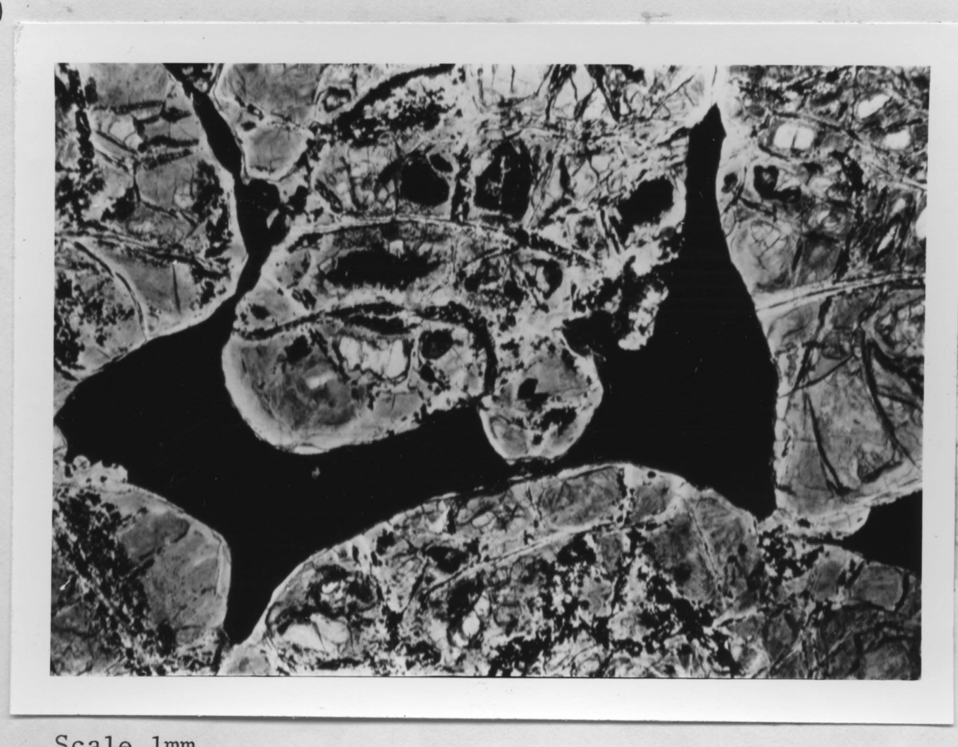
PLATE IV

(a)



Scale 1mm.

(b)



Scale 1mm.

PLATE V

(a) MEP4 228A, uralitized (clino)pyroxenite. Calcite partially filling miarolitic cavity in colloform serpentine vein. Nicols crossed.

(b) M1, serpentine amphibolite. Antigorite and fine grained actinolite. Nicols crossed.

PLATE V

(a)

Scale 1mm.

(b)

Scale 1mm.

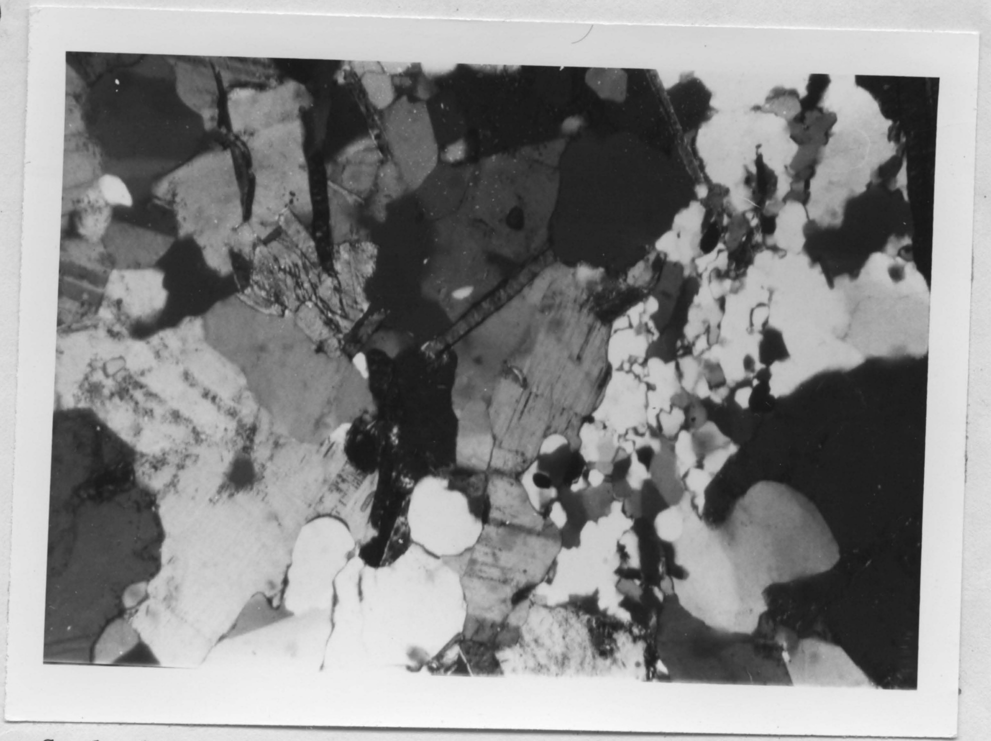
PLATE VI

(a) MIV, granodiorite. Biotite altered to chlorite. Untwinned plagioclase, minor K-feldspar. Some granulation right central part of picture. Nicols crossed.

(b) M3, gabbro. Untwinned and twinned plagioclase, hornblende. Nicols crossed.

PLATE VI

(a)



Scale 1mm.

(b)

Scale 1mm.

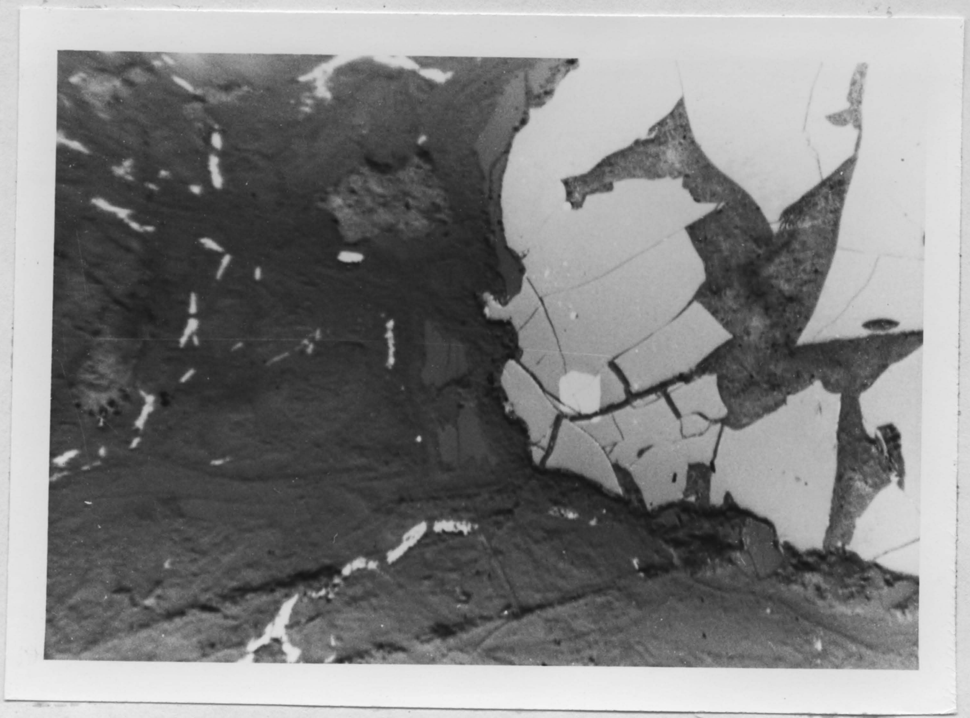
PLATE VII

(a) 2006. Magnetite grain with a small cubiform pentlandite inclusion. To the left, magnetite in alteration hydrous silicates. Note fractures in primary magnetite. Nicols uncrossed, reflected light.

(b) 4015. Primary magnetite. One grain including sulphide bleb. Lower part of bleb is pentlandite, upper part pyrrhotite. Minor haematite alteration of magnetite along edges (white in contrast to grey magnetite). Nicols uncrossed, reflected light.

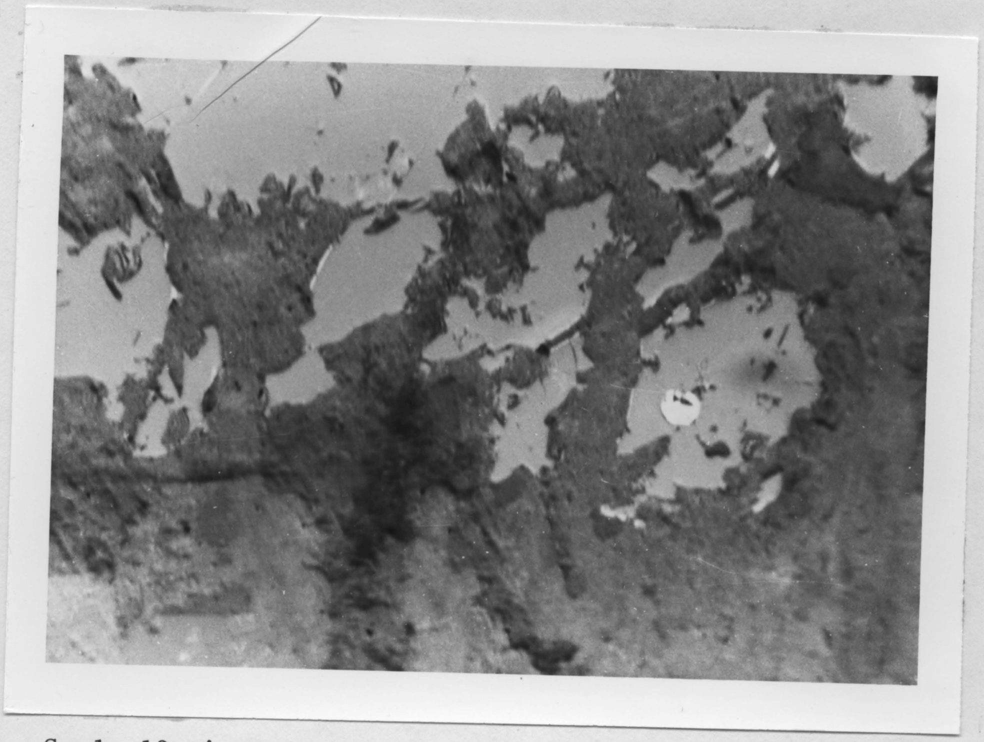
PLATE VII

(a)



Scale 10 microns.

(b)



Scale 10 microns.

PLATE VIII

(a) 2003A. Rounded bleb of chalcopyrite in pentlandite. The pentlandite is also altered to minor bravoite (upper left hand corner). Long bleb of chalcopyrite along a fracture or edge of a pentlandite crystal. Small chalcopyrite grains in the silicate material left hand side of picture. Pyrrhotite on right hand side of picture, slightly out of focus. Note clean straight contact with pentlandite. Nicols uncrossed.

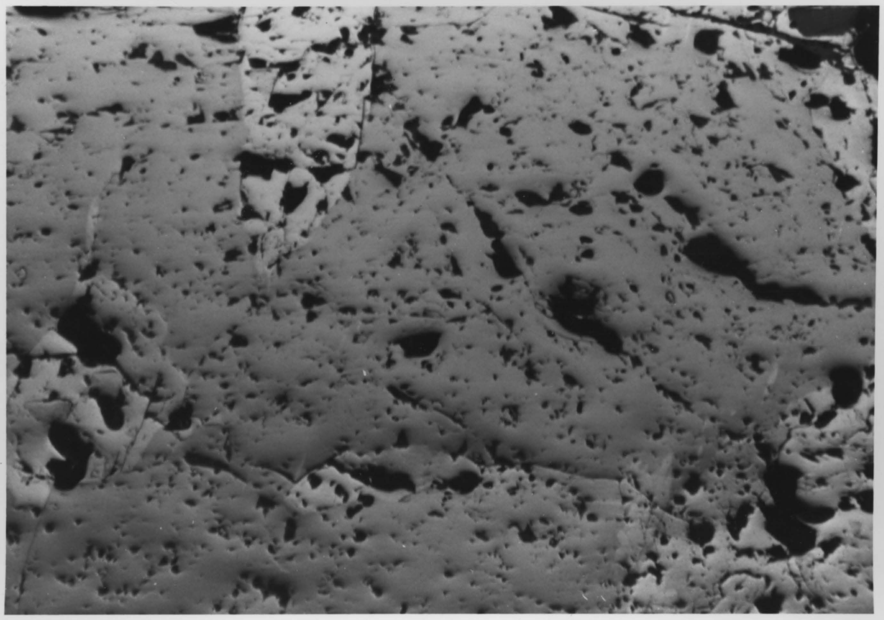
(b) XII. Two pentlandite blebs in pyrrhotite, and one chalcopyrite bleb in pyrrhotite (left hand side). More pentlandite in lower right corner, note rounded irregular contact. Nicols crossed. From Dunlop Mining core, in "ore zone".

PLATE VIII

(a)

Scale 10 microns.

(b)



Scale 0.2mm (200 microns).

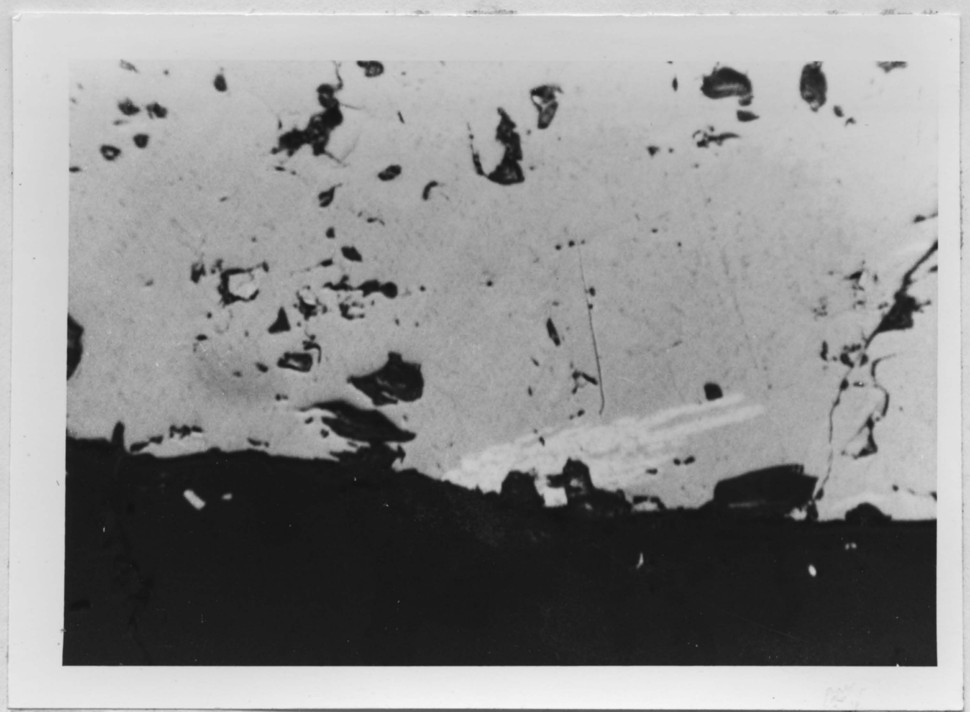
PLATE IX

(a) 2003A. Pentlandite exsolutions at the edge of a large pyrrhotite grain. Nicols uncrossed.

(b) 2003 A. Chalcopyrite on the left side, pyrrhotite on the right. Pentlandite in both phases with mostly idiomorphic contacts in chalcopyrite and feathery into pyrrhotite. Marcasite and haematite lamallae in pyrrhotite. Nicols uncrossed.

PLATE IX

(a)



Scale 10 microns.

(b)

Scale 10 microns.

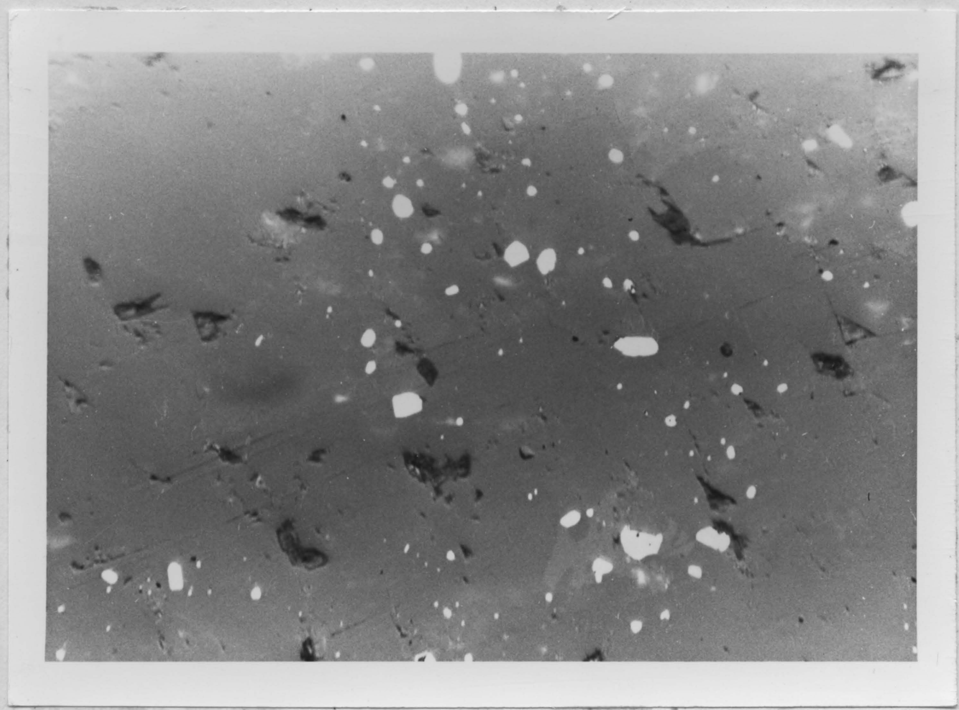
PLATE X

(a) XII Sulphide opaque dust in tremolite, larger and more numerous than usual, in this sulphide rich rock. Pyrrhotite, chalcopyrite, some marcasite. Nicols uncrossed.

(b) 2003A. Composite grain with pentlandite in the middle, minor chalcopyrite at the bottom, pyrrhotite each side. Clean curved contacts. Violarite alteration of pentlandite. Minor chalcopyrite specks in silicate mass. Nicols uncrossed.

PLATE X

(a)



Scale 10 microns.

(b)

Scale 10 microns.

PLATE XI

(a) 2003A. Chalcopyrite (darker phase) and pentlandite largely altered to violarite. Contact mostly clean and curved except in upper left hand corner where chalcopyrite seems to invade pentlandite (unmixing, or metamorphic effect?). Nicols crossed.

(b) 2003C. Chalcopyrite bleb at the edge of a pyrrhotite grain. The chalcopyrite is altered to haematite along its edges especially near the contact with pyrrhotite and to covellite (higher relief). Nicols uncrossed.

PLATE XI

(a)

Scale 10 microns.

(b)

Scale 10 microns.

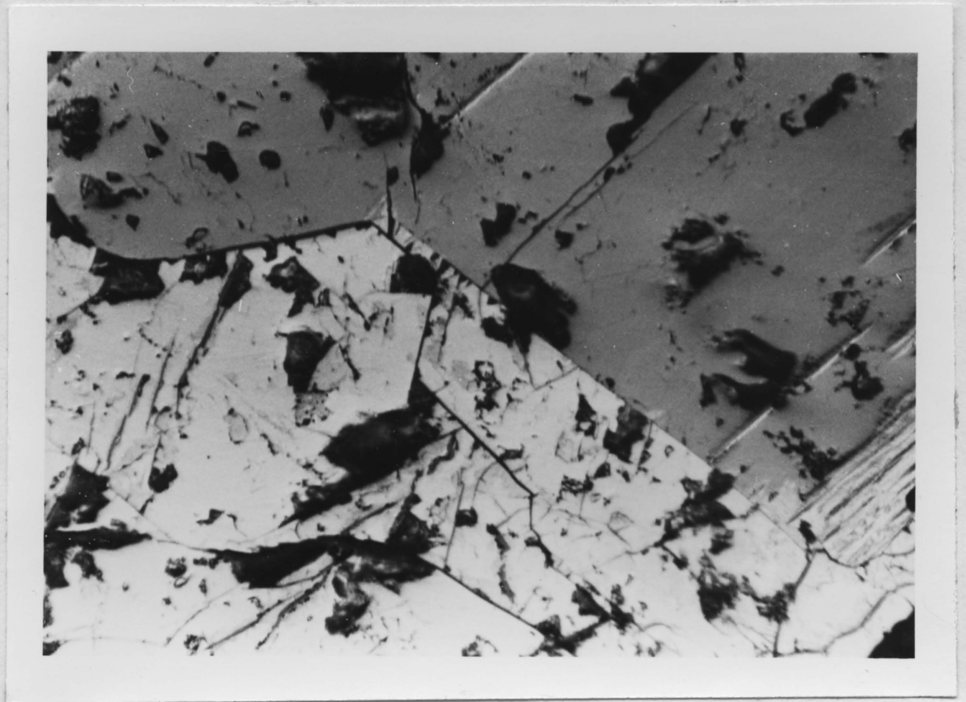
Plate XII

(a) 2003 A. Lower half is pentlandite with violarite and haematite alteration. Straight idiomorphic contact with pyrrhotite altering to marcasite and haematite along cleavage planes. Nicols crossed.

(b) 2007 A. Pentlandite with patchy alteration to violarite. Nicols crossed.

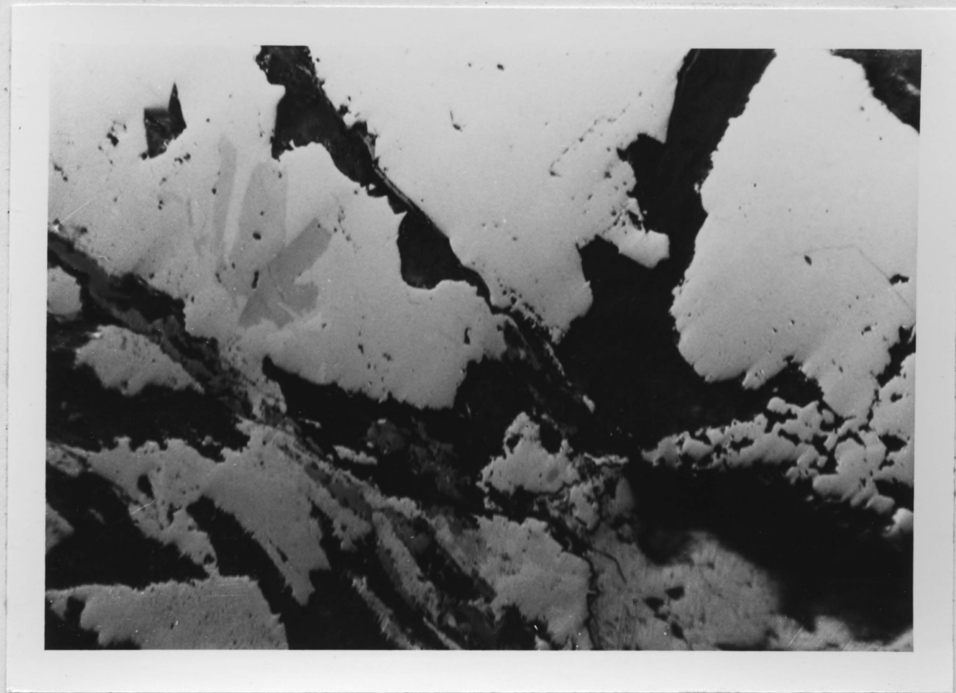
PLATE XII

(a)



Scale 10 microns.

(b)



Scale 10 microns.

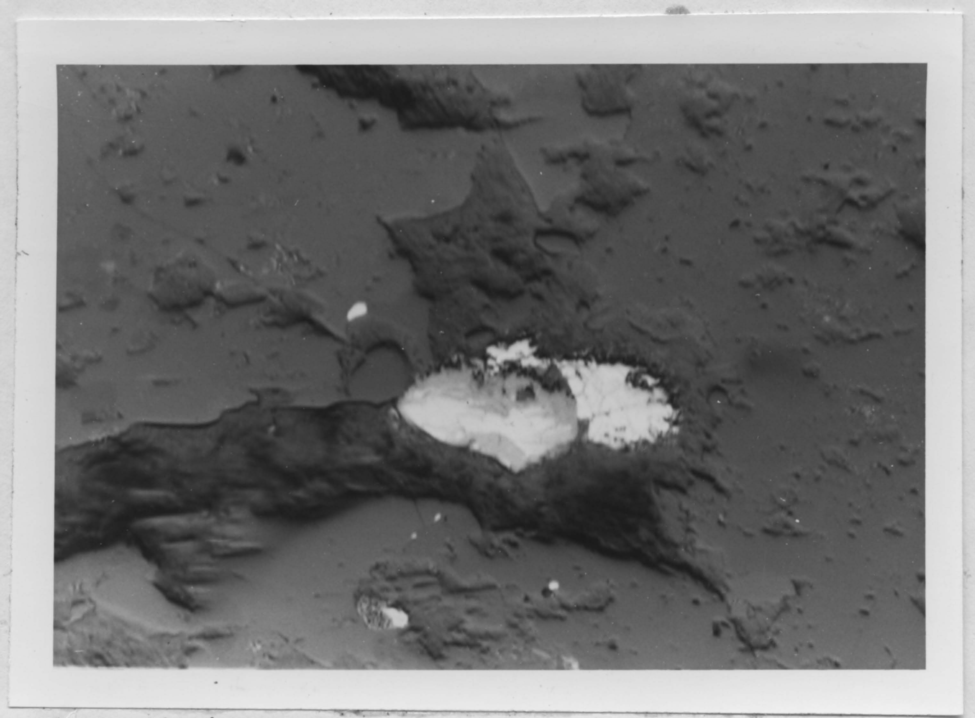
PLATE XIII

(a) 2003 C. Left side is chalcopyrite altered to haematite and minor chalcopyrite on edges, pyrrhotite on right side. Nicols uncrossed.

(b) 2006. Pyrrhotite altered to marcasite, cubic pyrite, and haematite (light grey). Dark grey magnetite veins. Chalcopyrite on upper right hand corner, out of focus. Nicols uncrossed.

PLATE XIII

(a)



Scale 10 microns.

(b)

Scale 10 microns.

PLATE XIV

(a) 2003 C. Marcasite and minor haematite, magnetite alteration along cleavage planes of pyrrhotite. Chalcopyrite in lower right, smooth curved contact. Nicols uncrossed.

(b) 2003A. Pyrrhotite on left, pentlandite on right. Straight idiomorphic contact. Alteration of pentlandite (out of focus due to relief) to violarite, minor bravoite (darker). Marcasite with magnetite-haematite alteration of pyrrhotite. Some idioblastic pyrite after marcasite (lower part of marcasite mass). Minor cubanite specks associated with the magnetite. Nicols uncrossed.

PLATE XIV

(a)

Scale 10 microns.

(b)

Scale 10 microns.

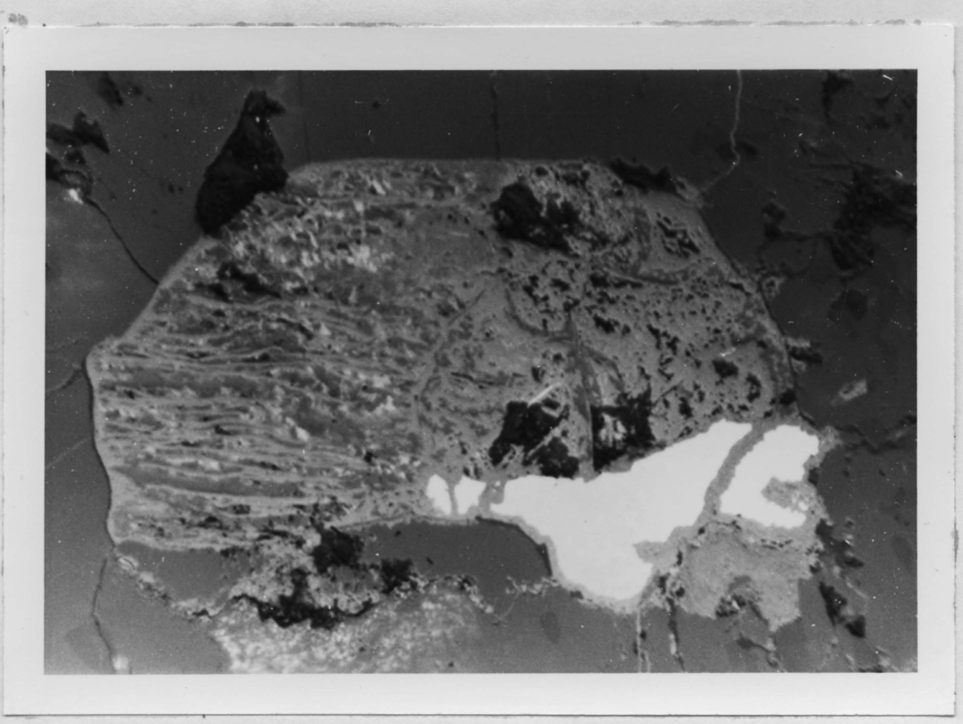
PLATE XV

(a) 3004. Altered chalcopyrite grain included in a slightly uralitized clinopyroxene grain. Mostly haematite on the left side in the uralitized part of the pyroxene, mostly covellite next to the remnant chalcopyrite on the right side of the grain, in fresh pyroxene. Nicols uncrossed.

(b) 4015. On the right, pentlandite altered to violarite and haematite (darker grey). On the left, same, and primary magnetite grains also somewhat altered to haematite. Nicols crossed.

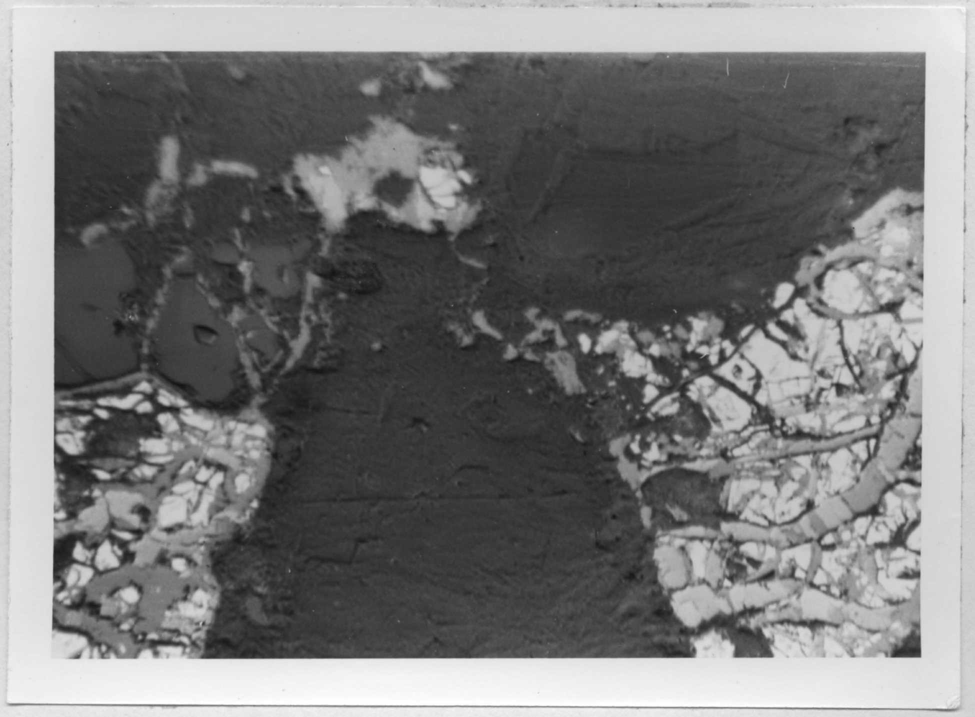
PLATE XV

(a)



Scale 10 microns.

(b)



Scale 10 microns.

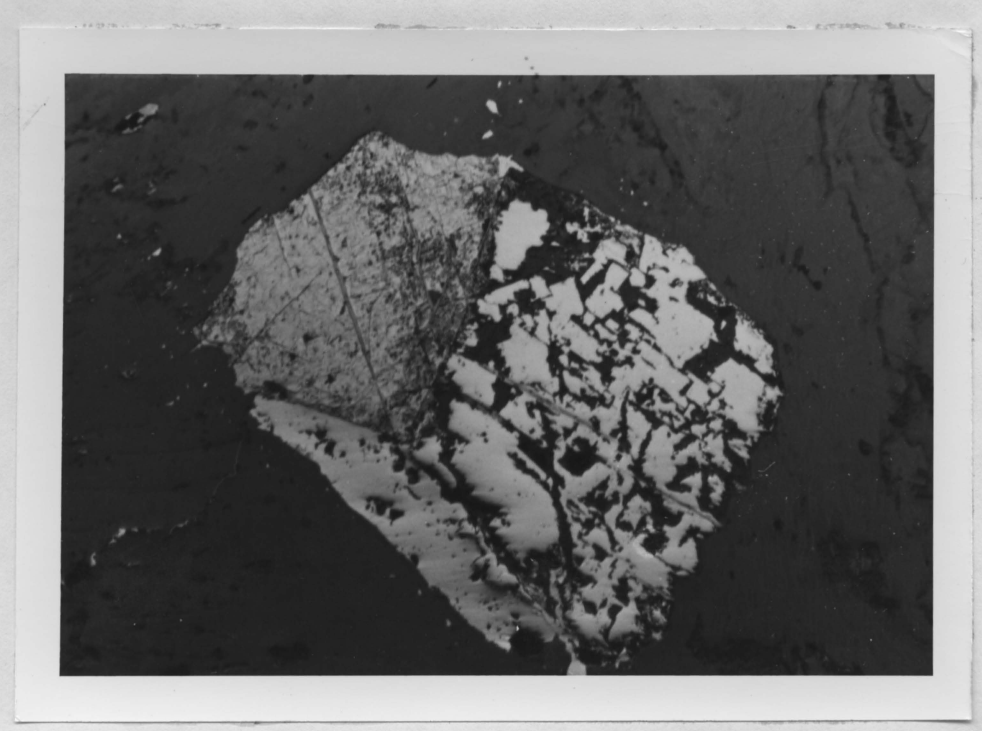
PLATE XVI

(a) 2007C. Typical composite grain, altered. Pentlandite on right side relatively fresh, idiomorphic cubic shapes, with minor violarite. Pyrrhotite on left, altered to marcasite and haematite. Chalcopyrite minor phase. Thin chalcopyrite vein lower left part of picture. Specks of chalcopyrite in silicate mass. Nicols uncrossed.

(b) 2007C. Another typical composite grain. Pentlandite in upper half, mostly unaltered. Pyrrhotite brownish and altered to a reticulate network of haematite. Chalcopyrite specks in silicate mass of incipiently altered clinopyroxene.

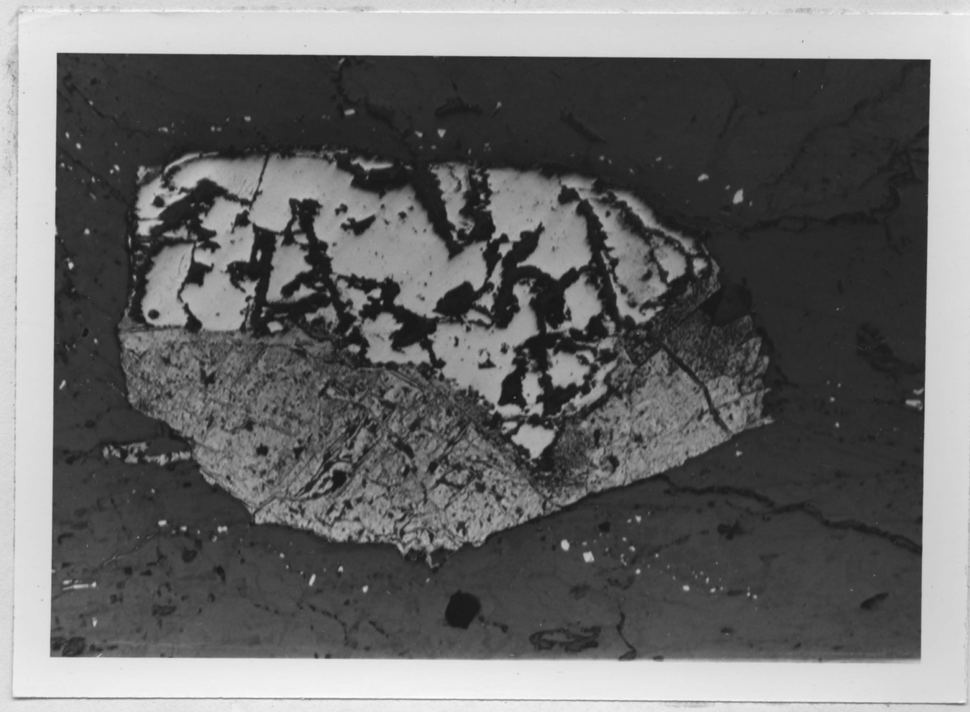
PLATE XVI

(a)



Scale 0.2mm (200 microns).

(b)



Scale 0.2mm (200 microns).

PLATE XVII

(a) 3005 Bi. Birds eye structure, marcasite and magnetite alteration of pyrrhotite. Nicols uncrossed.

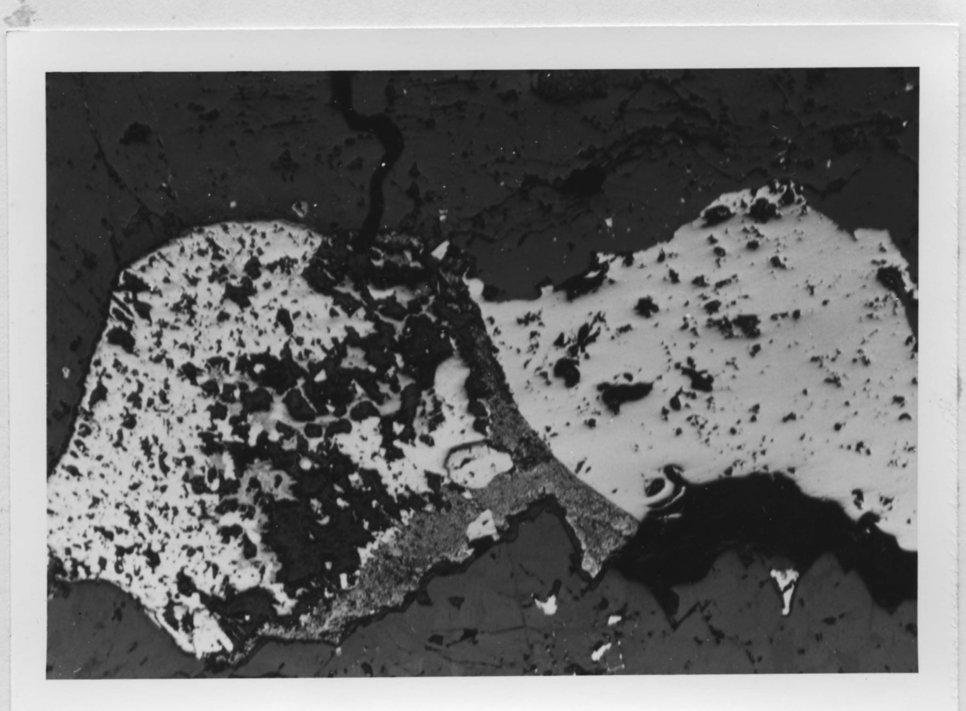
(b) 3005Bi. Chalcopyrite on the right. On the left, pentlandite altered to violarite and minor bravoite, haematite. "Grunge" between the primary phases is mostly bravoite and haematite. Nicols uncrossed.

PLATE XVII

(a)

Scale 0.2mm (200 microns).

(b)



Scale 0.2mm (200 microns).

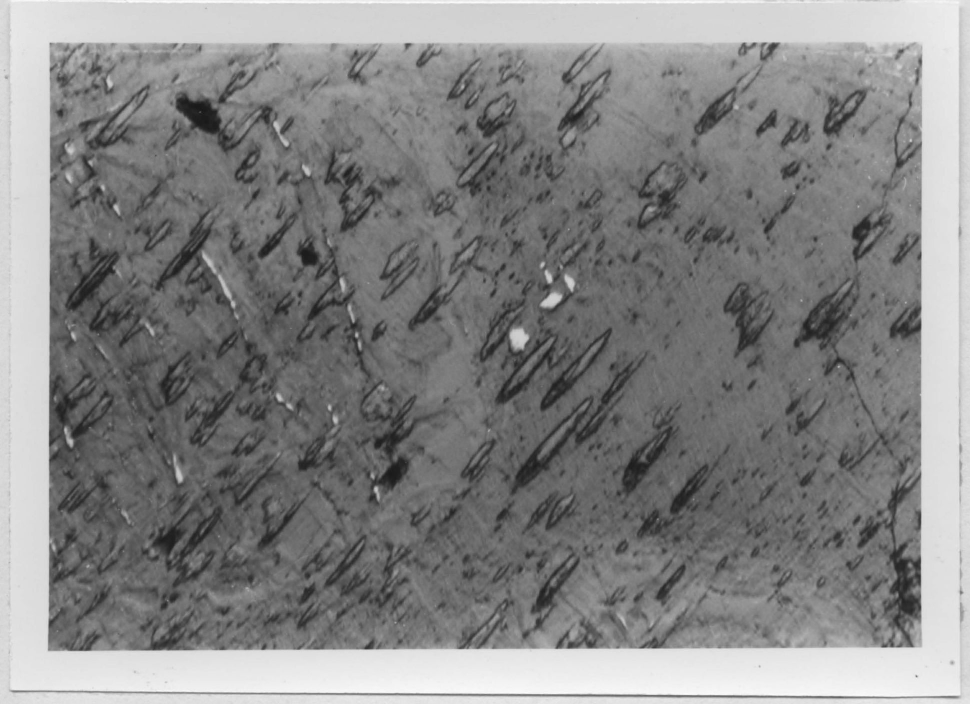
PLATE XVIII

(a) 2008B. Probable awaruite at centre of picture. White with tinges of yellowish green, some cubic forms, isotropic. Haematite-magnetite opaque dust on left. Nicols uncrossed.

