CANADA

MANITOBA

MANITOBA
DEPARTMENT OF ENERGY AND MINES
MINERAL RESOURCES DIVISION

ECONOMIC GEOLOGY REPORT
ER79-3

NICKEL-COPPER MINERALIZATION IN THE LYNN LAKE GABBRO

by
R.H. Pinsent
1980

Funding for this project was provided under the cost-shared Canada-Manitoba **N**on-renewable **R**esources **E**valuation **P**rogram by the Canada Department of Energy, Mines and Resources and the Manitoba Department of Mines, Resources and Environmental Management.

Electronic Capture, 2010

The PDF file from which this document was printed was generated by scanning an original copy of the publication. The file has been proofread to correct obvious spelling and punctuation errors in the original publication as well as errors resulting from the scanning process. Users should therefore verify critical information in an original copy of the publication.

Complete versions of Figures A1.4 (report page 69 or PDF page 79) and A1.23 (report page 93 or PDF page 103) are included at the end of this file.

MANITOBA
DEPARTMENT OF ENERGY AND MINES

HON. DONALD W. CRAIK
Minister

PAUL E. JARVIS
Deputy Minister

MINERAL RESOURCES DIVISION
IAN HAUGH
Executive Director

ECONOMIC GEOLOGY REPORT ER79-3

NICKEL-COPPER MINERALIZATION IN THE LYNN LAKE GABBRO

By
R.H. Pinsent

Winnipeg
1980

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont.)

LIST OF PLATES

LIST OF PLATES (Cont.)

LIST OF SYMBOLS AND CONVENTIONS USED IN MAPS AND CROSS SECTIONS

GENERAL

All measurements on plans and sections are expressed in feet

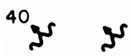
North on maps = mine north

2200′ L = 2200′ Level

GEOLOGICAL SYMBOLS

 Geological boundary (defined, approximate)

 Fault (defined, approximate, inferred)



Fault (dip known, dip inferred)

 Fault (relative movement shown)

 Outline of orebodies (defined, approximate)

DIAMOND DRILLING

#72 Position of collar and number of diamond drill hole (surface)

°72 Point of intersection and number of diamond drill hole collared on surface

U-250 Collar position and number of underground drill hole (prefix "U" means underground)

 Trace of drill hole projected onto plan or section. (Drill hole number at the end of hole)

OREBODIES

UK = Upper K

LK = Lower K

L = lower

LL = lower — lower

LLL = lower — lower — lower

HW = hanging wall

FW = footwall

LYNN LAKE Ni-Cu DEPOSITS

Chapter I — Introduction

1.1 INTRODUCTION

The Lynn Lake Ni-Cu deposit study was set up under the Joint Federal-Provincial (Manitoba) "Non-Renewable Resource Evaluation Program" to provide a description of the Ni-Cu deposits at Lynn Lake in northern Manitoba and to develop a genetic model for the deposit type. For convenience, detailed deposit descriptions have been assigned to an Appendix.

Sherritt Gordon Mines Limited, who operated the mines at Lynn Lake, provided access to relevant mine plans and sections, diamond drill logs and core and (during the period of salvage immediately prior to final closure of the Farley shaft) limited access to the underground workings in the Farley Mine. Parts of the "O" and "N" orebodies were all that were accessible to the author at that time. The Company ceased operation at the Farley Mine on the 1st of July, 1976 bringing to an end 24 years of production (1953-1976) from the "EL", "A" and Farley Mines. The Company produced 20 151 146 tonnes of ore at an average grade of 1.023% Ni and 0.535% Cu from eleven discrete but fault-disrupted orebodies in two complex mafic to ultramafic igneous plutons. The "A", "B", "C", "D", "E-J", "F-K", "G", "M-N", "O" and "P" orebodies were located in the larger of the two plutons (the "A" plug) and the "EL" orebody was located in the smaller pluton (the "EL" plug).

Many geologists employed by Sherritt Gordon Mines Limited have contributed substantially to the present understanding of the geology of the Ni-Cu deposit. The present study relies heavily on their observations, as well as on published and unpublished deposit descriptions by Allan (1948), Hunter (1950), Dorian (1950), Ruttan (1955), Milligan (1960), Emslie and Moore (1961), Macauley (1962) and Vellet (1963).

The description of the deposit is largely based on mapping conducted by Sherritt Gordon Mines and the rock unit nomenclature used in this report is an adaptation of that used by the Company. It maintains the mixed primary (igneous) and secondary (metamorphic) terminology used in the original mapping. Other Company conventions have also been retained. Strike measurements in the "A" and "EL" plugs were made with reference to "Mine North", 17° East of "True North", and mine measurements (e.g., depth to levels) are presented as footages. Measurements made in the course of the present study are given in metric units.

The assistance of Sherritt Gordon Mines Limited in the compilation and evaluation of the data in the report is gratefully acknowledged. The interpretation of the data is that of the author and does not necessarily reflect the opinion of Company geologists.

1.2 REGIONAL SETTING

The Ni-Cu deposits (Fig. 1.1) occur within two adjacent mafic to ultramafic igneous plutons in the Lynn Lake Greenstone Belt, which extends westward from Southern Indian Lake in the east to Laurie Lake on the Manitoba-Saskatchewan border.

Various aspects of the geology of the Lynn Lake Greenstone Belt have been discussed by a number of workers including Allan (1948, 1950), Milligan (1960), Emslie and Moore (1961), and Campbell (1962). More recently, H.V. Zwanzig, H.P. Gilbert and E.C. Syme have remapped the stratigraphy of the greenstone belt west of Hughes Lake (Fig. 1.1). The preliminary results of this project are reported in Manitoba Mineral Resources Division Geological Survey, "Report of Field Activities" for the years 1976, 1977 and 1978.

The "greenstone" component of the belt consists of deformed Precambrian metavolcanic and metasedimentary rocks which belong to the Wasekwan Group (Table 1.1) as defined by Bateman (1942) and redefined by Campbell (1969). This is overlain by a metasedimentary succession which is known as the Sickle Group. The structural and stratigraphic relationships between the two are complex. Although Zwanzig (1976) found little discordance between the two on the southern flank of the greenstone belt, Sickle Group metaconglomerates unconformably overlie Wasekwan Group metavolcanics (Gilbert, 1977) and post-Wasekwan tonalite intrusions (Syme, 1977) within the greenstone belt. McRitchie (1974) has discussed the significance of the Wasekwan-Sickle contact and the relation of the strata to comparable rocks (Amisk and Missi Groups), both in the Flin Flon greenstone belt to the south and also in the intervening Kisseynew gneiss belt.

Three intermediate to acid igneous plutonic complexes split the Lynn Lake Greenstone Belt along an east to west axis between Barrington Lake and Motriuk Lake (Fig. 1.1). The subcircular plutons form an axis of igneous intrusion which splits the greenstones into northern and southern belts. Small plugs and larger bodies of gabbroic composition have intruded Wasekwan Group metavolcanics north and south of the main axis. The two Ni-Cu mineralized plugs are located at Lynn Lake, in the northern section of the greenstone belt, northeast of Motriuk Lake (Fig. 1.1).

A break at the west end of the axis of acid igneous intrusion east of Motriuk Lake has been exploited by a weakly-deformed layered gabbro complex (Hulbert, 1978). The Fraser Lake gabbro complex appears to predate the main episode of acid igneous intrusion. It consists of a funnel-shaped gabbro complex within a synclinal structure separating Wasekwan Group metavolcanics and metasediments north and south of the main axis of igneous intrusion.

According to Gilbert (1977, 1978), the Wasekwan Group succession at Lynn Lake consists of a homoclinal sequence of metavolcanic and metasedimentary rocks (Fig. 1.2). A thick (2400 m) lensoid body of felsic volcanic rock (unit 7) structurally underlies a mafic to felsic heterogeneous succession of interlayered metavolcanic flows, tuffs and breccias (unit 4). This is overlain by fine and coarse-grained metasediments (unit 9) and an upper metavolcanic unit consisting of mafic and intermediate flows and breccias with local occurrences of oxide- and sulphide-facies iron formation (unit 4). The size, angularity and diversity of the clast material in the lowermost metavolcanic unit at the townsite of Lynn Lake may indicate close proximity to a volcanic centre (Gilbert, pers. comm.). The strata, which are isoclinally folded in the vicinity of Lynn Lake, are mostly either vertical or they dip steeply to the northwest. They strike approximately 065°. The strata have been metamorphosed to the staurolite subfacies of the lower amphibolite facies of regional metamorphism (Gilbert, pers. comm.).

According to Hulbert (1978), the funnel-shaped "gabbro" complex at Fraser Lake is part of a larger complex which extends northeast towards Lynn Lake. He contends, on the basis of "gabbro" inclusions in the younger diorite of the axial intrusion suite, that the Fraser body originally extended as far as Flag Lake. The small "gabbro" body at Flag Lake (Fig. 1.2) is probably an isolated portion of the larger body. The Fraser Lake pluton may have extended to within 2 km of the "A" plug and 1 km of the "EL" plug. The Cartwright Lake, Fraser Lake, Flag Lake, "A" and "EL" plug intrusions (Fig. 1.2) are probably comagmatic and approximately coeval.

Folded and schistose metavolcanic and metasedimentary inclusions are abundant at the structural top of the layered body at Fraser Lake (Hulbert, 1978), and they are found in the gabbroic rocks in the "A" plug at Lynn Lake. These inclusions, and the vertical attitude of both the mineralized plutons and the ore pipes they contain, indicate emplacement of the gabbro after at least one major period of deformation and metamorphism. Hulbert (1978) has recognized fold interference patterns in the inclusions in the Fraser Lake complex which are indicative of two periods of deformation.

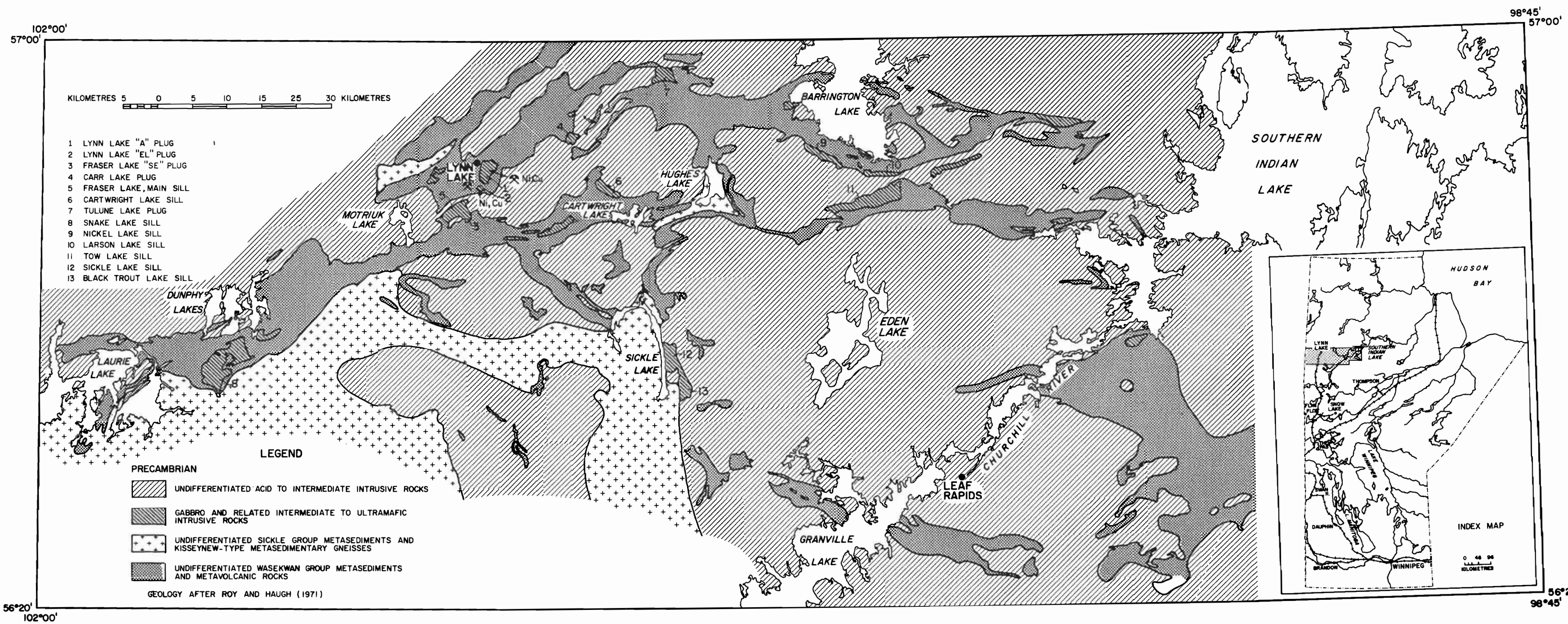


FIGURE 1.1: Regional geological map of the Lynn Lake Greenstone Belt (after Roy and Haugh, 1971).

TABLE 1.1* STRATIGRAPHIC COLUMN OF THE WASEKWAN-SICKLE GROUPS IN THE AREA BETWEEN WILMOT LAKE AND LYNN LAKE

Group	Division (Fig. 1.2)	Lithologies	Maximal thickness
Uncertain	1A	fine grained semi-pelitic sediment and paragneiss: subordinate mafic volcanic unit at southern margin	5000 m
Sickle	10a	conglomerate — mainly volcanogenic, sedimentary and granitoid clasts locally abundant	2650 m
	1F	iron formation	80 m
Wasekwan	4c,9d	mafic tuff, basalt, minor pyroclastics and sediments	425 m
	4a	mafic to intermediate flow and breccia, minor felsic extrusives, mafic tuffs and fine grained sediments; contain iron formation northeast of Lynn Lake	2500 m
	9b, c	fine grained sediments, conglomerate, minor quartz-plagioclase porphyry, basalt, tuff	760 m
	4b,c	mafic to felsic flows and fragmental rocks, minor quartz-plagioclase porphyry and fine grained sediments	1400 m
Uncertain (possibly correlates with 9b, c)	7a	quartz-plagioclase porphyry (with associated sediments and volcanic rocks in the upper part)	2400 m

*Table after Gilbert (1977); thicknesses based on a sequence between Eldon Lake and Zed Lake.

Similar structures were also recognized in inclusions in the "A" plug (A. de Carle, pers. comm.). Hulbert argues that emplacement of the "gabbro" plutons followed deformation of the Sickle Group. However, there is no direct evidence to indicate post-Sickle emplacement of the "gabbro" and, in the Hughes Lake region, at the east end of the axis of acid igneous intrusion, the tonalites and granodiorites inferred to be comagmatic with the "younger axial diorite" are clearly pre-Sickle in age (Syme, 1977). Alternatively, it is possible that the "gabbros" were intruded after deformation of the Wasekwan and prior to subsequent erosion and deposition of the Sickle Group.

All the gabbroic plutons in the vicinity of Lynn Lake show some evidence for post-emplacement deformation and metamorphism and this may, in part, reflect a post-Sickle orogenic event.

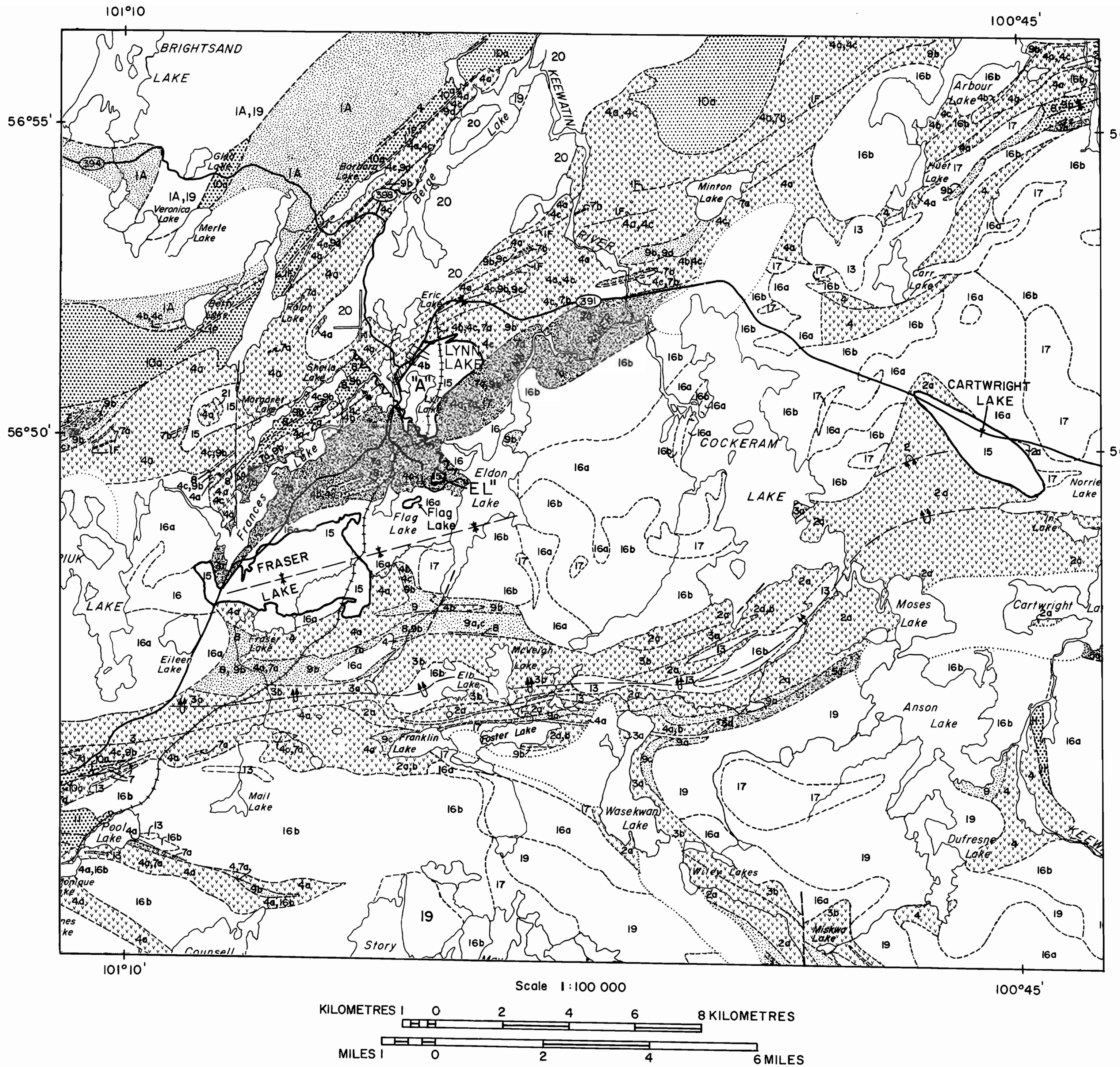


FIGURE 1.2: Geological map of the Motriuk Lake-Lynn Lake-Cockeram Lake area, showing the location and structural setting of the "A", "EL", Flag Lake, Fraser Lake and Cartwright Lake "gabbro" plugs: Detail from Gilbert (1976) and Syme (1976)

Legend

APHEBIAN

INTRUSIVE ROCKS (I.U.G.S. CLASSIFICATION)

Post-Sickle and similar rocks of unknown age

20 Granodiorite, granite

19 Tonalite, granodiorite

18 Gabbro, diabase diorite, minor ultramafic rocks

Pre-Sickle and similar rocks of unknown age

17 Granite, granodiorite, aplite, pegmatite, syenite

16 a) Diorite, quartz diorite

b) Tonalite, granodiorite

15 Gabbro, norite, diorite, pyroxenite, peridotite

14 Hornblende diorite, quartz diorite

13 Gabbro, diabase

METASEDIMENTARY ROCKS

Sickle Group

12 Sandstones and derived gneisses

a) arkose, pebbly arkose, muscovite schist, sillimanite gneiss

b) feldspathic greywacke, siltstone, biotite gneiss

c) hornblende-biotite-blastic arkose and siltstone, hornblende-biotite gneiss

11 Polymictic conglomerate

Rocks of uncertain age: late Wasekwan or Sickle

10 a) Polymictic conglomerate

b) Staurolite schist, greywacke

Wasekwan Group

9 Fine-grained sedimentary rocks

a) hornblende-blastic greywacke, siltstone, pebbly greywacke

b) biotite-blastic greywacke, siltstone, schist

c) siltstone and amphibolite

d) mafic sandstone, mudstone, amphibolite

8 Conglomerate

METAVOLCANIC ROCKS

Wasekwan Group

7 Rhyolite: a) massive and brecciated flows; b) tuff

6 Dacite: a) flows; b) breccia and tuff

5 Intermediate and felsic rocks: a) andesite; b) dacite; c) pyroclastic breccia; d) tuff

4 Mafic and intermediate rocks: a) porphyritic and aphyric basalt, flows and breccias; b) interlayered mafic and intermediate flows and breccias; c) tuff; d) mafic schist

3 Mafic and minor ultramafic rocks, predominently porphyritic (hornblende after pyroxene ± plagioclase): a) massive and brecciated porphyritic flows, minor tuff; b) interlayered porphyritic and aphyric flows

2 Aphyric basalt: a) flows, commonly pillowed, pillow breccia; b) tuff

METASEDIMENTARY ROCKS, VOLCANIC ROCKS AND DERIVED GNEISSES AND MIGMATITES
(Probable Wasekwan age, Burntwood River Supergroup in part)

1 B) Layered and massive amphibolite, minor felsic tuff, greywacke, ultramafic rocks, marble

A) Greywacke, mudstone, paragneiss, migmatite

Symbols

Area of no outcrop

Geological contact

Fault (approximate or inferred)

Metamorphic gradient lines:

a) approximate limit of sillimanite in greywacke, mudstone

b) approximate limit of anatexis

c) approximate limit of extensive anatexis

Axial trace of anticline (approximate, overturned)

Axial trace of syncline (approximate, overturned)

Road

I.F. Iron formation

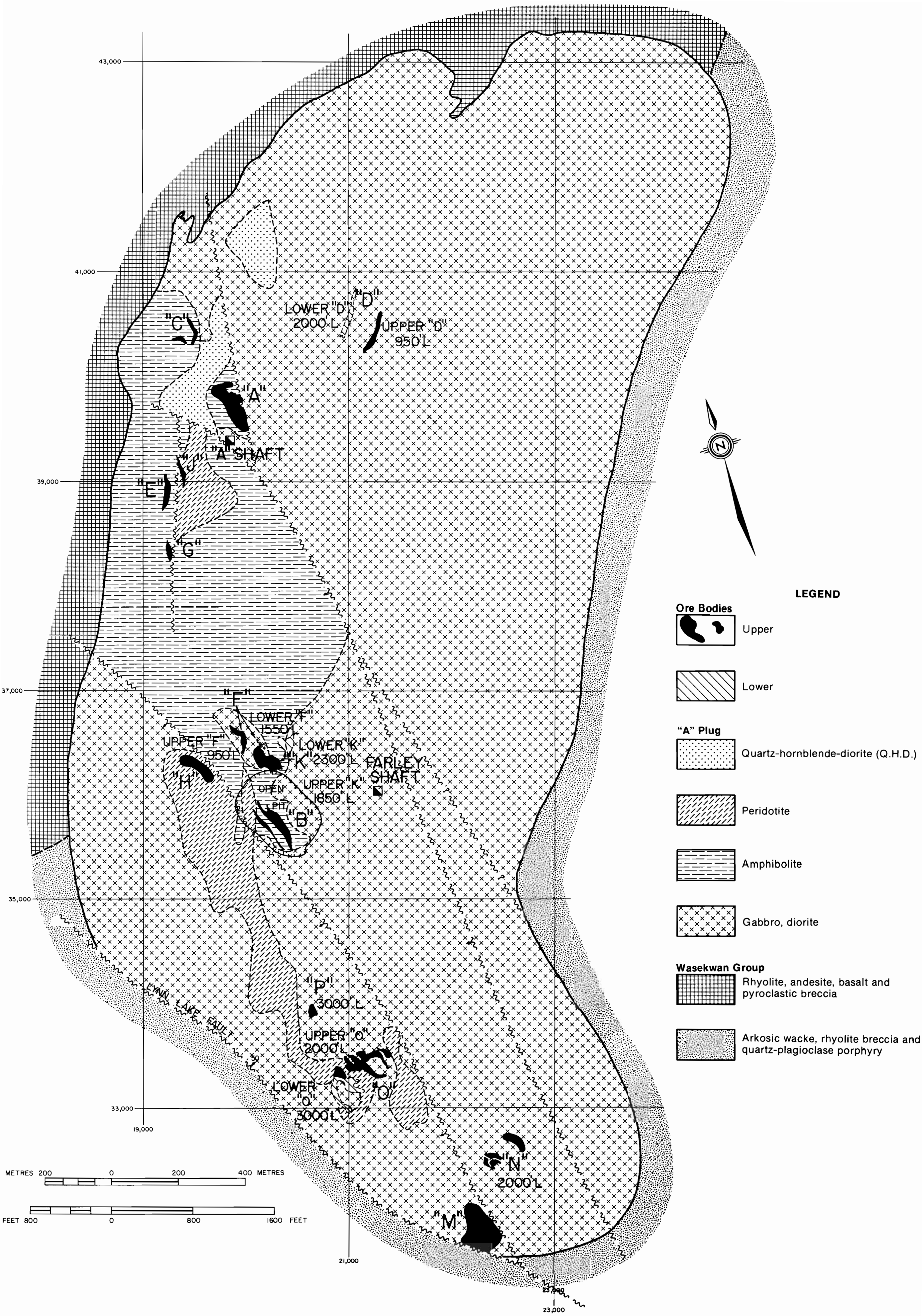


FIGURE 2.1: Surface projections of orebodies in the "A" Plug, Lynn Lake: with simplified geology after Sherritt Gordon Mines Limited.