(b) MEP2 390. Small speck of gold(?): bright yellow, tinges of green, isotropic. A few specks of bornite in the vicinity. Remnants of and inclusion in chalcopyrite? Nicols uncrossed.

PLATE XVIII

(a)



Scale 10 microns.

(b)

Scale 10 microns.

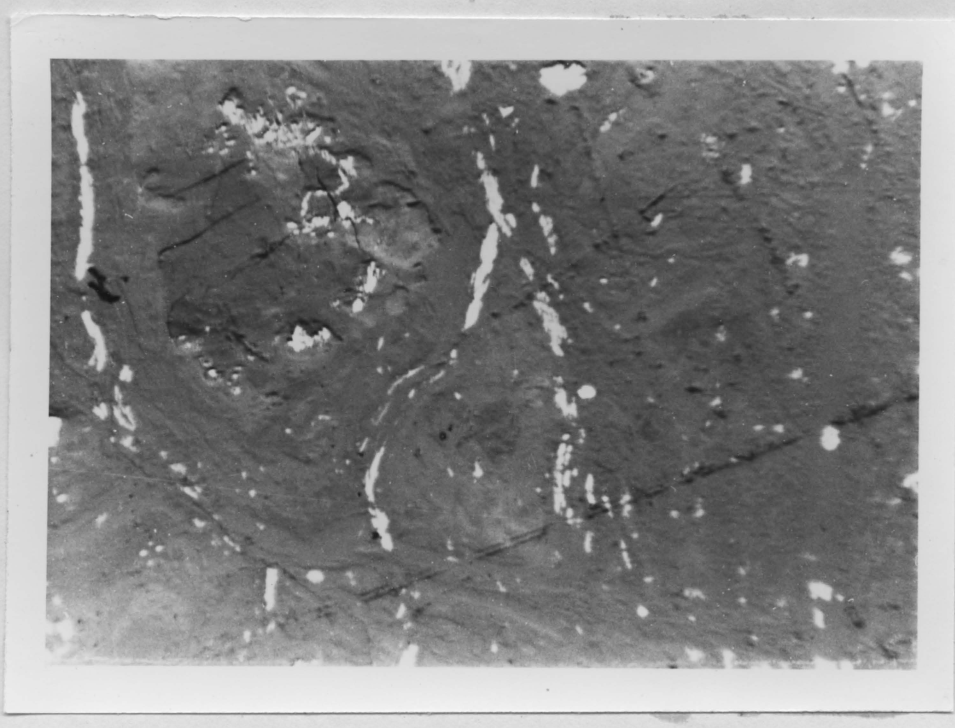
PLATE XIX

(a) 2001. Typical opaque dust in serpentinite. Two pyrite grains, the rest is magnetite. Nicols uncrossed.

(b) MEP4 26. Two thin copper veins, lower middle of picture. One copper speck, upper left corner. Rest is magnetite. Nicols uncrossed.

PLATE XIX

(a)



Scale 10 microns.

(b)

Scale 10 microns.

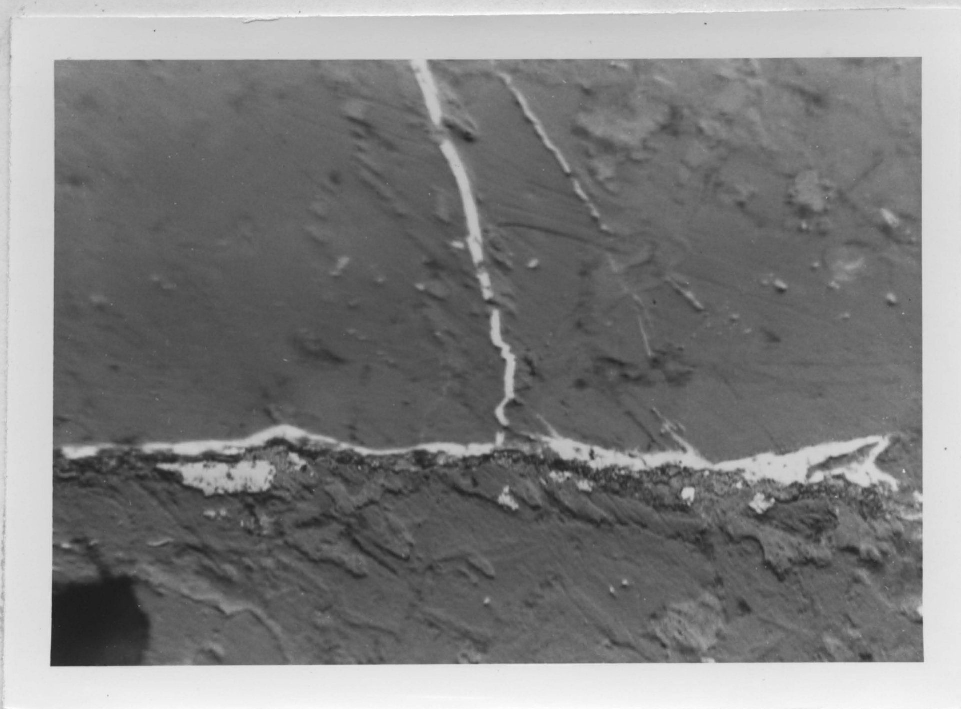
PLATE XX

(a) 4015. Marcasite and minor haematite, veins between silicate pseudomorphs. Minor goethite. Nicols uncrossed.

(b) XII. Marcasite in "cleavage planes" of tremolite pseudomorphs after pyroxene. Nicols uncrossed.

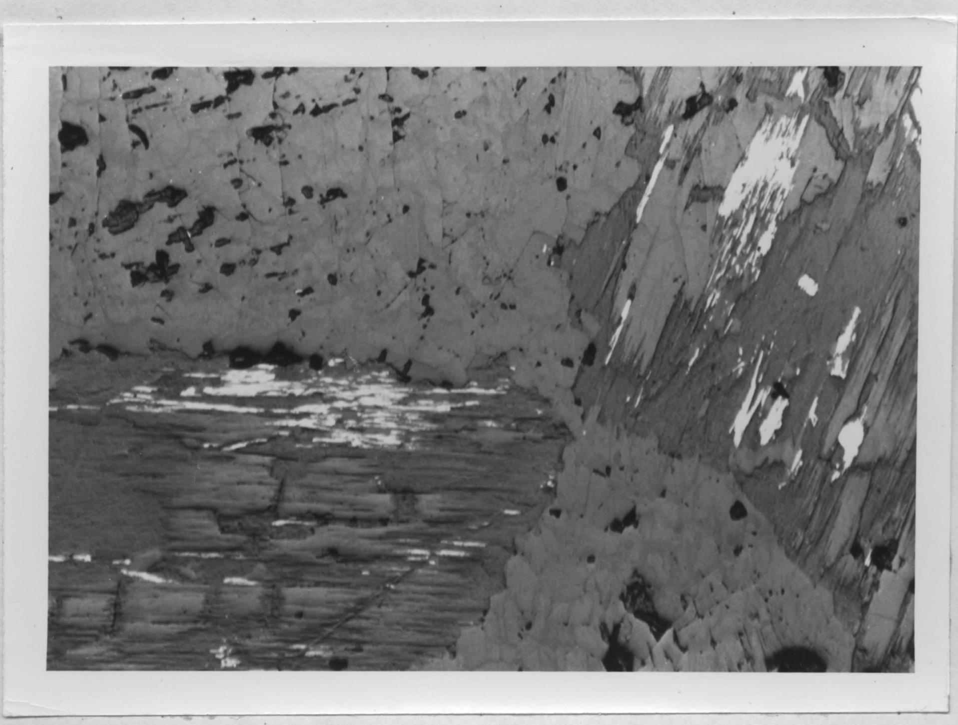
PLATE XX

(a)



Scale 10 microns.

(b)



Scale 0.2mm (200 microns).

PLATE XXI

(a) Z Dunlop Mining core sample. Chalcopyrite and minor pyrrhotite in cleavage planes of altered clinopyroxene. Nicols uncrossed.

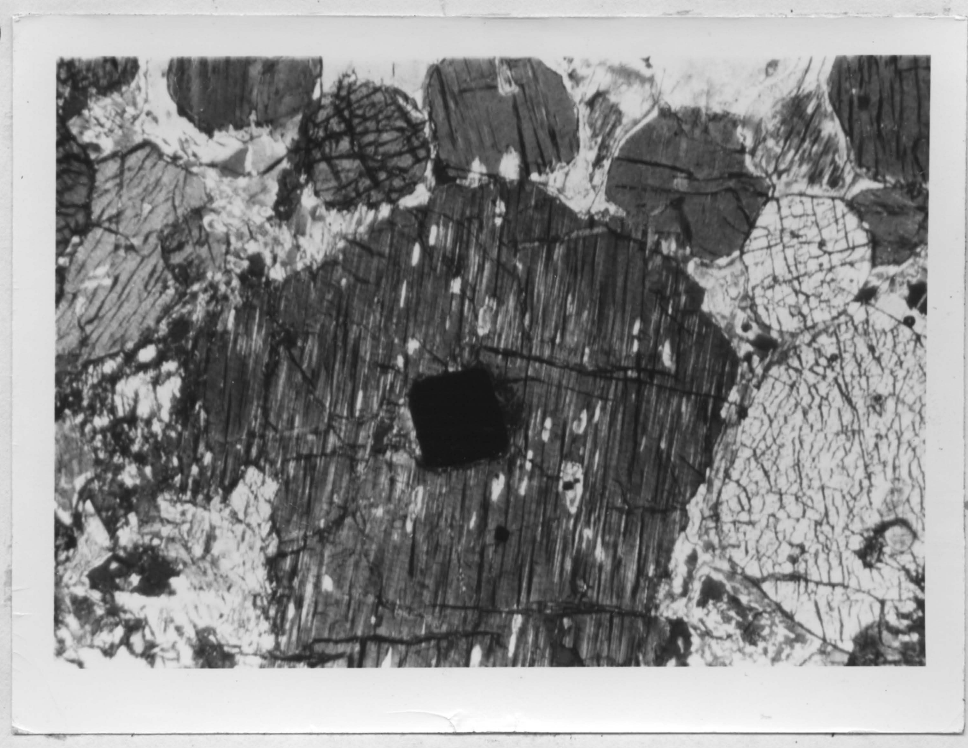
(b) M14. Feldspathic websterite. Magnetite cubes in orthopyroxene, clinopyroxene exsolutions. Small fractured round olivine grains. Clinopyroxene, tremolite alteration. Nicols crossed.

PLATE XXI

(a)

Scale 10 microns.

(b)



Scale 1mm.

REFERENCES CITED*

Agarwal, R.G., 1970, Report on gravity survey for Dunlop Mining Limited, Nemeiben Lake area, La Ronge Saskatchewan: Saskatchewan Department of Mines and Resources, assessment file No: 73P06-SE-0062.

Alcock, F.J., 1920, Reed-Wekusko map-area, Northern Manitoba: Geological Survey of Canada Memoir 119.

Ashton, K., 1978, MSc. thesis, University of Saskatchewan, Department of Geological Sciences: in progress.

Atlas, L., 1952, The polymorphism of $MgSiO_3$ and solid state equilibria in the system $MgSiO_3$-$CaMgSiO_6$: Journal of Geology, v.60, p.125.

Atkins, F.B., 1969, Pyroxenes of the Busveld Intrusion, South Africa; Journal of Petrology v.10 p.222.

Beck, L.S., 1959, Mineral occurrences in the Precambrian of northern Saskatchewan(excluding radioactive minerals): Saskatchewan Department of Mineral Resources Report No: 36.

Binns, R.A., R.J. Gunthorpe, and D.I. Groves, 1976, Metamorphic patterns and development of greenstone belts in the Eastern Yilgarn Block, Western Australia, in: The early history of the earth, B.F. Windley, editor; John Wiley & Sons.

Bowen, N.L., and Tuttle, O.F., 1949, The system MgO-SiO_2-H_2O: Bulletin of the Geological Society of America, v.60, p. 439.

Boyd, F.R., 1954, Carnegie Institute of Washington, annual report District Geophysical Laboratory, 1953-54 p.109, stability field of tremolite.

__________, and Scharier, J.F., 1964, The system $MgSiO_3$-$CaMgSi_2O_6$: Journal of Petrology, v. 5, p. 275.

Budding, A.J., 1955, The geology of the Settee Lake Area (East Half): Saskatchewan Department of Mineral Resources, Report No: 17.

Byers, A.R., 1948, Preliminary report, the geology of the Waddy Lake Area Rottenstone Mining Division, Saskatchewan: Saskatchewan Department of Mineral Resources and Industrial Development.

Camfield, P.A., and Gough, D.I., 1977, A possible Proterozoic plate boundary in North America: Canadian Journal of Earth Sciences v. 14 p. 1229.

Campbell, N., 1945, Consolidated Mining and Smelting Company of Canada Ltd. (Cominco) Complex claims; assessment file No: 73P06-SE-0003.

Campbell, and Chamberlain, 1969, Geochemical soil survey over the Nemeiben Lake body: Saskatchewan Department of Mines assessment files.

*Includes references cited in the Appendeces.

Canadian Aero Service Ltd., 1953, Airborne magnetic survey for the Department of Mineral Resources of Saskatchewan, Nemeiben Lake Sheet, redrawn in 1966 to a scale of 1:63 360: Geophysics Paper 4809, Saskatchewan Department of Mineral Resources.

Carstens, H., 1958, Note on the distribution of some minor elements in co-existing ortho and clino-pyroxene: Norsk. Geol. Tidsskr., v. 38, p. 257.

Challis, G.A., 1965, The origin of New Zealand ultramafic intrusions: Journal of Petrology, v. 6, p.322.

____________, and Lauder, W.R., 1966, The genetic position of Alpine type ultramafic rocks: Bulletin of Volcanology, v. 29, p.283.

Cheesman, R.L., 1959, The geology of the Wapus Bay Area (West Half) Saskatchewan: Saskatchewan Department of Mineral Resources, Report No: 35.

Cochrane, and Richards, 1973, Report on Nemeiben Lake properties: p. 16, annual report Studer Mines Ltd., (1973), in Saskatchewan Department of mines and Resources, assessment file No: 73P06-SE-0072.

Coleman, L.C., 1970, Rb/Sr isochrons for some Precambrian rocks in the Hanson Lake Area, Saskatchewan: Canadian Journal of Earth Sciences v. 7, p. 338.

Cumming, G.L., and Scott, B.P., 1976, Rb/Sr dating of rocks from the Wollaston Lake Belt, Saskatchewan. Canadian Journal of Earth Sciences v. 13, p. 355.

____________, J.T. Wilson, R.M. Farquhar, and R.D. Russel, 1955, Some dates and subdivisions of the Canadian Shield: Geological Association of Canada, v. 7, pt. 2, p. 68.

Davis, B.T.C., and Boyd, R.R., 1966, The join $Mg_2Si_2O_6$-$CaMg_2Si_2O_6$ at 30Kb pressure and its aplication to pyroxenes from kimberlites: Journal of Geophysical Research v. 71, p.3567.

Deer, W.A., Howie, R.A., Zussman, J., 1966, An introduction to the rock-forming minerals : Longman, 1975 edition.

Dewey, J.F., and Burke, K.C., 1973, Tibetan Variscan and Precambrian basement reactivation: products of continental collision: Journal of Geology v. 81, p. 683.

Dolomage, Campbell, and Associates Ltd., 1970, Summary report No: 4 on the Nemeiben Lake property.

______________________________, 1974, Gravity data CBS 2895: Detailed gravimetric survey of the northeast corner of CBS 2895: Saskatchewan Department of Mines and Resources, assessment files.

Dunlop, W.B., 1966, Nemeiben nickel-copper prospect Nemeiben Lake, La Ronge Area, Saskatchewan: Saskatchewan Department of Mines and Mineral Resources assessment file No: 73P06-SE-0036.

__________, 1966-67, Electromagnetic and magnetic survey of the Nib and Ben claims and part of CBS 505 and 638, in: Saskatchewan Department of Mines and Mineral Resources assessment file No: 73P06-SE-0036.

__________, 1967, Dunlop Mining Ltd., Merritt Copper Co. Ltd., financial report in : Saskatchewan Department of Mines and Mineral Resources assessment file No: 73P06-SE-054.

Eckstrand, O.R., .975, The Dumont serpentinite: a model for control of nickeliferous opaque mineral assemblages by alteration reactions in ultramafic rocks: Economic Geology v. 70, p. 183.

Fano Mining and Exploration Ltd., 1956, Saskatchewan Department of Mines and Mineral Resources assessment file No: 73P06-SE-0006

Fleischer, M., 1955, Minor elements in some sulphide minerals : Economic Geology, 50th anniversary Volume, p. 970.

Forsythe, L.H., 1968, The geology of the Stanley Area (West Half) (MacKay Lake Area) Saskatchewan: Saskatchewan Department of Mines and Resources, report No: 115-I.

__________, 1971, The geology of the Nemeiben Lake Area (East Half) and the geology of mineral deposits in the Nemeiben Lake-Stanley Areas (73P-6-E:73P-7-W) Saskatchewan: Saskatchewan Department of Mineral Resources report 115-II.

__________, 1971b, The geology of the Clam Lake Area(West Half) Saskatchewan department of Mineral Resources report No: 136.

__________, 1972, The geology of the Clam Lake Area (East Half) Saskatchewan : Saskatchewan Department of Mineral Resources report No: 138.

__________, 1975, The geology of the Nemeiben Lake Area (West Half) and the La Ronge Area (West Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 152.

Franklin, Sir. J., 1823, Narrative of a journey to the shores of the Polar Sea in the years 1819, 1820, 1821, and 1822: John Murray, London.

Fumerton, S.L., 1978, PhD., thesis University of Saskatchewan, Department of Geological Sciences, in progress.

Gaskarth, J.W., 1971, Petrogenesis of the Precambrian rocks in the Hanson Lake Area, East Central Saskatchewan: Canadian Journal of Earth Sciences, v. 8, p. 820.

Gilboy, C.F., 1975, Foster Lake Area, in : Summary of investigations 1975 by the Saskatchewan Geological Survey, editors J.E. Christopher and R. Macdonald p. 29.

__________, in press, The geology of the Foster Lake Area (Central Region), Saskatchewan: Saskatchewan Department of Mineral Resources report No: 193.

Goodwin, A.M., 1965, Mineralized volcanic complexes in the Porcupine-Kirkland Lake-Noranda region, Canada: Economic Geology v. 60, p. 955.

Gracie, A.J., 1965, The geology of the Kickson Lake Area (East Half) Saskatchewan: Saskatchewan Department of Mineral Resources Report No: 100.

__________,1967, The geology of the Maribelli Lake Area (West Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 113.

Green, D.H., 1964, The petrogenesis of the high-temperature peridotite intrusion in the Lizard Area, Cornwall: Journal of Petrology v. 5, p. 134.

Hajnal Z., and Rose, J.C., in press, Comparison of the Nelson Front to some present plate margins: (Preliminary draft only was consulted).

Hakli, T.A., 1963, Distribution of nickel between silicate and sulphide phases in some basic intrusions in Finland: Geoschimica et. Cosmoschimica Acta v. 29, p. 1.

__________, and Wright, T.L., 1967, The fractionation of nickel between olivine and augite as a geothermometer: Geoschimica et. Cosmoschimica Acta v. 31, p. 877.

Herz, H.H., 1960, Stillwater igneous complex, Montana: Geological Memoir of the Geological Society of America, v. 80.

Hills, F.A., Houston, R.S., and Sabbarayudu, G.V., 1975, Possible Proterozoic plate boundary in southern Wyoming: Geological Society of America, Abstracts with Programs 7, p. 614.

Howey, H.O., 1972, Letter to Studer Mines, in: Dolomage Campbell and Associates, Cochrane (1973) : in Saskatchewan Department of Mines and Mineral Resources assessment file No: 73P06-SE-0068.

Hulburt, C.S., 1971, (18th edition) Dana's Manual of Mineralogy: John Wiley and Sons Inc..

Hyndman, D.W., 1972, Petrology of igneous and metamorphic rocks: McGraw-Hill book Co..

Inco, 1954, Saskatchewan Department of Mines and Resources, assessment file No: 73P06-SE-0011.

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.

Johnston, W.G.Q., 1968, The geology of the Kelly Lake Area: Saskatchewan Department of Mineral Resources report No: 106.

________________, 1969, The geology of the eastern portion of the Waddy Lake Area, Saskatchewan: Saskatchewan Department of Mineral Resources report No: 127.

________________, 1970a, The geology of the May Lake Area (East Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 130.

________________, 1970b, Southend Area (West Half) in : Summary report of geological investigations conducted in the Precambrian area of Saskatchewan, Editor L.S. Beck, p. 6.

________________, 1972, Southend (East Half), in: Summary report of geological investigations conducted in the Precambrian area of Saskatchewan, Editor L.S.Beck, p.15.

________________, 1973a, Wathaman Lake (East Half), in: Summary report of geological investigations conducted in the Precambrian area of Saskatchewan, Editor L.S. Beck, p.14.

________________, 1973b, The geology of the May Lake Area (Northwest Quarter), Saskatchewan: Saskatchewan Department of Mineral Resources report No: 149.

Kirkland, S.J.T., 1959, The geology of the Brabant Lake Area, Saskatchewan: Saskatchewan Department of Mineral Resources, report No: 33.

Kretz, R., 1961a, Some applications of thermodynamics to coexisting minerals of variable composition. Examples, orthopyroxene-clinopyroxene and orthopyroxene-garnet: Journal of Geology v. 69, p. 361.

_________, 1961b, Coexisting pyroxenes: Geological Magazine, v. 93 p. 344.

_________, 1963, Distribution of magnesium and iron between orthopyroxene and calcic pyroxene in natural mineral assemblages: Journal of Geology, v 71, p.773.

Kullerud, G., and Yund, R.A., 1962, The Ni-S system and related mineralogy: Journal of Geology v.3, p. 126.

__________________________, and Moh, 1969, Phase relations in the Cu-Fe-S, Cu-Ni-S, and Fe-Ni-S systems: Economic Geology Monograph 4 p.323.

Kuno, H., 1954, Study of orthopyroxenes from volcanic rocks: American Mineralogist, v. 39, p.30.

Langford, F.F., Stauffer, M.R., Coleman, L.C., Mossman, D.J. 1975, Reindeer Lake South (Northeast Quarter), in: Summary of investigations, 1975, by the Saskatchewan Geological Survey, Editors J.E. Christopher, and R. Macdonald, p. 19.

Lewry, J.F., 1975, Reindeer Lake South (Northwest Quarter), reconnaissance geological mapping of 64D-11-12-13(W)and 14(W), in: Summary of investigations 1975, by the Saskatchewan Geological Survey, Editors J.E. Christopher, and R. Macdonald, p.24.

__________, 1976, Reindeer Lake North (S.W.) Area, in: Summary of investigations 1976, by the Saskatchewan Geological Survey, Editors, J.E. Christopher, and R. Macdonald, p.29.

__________, 1977, Reconnaissance geology: Compulsion Bay Area, Wollaston Lake (part of NTS area 64E-NW), in: Summary of investigations 1977, by the Saskatchewan Geological Survey, Editors J.E. Christopher, and R. Macdonald, p. 30.

__________, and Sibbald, T.I.I., 1977, Variation in lithology and tectonometamorphic relationships in the Precambrian basement of northern Saskatchewan: Canadian Journal of Earth Sciences, v. 14, p. 1453.

Mason, B., 1966, (3rd Edition), Principles of geochemistry: John Wiley and Sons Inc..

Mathieu, G.I., 1964, Concentration tests on a copper-nickel ore from the Rottenstone Lake Area in northern Saskatchewan: Mines Branch Investigation Report I.R. 64-100, Department of Mines and Technical Surveys, Canada.

_____________, and Bruce, R.W., 1968, Plant metallurgical survey for Rottenstone Mining Ltd., La Ronge, Saskatchewan: Canadian Department of Energy Mines and Resources, Mines Branch Investigations Report I.R. 68-79.

Mawdsley, J.B., 1946, Rottenstone Lake Area Saskatchewan, (report and map): Geological Survey of Canada Paper 46-24, reprinted 1954.

_____________, and Grout, F.F., 1951, The geology of the Stanley map area: Department of Natural Resources Precambrian Geology Series report No: 4. (Saskatchewan).

McCormick, C., 1973, National Nickel drilling project: internal mineral evaluation report, Department of Mineral Resources Regina, Saskatchewan.

McInnes, W., 1908, Explorations on the Churchill River and South Indian Lake: Geological Survey of Canada Summary Report, 1908, p. 87.

__________, 1909, Lac La Ronge District, Saskatchewan: Geological Survey of Canada Summary Report, 1909, p.151.

__________, 1913, The basins of the Nelson and Churchill River: Geological Survey of Canada Memoir 30.

McLarty, D.N.E., 1936, Lac La Ronge Sheet (West Half), Map 357A: Geological Survey of Canada, mapped in 1935.

Miller, M.L., 1949, The geology of the Windrum Lake Area (Maribelli Lake-East Half), Saskatchewan: Saskatchewan Department of Mineral Resources report No: 3, (reprinted 1967).

Money, P.L., 1961,The geology of the Barnett Lake Area (West Half), Saskatchewan: Saskatchewan Department of Mineral Resources report No: 60.

__________, 1965, The geology of the area around Needle Falls, Churchill River, comprising the Eulas Lake Area (West Half), Sandfly Lake Area East Half), and Black Bear Island Lake Area(West Half), Saskatchewan: Saskatchewan Department of Mineral Resources Report No: 88.

__________, 1967, The Precambrian geology of the Needle Falls Area, Saskatchewan: PhD. thesis, University of Alberta, Edmonton.

Morris, A., 1960, The geology of the Trout Lake area (East Half), Saskatchewan: Saskatchewan Department of Mineral Resources report No: 42.

__________, 1961, The geology of the Settee Lake Area (West Half) : Saskatchewan Department of Mineral Resources, report No: 55.

__________, 1963, The geology of the Trout Lake Area (West Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 77.

__________, 1965, The geology of the Black Bear Island Lake area (East Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 86.

Mukherjee, A.C., Stauffer, M.R., and Badsgaard, H., 1971, The Hudsonian Orogeny near Flin Flon, Manitoba: A tentative interpretation of Rb/Sr and K/Ar ages : Canadian Journal of Earth Sciences v. 8, p. 939.

Munday, R.J.C., 1974, Ile-a-la-Crosse (East) area, reconnaissance geological survey of 73-O-NE and 73-O-SE, in: Summary report of field investigations by the Saskatchewan Geological Survey 1974, Editors, L.S. Beck, and R. Macdonald, p. 20.

Naldrett, A.J., 1966, The role of sulphurization in the genesis of iron-nickel sulphide deposits of the Porcupine District, Ontario: Canadian Mining and Metallurgical Bulletin, v. 59, No: 648, p. 489.

______________, 1969, A portion of the system Fe-S-O between 900-1080°C and its application to sulphide ore magmas: Journal of Petrology v. 10, p. 171.

National Nickel Ltd., 1966, Three drill holes, Nemeiben Lake Area, CBS 505, in: Saskatchewan Department of Mineral Resources assessment file No: 73-P06-SE-0047.

___________________-Dunlop Mining Co. Ltd., 1968, Electromagnetic survey, and Magnetic survey: Saskatchewan Department of Mineral Resources assessment file No: 73P06-SE-0050.

O'Hara, M.J., 1967, Mineral facies in ultrabasic rocks (pp. 7-18), and Mineral paragenesis in ultrabasic rocks(pp. 393-402), in: Ultramafic and related rocks, Editor P.J. Wyllie, Wiley & Sons., New York.

Padgham, W.A., 1960, The geology of the Otter Lake Area (West Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 41.

_____________, 1963, The geology of the Otter Lake Area (East Half), Saskatchewan: Saskatchewan Department of Mineral Resources report No: 56.

______________, 1966, The geology of the Guncoat Bay Area Saskatchewan: Saskatchewan Department of Mineral Resources report No: 78.

Pauly, H.I., 1958, Igdlukunguaq nickeliferous pyrrhotite: Meddelser om Groenland, 157, 3.

Pearson, W.J., 1957, An investigation into the geological significance of some magnetic anomalies in the Lac La Ronge Area of northern Saskatchewan: Saskatchewan Department of Mineral Resources report No: 29, pp. 21-30, Nemeiben Lake Anomaly.

_____________, 1973, Mineral evaluation program (pp. 63-64, Nemeiben Lake): Summary report of Geological investigations conducted in the Precambrian area of Saskatchewan, L.S. Beck et. al..

__________, and Froese, E., 1959, The geology of the Forbes Lake Area Saskatchewan: Saskatchewan Department of Mineral Resources report No: 34.

Peddada, A., 1972. Petrology of the Nemeiben Lake ultramafic and associated nickel-sulphide deposits: MSc. thesis, State University of New York at Albany.

Pyke, M.W., 1960, The geology of the Wapus Bay Area (East Half) Saskatchewan : Saskatchewan Department of Mineral Resources report No: 40.

Raleigh, G.B., 1965, Glide mechanism in experimentally deformed minerals: Science, 150, p. 3697.

Ramdohr, P., 1969, The ore minerals and their intergrowths: Pergamon Press.

Ray, G.E., 1974, Foster Lake (South)-La Ronge(NW) Area, in : Summary report of field investigations by the Saskatchewan Geological Survey, 1974, Editors L.S. Beck, and R. Macdonald, p. 14.

__________, 1975, Foster Lake (NE)-Geikie River (SE) Area. Reconnaissance geological mapping of 74A-15H-16, and 74H-1, and 2, in: Summary of investigations 1975, by the Saskatchewan Geological Survey, Editors J.E. Christopher, and R. Macdonald.

__________, in press, The geology of the Foster Lake (NE) and Geikie River (SE) Area, Saskatchewan: Saskatchewan Department of Mineral Resources report No: 190.

Richards, B.R., and Robinson, B.G.W., 1966, Mining and milling a small ore deposit...Rottenstone Mining Ltd. : Canadian Mining and Metallurgical Bulletin, v. 59, p. 1423.

Ross, C.S., Foster, M.D., and Myers, A.T., 1954, Origin of dunites and olivine-rich inclusions in basaltic rocks: American Mineralogist, v. 39, p. 693.

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.

Saxena, S.K., 1968, Crystal-chemical aspects of distribution of elements among certain co-existing rock forming silicates: Naues. Pb. Miner. Abh., v. 108 p. 292.

Schouten, C., 1962, Determination tables for ore microcopy : Elsevier Publishing Co..

Scott, B.P., 1970, The geology of the Combe Lake Area, Saskatchewan: Saskatchewan Department of Mineral Resources report No: 135.

Selwyn, A.R.C., 1895, Summary report of the operations of the Geological Survey for the year 1892, by the Director: Geological Survey of Canada, Annual Report 4.(New series) v. VI, 1892-1893, p. 18.

Shewman, R.W. and Clark, C.A., 1970, Pentlandite phase relations in the Fe-Ni-S system and notes on the monosulphide solid solution: Canadian Journal of Earth Sciences, v. 7, p. 67.

Shklanka, R., 1961, The geology of the Oliver Lake Area (East Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 39.

___________, 1962, The geology of the Deception Lake Area (East Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 57.

___________, 1962b, The geology of the McLean Bay Area Saskatchewan (map with marginal notes): Saskatchewan Department of Mineral Resources report No: 74.

Shteinberg, D.S., and Malakhov, P.A., 1963, Distribution of nickel in ultramafic rocks in the Urals: geochemistry, No:11, p. 1020.

Sibbald, T.I.I., 1977, The geology of the Milton Island Area (West Half) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 153.

______________, Munday, R.J.C., and Lewry, J.F., 1976, The geological setting of uranium mineralization in northern Saskatchewan, in: Uranium in Saskatchewan, Editor C.E. Dunn, Saskatchewan Geological Society, special publication No: 3.

Smith, C.H., 1962, Ultramafic intrusions in Canada and their significance to upper mantle studies: Canadian Geophysical Bulletin, v. 14 p. 157.

Spry, A. 1969, Metamorphic textures : Permagon Press.

Stanton, R.L., 1972, Ore petrology : McGraw Hill Book Co..

Stauffer, M.R., Coleman, L.C., Langford, F.F., Mossman, D.J., 1976, Reindeer Lake north (SE) Area, in : Summary of investigations 1976 by the Saskatchewan Geological Survey, Editors, J.E. Christopher, and R. Macdonald, p. 24.

______________, Fumerton, S.L., Langford F.F., Mossman, D.J., 1977 Ballentin Island Area, Reconnaissance geological mapping of 64E-9, 10, 15, and 16, in: Summary of investigations 1977 by the Saskatchewan Geological Survey, Editors, J.E. Christopher, and R. Macdonald. p. 17.

___________, Langford, F.F., Coleman L.C., Mossman, D.J., In press a, The geology of the Reindeer Lake south Area (NE Quarter) Saskatchewan: Saskatchewan Department of Mineral Resources report No: 191.

___________, In press b, The geology of the Reindeer Lake North Area (SE Quarter), Saskatchewan : Saskatchewan Department of Mineral Resources, report No: 200.

Stockwell, C.H., 1946, Flin Flon-Mandy Area, Manitoba and Saskatchewan: Geological Survey of Canada, Paper 46-14.

Streckeisen, A., 1976, To each plutonic rock its proper name : Earth Science Review v. 12, p. 1.

Studer, D., 1974a, Report on a self potential survey, CBS 2895, La Ronge Mining District, N.T.S. 73-P-6-SE, for Studer Mines Ltd., in: Saskatchewan Department of Mineral Resources assessment file No: 73P06-SE-0072.

__________, 1974b, Report on residual bouguer gravity map Ben and Nib claims, CBS 2895, La Ronge mining district, N.T.S. 73-P-6-SE in: Saskatchewan Department of Mineral Resources assessment file No: 73P06-SE-0072.

Suitor, K.A., Dolomage, Campbell, 1972, Proposal to the Government of Saskatchewan, Department of Mineral Resources, in: Saskatchewan Department of Mineral Resources assessment file No: 73P06-SE-0068.

Syme, E.C., and Forrester, R.W., 1977, Petrogenesis of the Boundary Intrusions in the Flin Flon Area of Saskatchewan and Manitoba: Canadian Journal of Earth Sciences, v. 14.

Taylor, H.L. 1970, Evaluation report on the Nemeiben (West) property: Saskatchewan Department of Mineral Resources Assessment files.

Thompson, J., and Brady, P., 1957, Nemeiben Creek Area, two drill holes, in : Saskatchewan Department of Mineral Resources assessment file No: 73P06-SE-0009.

Tyrell, J.B., and Dowling, D.B., 1896, Report on the country between Athabasca Lake and Churchill River : Geological Survey of Canada, Annual report (New series) v. VIII, 1895, report D. p. 110.

Uytenbogaardt, W.O., and Burke, E.A.J., 1971, Tables for microscopic identification of ore minerals : Elsevier Scientific Publishing Co..

Veen, Van der R.W., 1925, Mineragraphy and ore deposition ; the Hague 1

Weber, W., Schledewitz, D.C.P., Lamb, C.F., and Thomas, K.A., 1975a, Geology of the Kasmere Lake-Whiskey Jack Lake (North Half) Area (Kasmere project), Manitoba: Manitoba Mineral Resources Division, Geological Services Branch Publication 74-2.

__________, Anderson R.K., and Clark, G.S., 1975b, Geology and geochronology of the Wollaston Lake fold belt in northwestern Manitoba: Canadian Journal of Earth Sciences v. 12, p. 1749.

Whitaker, S.H., and Pearson, D.E., 1972, Geological map of Saskatchewan, scale 1:1 267 200: Department of Mineral Resources, Regina, Saskatchewan.

Williams, R.G., and Ugster, H.P., 1969, An experimental study of (fe,Mg) olivine-(Fe, Mg) pyroxene reactions and their geological applications: Geological Society of America abstracts for 1969, part 7, p. 239.

APPENDIX A

REGIONAL GEOLOGY

This section includes a summary of the information considered relevant from the Saskatchewan Department of Mines Reports covering the La Ronge and Rottenstone domains. FigureII(iv) shows the reports consulted and their coverage.

D.M.R. REPORT NO. 115 - II: Forsythe (1971)

Map sheet 73-P-6E is mostly underlain by granites "but bands of metasedimentary rocks and local mafelsic, ultramafic intrusives occur" (Forsythe 1971). Small ultramafic and mafic plugs and sills occur in the southern part of this map sheet; in Nemeiben Lake, on the east shore of Nemeiben lake and the Western end of Lac La Ronge. Elongate dioritic gabbros trend sinuously northeasterly in the northeastern part of the map sheet.

The Nemeiben Lake ultramafic pluton is the largest of its kind on this map sheet; being about 1.5 Km in diameter. The other plugs and sills of ultramafic rocks are very small, although the diorites and gabbros are much more extensive.

Forsythe (1971, 1968) considers the granitic rocks east of Nemeiben Lake to be of igneous origin, and notes the presence of metasedimentary and metavolcanic xenoliths.

D.M.R. REPORT NO 115 - I: (Forsythe 1968)

In this area, just east of that covered by Report 115-II, scattered ultramafic rocks occur on the eastern end of Lac La Ronge, and small plugs of diabasic gabbro occur in the crustal part of the map. The ultramafic rocks are in large part completely serpentinized and uralitized, some diopside and altered olivine has survived in places.

Calcite and epidote occur as metamorphic minerals.

Forsythe has recorded that ultramafic rocks locally intrude his units (3), (6), and (7) which are mafelsic, mafic schists and gneisses; layered, grey-black, felsic granulites schists and gneisses; and layered grey-brown felsic schists and gneisses respectively. According to Forsythe (1968, table III) ultramafic intrusion occurred at a depth of at least ten kilometres and was the first event after burial and consolidation of the supracrustal succession.

Only scattered anomalous nickel values were picked up by a bedrock survey except in areas of granodiorites. The Anglo-Rouyn Mine has an associated anomalous copper zone trending away from it in a quartz-biotite-feldspar gneiss.

D.M.R. REPORT NO. 4 (Mawdsley and Grout 1951):

A series of highly metamorphosed and folded sedimentary rocks invaded by gneissoze granites with wide migmatitic margins occurs in the area. "Basic and ultrabasic rocks, most of them definitely intrusive, occur in minor amounts and are considered older than the main granitic invasion" (Mawdsley and Grout, 1951).

A few metagabbro dykes and sills and small bodies of meta-peridotite are recorded. Apart from a few olivine remnants, antigorite, anthophyllite, chrysotile and dusty iron oxide form most of the peridotites. A few chromite crystals project from weathered outcrops of the Hunt Lake ultrabasic mass.

Evidence for both in-situe granitization and actual liquid or partial liquid intrusion was seen, both processes formed the granites in the area.

The authors discarded the term Wekusko Group used by McLarty (1936) because although similar to Alcock's (1920) Wekusko in northeastern Manitoba they felt distances were too great for meaningful correlation. They suggested the term La Ronge Group to replace McInnes' term Lac La Ronge Series for the assemblage of supracrustals, as group has no precise time significance and the name is less cumbersome. Forsythe in turn, felt that "the La Ronge Group should be negated as it adds little to the understanding of the geology of the Shield in this region" (Forsythe 1968).

D.M.R. REPORT NO 152: Forsythe (1975)

The Precambrian Geology of the area just west and south of the map sheet containing the Nemeiben Lake ultramafic pluton is covered by this report.

The boundary between the Rottenstone and La Ronge domains crosses the northwest corner of the Nemeiben West map sheet; represented here by the Birch Rapids fault zone. West of the fault zone cataclastised and mylonitized granites and porphyroblastic feldspar-biotite gneiss form a linear belt trending north-northeast. East of it in the La Ronge domain, the rocks swing east with a more open style of structure, with granitic rocks and migmatized remnants of supracrustals predominating.

An amphibolite-gabbro complex intruded by granite occurs east of North Bay, Nemeiben Lake, down to Lac La Ronge. Irregular "plutons" of gabbro and rare pyroxenite occur north of North Bay and throughout most of the map sheet.

The ultramafic rocks in this area commonly occur as remnants in in hornblende granodiorite/quartz diorite gneisses and gabbroic rocks, or with gradational contact to gabbros. They are mottled green-brown and black, massive to schistose and coarse grained. Mineralogically they are composed of diopside, hypersthene, actinolite after hypersthene, minor feldspar, mica,serpentine, calcite, sphene, pyrite, and magnetite.

The ultramafic rocks in this area are similar to the mineralized Nemeiben Lake body; but the Flatland Lake body which contains scattered pyrite and pyrrhotite tested only slightly positive for nickel.

Forsythe (1975) believed that some of the granite gneisses in this area may be Kenoran in age; the other granites and granodiorites being Hudsonian. The later granites cut the gabbro complexes which in turn are coeval or younger than the pyroxenites; these are therefore at least Early Hudsonian in age.

D.M.R. REPORT NO. 138: (Forsythe 1972):

The boundary between the La Ronge and Rottenstone domains crosses this map sheet from N.E. to S.W..No striking change is obvious on the published map accross this boundary. Most of the map area is occupied by a north-northwest trending belt of migmatites and granites which Forsythe (1972) places into Padgham's (1966) "Northwest Migmatite Zone".

Differences in fold styles do occur, in the northwest and the southeast parts of the map open style folds warp tight folds (Forsythe 1972). In the extreme southeast part of the region an open fold style region abuts and merges into the north-northwest trending belt of rocks; this is the vague boundary between the Rottenstone and La Ronge domains.

Ultramafic rocks are rare in this region and are commonly associated with diorite-gabbro. A small complex body of hornblende quartz-diorite, gabbro, and pyroxenite occurs in the south central part of the map sheet (Howard Lake). Another small ultramafic body occurs in the centre of the map sheet.

The metapyroxenites are compsoed of subhedral, poikilobastic actinolite probably after hypersthene, up to 20 percent plagioclase (An_{60}) when grading into metagabbro, and up to 30 percent diopside interstitial to the amphibole. In places gabbro cuts the pyroxenite rather than grading into it. Locally, magnetite may constitute five percent of the rock.

At Howard Lake veinlets and disseminations of iron and minor nickel and copper sulphides locally make up to 20 percent of the rock volume. This mafic-ultramafic body is probably boudinaged and folded, and plunges steeply north-northeast.

D.M.R. REPORT NO 136: Forsythe(1971b)

Granites, granite gneiss and migmatites abound in the area, while "greenish-black diorite..., mafic gabbro and pyroxenite... occur as remnants in the vicinity of Besnard Lake...(and) as inclusions in (granites) locally" (Forsythe 1971b).

The mottled green-black pyroxenites are gradational to mafic gabbro and are intruded and impregnated by granite. They contain poikiloblastic hypersthene ($<75\%$) and diopside ($<30\%$), some plagioclase and phlogopite. Five percent sutured, undulatory quartz, minor olivine, magnetite, and rare pyrite were observed in places. This is essentially a websterite.

Munday 1974:

The area was mapped at the reconnaissance level by Munday (1974) and a preliminary report published. The boundary between the Rottenstone and Mudjatik domains, (as defined by Munday 1974) occurs along the Needle Falls shear zone. The rocks east of this zone are "predominantly granitoid gneisses which pass, easterly, into the greenstones of the La Ronge belt" (Munday 1974). Ultramafic hornblendites occur but they "bear little resemblance to the hornblende-harzburgites of the mudjatik (east) area" (Munday 1974).

A small amount of chalcopyrite occurs disseminated in metasediment in one locality, and disseminated pyrrhotite occurs in a mafic rock.

D.M.R. REPORT NO. 88: (Money 1965)

This area stradles the boundary between the Rottenstone and Wollaston domains.

In 1965, K-Ar dating indicated the map area had been involved in the Hudsonian orogeny and that a large area of granitic rocks is probably pre-Hudsonian possibly Kenoran. Metamorphic rocks form fold belts trending northeast to north-northeast and are separated by areas of granitic rocks.

Small areas of mafic hypersthene amphibolite occur as mappable units, they are made up mostly of hornblende ($\approx$60%) plagioclase ($\approx$25%) and hypersthene ($\approx$10%). A small outcrop of ultramfaic clinopyroxene amphibolite occurs on a small island in Sandfly Lake; it is made up of seventy-five percent hornblende, twenty-five percent clino-pyroxene. A CaO content of 15 percent was found in this rock by X-Ray fluorescence analysis, Money (1965) states this suggests derivation from an impure calcareous sediment.

This is not necessarily so, the CaO content of the olivine websterite from Nemeiben Lake (see tableIIIii) is fourteen percent yet there is no doubt about its original igneous origin.

The composition of this occurence, if igneous, would originally have been websteritic if the hornblende is after pyroxene, a reasonable assumption. If this is the case, websteritic ultramafic bodies similar to those found in the La Ronge - Rottenstone domain occur in Munday's Mudjatik domain as well as harzburgitic bodies.

Money's (1965) western granites in the Mudjatik (now Wollaston) domain were tentatively dated at greater than 2100 million years. The eastern granite, in the Rottenstone domain, dated at 1600 - 1800 million years.

D.M.R. REPORT NO 86: Morris (1965)

Migmatitic metasedimentary rocks underlie two thirds of this area, granites most of the rest. Mafic rocks are restricted in occurrence and may be metamorphic in origin. The dominant gneissic trend is northeasterly. The metasedimentary gneisses reached upper amphibolite to granulite facies of metamorphism.

Gossan zones in hornblende gneisses occur, caused by disseminated pyrite-pyrrhotite. This area, wholly in the Rottenstone domain, contains no obvious ultramafic bodies; and the high metamorphic grades also almost preclude the survival of any sulphide deposits of interest.

D.M.R. REPORT NO. 77: (Morris 1963):

The Trout Lake area West, is over half underlain by biotitic migmatites while dioritic rocks which include small bodies of amphibolite are restricted in occurrence to the extreme southern part of the map sheet. Field observations indicated that these rocks were probably derived by metamorphism of hornblende-rich metasedimentary rocks. Some diopside occurs in one of these amphibolites. The development of the granites which grade into migmatites was probably due to in – situe granitization and fusion of metasedimentary rocks (Morris 1963).

The boundary between the Rottenstone and La Ronge domains crosses the southeastern part of this map sheet. The dominant trend of the gneissic structure is northeasterly except in this southeastern quadrant where it is more northerly. There is little field evidence of large scale faulting except for a zone of mylonitic rocks in the southern part of the map area.

D.M.R. REPORT NO 42: (Morris 1960).

This area lies just north of the map sheet containing the Nemeiben Lake ultramafic body. One third of the area is underlain by metamorphosed to migmatitic sediments, the rest by igneous rocks: granites and ultramafic to mafic intrusives. The diorites, gabbros, and meta-pyroxenite are intruded by granitic and intermediate rocks and contain lenses of metasedimentary rocks. Gabbro hornblendite and meta-pyroxenite "form small stock like bodies generally associated with the hornblende diorite" (Morris 1960). Diopside is a major constituent of the meta-pyroxenite along with up to twenty percent andesine, tremolite (36-77%), opaques, and traces of sphene.

One plug-like body contains disseminated pyrrhotite and minor associated chalcopyrite. Only trace values of nickel and no nickel bearing minerals are reported in this gabbroic plug. The best mineralized core section assayed 0.52 percent copper, 0.31 percent nickel and 0.01 percent cobalt with traces of gold and silver (Beck 1959).

The boundary between the La Ronge and Rottenstone domains crosses the northwestern part of the map sheet; in the Rottenstone domain the structural trend is predominantly northeasterly while it is dominantly northerly in the La Ronge domain.

D.M.R. REPORT NO 41: (Padgham 1960)

This region lies wholly in the La Ronge domain and predominant are metasedimentary rocks. A band of mafic to intermediate volcanic rocks with interbedded mafic sedimentary and intrusive rocks trend northwesterly through the centre of this area.

The rocks in this area belong to the almandine amphibolite facies as dark green hornblende and calcic plagioclase predominate. Considerable magnetite and small amounts of pyrrhotite and chalcopyrite occur in some trachytic andesites in the area. Some mafic intrusive rocks are coeval with these volcanic rocks.

Large gabbro and diorite bodies occur in the western part of the map area, similar bodies of unmappable size occur elsewhere. Hornblende and plagioclase are the major minerals. One specimen showed evidence of originally containing pyroxene in that uncrused hornblende grains showed a prominent diallage-type parting reminiscent of pyroxene. One of the gabbro bodies has definite altered pyroxenite associated with it, now represented by serpentine and chlorite. Padgham (1960) observed colourless hypersthene and clinopyroxene remnants with high relief and low birefringence in this rock; the hypersthene with parallel extinction and negative optic sign and clinopyroxene with an extinction angle of 35° and a large positive optic angle.

All these rocks were extremely deformed after crystallizing; they were therefore intruded before or very early in the period of metamorphism and deformation and indeed were probably metamorphosed by the later granite intrusive phases (Padgham 1960). The gabbros contain minor pyrite, pyrrhotite, pentlandite and chalcopyrite.

D.M.R. REPORT NO 56: (Padgham 1963)

The Otter Lake East area is sixty percent underlain by metasedimentary and metavolcanic rocks. Granites, granitic gneisses of metamorphic origin, and pegmatites underly most of the rest.

Small bodies of mafic to ultramafic rock occur, some of igneous origin, some hornblendites are probably of metamorphic origin. Metaperidotite outcrops in only two places as small narrow bodies. They are sheared and altered to various degrees. Tremolite, talc and serpentine are the main metamorphic minerals. Enstatite "sieved with opaque iron oxides," crushed, partly altered olivine, and hypersthene survived complete alteration in one body. 'These rocks represent ultrabasic flows or intrusives that have been regionally metamorphosed". (Padgham 1963).

The regional volcanic belt which crosses this area has associated with it gold and sulphide mineralized zones.

D.M.R. REPORT NO 78 (Padgham 1966).

The southeastern boundary of the La Ronge domain cuts accross the Guncoat Bay Area map sheet. Differences in structural character each side of this can be seen in the map of the area. Small scale isoclinal folds occur in the western La Ronge domain half of the area, large scale open folds in the eastern half. Metamorphosed sedimentary rock is the most abundant type. Similar successions occur both sides of the Stanley Fault zone which is taken as the southern boundary of the La Ronge domain. In the west half of the area, a northeasterly gneissose structure predominates while in the east, easterly trending attitudes are locally dominant. There is also a slight reduction in the degree of recrystallization from west to east.

The supracrustals have been metamorphosed to upper amphibolite and locally to lower granulite facies. According to Padgham (1966) these rocks were intruded by pretectonic metapyroxenite and metagabbro, syntectonic granites and granodiorites, followed by post-tectonic pegmatite and granite dykes.

Basic and ultrabasic masses of small size are found throughout the quadrangle and "consist of dark-green or black rocks that contain abundant hornblende with varying amounts of pyroxene, epidote, biotite and plagioclase...Most of the masses appear to be elliptical in plan" (Padgham 1966). The Glennie Lake domain therefore also contains small ultramafic bodies which are presumably dimilar to those in the La Ronge - Rottenstone domain.

One olivine bearing metaperidotite and several hornblende-diopside bodies occur.

The metaperidotite is made up of fifty percent sheared and fractured hornblende (probably tremolite as it is reported to be almost colourless), olivine, and serpentine with associated dusty opaques. Padgham thought this body may be a metamorphosed peridotite sill.

The altered pyroxenites are made up of augite, greenish hornblende, epidote, plagioclase, and calcite. One of these appears to be definitely of intrusive origin, as the metasedimentary rocks are bent around it. The mafic rocks only carry very small quantities of sulphide.

Minor disseminations of pyrite-pyrrhotite-chalcopyrite-gold occur in the biotite gneisses and calc-silicates of the region.

There is a gradual increase of metamorphic grade eastward from amphibolite upper amphibolite to lower granulite facies in this region, corresponding to a change from La Ronge type supracrustals to higher grade Kisseynew type supracrustals. These rocks probably correlate, metamorphism grade being their only difference.

D.M.R. REPORT NO 106: Johnston (1968).

The boundary between the La Ronge and Glennie Lake domains crosses the western part of this map sheet. Kisseynew type gneisses or migmatites are extensive in the La Ronge domain; agmatitic granites abound in the Glennie Lake domain southeast of the Stanley fault. The degree of metamorphism is obviously greater than in the area just to the southeast (described by Padgham 1966). Intrusive pyroxenite dykes occur in the area. A supracrustal succession in the Glennie Lake domain, termed Bailey Lake Group, (probably correlative with the La Ronge Group), contains some basic volcanics with ten percent sphene and clinopyroxene and subequal amounts of plagioclase and hornblende. The plagioclase in fresh rocks ranged from An_{38} to An_{50}. The volcanics of gabbroic composition were probably derived by partial melting of upper mantle material, which may be represented more directly by the occurrences of ultramafic rocks.

The Kisseynew gneisses are of higher metamorphic grade, and contain some clinopyroxene bearing metabasalts and quartzofeldspathic gneisses. Hornblende rich recrystallized gabbroic-type rocks "cut by much granitic material underlie a considerable area in the northeast extremity of the map area. Bodies of similar rocks...occur in many localities underlain by granitic rocks " (Johnston 1968). At some localities traces of sulphide including specks of chalcopyrite occur in these rocks.

One of the pyroxenite dykes in the Glennie Lake domain appears to cut accross the gneiss, another is cut by stringers of granitic material. This latter dyke is devoid of feldspar it is composed of olivine and orthopyroxene. It is essentially harzburgitic. The first dyke is composed of hornblende, pyroxene, olivine and minor sulphide. It was assayed at 0.16 percent nickel.

D.M.R. REPORT NO. 17: Budding (1955).

The Settee Lake East area is mostly underlain by a supracrustal succession "cut by intrusive rocks ranging from acidic to ultrabasic in composition" (Budding 1955). Only a few outcrops of ultrabasic rock were found: brownish green hornblende pyroxenite and dark green coarse grained hornblendite which in places grade into gabbro. Calcite, scapolite, talc, epidote, biotite and hornblende are the alteration minerals. The remnant pyroxene is rounded colourless clinopyroxene.

D.M.R. REPORT NO. 55: (Morris 1961).

This area, just west of the previous one discussed, is essentially underlain by the same type of supracrustal succession with ultramafic to felsic intrusions. Gabbro and hornblendite are believed to be the oldest intrusive phase, followed by quartz diorite and later by more felsic phases. The metamorphic sedimentary and volcanic rocks are intruded and separated by lenticular syntectonic granitoid rocks. The mafic to ultramafic rocks only form several small bodies, many too small to be mappable. These diorites, minor gabbros, and hornblendites are interrelated and locally contain pyrite and pyrrhotite. The hornblende is chloritized, the plagioclase saussuritized.

Disseminated pyrite, minor chalcopyrite, and minor associated gold occurs in the volcanic succession.

D.M.R. REPORT NO. 34: (Pearson and Froese 1959).

Biotite gneisses, granulites, migmatites and metavolcanic rocks of this area are intruded by granites, diorites, and small bodies of gabbro and pyroxenite some of which are too small to be mappable. The mappable bodies occur mainly in the west half of the area in a northeasterly trending zone. These bodies are massive to sheared and some metagabbros grade into metapyroxenite completely altered to hornblende.

No special mention is made by Pearson and Froese (1959) of marked structural change between the areas belonging to the Rottenstone and La Ronge domains; but the northwestern part of the map sheet is mainly granite, granite gneiss and agmatite, while in the La Ronge domain supracrustals are abundant. In this area, the difference between the Rottenstone and La Ronge domains is therefore one of degree of metamorphism and intrusion; the supracrustal succession having been preserved in the La Ronge domain but only survived as remnants in the Rottenstone domain.

Ray 1974:

The areas 73-P-14, 13(E); 74-A-2, 3, and 4(E) were mapped at the reconnaissance level and a preliminary report published (Ray 1974). This map area spans from the La Ronge domain through the Rottenstone domain to the Wollaston domain. Feldspathic migmatites and felsic gneisses predominate in the Rottenstone, pelitic gneisses and metavolcanics in the La Ronge domain. The Needle Falls shear zone marks the boundary between the Rottenstone and Wollaston domains. All "three lithological domains are believed to have shared a common structural history and can thus be grouped within what is believed to be the Hudsonian Orogenic Belt" (Ray 1974).

No mentions of ultramafic bodies in the Rottenstone is made, outcrops of coarse grained hornblende metagabbro intimately associated with amphibolite occurs in the La Ronge domain-part of this map area. It contains a small showing of chalcopyrite.

D.M.R. REPORT NO 113: (Gracie 1967).

The Maribelli Lake Area West is underlain by metasedimentary gneisses and in the southeastern part of the map sheet by metavolcanics. These supracrustals are intruded by granodiorite, minor diorite, and "greenstone". Pyrite occurs in a brecciated zone in a rhyodacite, pyrrhotite in gneissoze amphibolite. A tremolite-actinolite body described is probably a completely altered pyroxenite. The colourless to light-green hornblende and associated opaques further altered to calcite and limonite.

Greenstone "layers" are also mentioned, some of which were recognised to be pyroxenitic in character. They contain fifty to ninety percent diopside, calcite, clinozoisite, sericite and kaolin.

D.M.R. REPORT NO 3: (Miller 1949)

In this area a metasedimentary and metavolcanic succession is intruded by early intermediate to basic rocks including amphibolite and later felsic rocks. The mafic volcanics contain up to 30 percent tremolite-actinolite. Due to spatial relations, it was postulated that the diorite and associated amphibolite were due to the contact metamorphic effect of granite intrusions on mafic volcanic flows (Miller 1949).

The usual disseminations of pyrite-pyrrhotite-gold are found at some localities in the volcanics.

D.M.R. REPORT NO 33: (Kirkland 1959)

Metapyroxenite and serpentinized ultrabasic rocks occur as the oldest intrusive rock in this map area. They are not of mappable size. Quartz-feldspathic biotite and calc-silicate gneisses, quartz diorite and granodiorite are the major rock types.

A greenish-black highly serpentinized ultrabasic rock with veinlets of asbestiform serpentine is intrusive into hornblende gneiss at one locality. A coarse grained greenish-black sill-like body, occurring in an area of garnetiferous biotite migmatite, consists almost entirely of blotchy pyroxene grains partly altered to hornblende.

Johnston (1972b) conducted a base metal geochemistry survey over the area. Bedrock X-Ray fluorescence analyses for Fe, Ni, Cu, Zn and Pd were carried out. Zinc with traces of copper and lead is associated with pegmatite. Some barren conformable pyrite-pyrrhotite zones also occur, those in hornblende and calc-silicate gneisses are higher in zinc and copper than similar zones in graphite-rich metasediments.

D.M.R. REPORT NO. 127: (Johnston 1969)

The boundary between the Glennie Lake and La Ronge domains crosses the southeastern corner of this map sheet. Three quarters of the map area is underlain by Kisseynew type gneisses increasing in metamorphic grade south-eastward. There is no discordance between these and the gneisses of lower grade to the northwest which contain more metavolcanics.

Mafic and ultramafic sills, dykes and small bodies occur throughout the map sheet, later granites and granodiorites also intruded the supracrustal rocks.

Field evidence suggested the ultramafic bodies are conformable to the enclosing rocks and are therefore sill-like. An altered pyroxenite associated with gabbro is cut by stringers of granite, and thin pink carbonate veinlets contain a few specks of chalcopyrite. An in-situe weathering gravel occurs in a few places on this ultramafic complex, a similar weathering phenomenon occurs at the Nemeiben Lake and the Rottenstone ultramafic bodies.

A pyroxene-brown hornblende-plagioclase (20%) body which is relatively fresh and undeformed also occurs in this map area. It would seem to be later than most of the ultramafic bodies discussed to date in this chapter since most are highly deformed and altered. This one contains pyrrhotite and minor specks of chalcopyrite. The normal type of sulphide disseminations occur in the metasedimentary and metavolcanic gneisses of the area.

D.M.R. REPORT NO 145:

Johnston (1970b) and Johnston (1972) published preliminary reports on this area. The rocks are essentially similar to those described in the previous map sheet, with metamorphic grades increasing southeastward from biotite gneisses to garnet-biotite-cordierite gneisses to hypersthene gneisses. The volcanic rocks are also continuous from map areas to the southwest. Iron sulphides and minor zinc and lead occurrences are scattered in these gneisses, probably spatially related to the Kisseynew metamorphic front. Also occurring in this area is "a widespread group of relatively small ultramafic intrusives, largely metapyroxenites, (which) appear to have been folded with the layered rocks" (Johnston 1972).

D.M.R. REPORT NO 130: (Johnston 1970a):

Johnston (1970a) notes the presense of mafic and ultramafic rocks mainly in the central and southeastern parts of the area described in this report. These include metagabbro, meta-pyroxenite, peridotite, and soapstone. Metasedimentary and metavolcanic schists and gneisses, Kisseynew gneisses, and granodiorite underlie most of the map area. Igneous rocks make up two thirds. The granitoid rocks are younger than the mafic to ultramafic rocks.

Equidimentional grains of hornblende after pyroxene occur in the basic volcanics which are 50 to 80 percent amphibole and less that 50 percent plagioclase (An_{38}). They contain minor quartz, biotite, sulphides, and magnetite. Metamorphic pyroxene (diopsidic augite) occurs in metavolcanics within the Kisseynew gneisses.

"Except for a few small sills, the mafic and ultramafic rocks are confined to a belt about two miles (3 Km) extending northward from the south boundary of the area" (Johnston 1970a). This belt joins a more northeasterly trending belt halfway up the map sheet. The mafic and ultramafic intrusives appear conformable to the enclosing layered rocks. Sills thirty centimetres or more thick are common near larger bodies. "Larger bodies of the mafic intrusives such as (a) metapyroxenite...have been extremely resistant to the emplacement of the granitic rocks and remain as roof pendants in the granodiorite " (Johnston 1970a). The granitic rocks have in places assimilated the ultramafic rocks which survive as small xenoliths. Gabbro and ultramafic rocks are often very intermingled. Black to rusty red peridotite with small soapstone occurrences is the least abundant ultramafic rock type. Dark green metapyroxenite is more widespread, and often contains nodules of stubby amphibole crystals after pyroxene. Magnetite occurs as small grains between the amphiboles. No orthopyroxene was found in thin section, mostly titanium rich augites and amphibole peppered with small sphene inclusions and secondary magnetite.

Sparsely disseminated chalcopyrite-pyrrhotite occurs in mafic to ultramafic rocks. Nickel content of the latter type occurrence is low, that present is probably in the silicates rather than the associated sulphides.

D.M.R. REPORT NO. 1: (Byers 1948):

Byers (1948) records the occurrence of intrusive hornblendite, pyroxenite, peridotite, amphibolite, and serpentine in metavolcanic and metasedimentary rocks. Granite and granodiorite represent a later intrusive phase. The ultramafic rocks are represented by dunites (90 percent olivine) to pyroxenites (100 percent pyroxene). Small irregular bodies and dykes of these intrude volcanics. One larger mass is composed of alternating bands of peridotite and pyroxenite, cut by dykes of younger pyroxenite.

The ultramafic rocks are partly to wholly altered to serpentine, chlorite, and uralite. Enstatite or diallage, or both occurs in the peridotite; it is probably lherzolite. The pyroxenite contains enstatite and diallage with or without minor olivine, it is therefore websterite.

D.M.R. REPORT NO. 149: (Johnston 1973b)

Gabbro and meta-pyroxenite occurs in the western part of this area. The oldest rocks are garnetiferous biotite schists, overlain by amphibole-plagioclase basic volcanics which are in turn overlain by what may be arkose or acid metavolcanics. The most extensive supracrustal succession in the area is the younger arkoses, argillites and slates. Folded sill or plug like bodies of gabbro and pyroxenite cut the upper metasedimentary rocks, large bodies of granodiorite also occur in the area.

One body of pyroxenite is definitely cut by granite. Most of these ultramafic rocks are coarse grained, made up of equidimensional 1 cm grains of amphibole after pyroxene. Magnetite, carbonate, and biotite are common accesory minerals. Only minor parts contain enough serpentine to have been peridotitic in composition, gabbro is not abundant.

One sill like body occurs in metavolcanics and is made up almost entirely of tremolite, it contains large black tourmalines up to 2.5 cm long.

Amphibole-asbestos occurs in one ultramafic body. Pyrite and sparsely disseminated pyrrhotite with traces of chalcopyrite occur in mafic rocks at several localities. They contain only very small amounts of Ni and Cu, 0.1 and 0.5 percent respectively.

D.M.R. REPORT NO. 100: (Gracie 1965)

The boundary between the La Ronge and Rottenstone domains is placed such that it crosses the northwest corner of this area. Intrusive type hornblendite occurs as a minor phase. The area is divided into two major parts, the Missie Lake complex of granodiorite and gneiss in the northwest grading southeasterly into the Reef Lake complex of foliated granodiorite and mafic rocks sometimes containing minor sulphides.

At one locality a hornblendite dyke cuts an amphibolite body. The dyke contains radiating hornblende crystals and disseminated sulphide. Elsewhere, Gracie (1965) records minor hornblendite which are stated to cut grey foliated granodiorite. From the description and plates one can interpret these as highly metamorphosed, partially melted metasedimentary type gneisses.

D.M.R. REPORT NO. 193:

This area was mapped at the reconnaissance level by Gilboy and a preliminary report published in 1975. Report no. 193 is yet to be published, but a manuscript of it was available for the writer's perusal. Most of the area is underlain by the Rottenstone domain, the northeastern corner by the Wollaston domain. The deformed granitic rocks and metasediments of the Wollaston domain are separated from the migmatites and deformed intrusive plutons of the Rottenstone domain by an extention of the Needle Falls shear zone represented by a zone of mylonitization and calaclasis. The La Ronge domain contains massive plutonic intrusives injected into metasedimentary schists and gneisses and is separated from the Rottenstone domain by a shear zone (Gilboy 1975).

Most of the rocks in the Rottenstone domain then, are intrusive. There are only a few remnants and migmatites of supracrustal origin. The Wathaman porphyritic or porphyroblastic(?) granite occurs in this area. This large igneous syntectonic body was recognised and named by Ray (1975) and Lewry (1975) and is now known to extend from the La Ronge region north-northeastward to the Manitoba border in the northern Reindeer Lake region. In this area it hugs the northwestern boundary of the Rottenstone, further north another complex termed the "Northern Igneous Complex" by Ray (1975) lies between the Wathaman complex and the Wollaston domain.

In the Wollaston domain the metasediments are Aphebian and rest on an Archean basement (Gilboy in press). The early metasedimentary and meta-igneous rocks in the Rottenstone domain have been intensely migmatized and injected, those in the La Ronge domain less so.

Gilboy (in press) estimated from metamorphic assemblages that the conditions of the first metamorphic event in the La Ronge domain reached about 640 - 750°C and 5 - 6.5 Kb pressure.

Apart from the sulphides in ultramafic rocks in the vicinity of Rottenstone Lake evidence for other potentially viable mineral deposits in the Rottenstone domain is poor. In this domain all the known economic minerals are confined to the migmatite/intrusive complex. In the La Ronge domain visible disseminations of sulphide are limited to pelitic metasediments and commonly consist of pyrite, pyrrhotite and minor chalcopyrite.

The Rottenstone Mine

Ultramafic rocks occur in the area, especially in the vicinity of Rottenstone Lake, where the Hall showing (the now closed Rottenstone Mine) and the Tremblay-Olsen showing of nickel-copper sulphide occur. An open pit was in operation from 1965 to 1968 at the Hall showing on Rottenstone Lake, hoisting 28,724 tons of copper-nickel-palladium-platinum-gold-silver ore. The pyroxenites which contain the ores occur as rafts in the quartz diorite-migmatite complex of the Rottenstone domain (Kisseynew-type gneiss). This body was known to the Indians for many years as the "Hill of Rottenstone", the lake and later the regional geological belt were similarly named (Richard and Robinson 1966).

Mawdsley (1946) records that the first serious interest in nickel and copper bearing sulphide bodies in the Rottenstone Lake area was in 1928 and 1929, although the deposit was earlier drawn to the attention of white trappers by Indians in the early part of this century (Richard and Robinson 1966).

The granite gneiss in the area contains many small to large (up to 30 metres wide) inclusions in various stages of digestion. The least altered xenoliths are pyroxenites and gabbros which were probably dykes or sills intruding the older rocks prior to their granitization. Mawdsley (1946) attributes the gneissoze structure to movement at depth in the zone of flowage. The enstatite pyroxenite of the Hall and Tremblay-Olsen showings are engulfed by granite but are relatively unmetamorphosed. The Tremblay-Olsen body is 75 percent enstatite, altered olivine, and antigorite peppered with magnetite dust; this rock is harzburgitic in composition. The heavily mineralized part of the Hall showing is in similar rock. In this body spinel aggregates, interstitial and inclusion pyrrhotite, and veins of chalcopyrite occur.

Mineralized lenses of limited tonnage were found in both these ultramafic bodies, only the Hall showing has been mined. The sulphides form 20 to 50 percent of the ore bearing rock: pyrrhotite and chalcopyrite being megascopically recognisable. The grain size of the minerals is usually around one millimeter, some larger aggregates occur. The contacts with the silicates is smooth. Dirty white to light violet-grey violarite was identified in polished section as apparently replacing magnetite and pyrrhotite. Tiny blebs and needles of pentlandite in pyrrhotite are also reported by Mawdsley (1946). He had two samples assayed, they yielded 0.70 percent copper, 4.29 percent nickel; and 2.07 percent copper, 4.29 percent nickel respectively. Very respectable amounts, certainly richer than the ore at Nemeiben Lake.

Mathieu (1964) records the presence of sphalerite, cubanite and sperrylite as well as pyrrhotite, chalcopyrite, violarite and pentlandite. Mathieu and Bruce (1968) and Mathieu (1964) recorded the presence of palladium, rhodium, gold and silver, as well as platinum. These elements must be present as elements or impurities in the sulphides or as unidentified platinum group minerals other than sperrylite. Mathieu (1964) provides an adequate mineralogical description of the ores: pyrrhotite is the most abundant sulphide and is present as relatively large grains. It contains "flames" of pentlandite and sperrylite. Violarite is abundant, also occurring as large grains frequently intergrown with fine sperrylite and pentlandite and contains sphalerite and cubanite veinlets. These veinlets also occur in pyrrhotite and the silicates. Chalcopyrite is present as small irregular masses and is frequently intergrown with pyrrhotite and violarite.

D.M.R. REPORT NO 60: (Money 1961)

The northwestern part of this map sheet is underlain by the Wollaston domain, the southeastern part by the Rottenstone. Pegmatites north of this area in the Wollaston fold belt were dated as 1780 ± 120 million years old (Cumming et al 1955). These are probably some of the youngest igneous rocks of the area produced during the Hudsonian orogeny.

Highly metamorphosed metasedimentary and possibly in part metavolcanic rocks, two granitic batholiths and several smaller plutons in the migmatitic zones account for most of the rock types in the area. No mafic or ultramafic rocks were reported. Apart from minor pyrite in biotitic supracrustal gneisses and minor uraninite-bearing pegmatites, no economic minerals of interest occur in the area.

D.M.R. REPORT NO. 57: (Shklanka 1962)

The Deception Lake East area is almost wholly in the Rottenstone according to figure I(iv). Possibly the sketched in boundary is not very accurate since Shklanda (1962) states that "this area is situated in a regional geological contact which divides a large expanse of granitic rocks to the northwest from metasedimentary rocks to the southeast". Possibly though, he refers to the Wathaman Batholith rocks to the northwest and the migmatite/tonalite complex in the southeast, both are part of the Rottenstone as defined by Munday (1974) and Ray (1974). No ultramafic or even mafic rocks were reported in this area which is metamorphosed to the lower almandine amphibolite facies.

Lewry 1975:

Six map sheets of the Reindeer Lake West area were mapped at the reconnaissance level and a preliminary report published. Both the La Ronge and Rottenstone domains are represented. The southeastern part of the map is underlain by unmigmatized supracrustal rocks which give way northwestward to intrusive rocks with minor highly recrystallised metasedimentary remnants. A migmatite belt and then the Wathaman granite occur northwest of these rocks. No mention of gabbro or ultramafic rock is made in the preliminary report of the area except for the late diabase or gabbro dykes.

Johnston 1973a:

This enclave in the Reindeer Lake South area was mapped in 1973 and a preliminary report published. Most of the rocks are granitic, with little metamorphosed metasedimentary inclusions. The southeastern part of this map sheet is underlain by migmatites.

D.M.R. REPORT NO. 39: (Shklanka (1961)

The Oliver Lake East area is underlain by the migmatites and supracrustals of the La Ronge domain. Most rocks are migmatitic. The latest intrusive phase is diabase composed of labradorite, augite, hornblende and "iron ore". Around 30 percent augite is average, some of the hornblende is due to partial replacement of this clinopyroxene so that Shklanka (1961) estimates the original content to have been around 45 percent.

D.M.R. REPORT NO 153: (Sibbald 1977):

A few small ultramafic bodies occur in the area. The southern part of the map is underlain by migmatitic biotite, hornblende, and calc-silicate gneisses. These rocks pass northward into metavolcanic hornblende gneisses and metasedimentary quartzo-feldspathic gneisses These are intruded by tonalites and granodiorites. The ultramafic rocks are thought to be the oldest intrusive rocks.

The massive amphibolite horizons of the metavolcanic series contain 10 - 20 percent clinopyroxene which is presumed to be of primary igneous origin.

The ultramafic rocks of probable intrusive origin occur as concordant to subconcordant lenses or discontinuous sheets. A granodiorite intrusive cuts one body in half. These ultramafic rocks are deeply weathered and metamorphosed to green fine grained amphibole. "Three generations of mineral growth can be seen in thin section, a primary igneous generation, a high grade metamorphic (retrograde) generation and a late low grade metamorphic (retrograde) generation" (Sibbald 1977).

Largely altered and fractured crystals of olivine are the sole remnants of the primary mineralogy. They are quite iron-rich, in the range Fo_{85} - Fo_{65}. This is more iron-rich than typical in ultrabasic rocks, more usual of values in basic rocks (Sibbald 1977).

These olivine remnants are enclosed by a matrix of weakly pleochroic pale green tremolite which belong to the first generation of metamorphic minerals. Secondary are chlorite, and serpentine-iddingsite. One group of ultramafics contains large (up to 1 cm) crystals of hypersthene and small disseminated crystals of green chrome spinel and magnetite. Two poorly exposed lensoid masses contain small numerous grains of clinopyroxene enclosed by secondary amphibole.

Sibbald (1977) estimates the physical conditions of metamorphism to have been around 5 - 6 Kb PH_2O and 675 - 725°C.

Sibbald (1977) did not consider this area as a high priority exploration target as the metavolcanic succession is interpreted to be representative of an environment divorced from centralized volcanic activity. Syngenetic base metal deposits and gold bearing quartz veins are usually near the centres of volcanic activity. Furthermore, notable mineral occurrences in the Abitibi greenstone Belt all occur in the acidic pyroclastic rocks near the top of the metavolcanic sequences (Goodwin 1965) as there is a tendency for the mineralizing agents to be progressively concentrated in residual magmatic fractions (Stanton 1972). Most of the metavolcanics in this and surrounding areas are mafic and therefore only minor syngenetic sulphide disseminations occur, pyrite, pyrrhotite, and minor chalcopyrite. Also, since the area is divorced from the centre of intrusion as interpreted by Sibbald, major ultramafic intrusions would not occur. These would be closer to the central activity.

D.M.R. REPORT NO 35: (Cheesman 1959)

The northern half of this map sheet is underlain by La Ronge domain metasedimentary and metavolcanic rocks intruded by mafic, ultramafic and granodioritic rocks. The southern half is underlain by Kisseynew domain migmatites intruded by granodiorite.

The metavolcanics occur in the east-central part of the area and are metamorphosed to plagioclase amphibolites or hornblende schists.

Some amphiboles are pseudomorphic after pyroxene.

Amphibolite and metagabbro occur as large bodies and as numerous sometimes boudinaged lenticular sill-like bodies in the supracrustals and as remnants in the granodiorites. The plagioclase is in the andesine to labradorite range, the amphibole is mostly after pyroxene. They are therefore metamorphosed basic pyroxene gabbros. Magnetite, epidote, sphene, apatite, and zircon are minor constituents.

Thin layers of metamorphosed ultramafic rock occur associated with these gabbros, or interlayered with the metavolcanics. They contain colourless to pale green amphibole and remnant olivines.

These mafic to ultramafic rocks are probably metamorphosed remnants of gabbros and peridotites intruded into the sedimentary and volcanic sequence as sills and laccoliths prior to regional metamorphism and associated granodiorite intrusion.

D.M.R. REPORT NO 40: (Pyke 1960).

The northern half of the area, in the La Ronge domain, is almost wholly underlain by foliated granodiorite to quartz diorite. Remnants and small areas of metavolcanics also occur, with minor boss-like bodies of amphibolite, metagabbro and metapyroxenite. These also occur as xenoliths in the granodiorites.

The metagabbro forms a northerly trending zone within the metavolcanic unit. One small body of metapyroxenite is recorded, a dark green massive amphibole rich rock surrounded by syenodiorite. The contacts are not exposed. The rock is made up of 70 percent pale to light green hornblende, eight percent strained labradorite, nine percent clinopyroxene, sphene, chlorite, opaques, and introduced potash feldspar. Minor pyrrhotite-chalcopyrite occurs in the gabbro.

The usual disseminations of sulphide occurs in the supracrustals, molybdenite occurs in a granodiorite and minor pyrrhotite-chalcopyrite in gabbro.

D.M.R. REPORT NO. 191:

This map area was mapped at the reconnaissance level by Langford et.al. in 1975 and a preliminary report published. Report 191 by Stauffer et.al. is yet to be published. The southern part of the 64D SE area is underlain by the Kisseynew domain, the rest by the La Ronge domain. The rock types are typical of this area, supracrustals, migmatites and syntectonic intrusive gneisses. Seven metagabbro bodies occur in the La Ronge domain. They contain five percent diopside, 70 percent actinolite and only 10 percent plagioclase (An_{50}) (Stauffer et.al. in press a).

Ashton (pers comm.) reports the presence of pseudomorphs of primary olivine in the Reindeer Lake volcanics: remnants of fractured olivine altered to amphibole.

Four small bodies of ultramafic rock occur in the southern quadrant; two in the Kisseynew domain, two in the La Ronge domain. These may be at least two generations of ultramafic intrusion, one pre-tonalite, one post tonalite but pre the major granitic intrusive phase (Ashton person. comm.).

One of the ultramafic occurrences is relatively fresh and is surrounded by tonalite. It may be akin to the younger ultramafic body described by Johnston (1969) in the Waddy Lake area. Both may be related to the late diabase dykes as described by Lewry (1975) and Shklanka (1961).

The outcrop appearance is quite distinctive, with large diopside "nodules" which weather positively in a mattrix of amphibole. This body appears to be dyke-like and younger than the tonalite and in view of its relatively fresh appearance may be of a different generation than the other bodies which are highly deformed and foliated. Ashton however, does not exclude the possibility that this body may be a rafted remnant and therefore older than the tonalite (Pers. comm.) Sibbald (1977) in the area just to the west, placed the ultramafics as younger than the tonalite. Thin sections of these four bodies were kindly provided by K. Ashton. The largest peridotite body in the Kisseynew domain is made up of 40 percent pseudomorphs after olivine, about 55 percent cummingtonite, and minor orthopyroxene. It may have been a wehrlite. Accessory opaque minerals mostly occur in small serpentine fracture fillings and in the olivine pseudomorphs. The other smaller body in the Kisseynew is a clinopyroxene-rich websterite. One of the bodies in the La Ronge domain is a slightly altered feldspathic websterite, the other a highly altered and deformed mixture of fine grained amphibole, serpentine, remnant clino-pyroxene and minor strained plagioclase.

D.M.R. REPORT NO 200:

Stauffer et.al. mapped the southeast quadrant of the Reindeer Lake North map sheet and published a preliminary report in 1976. The writer was a member of the mapping crew. Report 200 has yet to be published.

The boundary between the La Ronge and Rottenstone domains, according to figure II(iv)taken from Sibbald et.al. (1976), crosses northeasterly through the area from its southwestern corner.

Extensive mapping across this region in 1976 revealed no differences warranting each side belonging to separate lithostructural domains. (pers. observations). The marked differences noted by other authors to the southwest do not exist in the area. There is an indication that at least part of the Rottenstone and La Ronge domains are separate limbs of a regional isoclinal fold plunging northeasterly, its nose being in the Malcolm Island area of this map sheet (Fumerton pers. comm.). As one proceeds further southwest away from this nose region differences between the two limbs increase, and are made more noticeable by faults and the greater amounts of migmatite and igneous rocks in the Rottenstone. It must be noted however, that in the northeastern part of the La Ronge domain in Saskatchewan the degree of migmatization and intrusion is much greater than further south and closely approaches the degrees reached in the Rottenstone domain.

The southern half of the area is underlain by metasedimentary gneisses, migmatites, agmatites and syntectonic plutons. The northern half is underlain by the intrusive rocks of the Wathaman Batholith and its related anatectic products. The Wathaman Batholith contains a few small to large xenoliths, some of which are mafic. One large raft may be migmatitic metagabbro. It contains 70 to 80 percent plagioclase, 5-10 percent biotite, 10 or more percent hornblende and minor quartz and alkali feldspar which were probably introduced. (Stauffer et.al. in press b).

<u>Lewry 1976</u>:

This area mapped at the reconnaissance level lies wholly in the Rottenstone Lithostructural domain and is underlain almost entirely by plutonic rocks with only minor supracrustal remnants (Lewry 1976).

The area is divided from southeast to northwest into the tonalite-trondhjemite complex, the Wathaman batholith, and the northern intrusive complex northwest of the Parker Lake Shear zone.

The northern intrusive complex was named by Ray (1975) and contains rocks ranging in composition from gabbro to alaskite. "Medium to coarse grained metadioritic-metagabbroic rocks, with minor associated coarse amphibolite (? metapyroxenite)...comprise an important, though subordinate part of the complex" (Lewry 1976). Mafic content ranges from 20 to 90 percent. These rocks contain numerous metavolcanic and metasedimentary xenoliths.

A belt of metasediments and possible metavolcanics also occurs in the northern intrusive complex, including local high percentages of disseminated pyrite-pyrrhotite with minor sphalerite and chaclopyrite. Disseminations of pyrite-pyrrhotite are also widespread in the diorite-gabbro bodies.

D.M.R. REPORT NO 135: Scott(1970):

The northwestern half of this map area is underlain by metasediments and granites of the Wollaston Fold Belt, which strikes easterly in this area. The southeastern half, underlain by northeasterly striking Rottenstone rocks, is separated from the Wollaston trend by a strike fault zone. Dioritic, gabbroic, and granitic plutons of unknown age as well as minor supracrustal rocks occur in the Rottenstone.

Scott (1970) places the intrusions of the dioritic gabbros as pre-granitic rocks but post gneissic granite. This gneissic granite is possibly Archean basement in the Wollaston domain and a similar gneiss occurs as a marginal facies of coarse grained granite plutons in the Rottenstone. These gabbros contain on the average 40 percent plagioclase (An$_{38}$) 40 percent hornblende, five percent each of microcline and biotite, opaque minerals, and diopside at one locality. Disseminations of minor chalcopyrite and accessory pyrite and pyrrhotite were found in hornblende gneiss and in a diorite-gabbro. The later assayed 0.17 percent Cu and 0.54 percent Ni (Scott 1970).

D.M.R. REPORT NO 190: Ray (in press).