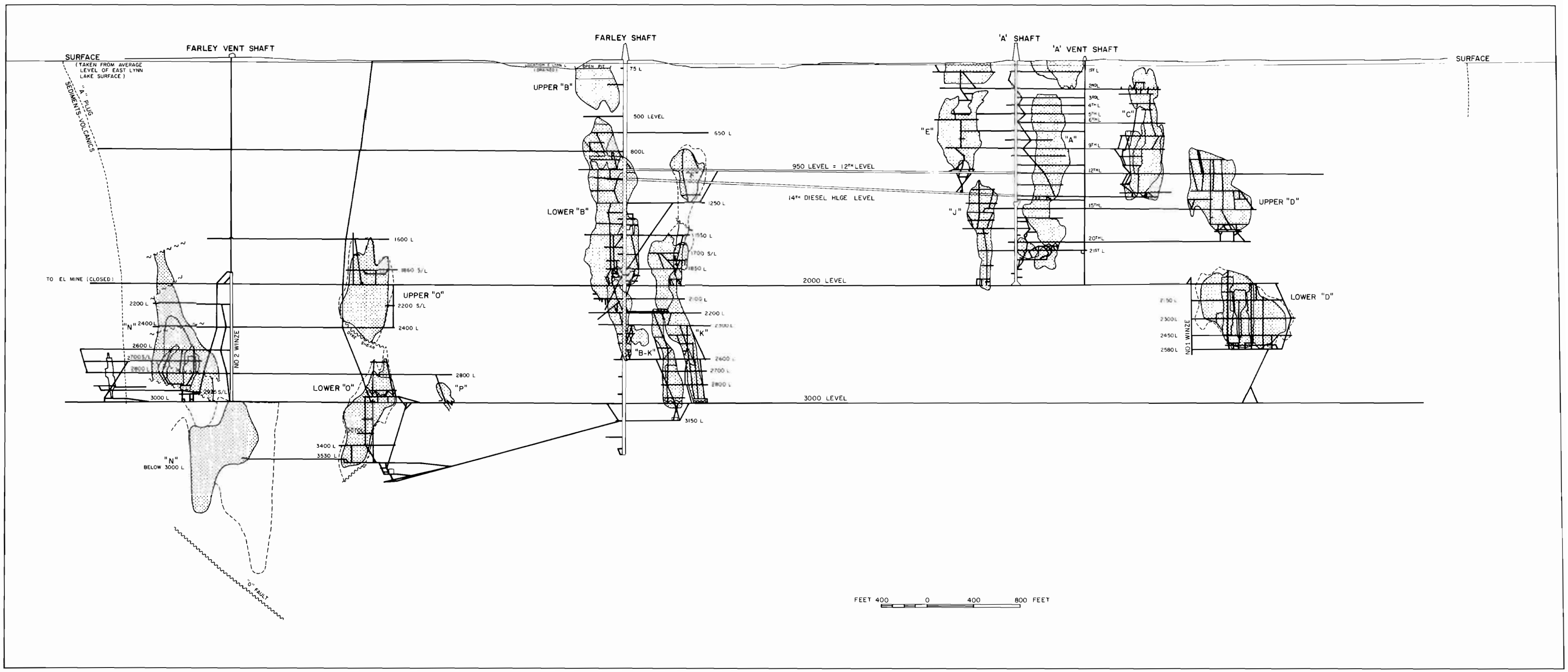


FIGURE 2.2: *Schematic vertical longitudinal section through "A" Plug, Lynn Lake, showing the "A" and Farley Mine workings and orebody outlines: Data from Sherritt Gordon Mines Limited.*

Chapter II - "A" and "EL" plug geology and structure

2.1 INTRODUCTION

Detailed descriptions of "A", "B", "C", "D", "E-J", "F-K", "G", "M-N", "O" and "P" orebodies in the "A" plug and the "EL" orebody in the "EL" plug are presented in Appendix I. In addition, the appendix contains data on mine development and production.

The rock unit terminology used in the deposit study is given in Table 2.1 (a,b). Mine nomenclature has been retained in this report. Norite is the only anhydrous igneous rock found in either of the plugs and anhydrous rock names given in quotation marks (e.g. "gabbro") are inferred primary igneous compositions. The present interpretation of each of the rock units is also indicated in Table 2.1 (a,b).

2.2 GEOLOGY OF THE "A" PLUG

The "A" plug is a kidney-shaped composite ultramafic to intermediate igneous pluton (3.0 km x 1.5 km) intruded into Wasekwan Group metavolcanic strata (Fig. 1.2). It is a near concordant vertical intrusion oriented parallel to the prevailing regional structural trend (NE-SW). Inclusions of country rock in the "A" plug are schistose and locally show evidence of an earlier folding event (A. de Carle, pers. com.). The "gabbros" commonly display a weak cataclastic, igneous fabric but they do not, as a rule, show the pronounced foliation characteristic of the country rock. The country rock contacts are not well exposed, but where visible in outcrop, in the northwest corner of the plug, and in diamond drill core, the marginal "gabbros" are strongly sheared for 3 - 5 m into the plug.

The surface projections of the orebodies in the "A" plug are presented in Figure 2.1 and a vertical longitudinal section through the plug is shown in Figure 2.2. The figures show that the "A", "C", "D", "E-J" and "G" orebodies cluster towards the north end of the plug, around the "A" shaft. The "B", "F-K", and subeconomic "H" zones cluster in the centre of the plug, in the vicinity of the Farley shaft. The "M-N", "O" and "P" orebodies occur towards the south end of the plug.

Orebodies are defined on the basis of company usage at any given time. The economic cut-off grade varied with time and production technique. The undiluted reserve tonnages and grades in Table 2.2 (a,b) appear to be reasonable estimates of metal contents prior to development. During the early development of the deposits 0.5% Ni was used as a cut-off figure. More recently, during cut and fill mining the Company used 0.7% Ni as a cut-off figure for ore-grade material. The Lower "D" ("D" (L)) and Lower"N" ("N" (L)) and Lower "O" ("O" (L)) "ore zones" were considered uneconomic at the time of closure.

Sherritt Gordon Mines Limited systematically drilled the "A" plug on the 800', 950' (12th level), 2000' and 3000' levels in the Farley Mine and the data generated, supplemented by a larger body of data on individual ore zones, have been used in an interpretation of the geology of the "A" plug. For a detailed description of both the plug and the orebodies within it, the reader is referred to Appendix I.

The mine plan for the 2000' level (Fig. 2.3) shows that the bulk of the "A" plug comprises a rnixed "gabbro" and amphibolite assemblage which appears to be intruded by irregular bodies of diorite, "peridotite" and quartz-hornblende diorite (Q.H.D.). The amphibolites and "gabbros" appear to interfinger and the proportions of each varies considerably from level to level. The "gabbro" locally displays compositional banding (mafic rich to mafic poor) concordant with both the western contact of the "A" plug and the country rock foliation.

The "A" plug has undergone several stages of (reverse) block faulting. The extent of the faulting is not always evident in the host amphibolites and "gabbros" but most of the orebodies are strongly disjointed or completely disrupted by local reverse fault movement.

The southwest portion of the "A" plug has been offset by two major reverse faults. The "O" fault and the Lynn Lake fault (which is referred to as the "Griffith Shear" in mine plans) have caused sections of the "A" plug to move to the southwest and override country rock Wasekwan metavolcanics. These two faults, which strike N45°W and dip approximately 50° NE, post-date emplacement of the subvertical ore pipes which contain the mineralization associated with the "O" and "N" orebodies. The mineable portions of these ore pipes occur between the faults. The footwall extensions of the "O" and "N" orebodies below the "O" fault have not been located. Both bottom out on Wasekwan metavolcanics below the 3500' level. The tops of "O" and "N" ore pipes are also truncated approximately at the 1600' level. Movement on the Lynn Lake fault, which defines the southwest contact of the "A" plug on surface (Fig. 2.1), has off-set both ore-bearing structures to the southwest. The "M" ore zone, encountered in drilling between surface and the Lynn Lake fault on the 500' level at the south end of the "A" plug, is probably the hanging wall extension of the "N" orebody. The hanging wall extension of the "O" orebody was located on the 800' level but it was subeconomic through to the surface. The net slip on the Lynn Lake fault is probably in the order of 570 m. The net slip on the "O" fault is probably similar.

Although the Lynn Lake fault dips to the northeast and it intersects the large body of "peridotite" located under the east arm of Lynn Lake (Fig. 2-1), there is no evidence of a major dislocation in the "B", "K", "F-K" and" B-K" ore zones west of the Farley Shaft. The fault may steepen and rotate into a major structure which runs subparallel to the northeastern contact of the "peridotite" body. This structure, which strikes NW and dips steeply to the NE, appears to be a major break and the locus of intrusion of a lens of a specific variety of mottled "gabbro", and a major dyke of Q.H.D. (Vellet, 1963). In addition, it hosts the "B", "K", "F-K" and "B-K" ore lenses which extend down dip from the "B" pit (on surface) to below the 3000' level.

The "A" orebody, at the north end of the plug, bottoms out on the "Footwall "A" fault", which has a similar orientation to the Lynn Lake fault. Movement on this fault has also caused a mineralized ore pipe to be thrust to the southwest, in this case over barren "peridotite". Similarly, the "C" orebody terminates above the easterly dipping "C-contact" fault on the 14th level (Fig. 2.2).

All the orebodies are cut by moderate to steep westerly dipping reverse faults which strike anywhere from NW to NE. These faults appear to post date movement on the "Footwall "A" fault" but their relationship to the "G-contact", Lynn Lake and "O" faults is less certain. Movement on these westerly dipping, imbricate faults has caused successively higher thrust blocks to be moved to the east. This movement has caused several easterly plunging orebodies (e.g., "A", "B", "C") to be structurally steepened. These faults rarely show a displacement in excess of 35 m.

The westerly dipping fault sets have acted as the locus of intrusion of major post-ore acid (quartz-feldspar porphyry) and mafic (diabase) dyke swarms (Fig. 2.3). At the south end of the plug, the "O" and "N" orebodies are cut by dykes of a foliated granitic rock, which is referred to as "Hybrid" in the mine nomenclature. Elsewhere the term is also applied to metasedimentary inclusions. These dykes exploit both easterly and westerly dipping fracture sets. The mafic dykes have been metamorphosed and the period of deformation appears to predate final metamorphic equilibration.

2.3 "A" PLUG OREBODIES

The orebodies in the "A" plug occur as near-vertical pipes and lenses in the western half of the plug (Figs. 2.1 and 2.2). The ore structures characteristically display a deformed lensoid or subcircular outline in plan section. They are characteristically restricted in plan area and extensive in vertical section.

Detailed descriptions of the "A", "B", "C", "D", "E-J", "F-K", "G", "M-N", "O", "P" orebodies are presented in Appendix I. These

TABLE 2.1(a) ROCK TYPE NOMENCLATURE: "A" PLUG

Sherritt Gordon Mines Limited	Inferred Composition
a) **Coarse Grained (Cumulate) Intrusions**	
"Peridotite"	- Ultramafic cumulate (olivine-rich)
Amphibolite (<10% feldspar)	- Ultramafic to mafic cumulate (pyroxene-rich)
Norite	- Noritic cumulate
Silicified "gabbro"	- Silicified noritic cumulate (hybrid rock)
Normal "gabbro"	- Gabbroic and noritic cumulate
b) **Coarse Grained Intrusions**	
Mottled "gabbro"	- High-alumina "gabbro" (norite)
Diorite	- High-alumina "diorite" (noritic)
Quartz biotite diorite	- High-alumina "gabbro" (hybrid rock)
c) **Minor Intrusions and Veins**	
Mottled diabase	- High-alumina "diabase" dykes
Quartz-hornblende diorite (Q.H.D.)	- Metadiabase dykes and metavolcanic inclusions
Quartz-feldspar porphyry (Q.F.P.)	- Quartz-feldspar porphyry dykes
Hybrid	- Foliated granite dykes
Siliceous felsite	- Quartz-plagioclase-pyrrhotite veins

TABLE 2.1(b) ROCK TYPE NOMENCLATURE: "EL" PLUG

Sherrill Gordon Mines Limited	Inferred Composition
a) **Coarse Grained (Cumulate) Intrusions**	
"Peridotite"	- Ultramafic cumulate (olivine-rich)
Amphibolite (<10% feldspar)	- Ultramafic to mafic cumulate (pyroxene-rich)
b) **Coarse Grained Intrusions**	
"Contact-diorite"	- High-alumina gabbro
c) **Minor Intrusions and Veins**	
"Mottled diabase"	- High-alumina "diabase" dykes

descriptions show similarities and differences between the various orebodies. In some, the ore is restricted to the confines of discrete, subcircular mafic to ultramafic intrusions within the "A" plug host "gabbros" and amphibolites, and in others, the ore occurs directly within gabbroic host-rock.

The mineralization comprises five "ore-types" (Pinsent, 1977) which occur in different proportions in each of the orebodies:

(1) disseminated ores;
(2) plutonic breccia ores;
(3) sulphide breccia ores;
(4) massive sulphide vein ores; and
(5) "siliceous felsite" ores.

A more detailed discussion of the ore-types is presented in Chapter V. Ore-types 1 and 3 are considered to be largely magmatic in origin, as primary pyroxenes have been found in disseminated ores (ore-type 1) in the cores of the "A" (Hunter, 1950) and "N" orebodies, and in sulphide breccia ores (ore-type 3) in the "EL" orebody (Vellet, 1963). Some of the disseminated ore may, however, be hydrothermal in origin and there is evidence for local hydrothermal dispersion of sulphide. The plutonic breccia ores (ore-type 2) are clearly the result of interaction between an intrusive disseminated ore-bearing magma and host-rock "gabbro". The breccia matrix, which grades into disseminated ore, is invariably modified by hydrothermal activity and there may be local mobilization of the sulphide

TABLE 2.2(a) MAXIMUM ORE TONNAGES AND GRADES IN "A" PLUG OREBODIES

Orebody	Tons	Ni	Cu	Ni-Cu Ratio
"A"	5,306,132	1.065	0.550	1.94
"B"	4,277,315	0.738	0.499	1.48
"C"	1,206,563	0.759	0.491	1.55
"D" (U)	960,514	1.564	0.743	2.10
"D" (L)	1,597,500	0.668	0.348	1.92
"E"	1,021,207	1.055	0.484	2.18
"F" (M)	389,599	0.79	0.54	1.46
"F" (E)	52,461	1.19	0.76	1.56
"G"	217,910	0.95	0.39	2.43
"J"	461,335	1.09	0.47	2.32
"K"*	1,868,663	1,336	0.978	1.37
"N" (U)	3,921,442	0.84	0.38	2.21
"N" (L)	2,228,687	0.67	0.37	1.81
"O"*	4,740,552	0.81	0.35	2.31
"P"	260,690	1.08	0.69	1.56
Total:	28,410,570	0.906	0.489	1.85

*U and L "K" and "O" lenses are not differentiated

TABLE 2.2(b) MAXIMUM ORE TONNAGE AND GRADE IN "EL" PLUG OREBODY

Orebody	Tons	Ni	Cu	Ni-Cu Ratio
"EL" (U)	1,034,170	3.25	1.09	2.99
"EL" (L)	875,503	0.67	0.38	1.76
Total: (weighted average)	1,909,673	2.07	0.76	2.72

component. Massive sulphide pods and veins (ore-type 4) may either have formed from (a) *in situ* segregation of liquid sulphide, out of ore-types 1 and 3, (b) through hydrothermal mobilization into faults and fractures, or (c) remobilization through deformation (A. de Carle, pers. comm.). The three are not always distinguishable. Siliceous felsite ore (ore-type 5) occurs in veins both peripheral to, and within the ore zones, and more commonly as inclusions in sulphide and plutonic breccias. Siliceous felsite veins appear to have developed by hydrothermal processes prior to the main period of ore pipe intrusion.

The "A", "C", "O" and "M-N" orebodies comprise ore-grade lenses within what appear to be subcircular, subvertical, mafic to ultramafic igneous intrusive pipes. The four pipes are faulted out at depth and the "A" and "M-N" ore pipes are dislocated near surface. The ore occurs in discrete lenses within the pipes.

The "B", "D", and "F-K", orebodies consist of pipes or lenses of sulphide-cemented breccia (ore-type 3) or massive vein sulphide (ore-type 4) in "A" plug host-rock amphibolite, "gabbro" or Q.H.D. The massive ore is commonly associated with lenses of weakly mineralized host-rock and/or lenses of a younger mineralized "gabbro".

The "E-J" and "G" orebodies comprise ore-grade portions of what are probably structurally controlled late intrusive lenses within the "A" plug host "gabbros" and amphibolites.

The "footwall" and "hanging wall" portions of the "A" orebody, at the north end of the "A" plug, are contained in a pipe of weakly to strongly mineralized hydrous amphibolite (ore-type 1). The amphibolites grade into anhydrous mineralized norites and pyroxenites in the core of the pipe, away from faults (Hunter, 1950). The pipe abuts, and is partially enveloped by, a large irregular body of Q.H.D. which is known to extend from surface to below the 3000' level. The Q.H.D. body has been described as an inclusion (Emslie and Moore, 1961) or a fine grained igneous intrusion (Vellet, 1963). An off-shoot from the Q.H.D. mass, or a younger mafic dyke, separates the "hanging wall" from the "footwall" ore lenses and emplacement of the ore pipe may pre-date emplacement of the Q.H.D. mass. No Q.H.D. inclusions have been recorded in the "A" pipe but the amphibolites contain fragments of altered meta-"peridotite" (Vellet, 1963).

The "C" ore pipe is asymmetric. Low-grade mineralization (ore-type 1) in amphibolite in a "hanging wall" lens within the pipe is separated from high-grade sulphide breccia (ore-type 3) in a "footwall" lens by a zone of fine grained "hybrid" gabbro. According to Vellet (1963), the "gabbro", which contains pods and inclusions of coarse grained "gabbro" and diorite, is either barren or fractured and stockwork veined (ore-type 4). The "C" orebody abuts the same mass of Q.H.D. that controls the disposition of the "A" orebody, and fragments of Q.H.D. occur in the sulphide breccia.

Much of the ore in the "O" orebody occurs in a zone of plutonic breccia (ore-type 2) between "A" plug host "gabbros" and a central core of weakly mineralized amphibolite (ore-type 1). The mineralized pipe is cut by structurally controlled "high-grade" lenses of sulphide breccia ore (ore-type 3) on the 2000' level (Pinsent, 1977).

The "N" orebody (above the 3000' level) comprises a pipe ("M-N") containing two principal rock types. Barren, "silicified gabbro" within the pipe appears to be intruded by amphibolitized norite or pyroxenite. The norite, which is relatively undisturbed, contains disseminated mineralization (ore-type 1). The contact between the two rock units is sharp (Plate 2.1). The disseminated ore is cut by a major vein of massive sulphide (ore-type 4) on the 2600' level, and sulphides are concentrated in late veins adjacent to major faults. The

N3 orebody is a discrete body of anhydrous, barren and mineralized norite which forms a subsidiary vertical pipe either within or adjacent to the main "N" ore pipe. Norite intrudes barren "silicified gabbro".