This area was mapped at a reconnaissance level and a preliminary report published (Ray 1975).

The Needle Falls shear zone divides this area into the Rottenstone domain in the southeast and the Wollaston domain in the northwest. The northern part of the Rottenstone is underlain by numerous intrusive bodies ranging in composition from granite to gabbro. This complex gives way southward to a wide shear zone (Parker Lake gneiss) and then to the Wathaman batholith (Ray 1975).

The most basic gabbros and amphibolites in the northern complex appear to be the oldest intrusives.

The entire Rottenstone domain in this area has originated from intrusive igneous rocks (Ray in press).

In some localities the meta-gabbro/meta-diorites contain abundant pyrite and some magnetite. These rocks are made up of 35-55 percent altered plagioclase and green hornblende. No mention of ultramafic occurrences is made.

Ray (in press) states that the first period of deformation in the Rottenstone domain may be Archean, this event was either preceeded or accompanied by the emplacement of basic to felsic rocks of the "Northern Intrusive Complex".

The Rottenstone domain in this area contains little of economic interest apart from uneconomic sulphide disseminations in the mafic rocks and the Parker Lake Shear Zone.

Stauffer et.al. 1977 Lewry 1977:

The Reindeer Lake North area, NE quadrant was mapped at the Reconnaissance level by Stauffer et.al., the writer was a member of this mapping crew. The Reindeer Lake North NW quadrant was mapped by Lewry. Preliminary reports and maps were published in 1977. Shklanka (1962b)had also previously mapped the 64-E-16 map sheet.

The boundary between the Wollaston and Rottenstone domains cuts accross the southeastern part of the NW quadrant and the extreme northwestern corner of the NE quadrant.

The rocks in the Rottenstone domain of these areas belong exclusively to the northern complex and the Wathaman batholith and are therefore very similar to those described by Ray (in press). It was observed that the Parker Lake Gneisses or Shear Zone splays out and tends to disappear in the Reindeer Lake North NE area. This shear zone ceases to be a marked transition between the Wathaman batholith and the northern complex. Similarly, the extention of the Needle Falls Shear zone, a major break in the crust and used as the boundary between the Rottenstone and Wollaston domains, splays and virtually disappears as a recognisable entity in the Reindeer Lake NE area. In this area, the northwesterly transition from the Rottenstone to the Wollaston domain becomes gradual and much less pronounced than further to the southeast a situation similar to the transition between the La Ronge and Rottenstone domains in the Reindeer Lake North SE area.

The usual minor sulphide disseminations occur in the mafic rocks of the northern complex. Shklanka (1967b)reports a small meta-pyroxenite containing minor disseminated pyrrhotite. A large gabbro-anorthosite-quartz-diorite complex occurs in the west-central part of the 64-E-16 area, and contains pyrrhotite and pyrite as constant accessory minerals (Shklanka 1962b). Fumerton (pers. comm.) reports the presence of primary pyroxenes in diorites of the area.

An undeformed porphyritic diorite to quartz diorite and associated anorthosite body occurs in the southwestern corner of the Reindeer Lake North NE map sheet (Stauffer et.al. 1977). This is the largest possibly post-granite (Hudsonian) mafic pluton known in the Rottenstone domain. Most other mafic to ultramafic rocks are believed to be pre-granites, with a few exceptions. This pluton may however be pre-Hudsonian, a feeder dyke for volcanic rocks of "La Ronge Group" age (Fumerton pers. comm.).

APPENDIX B

PREVIOUS WORK, NEMEIBEN LAKE AREA

A summary of the work carried out investigating the nickel-copper prospect on the east shore of Nemeiben Lake.

Cominco 1945:

The original ten complex claims on the ultramafic body were staked in August of 1944 for Consolidated Mining and Smelting Company of Canada Limited, twelve other claims were staked in 1945. A report by Neil Campbell (1945) of Cominco was filed with the Saskatchewan Department of mineral Resources. The work report consists of a geological survey, trenching, a magnetometer survey and three short diamond drill holes totaling 123.9 metres. (406.5 feet).

Campbell (1945) referred to McLarty's (1936) map and supported his view that the "ultrabasic" rocks were intrusive into highly metamorphosed schists and gneisses derived from the Wekusko Group of lavas and sediments.

Two major rock types were distinguished: a fresh appearing medium to coarse grained pyroxenite, greenish-grey on its fresh surface; and a dark grey to black very fine grained commonly foliated rock showing fine scintillating crystals of hornblende or black mica. Sharp contacts were noted between these two rock types. Some faulting was recorded.

Two types of ore mineral occurrences were reported, an early assemblage of disseminated pyrrhotite and chalcopyrite; and a secondary assemblage of minerals including colloform specularite, red iron oxides, nickeliferous silicates, native copper, and marcasite, derived from the primary minerals by low temperature solutions including ground water (Campbell 1945).

Nickel bearing Minerals:

1) Nickeliferous pyrrhotite up to one cm **across** disseminated. More abundant in the coarse grained pyroxenite than in the finer grained rocks, according to Cominco's drill hole data. It is indigenous and occurs as small irregular veinlets.

2) Garnierite, as veinlets and small irregular masses in the host rock in the mineralized zones, this silicate tested positive for nickel with the dimethylgloxine wet chemical test. Olivine in the body is probably nickeliferous, Campbell concludes.

3) Small amounts of fibrous crystals of millerite on walls of small fissures.

4) Annabergite, (nickel bloom) was seen in the thin cracks of some hand specimens.

Copper Bearing Minerals:

1) Chalcopyrite as disseminated grains and fine veinlets. This mineral was reported as being in intimate association with pyrrhotite.

2) Native copper as thin veinlets with other minerals or disseminated in both rock types.

3) Bornite etc. were noted on the surface.

Other Minerals Noted:

1) Marcasite as veinlets or disseminated.

2) Specularite, quite abundant in veinlets or as colloform deposits in open fissures.

3) Red iron oxides, ubiquitous at the surface,

4) Magnetite was assumed to be present although none was actually

isolated and identified because of the effect on a compass needle of rock barren of pyrrhotite.

5) Similarly chromite was assumed to be present even though none was isolated and identified because Cr was reported in assays.

Two prominent highs in the northern end of the intrusive were revealed by the magnetometer survey, and the approximate contact of the ultramafic body outlined.

The drill core assays were not very promising, average drill hole 1:0.38% Ni, 0.21% Cu, 0.34% Cr.

Average drill hole 2: 0.36% Ni, 0.21% Cu, 0.35% Cr.

Average drill hole 3: 0.15% Ni, 0.09% Cu, 0.35% Cr.

The property lapsed and was restaked in 1950 by A. Studer as the Mac claims and transferred in 1951 to A. White of Brewis Red Lake Mines Limited, who did some unreported geophysical work. The claims were then transferred in 1952 to the Thompson brothers who optioned them in 1953 to the Canadian Nickel Company Limited after carrying out some trenching and sampling.

Inco 1954:

Inco filed records for five drill holes including logs, assays a geological map and report. This report recognised two rock types; a coarse grain pyroxenite with some peridotite, gabbro and diorite; and a fine grained dark green to black peridotite. Dunite, pyroxenite, and amphibolite are terms used in the core logs. Chalcopyrote, pyrite, pyrrhotite, magnetite, haematite, serpentine and talc were reported in the logs.

Fano Mining: 1956

Fano Mining and Exploration Limited (1956) took over the property in 1955 and carried out more geological and geophysical surveys, trenching and extensive drilling. A map of the geology and claim boundaries, drill plans and records for 33 of the 34 holes drilled are available in the files.

W. J. Pearson 1957

Pearson (1957) investigated the geological significance of some of the magnetic anomalies in the La Ronge region, including the Nemeiben Lake anomaly. The airborne magnetic survey of the Lac La Ronge area was done by Canadian Aero Service Ltd. in 1953. Part of the resulting map is reproduced in figure I (i) showing the anomaly over the Nemeiben Lake ultramafic body.

W.J. Pearson mapped this anomaly in the summer of 1956 and found an oval ultrabasic intrusive with north-south dimensions of 1,950 metres (6,400 ft) and east-west dimensions of 1,220 metres (4,000 ft), findings contrary to the ones by Campbell (1945), who considered the axis to have a north-eastern trend and the body to be slightly larger.

The intrusive was found to be entirely surrounded by low-lying often muskeg covered ground. The best exposed outcrops occur in the northern third of the body. Pearson recognised three main rock types; two varieties of pyroxenite, serpentinized ultrabasic rock which he interpreted as being peridotite, and gabbroic dykes. He interpreted the peridotite as the earlier phase since it occurs as inclusions in the pyroxenite, the dark green pyroxenite next in age and the light green pyroxenite as the youngest ultramafic phase. Gabbro is the youngest phase crosscutting all of the above.

"The serpentinized ultrabasic rock is a fine-grained, greenish black rock which is commonly finely fractured, with the fractures carrying fine stringers of pale green serpentine. Serpentine also occurs in veins and lenses from one-eighth to one-half inch wide in some localities. Talc has been developed on some of the fault and slippage planes in this rock" (Pearson 1957).

The dark green pyroxenite is coarser grained than the lighter green variety, presumably an increase in grain size accompanied the recrystallization and alteration of the pyroxenite. The lighter green variety consists almost entirely of pyroxene with olivine, magnetite, pyrrhotite, and pyrite present as accessory minerals. The dark green pyroxenite on the other hand contains 15 to 25 percent olivine, accounting for its greater degree of alteration.

Pearson also considered the southwest of the body to be slightly less mafic than the northern part. Specimens from two outcrops to the extreme southwest are composed of plagioclase (An_{42}), pyroxene and pale greenish brown amphibole.

Pyroxene in all varieties is augite, colourless to pale greenish brown and weakly pleochroic. It alters to actinolite, serpentine, talc, and carbonate.

The gabbroic dykes mainly occur at the northern end of the body. The largest one, trending northeasterly, consists chiefly of hornblende and plagioclase with minor quartz in parts. Pyroxene was noted in some of the dykes. They all contain some nickel and copper sulphides.

Pearson (1957) records the presence in the centre of the body of a large metasedimentary gneiss inclusion. It is composed of 50 precent hornblende, 27 percent plagioclase, 13 percent pyroxene, 4 percent epidote, quartz, and carbonate.

Pearson describes the country rock surrounding the ultramafic body as largely granodiorite gneiss, foliated granodiorite, and pegmatite. The granodiorite contains 30 - 36 percent quartz. Pearson (1957) stated that "no part of the ultramafic body contains any granitic intrusion of any kind, the intrusive is therefore considered to be younger than the surrounding country rock".

Figure I (v) on page 7 shows the general structure and ore mineral locations according to Pearson (1957). Most of the rock is massive, but where present, faint to moderate foliations tend to trend parallel to the periphery of the body. They dip outward toward the outer edges of the body in the southwest, south, and east; and inward in the north part of the body.

Pearson notes two main sets of minor shears in the ultramafic mass, striking in northeasterly and northwesterly directions. Faulting is mostly confined to the two northernmost outcrops. One of these faults terminates the gabbro dykes.

Disseminated pyrrhotite, pyrite and magnetite occur throughout the body but at the surface only reach appreciable quantities in the northern outcrops, where according to Pearson they are related to the fauling and shearing. The mineralized zones are confined chiefly to the olivine pyroxenite and to the gabbroic dykes.

Nickeliferous pyrrhotite, chalcopyrite, and pyrite occur as disseminated grains and in fine irregular veinlets. A later set of minerals is described: native copper, marcasite, specular haematite, iron oxide malachite, azurite, bornite, graphite, and garnierite. The secondary copper minerals occur in very small amounts. Native copper was seen in thin veinlets in a contact zone between serpentinized ultrabasic and pyroxenite. Pearson (1957) thought it was probably derived from chalcopyrite. Specular haematite is particularly common in fine fractures in the serpentinite. Unlike Campbell (1945) Pearson did not see any millerite. The graphite was seen in a few shears in some of the trenches.

Beck 1959 :

The next mention of the Nemeiben ultramafic body was in Beck's (1959) listings of the mineral occurrences in the Precambrian of Saskatchewan. He reports that a large tonnage low grade ore deposit was indicated at that time, grading 1.08 percent combined copper and nickel. Contrary to Pearson, who called the country rock granodiorite, Beck (1959) called it quartz-biotite schist and gneiss, and garnet schist and gneiss. The ultramafic body intruded these gneisses.

Dunlop Mining:

Fano Mining dropped the property in 1966. It was restaked by W.B. Dunlop as the Nib and Ben claims. Dunlop Mining ran geophysical surveys (E.M., Mag., S.P.) and an extensive drilling program. Dunlop wrote an extensive property evaluation amalgamating all the previous work into one report, including sections and plans from surface to the 500 foot level. Previous work had indicated a copper-nickel mineralized zone extending 570 metres (1 700 feet) with variable widths and grades.

The deepest hole was drilled at 79° northerly in the central part of the body, to a depth of 467.5 metres (1534 feet) without crossing the contact with the country rock.

Dunlop only used the assayed sections of the core to calculate tonnage, but since many mineralized core sections were never sampled or even split, especially some peridotites containing fine networks of sulphide, tonnages may be greater than indicated. From his calculations Dunlop (1966) concluded that a large tonnage of proven and potential copper-nickel ore exists at Nemeiben Lake.

The total proven tonnage calculated was 871 750 tons of 0.66% nickel and 0.35% copper. Assuming 90% recovery Dunlop (1966) calculated that 11.88 lbs of nickel and 6.31 lbs of copper were recoverable per ton of proven ore. The total potential nickel-copper tonnage was calculated to be 2 902 750 tons, which translates to a gross value of $79 941 735.

Following this report Dunlop (1966-67) carried out an electromagnetic and magnetic survey in which measurements were made every hundred feet along lines two hundred feet apart. Three hundred feed coil spacings were used. A number of anomalies at or near the ultramafic body's contact were found as well as a few isolated conductive zones outside it. This survey outlined the main known sulphide zone along the northern contact, produced an anomaly under Millar Lake, and anomalies under Nemeiben Lake.

Magnetometer readings were taken every hundred feet along lines two hundred feet apart. Many known zones of sulphide were not conductive.

probably due to its sparse disseminated nature. The magnetometer survey however outlined the plug and there were a few areas with higher than normal readings both inside and outside the body.

National Nickel-Dunlop Mining Co. Ltd. (1968):

Merrit Copper Co.Ltd. optioned the property in 1967. They changed their name to National Nickel Company Limited in 1968. An electromagnetic survey was carried out and a 400 metre (1,200 feet) conductive zone outlined, with a maximum width of 40 metres (120 feet). No associated direct magnetic response was found.

National Nickel Limited [Merrit Copper Co. Ltd.](1967-69):

79 drill holes were completed and assayed for Cu and Ni. Dunlop (1967) made more calculations of possible ore value, dividing the northern part of the body into the Dunlop West ore body of 796,650 tons and the Dunlop East ore body of 3,482,000 tons; of 0.36% Ni, 0.18% Cu; and 0.38% Ni, 0.18% Cu respectively. From this, taking into account reasonable recovery rates, he calculated that the Dunlop West ore body contained 5.801 lbs of nickel and 3.25 lbs of copper per ton. This translates to $13.71 a ton or a total value of $10 922 071 with nickel at $2 a pound and copper 65 cents a pound.

The Dunlop East ore body contains 6.121 lbs of nickel and 3.25 lbs of copper per ton, which at $2 for nickel and 65 cents for copper translates to $14.35 per ton or total value of $49 966 700. Dunlop (1967) considered there was enough ore to support a 500 ton mill for nineteen years at profit. Dunlop (1966) includes into his report level plans and cross sections of the possible ore bodies.

Three evaluation reports by D. D. Campbell, an ore report by Britton Research Ltd., and a geochemical soil survey report by Campbell and Chamberlain were also included into the assessment files at that time (1969).

Dunlop 1970:

In 1970 National Nickel returned the property to Dunlop Mining Ltd.. R. G. Agarwal (1970)completed a gravity survey over the ultramafic body for Dunlop. The purpose of this survey was to evaluate whether a gravity technique is useful in delineating the intrusive body and associated sulphide deposits.

Agarwal (1970) describes the property as lying within a northeasterly trending lens-shaped band of granitized schists and gneisses, 24 Kms (15 miles) long by eight Km (five miles) wide surrounded by relatively unmetamorphosed sedimentary and volcanic rocks. "The metamorphic rocks in the claim area are principally quartz-diorite and garnetiferous schists and gneisses, presumably derived from the enclosing sedimentary and volcanic rocks... it is intruded extensively by small masses of pyroxenite and hornblendic rocks" (Agarwal 1970) such as the Nemeiben Lake body, which he called a peridotite and hornblendite plug.

The density of the granite was taken to be 2.7 gm/cm^3 and of the basic and ultrabasic rocks 3.9 gm/cm^3. The gravity survey was done at 50 foot station intervals with a Sharpe 193 gravitometer; elevations were taken with a Wilde T.I.A. theodolite. The results were corrected for latitude, free air, and terrain effect; and for Bouger assuming a bedrock density of 2.7 gm/cm^3. The results varied over a range of eight milligals and the map contoured at 0.25 milligal intervals.

This survey outlined the ultramafic pluton. The amplitude of the gravity anomaly increased toward the centre indicating the mass of ultramafic to mafic rocks increases toward the centre. This could also be interpreted to mean that the basement contact between the pluton and the surrounding rocks becomes deeper towards its centre. The centre of the gravity-high over the pluton coincides with low lying topographic features.

This survey also outlined several small anomalies of small amplitude and shallow depths, 120 - 200 feet below the surface calculated Agarwal This could represent sulphide rich zones or possible near surface rocks differing in density; they could be prospective drilling targets. Figure I (iii) from Cochrane (1973) crudely shows the results of this gravity survey as well as geochemical targets outlined by previous geochemical surveys.

Further Work and Reports:

Shortly after the property was returned to Dunlop by National Nickel Company Limited in 1970, it was acquired jointly by Cadillac Explorations Ltd. and National Nickel Co. Ltd., now called Aberdeen Minerals. In the spring of 1972 Studer Mines Limited made an agreement with these companies for the right to acquire 61 percent of the property for exploration expenditures (Cochrane and Richards 1973).

Various economic feasibility studies were carried out subsequent to this. In the summer of 1973 the Saskatchewan Department of Mineral Resources collared four diamond drill holes totaling 660.8 metres (2168 feet) under the Mineral Evaluation Program (MEP1-4). Some EM-16, EM-17, and magnetometer work was also carried out to try and pinpoint suitable targets. Disseminated native copper was intersected in these holes, drilled in the east central and west central contact zones of the ultramafic body (pearson 1973).

Mineralized zones were sporadic "Of note was native Cu easily observed in all four holes and the lack of chalcopyrite" (McCormick 1973). This native copper was seen in peridotite and pyroxenite but was most abundant as veins and blebs in haematized dunite. McCormick (1973) also recognized sporadic needle aggregates of millerite on fractures in this haematized dunite. Disseminated pyrrhotite, pyrite, and pentlandite occur in the pyroxenites and peridotites of these drill holes, as well as small massive veins of pyrite and pyrrhotite associated with carbonates and specularite.

The assay results on drill core from these MEP holes were disappointing; generally averaging .02 percent copper and .05 percent nickel. "There were two notable exceptions: Hole no. 2, assayed from 388'-418', ran .8 Cu and .24 Ni. Hole No. 4, assayed from 16'-28', ran at .03 Cu and .24 Ni. This is surprising since only native Cu was observed in the dunite sampled" (McCormick 1973).

Howey (1972) stated that there were sufficient proven reserves to generate an operating profit of $3.5 million over six years at 1000 tons a day, based on mining 2 050 000 diluted tons of ore at 0.35% Cu and 0.61 % Ni at the then current prices of $0.45 per pound of copper and $1.33 per pound of nickel. Previous to this Dolomage Campbell and Associates (1970) had concluded in their feasibility study that "net operating revenues indicated by preliminary cost studies for the underground ore are: Underground (highgrade only) 450T.P.D., 10 years,

$3 355 000. Underground (all grades) 1000 TPD., 10 years, $5 157 000. These calculations were based on Canadian Smelter terms at that time; the price of nickel has increased substantially since, that of copper increased slightly; but development costs have probably increased greatly.

The Studer proposal to the Saskatchewan government (Suitor et. al. 1972) indicated that mining, as devised by Mr. Ernewin (mining contractor), would be by an underground trackless decline method with estimated costs of $3.16 per ton while the upper section of the "West zone" would be amenable to mining by open pit. Mining widths would range from five metres to 26 metres (15 - 75 feet), averaging 16 metres (46 feet).

Drilling across the ultramafic-granite contact has shown that it is complex, and that normally the pyroxenite is fine grained or chilled near the contact. Breccia and interbanding of pyroxenite and granite is common (Cochrane and Richards, 1973). The granite may be moderately well mineralized: in hole DM9 mineralized granite breccia averaged 0.70% nickel-copper accross twenty feet. Cochrane describes the copper-nickel zones as occurring in discontinuous lenses and irregular bands at or near the outer contact of the ultramafic plug. His inference, using drill information and the gravity survey results, is that the Nemeiben Lake body is a lopolith. "the complexity of structure, lithology, and mineralization at the contact suggests that metamorphic overprinting and probable remobilization of sulphides from their original 'near' basal position within the ultramafic body has taken place in varying degrees" (Cochrane and Richards 1973).

An S.P. Survey was carried out over the southern part of the claim blocks, using a Scintrex VP-7 with a sensitivity of two millivolts. An S.P. low trough seems to outline the contact of the ultramafic body, there are two other small lows outside this body. There were readings above 150 millivolts over the known sulphide conductors, but no new conductive zones were outlined by the survey (Studer 1974a).

Studer (1974b) reinterpreted the gravity data gathered by Agarwal (1970); he digitized the data and ran it on a second derivative computer program to remove the regional effect. Studer hoped to remove the effects of the ultramafic rocks from the data and therefore delineate anomalous areas in greater details. The previous effort had produced a pattern closely resembling the terrain and contained poorly defined anomalies while other geophysical methods had indicated the possibility of more deposits along the sides and bottom of this body.

The second derivative method plots the rate of change of the gravity values. The effect of the ultramafic rock should be linear, with a zero rate of change.

The zero contour of this new pattern outlines the contact, much as predicted by the magnetometer survey. The results of this work are somewhat uncertain due to errors involved in interpreting data from the original contour lines, but it shows that definite density contrasts exist in the ultramafic body which could be caused by varying rock types, structural features or sulphide rich zones.

Dolomage, Campbell and Associates (1974):

The ultramafic body "cuts across the gneissic banding of the surrounding granitic rock and is clearly an intrusive, with its north contact dipping steeply inward (southward). The layering of peridotite and pyroxenite is parallel to the contact of the body, suggesting a gravity segregated intrusive body" (Dolomage Campbell and Associates 1974). They also suggested the body takes the form of a laccolith.

In the northern section the predominant rock type is pyroxenite but within 300 feet of the contact this becomes extensively interlayered with peridotite in lensy bands up to 30 metres (100 feet) in thickness and much thinner bands, 3-6 metres of hornblendite or gabbro. Near the contact hybrid or altered quartz-dioritic rocks occur. The contacts between rock types are sinuous but sharp (Dolomage, Campbell and Associates 1974).

The ore zones form diffuse bands of various grades characterized by fairly good continuity in width and grade. In the higher grade core the ore minerals occur as blebs or irregular clusters intimately intermixed with the crystals of the host pyroxenite. There is no evidence in the drill core for a relationship to fractures or shear zones of this type of ore. Irregular concentrations along and beside fractures occur within high grade ore layers.

The best ore concentrations occur at or near embayments or irregularities in the contact, and geochemical surveys as well as reconnaissance drilling have indicated that there are nickel-copper anomalies around the entire periphery of the body. Moreover, geochemical and second deritative gravimetric anomalies somewhat coincide in the southern part of the body, this strengthens the possibility that the anomalies are due to sulphide-rich concentrations (Dolomage, Campbell and Associates 1974).

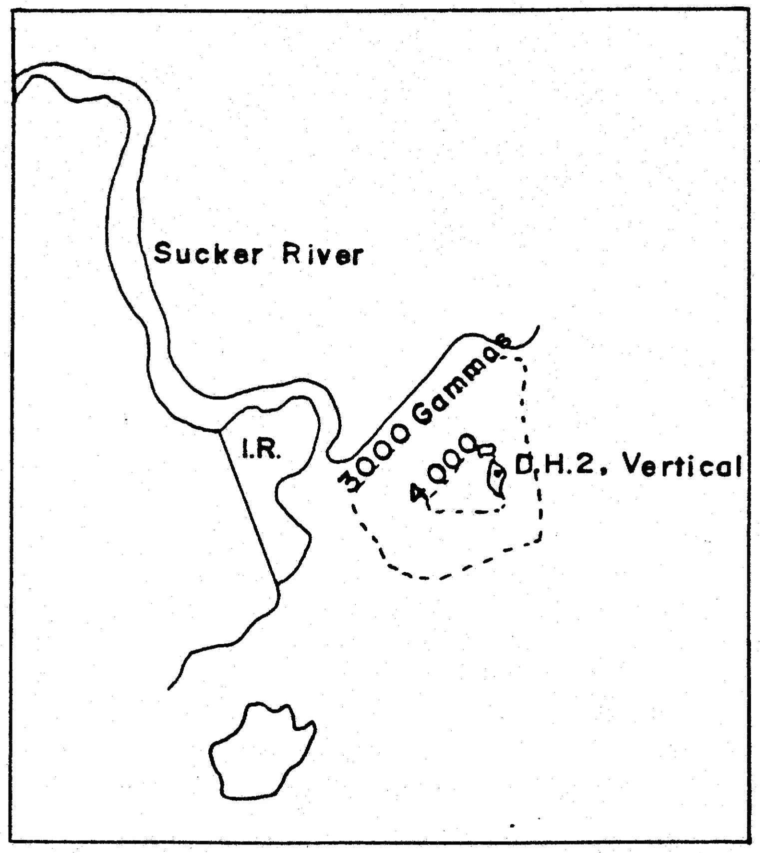
This covers most of the work in the open assessment files of the Saskatchewan Department of Mineral Resources which deals with the Nemeiben Lake nickel-copper property. Numerous investigations have been carried out in the region and even in the immediate vicinity of this property, two of which may be of interest.

Other Industry Work of Interest:

Thompson and Brady (1957) drilled two magnetic anomalies east of Sucker River and found some pyroxenite "dykes". Figure B(a) shows the location of the vertical drill hole 2 over a small anomaly west of Eliason island in Lac La Ronge, in which minor pyrite and some aplite dykes were reported as well as pyroxenite.

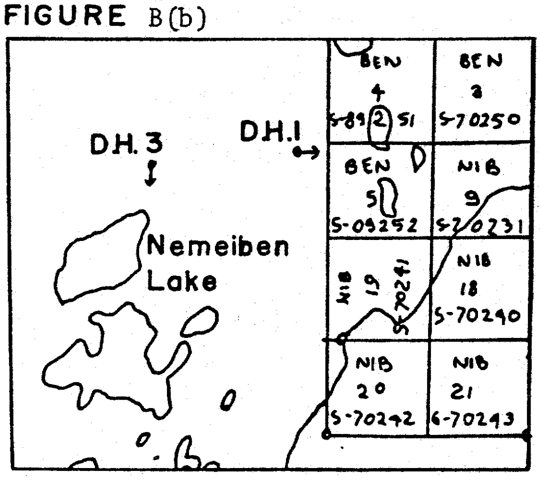
National Nickel drilled three holes over Nemeiben Lake in 1966, two of these near the Nemeiben Lake ultramafic body; their location is shown in figure B(b). Hole No. 1 encountered strongly altered and fractured pink granite, pegmatite, and quartz stringers. Hole No. 2 cuts through quartz-biotite gneiss and biotite schist containing some sulphide stringers of pyrite and pyrrhotite. At 56.4 metres (195 feet) a gneiss with massive sulphide zones was encountered. This was made up of pyrrhotite and pyrite averaging 0.04% copper and 0.09% nickel. The country rock a kilometre or so west of the ultramafic

FIGURE B(a)



Thomson and Brady (1957)

FIGURE B(b)



National Nickel (1966)

body is therefore mostly granite and gneiss with minor pyrite and pyrrhotite rich zones some of which may be nickeliferous.

Forsythe(1971):

Forsythe (1971) describes the ultramafic complex on pages 133-144 of his report on the geology of the mineral deposits in the Nemeiben Lake and Stanley areas. Figure I (iv) is basically his outcrop and geological map.

Forsythe mapped the ultramafic rocks according to a threefold classification; light green pyroxenite, grey-green uralitized and serpentinized pyroxenite, and black serpentinite. Small dykes of dioritic gabbro cut the northern part of the body and a small xenolith occurs in the southern part in a small band of pyroxenite.

The country rocks are light-brown biotite granite and alaskite which contain xenoliths of mafelsic to mafic schists or gneisses. The contact between the country rocks and the ultramafic body is not exposed at the surface.

Pyroxenite ovoids occur in altered pyroxenite with sharp to gradational contacts; these two rock types also occur as intermixed zones. Linear zones of altered grey-black rock occurs in pyroxenite while the black serpentinite occurs sporadically throughout the body exhibiting sharp, or sometimes contiguous contacts with the grey-green altered pyroxenite. Sporadic mineralogical layering varies from one to five centimetres in width. The rocks are commonly massive but with foliations of several ages visible in places; shearing is also present locally.

The light green pyroxenite consists of subequal proportions of medium to coarse grained hypersthene and diopside, with locally up to 20 percent round olivines. The olivine may be unaltered, or altered to iddingsite and serpentine, the pyroxenes may be slightly uralitized. Some chrysotile, anthophyllite, talc, and opaques occur.

The grey-green pyroxenite is simply a more highly uralitized and serpentinized version of the light green pyroxenite. Hypersthene shows greater alteration than diopside reports Forsythe (1971), and this rock contains more scattered opaque minerals.

The black serpentinite is mainly antigorite with chrysotile lined fractures. It contains rare pyroxene, olivine and uralite remnants. Disseminations of magnetite and haematite are numerous. Serpentine was observed cutting some magnetite grains. Uralites can be seen to grade into serpentinites.

The gabbro is a "medium to coarse grained, massive, mottled grey and black rock that is in sharp contact with the metapyroxenite" (Forsythe 1971). This rock occurs as dykes and "drilling indicates numerous narrow bodies at depth" (Forsythe 1971). Disseminations and veinlets of pyrrhotite, pyrite and chalcopyrite occur in this rock composed of 78 percent labradorite ($An_{60}\pm$) and 22 percent hypersthene and uralite.

The incipient alteration which caused uralitization of the pyroxenite was probably fracture controlled Forsythe concluded.

The mineralized zone drilled by Fano Mining is an electromagnetic conductor with pyrrhotite-pyrite-chalcopyrite and rare pentlandite bearing veins and lenses, which are structurally controlled as this zone cuts all ultramafic variants, gabbro, and also locally penetrates the country rocks. This zone is truncated locally by granite (Forsythe 1971).

Forsythe (1971) sampled trenches 1-4 [see figure III(i) for location] for geochemical analyses.

Trench 1 is in a sheared and fractured pyroxenite, serpentine and calcite line the fractures. Blebs and small veinlets of pyrrhotite, pyrite, and chalcopyrite were observed. A grab sample from the north end of this trench assayed 0.27 percent copper, 0.41 percent nickel, 0.15 percent cobalt, 0.22 percent chromium, and traces of silver and platinum. Geochemical analyses showed a range of 0.08 to 0.8 percent nickel and 0.03 to 0.39 percent copper.

Trench 2 is in a black fractured serpentinite with a few oval remnants of pyroxenite. Haematite is abundant in the fractures. The geochemical sample contained 0.08 percent copper and 0.37 percent nickel.

Trench 3 occurs in brecciated and sheared pyroxenite with serpentine along the fractures. Pyrrhotite disseminations are sporadic, metal values low; 0.2 - 0.4 percent copper and 0.35 - 0.82 percent nickel.

Trench 4 exposes a highly sheared and brecciated uralitized pyroxenite in serpentinite. It shows sporadic disseminations of pyrrhotite,pyrite and rare chalcopyrite. The geochemical analyses show a range of 0.1 to 0.95 percent nickel and 0.0006 to 0.76 percent copper.

Forsythe records the presence of minor pentlandite, as well as nickeliferous pyrrhotite and chalcopyrite as the main economic minerals. He did not recognise any annabergite garnierite or marcasite as reported by Campbell (1945) but unlike Pearson (1957) he did see some millerite occurring as sporadic needle aggregates on fractures in serpentinite.

Native copper occurs in haematized serpentinites.

"The mode of occurrence of the potential ore veins and their fabric, suggest fracture fill and replacement deposition" (Forsythe 1971). He also thought though, that the disseminated sulphide in the northern part of the body suggests late magmatic crystallization in the intrusive. The sulphide relationships to microftactures revealed by thin section study indicated an "exogenic origin of sulphides or local migration. An inclusion-sulphide rock occurs... Probably a dynamic metamorphism-hydrothermal solution hypothesis of origin explains the fabric here better than an immiscible sulphide-silicate melt... The ultramafic complex is an abundant source of Cu and Ni and during metamorphism, sulphides could migrate to structural channelways or be redistributed" (Forsythe 1971). He also noted though, that there is little contact alteration associated with the sulphide veins. Considering the upper stability limit of serpentine such alteration would occur if a melt or hot hydrothermal solution were involved in ore deposition.

Peddada 1972:

Anantaraman Peddada presented an M.Sc. thesis to the State University of New York at Albany on the "Petrology of the Nemeiben Lake Ultramafic and Associated Nickel-Sulphide Deposits". An account of his work, results, and conclusions follow.

Petrology:

Peddada (1972) derives his regional and local geology from Pearson (1957) and Forsythe (1971);he used the same rock unit terminology as Forsythe.

Peddada mapped the body at a scale of 1 : 2400; studied thin sections, polished thin sections, polished sections; carried out partial chemical analyses for major constituents by X-Ray fluorescence and atomic absorption, and had electron microprobe analyses of two each of olivine, orthopyroxene, and clinopyroxene carried out by the research laboratory of the Autokumpu Co., Finland, courtesy of A. Hakli.

Peddada estimates that 50 percent of the outcrop area is underlain by pyroxenite, 45 percent by partly serpentinized and uralitized pyroxenite and five percent by serpentinite. Layering of serpentinite and pyroxenite, where present, is exactly parallel to the contact, as would be expected in a gravity segregated body.

In the serpentinites, all the original olivine and orthopyroxene have been converted to mesh textured lizardite and chrysotile, magnetite, talc, and carbonates. Peddada estimates their modal compositions to be 90-98 percent serpentine and 5-10 percent opaques and sulphides.

The uralitized and partly serpentinized pyroxenite contains two percent olivine, 10-20 percent orthopyroxene and 10-15 percent clinopyroxene as remnant primary minerals. 10-20 percent serpentine, 40-50 percent tremolite, talc, carbonate, and opaque oxides are the secondary alteration minerals. Sulphides make up 10-15 percent of this rock according to Peddada. The increased degree of alteration may reflect the original presence of larger amounts of olivine than in pyroxenite. Orthopyroxene in this rock is more uralitized than the clinopyroxene.

The pyroxenite phase is made up of 40-45 percent orthopyroxene, 35-40 percent clinopyroxene. It contains traces of alteration minerals and oxides and 10-20 percent sulphides. Minor olivine and altered olivine occurs locally, the pyroxenite has a granular texture with an average grains sixe of two to five millimeters.

Sulphides average two percent by volume overall in the ultramafic rocks.

Fresh olivine is rare, it usually occurs as serpentine pseudomorphs in serpentinites or as partially serpentinized grains poikilitically enclosed in orthopyroxene in the altered pyroxenite. The compositions of the two olivines analysed by electron microprobe were $Fo_{86.75}$ and $Fo_{88.3}$. Table B (i) shows the analytical results of the partial microprobe analyses of the olivines, orthopyroxenes and clinopyroxenes as reported by Peddada (1972).

Orthopyroxene is very abundant, occurring as broad, ragged plate like crystals. It is colourless and pleochroic, has a large 2V, and a negative optic sign. It is replaced by tremolite and talc. The composition of two orthopyroxenes analysed by electron microprobe is En 87.05 and En 90.5 or about $Ca_3\ Mg_{86}\ Fe_{11}$.

The clinopyroxenes are chromian diopside, optically positive with a 2V of about 60°. They are coarse grained and equiangular.

COMPOSITIONS OF ORTHO AND CLINOPYROXENES
TABLE B (i)

OXIDE	ORTHOPYROXENE 1	2	CLINOPYROXENE	
SiO_2	54.6	55.3	52.4	52.4
Al_2O_3	3.8	2.4	4.6	2.9
FeO	8.3	6.1	3.9	3.0
MgO	31.3	32.6	18.5	19.5
CaO	1.7	1.1	20.1	21.7
Total	99.7	97.5	99.5	99.5
En	87.5	90.5		
Ca	3.29	2.14	41.12	42.42
Mg	84.19	88.56	52.65	53.00
Fe^{+2}	12.52	9.30	6.23	4.58
Al_2O_3	3.50	2.43	4.62	2.84
$(MgFe)SiO_3$	92.72	95.18	53.52	53.06
$CaSiO_3$	3.84	2.84	44.86	44.10

COMPOSITION OF OLIVINES

OXIDE	1	2
SiO_2	39.2	39.4
MgO	46.3	48.2
FeO	12.6	10.8
Total	98.1	98.4
Fo X Mg x 100 X X Mg x Fe X	86.5	88.83

Electron microprobe analyses by Häkli in
Research laboratory, Autokumpu Co. Finland.

The average composition of the two grains analysed by electron microprobe is Ca_{42} Mg_{53} Fe_{5} .

Lizardite, colourless to pale green, is the main mineral directly replacing olivine and pyroxene. Chrysotile occurs in veins and at mesh rims. Talc occurs with lizardite or in fine grained aggregates with carbonate. Both calcite and dolomite occur in late veins or in association with fine granular magnetite or in serpentine mesh centres. Weakly pleochroic colourless to pale green tremolite occurs as fibrous bladed aggregates often pseudomorphic after pyroxene. It is optically negative with 2V of 70-80 degrees.

Ore Petrology:

Concerning the ores, Peddada (1972) states that some of the ore minerals occur as blebs and irregular clusters intimately intermixed with the host silicates in the fashion accepted to be magmatic sulphide segregation textures. Irregular concentrations along and beside fractures occur only within serpentinite and adjacent to it.

Peddada identified various oxides in the Nemeiben Lake ultramafic rocks, including haematite, chromian spinel and several varieties of magnetite.

Magnetite occurs as primary subhedral grains 0.3 mm in diameter on the average, and as secondary fine grained disseminations or aggregates in the serpentinites. Specular haematite was also produced during serpentinization according to Peddada. The Lizard ultramafic (Green 1964) is the only well known locality with appreciable secondary haematite.

A primary chrome spinel phase occurs as small irregular blebs or euhedral grains one to two millimetres in size, it is quite scarce only locally making up to 0.5 percent of the rock.

Pyrrhotite, pentlandite, chalcopyrite, violarite-bravoite after nickeliferous pyrrhotite and pentlandite, marcasite-pyrite, and rare platinoid in chalcopyrite were identified by Peddada (1972).

Pyrrhotite is usually associated with pentlandite, pyrite, and chalcopyrite; as rounded to irregular grains 0.2 to 1 cm in size. Irregular contacts with other sulphides are common; occasionally small exsolution flames, lamellae, or rims of pentlandite occur in pyrrhotite. The lamellae are 1 micron or less wide and 0.03 mm long, the rims are 0.1 to 0.2 mm thick.

The pentlandite altered readily to violarite which in turn altered to bravoite, pseudomorphic after the parent mineral. Chalcopyrite has a grain size from 1 to 10 mm. It surrounds pyrrhotite or is included in it as narrow exsolution lamellae, where it cuts the pentlandite exsolution lamellae.

The secondary sulphides formed by supergene or hypogene alteration include marcasite and pyrite replacing pyrrhotite. A second generation of chalcopyrite is formed by the transformation of pyrrhotite to pyrite.

Peddada, as did Forsythe (1971), noticed the same relationship of fibrous crystals of native copper to haematite bearing serpentinites, they are probably due to the reduction of copper-bearing sulphide.

Silicate Petrogenesis:

Peddada (1972) used the partial microprobe analyses of two each of the three main minerals for petrogenetic studies. He compared olivines from Nemeiben Lake to others from the Cordilleran, the Appalachian, and the Precambrian shield areas of Canada using data of Smith (1962); and to the olivines from basaltic magma, peridotite nodules in basalts, and ultramafic intrusives in orogenic belts using data of Green (1964) and Challis (1965, and Lauder 1966). From this he determined that the olivines from the Nemeiben Lake ultramafic rocks "are similar to olivines in peridotite nodules in basalts and ultramafic intrusives in orogenic belts" (Peddada 1972).

The bulk compositions of rocks have a profound effect on the Al_2O_3 content of orthopyroxenes. It is thought by some to be pressure controlled (Herz 1960, Green 1964). The values at Nemeiben Lake corresponds to those obtained by Green (1964) in the Lizard area thought to suggest pressures intermediate between upper mantle and lower crustal environments.

The CaO content of orthopyroxenes has been interpreted as a qualitative temperature indicator (Atlas 1952, Kuno 1954), especially if the system is saturated with calcium. The relatively high CaO content of the orthopyroxenes in the Nemeiben Lake intrusion indicates a rather high temperature of formation; they correspond to the highest part of the range for orthopyroxenes from intrusive peridotites of ultramafic magma and to the lower part of the range from peridotite inclusions in some basaltic rocks (Ranges from Ross et.al. 1954).

Peddada then considered the relationship between the atomic proportion of Si and Al in clinopyroxenes and compared that of Nemeiben Lake to various ultramafics. The "Nemeiben Lake clinopyroxenes fall in the higher Al_2O_3 and lower SiO_2 region namely the alkaline field of igneous rocks" (Peddada 1972).

The distribution of elements between co-existing minerals can provide useful estimates of environmental conditions at the time of their formation. Peddada calculated the Kd value for the distribution of Mg and Fe between coexisting orthopyroxene and clinopyroxene to be 0.8086 using the method used by Kretz (1961a). This value is higher than for most igneous pyroxene pairs as reported by Kretz (1961b) and Saxena (1968); it is comparable to values from peridotite inclusions in basalt. Kd is somewhat dependent on temperature of formation but is also affected by pressure, composition, and mineral equillibrium. Using the tentative correlation between Kd and temperature worked out by Kretz (1963), Peddada estimated a temperature of around 1350°C for pyroxene pairs at Nemeiben.

The partitioning of Fe and Mg between olivines and orthopyroxene is relatively insensitive to changes in temperature and therefore cannot be used as a geothermometer (Williams and Eugster 1969). Peddada however, determined that the olivine-orthopyroxene pairs from the Nemeiben Lake pyroxenites plot close to the distribution curve determined experimentally at 900°C and 500 bars pressure; indicating that this probably represents an equilibrium assemblage.

The next avenue of investigation followed by Peddada is the nickel fractionation between olivine and clinopyroxene using the preliminary data from Hakli and Wright (1967). From this Peddada estimates the Nemeiben Lake ultramafic body crystallization temperature to be 1165°C.

The clinopyroxene compositions from Nemeiben Lake plot at temperatures between 1100°C and 1200°C and a pressure range of five to nine kilobars using O'Hara's (1967) provisional petrogenetic grid (Peddada 1972).

The solubility of $MgSiO_2$ in coexisting clinopyroxenes is largely affected by temperature and somewhat by pressure. The equilibrium temperature for the clinopyroxenes at Nemeiben Lake has been determined to be between 1100 and 1170°C using the curves by Boyd and Scharier (1964) at 1 atm. and the curve by Davis and Boyd (1966) at 30 Kb. The equilibrium temperature determined would be lowered if the Fe and Al content were also taken into account.

Taking all this work into account Peddada (1972) considered "the best possible temperature and pressure conditions which can be attributed to the Nemeiben Lake ultramafic body are between 1100° - 1200°C and 5 to 9 K-bars respectively."

Geochemistry:

Peddada carried out partial chemical analyses of bulk rock samples, table B (ii) shows his results. He recalculated the serpentinite values to an original water free composition assuming a water content of 10% by weight, he did not carry out similar calculations for the partly serpentinized and uralitized pyroxenite.

Peddada thought much of the variation in iron content in the Nemeiben Lake serpentinites is related to the variation in the amount of the sulphide phases present.

Table B(ii)

Average Compositions of Nemeiben Lake Ultramafic Rocks

OXIDE %	* SERPEN-TINITES	** PARTLY SERPEN-TINIZED PYROXENITE	** URALITIZED PYROXENITE	PYROXENITE	*** GABBRO
SiO_2	46.32	48.48	52.43	54.31	52.15
MgO	37.90	29.12	20.55	23.20	9.1
CaO	0.25	12.92	17.30	13.31	10.9
Al_2O_3	1.16	01.89	3.12	2.20	17.7
FeO	14.25	7.41	6.38	6.78	6.5
TiO_2	0.09	0.16	0.19	0.16	0.37
Trace Elements (ppm)					
Ni	3000	1203	360	558	57
Cr	3637	3590	3205	3557	40
Cu	1520	458	173	203	122
Zn	84	79	83	72	34

* recalculated anhydrous

** not recalculated anhydrous but made to 100%

*** raw gabbro results

FROM: Peddada 1972

Table B(iii) shows the Co, Ni, Cu, and Cr content of some minerals in the pyroxenites of Nemeiben Lake, determined by the electron micro-probe or emmersion methods as reported by Peddada (1972). In his discussion of this data he notes that most of the chromium content in the serpentinites is concentrated in chrome spinel because olivine discriminates against Cr. In the pyroxenites, clinopyroxene contains 0.40 percent and orthopyroxene 0.75 percent chromium. Peddada compared the distribution of nickel, chromium and titanium between co-existing pyroxenes in the Nemeiben Lake pyroxenites to examples from the literature (Carstens 1958, Atkins 1969) and found them similar. In general clinopyroxene is richer in chromium and titanium and the orthopyroxene in nickel.

The copper values in silicate mineral phases at Nemeiben Lake appear unrelated to the copper values in the whole rock; the olivines, pyroxenes and amphiboles all probably include some in their mineral lattices, but copper occurs predominantly in the sulphide phase.

The order of decreasing content of nickel and cobalt in the silicate minerals can be arranged in the series olivine > orthopyroxene > serpentine > clinopyroxene. The Ni/Co ratio is higher in olivine and hypersthene than in diopside and serpentine. Nickel also shows a tendency for sympathetic relationship with magnesium in the primary silicate minerals.

Serpentinization:

Serpentinization was irregular at Nemeiben, and was most intense in the fractured areas of the body. Olivine is the most altered mineral, orthopyroxene was also susceptible to serpentinization.

TABLE B(iii)

Ni, Cu, Co (ppm), Values in Minerals from Nemeiben Lake Ultramafic (Microprobe determinations)

Rock Pyroxenite	Elements	Olivine	Orthopyroxene	Clinopyroxene	Serpentine
Secimen No's.					
	Co	160	70	40	70
125	Ni	2030	610	340	230
	Cu	40	30	30	0
	Co	170	90	60	50
92	Ni	1840	410	250	250
	Cu	30	40	40	30
	Co	150		40	70
127	Ni	1910		330	240
	Cu	20		40	50
	Co	180	100	50	30
156	Ni	1860	530	300	450
	Cu	20	20	30	20
	Co			40	
75	Ni			230	
	Cu	20	60	30	10
	Co	190	90	60	90
85	Ni	1510	400	230	370
	Cu	20	60	30	10
	Co		120	60	
135	Ni		410	190	
	Cu		50	40	
	Co	170	70	60	60
98	Ni	1850	540	310	580
	Cu	20	30	30	20

Ti and Cr values in Minerals from Nemeiben Lake Ultramafic rocks (Emission Method)

Number	Orthopyroxene		Clinopyroxene	
	Ti	Cr	Ti	Cr
72 (Pyroxenite)	0.02%	0.2%	0.07%	0. 4%
102 (pyroxenite)	0.02%	0.3%	0.07%	0.4%

From Peddada 1972

The serpentinites at Nemeiben Lake contain no brucite and 5-10 percent magnetite; their silica content (recalculated anhydrous) is 46 percent, indicating large amounts of original pyroxene.

Peddada (1972) documents textural evidence for expansion in the Nemeiben Lake serpentinites; chromite grains have expansion fractures filled with serpentine. The presence of serpentine veins cutting accross orthopyroxene and sulphide grains may also be evidence.

From his investigation Peddada (1972) suggested that "serpentinization in Nemeiben Lake rocks was accompanied by the introduction of water with no changes in relative amounts of SiO_2 and MgO. A minor removal of CaO is the only apparent chemical change".

(6) Ore Petrogenesis:

Peddada (1972) investigated the compositional and textural relations of the sulphide ores and the distribution of nickel and copper between silicate and sulphide phases of some rocks in the Nemeiben Lake ultramafic body. From this he concluded the Nemeiben Lake nickel copper deposit is of magmatic origin. The disseminated nature of the sulphides suggest late magmatic crystallization.

Table B (iv) shows the nickel and copper values of the sulphide phase, silicate phase and whole rock phase of the body. Taking into account reported phase relationships it is deemed probable that the chalcopyrite and pentlandite present in the ores exsolved from a Fe-Ni-Cu monosulphide solution forming flames or lamellae of both, and round to euhedral bodies of chalcopyrite (Peddada 1972).

There is a tendency towards equilibrium in the distribution of nickel between the primary silicate and sulphide phases of basic

Table B(iv)

Nickel, Copper Values (ppm) of the Sulphide Phase, Whole Rock and Silicate Phase

Nickel			Copper			
hole Rock	Sulphide*	Silicate	Whole Rock	Sulphide*	Silicate	Ni/Cu in sulphide
erpentinites (core)						
868	1640	228	599	520	79	3.15
949	3300	649	1698	1500	198	2.2
531	4500	1031	2314	2250	64	2.0
128	700 (weathered)		33	5	28	
erpentinites (surface, weathered)						
885	122	763	26	2	24	
305	2500	616	915	800	115	
035	210	825	163	85	78	
yroxenites						
674	425	249	216	200	16	2.12
666	515	151	333	325	8	1.58
396	200	196	133	125	8	1.6
426	45	381	66	53	13	0.8

* Sulphide phase is determined by absorbic acid leach method.

FROM Peddada 1972

and ultrabasic rocks (Hakli 1963); but usually the content of sulphide nickel is proportional to the sulphur content. It forms in situ at the expense of silicate nickel as a result of the relative immobility of nickel and mobility of sulphur (Shteinberg and Malakhov 1963).

The nickel content in olivine is about 1800 ppm, the serpentinites however contain about 3000 ppm, 375 ppm of which is in the silicate phase. Primary magmatic sulphides were obviously present in the ultramafic rock prior to alteration and more nickel was released from the silicate phase during the formation of opaque minerals druing serpentinization. Another indication that this took place is the higher Ni/Cu ratios of the sulphide phases in serpentinites as compared to the pyroxenites.

The serpentinites, in addition to a primary sulphide assemblage, contain small (one micron) sulphide grains evenly dispersed through serpentine pseudomorphs after olivine.

APPENDIX C

(a)

PETROGRAPHY

Table III (i) shows the rock types into which the ultramafitite body at Nemeiben Lake is divided. Appendix C (b) lists the samples and sections examined, determined rock type, and the corresponding University of Saskatchewan number. Petrographical notes follow.

ABBREVIATIONS:

Gc	Geochemical Analysis
P	Electron microprobe examination of opaque minerals
TS	Thin section
PTS	Polished thin section
PS	Polished section
HS	Hand specimen
GS	Grain size
fg/mg/cg	Fine/medium/coarse grained
CPX	Clinopyroxene
OPX	Orthopyroxene
OL	Olivine
Fd	Feldspar
trem	tremolite
act	actinolite
serp	serpentine
po	pyrrhotite
py	pyrite
pn	Pentlandite
cp	Chalcopyrite

M1-M30, samples collected by McCormick.

1001A-5008, samples collected in September 1976.

F---- Thin sections provided by Forsythe, Saskatchewan Geological Survey.

MEP1-MEP4, core samples, Minerals Evaluation Program

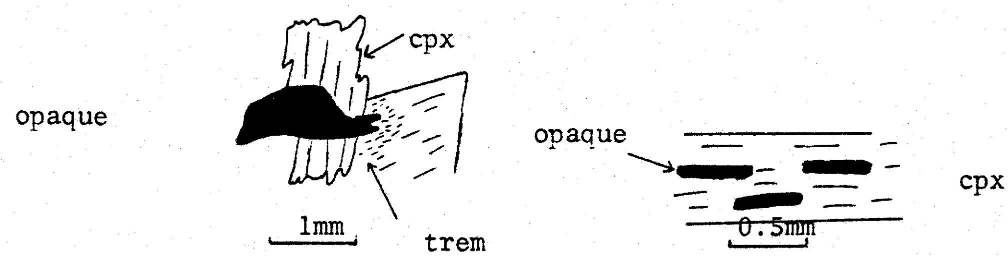
DM core samples, Dunlop Mining Ltd.

1) WEBSTERITE:

F67F-614 TS. 45% cpx, 25% opx, 30% trem. Opx up to 5mm, with numerous exsolution cpx lamallae along C axis cleavage. cpx 1-3mm, extensive alteration to trem. Some trem altered opx. Deformation twin at 30° to C axis in one cpx. Opaque dusting in trem, irregular rounded margins.

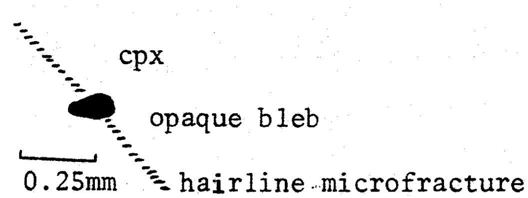
M5 TS HS 45% cpx, 30% opx, 20% trem, 2% serpentinized ol, 2% primary opaques 1% secondary opaques. Trem after cpx mostly. cpx 1.5-2.5mm. opx 1-1.5mm, euhedral. Some cpx highly fractured, strained, undulatory and patchy extinction. ol 1mm, serpentinized, associated opaques. Opaque grains and blebs, interstitial 0.1-0.3 mm or surrounded by altered silicate. One sulphide bleb cuts through cpx, see text figure C(i). Rectangular opaques in cleavage plane of cpx, text figure C(i). ~~A few pinkish pleochroic opx, bronzitic?~~ HS gs 2mm, greenish, reddish haematite stain. Brownish to bluish green weathered surface.

Text Figure C (i)



M8 HS TS 73% cpx, 25% opx. 3 point junctions, twinned cpx, fractured cpx, opx, minor trem along fractures. Small cpx inclusions in a few large 2mm opx. cpx 2-3mm, anhedral, ragged. opx 1mm, euhedral to subhedral. 2% interstitial and included opaques, in cpx, with hair line fracture, texts figure C(ii). Small euhedral opx inclusions, poikilitic opx. HS green, medium grained.

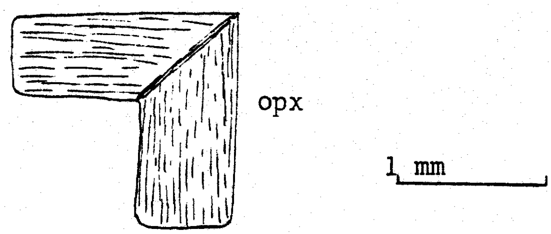
Text Figure C(ii):



M9 HS TS PTS. 65% cpx, 20% opx, 8% trem, 2% ol (serp) 2% opaques, calcite. trem alteration in bands. 3 point junctions. Fractured but little altered. 2 generation opx, 0.5-1mm, some included poikilitically in cpx, and large 1-2mm with cpx exsolutions. Minor alteration of included opx to talc. A 0.5 mm serpentinized ol in cpx. Secondary opaque with calcite rim. 3 phase sulphide grain: po, cp, pn, alteration of pn to violarite. Vein of chalco extending from this grain. A few pn/cp minor po composites 0.1-0.2mm. Small cp blebs in uralite, opaques oxidised and weathered, some haematite. po-cp grain, po-pn grain. HS reddish to greenish mg.

M13 HS,TS.80% cpx, 15% opx, 3% ol, 2% opaques. cpx 1-2mm, opx 1-2mm ol 2mm. cpx with undulose extinction. Pinkish microfractured opx bronzitic? opx twin, see text figure C(iii) a few twinned cpx, microfractured. One large opx with cpx inclusions but another cpx jutting into it, Opaques 0.1-0.3mm, interstitial, some blebs in cpx. HS light greyish green, fg-mg.

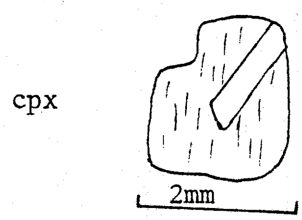
Text Figure C(iii):

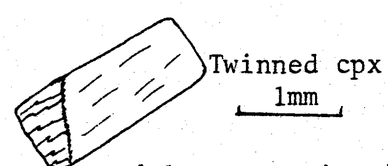


M20 HS TS PTS P 25% cpx, 20% opx, 50% trem, minor serp. 5% opaques. trem pseudomorphic after pyroxene, serp after ol, gs 1-1.5mm. cpx with undulose extinction, 2 bands of microfractures at 70°. Pinkish opx (bronzitic?) with slightly inclined and undulose extinction, exsolution cpx lamellae. 3 point junctions between primary minerals. Opaque dusting, magnetite in trem, po-cp-pn composite primary sulphide grains, violarite after pn. Small cp rectangular grain in silicate cleavage. po-pn grains, some very marked cleavage planes in po, cp blebs, po monomineralic grains. pn-cp composite grains. HS greenish-red, mg, mineralized.

M21 HS TS. 80% cpx, 20% opx, cpx 1.5-2mm, opx 1mm. Some cpx with sharp twins. opx pinkish in places, one 3 x 1 mm with cpx exsolutions. Irregular deformation bands in cpx, often crossing at 30°. Opaques 0.05 mm and 0.2 mm, interstitial. HS fg greenish grey, brown weathered surface.

Text Figure C(iv):





M26 HS TS 70% cpx, 30% opx. A fracture cuts through grains, 0.5 mm alteration each side of it. Minor 0.1mm interstitial opaques. 3 point junctions. Twinned cpx, some with undulose extinction. Deformation bands in cpx. gs 1-2mm. One large opx, 1.5 mm, with "patches" of cpx inside it. All twin bands oriented within 30°. opx slightly more euhedral than cpx. HS reddish green, pitted, weathered down 1 cm.

4008 HS TS. 85% cpx, 10% opx, 4% trem, 1% opaques 0.1-0.2mm, and large cpx including smaller cpx and opx grains. Patchy strain shadow development on some cpx, possible symplectite, or narrow crushed bands, feature not seen developed in any other section. Hs green, massive, mg.

4017 PTS HS 80% cpx, 10% opx, 7% ol, 0.5% Fd, 2% interstitial opaques. cpx 2-4mm, irregular boundaries, patchyly uralitized, some slightly twinned. ol 1mm, rounded grains. opx 2mm, cpx exsolutions. One large opx with 0.5mm goethitic inclusion, cpx with opaque inclusions. Opaques largely haematized, minor cp remnant some po. Tiny secondary sulphide blebs in uralite. HS has reddish brown weathered surface, greenish grey fresh surface.

2) OLIVINE WEBSTERITE:

FC67-618 TS 35% cpx, 30% opx, 10% ol, trem. ol, 1mm round. opx, cpx 1-2mm, some 5 mm. fg uralite after cpx, minor interstitial opaques 0.1-1mm, opaque dust.

FC67-614 TS 60% cpx, 20% ol, 20% opx. ol roundish, in chains or "minor layers". 5-1mm. opx, cpx 1-2 mm opx are the largest grains, with cpx exsolutions. Some large opx with square euhedral opaque inclusions, only those with ~~cpx exsolutions~~. cpx ragged outlines, strain bands in some. ol included in an opx. Crystallization seems to have been ol-opx-cpx. fg alteration of opx, brownish bastite.

67F 615B TS 60% cpx, 30% ol, 10% opx. cpx 1.5mm, opx, ol 1mm. Opaques haematized extensively. cpx strained and twinned. opx euhedral, prismatic. Minor intracrystalline "folding".

67F 615A TS 2 rock types one as above. One large ol grain 1 x 2 mm, surrounded by smaller cpx and much smaller opx, one 3mm cpx also growing around accomodating small crystals next to it. Minor serpentinization of ol, light green, irregular boundaries, other silicates impinge upon ol. 3 % interstitial opaques, some in veins of uralite. Contact with second rock type sharp, fg colourless tremolite, interlocking 0.1mm crystals. Some pseudomorphic after cpx, minor remnants seen, one pseudomorph after opx. Opaque dusting in trem. Brownish "bastite" pseudomorphs after opx. Vein with fracture fill chrysotile.

M2 HS, TS. 75% cpx, 7% ol, 5% opx, 10% trem. Some yellowish-green, isotropic serpophite altering small 1mm ol grains and rims of larger 2 mm ol grains. Zone of alteration and minor deformation, refracts accross grain boundaries. Many triple junctions between cpx grains averages 2 mm, some with ragged boundaries. Some cpx with criss-crossed network of fractures at right angles, with some fine granulation at 45°. Mesh textured trem. One ol with extremely undulatory extinction, all are oval, seemingly somewhat flattened. HS dark green, yellowish to red weathered surface. gs 2-3mm, small platy opx crystals.

M4 HS, TS. 60% cpx, 30% opx, 7% ol. ol 1-2.5mm, fractured, altering to yellow isotropic serpophite along the edges. opx 0.5-1mm with tiny cpx exsolutions (inclusions?) subhedral cpx larger, ragged outlines, some twinned or with strain shadows. One opx with fabric at 45% to rectangular shape. Some ragged cpx growing around earlier generation cpx. Triple points, with rounded to hexagonal opx, cpx. HS rusty red to grey, fresh surface light to dark olive green, rough, 2-3mm.

M12 HS,TS. 50% cpx, 30% opx, 10% ol serpentinized 10% trem. ol 2mm, fractured, half serpentinized to light green mesh serpentine. opx 1-1.5mm, pinkish (bronzitic?), finely fractured, some roundish included in cpx. Most subhedral cpx 3-4mm. One with deformation twin at angle to fabric. At one end of slide, opx cpx 1mm polygonal grains with three point junctions. Interstitial opaques, some with stringers into adjacent silicates. Serpentine veins (chrysotile?) cutting accross opaques. HS greenish-greyish black, mg.

4004B HS, TS, PTS. 75% cpx, 15% opx, 9% ol+ 1% opaques. opx 1-2 mm, cpx 1-3mm, ol 1-1.5mm serpentinized to light green serpentine along rims and fractures. Strain bands and twins in a few cpx. Minor serpophite, antigorite, talc. Incipient alteration to trem. Opaque veins where rock is uralitized. Magnetite grains in uralite. po in a cpx, and interstitial between opx, cpx. Larger light yellowish brown po, some darker brown oxidized po. Small greenish yellow exsolution of cp along rims of some po. Patchy exsolution cream pn near edges of po, often associated with cp. Inclusion of rounded cpx in sulphide mass. Composite 90% po 10% cp grains. Some very small (at x 100) po, cp blebs, tiny pn exsolutions in po. HS green mg, greyish rough weathered surface.

MEP1 470.10 HS, PTS. 77% cpx, 10% opx, 10% ol, 2% opaques. Minor trem, plagioclase, calcite. opx 0.5mm, a few 2.5mm, ol 1.5mm. cpx 2mm, many twinned, some highly fractured. One twinned olivine, highly fractured. cpx altering to trem. One trem patch of interlocking crystals has a brown pleochroic hornblende growing in it. One large interstitial opaque, 2mm, po and cp. po pinkish brown, slightly anisotropic, brassy yellow cp in two round blebs inside the po. 0.5mm po blebs, with minor cp exsolutions, some included in cpx. HS mesh textured light green to greyish.

3) FELDSPATHIC WEBSTERITE:

M14 TS, PTS, TS. 50% opx, 40% cpx, 3% Fd, 5% brown hornblende 2% opaques. Feldspar An 50. A few large opx, 4mm. 1mm pleochroic reddish brown hornblende, near plagioclase, seems primary. One large cpx with parallel extinction includes three small magnetite cubes. One large magnetite cube in an opx. Minor tiny specks of sulphide. HS greyish-green, mg, massive.

Z HS, PTS.,. 60% cpx, 10% opx, 10% Fd, 10% trem, 5% ol, 5% opaques. Some brown hornblende with tiny magnetite grains inside it. One large interstitial plagioclase grain including small cpx. Most seem "intercumulus". Opaques occupy intergranular spaces, "flowing" between pyroxenes. Composite pinkish brown po and brass yellow cp rims. One cp mass cutting plagioclase. 1mm po and cp monomineralic grains clean curved sulphide contacts. Some tiny sulphide grains in plagioclase. Overall 35% cp, 65% po. HS greyish, fg.

4) CLINOPYROXENITE:

M19 HS, PS. 75% cpx, 15% trem, 5% ol, 5% opx. One large brown, slightly pleochroic hornblende 1 x 0.8 cm, including minor calcite, it grew at the expense of trem after cpx. cpx also altering slightly to greyish serpentine. Pink opx, bent with undulatory extinction. cpx grew around minor ol in intercumulate fashion. Interstitial opaques 0.05 mm. HS greyish-green, massive, brown pitted weathered surface.

M29 HS, TS, PTS. 95% cpx, 3% opx, 2% opaques. Bimodal silicate gs, 0.5mm and 2 mm. Some cpx twinned, wide bands. One cpx completely encloses and somewhat replaces another. opx 0.5mm. Opaques 0.1-0.3 mm, po-cp-pn to violarite. Only sulphides present. HS greenish grey, reddish brown weathered surface affects down 3 mm.

2003C HS, PTS. 95% cpx, 1%opx, 3% opaques. Minor interstitial plagioclase seen. opx euhedral to subhedral, cpx anhedral, ragged. A bit of pleochroic brown hornblende, low relief, high birefringence, irregular accomodating shape. One plagioclase grain has undulatory extinction, none of the cpx in this slide. po-cp-pn. brown po with tint of pink, partially replaced by marcasite and magnetite, and marcasite lamallae, some slightly bent. Minor cubanite in cp. Minor covellite, alteration of cp. po with cp blebs and narrow exsolution in cleavage planes. Small monomineralic cp and brown to pinkish cream po blebs, some in cpx. Fine microfractures filled with cp veinlets, altering to haematite and goethite. Composite grains from 90% to 10% po to 80% pn. Some po-cp-magnetite grains. Violarite alteration of pn, associated with minor magnetite. HS has a reddish goethite rich weathered surface, greenish coarse grained fresh surface.

2007A PTS, HS, P. 70% cpx, 21% trem, 5% opx, 4% opaques Irregular slightly altered cpx grain boundaries, gs 2mm. Many twins, contrasting birefringence. Opaque dusting-magnetite and haematite-in crystallographic planes of altering cpx. Minor cross-fibrous calcite in an extention fracture accross a cpx grain. Interstitial sulphide blebs, some completely altered to py and minor marcasite, magnetite, haematite; some birds eye textures, mostly grains in trem. cp unaltered. Haematization and goethitization often complete. Tiny po, cp, pn grains, blebs in uralite. po-cp veinlets in fractures, haematized. Composite cp-pn grains, patchy alteration to bravoite. pn sometimes has straight, idiomorphic borders against cp, po, mostly contacts are smooth and curved. Magnetite dust in uralite. Many monomineralic po grains, few three phase grains. HS greyish green, massive, reddish brown weathered surface.

3004 HS, PTS. 90% cpx, 5% opx, 2% ol, 3% opaques. Minor brown pleochroic hornblende invading adjacent cpx. gs 1-2mm, some twinned, many highly fractured cpx. Many poikilitic cpx with small cpx inclusions, a few opaque inclusions. ol 0.8mm. A few large opx with inclusions and exsolutions of cpx, displaced and grew into surrounding cpx. Inclusion opaque is cp, altering to covellite, both in turn altering to haematite. po-cp composite grains, po almost completely altered to haematite.

cp interstitial blebs common, a few unaltered po blebs. Minor pn, altering to haematite. Some covellite in po-replacement of po? and covellite replacing cp. Network of bravoite in pn. Idiomorphic straight boundary between pn-cp, clean curved boundary between po and pn. Minor rims of pn, cp in po. Small speck of primary metal, high reflectance, ragged edges, isotropic but without complete extinction (silver?). HS has reddish brown, gossan-like weathered surface, green medium grained fresh surface. Weathered down 1 cm.

3005B PTS(x2) HS. 90% cpx, trem, minor ol, 2% opx, 5% opaques 1-2mm. One large weakly pleochroic brown hornblende, low relief high birefringence with small opaque dust in cleavage. Fractured, twinned cpx, incipient alteration to trem along edges. cpx 1-3mm, opx 1-2mm, one large including bleb of sulphide 0.5mm. cpx, 1mm, in sulphide. cp-po composite grains common, cp veinlets in cracks, minor po. Interstitial blebs rounded by three cpx, pn-po-cp. Birds eye texture, marcasite magnetite replacing po. po brownish to reddish brown when somewhat altered . Goethite-haematite replacement common, bravoite replacing pn. tremolite blades grow into sulphide masses . One mass 1cm in diameter, 2/3 cp 1/3 po altered to marcasite and haematite. A grain 90% pn, altered to bravoite along cubic cleavage. HS green mg, reddish brown weathered surface.

MEP3 322 HS, PTS. 90% cpx, trem, minor plagioclase HS greyish, fine grained, extensively veined by calcite, serpentine, sulphide. Fractured, twinned cpx. trem, and incipient alteration of cpx to trem. Serp veins (chrysotile). Some cpx slightly bent. Vein of haematized py mixed with granulated cpx. Few speck cp in rest of slide, between fractured cpx grains and in uralite, small cp-po composite grains in uralite also. Thin cp and thin haematite veins cutting through cpx.

5) (FELDSPATHIC) CLINOPYROXENITE:

1004A HS, TS, PTS. 75% cpx. 7% Fd (An44) 5% brown hornblende and plagioclase closely associated, "intercumulate". A few large late opx. minor incipient alteration of cpx to trem. Minor fibrous serpentine after cpx. Opaques 0.2-1 mm, interstitial, some included. po-cp composite grains. Round cp bleb in po. pn altered to violarite in pn-po-cp grain, cp-pn blebs in cpx. po with round cp exsolution and pn cubes inside it. HS greenish grey, mg.

2003A HS PTS P. 90% cpx, 2%Fd, 3%opx, 5%opaques. cpx, many twinned, deformation bands, some narrow exsolutions opx. Intercumulate plagioclase, between three pyroxene grains. Some cpx with parallel extinction. opx 0.5mm, cpx 4-6mm, ragged, discoloured to altered. One cpx with interrupted "patchy" twin. Two phases of po, intermingled light and dark phases, exsolution lamallae pn, secondary idiomorphic py cubes, in marcasite after po, violarite alteration of pn, cubanite, Magnetite associated with py. Marcasite altered po, patchyly or along cleavage planes. Many tiny cp specks. Large po with minor cp on edges. po-cp, some po-pn grains greyish to slightly bluish bravoite network in pn. po much altered to haematite. Symplectic like exsolution of worm like cp in po. Feathery pn at contact between po and cp, through both phases. A round bleb of cp in a pn. Idomorphic pn juxtaposed against po. po contains some Cu. A po with a cp cube inside it. Opaques 0.2-1 mm. HS is green, mg and rough, weathered surface reddish.

XII HS, PTS. 85% cpx, 8% opx, 2% Fd 5% opaques. Half of slide is uralite with cpx remnants. Opaques 0.1 - 10mm. Large composite grains of po with pn exsolutions, pn and cp. Large sausage like and rounded blebs cp in po. Subhedral hexagonal pn grains in po. Pseudo-hexagonal uralitized silicate grain in the middle of this large sulphide mass. In uralite, small po, cp and po-cp blebs. Interstitial cp blebs. Marcasite, haematite and po specks between tremolite blades of uralite. A few po-pn-cp grains.

6) OLIVINE CLINOPYROXENITE;

FC67-619 TS. 70% cpx, 20% ol, 5%opx, trem, interstitial opaques and veins. rounded to subhedral opx, concentrated in small layers - rhythmic layering?

FC67-612 TS. 55% cpx, 35% ol, 5%opx, 5% opaques. A few pleochroic greenish brown opx. ol round, 0.5 mm. A few diagonal deformation bands in cpx, twinning is also present.

FC57-611 TS. 60% cpx, 30% ol, 5% opx, 5% opaques. Olivine mostly altered to fine grained light green serpentine. Some cpx include small ol grains poikilitically. A few light green serpentine pseudomorphs after cpx. gs 2mm, or granulated to 0.5 mm, ol either 1-1.5mm or 0.5mm and included in cpx. Cross-fibrous calcite vein.

M18 Gc, TS, PTS, HS. 70% cpx,20% ol (serp) 5% opx, 2% opaques. Many 3 point junctions, minor fracturing twinned cpx altered to trem at one end, twinning mimicked by the trem. Coarse undulatory extinction along some of the opx. cpx cloudy to patchyly altered to trem. some definitely intercumulus cpx, large and ragged, filling intersteces between smaller cpx. ol 2mm, slightly to wholly altered to light green serpentine. cpx 1-1.5mm, some larger. Opaques small, cp in cpx, and others altered to marcasite and haematite. HS grey, brownish weathered surface.

M22 HS, PTS, TS,P. 80% cpx, 17% ol (serp), 2% opx, 1% opaques. +.01 2-3mm, cpx 1-2mm, opx 1mm. Mineralogical layering apparent, silicates aligned, ol concentrated along narrow discontinuous layers. Opaques 0.1-0.5mm, po, cp, (pn). Small cp in cleavage plane of cpx. Magnetite in serpentine pseudomorphs after olivine. cp reddish in places. Altered, almost weathered out cubic pn. A few anhedral 0.5mm chromite grains, a few 0.5mm magnetite grains, both primary. HS greyish yellowish brown weathered surface, bluish grey to green, blotchy fresh surface. Mineralogical layering apparent on cut surface.

M28 HS TS 83% cpx, 10% ol (serp) 5% calcite and trem, 1% opx, 1% opaques ol 2mm, often serpentinized pseudomorphically to light green to black serpentine. cpx 1.5-2mm, ragged edges, often twinned. Calcite and tremolite intermixed. opx 0.5mm. Fractures, through grains. Opaques 0.2mm. HS mottled and pitted, brownish green with red staining. A few large platy minerals (cpx) whose cleavage surface "wink" in the sun.

MEP2-390 HS,PTS. 65% cpx, 15% ol, 18% trem, 2% opaques. Reported assays 388-418,0.08Cu, 0.24 Ni. Fractured, interlocked cpx 1-1.5mm. Tiny cp-po interstitial specks, some altering to haematite and goethite. A large po-cp grain juxtaposed to two bluish-steely grey magnetite. Thin stringers of sulphide in trem. po with exsolution lamellae and blebs of cp, pn. pn with beautiful cubiform replacement by violarite. Possible speck of gold. Oriented po blebs in trem, some so pinkish cream, anisotropic, may be Cu-bravoite(?). HS greyish green, mottled.

MEP3 337 HS,PTS. 75% cpx, 15% ol, 3% opx, 7% trem ol 0.5mm, a few 1mm, round grains. opx 1-1.5mm. Two generations cpx, 0.5-1mm, 2-3mm, anhedral, a few twinned, growing around the scattered ol. Small cpx more fractured than larger ones. po, cp specks in silicates. Blue covellite after cp. A few tiny po-cp grains. Only one larger interstitial opaque mass, almost completely altered to haematite and goethite.

7) FELDSPATHIC OLIVINE CLINOPYROXENITE:

MEP1 582.7 HS,PTS, P. 68% cpx, 15% ol, 5% Fd, 1% brown hornblende, 2% opaques, tremolite saussurite. Plagioclase untwinned, some slightly twinned, one with two twin laws, minor saussuritization. Minor light brown hornblende associated with the Fd. Some plagioclase has undulatory and wavy extinction. ol 0.5 - 1.5mm, a few 3mm. Opaques 0.2mm, interstitial composite po-cp-pn blebs. Clean boundaries between phases. cp, po-cp, po-pn one with cp bleb in pn. Some oxidation of po to variated colours. Some tiny sulphide specks in silicate . One composite cp-po-magnetite. Slight flowage of cp into adjacent silicates apparent. HS grey, fine to coarse grained and massive.

8) WEHRLITE:

FC67-616 TS. 50% serp pseudomorphic after ol, 50% trem with cpx remnants. ol 1-3mm, altered to light green to brownish serp. trem is colourless to light brownish, a few pseudomorphs after pyroxene. ol and cpx remnants.

M11 HS,TS. 40% green serpentine, mostly pseudomorphic after ol, some mesh textured and fibrous. 55% cpx, 2% calcite in a vein, 3% opaques. Minor greyish green serp after cpx. Very minor opaque dusting in serpentine. HS medium grained, grey with small green cpx crystals.

M16 HS, TS. 75% ol or serp after ol, 20% remnant cpx, calcite, trem, 5% opaques. Opaques 0.2mm, scattered between ol serp pseudomorphs, plus opaque dusting in serpentine. The mattrix or intercumulate silicates, almost completely altered to trem and calcite cpx remnants which are fractured and often exhibit deformation bands. Some opaques have inclusions of calcite-trem. Serpentine grows into opaques. HS reddish to bluish grey, mottled.

1001A TS HS. 80% green serp pseudomorphic after ol, 15% brown serp containing cpx remnants, 5% opaques. ol 2-3mm, apparent cumulate texture. Intercumulate cpx almost totally altered to fibrous brownish serp, of lower relief than the green serp after ol. A few small primary chromite grains, reddish and isotropic. Small reaction zone between chromite and serpentine, forming chlorite. HS greyish black, with many altered poikilitic pyroxene grains with cleavage surfaces that wink in the sun. Minor talc in the serpentine.

2012 TS (PTS is dunite) 85% green serpentine, some of which obviously pseudomorphic after ol, 12% brown serp containing cpx remnants 3% opaques. Dolomite in fracture, some of the crystals are bent. Light green amourphous serpentine veins in HS, fg black with a goethitic surface. Minor chromite, translucent red, isotropic.

4015 HS,TS PTS. 70% green serp pseudomorphic after olivine, 5% opaques brown serpentine, tremolite, cpx remnants, one including small cpx. ol 3mm. Scattered grains and veins of opaques, highly haematized. Marcasite-haematite veins, much magnetite opaque dust. Some primary magnetite, one with small rounded po blebs in it. Composite oxide-po grains, or simply juxtaposed. Some euhedral cubic magnetite. A few pn grains, altered to bravoite, violarite, haematite vein cutting through primary sulphides and oxides. HS bluish grey, blotchy, weathered surface pitted.

4016 GS,PTS, P. 45% ol (serp), 45% cpx, 5% opx, 5%opaques. ol 2mm, slightly to wholly altered to green serpentine. Distinct impression of primary mineralogical layering of ol. cpx 1-2mm, many twinned. opx 1.5 mm. ol highly fractured, many 3 point junctions, interlocking cpx. Opaques 0.3mm, interstitial, some tiny, 10 micron sulphide specks in serpentine, po in serpentine is nickeliferous.One magnetite grain includes a small py cube. po- p-pn grains, alteration of pn to violarite, cp blebs. Millerite in dust. Much alteration to haematite, goethite. HS greenish-bluish black, reddish brown weathered surface.

4018 HS, TS PTS 20-45% ol, 45-70% cpx 1% opaques, 10% trem. ol 0.1-3mm, fractured, much altered to green serpentine. cpx have ragged edges, some are twinned, to partially twinned. Haematite and magnetitedust outline serp pseudomorphs; cp, altered to haematite Minor covellite alteration of cp. HS bluish green mg.

9) LHERZOLITE(?)

2006 HS, PTS, 60% serp, pseudomorphic after ol, 37% trem, with cpx and opx remnants; 3% opaques. Opaques richest where slide rich in ol-bottom of cumulate layer? pyroxene, now altered, in intercumulate sites. ol rounded to pseudo-hexagonal, 2-3mm. Magnetite, primary, altering to haematite, one with small pn cube inside it. po with minor cp. po-cp-pn, pn altering to violarite-bravoite, po to pyrite-haematite. Some fine grained disseminated cp. cp-po grain cut by a magnetite vein.. In the olivine rich region, 1/4 magnetite, 3/4 composite sulphide blebs. HS greyish-bluish green, brown weathered surface.

10) HARZBURGITE (?)

M15 TS, PTS, HS 10% opaques, 30% light green serpentine, 40% opx, 5% trem, minor cpx remnants, 15% ol remnants. The light green serpentine is almost isotropic. Opx remnants fractured. Square to rectangular subhedral magnetite. A roundish magnetite grain included in an opx. Magnetite and haematite dusting in alteration silicates. Minor cp. HS reddish-greyish black.

11) DUNITE/SERPENTINITE:

67F 616 TS Serpentine, minor cpx, 5-8% opaques. Light green fg serp pseudomorphic after ol. Some chrysotile, fibrous. Minor uralite. Large opaque minerals cracked and veined by serp. Opaque blebs in minor cpx.

2001 HS,PTS. 90% serp or ol, 8% opaques, minor cpx remnants, brown serpentine and calcite. Dusting, veins, and primary opaques. ol up to 3mm, round to sub-rectangular pseudomorphs of serp, minor remnants. Brown serpentine fibrous, interstitial, associated with calcite and contains cpx remnants. Opaques mostly haematite and magnetite dusting, some sulphide blebs in opaque dusting, primary magnetite grains. cp grains po almost totally haematized, or altered to marcasite. A few small py cubes, py and millerite specks in opaque dust due to serpentinization. HS fg, grey, brownish grey weathered surface.

2008B HS PTS. 90% serp, 6% brown serp, 4% opaques. Green serp. pseudomorphic after ol 1-2mm. Interstitial material brown fibrous serp Veins of amourphous isotropic serpentinite, opaque veins 0.2-0.3mm wide. Opaques, primary 0.2-0.3mm, dusting and veins. Sulphides almost completely haematized. Awaruite grains in serp, yellowish to white, highly anisotropic, tinges of greenish yellow. Smallish rounded magnetite grains in serp, much haematite. po, marcasite remnant, a little bit of covellite in a haematite grain probably indicating former presence of cp. HS fg, black; reddish green weathered surface. Some large poikilitic cleavage faces that "wink" in the sun.

2012B PTS HS (TS is wehrlite). 90% green serp pseudomorphic after ol. Interstitial brown serp, calcite, no remnants. Amorphous isotropic light green to yellowish serp veins. Opaques 3-5%, mostly haematized. Minor cp,po remnants, some marcasite. Magnetite, haematite, cp and po in opaque dusting 2-15 microns. cp most resistant to alteration, rest of former probable composite sulphide blebs haematized, one such with remnant cp, marcasite, violarite.

3002 HS, PTS, P. 85% + green serp, 5% calcite, brown serp, tremolite, 8% opaques. Some pseudomorphs after ol. Calcite cross fibrous in veins, associated with haematite. Brown serp and tremolite is interstitial material, very small gaps between roundish ol. Primary chromite, small cubic magnetite. Remnant po, cp, marcasite in large haematized blebs, some goethite. Chromites approximately Fe=Co, 2-3mm, fractured and in aggregates. Most remnant sulphide Ni-Fe. Chromites roundish blebs and as subhedral to euhedral grains. Some tiny Ni-Fe sulphides, 2 x 4 microns in opaque dust, millerite. Minor harzburgite. HS has a greyish brown weathered surface, white dolomite veins.