The "B" and "F-K" orebodies form a complex of mineralized pipes and lenses which project downward into an intermediate "B-K" zone at depth. The "B" orebody comprises a series of *en echelon* ore lenses separated by barren "A" plug "gabbro". The "low-grade" B0, B1 and B3 ore lenses consist largely of disseminated mineralization (ore-type 1) in amphibolite, and what appears to be "A" plug "gabbro". Although the mine plans indicate the presence of plutonic breccia, it was not recorded by Macauley (1962) or Vellet (1963). The lenses are locally siliceous and they are cut by a complex micro-vein stockwork (ore-type 4). The "high-grade" B2 ore lens comprises a body of sulphide breccia (ore-type 3) subparallel to the disseminated ore lenses. The sulphide breccia is locally siliceous (ore-type 5), particularly adjacent to host-rock contacts, and it is cut by veins of massive sulphide (ore-type 4). Below the 2000' level the lenses coalesce to form a pipe-like sulphide breccia lens enveloped by weakly mineralized "A" plug "gabbro". The lower part of the "B" orebody projects into the "B-K" ore zone, which consists of disseminated sulphide mineralization (ore-type 1) in discontinuous amphibolite lenses in "A" plug "gabbro". The ore "B-K" zone is found between two parallel dykes of Q.H.D.

The Q.H.D. dykes, which coalesce immediately to the north of the "K" orebody, exert a major control on the structure of the orebody. The upper part of the "K" orebody consists of a heterogeneous pipe of disseminated, plutonic, sulphide breccia and massive sulphide ore (ore-types 1, 2, 3 and 4). At depth, this is funnelled into a single, sulphide breccia (ore-type 3) or massive sulphide (ore-type 4) ore lens within one of the dykes of Q.H.D. The "F" (east) lens is a vertical sulphide breccia off-shoot in Q.H.D. which diverges from the main "K" orebody and extends upward to the "F-K" fault. The "F" ore zone above the fault lies within an embayment in the Q.H.D. mass. It largely consists of local sulphide concentrations in weakly mineralized amphibolites and "gabbros". The ore zone dies out but mineralization continues above a major fault (No.1) on the 950' level and it may project into a major body of "peridotite". Weak, disseminated mineralization in the subeconomic "H" zone in "peridotite" adjacent to the "F" ore zone is probably related to the complex "B" and "F-K" mineralization process.

The "Upper" and "Lower" "D" ore lenses occur within the same structural plane, in "A" plug diorites in the hanging wall of a "peridotite" dyke northeast of the "A" shaft. The "Upper D" ore lens comprises a tabular body of disseminated, semi-massive and massive sulphides (ore-types 1, 3 and 4) in fine grained gabbro and diorite. According to Vellet (1963) the top of the massive ore lens is siliceous and consists of siliceous felsite ore (ore-type 5). The "Lower D" ore lens consists of weak to moderately disseminated and banded sulphide in a fine grained diorite lens down-dip from the "Upper D" lens. The diorite is weakly silicified and is cut by narrow (2-10 cm) veins of siliceous felsite which are parallel to the structural trend of the ore lens.

The "E" and "J" ore lenses are considered to be the "Upper" and "Lower" counterparts of the same faulted ("E-J") orebody. The two lenses contain weak to strong sulphide disseminations (ore-type 1) which occur, largely, in amphibolites and talcose amphibolites. These were thought, by Vellet (1963), to be derived from pyroxenites and "peridotites". The lenses contain pods of sulphide breccia (ore-type 3). The lenses are strongly faulted and sheared, and they are cut by dykes of diabase and quartz-feldspar porphyry. The western "footwall" contact of each lense is defined by a body of early "diabase" or Q.H.D. Inclusions of Q.H.D. that occur in the sulphide breccias in the "footwall" predated "emplacement of the (ore) lenses" and subsequent disruption. He concluded that the "E-J" orebody was a late, structurally controlled intrusion into "A" plug "gabbro" and amphibolite. The "Gil ore lens, which is located on strike to the south of the "E-J" zone, is largely subeconomic. It consists of faulted lenses of weak sulphide mineralization in "gabbro" and amphibolite which trends towards a peridotite on the 3000' level.

2.4 GEOLOGY OF THE "EL" PLUG

The "EL" plug is a composite intrusion which cuts quartz-feldspar porphyry flows and breccias (unit 7) 3.8 km southeast of the "A" shaft at Lynn Lake (Fig. 1.2).

The intrusion has the form of a cored pipe which tapers from a surface diameter of approximately 500 m (Fig. 1.2) to a diameter of 200 m on the 2000' level (Fig. 2.4). The pipe has a vertical attitude and it has been traced for a depth of over 1500 m (Fig. 2.5).

The "EL" pipe comprises an outer (marginal) unit of "contact-diorite" and an inner (core) unit of amphibolite, "peridotite" and minor "core-gabbro" (Vellet, 1963). The orebody occurs in the mafic to ultramafic core, which is centrally located within the "contact-diorite" pipe. The core has a diameter of 120 m on surface and 92 m on the 2000' level. There is no sign of chilling between "contact-diorite" and country rock acid volcanics and, according to Vellet (1963), the contact appears to be sheared. Vellet (1963) noted a marked increase in the garnet and biotite content of the acid volcanics adjacent to their mutual contact. He attributed this to thermal metamorphism on emplacement of the "contact-diorite". A. de Carle (pers. comm.) considers that extensive hybridization occurred near the contact and that some of the diorite resembles "Hybrid" and Q.H.D. found in the "A" plug.

2.5 "EL" PLUG OREBODY

Vellet (1963) has shown that the mineralization in the core of the "EL" plug occurs in three settings:

(a) "High-grade" sulphide breccia ore (ore-type 3) occurs in an ore lens between the surface and the 6th level.
(b) "Low-grade" disseminated (ore-type 1) and plutonic breccia ore (ore-type 2) occurs at the core-envelope interface between the surface and the 6th levels; and
(c) a subeconomic "root-zone" of disseminated sulphide in amphibolite and "peridotite" extends from the 6th level (Fig. 2.5) down to the 925 m level.

Mineable ore was restricted to the top 270 m in the "EL" plug. An estimate of the metal content of the "EL" plug is given in Table 2.2(b).

The "EL" plug has been cut by a series of reverse faults (Fig. 2.5), of which the upper and lower "EL" faults are the most important. The upper "EL" fault, which strikes 300° and dips 35°NE, is similar in disposition to the Lynn Lake fault. It cuts the "EL" orebody on 1st to 3rd levels and defines the footwall of the main "high-grade" ore lens on surface. The fault has thrown the hanging wall southwest and has controlled the intrusion of a suite of post-ore uralitic diabase dykes. The dykes penetrate the mafic to ultramafic core and extend a small way into the "contact-diorite" envelope. The lower "EL" fault, which strikes 290° and dips 60°-80°N, dislocates the orebody on the 4th level and gives a small throw to the south. Splays from the lower "EL" fault, oriented E-W and vertical, have sheared the orebody between the upper and lower "EL" faults and have localized mafic dykes and ore veins.

Movement along the upper "EL" fault appears to have elevated the bulk of the "high-grade" sulphide breccia lens above the plane of erosion and the remnant lens, visible in surface plan, is all that remains of a far more extensive body of sulphide breccia which is still found in the footwall of the fault.

The "root-zone" of the orebody was not mined below 7th level. It consists of weak disseminated mineralization in a near vertical lens of intermixed amphibolite and "peridotite" (55 m x 15 m) which strikes 340°. The mineralized lens occurs within the core of the intrusion in a pipe of barren amphibolite and "peridotite", which has been traced by drilling to the 1000 m level. The mafic to ultramafic pipe has been disrupted by two faults (the "Contact" and "L" faults) above the 2000' level (Fig. 2.4) and the mineralized zone is cut out on the 2000' level. It reappears, at depth, against the east wall of the "contact-diorite" and it dies out at depth.

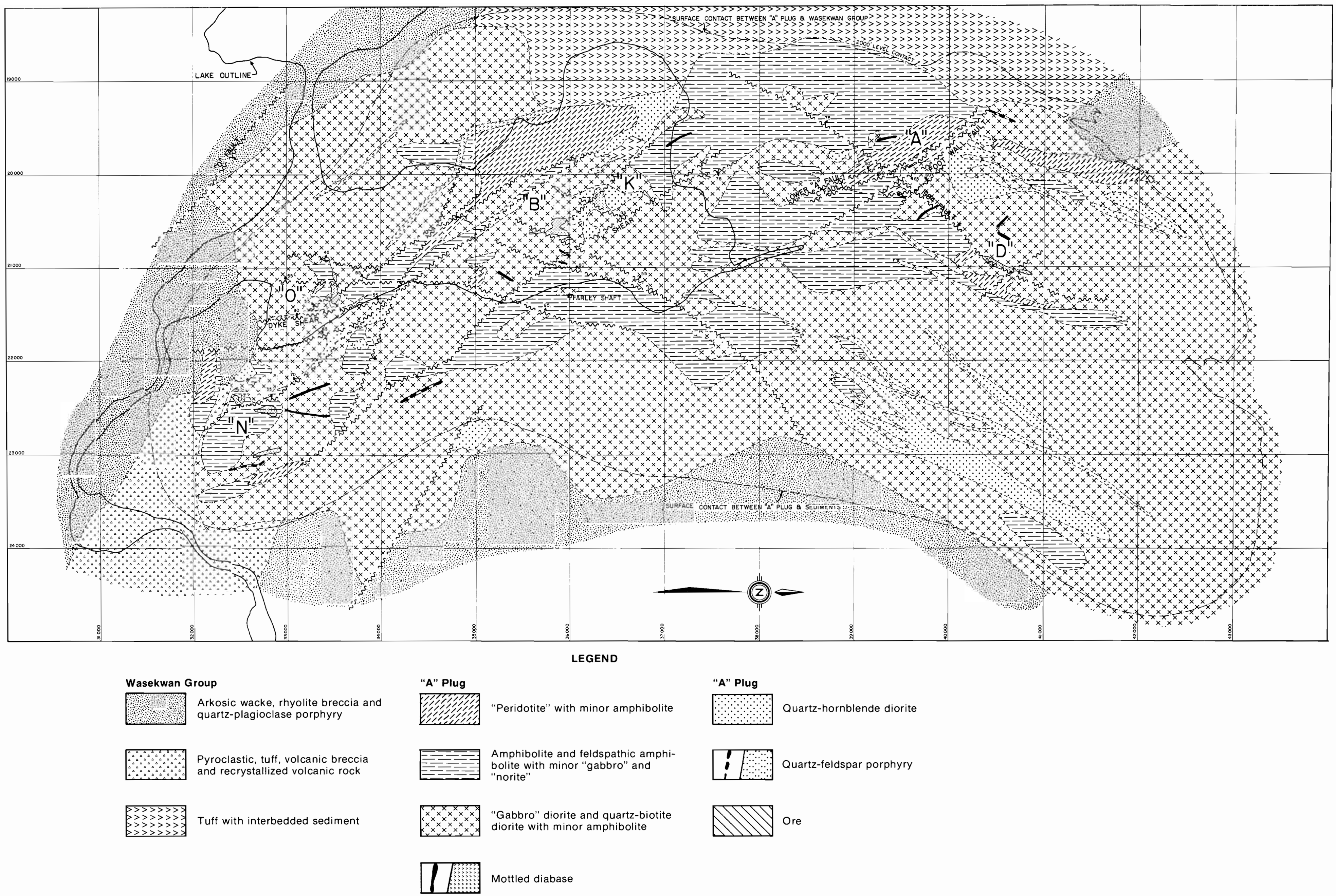


FIGURE 2.3: Simplified geological plan of the "A" Plug, 2000' level; Geology after Sherritt Gordon Mines Limited

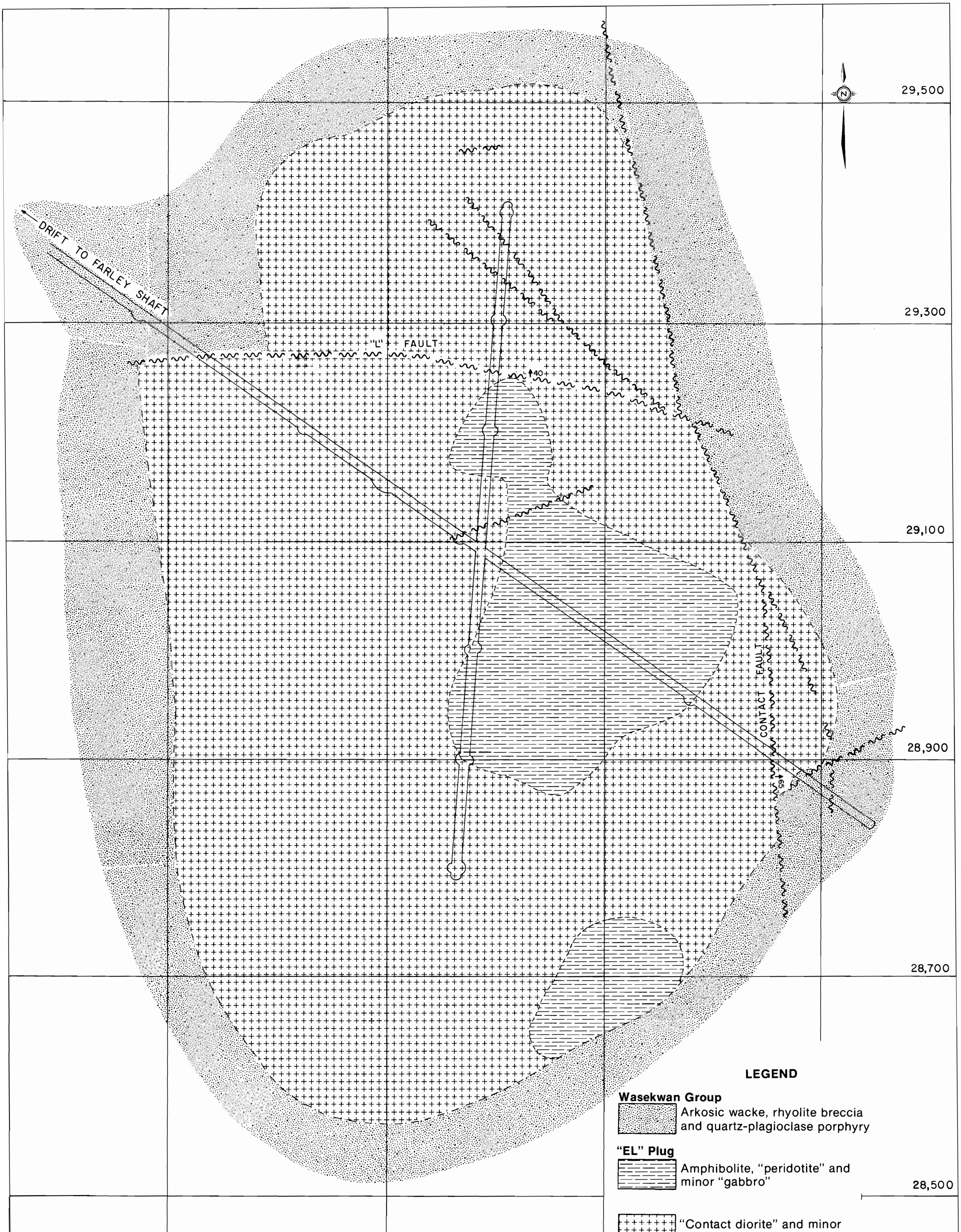


FIGURE 2.4: "EL" plug 2000' level: Geology simplified after Sherritt Gordon Mines Limited.

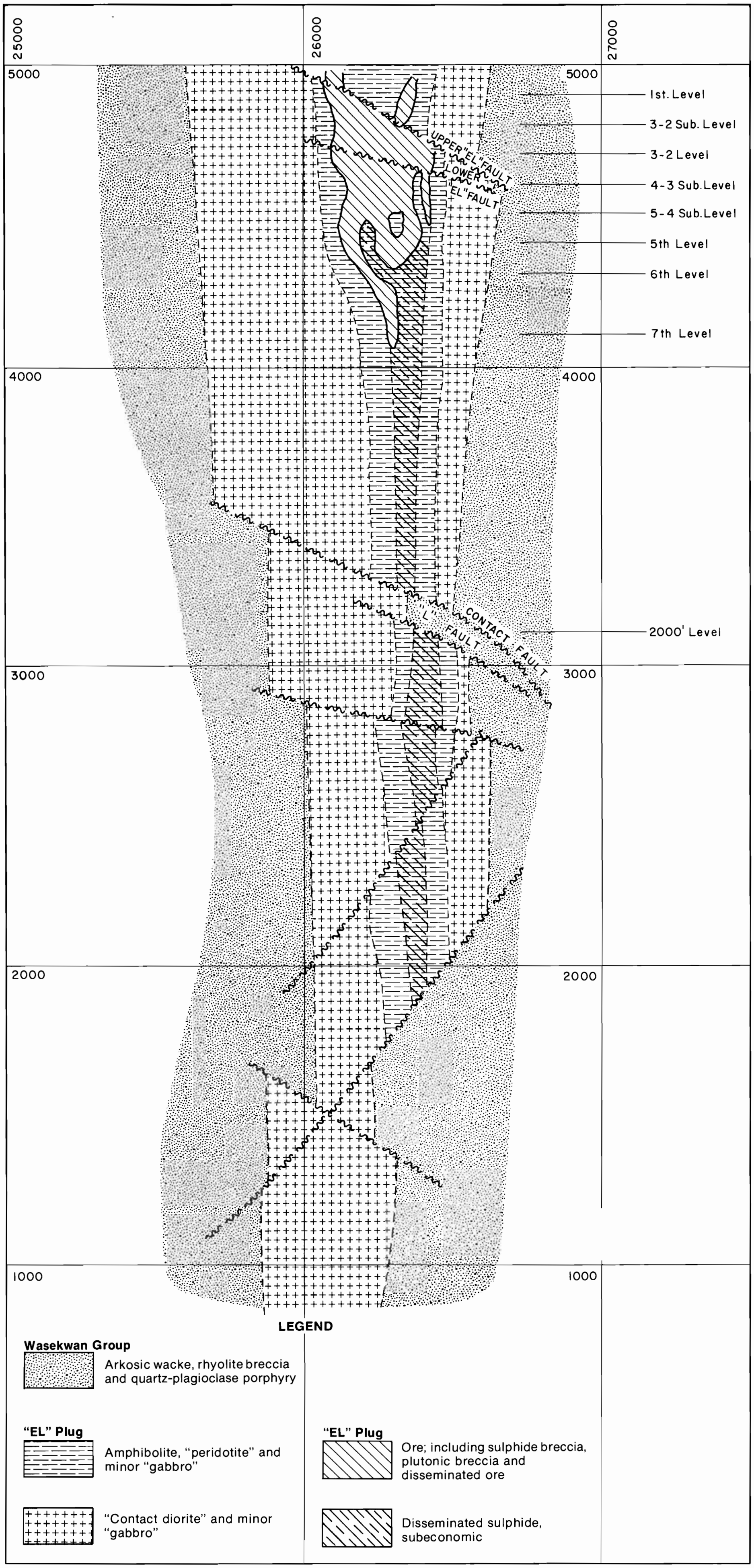


FIGURE 2.5: Section (W.29150E) through the "EL" plug, Lynn Lake: Geology simplified after Sherritt Gordon Mines Limited.

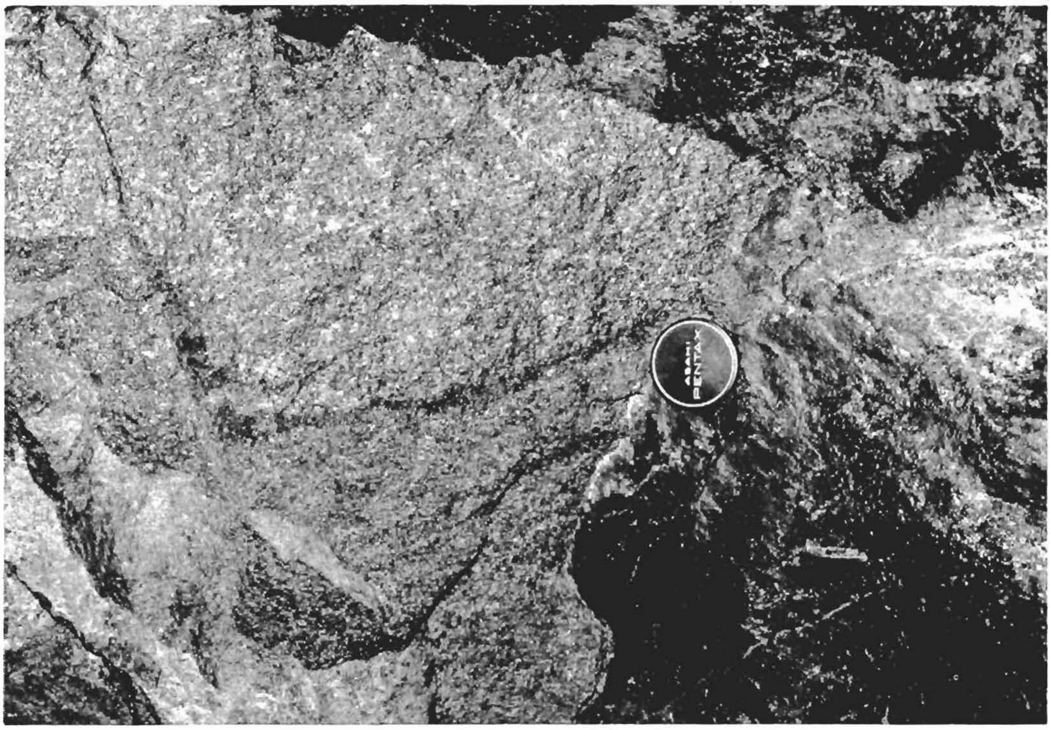


PLATE 2.1: Intrusive contact between barren and mineralized "gabbro" in the "N" ore pipe. Note minor off-set on a cross-cutting fault: disseminated ore (ore-type 1) 2600' level, "N" orebody.

Chapter III - Petrography of "A" and "EL" plugs

3.1 INTRODUCTION

The rock types recognized in the "A" and "EL" plugs are listed in Tables 2.1 (a,b). The Company nomenclature evolved over the productive life of the Ni-Cu deposits and usage was, in essence, pragmatic. Rock type definition was complicated by metamorphism which reduced all the mafic and intermediate rocks (except norite) to an assemblage of amphibole (pargasite), plagioclase feldspar and small amounts of quartz, biotite and chlorite. The Company did not discriminate between different types of "gabbro" and diorite in the "A" plug, and it is not always clear whether the diorite referred to in the plans is a late, fine grained intrusion, known from the vicinity of the "O" orebody (Plate 3.1), or a particularly feldspathic facies of the "gabbro". The sections and plans in Appendix I have been simplified and the "gabbro" unit contains small amounts of diorite. The amphibolites appear to grade into a mafic facies of the "gabbro", and inconsistencies in the mapping occurred locally over the life of the deposit. Norite was not identified as such in any of the plans or sections, although it was known to occur within, or in close proximity to, the "A", "B", "E-J" and "N" orebodies and in fragments in plutonic breccias in the "O" orebody (A. de Carle, pers. comm.). Although fresh norite was found in a drill hole between the Lower "K" and "G" orebodies (on the 3000' level), there is no associated mineralization.