5001 HS, PTS. 85% light green serp, pseudomorphic after ol. 10% interstitial fibrous brown serpentine, 5% opaques. Minor ol remnants. Calcite veins cut trough pseudomorphs. Minor cpx remnant, one 4mm containing ol poikilitically, 0.5-1mm. An opaque grain, 0.5mm, has an altered silicate inclusion. Haematite, magnetite grains predominant. Marcasite, magnetite, haematite in opaque dust. HS black, fine grained with altered cpx, poikilitic, with cleavage phases that "wink" in the sun.

5008 HS,TS,PTS. 90% green serp pseudomorphic after ol; 5% white serp, calcite; 5% opaques. No remnants. Primary opaques, secondary dusting due to serpentinization and veins. Opaques definitely intercumulate in places, moulded around and filling spaces between former ol now serpentinized. Opaques weathered and pitted, mostly haematized. Minor cp, violarite remnants. Haematized cp + minor millerite dusting. HS fg, greenish grey; reddish grey weathered surface.

MEP2 195 HS, PTS. 90% green serp, 5% brown serp, 4% opaques, 1% calcite. serp almost isotropic. A few pseudomorphs after ol in green serp. Calcite crystals, bent. Thin veins in microfractures, cp, haematite, magnetite. Marcasite-py vein cutting through a fractured magnetite grain. Reticulate rectangular network of haematite in primary magnetite grains. Calcite vein with scattered cp and marcasite grains. Small interstitial cp blebs and worms. Some cubic magnetites. HS black, fg, with a calcite vein 2mm thick accross it.

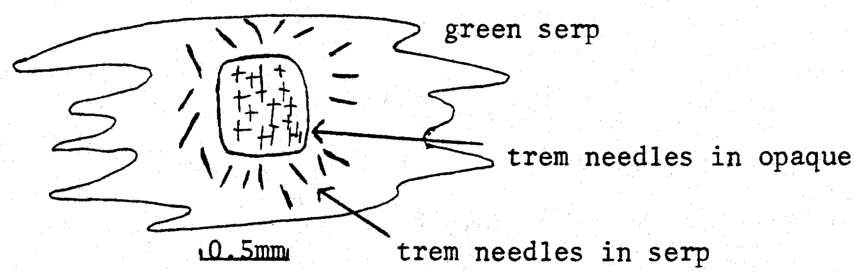
MEP4 26 HS PTS. 90% green serp, brown serp, calcite. Pseudomorphs after ol, slight pseudomorphism of brown fibrous serpentine, after poikilitic cpx. A few tiny 2-5 microns copper specks, pinkish red with a high reflectance. A few thin tarnished native copper veins in fractures, similar specks were seen in other dunites without having been identified positively. Minor cp bleb, a thin cp vein. Large formerly interstitial opaque grain, completely haematized, with a largish copper grain in it, remnant sulphides weathered out. HS black, fg, visible native copper specks and veinlets.

MEP4 131 HS PTS. 90% + green serp. 5% opaques. Calcite, brown serpentine, interstitial and veins of both. A few pseudomorphs after ol. Haematized, goethitized veins, interstitial grains, and dusting. Small cube of py, probably secondary. Minor cp remnant in haematized bleb. HS greyish green, fg, red goethite stain, calcite and green amourphous serp veins.

12) URALITIZED AND SERPENTINIZED PERIDOTITE:

M7 HS, TS. 30-45% green serp, pseudomorphic after ol, 20% opaques, 35% brown serp after pyroxene. Much is uncoloured to light green, almost isotropic mesh serp. Fibrous brown serp with undulatory extinction. Some opaques with silicate needles in them, such as the network illustrated in text Figure C(v). Much of the opaques due to serpentinization in aggregates in and around pseudomorphs; some probably primary.

TEXT FIGURE C(v):



MEP 4 132 HS, PTS. 80% green serp, half pseudomorphic after ol. 12% brown serp, 1% calcite, 7% opaques, veins and 1-5mm primary masses. calcite in brown serp suggest it is after cpx. An opaque mass has bent calcite crystals growing in it. Possible wehrlite. Opaques are mostly haematite, some magnetite slightly altered to haematite, cubiform. Interstitial sulphide blebs almost completely haematized, minor cp remnants. Opaque dusting of haematite and minor wormlike threads of cp. Most remnant cp almost totally weathered out. HS mottled greenish black and light greenish grey, limonite stained, fg.

DM4 130 HS, PTS, PS. 40% green serp, 5% calcite, 50% tremolite/ white serp, ol remnants. Vein of haematite-goethite-calcite, radiating crystals of haematite in an extention fracture, minor po blebs in part of this vein. Opaque dusting is haematite, magnetite, minor po and cp. A few cubic magnetite grains. ps shows "meshed" network of low temperature haematite, vugy. HS black, fg, with a 5mm haematite and calcite vein.

12(8) SERPENTINIZED WEHRLITE.

M27 HS,TS. 45% green serp (ol), 50% trem, calcite, a few cpx remnants. Calcite associated with trem, cpx remnants in trem suggest uralite after cpx. A few mesh textured, almost isotropic light green serpentine pseudomorphs after ol, 2mm. 1% or so primary opaques, 0.2 mm. Veins of haematite, calcite, clear tremolite. HS greyish and rough, red stained. Weathered surface brown.

M30 TS. 50% green serp, pseudomorphic after ol, 2mm. 3-4% opaques 0.2mm and opaque dust, haematized. 45% fg clear trem, 0.1-0.2mm blades. Minor cpx remnants.

5007 HS,PTS. 45% brownish green serp, mostly pseudomorphic after ol, 2mm. Clouded white tremolite containing a few cpx remnants, interlocking network of needles 0.1-0.3 mm long. Calcite, serpentine, and opaque veins. Much tiny po,cp, po-pn. Covellite, haematite, and magnetite opaque dust. Haematite of slightly different reflectively and colour, replacing probable former composite sulphide blebs. Some remnant secondary marcasite, with cubiform py grown in it. Oxidized, brown po, with cubiform haematite forms at one end possibly pseudomorphic after pn. A whitish, anisotropic, somewhat cubiform sulphide associated with haematite in a pitted po, probably a form between marcasite and pyrite (Ramdhor 1969). cp resisted alteration the most, po somewhat, very minor po or violarite probably after pn is present. A few scattered, probably secondary cubic py grains. The olivine pseudomorphs are surrounded by haematite veins, the uralite contains an evenly distributed assemblage of small magnetite grains. HS black, fg smooth; brownish weathered surface.

MEP2 526 HS, PTS. 45% green serpentine containing a few pseudomorphs after ol, 15% calcite, 35% brown serp. containing cpx remnants. Calcite and brown serp intermixed, some calcite veins also. Amorphous to cross-fibrous serp in a vein. A few brown serp-calcite pseudomorphs after pyroxene (cpx?). Scattered opaque dusting of magnetite and haematite. Cubic to circular primary magnetite, 0.2mm. Minor cp remnants in large haematite grains. Minor tiny cp,py, native metal specks in opaque dust. One large interstitial, primary sulphide grain (0.5mm) is rimmed by magnetite, pn altering to purplish violarite, pale yellow cp, po altering to marcasite and haematite. Possible small greenish yellow highly reflectant cubes of awaruite. Ilmenite grain, dark grey next to magnetite, isotropic, no internal reflections. Minor possible chromite, high Fe is not translucent red. HS fg, mottled greyish white to greenish black, calcite veins.

MEP4 19 HS, PTS. 80% green serp pseudomorphic after ol, some bent calcite crystals also in this serp. Brownish to grey fibrous serp containing one small cpx remnant, a few ol remnants in green serp. Opaque-calcite veins, 2% opaques 0.3mm primary blebs, veins, and dusting. Copper vein. po altering to marcasite, much haematite. Many former grains weathered out, leaving behind a rim of haematite. Possible highly reflectant whitish awaruite specks (MEP4 16-28 assayed 0.03Cu, 0.24 Ni). A copper vein at middle of goethite mass, vein due to direct reduction of sulphide? Minor cp remnants, a few small cp-po blebs, a thin cp vein, many haematite veins.

1?(9) SERPENTINIZED LHERZOLITE:

Fc67-615 TS. 50% green serp, pseudomorphic after ol, 1-3mm, 5% white to light brownish serpentine some pseudomorphic after pyroxene, cpx and opx remnants, a few cracked ol remnants. Strained opx remnant with undulatory extinction. Some pseudomorphs retain twin bands, topotactic replacement.

M24 HS,TS,PTS. 65% green serp, mesh textured. 30% trem, opx and cpx remnants and grey serp. 4% opaques. Needles of trem growing into a mesh textured probable pseudomorph after ol; serp formed before trem. a few pseudomorphs pseudohexagonal, 5mm. Pyroxenes altered to grey serp, trem needles. Magnetite-haematite veins, magnetite opaque dust, altering to haematite. Small subhedral hexagonal translucent isotropic chromite grains. Many are translucent in the middle to opaque near the edges indicating they are richer in Fe at the rims. Rectangular to square primary magnetites, altering to haematite. Little po,cp remnants, most probable primary sulphides haematized and weathered out. HS black to brownish, very rough and coarse grained.

M25 HS, TS. 5% green serpentine, rounded "blotches", haematite stained, almost isotropic. 40% trem, 5% opaques, calcite, opx and cpx remnants. Ghost fracture pattern in serp resembling that of ol, gs of these possible pseudomorphs after ol is 5mm. Trem is fg, 0.1-0.2mm, interlocking network of needles, a few half digested cpx remnants, small opx remnants only slightly encroached by trem. Probable former interstitial sulphide masses, filling some former intercrystalline spaces. HS(9), shistoze, mottled greyish-brown,

13 a AMPHIBOLITE:

FC67 613A TS. Minor brownish serp pseudo after ol, minor ol remnants. The pseudomorphs are fibrous brownish to white serp rimmed by amorphous isotropic serp, brown. The mattrix around these is fg trem, 10% 0.01mm opaque dusting. A few good pseudomorphs of trem after pyroxene, oriented needles, rest is interlocking haphazard network of clear to light green tremolite.

M10 TS. PTS. Amphibolite schist or tectonite. Grains very alligned to subaligned, 10% opaques concentrated in linear zones. White to greyish brown haematite, minor calcite, minor remnant cpx. Haematized opaque dusting, minor cp, magnetite remnants. py vein. Minor cp-po grains. One rhombohedral magnetite grain, may have deformed from more usual cubic shape during deformation which formed this sheared rock, aligning all the tremolite crystals. HS has slickensides smooth earthy red surfaces. Can see marked parallelism or shistosity of the sheared rock on cut surface.

MEP4 477 PTS, HS. 95% pleochroic brown hornblende, up to 1cm gs undulatory extinction, often bent at the ends, "fibrous" appearance of cleavage planes. Minor plagioclase, one small 0.5mm ol grain. Minor opaques. Minor fg altered hornblende. Therefore is this hornblendite? Ultramafic rocks intruded wet sediments or sedimentary rocks, hydrated minerals formed near the contact. Tiny specks of cp.po, larger blebs po-(cp), quite a few tiny sulphide specks inside the hornblendes, is that evidence for possible metamorphic origin? Hornblendite. HS greyish green, mixed fg and cg material up to 1 x 5 cm.

13 b SERPENTINE BEARING AMPHIBOLITE:

M1 HS, TS. 60% actinolite, 10% calcite, 23% brown serp, 2% opaques, cpx remnants. Length show fibrous greenish serpentine pseudomorphs after pyroxene, minor cpx remnants in serp so may be after cpx. White to dark green pleochroic euhedral actinolite crystals, fg mesh, with minimal opaque mineralogy associated. Blades and plates of antigorite serpentine, bent, exhibiting undulatory extinction. Opaque mineralogy primary, 0.2mm, cut by antigorite. HS dark bluish green, platy minerals 1 x 1.5 cm that catch the sun; abundant white calcite, minor talc.

M6 HS, TS. 65% trem, 15% serp pseudomorphic after ol, 20% brown serpentine. Light green, almost isotropic serp, tinged red by haematization.of opaque dusting.. Brownish serp possibly after cpx. Trem blades are seen growing into serp, some trem also directly replacing serp. Much opaque dust is trem and serp. HS greenish red, 1mm platy green minerals; weathered surface brownish-bluish green, extensive haematization.

MEP2 249.6 HS, PTS. 80% trem, minor cpx remnants; 20% amorphous isotropic veins serpentine. Granulated fg colourless trem. Tiny specks and blebs of magnetite-haematite. Copper specks, some tarnished. HS light green, fg vein of amorphous serp and tinygrains of native copper.

MEP2 505 HS, PTS. Two juxtaposed rock types, a serpentinized dunite and a tremolite Sharp contact, cpx seen in both, ol seen only in the dunite. Opaque dusting ubiquitous. Numerous tiny white specks, may be awaruite. Remnant po,cp, much haematite. cp veins into fracture, mobilized from a bleb. Haematite aligned along cleavage planes of trem pseudomorphs after pyroxene. Cracked po, with a cubic pn juxtaposed. Native copper,vein of po, and small inclusions of magnetite.

MEP3 171A PTS,HS. 65% brown hornblende to greenish actinolite. 30% brown serp, minor trem, cpx remnants. Many hornblendes do not extinguish on rotation, colouration moves around 2mm. Amorphous brownish serpentine vein po,cp blebs, tiny, in and between alteration minerals. Stringers of sulphide in cracks and cleavage planes of hornblende. Larger primary sulphides much altered, remnant po, cp, violarite. No oxide dust seen. HS greenish grey with veins of py, and amorphous light green serp.

MEP3 171B PTS,HS. As above, but section cut along core to intersect vein of fg pyrite. Apart from this vein section is almost devoid of opaques. Vein is py, half weathered out, minor silicate inclusions, some cubic forms. Some tiny bluish covellite grains with an alteration haloe around them, this effect was also seen in other sections. A fractured triangular interstitial cp grain .

MEP3 194 PTS, HS. 75% brown hornblende to greenish actinolite, 25% interstitial brown serp, trem, cpx remnant . A brownish green serpentine vein full of 0.1mm fragments of cpx, minor opaques and calcite. Brownish hornblende to greenish tremolite form pseudomorphic outlines after pyroxene, but the crystals in the pseudomorphs are oriented haphazardly. Minor cp, po blebs, a few magnetite specks in the alteration silicates. HS greyish, with green amorphous serp veins with smooth possibly slickensided surfaces at each end.

13) (1) URALITIZED WEBSTERITE

M23 HS,TS. Trem, minor actinolite, 3% opaques, opx and cpx remnants. Trem is 0.1-0.5mm, fibrous to bladed, white to slightly greenish and pleochroic, a few pseudomorphic shapes after pyroxene which indicate the primary silicates had three point junctions. Some remnant cpx twinned, alteration amphibole mimic twinning.

MEP1 537 HS, PTS. 75% trem, 15% cpx, 5% px, 3% serp, 2% opaques. Serp in a light greenish-brown vein , trem 0.2-0.3mm, some euhedral prismatic crystals to 0.5mm radiating from a nucleus. A large opx, 1 x 4 mm, incipiently altered to brownish fibrous serp. Opaques, dusting and primary masses 1-2mm, interstitial po-pn-cp composite grains, pitted and weathered. cp blebs and grains, pinkish po. po-pn contact clean to mixed, some po inclusions in pn. cp-pn contacts clean, rounded. pn flames in po. In places all three phases in contact, pn somewhat euhedral, cubic. One pn, associated with po and cp, includes a triangle of cp. Composite po-pn, with rounded bleb of po in pn. HS dark green, fg, vein of serp-calcite; radiating crystals of marcasite on its surface.

13(4) URALITIZED PYROXENITE, with cpx remnants:

FC67 613B TS. Trem, a few cpx remnants. Much opaque dusting. Network of fg 0.1mm trem.

F67F613 TS. Trem, cpx remnants, 5% opaques, mostly secondary dusting. Pseudomorphic after pyroxene rimmed by opaques, 2mm. Primary opaque bleb 0.25mm.

M17 HS, TS. 96% trem, 2% opaques,fibrous serp, calcite, remnant cpx. trem 0.2mm, minor cpx remnants exhibit strain twinning. A few 1cm fibrous serp crystals, antigorite? Opaque dusting much haematized.

1006 Gc, HS,PTS, TS, 90% + trem, 5% opaques, 1% calcite, serp, remnant cpx. Trem mesh, some radiating crystals. Pseudomorph after pyroxene, 1-2 mm. Opaque dusting mostly haematite, minor magnetite, minor sulphide. larger primary sulphide belbs almost completely haematized, minor po,pn remnant, marcasite. HS grey, fg. cpx remnants twinned, many exhibit undulatory extinction, contain opx exsolutions.

2007 C HS, PTS. 95% trem, 2% remnant cpx, 2% opaques, 1% calcite. Trem slightly greenish in places, opaque dusting not as concentrated as usual. Remnant cpx with undulatory extinction. Bent calcite crystals. A calcite-serp-haematite vein. Magnetite, haematite dusting alligned between trem crystals. cp-po grains, greenish yellow cp, very haematized po. Bird's eye texture, marcasite-magnetite replacement of po. Covellite alteration of cp. Many 0.05 mm wide haematite veins. Yellowish to whitish-grey, slightly anisotropic py cubes. HS reddish green, mg; rusty red to greenish brown weathered surface.

2009A HS, PTS. 95% trem, minor cpx remnants, 5% opaques. Large, fibrous, striated trem plates, 3-5mm wide, minor green serp veins. Minor small cpx remnants, one 2mm with ragged twinning and undulatory extinction. Opaques 2-3mm, and opaque dust. po-cp-pn composite grains, purplish violarite altering pn; po reddish brown weathered, oxidized and altered to marcasite needles in places. Some bent, altering cleavage planes in po. Vein cutting primary sulphide ,stringers and grains of po. Cubic inclusion of py in po partially altered to bravoite. HS green cg; weathered surface red to reddish green, disseminated sulphides 2-10mm, cp and po veins.

2010A HS, PTS. 75% trem/actinolite, 20% cpx, 4% opaques, 1% calcite, serp. Vein of fibrous crysotile, cutting an opaque mass. Light green pleochroic actinolite and very fg trem. Fractured cpx, with undulatory extinction. Secondary silicates inpinge on and grow into grains, po altered to haematite and magnetite. Abundance of cp in part of slide. Whitish, highly anisotropic haematite altering po, cp. Pn with cubic fracture pattern partially altered to bravoite and purple violarite. cp-pn grains, pn often has idiomorphic boundary with cp, incipient alteration to violarite. cp-po, latter altering to marcasite and magnetite. HS greenish-grey, fg.

2010B HS, PTS. 90% trem, 5% opaques, 5% serp, minor cpx remnants. Numerous narrow green amourphous serp veins. Fibrous, bent, trem pseudomorphic after pyroxene. Interstitial sulphides, po-pn-(cp). cp vein, granular. po, pn highly altered, oxidized, cp fresh. po-pn blebs common, some intermixed, others with idiomorphic pn contacts. pn monomineralic grains. HS green, 5% disseminated sulphides, reddish brown weathered surface.

3003A HS, TS. 90% trem, 5% calcite, 4% opaques, talc, cpx remnants. Trem 0.2mm, bent calcite crystals. No pseudomorphs. Minor cpx remnants twinned. Opaques 0.1-0.3mm, needles of trem growing into them. Opaque dust. HS sugary, dark bluish-green. Earthy brown weathered surface.

4004A HS, TS, PTS. 85% trem, 10% opaques, 3% brown serp, 2% cpx remnants, 2mm cloudy and incipiently altered. Half the trem is fg, unoriented, meshed, other half replaced pyroxene exactly with opaques outlining former crystallographic planes, 1.5-2mm, magnetite. po, cp dusting. Primary po-pn 0.2mm. Hs green, rough, massive. Reddish green weathered surface.

4009 HS, TS 85% trem, minor brown hornblende, 10% opaques, 2% green serp, 1% calcite, 2% cpx remnants. Interlocking mesh of trem, one ol pseudomorph, 1.5mm. Opaque dusting, minor 0.1 mm primary opaque blebs. Pleochroic brown hornblende, euhedral, altering to serpentine. HS grey, f-mg 1-3mm, brownish goethite rich weathered surface.

4013 HS, PTS. 80% trem, 10% remnant cpx, 5% ol or serp pseudomorphic after ol, 5% opaques. Undulatory extinction exhibited by some cpx, 2mm. Trem fg mesh,some pseudomorphic shapes after pyroxene. Haematite, minor magnetite paque dusting. cp-po, highly altered, po much haematized. Sub-cubic pn grain. HS greenish, red stained. Brown to reddish brown weathered surface, deeply weathered, much goethite.

4014 HS, PTS. 90%+trem, 5% opaques, 2% remnant cpx. Clouded, incipiently altered cpx, much colourless trem, pseudomorph after pyroxene have higher relief than trem mesh. Magnetite, haematite, minor sulphide opaque dusting. cp remnant, much of the primary interstitial sulphides altered to haematite. Minor remnant po,pn cp-po, cp-po dusting. po brownish pink. cp fresh, clean curved boundary between them. Specks of covellite. Alteration of numerous cp blebs to haematite and magnetite along rims. HS mg, grey; dark grey to black weathered surface.

5002 HS, PTS. 80% trem, 15% cpx, 5% opaques. Some cpx remnants twinned, 1-2mm. fg colourless trem. Opaque dusting of haematite, thin haematite veins. Interstitial cp, cp-po, cp-po-(pn), Much alteration of po, haematization, and marcasite-magnetite birds eye texture. cp-pn grains, primary magnetite. A cubic pn, partially altered to violarite, in cp. cp altered to reddish brown isotropic to weakly anisotropic bornite. HS, green massive to fibrous, red to reddish brown weathered surface. Opaques weathered to goethite and limonite.

MEP1 85 HS, PTS. 90%+ trem, 5% cpx remnants, 2% opaques, calcite. Trem 0.1-0.2mm mesh, 1mm cpx remnants. Opaques mostly haematized and weathered out. HS gritty, light green, calcite veins and limonite; highly weathered.

MEP1 513.5 PTS, HS. 85% trem, remnant cpx, calcite, antigorite with fg bright green pleochroic chlorite next to it. Some large, radiating, acicular trem blades. Large fibrous oriented trem plates made reddish by haematized opaque dust. Incipient alteration of trem to brownish serp, outlining pseudomorphically former pyroxenes. Calcite associated with tremolite and chlorite Minor composite po-pn, po-cp blebs. Minor po, magnetite in opaque dust, mostly haematite.

HS dark green to black, some fibrous greenish platy minerals (antigorite).

MEP3 134 HS, PTS. 90% hornblende, 3% cpx remnants, 2% opaques, 5% calcite/dolomite. Serp-calcite vein, 2.5 mm wide, euhedral calcite crystals. Colloform textures in calcite and serp. Opaques 0.2-0.4mm. Hornblende cloudy, 2mm. Hornblende may be pseudomorphic after pyroxene. Rotary cruciform extinction in serp. Opaques very altered, pitted, haematized. Haematite in hornblende cleavage planes. HS granular, blotchy greenish. Calcite-serpentine veins. Rock seems to be recrystallized metamorphically.

MEP4 228, A,B HS, PTS, TS. 89% trem, 10% cpx remnants, 1% opaques Brown, low temperature colloform serp vein. Minigeodes with calcite crystals at the focus. fg trem, some fibrous and pseudomorphic after pyroxene. py vein. Haematite dusting and thin stringers . py cube in trem. cp belbs in opaque dust. HS light grey, fg, dolomite-calcite and serp veins.

MEP4 233 HS, PTS. trem, minor calcite intermixed, cpx remnants. Calcite vein, interlocking grains with some opaque grains in their centre. Small round bleb of cp in cpx remnant. Round po bleb, half altered to py. Much haematite, minor magnetite dusting. po-pn, altering to haematite, violarite, bravoite. Composite po-cp blebs. py vein. HS greenish grey, calcite-haematite-py veins.

MEP4 539.3 P, HS, PTS. 60% trem (fg), 10% cpx remnants, 10% brown hornblende, 5% serp, 15% cg trem. cpx remnant, 0.5mm, some twinned. Brown hornblende 1mm, cg trem 0.5-1mm, euhedral. Scattered sulphides seem broken up and mixed with alteration silicates cp-po,po-pn, po-pn-cp. Alteration of po to marcasite. po with small round pn bleb. cp, po-pn veinlets. Large cp grains, impinged by trem. Some pinkish to purplish oxidation of po, possibly indicating Ni content. cp brass yellow, fresh, clean and curved boundary with po. Cubic idiomorphic pn between po, cp. Magnetite, sometimes cubic, haematite and minor sulphide opaque dust.

Y HS, PTS. 78% trem, 2% brown hornblende, 15% cpx, 5% opaques. cpx incipiently altered to trem. Brown hornblende after pyroxene. cp vein, intermixed with some silicates. po-cp, pinkish po. Scattered cp specks. Completely haematized to weathered out blebs of former sulphides. HS greyish green, cp veins, calcite and limonite.

DM4 135 HS, PTS. 95% trem, 5% cpx remnants, brown serp veins. opaque veins cutting through cpx. Haematite vein cutting py vein, altering to marcasite except where cut by haematite veins. Some mixed py, haematite veins. Altered on-po grain, 1mm, pinkish po oxidized pn.

13(5) URALITIZED FELDSPATHIC PYROXENITE: With cpx remnants.

MEP2 125 HS, PTS. 75%+ trem, 15% cpx remnants, 2% Fd, 3% serp, 2% opaques, mostly haematite-magnetite dust, a few cp, cp-po blebs. Native copper vein, specks, one in middle of haematite mass. Serp yellowish green, almost isotropic, untwinned plagioclase, colourless fg trem. HS greyish black, fg, visible native copper.

MEP2 248.6 HS. PTS. 95% trem, minor cpx, Fd. gs 0.2-0.3mm, granular trem with 3 point junctions common, Minor remnants cpx, raggedly twinned. cp, cp-po specks, 2-3 microns. HS greyish green, fg.

MEP4 303 HS, PTS. 85% trem, 10% serp, opaques, cpx remnants, plagioclase. Serp greenish brown; trem colourless, fg. Haematite dusting, native copper specks, larger 0.2mm grains completely haematized.

XI HS, PTS, P. 50% trem, 30% hornblende, 10% cpx, 7% opaques, Fd, serp. Hornblende greenish brown, pleochroic, cpx remnants. cp-po, po-pn, cp-po-pn grains. Exsolution blebs cp in po. cp veinlets off cp in composite grains. Some intimate mixture po-pn in centre of po grain, unmixing? Boundaries between phases usually clean, or less sharp in direct exsolution features. pn flames in po. The larger grains contain the most pn, possibly the smaller po grains are nickeliferous, Many cp, po, cp-po blebs, 5 microns, larger interstitial blebs up to 4mm. Cobalt content of po seems to drop with production of marcasite-py alteration minerals, po, cp predominate pn proportionally less than in rocks with less sulphide. HS greenish blck, 10-15% sulphide, minor oxide grains.

13(6) URALITIZED, SERPENTINIZED OLIVINE CLINOPYROXENITE

MEP4 286 HS, PTS. 60% + trem, 10% cpx remnants. 20% serp, 7% opaques, 3% calcite. fg green to colourless alteration minerals, remnant cpx 3mm, mostly twinned, intermixed calcite. Opaques up to 2mm, haematite-calcite veins. Altered, weathered po, small 2 micron round cp in a cracked cpx. A few small cp-po grains. Mostly dendritic haematite veins. HS greyish-white, much haematite, limonite and calcite.

14 GABBRO:

M3 HS, TS, PTS, P. 70% Fd, An50; 27% green pleochroic hornblende, minor trem. Some of the plagioclase untwinned, some with undulatory extinction along twin boundaries. Some radial strain shadows. Hornblende (pargasitic?) at times twinned about C axis. fg trem may be after pyroxene. Hornblende 2-4mm, plagioclase 0.5-3mm. Opaques 0.1-1mm. cp, ilmenite predominant.Magnetite blebs in amphiboles. Composite po-ilmenite grains. cp veins, cp-pn grain in a hornblende. Some violarite alteration of po, pn. Ilmenites contain subequal amounts of Fe, Ti, some Ca, Si as well as Fe, Ti containing spinels. Most the ilmenites are rounded, anhedral blebs, some euhedral, hexagonal. po vein. A magnetite-cp grain, magnetite altering to haematite. HS light grey, gs 3-4mm, long bladed hornblende crystals.

MEP1 627.7 HS, PTS. 45% Fd, 10% cpx, 10% chlorite and hornblende, 35% trem. Light green, fg, pleochroic chlorite, greenish pleochroic hornblende. Trem and calcite. Much of the plagioclase is untwinned. Trem growing into plagioclase. Opaques very low, tiny haematite specks, cp, po specks. HS greyish to white, massive.

MEP1 637 HS, PTS. 55% Fd(An50), 5% trem, 40% green hornblende, pleochroic, 1-2mm. Plagioclase half untwinned, interlocking network 3mm and 1mm grains, metamorphically annealed, patchy, strained extinction. Minor po, cp grains 3-20 microns, some tiny haematite grains. HS whitish grey.

DM3 144 HS, PTS. 55% Fd, 30% hornblende, 5% opaques, veins and 1mm blebs. Hornblende greenish-brown, pleochroic, plagioclase mostly untwinned. cp predominant, minor po. A cp with plagioclase blade growing through it. cp-pn, cp-po-pn grains. HS light grey, mg, some fibrous marcasite on the surface.

DM3 152 HS, PTS. 55% Fd (An40), 40% hornblende, 5% opaques. Hornblende green, pleochroic, often surrounded by Fd. po-cp-pn composite grains, po-(cp), cp. Smooth, clean rounded contacts between cp, po; straight contacts between po, pn. pn with triangle of po inside it. HS greyish green, visible disseminated cp.

14(13) GABBROIC AMPHIBOLITE:

MEP4 374 2 rock types, HS, PTS. 1) 40% actinolite, 40% brown serp, 20% Fd. 2) cpx, twinned.contact to clinopyroxenite quite sharp, latter contains only a little plagioclase. Minor opaque specks in 2, little in 1. po, cp, stringers of cp off larger grains. Minor small po grains in 1.

15) GRANITE:

M40 HS, TS, Gc. 3-4% pleochroic greenish to brown biotite, some alteration to chlorite. 35% quartz, 1-2mm, some isotropic. 40% plagioclase, untwinned, 20% K feldspar granoblastic. A slight shear, recrystallized fg patch in slide. Granodiorite. HS greyish, biotite granite, white and pink feldspar, gneissic banding, 5% biotite, gs 1-2mm.

MEP3 233 HS, PTS. Quartz vein. Network of welded 5mm quartz grains, each with an interlocking network of fine fractures, undulatory incomplete extinction. No opaques.

DM3 185 A,B HS, PTS. Contact region between granite and greenish fg amphibolite from DM3 169 to 196. Granodiorite is 7% green pleochroic hornblende, biotite, chlorite. 25% quartz, 1mm, some grains annealed. 40% plagioclase, 30% K feldspar, Granoblastic. Grain size in bands of 2-3mm and 0.5mm, all annealed and sutured Opaques are haematite, minor remnant sulphide. Contact with uralite is quite sharp, except that the granodiorite is richer in mafics near it. Ultramafitite is 80% fg greenish brown hornblende, and 20% granitic material: plagioclase, minor quartz and orthoclase. The ultramafitite seems more contaminated than the country rock, and much finer grained - Q- dioritic. Haematite specks, tiny cp po specks 5 - 10 microns.

(b)

List of sections, determined rock type, and University of Saskatchewan number where applicable.

Abbreviations:

TS	Thin Section
PTS	Polished thin section
PS	Polished section
HS	Hand sample
P	Electron microprobe analysis
Gc	Geochemical analysis
S	Sulphur analysis
serp	Serpentinized
ur	Uralitized
(cl)	Clinopyroxene remnants
Feld	Feldspathic

Thin Sections Provided by L.H. Forsythe, Saskatchewan Geological Survey:

Number	Rock Type	
F C67-611	Olivine clinopyroxenite	TS
F C67-612	Olivine clinopyroxenite	TS
F C67-613A	Amphibolite	TS
F C67-613B	(cl)ur. pyroxenite	TS
F C67-614	Olivine websterite	TS
F C67-615	serp. Lherzolite	TS
F C67-616	Wehrlite	TS
F C67-618	Olivine websterite	TS
F C67-619	Olivine clinopyroxenite	TS
F 67F-613	(cl)ur. pyroxenite	TS
F 67F-614	Websterite	TS
F 67F-615A	Olivine websterite	TS
F 67F-615B	Olivine websterite	TS
F 67F-616	Serpentinite(Dunite?)	TS

Samples Collected by McCormick:

Also included in this suite are core samples from MEP1, MEP2, MEP3, MEP4 drill holes, and a few core samples from D.M. holes, these are not given University of Saskatchewan numbers except the ones that were sectioned.

Number	Location	UofS Nos.	Rock Type	
M1	13E 25S	11878	Serpentine amphibolite	HS,TS
M2	12W 65S	11879	Olivine websterite	HS,TS
M3	02001	11880	Gabbro	Gc,PTS,HS,TS.P
M4	17S 22W	11881	Olivine websterite	HS,TS
M5	00BL 11E	11882	Websterite	HS,TS
M6	06W+60 250S+25	11883	Serpentine amphibolite	HS,TS
M7	00BL 8E+20	11884	Ur.serp. peridotite	HS,TS
M8	11+30W 500S	11885	Webserite	HS,TS
M9	12W+25 25S	11886	Websterite	PTS,HS,TS
M10	5W 125N	11887	Amphibolite schist	HS,TS
M11	17W 25S	11888	Wehrlite	HS,TS
M12	12W 24S	11889	Olivine websterite	HS,TS
M13	12W25 25S	11890	Websterite	HS,TS
M14	12W 18S	11891	Feld. Websterite	PTS,HS,TS
M15	008BL-9E float	11892	Harzburgite	PTS,HS,TS
M16	14W+40 40S+25	11893	Wehrlite	HS,TS
M17	00BL 8E+20	11894	(cl)ur. pyroxenite	HS,TS
M18	00BL 13E	11895	Olivine clinopyroxenite	Gc,PTS,HS,TS
M19	00BL 15E	11896	Clinopyroxenite	HS,TS
M20	3S+16E trench	11897	Websterite	HS,TS,P
M21	00BL 14E	11898	Websterite	HS,TS
M22	16+25S	11899	Olivine clinopyroxenite	HS,TS,P
M23	00BL 17E	11900	Serp. Websterite	HS,TS
M24	12W 17S+50	11901	Serp. lherzolite	PTS,HS,TS
M25	5W 125N	11902	Serp. Lherzolite	HS,TS
M26	16W+50 2500S	11903	Websterite	HS,TS
M27	30W+13 26S+20	11904	Serp. wehrlite	HS,TS
M28	12E 1S	11905	Olivine clinopyroxenite	HS,TS
M29	12+50W 20S	11906	Clinopyroxenite	PTS,HS,TS
M30	13+30W 26S	11907	Serp. wehrlite	TS
M31	14W+30 26S	11908	Uralite	HS
M32	North end	11909	Pyroxenite dyke in serpentinite	HS
M33	"	11910	Feld.ur. peridotite	HS
M34	"	11911	Granite gneiss	HS
M35	"	11912	Granite gneiss	HS
M36	"	11913	Granite gneiss	HS
M37	"	11914	Granodiorite gneiss	HS
M38	"	11915	Porph. granodiorite	HS
M39	"	11916	Q-B-F-gneiss	HS
M40	"	11917	Granodiorite	TS,HS,Gc.

Drill core samples sectioned:

Number	UofS No.	Rock Type	
MEP1 85'	11918	(cl)ur. pyroxenite	PTS
MEP1 470.10'	11919	Olivine websterite	PTS
MEP1 513.5'	11920	(cl)ur. pyroxenite	PTS
MEP1 537'	11921	serp. websterite	PTS
MEP1 582.7'	11922	Feld. olivine clino-pyroxenite	PTS,P
MEP1 627.7'	11923	Gabbro	PTS
MEP1 637'	11924	Gabbro	PTS
MEP2 125'	11925	(cl)ur. feld. pyroxenite	PTS,PS
MEP2 195'	11926	Dunite	PTS
MEP2 248.6'	11927	(cl)ur.feld. pyroxenite	PTS
MEP2 249.6'	11928	serpentine amphibolite	PTS
MEP2 390'	11929	olivine clinopyroxenite	PTS
MEP2 505'	11930	serpentine amphibolite	PTS
MEP2 526'	11931	Serp. wehrlite	PTS
MEP3 134'	11932	(cl)ur. pyroxenite	PTS
MEP3 171'A	11933	Serpentine amphibolite	PTS
MEP3 171'B	11934	Serpentine amphibolite	PTS
MEP3 194'	11935	Serpentine amphibolite	PTS
MEP3 233'	11936	Quartz vein	PTS
MEP3 322'	11937	Clinopyroxenite	PTS
MEP3 337'	11938	Olivine clinopyroxenite	PTS
MEP4 19'	11939	Serp. wehrlite	PTS
MEP4 26'	11940	Dunite	PTS
MEP4 131'	11941	Dunite	PTS
MEP4 132'	11942	Ur. serp. peridotite	PTS
MEP4 228'A,B	11943	(cl)ur. pyroxenite	PTS
MEP4 233'	11944	(cl) ur. pyroxenite	PTS
MEP4 286'	11945	Ur. serp. olivine clinopyroxenite	PTS
MEP4 303'	11946	(cl)ur.feld pyroxenite	PTS
MEP4 374'	11947	Gabbroic amphibolite	PTS
MEP4 477'	11948	Amphibolite	PTS
MEP4 539.3'	11949	(cl)ur. pyroxenite	PTS,PS,P
XI, II(Dunlop)	11950	clinopyroxenite(feld)	PTS,P
Y(Dunlop)	11951	(cl)ur. pyroxenite	PTS
Z(Dunlop)	11952	Feld. websterite	PTS
DM3 144'	11953	Gabbro	PTS
DM3 152'	11954	Gabbro	PTS
DM3 185' A,B	11955	Granodiorite	PTS
DM4 130' A,B	11956	Ur.serp. peridotite	PTS,PS
DM4 135'	11957	(cl)ur. pyroxenite	PTS

Rock samples collected by Neil Macfarlane:

Numbers		U of S No.	Rock Type	
1001A	North end	11958	Wehrlite	HS,TS
1004A	North end	11959	Feld. clinopyroxenite	HS,PTS,TS,Gc
1006	Unknown location	-	Ur. pyroxenite	PTS,TS,Gc
2001		11960	Dunite	HS,PTS
2003A		11961	Feld. clinopyroxenite	HS,PTS,P
2003B		11962	Pyroxenite	HS
2003C		11963	Clinopyroxenite	HS,PTS
2004A	trench 1	11964	Ur. pyroxenite	HS
2005		11965	Ur. pyroxenite	HS
2006		11966	Lherzolite	HS,PTS
2007A		11967	Clinopyroxenite	HS,PTS,P
2007B		11968	Pyroxenite	HS
2007C		11969	Ur. Pyroxenite	HS,PTS
2008A		11970	Dunite	HS
2008B		11971	Dunite	HS,PTS
2009A		11972	Ur.Pyroxenite	HS,PTS
2010A		11973	Ur. pyroxenite	HS,PTS
2010B		11974	Ur. pyroxenite	HS,PTS
2010C		11975	Ur. pyroxenite	HS
2010D		11976	Pyroxenite	HS
2011	trench 4	11977	Pyroxenite	HS
2012A	"	11978	Dunite, wehrlite	HS,TS,PTS,Gc
2012B	"	11979	Dunite	HS
3002		11980	Dunite	HS,PTS,P
3003A		11981	(cl)ur. pyroxenite	HS
3003B		11982	Serpentinite	HS
3004		11983	Clinopyroxenite	HS,PTS
3005		11984	Pyroxenite	HS
3005B		11985	Clinopyroxenite	HS,PTS(x2)
3005C		11986	Ur. pyroxenite	HS
3005D		11987	Ur. pyroxenite	HS
3005E		11988	Ur. pyroxenite	HS
3005F		11989	Ur. pyroxenite	HS
3006	trench 3	11990	Ur. pyroxenite	HS
3007	"	11991	Ur. pyroxenite	HS
4004A		11992	Ur. pyroxenite	HS,TS,PTS
4004B		11993	Olivine websterite	HS,TS,PTS,Gc
4004C		11994	Ur. pyroxenite	HS
4004D		11995	Ur. pyroxenite	HS
4008	East central	11996	Websterite	HS,TS
4009	"	11997	Ur. pyroxenite	HS,TS

Numbers	U of S Nos.	Rock Type	
4013	11998	Ur. pyroxenite	HS,PTS
4014	11999	Ur. pyroxenite	HS,PTS
4015	12000	Wehrlite	HS,TS,PTS
4016	12001	Wehrlite	HS,PTS,P
4017	12002	Websterite	HS,PTS
4018	12003	Wehrlite	HS,TS,PTS
5001	12004	Dunite	HS,PTS
5002 A	12005	Ur. pyroxenite	HS,PTS
5002 B	12006	Uralite	HS
5003	12007	Ur. pyroxenite	HS
5004	12008	Ur. pyroxenite	HS
5005	12009	Ur. pyroxenite	HS
5006	12010	Ur. pyroxenite	HS
5007	12011	Serp. wehrlite	HS,PTS
5008	12012	Dunite	HS,TS,PTS
5009	12013	Wehrlite	HS

APPENDIX D

ELECTRON MICROPROBE ANALYSES

Tables IV(iii) to IV(xii) are placed in this appendix. They are tabulations of the analytical results, calculations, and pertinent notes on each phase analysed using the Acton MS64 electron microprobe at the University of Saskatchewan. The ten slides chosen for analysis were first examined using the energy dispersive system with the Princeton Gamma Tech 1000 visual display for selection of suitable grains. Analysis was by the wavelength dispersive spectrometer method with an accelerating potential of 25 Kv, a sample current of 30 mV and a 40 s. counting time. The first batch run on each sample analysed for Fe, S, and Cu. A pyrrhotite standard (No:048) was used for S and Fe, a copper standard (NO:004) for Cu. The second batch analysed for Ni and Co with a millerite (NO:055) and cobalt (NO:059) standard respectively. Three to five spots per grain, depending on size and homogeneity, were averaged. The EMPDAR matrix correction procedure was used in calculating results after the counts were automatically punched onto computer cards.