The fine grained mafic rocks in the "A" plug (Q.H.D. and diabase) are not always clearly differentiated, and some of the Q.H.D. in the plug is metavolcanic inclusion material (A. de Carle, pers. comm.).

Hunter (1950) subdivided the "A" plug into three units (A, B, C) on the basis of (a) the proportion of amphibole and plagioclase in the principal gabbroic rock type, (b) the internal structure of the rock and (c) the compositions of the amphiboles and feldspar. He considered that unit "A" gabbro in the north and west of the plug was, in general, foliated and more amphibolitic (>65% amphibole) than the homogeneous (unit "B") gabbro in the centre of the "A" plug (<65% amphibole).

Unit "C" gabbro, found on surface along the east margin of the plug, was described by Hunter (1950) as a younger intrusion related to the post-ore dyke swarm. Unit "C" gabbro is fine grained. It has the same modal composition as unit "B" gabbro, but the amphibole has a characteristic blue-green pleochroism.

Emslie and Moore (1961) found no basis for subdividing units "A" and "B", as defined by Hunter (1950), and they attributed the altered (uralitized), rhythmically layered assemblage of pyroxenites, norites and anorthosites to a "Western" unit. They differentiated an "Eastern" unit, equivalent to unit "C" (Hunter, 1950), on the basis of amphibole composition, and the fact that the rock probably contained relatively abundant primary (hornblendic) amphibole.

Macauley (1962) examined the gabbro in the vicinity of the "B" orebody. He also found no reason to differentiate between unit A and unit B (Hunter, 1950), and he assigned both to a unit of "actinolitic uralite gabbro" ("B" gabbro). In addition, he identified a body of "hornblende uralite gabbro" ("mottled" gabbro) west of the "B" orebody. This strongly resembles the "gabbro" in unit C, as defined by Hunter (1950)

Vellet (1963) conducted a comprehensive study of the petrography of the core recovered from a systematic, horizontal drilling program on the 2000' level in the "A" plug. He identified four varieties of "gabbro":

(a) medium grained
(b) banded
(c) feldspathic
(d) mottled.

According to Vellet (1963), medium grained "gabbro" is the principal rock-type on the 2000' level. It hosts the "O" and "N" orebodies at the south end of the "A" plug and it includes much of the north end, and the east half of the plug (Fig. 3.1). Banded "gabbros" host the "O" orebodies and they appear to be well developed east of the ore zone. Vellet (1963) indicated a probable gradation between the gabbros and quartz diorites. Feldspathic "gabbros" occur in the core of the "A" plug, and partially envelop the "B" orebody. A belt of feldspathic "gabbro" in amphibolite (uralite) extends northward from the "B-K" zone to the "A" shaft (Fig. 3.1). The age relations displayed by these rock facies are obscure and they appear to be gradational. All display rhythmic layering and compositional banding.

Mottled "gabbro", which is intruded along the length of the shear zone west of the "B-K" zone (Fig. 3.1), is homogeneous and, according to Vellet (1963), it experienced a magmatic history which is quite distinct from that of the rest of the plug "gabbro". Vellet (1963) made no mention of finding mottled "gabbro" along the eastern margin of the plug, on the 2000' level. The reason for its apparent absence is not clear.

Geochemical data presented in this study indicates that much of the "A" plug is comprised of remobilized cumulate, and the rock units in Table 2.1 are grouped into cumulate and non-cumulate intrusions. The medium grained feldspathic and banded "gabbros" are considered to be textural and compositional variants of the same mafic cumulate unit referred to as normal "gabbro" in Table 2.1.

3.2 COARSE GRAINED (CUMULATE) INTRUSIONS

1) "Peridotite" (ultramafic, olivine-rich, metacumulate)

Olivine-bearing ultramafic rocks, variously described as peridotite (Macauley, 1962) or dunite (Vellet, 1963), occur in both the mineralized plugs at Lynn Lake. The composition of the rock is variable and there is a complete gradation from olivine-rich "peridotite" to olivine-poor amphibolite.

The rock is invariably altered and metamorphosed, and the only widespread primary mineral phase is olivine. Euhedral to subhedral (1-6 mm) olivine crystals ($Fo_{79 \pm 3}$, J.D. Scott, pers. comm.) are randomly oriented in a matrix which now consists of chlorite and tremolitic amphibole (Plate 3.2). Olivine crystals are commonly fractured and some show dislocation lamellae. The fractures are exploited by a mixture of serpentine, chlorite, tremolite and magnetite dust. The original olivine outlines are commonly sharp, although tremolite locally replaces the outermost, marginal olivine. Some olivines contain opaque granules of what may be a primary spinel.

Much of the "peridotite" retains an igneous cumulate texture and olivine crystals are either distributed in a chloritic matrix or they are poikilitically enclosed within tremolite-chlorite pseudomorphs after pyroxene. The pseudomorphs occur as (a) relatively abundant euhedral to subhedral laths (0.5 — 1.0 cm) with a fine dusting of magnetite and (b) less common euhedral intercumulus patches (0.2 — 0.8 cm) with a heavy dusting of magnetite which enhances an original pyroxene cleavage. The former are thought to pseudomorph and replace laths of orthopyroxene and the latter clinopyroxene. Relict cores of enstatite (En_{90}) and endiopside ($Ca_{37}Mg_{59}Fe_4$) were found in diamond drill core samples U850 — 1481', and U850 — 1471', respectively (J.D. Scott, pers. comm.). These samples are from the "peridotite" mass to the west of the "B-K" zone on the 2000' level. The pyroxene content of the "peridotite" is extremely variable.

Some "peridotite" samples contain a primary yellow-green, pleochroic clinoamphibole with an intercumulus texture and all contain patches of what is now intercumulus chlorite. The chlorite is thought to pseudomorph primary feldspar, although no feldspar relicts were identified. Chlorite is the dominant intercumulus mineral in "pyroxene"-poor rocks. Intercumulus troilite in juxtaposition to fresh olivine was found in a few of the "peridotite" samples, but most are barren of sulphide. A colourless tremolitic amphibole overprints and replaces the intercumulus variety and they are locally in optical continuity. Feathery tremolite pseudomorphing orthopyroxene characteristically displays a mottled or "cross-hatch" extinction pattern.

The "peridotites" appear to have been deformed subsequent to metamorphism and broken tremolite blades are commonly associated with minor secondary mineral phases such as serpentine, carbonate, talc, chlorite and magnetite.

A fine grained (0.5 mm) rock from the N1 (west) orebody on the 2800' level was found to consist of an altered olivine suspension in pyrrhotite. This unit, which is distinctive, may occur in the "B-K" peridotite (A. de Carle, pers. comm.).

2) Amphibolite (ultramafic, pyroxene-rich, metacumulate)

Much of the barren amphibolite in the "A" plug consists of a colourless to light green, pleochroic clinoamphibole (pargasite; J.D. Scott, pers. comm.) derived from a pre-existing pyroxene. In the less deformed amphibolites some of the original texture is retained and crystals of pargasitic amphibole display basal sections and twin characteristics of the earlier pyroxene. The amphibole displays the "cross-hatch" or "checkerboard" extinction pattern commonly found where orthopyroxene is replaced by amphibole (Plate 3.3). In a few undeformed samples, pyroxene outlines are preserved where the original crystal was enveloped by a primary, interstitial amphibole. The amphibole has a core which is strongly fractured and dusted with magnetite, and a clear outer margin (Plate 3.4). The amphibole in the core displays a weak yellow pleochroism and the outer-marginal amphibole is identical to the pargasite amphibole which replaces pyroxene.

In samples which display an increased level of deformation the original texture is lost, but the characteristic extinction pattern of the amphibole remains. The amphibole tends to be fibrous, but some deformed amphibolites contain local patches of recrystallized, idiomorphic amphibole in association with interstitial quartz and biotite. Amphibolites may contain a small amount of plagioclase, which is commonly disrupted and recrystallized into domains zoned from calcic cores to sodic margins, and veined by chlorite.

Mineralized amphibolites show all the features observed in barren amphibolites. In addition, they contain interstitial blebs of sulphide. The amphibole in the vicinity of a sulphide bleb is commonly dusted by sulphide (Plate 3.5).

Although mineralized amphibolites are, as a rule, more strongly altered and recrystallized than the barren amphibolite, this is not always the case. In a large number of mineralized amphibolites the rock is deformed and recrystallized. The feldspar is disrupted and fragments are unstable and/or zoned and they are veined by chlorite. The old pyroxene laths are commonly enveloped by magnetite-dusted, yellow-pleochroic, primary amphibole and this grades into the same pargasite amphibole which replaces the original pyroxene. Fresh, idiomorphic pargasite occurs in blebs, in association with quartz and biotite.

3) Norite (noritic cumulate)

Although norite was never mapped as a separate entity, it has a diagnostic texture which is readily distinguishable from "A" plug "gabbro". Norites characteristically consist of a suspension of euhedral orthopyroxene crystals in plagioclase (Plate 3.6) and/or sulphide (Plate 3.7). In "barren" norites from the N3 orebody the pyroxenes are either poikilitically enclosed within larger laths of weakly zoned feldspar or they are scattered throughout a matrix of interstitial feldspar. The pyroxene grain size is exceedingly variable (0.5 — 5.0 mm) and crystal orientation appears to be random. In the mineralized norites from the same locality, the sulphide forms interstitial blebs which coalesce in the more heavily mineralized samples to cause autobrecciation of the norite. Discontinuous pyroxene-feldspar "fragments" (0.5 — 1.0 cm) are enveloped by sulphide, which characteristically contains small crystals of orthopyroxene but no feldspar. Some ore-bearing samples consist of a pyroxene-plagioclase suspension in sulphide with no evidence of autobrecciation. In the latter case, plagioclase nucleation appears to have preceded that of orthopyroxene.

Norites are variable in composition. In addition to orthopyroxene (enstatite, Enao) and plagioclase feldspar (An_{75}), they contain small amounts of clinopyroxene (augite) and olivine (Fo_{82}).

All but the most anhydrous norites contain interstitial crystals of the typical primary amphibole. The amphibole, which is probably hornblendic, has a fractured and magnetite-dusted core. The core is yellow and pleochroic and it grades into clear, light green to colourless amphibole which is probably pargasite. It resembles the fibrous amphibole which characteristically replaces orthopyroxene in the more altered samples. Biotite and quartz also occur as secondary minerals.

As noted by Hunter (1950), the sulphide blebs found in fresh norites have sharp interstitial contacts. The sulphide becomes progressively dispersed by alteration. In the more deformed and altered rocks, sulphide granules occur along cleavages in amphibole pseudomorphs after orthopyroxene, located in the vicinity of original sulphide blebs.

4) Silicified "gabbro" (silicified noritic cumulate-hybrid)

Silicified "gabbros" are restricted to the "N" ore pipe, where they appear to host younger intrusions of mineralized norite. The gabbro" is characteristically barren to weakly mineralized, it has a gabbroic texture (2 — 4 mm), and it contains abundant blue interstitial quartz. It can readily be separated from norite on the basis of its secondary mineralogy and its texture. Samples of both, from DDH U168S, which cuts the "N3" ore lens below the 2000' level, were examined in detail.

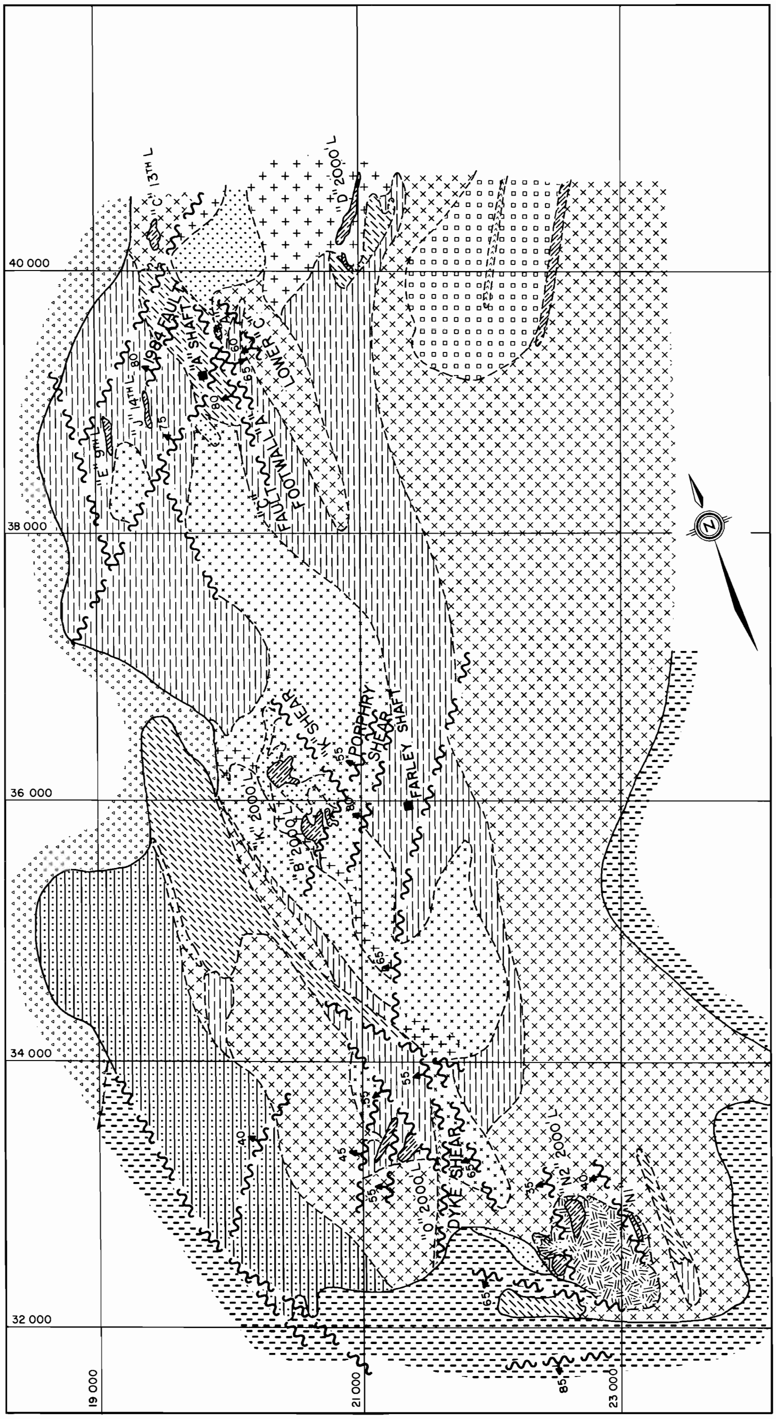
There is no fresh pyroxene and the principal mafic mineral in the silicified "gabbro" is a light green, fibrous, pleochroic amphibole which appears to pseudomorph a pre-existing pyroxene. The amphibole, which is probably a pargasitic actinolite, locally displays cross-hatch (checkerboard) twinning. Much of the amphibole probably pseudomorphs orthopyroxene. Some of the samples contain patches of what was probably primary amphibole. Patches of interstitial (hornblendic) amphibole zone outward from a dusty, yellow-brown, pleochroic core into light green (pargasitic) amphibole. In other samples, the dusty hornblendic patches appear to be completely replaced by pargasite. Stable biotite overprints the pargasitic amphibole and it is locally overprinted by it.

The feldspar component of the rock consists of laths of fresh, fractured plagioclase. The plagioclase laths are commonly strongly zoned. They consist of a core of uniform anorthite composition ($An_{80 \pm 5}$) and an outer rim of strongly zoned, less calcic plagioclase. The albitic overgrowth penetrates fractures in the plagioclase core and cuts across the twin lamellae in the core of the lath. The overgrowth clearly post-dates deformation. The development of a sodic rim to the plagioclase appears to be best developed where the feldspar is intimately associated with interstitial quartz. The outer margin of the feldspar commonly passes into a crystatlographically continuous, interstitial, patch of symplectic quartz-feldspar intergrowth. These intergrowths increase in crystallinity from a fine grained quartz-feldspar sponge (Plate 3.8) to an intergrowth of blades of plagioclase and quartz. The intergrowths may contain a small amount of orthoclase. There is evidence for silica replacement of plagioclase in some samples and stable coexistence of quartz and primary, yellow-brown, pleochroic amphibole.

Chlorite occurs in minor amounts as stable laths replacing both plagioclase and pargasitic amphibole.

5) Normal "gabbro" (gabbroic and noritic cumulate)

Although the medium grained, banded and feldspathic "gabbros" (Vellet, 1963) differ slightly in composition and texture, they appear to be facies of the same rock type (normal "gabbro") and they are treated as a single unit.



LEGEND

	Vellet (1963)	— This Report
Wasekwan Group		
	Andesites and pyroclastics	— Mafic to intermediate flow, tuff and breccia
	Gneissic granulite and paragneiss	— Quartz-plagioclase porphyry
"A" Plug Ultramafics		
	Peridotite-dunite	— Peridotite (olivine rich)
	Peridotite-pyroxenite	— Peridotite (pyroxene rich)
	Uralite	— Amphibolite
Gabbros		
	Norite	— Norite
	Medium grained gabbro	— Normal "gabbro"
	Feldspathic gabbro	— Normal "gabbro"
	Mottled gabbro	— Mottled "gabbro"
	Banded gabbro	— Normal "gabbro"
	Diabase dykes	— Mottled diabase
Diorites		
	Biotite diorite	— Quartz-biotite diorite
	Fine grained diorite	— Diorite
	Quartz-hornblende diorite	— Quartz-hornblende diorite

* Geology after Vellet, 1963

FIGURE 3.1: Geological plan of the 2000' level, "A" plug; after Vellet (1963).

Vellet (1963)		This Report
Wasekwan Group		
Andesites and pyroclastics	-	Mafic to intermediate flow, tuff and breccia
Gneissic granulite and para-gneiss	-	Quartz-plagioclase porphyry
"A" Plug		
Ultramafics		
Peridotite-dunite	-	Peridotite (olivine-rich)
Peridotite-pyroxenite	-	Peridotite (pyroxene-rich)
Uralite	-	Amphibolite
Gabbros		
Norite	-	Norite
Medium grained gabbro	-	Normal "gabbro"
Feldspathic gabbro	-	Normal "gabbro"
Mottled gabbro	-	Mottled "gabbro"
Banded gabbro	-	Normal "gabbro"
Diabase dykes	-	*Mottled diabase*
Diorites		
Biotite diorite	-	Quartz-biotite diorite
Fine grained diorite	-	Diorite
Quartz-hornblende diorite	-	Quartz-hornblende diorite

The banded portions of the "A" plug "gabbro" are particularly variable in composition. They consist of interlayered units of relatively mafic and felsic banded "gabbro". The most abundant "gabbro" in the "A" plug is a relatively homogeneous, medium grained variety which contains roughly equal proportions of "secondary" amphibole after pyroxene and relict "primary" or recrystallized feldspar.

Although the "gabbros" have been weakly to strongly deformed, and they have been uralitized to a common (metamorphic) mineralogy, many retain original igenous textures. The medium grained "gabbros" are commonly equigranular (3 — 4 mm) and subophitic, and the banded "gabbros", which have a similar grain size, display a layered, planar fabric. The original pyroxenes and feldspars in the banded "gabbro" commonly display a strong preferred orientation.

The "primary" mafic minerals in the "gabbro" are completely altered to a light green, pleochroic, fibrous amphibole (pargasite-actinolite). This amphibole pseudomorphs pyroxene basal sections and it commonly displays "cross-hatch" twinning under crossed nicols (Plate 3.9). The bulk of the amphibole in the "gabbro" is probably a replacement after orthopyroxene (Macauley, 1962). No fresh pyroxene remnants have been found. The pargasite amphibole is commonly ragged and fibrous and it partially overprints plagioclase. It may also partially replace an earlier hornblendic amphibole. This amphibole, which is not common, appears to be best developed in the more deformed "gabbros", where it occurs in interstitial patches (Plate 3.10). The hornblendic amphibole is yellow-brown in colour and strongly pleochroic. It is commonly fractured and the fractures are enhanced by deposition of a fine dusting of oxide. Small (1 mm) interstitial amphibole relicts and patches are found between laths of "pyroxene" and plagioclase and larger (5 mm) poikilitic amphiboles enclose laths of younger "secondary" pargasitic amphibole. The hornblendic amphibole patches are (a) replaced by pargasite, (b) enveloped by pargasite, or they are (c) zoned into pargasite. The hornblendic amphibole may be either an early replacement for clinopyroxene or an original, "primary" amphibole.

Pargasite is locally mantled by a more strongly (blue-green) pleochroic, but optically continuous, variety of amphibole which is less fibrous and more coarsely crystalline. This variety of amphibole is best developed at the contact between crystals of plagioclase and what were laths of pyroxene.

Relict plagioclase laths in the "gabbro" are weakly zoned or unzoned. Zonation is for the most part "normal", commonly with a marked An reduction in the outer layers. The plagioclase laths (An_{85} - An_{60}) are commonly fractured, deformed into a diffuse, patchy, crystallographic mosaic, or are completely replaced by an equilibrium mosaic of smaller crystals (< 1.0 mm).

The "gabbro" is characteristically quartz-free, except where the rock has undergone silicification. "Gabbros" in the vicinity of the "B" and "D" orebodies appear to be cut by narrow 2 — 10 cm veins of siliceous material, which resembles siliceous felsite and is commonly mineralized. The vein walls appear to be diffuse and quartz is abundant in interstitial spaces in the "gabbros" adjacent to the veins.

The more deformed "gabbros" and the silicified "gabbros" commonly contain small amounts of chlorite and biotite. Chlorite locally exploits fractures in, and grain boundaries between, laths of feldspar. Biotite is typically intimately associated with pargasite.

3.3 COARSE GRAINED INTRUSIONS

6) Mottled "gabbro" (High-alumina gabbro/norite)

Mottled "gabbros" have been separated from normal "gabbros", which they resemble, on the basis of the dominant amphibole pleochroism and mode of occurrence of the feldspar. Fresh feldspar laths occur in clusters which give a mottled appearance to the rock (Macauley, 1962) and Vellet (1963) noted that some mottled "gabbros" contain myrmekitic intergrowths of interstitial quartz and plagioclase, similar to that found in quartz-biotite diorite.

The amphibole in the mottled "gabbro" is strongly pleochroic (blue-green to green-brown) and, commonly, poikilitically encloses small amounts of fine grained free quartz (Plate 3.11). The amphibole resembles the blue-green amphibole which occurs as an overgrowth on "pyroxene" in normal "gabbro". According to Emslie and Moore (1961) this amphibole is "primary" and it formed prior to uralitization of the "pyroxene" in normal "gabbro" to pargasite-actinolite.

The feldspar is commonly zoned and it locally displays a sodic rim. The "gabbro" contains small amounts of oxide and traces of biotite and chlorite.