Abbreviations:

Po	.........Pyrrhotite	Marc	.... Marcasite
Pn	.... Pentlandite	Viol	.... Violarite
Cp	.... Chalcopyrite	M	.... Total Metals

TABLE IV(iii)a

M20 Uralitized Websterite

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
		Weight Percent					Molecular Proportions				
Po1	101.59	39.91	61.11	0.11	0.45	0.0	1.245	1.094	0.002	0.008	0.0
Po2	99.68	38.41	60.60	0.13	0.53	0.0	1.198	1.085	0.002	0.009	0.0
Po6	102.69	40.04	62.11	0.13	0.41	0.0	1.249	1.112	0.002	0.007	0.0
Pn1	97.97	32.49	30.60	0.78	34.10	0.0	1.013	0.548	0.013	0.581	0.0
Pn2	96.50	33.64	29.68	0.82	32.31	0.03	1.049	0.531	0.014	0.551	0.001
Pn4	96.61	32.82	30.58	0.80	32.40	0.02	1.024	0.548	0.015	0.552	0.0
Pn5	95.45	32.72	29.51	0.90	32.28	0.04	1.021	0.528	0.015	0.550	0.001
Pn6	95.89	33.17	29.51	0.96	32.24	0.01	1.034	0.528	0.016	0.549	0.000
Vio14	93.84	40.25	22.00	1.16	30.43	0.0	1.255	0.394	0.02	0.519	0.0
Cp1	101.01	34.21	31.19	0.06	0.0	35.50	1.064	0.558	0.001	0.0	0.559
Cp2	101.36	34.85	31.38	0.08	0.0	35.01	1.087	0.562	0.001	0.0	0.551
Cp3	103.30	36.66	31.25	0.06	0.08	25.19	1.143	0.560	0.001	0.001	0.554
Cp4	101.97	35.49	31.51	0.10	0.22	34.62	1.107	0.564	0.002	0.004	0.545
Cp5	101.85	34.35	31.67	0.08	0.04	35.66	1.071	0.567	0.01	0.01	0.561
Cp8	101.36	35.59	31.10	0.07	0.00	34.57	1.110	0.557	0.001	0.0	0.544

TABLE IV(iii)b

Versus 1S	Fe	Co	Ni	Cu	M	Notes
	Atomic Proportions					
Po1	0.879	0.002	0.006	0.0	0.887	Composite grain 1, altered.
Po2	0 906	0.002	0.006	0.0	0.916	Composite with Pn2, Cp2.
Po6	0.890	0.002	0.006	0.0	0.898	Composite grain with Pn6.

TABLE IV(iii)b
(Continued)

Atomic Proportions						Notes
Versus 8S	Fe	Co	Ni	Cu	M	
Pn1	4.33	0.10	4.59	0.0	9.02	From composite grain 1.
Pn2	4.05	0.11	4.20	0.0	8.36	Violaritized small bleb at edge of Po2.
Pn4	4.28	0.11	4.31	0.0	8.70	Altered slightly
Pn5	4.14	0.12	4.31	0.0	8.57	Discrete Pn grain.
Pn6	4.09	0.12	4.25	0.0	8.46	Composite with Po6.
Versus 4S						
Viol4	1.256	0.063	1.654	0.0	2.973	Alteration of Pn4.
Versus 1S						
Cp1	0.523	0.001	0.0	0.524	1.05	Composite grain 1.
Cp2	0.511	0.0	0.0	0.507	1.03	Composite grain 2.
Cp3	0.490	0.001	0.001	0.485	0.98	Small grain, included in clinopyroxene.
Cp4	0.509	0.002	0.004	0.492	1.01	Small, next to Pn4.
Cp5	0.529	0.001	0.001	0.524	1.06	Discrete bleb.
Cp8	0.502	0.001	0.0	0.490	0.99	Discrete bleb in clinopyroxene cleavage.

TABLE IV(iv)a
2003A Felspathic Clinopyroxenite

	Weight Percent						Molecular proportions				
Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po1	104.34	42.16	61.39	0.20	0.59	0.01	1.315	1.099	0.003	0.01	0.0
PoB	99.84	40.87	57.75	0.22	0.75	0.25	1.275	1.034	0.004	0.013	0.004
Po3	85.67	30.96	54.61	0.10	0.0	0.0	0.935	0.978	0.002	0.0	0.0
Po5	92.95	31.50	61.34	0.10	0.0	0.0	0.982	1.09	0.002	0.0	0.0
PoD	116.92	53.65	62.94	0.10	0.23	0.0	1.673	1.127	0.002	0.004	0.0

TABLE IV(iv)a [continued].

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po5b	74.30	27.08	47.13	0.09	0.0	0.0	0.845	0.844	0.001	0.0	0.0
Po6b	92.93	31.60	61.24	0.09	0.0	0.0	0.985	1.096	0.001	0.0	0.0
Po7	102.62	40.23	61.99	0.13	0.27	0.0	1.255	1.11	0.002	0.005	0.0
Po8	85.37	41.01	43.48	0.23	0.61	0.04	0.943	0.778	0.004	0.01	0.0
Po9	103.84	33.82	69.32	0.17	0.04	0.48	1.055	1.241	0.003	0.001	0.008
Cp1	98.6	34.34	30.70	0.11	0.0	33.45	1.071	0.550	0.002	0.0	0.526
Cp2	99.34	35.03	30.58	0.11	0.0	33.63	1.092	0.547	0.002	0.0	0.529
Cp3	108.6	43.21	31.91	0.15	0.19	33.15	1.348	0.571	0.002	0.003	0.522
Cp4	109.09	44.76	31.86	0.14	0.0	32.34	1.396	0.570	0.002	0.0	0.509
Cp8a	107.31	41.52	31.70	0.13	0.0	34.05	1.295	0.568	0.002	0.0	0.536
Marc1	100.46	52.49	43.96	0.18	3.81	0.03	1.637	0.787	0.003	0.065	0.0
MarcA	104.16	57.14	45.31	0.17	1.54	0.0	1.782	0.811	0.003	0.026	0.0
Marc2	76.85	39.53	36.81	0.12	0.39	0.0	1.232	0.659	0.002	0.006	0.0
Marc4	68.92	36.87	31.90	0.16	0.0	0.0	1.15	0.571	0.003	0.0	0.0
MarcC	68.76	36.55	32.06	0.15	0.0	0.0	1.14	0.574	0.003	0.0	0.0
Marc6	70.82	38.19	32.18	0.15	0.30	0.0	1.19	0.576	0.002	0.004	0.0
Marc7	107.39	50.35	56.41	0.17	0.46	0.0	1.57	1.01	0.003	0.008	0.0
MarcF	84.296	38.89	38.64	2.11	3.94	0.68	1.21	0.692	0.036	0.067	0.01
MarcC(2)	94.41	54.50	31.07	3.08	5.76	0.01	1.7	0.556	0.052	0.098	0.0
Pn2	91.39	33.01	25.72	1.07	31.60	0.0	1.029	0.46	0.018	0.538	0.0
Pn5	90.33	32.4	31.26	1.04	25.63	0.0	1.01	0.56	0.017	0.437	0.0
Pn7	98.80	31.24	42.29	0.99	24.28	0.0	0.974	0.757	0.017	0.414	0.0
ViolA	92.32	36.98	28.11	0.21	27.00	0.02	1.15	0.53	0.003	0.46	0.0
Viol8B	81.81	35.16	30.15	3.15	13.30	0.06	1.096	0.534	0.053	0.226	0.0
Viol8D	101.82	45.02	35.46	2.11	19.16	0.07	1.404	0.635	0.036	0.326	0.001
'Pn'4	101.18	27.65	47.02	0.90	25.61	0.0	0.862	0.842	0.015	0.436	0.0
'Cp'7	63.26	31.46	31.52	0.17	0.06	0.06	0.981	0.564	0.0	0.0	0.0
'Cp'8	61.26	0.51	28.02	0.19	0.01	32.52	-	-	-	-	-

TABLE IV(iv)b

Atomic proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
Po1	0.836	0.002	0.007	0.0	0.845	Greyish, oxidized.
PoB	0.811	0.003	0.01	0.003	0.827	Greyer phase Po1.
Po3	1.046	0.002	0.0	0.0	1.048	Brown, composite with Cp, Pn3.
Po5	1.110	0.002	0.0	0.0	1.112	Brown, oxidized.
PoD	0.673	0.001	0.002	0.0	0.676	Alteration of Po5, marcasitic, higher relief, plus haematite.
Po5b	0.999	0.001	0.0	0.0	1.0	In grain 5, low S, oxidized.
Po6b	1.112	0.001	0.001	0.0	1.113	Red, oxidized part of grain 6.
Po7	0.797	0.001	0.004	0.0	0.802	Large composite grain in tremolite, altered.
Po8	0.825	0.004	0.01	0.0	0.839	Minor phase of composite grain 8.
Po9	1.176	0.003	0.001	0.008	1.188	Altered, S low.
Cp1	0.513	0.002	0.0	0.491	1.006	Composite with Po1.
Cp2	0.500	0.002	0.0	0.484	0.986	Monomineralic grain.
Cp3	0.423	0.002	0.0	0.387	0.814	Oxidized, from 3 phase grain.
Cp4	0.408	0.001	0.002	0.364	0.774	Minor in composite grain 4.
Cp8a	0.439	0.002	0.0	0.414	0.855	Reddish, oxidized.
Marc1	0.480	0.002	0.04	0.0	0.522	Lamellae in Po 1.
MarcA	0.455	0.001	0.014	0.0	0.470	Oval in Po 1.
Marc2	0.534	0.001	0.005	0.0	0.540	Composite grain with Pn2 and oxidized pyrrhotite.
Marc4	0.496	0.002	0.0	0.0	0.498	Composite grain with oxidized pyrrhotite.
MarcC	0.503	0.002	0.0	0.0	0.505	Alteration of Pn2.
Marc6	0.484	0.002	0.003	0.0	0.489	Oxidized pyrrhotite from composite grain.
Marc7	0.643	0.001	0.006	0.0	0.650	Alteration of Po7 cubic in marc therefore pyrite plus haematite.
MarcF	0.572	0.03	0.055	0.0	0.657	In Pn2, nickel bearing marcasitic alteration.
MarcC(2)	0.325	0.03	0.057	0.0	0.41	Low M.
Versus 8S						
Pn2	3.576	0.136	4 184	0.0	7.896	Altered remnant Pn.
Pn5	4.435	0.134	3.46	0.0	8.0	Low in M, from grain 5.

TABLE IV(iv)b [continued]

Versus 8S	Fe	Co	Ni	Cu	M	
Pn7	6.2	0.140	3.4	0.0	9.74	High M, half of grain 7.
ViolA	3.5	0.02	3.20	0.0	6.72	High M for viol with haematite, in Pn2.
Viol8b	3.90	0.387	1.64	0.0	5.94	Low nickel viol in grain 8.
Viol8d	3.6	0.205	1.86	0.005	5.67	Low nickel viol in grain 8.
Versus 1S						
'Pn'4	0.977	0.017	0.506	0.0	1.5	Altered Pn in composite grain, low S viol?
'Cp'7	0.575	0.003	0.001	0.0	0.579	Greigite? Low total therefore very oxidized chalcopyrite?
'Cp'8	31.3	0.188	0.0	32.0	63.5	No sulphur left, only Fe, Cu, oxides? (Goethite)alteration of 8a.

TABLE IV(v)a
2007A Uralitized Clinopyroxenite

	Weight Percent						Molecular proportions				
Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po1	92.37	41.16	49.38	0.07	1.68	0.07	1.284	0.884	0.001	0.028	0.001
Po2	99.89	51.34	48.06	0.06	0.43	0.0	1.601	0.860	0.01	0.07	0.0
Po3	76.99	34.75	41.22	0.04	0.97	0.0	1.084	0.738	0.001	0.016	0.0
Po4	94.80	45.36	47.74	0.04	1.67	0.0	1.415	0.855	0.001	0.028	0.0
Po5	98.15	49.81	47.00	0.03	1.31	0.0	1.554	0.841	0.001	0.022	0.0
Po6	90.58	36.19	53.89	0.06	0.44	0.0	1.128	0.945	0.001	0.007	0.0
Po7	97.27	49.59	45.17	0.03	2.49	0.0	1.546	0.809	0.001	0.042	0.0
Po8	95.18	48.46	45.90	0.04	0.78	0.0	1.511	0.822	0.001	0.013	0.0
Po9	97.54	49.74	46.82	0.03	0.95	0.0	1.551	0.838	0.001	0.016	0.0
PoA	98.03	50.50	46.05	0.03	1.44	0.0	1.575	0.825	0.001	0.025	0.0
PoB	98.27	49.26	47.75	0.03	1.23	0.0	1.536	0.855	0.001	0.021	0.0
PoC	96.85	48.44	47.42	0.03	0.96	0.0	1.511	0.849	0.001	0.016	0.0
PoD	92.13	37.80	53.53	0.04	0.75	0.0	1.179	0.958	0.001	0.013	0.0
PoE	99.90	51.81	47.27	0.04	0.77	0.0	1.616	0.846	0.001	0.013	0.0

TABLE IV(v)a[Continued].

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Marc1	100.06	52.16	47.17	0.07	0.65	0.01	1.627	0.845	0.001	0.011	0.0
Marc6	101.14	51.53	48.31	0.06	1.25	0.0	1.607	0.865	0.001	0.021	0.0
Cp2	100.11	34.24	31.36	0.04	0.0	34.46	1.068	0.562	0.001	0.0	0.542
Cp4	88.85	28.35	29.60	0.03	0.0	30.87	0.884	0.530	0.0	0.0	0.486
Cp6	97.93	33.91	31.19	0.04	0.0	32.78	1.058	0.559	0.001	0.0	0.516
Cp8	93.53	30.27	29.04	0.03	0.44	33.75	0.944	0.520	0.0	0.008	0.531
Cp9	97.47	32.91	31.60	0.05	0.0	32.92	1.026	0.566	0.001	0.0	0.518
CpA	98.92	33.47	30.76	0.04	0.0	34.66	1.044	0.551	0.001	0.0	0.545
CpB	95.78	31.89	31.54	0.04	0.0	32.30	0.998	0.566	0.001	0.0	0.508
CpC	98.40	33.45	30.36	0.03	0.0	34.55	1.043	0.544	0.001	0.0	0.544
CpD	97.77	33.00	30.99	0.04	0.0	33.74	1.029	0.555	0.001	0.0	0.531
CpE	99.16	34.28	31.0	0.05	0.0	33.80	1.069	0.556	0.001	0.0	0.532
Viol 1	84.23	30.50	28.05	1.39	24.29	0.0	0.951	0.502	0.023	0.414	0.0
Viol 7	79.07	26.15	31.22	1.04	20.67	0.0	0.816	0.559	0.018	0.352	0.0
Viol 8	87.19	29.49	27.56	1.19	28.96	0.0	0.191	0.493	0.020	0.493	0.0
Viol 9	81.35	26.68	32.30	0.84	21.53	0.0	0.832	0.578	0.014	0.366	0.0
Viol A	88.74	30.14	30.41	1.20	26.99	0.0	0.940	0.544	0.020	0.459	0.0
Viol C	83.99	29.37	27.23	1.32	26.07	0.0	0.916	0.487	0.022	0.444	0.0
Viol E	93.47	33.67	23.74	1.00	35.05	0.0	1.050	0.425	0.017	0.597	0.0
Viol F	98.65	22.68	40.88	1.34	33.75	0.0	0.707	0.732	0.023	0.575	0.0

TABLE IV(v)b

Atomic Proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
Po1	0.688	0.0	0.022	0.0	0.710	Marcasite plus Fe oxides/hyroxides. Monomineralic grain.
Po2	0.537	0.0	0.004	0.0	0.541	Marcasite, plus haematite in composite grain with Cp2.
Po3	0.681	0.001	0.015	0.0	0.796	Marcasite, plus Fe oxides, altered monomineralic Po bleb.
Po4	0.604	0.0	0.019	0.0	0.623	Marcasite, plus Fe oxides. Vein with Cp4.
Po5	0.541	0.0	0.014	0.0	0.555	Monomineralic grain altered to marcasite, haematite.
Po6	0.838	0.0	0.006	0.0	0.844	Altered composite 2 phase grain.
Po7	0.523	0.0	0.027	0.0	0.550	Composite grain, Po altered to marcasite, haematite, and Pn.
Po8	0.544	0.0	0.008	0.0	0.554	Three phase composite grain, Po altered to marcasite and haematite.
Po9	0.540	0.0	0.010	0.0	0.550	Marcasitic alteration of Po, haematite in three phase composite grain.
PoA	0.524	0.0	0.016	0.0	0.540	Altered three phase composite grain.
PoB	0.556	0.0	0.013	0.0	0.569	Marcasite plus haematite after Po, composite grain with CpB.
PoC	0.561	0.0	0.010	0.0	0.571	Composite grain, altered Po, 1/8 Cp, Pn.
PoD	0.813	0.001	0.011	0.0	0.825	Greyish-whitish-yellow.
PoE	0.523	0.0	0.008	0.0	0.531	Altered Po, to marcasite-haematite.
Marc1	0.519	0.0	0.006	0.0	0.525	Marcasite plus haematite after Po.
Marc6	0.538	0.0	0.013	0.0	0.551	Yellowish alteration of Po6.
Cp2	0.525	0.001	0.0	0.507	1.03	Fresh Cp next to altered Po2.
Cp4	0.599	0.0	0.0	0.550	1.149	Oxidized, low total, excess M. In vein with Po4, haematite.
Cp6	0.528	0.001	0.0	o.483	1.011	Composite grain 6, with Po.
Cp8	0.551	0.0	0.008	0.562	1.113	Minor phase in composite grain 8. Oxidized, low total, high M.
Cp9	0.551	0.001	0.0	0.505	1.057	From three phase grain 9.
CpA	0.527	0.001	0.0	0.522	1.049	From three phase grain A.
CpB	0.567	0.001	0.0	0.509	1.077	Half of composite grain with PoB.
CpC	0.521	0.001	0.0	0.521	1.042	1/8 of composite grain C with PoC.
CpD	0.539	0.008	0.0	0.516	1.056	Three phase composite grain.
CpE	0.520	0.0	0.0	0.497	1.017	From grain E.

TABLE IV(v)b[Continued]

Versus 8S	Fe	Co	Ni	Cu	M	
Viol 1	4.223	0.193	3.482	0.0	7.89	Much oxidized material plus viol, very low total, high M.
Viol 7	5.48	0.172	2.45	0.0	9.1	Oxidized Pn in composite grain 7.
Viol 8	4.29	0.174	4.29	0.0	8.754	Slightly oxidized Pn, grain 8.
Viol 9	5.557	0.135	3.52	0.0	9.212	Slightly oxidized Pn.
Viol A	4.63	0.170	3.91	0.0	8.71	Altered, oxidized Pn.
Viol C	4.253	0.192	3.88	0.0	8.325	Altered, oxidized Pn, some haematite.
Viol E	3.238	0.129	4.548	0.0	7.985	Brownish, altered, oxidized Pn. F is greyish, has a higher relief.
Viol F	8.28	0.26	6.506	0.0	15.046	Very S poor phase about FeNiS,good total so not much oxide/hydroxide mixture of awaruite + violarite?

TABLE IV(vi)a
M3 GABBRO

	Weight Percent						Molecular Proportions				
Number	Total%	S	F	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po1	93.23	35.69	56.65	0.08	0.76	0.05	1.13	1.014	0.001	0.013	0.001
PoA	95.34	45.95	45.45	0.08	3.15	0.70	1.433	0.814	0.001	0.054	0.011
Po2	101.76	54.38	43.79	0.05	3.54	0.0	1.696	0.784	0.001	0.060	0.0
PoH	97.42	37.96	58.84	0.15	0.43	0.03	1.184	1.054	0.003	0.007	0.001
Po6	117.42	68.01	48.79	0.09	0.53	0.0	2.121	0.874	0.002	0.009	0.0
Po7	93.42	49.26	44.10	0.06	0.0	0.0	1.536	0.790	0.001	0.0	0.0
Po8	86.98	46.50	40.48	0.0	0.0	0.0	1.450	0.725	0.0	0.0	0.0
Po9	99.39	52.87	45.66	0.09	0.78	0.01	1.649	0.817	0.001	0.013	0.0
PoC	101.27	53.41	47.68	0.10	0.07	0.01	1.666	0.854	0.002	0.001	0.0
PnE	98.17	36.11	22.63	5.03	17.16	16.79	1.126	0.405	0.085	0.300	0.264
Cp1	97.66	33.05	30.85	0.08	0.01	33.66	1.031	0.552	0.001	0.0	0.530
Cp2	94.76	32.91	29.21	0.04	0.0	32.60	1.026	0.523	0.001	0.0	0.513

TABLE IV(vi)a[Continued]

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Cp3	98.45	32.96	30.27	0.06	0.0	35.16	1.028	0.542	0.001	0.0	0.553
Cp4	100.47	34.85	30.42	0.0	0.0	35.10	1.087	0.545	0.0	0.0	0.552
Cp5	86.14	31.10	25.56	0.10	0.01	29.37	0.970	0.457	0.001	0.0	0.462
Cp7	100.80	34.63	30.50	0.09	0.01	35.58	1.080	0.546	0.001	0.0	0.560
CpC	98.65	33.71	29.77	0.11	0.06	35.00	1.051	0.533	0.002	0.001	0.551
CpD	99.95	34.16	30.18	0.08	0.0	34.54	1.065	0.540	0.01	0.0	0.559
CpF	98.13	32.78	29.84	0.08	0.0	35.42	1.022	0.534	0.001	0.0	0.557
PnB	83.61	37.14	26.11	4.38	15.86	0.12	1.158	0.467	0.740	0.270	0.002
Pn5	90.67	33.27	39.75	2.88	14.17	0.60	1.037	0.711	0.048	0.241	0.009
PnD	75.79	26.53	16.44	6.65	22.52	3.65	0.827	0.294	0.113	0.383	0.057
PnF	77.22	32.92	12.46	2.28	29.14	0.42	1.026	0.223	0.038	0.496	0.006
Marc1	57.46	28.85	28.59	0.01	0.0	0.0	0.899	0.512	0.0	0.0	0.0
Marc8	100.02	51.77	42.03	0.08	5.97	0.17	1.614	0.752	0.001	0.101	0.002

TABLE IV(vi)b

Atomic Proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
Po1	0.897	0.001	0.011	0.001	0.91	Greyish brown alteration of Po composite grain with Cp1.
PoA	0.568	0.0	0.0	0.037	0.605	Thin sliver altering Po1, marcasite + oxide.
Po2	0.462	0.0	0.035	0.0	0.497	Marcasite alteration of Po. PnB part of former composite grain.
PoH	0.890	0.002	0.006	0.0	0.898	With Pn5, altered Po.
Po6	0.412	0.001	0.004	0.0	0.417	Monomineralic grain altered to marcasite.
Po7	0.514	0.0	0.0	0.0	0.514	Irregular pyrite vein in fracture.
Po8	0.500	0.0	0.0	0.0	0.5	Marcasite/pyrite grain + oxides.
Po9	0.495	0.0	0.008	0.0	0.503	Pyrite grain.
PoC	0.512	0.001	0.0	0.0	0.514	White marcasite after Po.

TABLE IV(vi)b [Continued]

Versus 1S	Fe	Co	Ni	Cu	M	
PnE	0.360	0.075	0.266	0.234	0.935	White band accross PnD, remnant pentlandite?
Cp1	0.535	0.001	0.0	0.514	1.05	Brass coloured, composite grain with Po1.
Cp2	0.509	0.001	0.0	0.5	1.01	One millimetre grain Cp, slightly oxidized.
Cp3	0.527	0.001	0.0	0.538	1.066	Cp from interstitial aggregate.
Cp4	0.501	0.0	0.0	0.507	1.008	Monomineralic Cp.
Cp5	0.471	0.001	0.0	0.476	0.948	Small oxidized bleb.
Cp7	0.505	0.001	0.0	0.518	1.02	Three millimetre Cp.
CpC	0.507	0.002	0.001	0.524	1.03	Composite grain with PoC.
CpD	0.507	0.001	0.0	0.525	1.03	Three millimetre Cp grain, 'Pn'B at rim.
CpF	0.522	0.001	0.0	0.545	1.06	Three x two millimetre Cp grain.
Versus 8S						
'Pn'B	3.226	5.112	1.865	0.013	10.2	Pn and oxides. Low Total,High M, very altered.
Pn5	5.485	0.370	1.859	0.069	7.78	Violarite and oxides, in Po-Pn small grain.
PnD	2.844	1.093	3.704	0.551	8.19	Cobaltiferous altered Pn at edge of CpD.
PnF	1.816	0.296	3.867	0.046	6.02	Violarite. Low total, greyish, goethite present.
Versus 2S						
Marc1	1.139	0.0	0.0	0.0	1.12	Very low total, goethite and marcasite.
Marc8	0.932	0.001	0.125	0.002	1.06	Marcasite alteration after Po in Cp7.

TABLE IV(vii)a

MEP4 539.3 Uralitized (Clino)pyroxenite

	Weight Percent						Molecular Proportions				
Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po1	102.8	42.82	59.89	0.05	0.04	0.01	1.335	1.072	0.001	0.001	0.0
Po2	96.11	37.77	58.13	0.05	0.09	0.06	1.178	1.041	0.01	0.002	0.001
Po3	94.65	35.84	58.97	0.09	0.04	0.0	1.118	1.056	0.002	0.001	0.0
Po4	95.89	37.65	57.03	0.09	1.12	0.0	1.174	1.021	0.001	0.019	0.0

TABLE IV(vii)a[Continued]

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po5	108.27	46.17	61.84	0.11	0.15	0.0	1.440	1.107	0.002	0.003	0.0
PoA	97.11	37.67	59.14	0.07	0.22	0.01	1.175	1.059	0.001	0.004	0.0
Po6	97.88	39.69	58.84	0.0	0.05	0.0	1.238	1.041	0.0	0.001	0.0
Po7	99.12	38.20	58.19	0.09	0.03	2.62	1.191	1.042	0.002	0.0	0.041
P08	61.63	24.71	36.85	0.0	0.07	0.0	0.771	0.670	0.0	0.001	0.0
PoB	102.23	41.67	60.35	0.13	0.08	0.0	1.300	1.081	0.002	0.001	0.0
PoC	106.19	44.97	61.11	0.11	0.0	0.0	1.403	1.094	0.002	0.0	0.0
PoX	100.44	39.86	60.50	0.02	0.03	0.04	1.243	1.083	0.0	0.001	0.001
PoF	99.23	38.67	60.42	0.09	0.04	0.0	1.206	1.082	0.002	0.001	0.0
PoG	102.88	42.23	60.56	0.09	0.0	0.0	1.317	1.084	0.002	0.0	0.0
PoH	100.75	41.44	60.19	0.09	0.03	0.0	1.292	1.078	0.002	0.001	0.0
Cp2	104.73	39.88	30.42	0.07	0.06	34.41	1.244	0.455	0.001	0.001	0.540
Cp5	104.17	39.42	30.81	0.05	0.0	33.88	1.229	0.552	0.001	0.0	0.533
Cp7	100.37	36.43	30.25	0.06	0.0	33.62	1.136	0.542	0.001	0.0	0.529
Cp9	98.18	34.60	32.39	0.06	0.03	31.11	1.071	0.580	0.001	0.001	0.490
CpA	101.68	36.81	30.27	0.05	0.0	34.55	1.148	0.542	0.001	0.0	0.544
CpC	103.62	40.25	31.18	0.04	0.0	32.15	1.255	0.558	0.001	0.0	0.506
CpX	101.53	36.65	30.29	0.04	0.0	34.55	1.143	0.542	0.001	0.0	0.544
CpF	100.60	36.28	30.21	0.06	0.0	34.04	1.132	0.541	0.001	0.0	0.536
CpG	100.04	36.35	29.49	0.05	0.05	34.11	1.134	0.528	0.001	0.001	0.537
Pn1	100.85	33.63	32.36	1.44	33.42	0.0	1.049	0.579	0.024	0.569	0.0
Pn2	104.16	34.40	33.95	1.47	31.32	0.02	1.166	0.608	0.025	0.534	0.0
Pn4	102.58	37.58	31.76	1.32	31.92	0.0	1.172	0.569	0.022	0.544	0.0
Pn6	89.30	32.66	29.54	1.24	25.86	0.0	1.018	0.529	0.021	0.440	0.0
Pn8	75.33	25.89	23.21	1.34	24.88	0.0	0.807	0.415	0.022	0.424	0.0
Pn9	105.28	38.43	31.94	2.11	32.80	0.0	1.198	0.572	0.036	0.559	0.0
PnA	112.11	45.13	32.82	1.74	32.41	0.0	1.408	0.588	0.030	0.552	0.0
PnZ	104.48	36.73	29.50	2.69	32.71	2.86	1.145	0.528	0.046	0.557	0.045
PnB	91.66	26.17	29.15	1.65	24.48	10.21	0.816	0.522	0.028	0.417	0.160
PnC	101.20	33.75	31.93	1.57	33.95	0.0	1.053	0.572	0.027	0.578	0.0
PnD	101.44	34.06	31.81	1.60	33.94	0.02	1.062	0.570	0.027	0.578	0.0
PnE	101.12	33.60	32.07	1.31	34.08	0.07	1.048	0.574	0.022	0.581	0.001

TABLE IV(vii)a[Continued]

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PnF	99.89	32.75	30.48	1.99	34.64	0.04	1.021	0.546	0.034	0.590	0.001
PnG	101.92	34.74	31.43	1.82	33.91	0.02	1.084	0.563	0.031	0.578	0.0
PnH	104.90	37.22	32.42	1.86	33.40	0.0	1.161	0.581	0.032	0.569	0.0
PnI	99.78	31.83	31.39	1.86	34.66	0.04	0.993	0.562	0.032	0.591	0.001
PnJ	99.54	32.29	31.46	1.76	33.92	0.08	1.007	0.563	0.030	0.578	0.001

TABLE IV(vii)b

Atomic Proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
Po1	0.803	0.0	0.0	0.0	0.803	Composite grain, oxidized, 2/3 Po 1/3 Pn.
Po2	0.883	0.001	0.001	0.0	0.885	Oxidized Composite grain 0.5 x 0.7 millimetre 1/3 Pn minor Cp.
Po3	0.944	0.002	0.001	0.0	0.947	Monomineralic grain 1 x 0.5 mm, slightly oxidized.
Po4	0.872	0.0	0.016	0.0	0.888	Composite grain 1/3 Pn4,0.7 x 0.5 mm Po slightly oxidized.
Po5	0.769	0.001	0.002	0.0	0.772	Dark brown, oxidized Po.
PoA	0.901	0.001	0.003	0.0	0.904	Less oxidized, yellower Po phase in grain 5.
Po6	0.840	0.0	0.0	0.0	0.840	Twenty micron Po grain.
Po7	0.875	0.001	0.0	0.034	0.910	Slightly weathered, composite grain 1mm x 20 microns, Cu bearing.
Po8	0.869	0.0	0.001	0.0	0.870	Small grain 5 x 10 microns in tremolite.
PoB	0.832	0.001	0.001	0.0	0.834	Composite grain 0.5 x 0.7 mm 1/3 PnB.
PoC	0.780	0.001	0.0	0.0	0.781	1 x 3 mm three phase grain 3/4 Pn, 4 microns Cp.
PoX	0.871	0.0	0.001	0.001	0.873	Composite grain 3/4 Po with Cpx.
PoF	0.897	0.002	0.001	0.0	0.900	Po slightly altered grain 1/8 Pn 1/8 Cp.
PoG	0.823	0.002	0.0	0.0	0.825	1 x 2 mm composite grain, marcasite + Po.
PoH	0.834	0.002	0.001	0.0	0.837	Composite grain 1/4 Po altering to marcasite.
Cp2	0.438	0.001	0.001	0.434	0.874	Brassy yellow, high total, S analysis unreliable.

TABLE IV(vii)b[Continued]

Versus 1S	Fe	Co	Ni	Cu	M	
Cp5	0.449	0.001	0.0	0.434	0.884	Minor Cp in grain 5, altered.
Cp7	0.477	0.001	0.0	0.466	0.944	Slightly weathered composite grain.
Cp9	0.537	0.001	0.001	0.454	0.993	In composite grain with PnZ intermixed.
CpA	0.472	0.001	0.0	0.473	0.946	2 x 2 mm Cp grain, relatively fresh.
CpC	0.445	0.001	0.0	0.403	0.849	Altered Cp in grain C.
CpX	0.474	0.001	0.0	0.476	0.961	Cp, composite grain with PoX.
CpF	0.478	0.01	0.0	0 473	0.952	Slightly altered, 1/8 of composite grain F.
CpG	0.466	0.001	0.001	0.474	0.942	Slightly altered in grain G.
Versus 8S						
Pn1	4.47	0.183	4.339	0.0	8.93	Fresh Pn in grain 1.
Pn2	4.170	0.172	3.664	0.0	8.01	Slightly oxidized Pn in grain 2.
Pn4	3.88	0.150	3.71	0.0	7.74	Pn altered slightly to violarite.
Pn6	4.16	0.165	3.46	0.0	7.79	4 x 10 microns monomineralic grain altered to violarite and haematite.
Pn8	4.11	0.218	4.20	0.0	8.23	Violarite and haematite intimately intermixed in grain 8 in trem.
Pn9	3.82	0.240	3.73	0.0	7.79	Cubic 25 micron grain, altered Pn.
PnA	3.34	0.170	3.14	0.0	6.65	Violarite grain after Pn, 40 x 30 microns.
PnZ	3.69	0.321	3.89	0.314	8.22	Intermixed composite grain with Cp9, gradual contacts, Cu content.
PnB	5.12	0.224	4.09	1.57	11.0	Cu bearing S poor Pn, Cu native?
PnC	4.35	0.205	4.39	0.0	8.95	Pn major phase of grain C.
PnD	4.29	0.203	4.35	0.0	8.84	0.7mm square Pn grain cut by alteration silicates.
PnE	4.38	0.168	4.44	0.007	8.99	1 x 0.5 mm Pn grain.
PnF	4.28	0.266	4.62	0.008	9.17	1/8 of composite grain, quite fresh.
PnG	4.15	0.229	4.26	0.0	8.64	Slightly altered, in grain G.
PnH	4.00	0.220	3.92	0.0	8.14	3/4 Pn in composite grain, slightly altered.
PnI	4.53	0.258	4.76	0.0	9.55	Brighter than PnJ, low S high M.
PnJ	4.47	0.238	4.59	0.008	9.30	Not as reflectant as PnI but still high M.

TABLE IV(viii)a
MEP1 582.7 Feldspathic Olivine Clinopyroxenite

	Weight Percent						Molecular Proportions				
Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po2	92.61	35.19	54.99	0.09	0.88	1.47	1.097	0.984	0.001	0.015	0.023
Po3	101.20	40.53	59.57	0.11	0.84	0.15	1.264	1.067	0.002	0.014	0.002
Po5	101.96	41.55	59.37	0.11	0.91	0.0	1.296	1.063	0.002	0.016	0.0
Po6	103.90	58.87	43.51	2.92	0.56	0.05	1.773	0.779	0.049	0.010	0.001
Po7	101.49	40.51	60.19	0.11	0.69	0.0	1.260	1.078	0.002	0.012	0.0
Po8	101.02	40.95	50.57	0.09	1.40	0.0	1.277	1.049	0.002	0.024	0.0
Po9	102.40	41.36	60.05	0.11	0.88	0.0	1.290	1.075	0.002	0.015	0.0
PoA	103.52	41.86	60.53	0.13	1.00	0.0	1.305	1.084	0.002	0.017	0.0
PoB	102.30	41.54	59.44	0.13	1.18	0.0	1.296	1.064	0.002	0.020	0.0
PoC	102.29	41.26	59.74	0.10	1.19	0.0	1.287	1.070	0.002	0.020	0.0
PoD	101.89	41.15	59.73	0.14	0.87	0.0	1.283	1.069	0.002	0.015	0.0
PoE	101.13	40.35	59.78	0.10	0.91	0.0	1.258	1.070	0.002	0.016	0.0
PoF	100.75	40.93	59.00	0.08	0.75	0.0	1.276	1.056	0.001	0.013	0.0
PoG	101.22	40.95	59.49	0.08	0.67	0.03	1.277	1.065	4.001	0.011	0.0
PoH	101.81	40.23	60.48	0.13	0.97	0.0	1.255	1.083	0.002	0.016	0.0
PoI	101.54	40.25	60.46	4.08	0.75	0.0	1.255	1.083	0.001	0.012	0.0
PoX	99.23	38.96	52.91	0.98	6.36	0.02	1.215	0.947	0.017	0.108	0.0
PoJ	100.77	40.01	59.82	0.10	0.84	0.0	1.248	1.071	0.002	0.014	0.0
Cp2	93.09	28.79	28.65	4.03	0.01	35.61	0.898	0.513	0.0	0.0	0.561
Cp3	105.0	37.36	29.56	4.02	0.0	38.06	1.165	0.529	0.0	0.0	0.599
Cp4	102.23	36.30	29.61	0.03	0.0	36.29	1.132	0.530	0.001	0.0	0.571
Cp5	105.93	37.56	30.61	0.05	0.0	37.71	1.171	0.548	0.001	0.0	0.593
CpZ	103.77	36.70	29.48	0.04	0.0	37.55	1.145	0.528	0.001	0.0	0.591
Cp6	103.98	37.08	29.09	0.02	6.96	30.83	1.156	0.521	0.0	0.119	0.485
Cp7	99.24	35.23	32.00	0.05	0.06	31.90	1.079	0.572	0.001	0.001	0.502
Cp8	100.21	35.92	29.35	0.05	0.11	34.79	1.120	0.525	0.001	0.002	0.547
Cp9	102.49	35.68	30.17	0.03	0.0	36.61	1.113	0.540	0.0	0.0	0.576
CpA	101.31	35.32	30.19	0.03	0.44	35.34	1.101	0.541	0.0	0.008	0.556
CpB	103.24	36.09	30.12	0.03	0.02	36.97	1.125	0.539	0.001	0.0	0.582

TABLE IV(viii)a[Continued]

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
CpC	103.76	36.87	30.09	0.02	0.07	36.72	1.150	0.539	0.0	0.001	0.578
CpD	104.72	37.17	29.57	0.03	0.0	37.95	1.159	0.529	0.001	0.0	0.597
CpF	104.39	36.31	30.52	0.03	0.02	37.51	1.132	0.547	0.001	0.0	0.590
CpG	102.67	35.45	29.63	0.03	0.36	37.21	1.105	0.530	0.001	0.006	0.586
CpI	97.67	34.33	30.18	0.03	0.0	33.13	1.071	0.540	0.001	0.0	0.521
Pn1	98.70	42.72	45.91	0.10	9.96	0.0	1.332	0.822	0.002	0.170	0.0
Pn2	100.04	33.91	26.70	2.53	36.59	0.31	1.058	0.478	0.043	0.623	0.005
Pn3	101.60	34.59	27.47	2.29	37.10	0.15	1.079	0.492	0.439	0.632	0.002
Pn9	101.66	34.45	27.92	1.88	37.39	0.02	1.075	0.500	0.032	0.637	0.0
PnA	101.82	34.20	29.20	2.31	36.06	0.05	1.067	0.523	0.039	0.614	0.001
PnB	100.55	33.37	27.53	1.97	37.67	4.01	1.041	0.493	0.033	0.642	0.0
PnZ	99.35	34.52	29.84	0.93	34.05	0.0	1.077	0.534	0.016	0.580	0.0
PnC	101.75	34.25	27.84	1.70	37.96	0.01	1.068	0.498	0.029	0.647	0.0
PnD	101.55	34.61	32.17	2.36	32.34	0.05	1.080	0.576	0.040	0.551	0.001
PnG	100.82	35.09	28.53	1.88	34.78	0.53	1.094	0.511	0.032	0.593	0.008
PnH	98.77	31.81	28.23	1.74	36.96	0.03	0.992	0.506	0.030	0.630	0.0
PnI	99.79	32.63	28.16	1.63	27.36	0.0	1.018	0.504	0.028	0.637	0.0

Note: Sulphur results seem high in part of this batch.

TABLE IV(viii)b

Atomic Proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
Po2	0.897	0.001	0.013	0.021	0.932	Composite grain 0.7 x 0.5 cm 2/3 Po.
Po3	0.844	0.001	0.011	0.01	0.857	Composite grain half oxidized Po, minor Pn.
Po5	0.820	0.002	0.012	0.0	0.834	Composite grain 9/10 Po 0.5mm.
Po6	0.439	0.027	0.005	0.0	0.471	Composite grain 3/4 marcasite.