7) Diorite (High-alumina (feldspathic) norite)

Fine grained (0.5 — 1.2 mm) intrusive diorites occur in the vicinity of the "O" orebody. The diorites are homogeneous and equigranular, and they display an altered subophitic to diabasic texture. The diorites consist of an irregular mosaic of strongly zoned laths of plagioclase, and pargasite-actinolite amphibole replacement patches after pre-existing pyroxene. The amphibole is similar to that found in normal "gabbro". It is commonly cross-hatched and it locally displays pyroxene basal sections. It is commonly fibrous and ragged and it displays the characteristic light green to yellow-brown pleochroism of the pargasite-actinolite.

The fine feldspar laths are zoned and alteration processes have preferentially affected the more calcic plagioclase cores. Deformed samples comprise a mixture of broken feldspar laths, ragged amphibole crystals, and small amounts of "secondary" biotite and quartz. The diorite mineralogy resembles that of normal "gabbro" cumulate. It differs in grain size and texture.

Contact diorite from the "EL" plug (Vellet, 1963) is a particularly feldspathic gabbroic" rock. It has a hypidiomorphic-granular texture and it consists of an assemblage containing weakly pleochroic light green pargasite-actinolite and laths of calcic plagioclase. According to Vellet (1963), it also contains well preserved relicts of clinopyroxene (augite).

8) Quartz-biotite diorite (High-alumina gabbro (hybrid?))

Quartz-biotite diorite forms a distinctive rock unit adjacent to the plug contact, west of the "B-K" peridotite and the "O" orebody. The diorite is homogeneous and it has a weak subophitic igneous texture (grain size 1 — 3 mm).

The diorite contains an early yellow-green pleochroic, primary, hornblendic amphibole which is enveloped by, and partially altered to, a secondary, light green pleochroic, pargasitic amphibole. The two amphiboles are intimately inter-related and cores of the former, which are commonly fractured and dusted with oxide, zone into the latter, which is clear and ragged. The pargasite is commonly granular and it poikilitically encloses crystals of quartz. None of the amphibole displays the "cross-hatch" twinning characteristic of amphibole derived from orthopyroxene. Biotite, with a weak brown pleochroism, overprints pargasite and is intimately associated with granules and interstitial patches of opaque oxide. Patches of pargasite, biotite and oxide appear to pseudomorph original mafic crystals. Traces of chlorite and zoisite are also found in the assemblage, and zircons with radiation haloes were observed in the biotite.

The plagioclase is strongly zoned and there is commonly a sharp break between an anorthite-rich core and an anorthite-poor margin (An_{75} — An_{30}). Rare reversals in compositions are found locally. Plagioclase cores were commonly strongly fractured. The fracturing is either less pronounced or absent in the outer marginal layers.

Strain-free quartz is abundant in the interstitial spaces between laths of zoned plagioclase and amphibole (Plate 3.12), and it occurs as small inclusions in the pargasitic amphibole.

3.4 MINOR INTRUSIONS AND VEINS

9) Mottled diabase (High-alumina diabase)

Late, post-ore, diabase dykes (Plate 3.13) are commonly fine grained (<0.5 m) to aphanitic. The dyke groundmass is equigranular and it has a basaltic to ophitic texture. The dykes are locally porphyritic. Some contain euhedral (0.5 — 1.0 mm) plagioclase phenocrysts (Plate 3.14) and others contain smaller, less abundant, amphibole replacement after pyroxene phenocrysts. The dyke groundmass is an assemblage of zoned plagioclase feldspar. The amphibole resembles that found in mottled "gabbro" (Vellet, 1963) and it is locally dusted by magnetite. The dykes contain granules of oxide.

The dykes have sharp but irregular contacts with "A" plug gabbros, which appear to be unaffected by injection of dyke fluid. The groundmass feldspar in the dyke is locally foliated parallel to the wall rock contact. The foliation extends for approximately 5.0 cm into the dyke. Dyke contacts with "gabbros" found in the vicinity of the "O" orebody are locally exploited by a slightly coarser grained and more differentiated facies of the dyke fluid. This facies of the dyke contains fragments of both country-rock "gabbro" and chilled mafic dyke material. The mafic dykes intrude "peridotite" west of the Farley Shaft and a biotite-chlorite assemblage has formed at the interface between the two.

10) Quartz-hornblende diorite (Q.H.D.)

"Quartz-hornblende diorite" is a general term for a wide variety of fine grained mafic to intermediate rocks. The term encompasses hornfels country-rock inclusion and recrystallized intrusive dyke material.

Quartz-hornblende diorities are fine grained (< 1.0 mm) to aphanitic and they commonly consist of an assemblage of amphibole, altered plagioclase, biotite, chlorite, quartz and local epidote. The intrusive samples are characteristically more deformed and more strongly recrystallized than the mottled diabase and they probably represent an early, pre-ore dyke swarm. The rocks have a hornfelsed, metamorphic texture. The rock contains laths of felty amphibole overprinted on an intergrowth of altered plagioclase and quartz. Q.H.D. is commonly cut by veins of quartz and locally appears to be silicified. Interstitial quartz replaces feldspar. The amphibole is light green and weakly pleochroic. It resembled pargasite found in fine grained diorite but there is no cross-hatch twinning or evidence of pyroxene replacement. Fractures cutting the cores of amphibole laths appear to be dusted with oxide. Outer margins are unaffected. The amphibole is overprinted by minor amounts of biotite and chlorite.

11) Quartz-feldspar porphyry

Dykes of quartz-feldspar porphyry comprise an assemblage of potassic and sodic feldspar phenocrysts in a matrix of quartz. Mafic minerals, such as biotite, chlorite, muscovite and amphibole, are rare. The feldspar phenocrysts are anhedral to euhedral and they range in size from 0.4 — 1.5 cm (Plate 3.15). The matrix quartz is anhedral and strain free. The feldspars show signs of alteration and both orthoclase and albite are commonly found with quartz in a symplectic intergrowth.

12) "Hybrid" (foliated granite dykes)

Dykes of foliated "hybrid" and irregular segregations of acid intrusive material (Plate 3.16) cutting the "O" and "N" orebodies at the south end of the "A" plug appear to consist of a siliceous biotite granite. The granite is fine grained (1 — 2 mm) and it locally develops a preferred fabric. It consists largely of discrete equigranular crystals of quartz set in a diffuse matrix of biotite and feldspar. The principal feldspars appear to be weakly zoned albitic plagioclase, orthoclase, and less common microcline (Plate 3.17). The feldspars are extensively altered (saussuritized) and are commonly intergrown with quartz.

The principal mafic mineral is brown, pleochroic biotite which occurs in fresh, large (2 — 5 mm), poikilitic laths. Small amounts of muscovite and chlorite were also found.

13) Siliceous felsite (quartz-plagioclase-pyrrhotite)

Siliceous felsite, or quartz plagioclase hornfels (Macauley, 1962), is a fine grained to aphanitic (<1.0 mm) assemblage which contains variable proportions of quartz, plagioclase, pyrrhotite and tremolite, with trace amounts of epidote, carbonate, sphene, chlorite and scapolite.

The rock has a strongly recrystallized, equigranular texture, and the groundmass largely consists of a mosaic of strain-free quartz, plagioclase and tremolite. Sulphide occurs either as fine, equigranular granules, disseminated throughout the silicate-carbonate assemblage, or, in more strongly mineralized samples, as an evenly distributed network of coalescing granules which have joined to form a sponge-like intergrowth with the silicate-carbonate assemblage (Plate 3.18). The sulphide is locally concentrated into layers, which gives a preferred fabric to the rock. The strongly mineralized felsites from the "O" orebody characteristically contain more quartz and less feldspar than less strongly mineralized siliceous felsite veins adjacent to the "B" orebody.

3.5 DISCUSSION

Petrographic investigations show that mineralized norite is the only rock to retain a "primary" anhydrous, igneous mineralogy. All the other mafic to intermediate rock units exhibit a metamorphic assemblage of secondary arnphibole and plagioclase feldspar. Three types of amphibole have been identified. (1) Small patches of yellow-brown pleochroic hornblende in normal "A" plug "gabbro" appear to be relicts of a "primary" amphibole or an early replacement after clinopyroxene. The relatively strong development of this amphibole in deformed rocks indicates that it was formed late, but prior to the main period of amphibolitization. (2) A strongly pleochroic, blue-green amphibole is found in some of the normal "A" plug "gabbros" and mottled "gabbros" and diabase dykes. The amphibole appears to be "primary" and there is no conclusive evidence for it replacing a pre-existing pyroxene. The amphibole is characteristic of late mafic intrusives which are more strongly differentiated and richer in iron. (3) A pargasitic-actinolite amphibole ($NaCa_2 Mg_4 Al_3 Si_6 O_{22} (OH)_2$) (J.D. Scott, pers. comm.) clearly replaces pre-existing orthopy-roxene and envelopes earlier hornblendic amphibole. This amphibole is clearly "secondary" and metamorphic in origin.

As fresh norite has survived in the cores of at least two of the ore pipes in the "A" plug ("A", "N"), much of the alteration of the "A" plug "gabbro" probably preceded emplacement of these particular ore pipes. This suggests that hydrothermal and intrusive activity in the plug were taking place more or less contemporaneously. The presence of broken blocks of siliceous felsite ore (which is probably hydrothermal in origin) in plutonic breccias in the "O" orebody also supports this contention.

PLATE 3.1: Intrusive contacts between fine grained diorite and mafic "gabbro": 3400' level, "O" orebody.

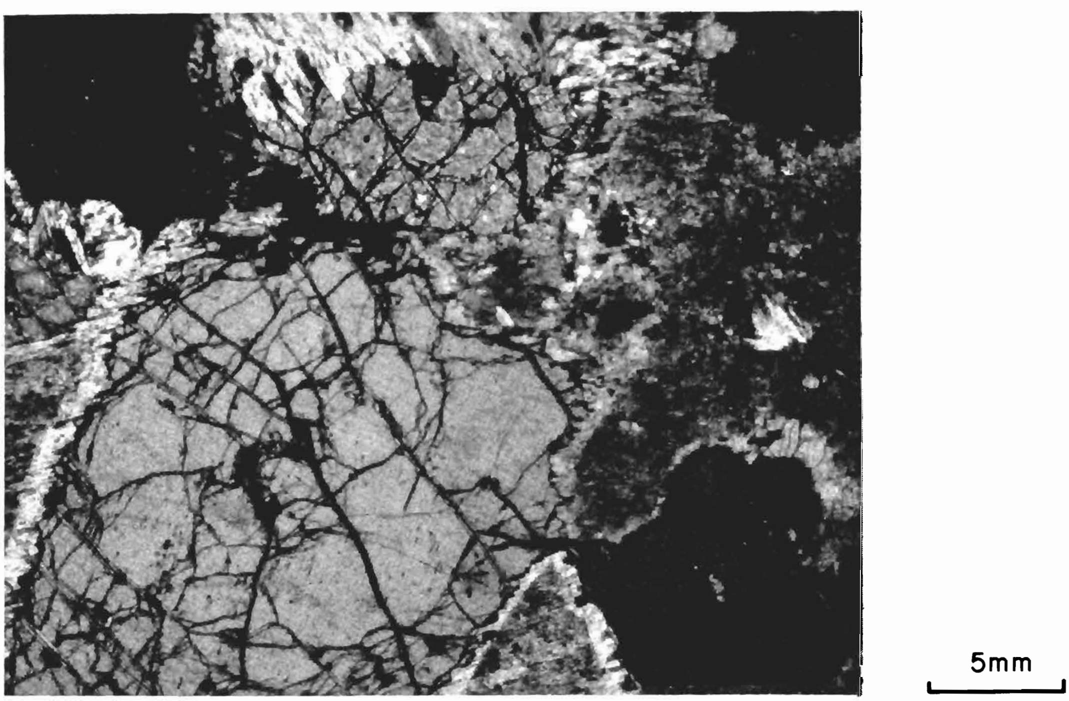


PLATE 3.2: Photomicrograph of "peridotite" sample U1025-1297 (from the ultramafic body, west of the Farley Shaft on the 2000' level). Crystals of fresh, fractured, olivine are partially enveloped by a platey amphibole pseudomorph after orthopyroxene and dark interstitial, patches of fibrous chlorite. Photograph taken with crossed nicols.

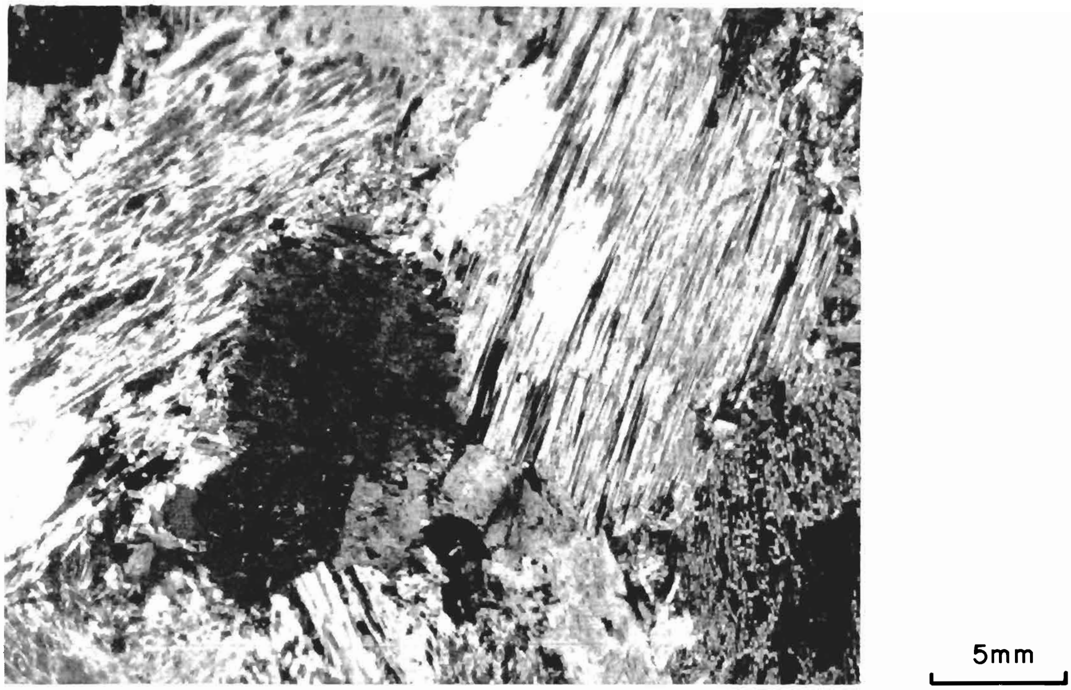


PLATE 3.3: Photomicrograph of amphibolite sample U681-363 (from vicinity of the "B" orebody on the 2000' level). A pargasite-actinolite amphibole pseudomorph after orthopyroxene displays a rectangular basal section and characteristic "cross-hatch" twinning. Photograph taken with crossed nicols.

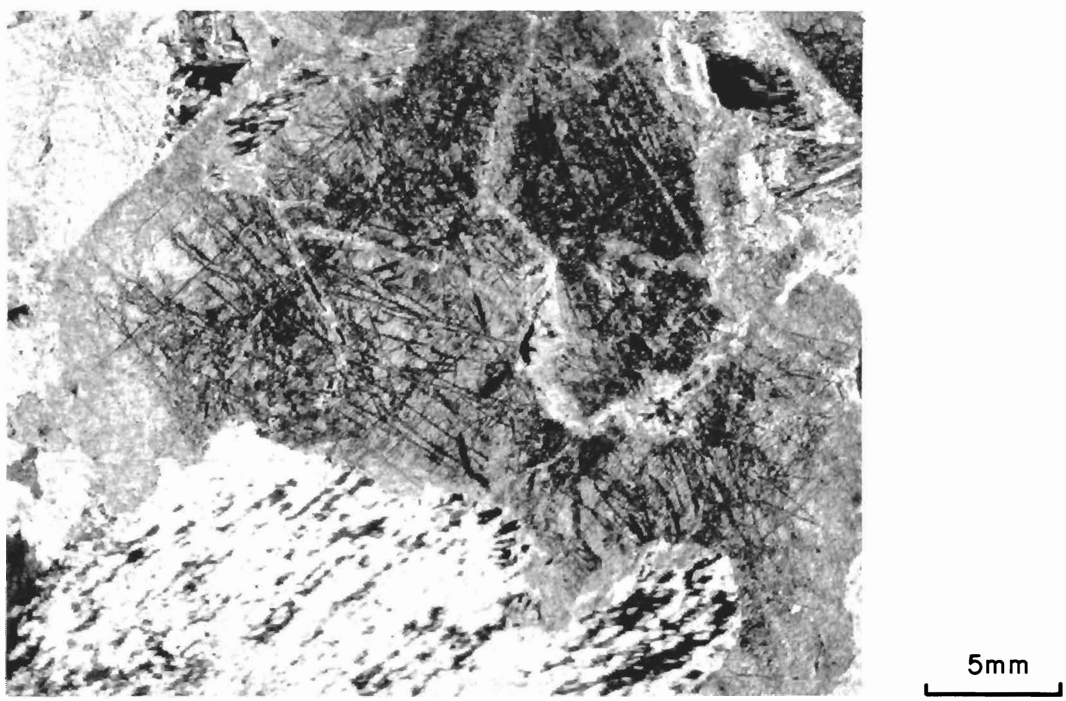
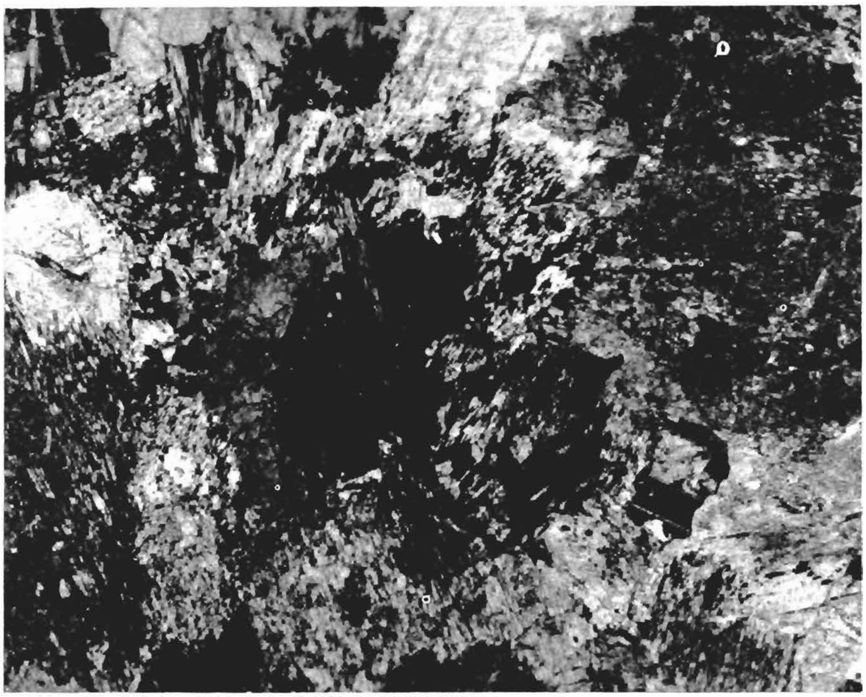
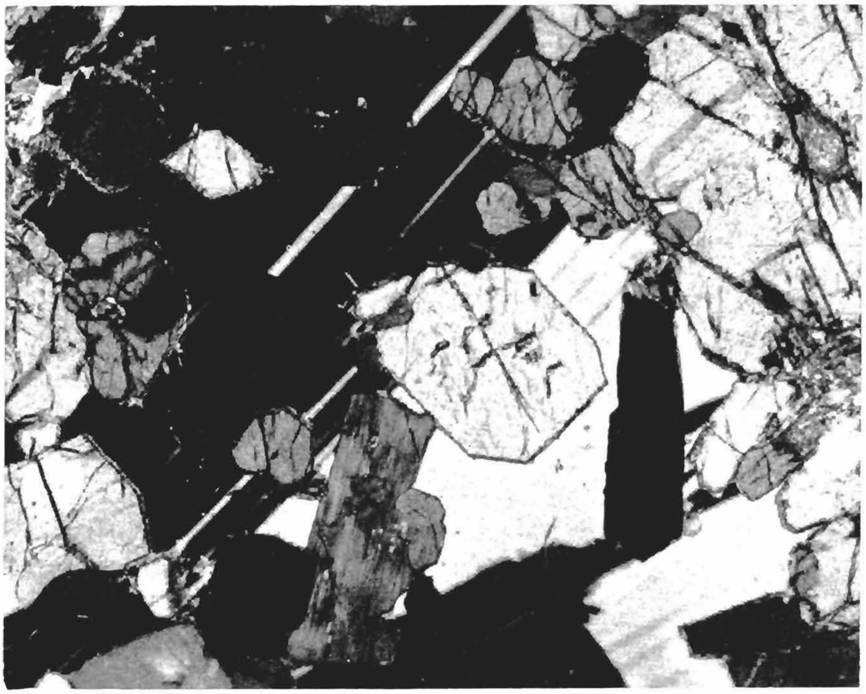


PLATE 3.4: Photomicrograph of amphibolite sample U1613-210 (from the vicinity of the "O" orebody on the 2000' level). A large, interstitial, primary amphibole with a fractured and oxide dusted core envelopes "cross-hatched" amphibole pseudomorphs after orthopyroxene and grades into a clear, oxide-free amphibole. Photograph taken with crossed nicols.



5mm

PLATE 3.5: Photomicrograph of amphibolite sample 57-77-101 (from the "N" orebody on the 2950' sublevel). The sulphide in a recrystallized rock shows local dispersion around an original bleb. Sulphide granules occur along amphibole cleavages. Photograph taken with crossed nicols.



5mm

PLATE 3.6: Photomicrograph of norite sample U1685-411 (from the "N" ore lense, 2000' level). Fresh, euhedral orthopyroxene crystals are poikilitically enclosed in larger crystals of plagioclase feldspar. Photograph taken with crossed nicols.

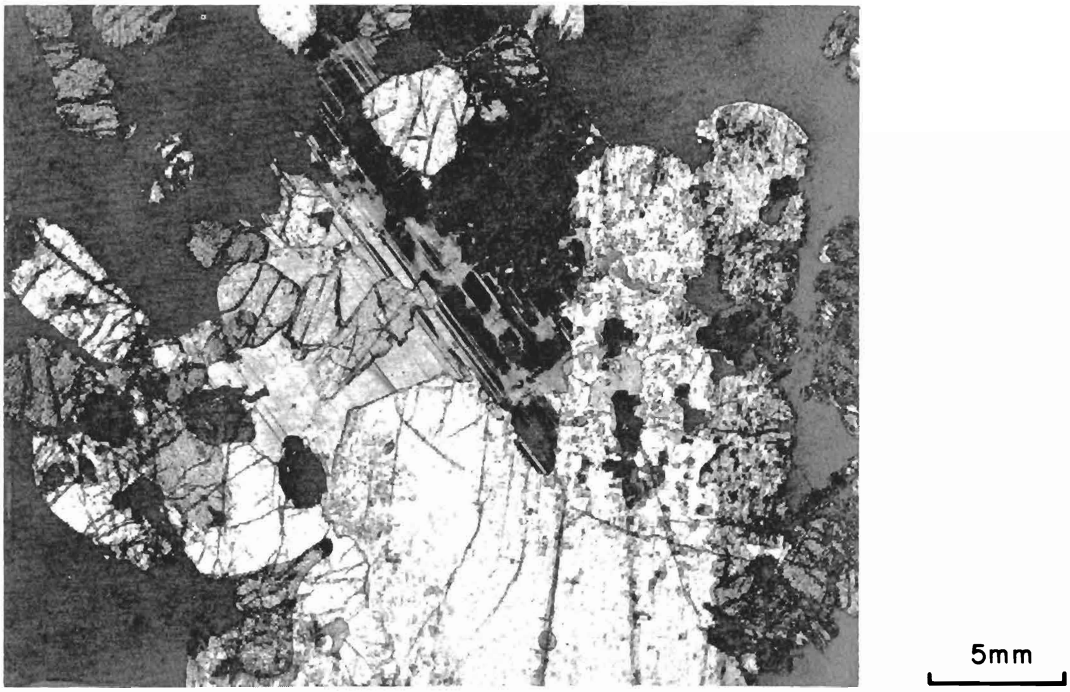


PLATE 3.7: Photomicrograph of norite sample 57-77-100 (from the "N" orebody on the 2950' sublevel). Large and small euhedral to subhedral orthopyroxene crystals poikilitically enclosed in sulphide and plagioclase feldspar. Photograph taken with crossed nicols.

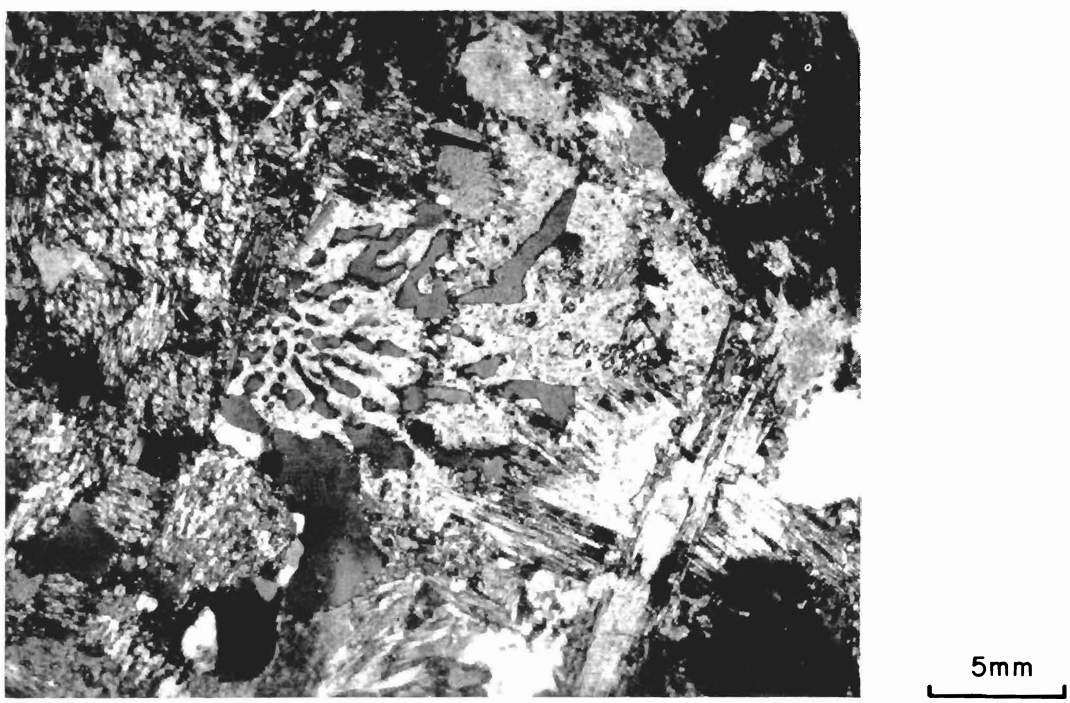


PLATE 3.8: Photomicrograph of silicified "gabbro" sample U1685-258 (from the "N" ore lense, 2000' level). Quartz and albitic feldspar form a symplectic intergrowth in interstitial patches between ragged amphiboles. Photograph taken with crossed nicols.

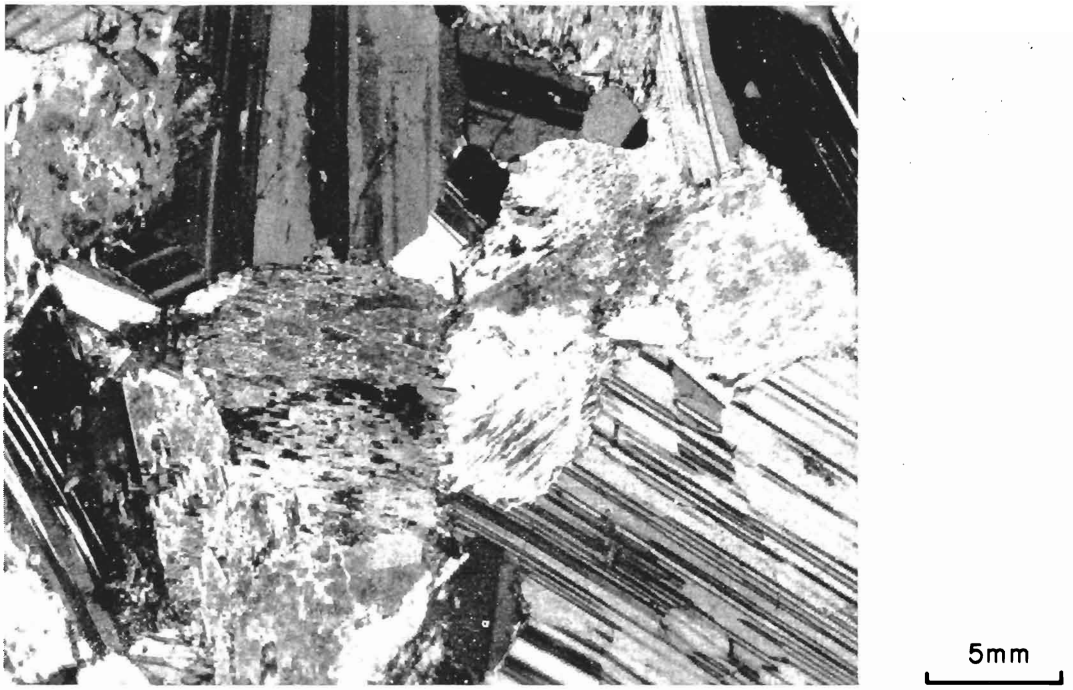


PLATE 3.9: *Photomicrograph of normal "gabbro" sample U1614-0 (from the 2000' level drift between the "B" and "O" orebodies). Typical, feldspathic, "A" plug "gabbro" showing "cross-hatch" twinning in pargasite-actinolite pseudomorphs after orthopyroxene, and laths of unaltered, primary calcic plagioclase feldspar. Photograph taken with crossed nicols.*

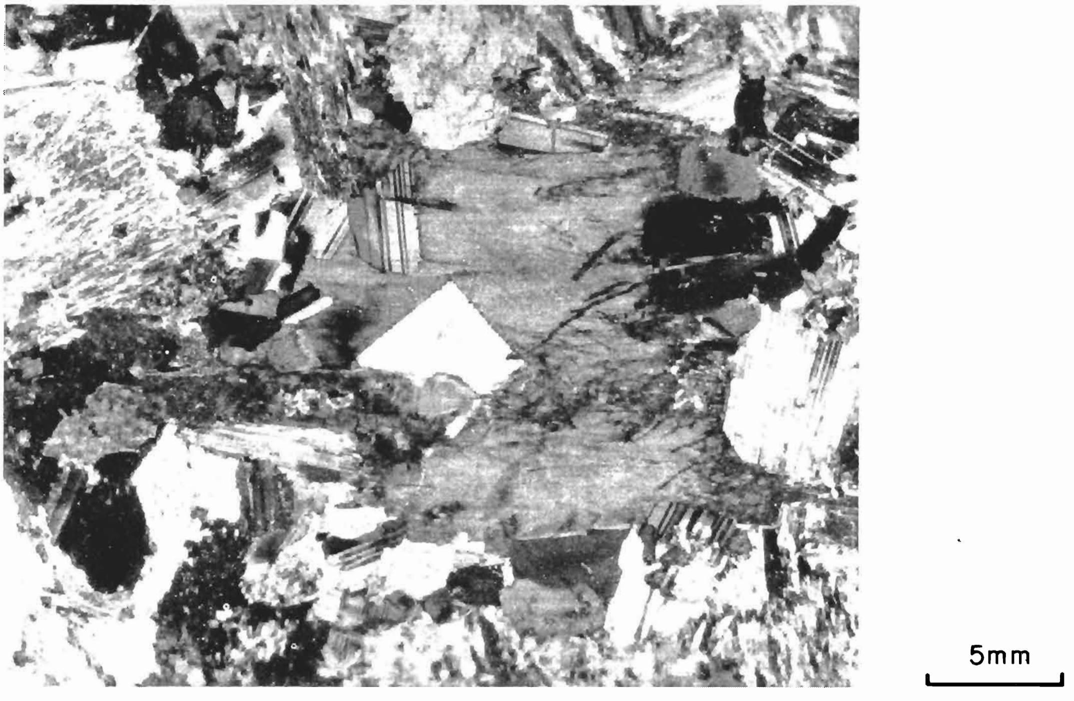


PLATE 3.10: *Photomicrograph of normal "gabbro" sample 57-76-37 (from the "O" orebody on the 2000' level). An unaltered primary amphibole, enclosing euhedral laths of plagioclase feldspar, occurs in an interstitial patch in a relatively deformed "gabbro". Photograph taken with crossed nicols.*

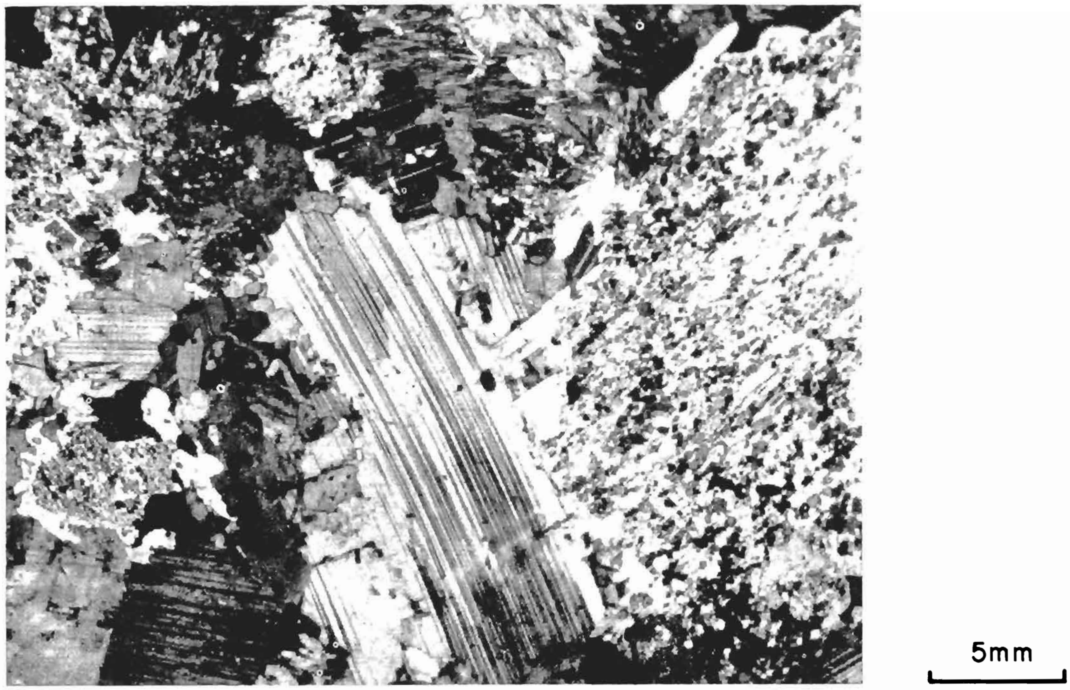


PLATE 3.11: Photomicrograph of mottled "gabbro" sample U767-756 (from the vicinity of the "B" orebody on the 2000' level). Laths of ragged amphibole poikilitically enclose small, discrete crystals of quartz. Photograph taken with crossed nicols.

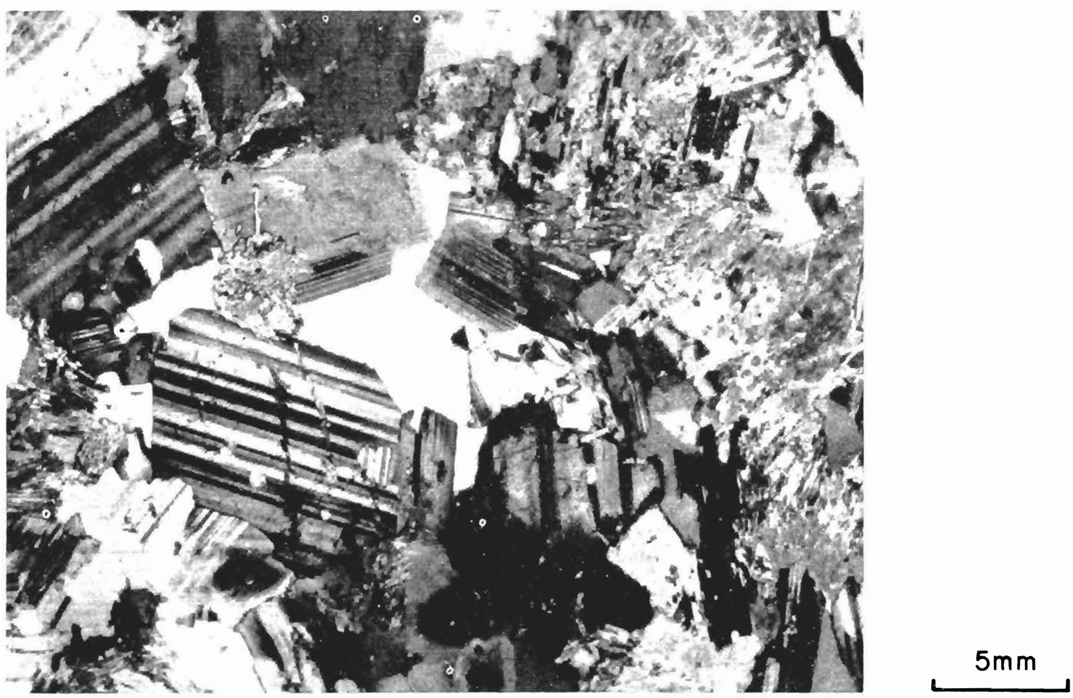


PLATE 3.12: Photomicrograph of quartz-biotite diorite sample U850-1878 (from the 2000' level in the "A" plug). Laths of zoned plagioclase and quartz occur in interstitial patches. Photograph taken with crossed nicols.

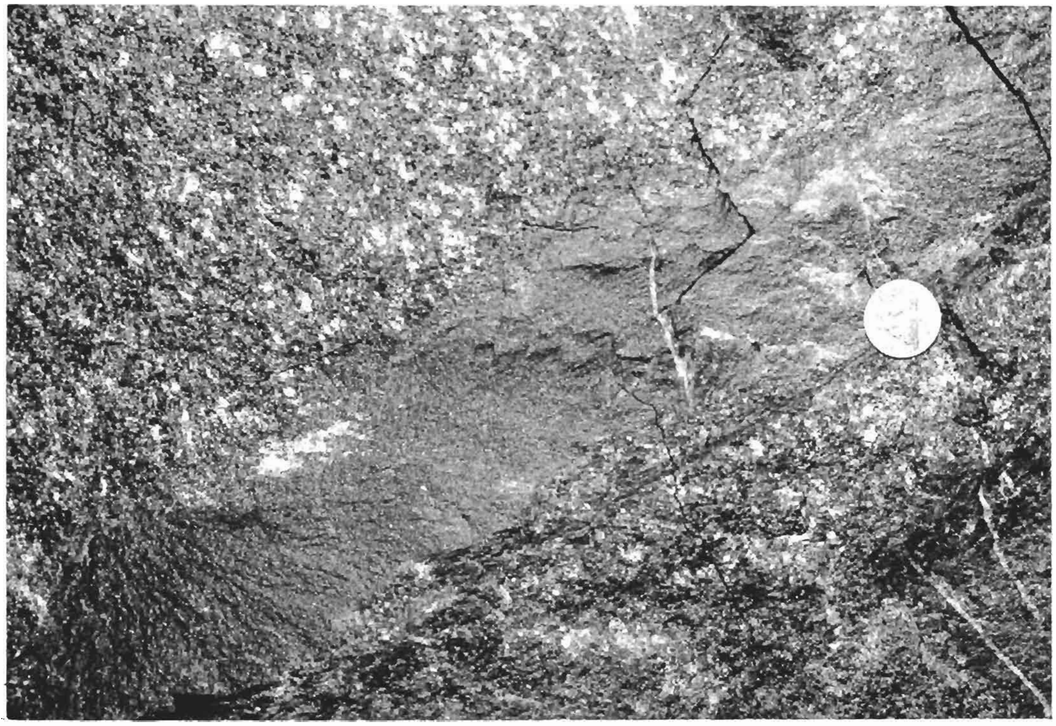


PLATE 3.13: *Intrusive contacts between a barren, mottled diabase, dyke and weakly mineralized noritic amphibolite: disseminated ore (ore-type 1) 2200' sublevel, "O" orebody.*

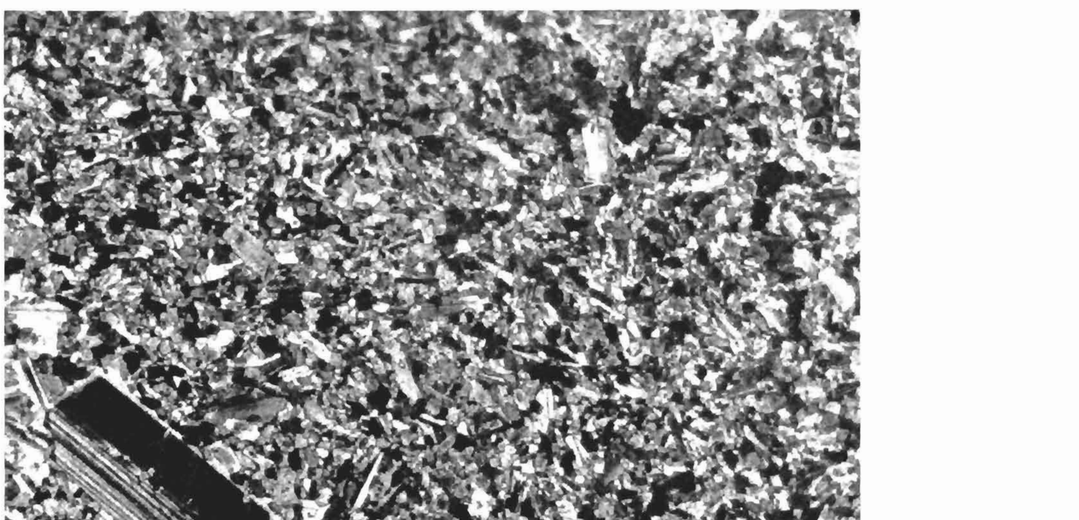


PLATE 3.14: *Photomicrograph of mottled diabase sample U767-498 (from the vicinity of the "B" orebody on the 2000' level). Plagioclase phenocrysts occur in a uralitized basaltic matrix. Photograph taken with crossed nicols.*

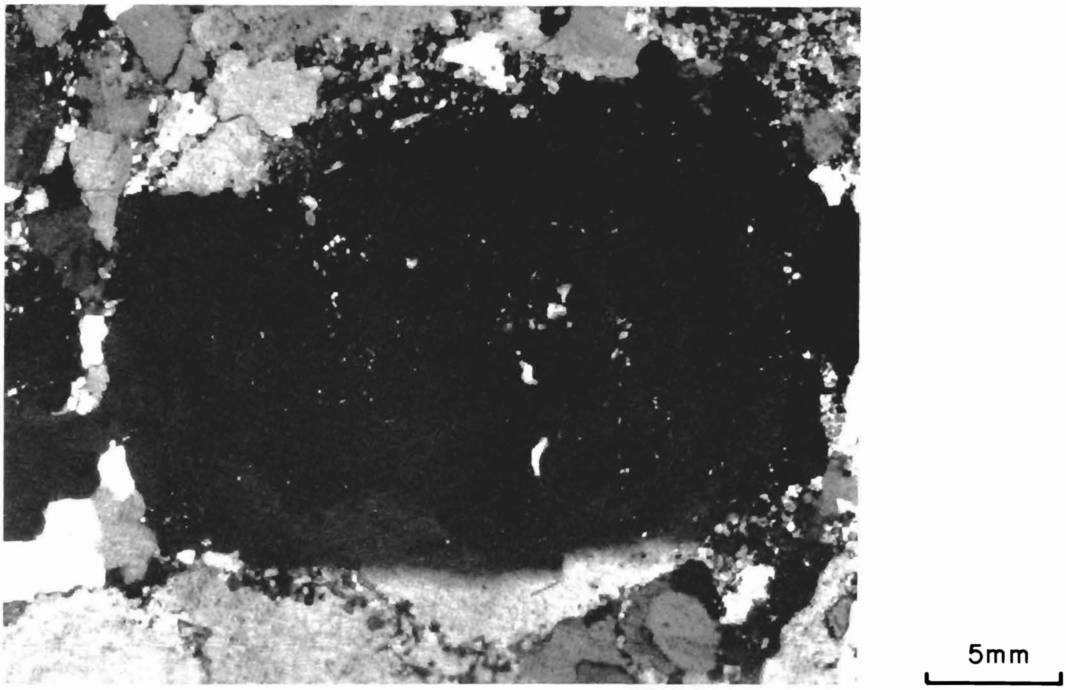


PLATE 3.15: Photomicrograph of quartz-feldspar porphyry sample U1026-783 (from the vicinity of the Lower "D" orebody on the 2000' level). Euhedral, zoned, orthoclase feldspar phenocrysts occur in a fine grained quartz-feldspar matrix. Photograph taken with crossed nicols.