TABLE IV(viii)b[Continued]

Versus 1S	Fe	Co	Ni	Cu	M	
Po7	0.854	0.001	0.009	0.0	0.864	1 x 1.5mm slightly altered bleb.
Po8	0.821	0.001	0.019	0.0	0.841	0.7 x 0.3mm 2/3 Po altered to marcasite slightly.
Po9	0.833	0.001	0.011	0.0	0.844	3mm slightly altered Po 7/8 of grain.
PoA	0.830	0.001	0.013	0.0	0.844	Composite grain 0.5 x 1mm slightly altered.
PoB	0.821	0.001	0.015	0.0	0.837	9/10 Po, slightly oxidized.
PoC	0.831	0.001	0.016	0.0	0.848	3mm composite grain 85% Po.
PoD	0.833	0.001	0.011	0.0	0.845	8/10 in 1 x 1mm composite grain.
PoE	0.850	0.001	-0.012	0.0	0.863	0.5mm slightly altered monomineralic grain.
PoF	0.828	0.0	0.010	0.0	0.838	o.7mm bleb, slightly altered to marcasite.
PoG	0.834	0.0	0.008	0.0	0.842	1.8mm 80% Po slightly altered.
PoH	0.863	0.001	0.013	0.0	0.877	3 x 2 mm Po.
PoI	0.863	0.001	0.010	0.0	0.874	1/3 each phase composite grain.
PoX	0.779	0.014	0.088	0.0	0.881	Nickeliferous phase below Pn in grain I.
PoJ	0.858	0.001	0.011	0.0	0.870	0.7 x 0.5mm grain.
Cp2	0.571	0.0	0.0	0.625	1.19	Minor oxidized phase in grain 2.
Cp3	0.454	0.0	0.0	0.512	0.966	Grain is half Cp, quite fresh.
Cp4	0.468	0.001	0.0	0.504	0.973	Small 4 x 15 micron composite bleb.
Cp5	0.468	0.001	0.0	0.506	0.975	1/10 of composite grain.
CpZ	0.461	0.001	0.0	0.516	0.977	Slightly less altered from grain 6.
Cp6	0.45	0.0	0.103	0.419	0.972	In composite grain, slightly altered, Ni bearing.
Cp7	0.521	0.001	0.001	0.457	0.98	Minor phase in grain 7.
Cp8	0.469	0.001	0.001	0.488	0.959	1/3 of grain 8.
Cp9	0.485	0.0	0.0	0.517	1.00	1/8 Cp in grain 9, quite fresh.
CpA	0.491	0.0	0.007	0.505	1.00	Composite grain A.
CpB	0.479	0.001	0.0	0.517	0.997	Minor bleb in grain B.
CpC	0.46A	0.0	0.001	0.503	0.972	5% Cp in composite grain.
CpD	0.456	0.001	0.0	0.515	0.972	Cp bleb in PoD.
CpF	0.483	0.001	0.0	0.521	1.00	Minor 4 micron bleb in PoF.
CpG	4.479	0.001	0.005	0.530	1.01	Minor Cp in grain G.
CpI	0.504	0.001	0.0	0.486	0.991	1/3 of grain I.

TABLE IV(viii)b[Continued]

Versus 8S	Fe	Co	Ni	Cu	M	
Pn1	4.93	0.012	1.02	0.0	5.96	Small 15 micron violarite grain.
Pn2	3.61	0.325	4.71	0.037	8.69	Slightly altered Pn in grain 2.
Pn3	3.65	0.289	4.69	0.015	8.63	Minor Pn phase of grain 3.
Pn9	3.72	0.029	4.74	0.0	8.49	Minor phase along edge of Cp9.
PnA	3.92	0.292	4.60	0.007	8.82	Pn from composite grain A.
PnB	3.79	0.254	4.93	0.0	8.97	Minor wedge in grain B.
PnZ	3.97	0.118	4.31	0.0	8.40	Altered Pn phase in grain C.
PnC	3.73	0.217	4.85	0.0	8.80	10% Pn in composite grain.
PnD	4.27	0.296	4.08	0.007	8.65	Minor Pn at edge of PoB.
PnG	3.74	0.280	4.34	0.058	8.42	Two sausages in Po, altered Pn.
PnH	4.08	0.242	5.08	0.0	9.4	Twenty percent Pn bleb in Po.
PnI	3.96	0.220	5.01	0.0	9.19	1/3 of grain I.

TABLE IV(ix)a
XI Uralitized Feldspathic Pyroxenite

	Weight Percent						Molecular Proportions				
Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PoA	99.17	38.98	53.48	0.04	0.66	6.00	1.216	0.958	0.01	0.011	0.094
PoB	97.72	38.93	58.25	0.06	0.48	0.0	1.214	1.043	0.001	0.008	0.0
PoC	99.97	40.59	59.01	0.06	0.30	0.0	1.266	1.057	0.001	0.005	0.0
PoD	99.48	40.18	58.68	0.06	0.57	0.0	1.253	1.051	0.001	0.010	0.0
PoE	101.54	41.86	59.17	0.07	0.44	0.0	1.306	1.059	0.001	0.007	0.0
PoF	100.84	4 .07	59.14	0.07	0.56	0.0	1.281	1.059	4.001	0.010	0.0
PoG	99.68	40.22	58.96	0.09	0.48	0.0	1.254	1.056	0.001	0.007	0.0
Po1	96.11	50.53	45.58	0.0	0.0	0.0	1.576	4.816	0.0	0.0	0.0
PoH	99.52	40.24	59.04	0.09	0.15	0.0	1.255	1.057	0.001	0.002	0.0

TABLE IV(ix)a[Continued]

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PoI	98.01	39.07	58.33	0.06	0.55	0.0	1.219	1.044	0.001	0.009	0.0
PoJ	101.34	42.30	58.55	0.06	0.43	0.0	1.319	1.048	0.001	0.007	0.0
PoK	100.46	40.73	59.20	0.03	0.50	0.0	1.270	1.060	0.001	0.009	0.0
PoL	103.41	41.23	59.52	2.59	0.07	0.0	1.286	1.066	0.044	0.001	0.0
PoM	99.98	41.06	58.76	0.04	0.13	0.0	1.280	1.052	0.001	0.002	0.0
PoN	98.62	39.42	58.80	0.0	0.41	0.0	1.229	1.053	0.0	0.007	0.0
PoO	97.19	38.42	58.10	0.01	0.67	0.0	1.198	1.040	0.0	0.011	0.0
PoP	99.74	40.28	59.26	0.08	0.12	0.0	1.256	1.061	0.001	0.002	0.0
PoQ	99.80	40.65	58.47	0.30	0.38	0.0	1.268	1.047	0.005	0.006	0.0
PoR	99.97	40.79	59.06	0.05	0.07	0.0	1.272	1.057	0.001	0.001	0.0
PoS	99.31	39.69	58.06	0.02	1.10	0.45	1.238	1.039	0.0	0.019	0.007
PoT	99.15	39.98	58.99	0.08	0.09	0.0	1.247	1.056	0.001	0.002	0.0
CpC	98.46	33.83	29.26	0.01	0.0	35.36	1.055	0.524	0.0	0.0	0.557
CpE	102.75	38.81	30.10	0.01	0.0	33.83	1.210	0.539	0.0	0.0	0.532
CpF	101.77	37.61	30.39	0.04	0.0	33.74	1.173	0.544	0.001	0.0	0.531
CpH	98.91	34.55	29.76	0.0	0.0	34.60	1.077	0.533	0.0	0.0	0.545
CpI	98.07	34.40	29.17	0.06	0.0	34.44	1.073	0.522	0.001	0.0	0.542
CpL	101.13	35.04	29.54	1.96	0.0	34.60	1.093	0.529	0.033	0.0	0.545
CpM	102.13	36.34	29.33	1.50	0.0	34.96	1.133	0.525	0.025	0.0	0.550
CpN	100.06	35.38	29.85	0.04	0.0	34.79	1.104	0.536	0.001	0.0	0.547
CpP	99.81	36.47	29.36	0.07	0.0	33.90	1.138	0.526	0.001	0.0	0.533
CpQ	104.77	37.49	29.61	2.73	0.0	34.95	1.169	0.530	0.046	0.0	0.550
CpR	100.12	35.27	29.45	0.10	0.0	35.31	1.100	0.527	0.002	0.0	0.556
CpS	100.06	34.89	29.55	1.22	0.0	34.40	1.088	0.529	0.021	0.0	0.541
CpT	100.58	36.00	29.33	0.02	0.0	35.23	1.123	0.525	0.0	0.0	0.554
PnA	99.64	34.43	27.84	1.59	35.74	4.04	1.074	0.499	0.027	0.609	0.001
PnC	98.69	33.07	27.79	1.70	36.07	0.06	1.031	0.498	0.029	0.615	0.001
PnE	97.86	34.79	28.12	0.01	34.95	0.0	1.085	0.503	0.0	0.595	0.0
PnF	100.10	33.24	27.37	1.69	37.74	0.06	1.037	0.490	0.029	0.643	0.001
PnG	99.82	32.22	27.68	1.61	38.31	0.0	1.005	0.496	0.027	0.653	0.0
Pn1	101.43	33.20	27.41	1.46	39.36	0.0	1.035	0.491	0.025	0.671	0.0
PnH	93.0	31.21	27.12	1.42	33.25	0.02	0.973	0.486	0.024	0.566	0.0

TABLE IV(ix)a[Continued].

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PnJ	97.63	37.48	40.02	0.62	19.40	0.11	1.169	0.716	0.011	0.331	0.002
PnK	95.15	37.87	30.57	0.08	36.63	0.0	1.181	0.547	0.001	0.454	0.0
PnL	100.80	32.11	36.89	0.07	41.72	0.02	1.001	0.481	0.001	0.711	0.0
Pn2	103.53	32.35	27.50	1.48	42.20	0.0	1.009	0.492	0.025	0.719	0.0
Pn3	98.00	39.79	31.23	1.50	25.47	0.0	1.241	0.559	0.025	0.434	0.0
PnM	98.23	35.31	28.90	0.08	16.45	17.49	1.101	0.517	0.001	0.280	0.275
PnP	102.43	37.42	40.95	0.01	24.05	0.0	1.167	0.733	0.0	0.410	0.0
PnQ	94.41	35.55	27.13	0.07	33.64	0.01	1.046	0.486	0.001	0.573	0.0
PnR	96.30	32.20	26.95	0.0	37.14	0.02	1.004	0.482	0.0	0.633	0.0

TABLE IV(ix)b

Atomic Proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
PoA	0.788	0.001	0.009	0.083	0.881	Twenty Micron bleb, slightly altered, Cu bearing.
PoB	0.859	0.001	0.006	0.0	0.866	1 x 8mm bleb.
PoC	0.835	0.001	0.004	0.0	0.840	1.5mm composite grain.
PoD	0.839	0.001	0.008	0.0	0.848	0.5 x 0.2mm monomineralic grain.
PoE	0.811	0.0	0.005	0.0	0.816	Composite grain 9/10 Po minor Pn.
PoF	0.827	0.001	0.008	0.0	0.836	9/10 altered Po.
PoG	0.842	0.001	0.005	0.0	0.848	4 x 2mm 1/2 Po, altered.
PoH1	0.518	0.0	0.0	0.0	0.518	Marcasite alteration of PoG.
PoH	0.842	0.001	0.001	0.0	0.844	Altered Po major phase.
PoI	0.856	0.001	0.007	0.0	0.864	2/3 altered Po in 0.5mm grain.
PoJ	0.795	0.0	0.005	0.0	0.800	Altered Po is half of composite grain.
PoK	0.835	0.001	0.007	0.0	0.843	0.5mm grain 1/2 Po, brownish.
PoL	0.829	0.034	0.001	0.0	0.864	5mm grain, Cp, Po major phases.
PoM	0.822	0.001	0.001	0.0	0.824	4 x 1.5mm composite grain, Po altered.

TABLE IV(ix)b[Continued].

Versus 1S	Fe	Co	Ni	Cu	M	
PoN	0.857	0.0	0.005	0.0	0.862	Altered Po in Po-Cp grain.
PoO	0.868	0.0	0.009	0.0	0.877	0.4 x 0.7mm monomineralic grain.
PoP	0.845	0.001	0.001	0.0	0.847	3 x 4mm Po grain with minor Pn exsolutions.
PoQ	0.826	0.004	0.005	0.0	0.835	1cm 3 phase grain, altered Po.
PoR	0.831	0.001	0.001	0.0	0.833	Altered Po in grain R.
PoS	0.839	0.0	0.015	0.006	0.857	Minor Po bleb in 0.5mm Cp grain.
PoT	0.847	0.001	0.001	0.0	0.849	Po with long unmixed Cp bleb.
CpC	0.496	0.0	0.0	0.528	1.02	Cp, grading to Pn.
CpE	0.445	0.0	0.0	0.440	0.885	Altered in composite grain E.
CpF	0.464	0.001	0.0	0.453	0.918	Minor Cp phase in grain F.
CpH	0.495	0.0	0.0	0.506	1.00	Minor exsolution Cp in PoH.
CpI	0.486	0.001	0.0	0.505	0.992	1/3 Cp in composite grain.
CpL	0.484	0.030	0.0	0.498	1.01	- - - - - - - - - - - - - - -
CpM	0.463	0.022	0.0	0.485	0.970	Cp blebs in grain M.
CpN	0.486	0.001	0.0	0.495	0.982	Curved sausage in PoN.
CpP	0.462	0.001	0.0	0.468	0.93	Minor Cp phase in grain P.
CpQ	0.453	0.039	0.0	0.470	0.962	Clean curved boundary with Po, PnQ.
CpR	0.479	0.002	0.0	0.505	0.986	Cp in grain R.
PoS	0.486	0.019	0.0	0.497	1.00	Cp containing small Po sausage-shaped bleb.
PoT	0.467	0.0	0.0	0.493	0.96	Cp sausage in large Po grain.
Versus 8S						
PnA	3.71	0.201	3.62	0.007	7.54	Nickeliferous phase of grain A.
PnC	3.86	0.225	4.77	0.007	8.86	Pn in composite grain C 1/4 of grain.
PnE	3.71	0.0	4.39	0.0	8.10	Minor phase altered Pn in grain E.
PnF	3.78	0.224	4.96	0.0	8.96	1/10 Pn, curved boundary with Po.
PnG	3.95	0.215	5.20	0.0	9.36	Unmixing sausage in PoG.
Pn1	3.79	0.192	5.18	0.0	9.16	Pn at one end of grain G.
PnH	3.99	0.197	4.65	0.0	8.84	Minor Pn blebs with PoH.
PnJ	4.90	0.075	2.26	0.013	7.25	Violaritized Pn in grain J.
PnK	3.70	0.006	3.07	0.0	6.77	1/2 of grain K violarite.
PnL	3.84	0.008	5.68	0.0	9.53	1/10 Pn at top of grain L.
Pn2	3.90	3.198	5.70	0.0	9.78	Fingers of Pn into Po in grain L, high M.

TABLE IV(ix)b [Continued]

Versus 8S	Fe	Co	Ni	Cu	M	
Pn3	3.60	0.161	2.80	0.0	6.56	Violarite from Pn next to a haematite vein.
PnN	3.76	0.007	2.03	1.99	7.79	Copper-Pentlandite? as oval blebs in grain M, altered.
PnP	5.02	0.0	2.81	0.0	7.83	2 micron wide exsolution in PoP, slightly altered.
PnQ	3.72	0.007	4.56	0.0	8.29	Slightly altered, 1/3 of grain Q.
PnR	3.84	0.0	5.04	0.0	8.88	Pn between Cp, Po in grain R.

TABLE IV(x)a
3002 Serpentinized Dunite

	Weight Percent						Molecular Proportions				
Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PoD	102.68	55.17	45.16	0.15	2.13	0.06	1.720	0.809	0.003	0.036	0.001
Po9	100.25	48.18	50.63	4.19	1.26	0.0	1.502	4.906	0.003	0.021	0.0
Pn1	83.79	21.21	19.90	0.52	42.16	0.0	0.661	0.356	0.009	0.718	0.0
PnA	72.92	20.63	12.41	0.68	39.20	0.0	0.643	0.224	0.12	0.668	0.0
Pn2	80.85	11.12	51.29	0.79	17.61	0.04	0.347	0.918	0.13	0.30	0.0
Pn3	95.88	33.77	4.75	0.32	56.65	0.39	1.053	0.085	0.005	0.965	0.006
PnB	95.16	33.76	4.89	0.28	55.30	0.93	1.053	0.088	0.005	0.942	0.015
PnE	100.42	33.12	5.99	0.38	60.57	0.37	1.033	0.107	0.006	1.032	0.006
Pn5	89.07	20.81	32.90	0.72	34.25	0.40	0.649	0.589	0.012	0.583	0.006
Pn6	76.59	24.61	7.76	0.38	43.67	0.17	0.767	0.139	0.006	0.744	0.002
PnF	93.25	31.90	5.74	0.51	54.90	0.20	0.995	0.103	0.009	0.935	0.003
PnZ	96.34	29.98	9.36	0.58	55.92	4.50	0.935	0.108	0.010	0.953	0.008
PnG	101.65	32.74	5.89	0.57	62.14	0.30	1.021	0.106	0.010	1.059	0.005
Pn8	76.98	17.62	18.28	1.51	39.29	0.27	0.549	0.327	0.026	0.669	0.004
Pn9	78.54	21.27	15.95	0.23	41.01	0.08	0.663	0.286	0.004	0.698	0.001
PnI	84.93	20.44	27.58	0.65	35.68	0.57	0.637	0.494	0.011	0.608	0.009
PnJ	99.95	41.15	8.05	1.82	42.23	6.71	1.283	0.144	0.031	0.719	0.106

TABLE IV(x)a[Continued].

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PnM	92.80	26.32	13.98	4.49	51.83	0.18	0.821	0.250	0.008	0.883	0.003
PnN	99.90	28.90	7.86	0.57	61.83	0.74	0.901	0.141	0.010	1.054	0.012
PnC	107.25	38.91	0.95	0.57	66.51	0.31	1.213	0.017	0.010	1.123	0.005
PnD	95.27	33.56	0.18	0.30	60.95	0.27	1.047	0.003	0.005	1.039	0.004
PnH	94.60	33.12	1.74	0.57	58.77	0.40	1.033	0.031	0.010	1.001	0.006
PnK	102.85	37.93	0.90	1.16	61.78	1.08	1.183	0.016	0.020	1.053	0.017
PnL	93.21	33.56	1.43	0.49	57.64	0.09	1.047	0.026	0.008	0.982	0.001

TABLE IV(x)b

Atomic Proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
PoD	0.470	0.002	0.021	0.0	0.493	Marcasite.
Po9	0.603	0.002	0.014	0.0	0.619	Yellowish marcasite with much haematite.
Versus 8S						
Pn1	4.31	0.109	1.08	0.0	5.5	Fe rich violarite and haematite.
PnA	2.79	1.49	8.31	0.0	12.5	Heazlewoodite type phase + oxides?
*Pn2	21.1	3.99	6.91	0.0	9.9	Goethitic red nickel-cobalt-iron phase with little remnant S.
Pn3	0.645	0.038	7.33	0.045	8.05	Fe bearing millerite phase + minor oxide.
PnB	0.688	0.038	7.15	0.114	7.97	Bluish-brownish millerite + oxide.
*PnE	0.828	0.046	7.99	0.046	8.08	Altered millerite.
*Pn5	7.26	0.148	7.18	0.074	7.4	More altered part of E, millerite and much haematite, goethite.
*Pn6	1.45	0.062	7.76	0.021	7.84	1 x 1.6mm millerite + much haematite.
PnF	0.824	0.072	7.52	0.024	8.43	Yellower phase of grain 6, purer millerite with minor oxide.
PnZ	1.36	0.085	8.15	0.068	9.66	Pentlandite remnant, oxidized, and nickel rich millerite.
PnG	0.830	0.078	8.29	0.039	9.24	Minor reddish phase, slightly altered millerite and goethite?

TABLE IV(x)b[Continued].

Versus 8S	Fe	Co	Ni	Cu	M	
Pn8	4.76	0.378	9.75	0.058	14.9	Goethite and remnant Pn.
Pn9	3.45	0.048	8.42	0.012	11.93	As 8, or possible heazlewoodite phase.
*PnI	6.20	0.138	7.63	0.112	7.88	Yellowish millerite and some goethite.
PnJ	0.898	0.193	4.48	0.661	6.23	2 x 4 micron produced during serpentinization, nickel-rich violarite.
*PnM	2.44	0.078	8.60	0.029	8.77	Millerite and remnant Pn phase + oxides.
PnN	1.25	0.088	9.36	0.106	10.8	Nickel-rich sulphide, iron bearing heazlewoodite?
PnC	0.112	0.066	7.47	0.033	7.68	Possible Fe bearing millerite, variable composition.
PnD	0.023	0.038	7.94	0.030	8.03	Millerite and minor oxide.
PnH	0.240	0.077	7.75	0.046	8.11	Millerite and oxide.
PnK	0.108	0.135	7.12	0.115	7.48	Altered millerite.
PnL	0.198	0.061	7.50	0.007	7.77	Altered millerite.

*Fe not included in M.

TABLE IV(xi)a
4016 Serpentinized Wehrlite

	Weight Percent						Molecular Proportions				
Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PoA	91.3	41.42	45.36	0.13	4.38	0.02	1.292	0.812	0.002	0.074	0.0
PoB	88.18	35.15	49.99	0.12	2.52	0.40	1.096	0.895	0.002	0.042	0.006
PoC	91.56	37.78	50.36	0.12	2.82	0.48	1.178	0.902	0.002	0.048	0.008
PoD	97.20	34.23	52.83	0.08	0.0	0.05	1.067	0.946	0.001	0.0	0.001
PoE	90.60	38.38	50.78	0.12	1.28	0.05	1.197	4.909	4.002	0.022	0.001
PoF	90.30	41.55	46.33	0.14	2.24	0.05	1.296	0.835	0.002	0.038	0.001
PoG	91.83	38.34	39.58	0.85	11.11	1.85	1.196	0.709	0.014	0.189	0.029
PoK	89.71	36.06	53.46	0.09	0.02	0.08	1.125	0.957	0.001	0.0	0.001
PoL	94.95	42.28	52.40	0.10	0.12	0.04	1.319	0.938	0.002	0.002	0.001
Po1	86.21	32.13	53.86	0.06	0.16	0.0	1.002	0.964	0.0	0.003	0.0

TABLE IV(xi)a [Continued].

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po2	87.94	35.47	52.28	0.11	0.04	0.05	1.106	0.936	0.001	0.0	0.001
PoM	89.48	36.94	42.45	0.91	9.18	0.01	1.152	0.760	0.015	0.156	0.0
PoO	88.98	34.76	53.73	0.11	0.31	0.07	1.094	0.962	0.002	0.005	0.001
PoP	89.96	36.17	53.67	0.09	0.0	0.03	1.128	0.961	0.001	0.0	0.0
PoQ	90.32	38.00	52.05	0.11	0.14	0.03	1.185	0.932	0.002	0.002	0.0
PoR	98.09	43.46	33.54	0.09	3.23	17.77	1.356	0.601	0.001	0.055	0.280
PoS	87.52	35.27	48.10	0.13	2.48	1.54	1.099	0.861	0.002	0.042	0.024
PoT	97.71	49.42	47.21	0.18	0.87	0.02	1.541	0.845	0.003	0.015	0.0
PoU	86.71	34.00	52.35	0.07	0.20	0.08	1.060	0.937	0.001	0.003	0.001
PoX	92.60	45.68	46.72	0.05	0.03	0.12	1.425	0.836	0.001	0.0	0.002
PoY	85.62	33.12	52.24	0.09	0.07	0.10	1.033	0.935	0.001	0.001	0.001
PoZ	89.55	34.23	42.50	0.66	12.04	0.12	1.067	0.761	0.011	0.205	0.002
CpA	88.07	26.50	27.65	0.08	0.0	33.84	0.826	0.495	0.001	0.0	0.533
CpC	98.56	33.37	30.15	0.09	0.0	34.96	1.041	0.540	0.001	0.0	0.550
CpD	99.32	34.32	30.26	0.10	0.05	34.59	1.070	0.542	0.002	0.001	0.544
CpH	99.03	33.07	32.57	0.09	0.10	33.20	1.031	0.583	0.002	0.002	0.522
CpJ	97.75	32.97	29.62	0.11	0.02	35.03	1.028	0.530	0.002	0.0	0.511
CpO	99.54	34.56	29.99	0.31	0.17	34.50	1.078	0.537	0.005	0.003	0.543
PoP	96.84	33.64	29.29	0.09	0.0	33.83	1.049	0.524	0.001	0.0	0.532
CpU	94.39	29.80	30.05	0.09	0.0	34.44	4.930	0.538	0.002	0.0	0.542
Cp1	66.64	12.08	28.59	0.04	0.0	25.93	0.376	0.512	0.0	0.0	0.408
CpX	98.97	33.40	30.29	0.06	0.0	35.22	1.042	0.542	0.001	0.0	0.554
CpY	93.79	29.47	29.00	0.22	0.40	34.69	4.919	0.519	0.004	0.007	0.546
PnA	83.00	31.55	17.97	2.02	31.27	0.17	0.984	0.322	0.034	4.533	0.003
PnB	89.66	30.41	28.05	1.37	29.76	0.08	0.948	0.502	0.023	0.507	0.001
PnD	89.85	35.32	20.25	2.05	32.19	0.05	1.101	0.363	0.035	0.548	0.001
PnE	78.71	29.96	15.19	2.13	30.50	0.94	0.934	0.272	0.036	0.519	0.015
PnJ	90.67	31.25	25.02	1.81	32.42	0.17	0.975	0.448	0.031	0.552	0.003
PnK	90.65	36.72	16.27	1.72	35.91	0.02	1.145	0.291	0.029	0.612	0.0
Pn1	89.98	27.87	29.66	0.74	12.47	19.24	0.869	0.531	0.013	0.212	0.303
PnN	92.78	33.53	25.57	1.82	31.12	0.74	1.046	0.458	0.031	0.530	0.012
PnO	96.04	39.71	22.57	1.52	31.65	0.59	1.239	0.404	0.026	0.539	0.009

TABLE IV(xi)a[Continued].

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PnS	93.89	35.22	22.78	1.74	33.81	0.34	1.098	0.408	0.030	0.576	0.005
PnV	97.01	43.43	14.39	0.08	38.80	0.32	1.354	4.258	0.001	0.661	0.005
Pn2	89.90	38.35	12.01	2.16	37.00	0.38	1.196	0.215	0.037	0.630	0.006
PnY	91.91	31.51	24.01	1.95	34.32	0.13	0.983	0.430	0.033	0.585	0.002

TABLE IV(xi)b

Atomic Proportions						Notes
Versus 1S	Fe	Co	Ni	Cu	M	
PoA	0.628	0.002	0.057	0.0	0.687	1mm Po altered to marcasite and haematite.
PoB	4.817	0.002	0.039	0.005	0.863	0.5 x 2mm grain 1/2 Po.
PoC	0.766	0.002	0.040	0.007	0.815	0.7mm grain minor weathered Po.
PoD	0.887	0.001	0.0	0.001	0.889	2mm grain slightly weathered.
PoE	0.759	0.001	0.018	0.001	0.959	1 x 0.5mm partly haematized Po, Pn.
PoF	0.644	0.001	0.029	0.001	0.675	3 x 8 microns, altered Po due to serpentinization, now marcasite.
PoG	0.592	0.012	0.158	0.024	0.786	10 micron less altered bleb due to serpentinization.
PoK	0.851	0.001	0.0	0.001	0.852	4 x 2mm, Po slightly altered.
PoL	0.711	0.001	0.001	0.0	0.712	3/4 weathered out marcasite and haematite remnant
Po1	0.962	0.0	0.003	0.0	0.965	Less altered Po remnant in grain L.
Po2	0.846	0.001	0.0	0.001	0.808	Marcasite and haematite after PoL.
PoM	0.660	0.013	0.135	0.0	0.808	5 microns, Fe rich violarite? After serpentinization(PoG similar?)
PoO	0.887	0.002	0.004	0.001	0.894	0.8mm Po altered to marcasite and haematite.
PoP	0.852	0.001	0.0	0.0	0.853	1 x 2mm weathered Po.
PoQ	0.786	0.002	0.002	0.0	0.790	1 mm yellow pyrite + haematite after Po.
PoR	0.443	0.0	0.041	0.206	0.690	Copper bravoite, 20 microns, after Po?
PoS	0.783	0.002	0.038	0.022	0.845	1mm, 1/4 altered Po, to marcasite and haematite.
PoT	0.548	0.002	0.010	0.0	0.560	Marcasite and goethite in 1/3 weathered out 1mm grain.
PoU	0.884	0.001	0.003	0.001	0.889	Yellowish grey marcasite-haematite after Po.

TABLE IV(xi)b[Continued]

Versus 1S	Fe	Co	Ni	Cu	M	
PoX	0.587	0.0	0.0	0.001	0.588	Yellow marcasite remnant + haematite.
PoY	0.905	0.001	0.001	0.001	0.901	1mm 3 phase composite grain, only slightly altered.
PoZ	0.713	0.010	0.192	0.002	0.917	Yellowish 7 micron nickeliferous violaritized grain due to serp.
CpA	0.599	0.001	0.0	0.645	1.24	Reddish Cp phase in grain A, very oxidized.
CpC	0.518	0.001	0.0	0.529	1.05	1/2 of grain, weathered out Cp S poor.
CpD	0.506	0.002	0.001	0.508	1.02	Minor phase in grain D slightly weathered.
CpH	0.565	0.002	0.002	0.506	1.07	Po completely haematized, Cp only slightly altered.
CpJ	0.515	0.002	0.0	0.536	1.05	9/10 haematized grain, Cp remnant with low S.
CpO	0.498	0.004	0.003	0.504	1.01	Reddish oxidized Cp in grain O.
CpP	0.499	0.001	0.0	0.507	1.01	Minor altered Cp in grain P.
CpU	0.578	0.002	0.0	0.583	1.16	Brownish oxidized Cp.
Cp1	1.36	0.0	0.0	1.08	2.44	Reddish-green alteration after Cp, covellite and goethite.
CpX	0.520	0.001	0.0	0.532	1.05	Cp veined by haematite, low S.
CpY	0.565	0.004	0.007	0.594	1.17	Oxidized Cp.
Versus 8S						
PnA	2.62	0.276	4.336	0.024	7.26	Brownish altered Pn, bravoite and haematite.
PnB	4.24	0.194	4.28	0.008	8.72	Half of grain B, brownish, slightly violaritized.
PnD	2.64	0.254	3.98	0.007	6.88	Violarite and haematite after Pn.
PnE	2.33	0.308	4.45	0.128	7.22	Half grain is haematized Pn, and violarite.
PnJ	3.68	0.254	4.53	0.025	8.50	Pn remnant, oxidized.
PnK	2.92	0.203	4.28	0.0	7.40	Violaritized brownish Pn much haematite.
Pn1	4.89	0.015	1.95	2.79	9.65	Reddish Phase in Pn, low in S, goethitized slightly.
PnN	3.50	0.237	4.05	4.092	7.88	Violaritized remnant Pn in haematite mass.
PnO	2.61	0.168	3.48	4.058	5.32	Violarite and haematite after Pn.
PnS	2.97	0.219	4.12	4.036	7.35	3/4 Pn altered to minor violarite, haematite dust.
PnV	1.54	0.006	3.91	0.029	5.5	1/3 yellowish vaesite(?) or bravoite and haematite after Pn.
Pn2	1.44	0.247	4.2	0.040	5.93	Brownish bravoite + haematite after Pn.
PnY	3.50	0.269	4.76	0.016	8.55	Pn, slightly altered to violarite and oxide.

TABLE IV(xii)a

M22 Olivine Clinopyroxenite

'Weight Percent | Molecular Proportions

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
Po1	99.61	38.68	56.96	1.53	1.03	1.41	Standard Po 048				
Po'K	101.86	38.39	27.06	0.83	11.75	23.84	1.197	4.487	0.014	0.200	0.375
Po'L	102.38	40.12	24.34	0.89	15.30	21.73	1.251	0.436	0.015	0.261	0.342
PoS	91.24	38.79	48.72	0.04	3.51	0.18	1.210	0.872	0.0	0.060	0.003
Po'T	75.41	25.71	21.74	0.35	9.87	17.73	0.802	0.389	0.017	0.168	0.279
PoX	97.63	47.14	47.00	0.01	2.84	0.63	1.470	0.842	0.0	0.048	0.010
CpB	101.73	35.67	31.73	0.33	0.13	33.87	1.112	0.568	0.006	0.002	0.533
CpC	86.43	22.32	38.64	0.07	0.36	25.05	0.696	0.692	0.001	0.006	0.394
CpD	101.5	35.52	31.67	0.03	0.0	34.27	1.108	0.567	0.001	0.0	0.539
CpG	95.09	29.30	36.73	0.04	1.76	27.26	0.914	0.658	0.001	0.030	0.429
CpI	101.74	36.75	30.11	0.04	0.47	34.37	1.146	0.539	0.001	0.008	0.541
CpJ	91.08	30.46	29.84	0.12	2.40	28.26	0.950	0.534	0.002	0.041	0.445
CpK	102.28	36.70	30.39	0.23	0.66	34.30	1.145	0.544	0.004	0.011	0.540
CpM	101.78	36.32	30.71	0.18	0.13	34.46	1.133	0.550	0.002	0.002	0.545
CpN	101.79	36.55	31.44	0.04	0.0	33.76	1.140	0.563	0.001	0.0	0.531
CpO(i)	100.16	36.48	26.46	1.73	8.23	27.26	1.138	0.474	0.029	0.140	0.429
CpO	100.64	36.30	30.36	0.05	0.0	33.93	1.132	4.544	0.001	0.0	0.534
CpP	95.64	29.41	36.42	0.20	1.70	27.91	0.917	0.652	0.003	0.019	0.439
CpR	102.44	36.72	30.46	4.05	0.0	35.22	1.145	0.545	0.001	0.0	0.554
PoS	102.93	36.75	30.63	0.03	0.0	35.51	1.146	0.548	0.001	0.0	0.551
CpT	101.61	36.48	30.59	0.05	0.0	34.49	1.138	0.548	0.001	0.0	0.543
CpU	78.04	26.98	24.89	0.89	3.67	21.61	0.841	0.446	0.015	0.015	0.340
CpV	101.85	35.34	30.67	0.04	4.03	34.77	1.102	0.549	0.001	0.001	0.563
CpW(i)	94.29	34.80	26.52	4.02	7.32	25.63	1.085	0.475	0.0	0.125	0.403
CpW	100.26	34.67	30.31	4.04	0.03	35.02	1.081	0.543	0.001	0.001	0.554
CpX	100.04	34.63	31.12	0.05	0.31	33.94	1.080	0.557	0.001	0.005	0.534
Pn'A	92.12	26.53	15.92	8.24	29.26	2.18	1.139	0.285	0.143	0.150	0.034
PnB	86.48	21.61	36.54	3.81	23.71	0.82	0.674	0.654	0.065	0.404	0.013
PnC	99.49	33.09	10.93	1.90	51.96	1.61	1.032	0.196	0.032	0.885	0.025
PnD	94.95	34.82	17.09	6.66	22.74	13.63	1.086	0.306	0.113	0.388	0.215

TABLE IV(xii)a[Continued].

Number	Total%	S	Fe	Co	Ni	Cu	S	Fe	Co	Ni	Cu
PnE	84.54	31.32	18.47	3.38	22.04	9.33	0.977	0.331	0.057	0.375	0.147
PnF	91.10	31.52	24.37	1.12	27.60	6.49	0.983	0.436	0.019	0.470	0.102
PnG	98.18	29.34	23.74	4.67	28.79	11.64	0.915	0.425	0.079	0.491	0.183
PnH	96.00	30.21	30.10	4.52	27.55	3.62	0.942	0.539	0.077	0.469	0.057
PnI	96.50	33.38	21.27	0.43	38.04	3.39	1.041	0.381	0.007	0.648	0.053
PnJ	96.17	35.76	11.61	0.77	44.23	3.80	1.115	0.208	0.013	0.754	0.060
PnK	105.65	44.4	18.40	0.81	37.21	4.82	1.385	0.329	0.014	0.634	0.076
PnL	102.56	39.15	13.88	1.21	41.99	6.33	1.221	0.249	0.021	0.715	0.100
PnM	103.54	43.65	17.47	0.79	36.36	5.27	1.361	0.313	0.013	0.620	0.082
PnN	98.03	36.88	20.96	1.98	34.82	3.29	1.150	0.375	0.034	0.592	0.053
PnO	95.59	29.61	30.88	2.88	25.70	6.52	0.924	0.553	0.049	0.438	0.103
PnP	99.85	34.27	21.68	1.42	28.24	4.25	1.069	0.388	0.024	0.481	0.067
PnQ	96.86	87.67	19.75	0.60	31.83	7.02	1.175	0.354	0.010	0.542	0.110
PnZ	96.69	37.03	22.82	0.35	19.64	16.74	1.158	0.049	0.006	0.335	0.263
PnR	96.84	33.50	8.01	2.88	49.84	2.61	1.045	0.143	0.049	0.849	0.041
PnS	97.29	33.84	31.24	0.93	14.63	16.66	1.055	0.559	0.016	0.249	0.262
PnT	97.01	36.38	21.27	0.32	34.53	4.41	1.135	0.383	0.005	0.588	0.069
PnU	99.74	38.14	20.42	4.25	22.21	14.73	1.189	0.366	0.072	0.378	0.232
PnD	95.65	35.70	22.11	0.98	23.34	13.51	1.113	0.396	0.017	0.398	0.213
PnW	88.45	29.72	22.21	0.34	26.52	9.66	0.927	0.398	0.006	0.452	0.152
PnX	98.94	38.84	25.52	0.98	23.07	10.53	1.211	0.457	0.017	0.393	0.166

TABLE IV(xii)b

Versus 1S	Fe	Co	Ni	Cu	M	Notes
	Atomic Proportions					
Po'K	0.404	0.012	0.167	0.313	0.900	Copper bearing violarite + oxide or nickel-copper-pyrrhotite?
Po'L	0.349	0.012	0.209	0.273	0.843	Copper violarite and oxide?
PoS	0.721	0.0	0.049	0.002	0.772	Yellowish marcasite and haematite.
Po'T	0.485	0.021	0.209	0.348	1.06	Cu violarite + much oxide.
PoX	0.573	0.0	0.033	0.007	0.613	1 x 1.5mm Po altered to marcasite.
CpB	0.511	0.005	0.004	0.479	0.999	Relatively unaltered Cp in grain B.
CpC	0.994	0.001	0.008	0.566	1.57	Goethitized Cp.
CpD	0.513	0.001	0.0	0.486	1.00	Cp, Pn, 9/10 haematized, remnant.
CpG	0.720	0.001	0.033	0.469	1.22	1mm S poor Cp weathered.
CpI	0.470	0.001	0.007	0.472	0.950	Cp with Pn in clinopyroxene 4 x 10 microns.
CpJ	0.562	0.002	0.043	0.468	1.07	0.8mm Cp + oxide.
CpK	0.475	0.003	4.009	0.472	0.959	3mm grain, Cp + Pn.
CpM	0.485	0.003	0.002	0.481	0.970	Cp in grain M.
CpN	4.494	0.001	0.0	0.466	0.961	1mm, reddish oxidized Cp with Pn.
CpO(i)	0.417	0.025	0.133	0.377	0.942	Slightly altered Cp in grain O, Ni bearing reddish yellow.
CpO	0.481	0.001	0.0	0.472	0.954	Slightly altered Cp in grain O.
CpP	0.711	0.003	0.032	0.479	1.225	Reddish, Cp and goethite.
CpR	0.476	0.001	0.0	0.484	0.961	Slightly altered Cp.
CpS	0.478	0.001	0.0	0.488	0.967	2 x 5mm grain, reddish slightly oxidized.
CpT	0.482	0.001	0.0	0.477	0.960	1.5mm composite, relatively fresh Cp.
CpU	0.530	0.018	0.018	0.404	0.970	0.8 mm minor Cp phase.
CpV	0.498	0.001	0.001	0.511	1.01	Minor Cp phase in grain V.
CpW(i)	0.438	0.0	0.115	0.371	0.924	Reddish Cp, oxidized.
CpW	0.502	0.001	0.001	0.512	1.02	Brassy Cp, fresh.
CpX	4.516	0.001	0.004	0.494	1.02	Cp in grain X, fresh.

TABLE IV (xii)b [Continued]

Versus 8S	Fe	Co	Ni	Cu	M	
'Pn'A	2.00	1.00	0.983	0.030	4.01	Bravoite after Pn, highly haematized.
PnB	7.76	0.771	4.79	0.154	13.47	Reddish goethitized Pn, 9/10 haematized.
PnC	1.52	0.248	6.86	0.194	8.82	1 x 1.5mm grain with CpC, only slightly altered Pn.
PnD	2.25	0.832	2.86	1.58	7.52	Cu violarite + haematite, after Pn?
PnE	2.71	0.467	3.07	1.20	7.45	Cubic violarite and haematite.
PnF	3.55	0.155	3.77	0.83	8.31	20 micron Pn, altered, copper bearing, in clinopyroxene.
PnG	3.72	0.691	4.29	1.60	10.3	Minor phase in grain G, low in S.
PnH	4.58	0.654	3.98	0.484	9.70	0.5mm Pn + oxide.
PnI	2.93	0.054	4.98	0.47	8.78	4 x 10 micron composite grain in clinopyroxene cleavage with Cp.
PnJ	1.49	0.094	5.41	0.430	7.42	Nickel-rich violarite and haematite after Pn.
PnK	1.90	0.081	3.66	0.439	6.08	Violarite in grain K.
PnL	1.63	0.138	4.08	0.655	6.50	2 x 3mm, altered, violarite.
PnM	1.84	0.076	3.64	0.488	6.04	3 x 10 mm 1/2 haematite and magnetite, viol after Pn.
PnN	2.61	0.237	4.12	0.369	7.34	S rich Fe poor altered Pn.
PnO	4.79	4.24	3.79	0.912	9.92	Yellowish alteration of Pn + oxides.
PnP	2.90	0.184	3.60	0.501	7.18	Violarite + oxides after Pn.
PnQ	2.41	0.068	3.69	0.749	6.92	0.8mm monomineralic Pn altered to violarite and oxide.
Pn2	2.83	0.041	2.31	1.82	7.00	Reddish goethite and violarite in Q
PnR	1.09	0.375	6.50	0.314	8.28	1 x 3mm grain, yellow millerite and S bearing goethite after Pn.
PnS	4.24	4.121	1.89	1.98	8.23	Brownish red, oxidized copper-Pn.
PnT	2.70	0.035	4.14	0.486	7.36	Violarite and oxide.
PnU	2.46	0.048	2.54	1.86	6.82	Cu violarite and oxide.
PnV	2.85	0.122	2.82	1.53	7.32	Altered interstitial Pn, to violarite and haematite.
PnW	3.43	0.052	3.90	1.31	8.68	1.5mm cubic brownish Pn, slightly oxidized.
PnX	3.02	0.136	2.59	1.10	6.85	Pn altered to violarite and haematite dust.