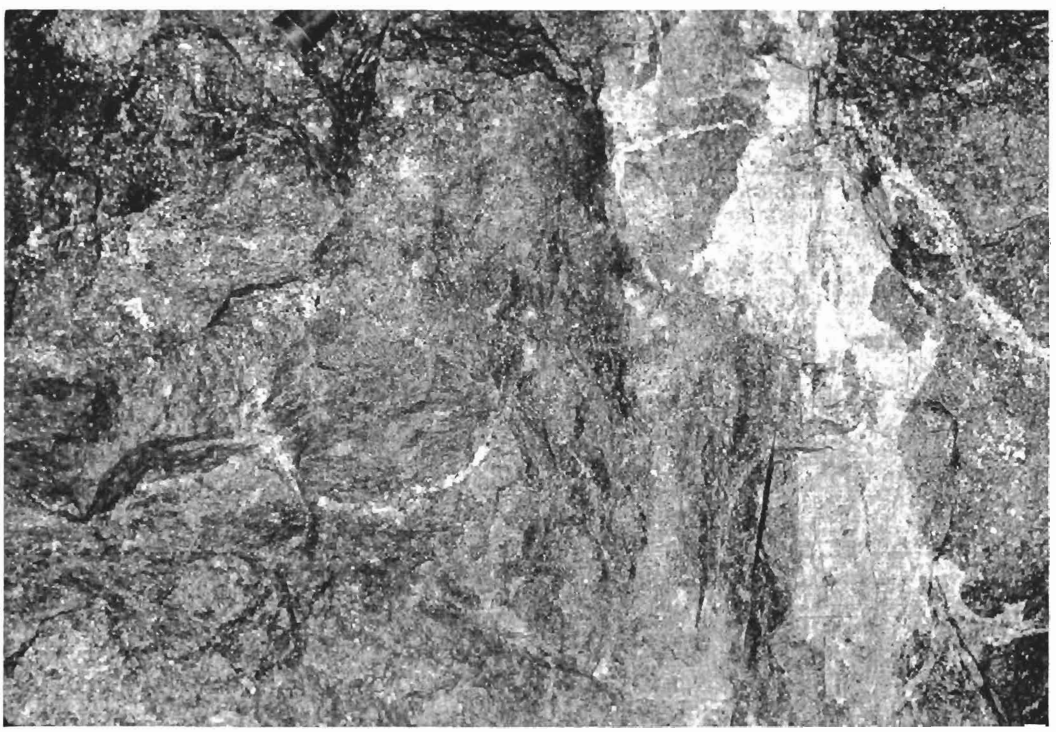


PLATE 3.16: Intrusive contacts between a granite segregation and weakly mineralized plutonic breccia ore. Plutonic breccia ore (ore-type 2) 2200' sublevel, "O" orebody.

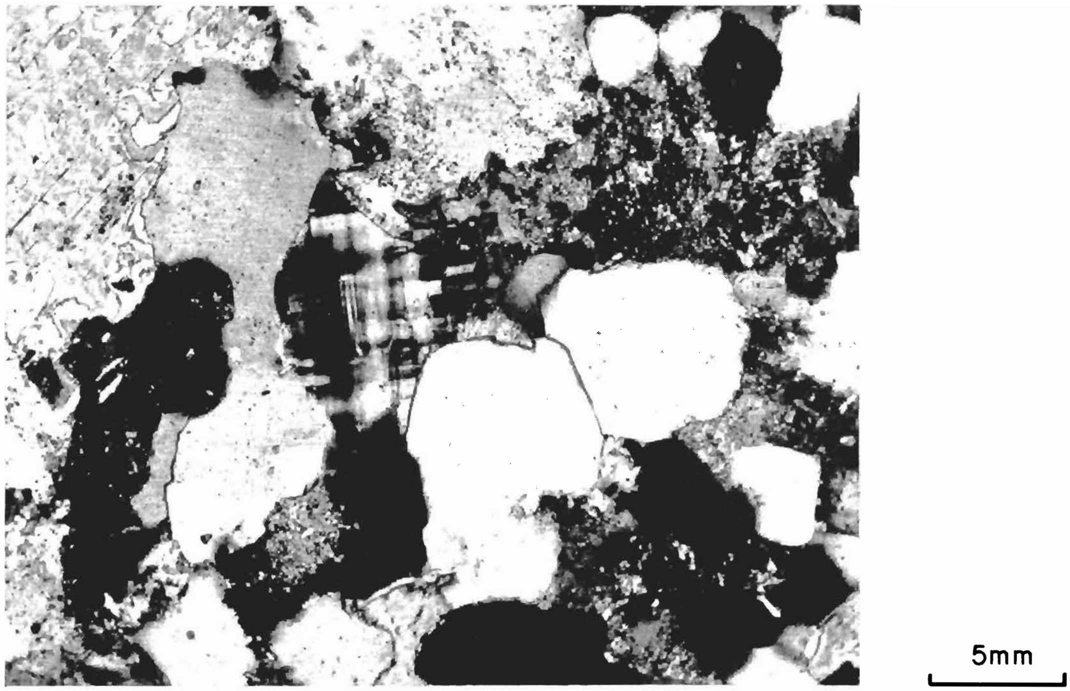


PLATE 3.17: Photomicrograph of granite sample 57-77-28 (from the "N" orebody on the 2000' level). Relict patches of fresh microcline occur in a diffuse feldspar matrix which encloses equigranular crystals of quartz and biotite laths. Photograph taken with crossed nicols.

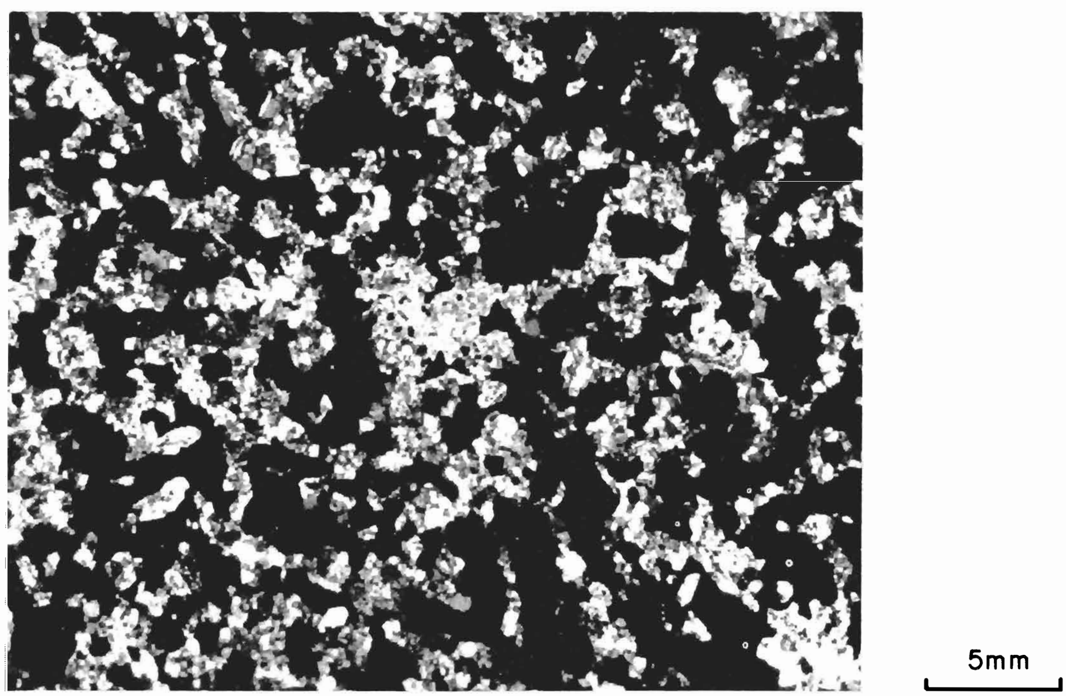


PLATE 3.18: Photomicrograph of siliceous felsite sample 57-76-136 (from the 2600' level in the "N" orebody). An intimate intergrowth of sulphide and fine quartz, plagioclase feldspar and amphibole. Photograph taken with crossed nicols.

Chapter IV — Rock Geochemistry of "A" and "EL" Plugs

4.1 INTRODUCTION

Selected samples from the "A" plug (66 specimens) and the "EL" plug (9 specimens) were analyzed in the Analytical Laboratories of the Province of Manitoba, Mineral Resources Division. The samples, which were chosen for diversity of composition, are listed in Table 4.1. They include specimens collected in stopes in the "O" and "N" orebodies and sections of diamond drill core, representative of the various rock types found in the main body of the "A" plug. Sample localities for those collected on the 2000' level are shown in Figure 4.1.

Analytical data for the samples listed in Table 4.1 are presented in Tables 4.2 and 4.3 (Appendix II). The "raw" data in Table 4.2 include values for NiO, CuO, H_2O and S. The data were recalculated and the results are shown in Table 4.3. In the calculation of the "corrected" data, Cu, Fe and S were removed as chalcopyrite (Cu Fe S_2); Ni, Fe and S were removed as pentlandite ($Ni_{4.5}Fe_{4.5}S_8$); and excess S was removed with Fe as pyrrhotite (Fe_7S_8). The total Fe remaining in the rock was subdivided into ferrous and ferric oxide components according to the equation % Fe_2O_3 = % TiO_2 + 1.5 (Irvine and Baragar, 1971).

The resultant analyses were recalculated to 100% to return the composition of the mafic to ultramafic rocks to their original, anhydrous state, and CIPW and Cation Equivalent "norms" were calculated by normal procedures.

The analytical data base has been augmented by analyses for 47 "A" plug rocks and 27 "EL" plug rocks collected by Dr. B. Henry (B.R.G.M., France). These analyses, listed by Hulbert (1978), were made available for use in the Non-renewable Resource Evaluation Program (B. Henry, pers. comm.). There are no petrographic data available for these samples and the extent to which their composition has been modified by hydrothermal activity is unknown. The samples appear to have relatively unaltered ultramafic and mafic igneous compositions, and the data have been used to supplement that produced for the present study. The analyses were recalculated (as above) and both sets of sample data were used in the production of Figs. 4.2 to 4.11.

4.2 GEOCHEMISTRY

Samples in Table 4.1 judged to be representative of a specific rock type have been averaged, and "average analyses" of 10 "A" plug rock types are given in Table 4.4 (a,b). The number of samples which contribute to the average and the samples concerned are indicated in the table. Despite considerable variation in the overall composition of the "peridotite" and the "gabbro" facies, the samples in Table 4.3 contributing to the average value in Table 4.4 show conformity of composition. The analyzed samples of other rock units (amphibolites, norites, siliceous "gabbros", mottled "gabbros" and quartz-biotite diorites) all show a reasonably high degree of homogeneity. The analytical data provided by Dr. B. Henry (pers. comm.) and listed by Hulbert (1978) show that the "EL" plug "contact-diorites", "peridotites" and amphibolites are also reasonably homogeneous. Averaged analyses, based on these data, are given in Table 4.5. Hydrothermally silicified "gabbros" (Table 4.1) have been omitted, as they are thought to be a hybrid and not representative of a true magma composition or product. The silicified "gabbros" are, however, discussed in the text.

Figures 4.2 and 4.3 show that the ultramafic cumulates and mafic plutonic rocks are all subalkaline, and that they conform to characteristically tholeiitic Fe enrichment trends. The effects of Fe and parallel Ti enrichment are particularly evident in the "A" plug mottled "gabbro" and the (post-ore) mottled diabase dykes (Table 4.4).

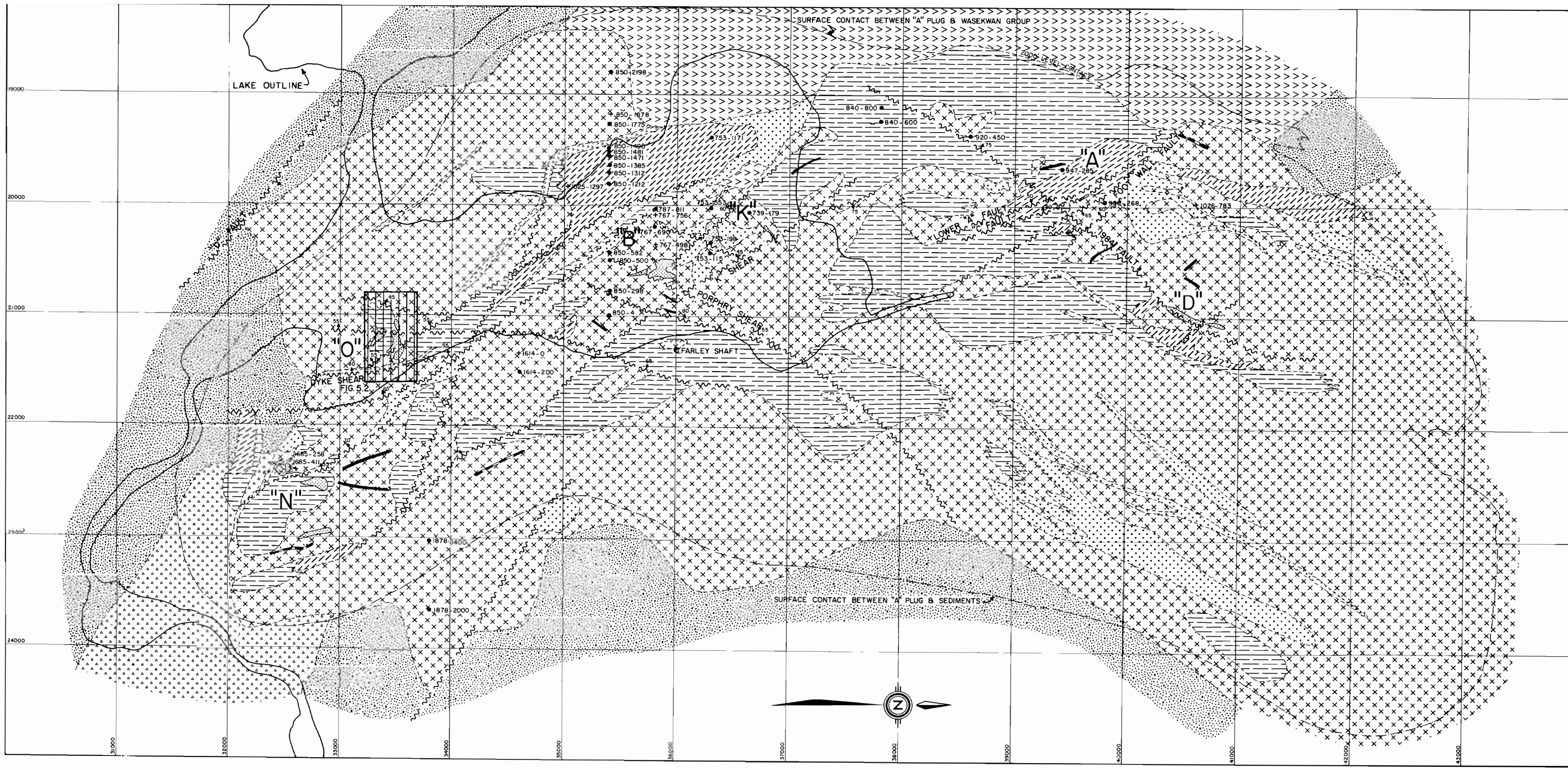
The principal chemical variation, in both suites of rocks, appears to occur in the proportions of CaO, MgO and Al_2O_3 (Figs. 4.4 (a,b)). The figures show that there is a systematic increase in Ca and Al with decrease in Mg. The data are compatible with a systematic increase in plagioclase content with a sympathetic decrease in olivine and/or enstatite content.

Although the mafic intrusive rocks are amphibolitic, and many have intermediate field names (e.g., "Contact-diorite", Quartz-biotite diorite), they are basaltic in composition. They fall in the field of basalt in terms of colour index and normative plagioclase composition (Irvine and Baragar, 1971). The "A" plug sample population (Table 4.3) displays a systematic Al_2O_3 increase with decrease in normative plagioclase anorthite content (Fig. 4.5a), and the most Al-rich gabbroic rocks in both the "A" and "EL" plugs fall in the empirical field of "Calc-alkali gabbro" (Irvine and Baragar, 1971). Neither sample population displays characteristic "Calc-alkali" alkali enrichment and the magma-cumulate system displays "High-alumina" tholeiite characteristics. Irvine and Baragar (1971) show that "Calc-alkali" or "High-alumina" magmas characteristically display a sympathetic increase in Al_2O_3 with increase in normative plagioclase composition. The "A" plug samples, as a whole, display Al_2O_3 enrichment with decrease in normative plagioclase content (Fig. 4.5a). The ultramafic rocks and some of the more mafic gabbroic rocks are, however, cumulate in origin, and they do not represent a magma composition. The high average MgO content of the normal "gabbro" (12.73%, Table 4.4) may also be an indication of cumulate origin for this particular rock type.

Figure 4.6(a) shows that "A" plug samples display a characteristic tholeiite trend on an Al_2O_3-FeO-MgO diagram (Besson, 1977). The ultramafic and Mg-rich mafic cumulates show progressive enrichment in Al. The more Al-rich "gabbro" cumulates and the late magmatic intrusions show a tendency towards Fe enrichment. The "EL" plug samples in Figure 4.6(b) define two distinct populations, (a) ultramafic and mafic cumulate and (b) eutectic "gabbro" ("contact-diorite").

Pearce (1970) has shown that when a basaltic magma fractionates a constant composition olivine or orthopyroxene the differentiate is relatively reduced in absolute amounts of MgO + FeO (in moles°) and SiO_2 (in moles°) and the cumulate is conversely enriched. A suite of unaltered rocks derived from a common parent that is fractionating a single mafic phase (e.g., olivine) should plot as a straight line on a molar MgO + FeO *vs* molar SiO_2 diagram, and the slope of the line can be compared with calculated values for each possible mineral phase removed. In Figures 4.7(a,b) the molar variables MgO + FeO and SiO_2 are divided by a constant Al_2O_3 (moles°). This does not affect the slope of the line in any way, given a single population, but it acts as a check on the consistency of the magma and the reliability of the plot (Pearce, 1970). Figure 4.7(a) shows that the "gabbroic" rocks define a slope of 1.0, which correlates with a calculated slope of 0.93, based on the composition of the orthopyroxene (En_{90}), found in ultramafic sample U850-1481 (J.D. Scott, pers. comm.). The figure shows that the "gabbros" and some of the ultramafic rocks could have been derived from a common basaltic magma by the simple process of enstatite fractionation. Some deviation from the trend line is to be expected in the "peridotites" which contain olivine (theoretical slope 2.0) and clinopyroxene (theoretical slope 0.65) in addition to orthopyroxene. A similar general relationship is found in the sample suite from the "EL" plug, although the composition range is incomplete. The "EL" plug consists of ultramafic cumulate and an Al and Mg-rich "gabbro" (contact-diorite).

The "normative" mineralogy of the rock suite is such that all the samples fall within the Ol: (olivine); Plag: (plagioclase), Qtz: (quartz), Cpx: (clinopyroxene) tetrahedron (Fig. 4.8) utilized by



LEGEND

Wasekwan Group

- Arkosic wacke, rhyolite breccia and quartz-plagioclase porphyry
- Pyroclastic, tuff, volcanic breccia and recrystallized volcanic rock
- Tuff with interbedded sediment

"A" Plug

- "Peridotite" with minor amphibolite
- Amphibolite and feldspathic amphibolite with minor "gabbro" and "norite"
- "Gabbro" diorite and quartz-biotite diorite with minor amphibolite
- Mottled diabase

"A" Plug

- Quartz-hornblende diorite
- Quartz-feldspar porphyry
- Ore

FIGURE 4.1: Simplified geological plan of the "A" plug, 2000' level showing the location of the 2000' level samples discussed in the text: (Geochemical samples (.) and photomicrograph samples (+)). Samples U1685-258 and U1685-411 have been projected from an inclined hole. "O" orebody data are shown in Figure 5.2.

TABLE 4.1 SAMPLES; WHOLEROCK GEOCHEMICAL ANALYSES: "A" AND "EL" PLUGS

Sample No.	Locality	Rock type	Comments
57-77-17	"N" 2800′ L	Amphibolite-"gabbro"	Mineralized
57-77-28	"N" 2000′ L	Biotite granite	Segregation
57-77-33	"O" 3550′ L	Biotite granite	Vein
57-77-39	"O" 3550′ L	Amphibolite-"gabbro"	
57-77-43	"O" 3550′ L	Amphibolite-"gabbro"	Silicified/mineralized
57-77-51	"O" 3400′ L	Amphibolite-"gabbro"	Epidotized/mineralized
57-77-73	"O" 3140′ L (W)	Amphibolite-"gabbro"	Mineralized
57-77-74	"O" 3140′ L (W)	Amphibolite-"gabbro"	Mineralized
57-77-81	"O" 3140′ L (E)	Biotite diorite	
57-77-91	"O" 3060′ L	Siliceous "felsite"	Mineralized
57-77-98	"O" 2940 L	"Gabbro"	Epidotized
57-77-100	"N" 2950′ L	Norite	Anhydrous/mineralized
57-77-104	"N" 2950′ L	Norite	Anhydrous/mineralized
57-77-120	"O" 2000′ L	Siliceous "felsite"	Mineralized
57-77-123	"N" 2000′ L	Diorite	Silicified
U1685-108	"N3" Orebody	"Gabbro"	Silicified
U1685-205	"N3" Orebody	"Gabbro"	Silicified
U1685-258	"N3" Orebody	"Gabbro"	Silicified
U1685-322	"N3" Orebody	"Gabbro"	Silicified
U1685-411	"N3" Orebody	Norite	Anhydrous/mineralized
U1685-524	"N3" Orebody	Norite	Hydrous/mineralized
U1685-621	"N3" Orebody	Norite	Amphibolitized
U1685-666	"N3" Orebody	Norite	Amphibolitized
U1685-751	"N3" Orebody	Norite	Anhydrous
U1685-862	"N3" Orebody	"Gabbro"	Silicified/mineralized
U1685-970	"N3" Orebody	"Gabbro"	Silicified
U840-600	2000′ L	Amphibolite	Host-rock
U840-800	2000′ L	Amphibolite	Host-rock
U1878-1400	2000′ L	"Gabbro"	Medium grained
U1878-2000	2000′ L	"Gabbro"	Medium grained
U1641-0	2000′ L	"Gabbro"	Feldspathic
U1614-200	2000′ L	"Gabbro"	Feldspathic
U767-690	2000′ L	"Gabbro"	Mottled
U767-756	2000′ L	"Gabbro"	Mottled
U850-1775	2000′ L	Diorite	Quartz-biotite
U850-2198	2000′ L	Diorite	Quartz-biotite
U850-1212	2000′ L	"Peridotite"	Olivine-rich
U850-1312	2000′ L	"Peridotite"	Olivine-rich
U850-1471	2000′ L	"Peridotite"	"Pyroxene"-rich
U850-1481	2000′ L	"Peridotite"	"Pyroxene"-rich
U850-1490	2000′ L	"Peridotite"	Amphibolitized
ELU10-8	EL 5th L	"Peridotite"	"Pyroxene"-rich/mineralized
ELU10-128	EL 5th L	Amphibolite	Mineralized
ELU11-20	EL 5th L	Amphibolite	Mineralized
ELU11-84	EL 5th L	Amphibolite	Mineralized
ELU11-157	EL 5th L	"Gabbro"	Mineralized
ELU190-62	EL 5th L	"Gabbro"	
ELU190-316	EL 5th L	Amphibolite	
ELU190-613	EL 5th L	"Peridotite"	Amphibolitized/mineralized
ELU190-650	EL 5th L	Amphibolite	
U753-115	2000′ L	"Gabbro"	Feldspathic
U753-198	2000′ L	Diabase	Mottled/dyke

Sample No.	Locality	Rock type	Comments
U753-553	2000′ L	Diabase	Mottled/dyke
U753-1171	2000′ L	Diabase	Dyke
U739-179	2000′ L	Diabase	Mottled/dyke
U767-498	2000′ L	Diabase	Mottled/dyke
U767-811	2000′ L	Diabase	Mottled/dyke
U850-4	2000′ L	"Gabbro"	Feldspathic
U850-298	2000′ L	Diorite	Dyke
U850-492	2000′ L	Diabase	Mottled/dyke
U850-582	2000′ L	Amphibolite	Dyke
U850-1385	2000′ L	Diabase	Mottled/dyke
U850-1878	2000′ L	Diorite	Quartz-biotite
U920-450	2000′ L	Diabase	Mottled/dyke
U947-285	2000′ L	Diabase	Mottled/dyke
U958-268	2000′ L	Diorite	
57-77-2	"N" 2600′ L (S)	Amphibolite-"gabbro"	
57-77-11	"N" 2800′ L	Amphibolite	Dyke
57-77-13	"N" 2800′ L	"Gabbro"	Amphibolitized/mineralized
57-77-21	"N" 2600′ L	"Gabbro"	Amphibolitized/mineralized
57-77-22	"N" 2600′ L	"Gabbro"	Amphibolitized/mineralized
57-77-126	2000′ L	Q.H.D.	
57-77-83	"O" 3140′ L (E)	Diorite	
57-77-41	"O" 3550′ L	Granite	
57-77-32	"O" 3550′ L	"Gabbro"	

TABLE 4.4(a) AVERAGE ANALYSES OF REPRESENTATIVE "A" PLUG ROCK TYPES

Oxide Percentage	Olivine-rich "peridotite"	Pyroxene-rich "peridotite"	Amphibolite	Norite	Silicified "gabbro"	Normal "gabbro"	Mottled "gabbro"	Qtz-bio diorite	Mottled diabase	Granite	
SiO_2	42.99	44.77	55.2	55.75	57.35	51.28	50.56	54.51	48.64	73.68	SiO_2
Al_2O_3	3.45	4.1	4.36	7.54	11.31	15.24	17.54	18.56	17.62	13.15	Al_2O_3
Fe_2O_3	1.61	1.69	1.79	1.77	1.76	1.74	2.98	1.86	3.21	1.76	Fe_2O_3
FeO	11.11	8.95	6.94	7.13	5.86	5.35	6.55	4.76	8.30	1.92	FeO
CaO	2.45	7.16	9.84	4.89	6.08	12.05	10.86	9.97	10.49	1.56	CaO
MgO	37.85	32.75	20.47	21.16	14.83	12.73	7.34	7.32	6.07	1.92	MgO
Na_2O	0.19	0.13	0.44	0.82	1.05	1.14	2.27	1.92	2.80	3.20	Na_2O
K_2O	0.01	0.02	0.44	0.44	1.30	0.13	0.10	0.61	0.54	2.42	K_2O
TiO_2	0.09	0.17	0.28	0.25	0.25	0.23	1.46	0.35	1.69	0.26	TiO_2
P_2O_5	0.06	0.05	0.05	0.05	0.04	0.03	0.16	0.07	0.36	0.01	P_2O_5
MnO	0.19	0.20	0.20	0.19	0.18	0.15	0.17	0.14	0.18	0.10	MnO
	100.00	99.99	100.00	99.99	100.01	100.07	99.99	99.97	99.9	99.98	
	X2*	X2	X2	X5	X6	X6	X2	X3	X9	X3	
	DDHU850	DDHU850	DDHU840	DDHU1685	DDHU1685	DDHU1878 DDHU1614 DDHU850 DDHU753	DDHU840	DDHU850	DDHU753 DDHU739 DDHU767 DDHU850 DDHU920 DDHU947	57-77-28 57-77-33 57-77-41	

*Number of samples averaged

TABLE 4.4(b) AVERAGE ANALYSES OF REPRESENTATIVE "A" PLUG ROCK TYPES

Cation Equivalent "Norms"	Olivine-rich "peridotite"	Pyroxene-rich "peridotite"	Amphibolite	Norite	Silicified "gabbro"	Normal "gabbro"	Mottled "gabbro"	Qtz-bio diorite	Mottled diabase	Granite	
Q	—	—	2.74	3.55	7.92	0.68	2.93	7.01	—	18.98	Q
Ab	1.57	1.09	3.86	7.14	9.29	10.08	20.48	17.20	25.39	26.74	Ab
Di	2.06	16.16	26.74	5.55	5.03	15.45	9.48	5.44	8.44	4.45	Di
Fs	2.08	1.52	6.99	9.01	7.19	5.35	4.86	5.01	4.67	0.92	Fs
il	0.12	0.22	0.38	0.34	0.34	0.32	2.04	0.49	2.38	0.35	il
Ap	0.12	0.10	0.10	0.10	0.08	0.06	0.34	0.15	0.76	0.02	Ap
An	7.86	9.86	8.43	15.14	21.98	35.55	37.57	40.15	34.26	—	An
He	0.32	2.28	4.46	0.93	0.96	3.07	2.95	1.57	4.31	1.44	He
Fo	61.38	49.27	—	—	—	—	—	—	2.66	—	Fo
Or	0.05	0.11	2.55	2.53	7.57	0.76	0.59	3.60	3.23	42.08	Or
Ac	—	—	—	—	—	—	—	—	—	0.64	Ac
En	13.35	10.77	41.91	53.92	37.82	26.89	15.62	17.44	9.16	2.86	En
Fa	9.55	6.96	—	—	—	—	—	—	1.36	—	Fa
Mt	1.55	1.65	1.83	1.80	1.81	1.79	3.13	1.94	3.39	1.52	Mt
$\frac{Mg \times 100}{Mg + Fe}$	86.53	87.63	85.70	85.68	84.02	83.41	76.27	77.67	66.22	75.61	$\frac{Mg \times 100}{Mg + Fe}$
$\frac{An \times 100}{An + Ab}$	83.34	90.04	65.58	67.93	70.30	77.91	64.72	70.01	57.44	0.00	$\frac{An \times 100}{An + Ab}$

TABLE 4.5(a) AVERAGE ANALYSES OF REPRESENTATIVE "EL" PLUG ROCK TYPES

Oxide Weight Percent	Pyroxene-rich "peridotite"	Amphibolite	"Contact-diorite"
SiO_2	46.01	51.93	51.16
Al_2O_3	4.19	5.81	18.63
Fe_2O_3	1.85	1.79	1.76
FeO	8.91	9.19	5.20
CaO	8.56	8.49	11.25
MgO	29.72	21.31	9.26
Na_2O	0.02	0.19	1.91
K_2O	0.03	0.52	0.36
TiO_2	0.34	0.28	0.25
P_2O_5	0.00	0.00	0.00
MnO	0.17	0.17	0.12
NiO	0.18	0.31	0.08
	99.98	99.99	99.98
No. of samples	X4	X4	X11

TABLE 4.5(b) AVERAGE ANALYSES OF REPRESENTATIVE "EL" PLUG ROCK TYPES

Cation Equivalent "Norms"	Pyroxene-rich "peridotite"	Amphibolite	"Contact-diorite"
Q	—	—	0.23
Ab	0.17	1.67	16.96
Di	20.53	18.30	9.14
Fs	2.46	9.55	5.50
il	0.45	0.38	0.34
Ap	—	—	—
An	10.67	13.18	40.76
He	3.15	4.14	2.43
Fo	38.61	4.71	—
Or	0.17	3.01	2.11
Ac	—	—	—
En	16.04	42.16	20.71
Fa	5.92	1.07	—
Mt	1.83	1.83	1.82
$\frac{Mg \times 100}{Mg + Fe}$	86.71	81.54	79.02
$\frac{An \times 100}{An + Ab}$	98.43	88.76	70.61

Irvine (1970). Figures 4.9(a,b), 4.10(a,b), 4.11 (a,b) illustrate the projections of "A" and "EL" plug sample points on the Ol-Plag-Qtz face, and the Opx + 4Q-Plag-Cpx plane, respectively. The figures show that most of the "A" plug samples lie within the olivine phase volume (Fig. 4.8), close to the orthopyroxene phase volume interface. The "gabbroic" rocks are generally olivine normative, although the norites and silicified "gabbros" in the "N3" ore lens, and the quartz-biotite diorites in the SW corner of the "A" plug (Table 4.4), are clearly quartz normative. The silicified "gabbros" are unusual in that they are rich in MgO, K_2O and SiO_2.

A large number of samples plot close to the plane Opx + 4Qtz-Cpx-Plag (Fig. 4.8), and Figure 4.11 (a,b) shows two discrete enrichment trends. The ultramafic "peridotites" show considerable variation in the proportions of the mafic phases (olivine, clinopyroxene, orthopyroxene) present, and relatively little variation in plagioclase content (Fig. 4.11 (a)). In contrast, the orthopyroxene-bearing amphibolites appear to become progressively enriched in plagioclase, and clinopyroxene enrichment is less marked. In "gabbroic" rocks, clinopyroxene is invariably subordinate to orthopyroxene and the "gabbros" in the "A" and "EL" plugs were originally noritic in composition. The "EL" plug consists of two principal rock types (a) ultramafic cumulate ("peridotite" and amphibolite) and (b) "contact-diorite". The "contact-diorite" is remarkably homogeneous in composition (Table 4.4) and it falls close to an inferred eutectic point (Fig. 4.11 (b)). The "A" plug contains more strongly orthopyroxenitic ultramafic cumulates ("peridotite" and amphibolite) and a less well defined eutectic "gabbro". The main "A" plug gabbro shows a scatter towards orthopyroxene enrichment (Fig. 4.11 (a)) consistent with orthopyroxene fractionation and a cumulate origin for the more mafic gabbroic rocks.

4.3 DISCUSSION

Analytical data presented in Tables 4.4 and 4.5, and illustrated in Figures 4.2(a,b) to 4.11(a,b), show that the Ni-Cu ores at Lynn Lake are associated with mafic to ultramafic differentiates derived from what was probably an Mg-rich, "High-alumina", tholeiite magma.

The results indicate that the "A" and "EL" plugs consist very largely of remobilized cumulate material and that much of the variation in the rock can be attributed to (a) early fractionation of olivine, orthopyroxene and clinopyroxene to form "peridotite" and "amphibolite" (pyroxenite), and (b) later fractionation of orthopyroxene to form "gabbro" and norite. The body of normal "gabbro" in the "A" plug is probably deformed, weakly differentiated, mafic cumulate. The "gabbro" appears to have been intruded by remobilized, barren, ultramafic ("peridotite") and mafic ("amphibolite") cumulate, and mineralized mafic norite. The mineralized norite has a high normative orthopyroxene content (63%, Table 4.4(b)) and it has a texture consistent with remobilization of an orthopyroxene suspension in a sulphide-silicate magma.

The origin of the silicified "gabbro" found with mineralized norite in the "N" orebody is enigmatic. The rock combines a high (Mg x 100)/(Mg + Fe) ratio (84) and orthopyroxene content (Table 4.4) with an increase in Si and alkali content. It lies on the quartz-rich side of the Opx + 4Qtz-Cpx-Plag plane (Fig. 4.8) and it plots between norite and normal "gabbro". The silicified "gabbro" is remarkably homogeneous (Table 4.3) and it is strictly confined to the "N" ore pipe. Textural evidence indicates that orthoclase, albite and quartz developed in interstitial spaces between laths of plagioclase and amphibole (after pyroxene). The rock is probably a mafic cumulate which developed into a hybrid at source, prior to emplacement in the "N" ore pipe. An original (noritic) "gabbro" cumulate was contaminated by a low melting point (granitic) component either through (1) hydrothermal addition or (2) magmatic contamination. The presence of irregular granite segregations and veins of granite "hybrid" in the ore pipe favour the latter.

The normal "gabbros" in the "A" plug plot close to the Opx + 4Qtz-Cpx-Plag plane in Figure 4.8 (Fig. 4.10(a), 4.11 (a)) and they appear to be orthopyroxene-enriched mafic cumulates. The precise composition of their parent magma is uncertain.

"Contact-diorite" found in the "EL" plug is remarkably homogeneous (Figs. 4.2(b) to 4.11(b)), and no orthopyroxene-enriched cumulates comparable to normal "gabbro" have been found in the "EL" plug. The "contact-diorite" composition appears to fall on a ternary eutectic (Figs. 4.9(b),4.11(b)) and it is probably a true magma composition. The magma is rich in Mg and Al and low in Ti.

Mottled "gabbro" in the "A" plug is appreciably more evolved than "contact-diorite". Although it has a similar eutectic composition, it shows significant enrichment in Fe, Ti and Na (Table 4.4). The late (post-ore) mottled "diabase" dykes also show similar enrichment (Table 4.4).

The quartz-biotite diorite body in the "A" plug resembles "contact-diorite" in composition but it shows significant enrichment in Si and, to a lesser extent, K. This rock unit may also show some contamination.

The Ni-Cu mineralization at Lynn Lake appears to be associated with a suite of ultramafic to mafic cumulates and related tholeiite magmas. The mafic cumulates show evidence of a strong tendency to fractionate orthopyroxene in the parent magma, which probably evolved into Mg-rich "High-alumina" tholeiite ("contact-diorite"). The "High-alumina" tholeiite subsequently followed an evolutionary trend towards Fe, Ti and Na enrichment.

The silicified "gabbros" combine characteristics of early mafic cumulates and late granites, and they probably indicate contamination of the magma source.

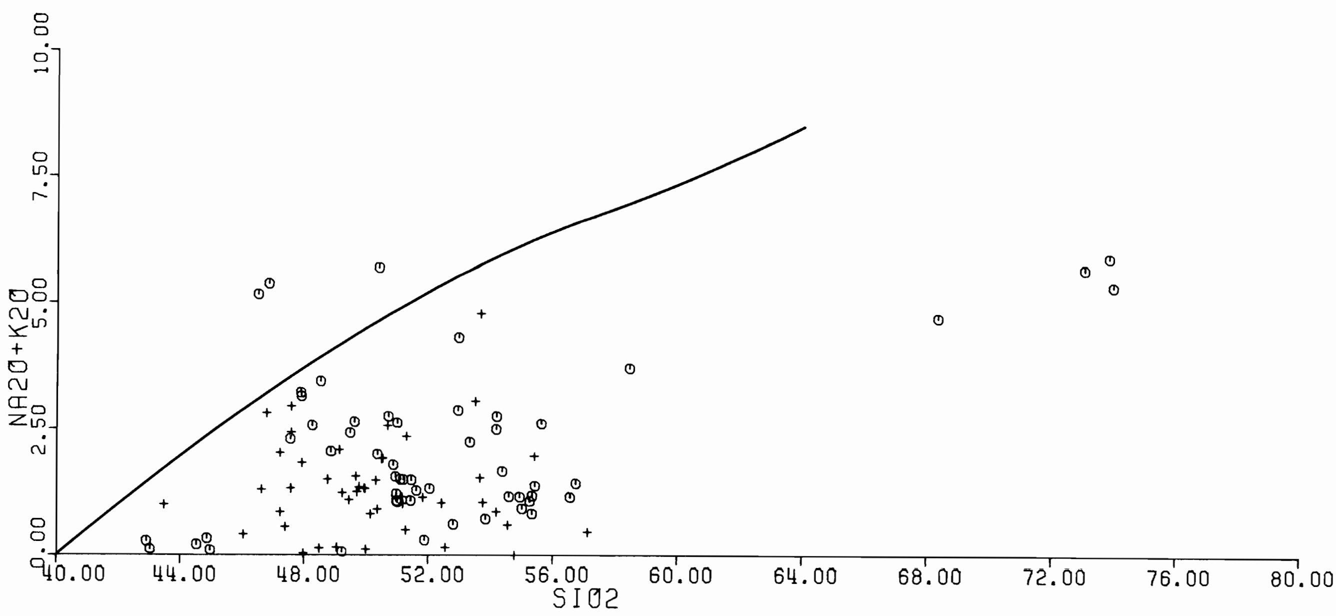


FIGURE 4.2 (a); SiO_2 vs (Na_2O+K_2O) diagram for "A" plug samples: Open circles (o) denote analyses made during the present study (Tables 4.1, 4.2, 4.3) and crosses (+) denote analytical data supplied by Dr. B. Henry, B.R.G.M. (personal communication). Alkali-subalkali divide taken from Irvine and Baragar (1971).

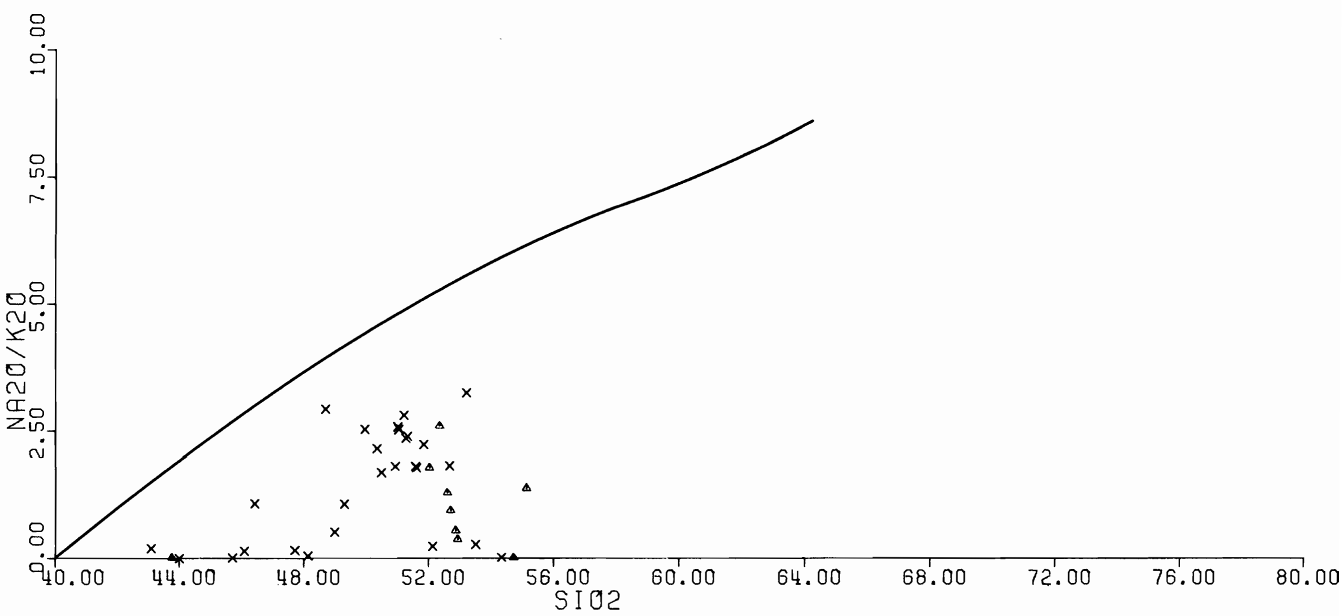


FIGURE 4.2 (b); SiO_2 vs (Na_2+K_2O) diagram for "EL" plug samples: Triangles (Δ) denote analyses made during the present study (Tables 4.1, 4.2, 4.3) and crosses(x) denote analytical data supplied by Dr. B. Henry, B.R.G.M. (personal communication). Alkali-subalkali divide taken from Irvine and Barager (1971).

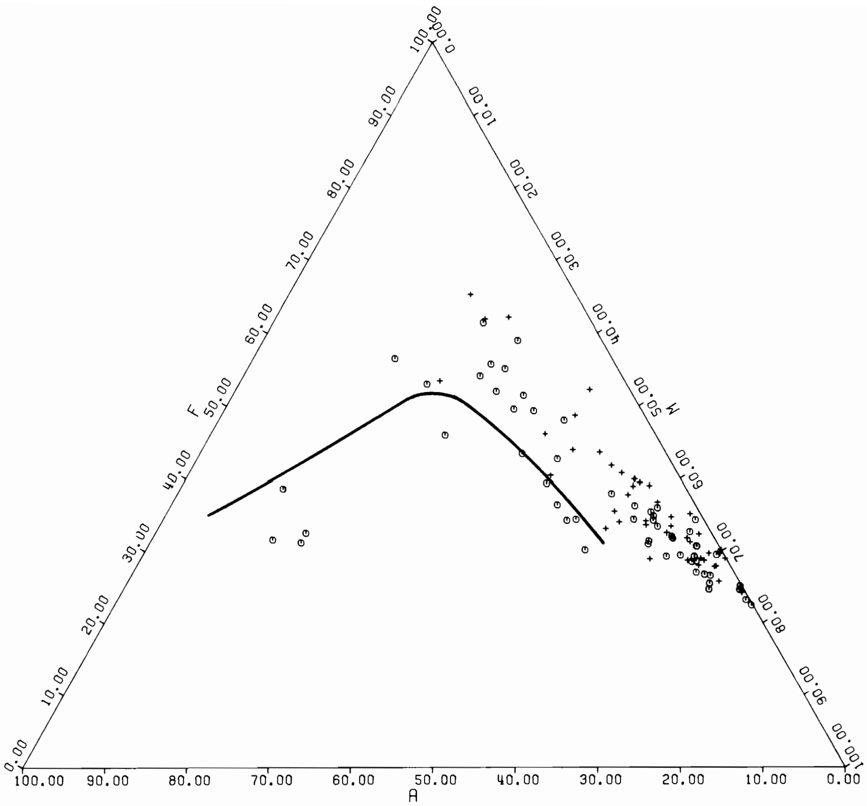


FIGURE 4.3(a): AFM diagram for the "A" plug. Symbol notation is as for Figure 4.2(a). The alkali-subalkali divide is taken from Irvine and Baragar (1971).

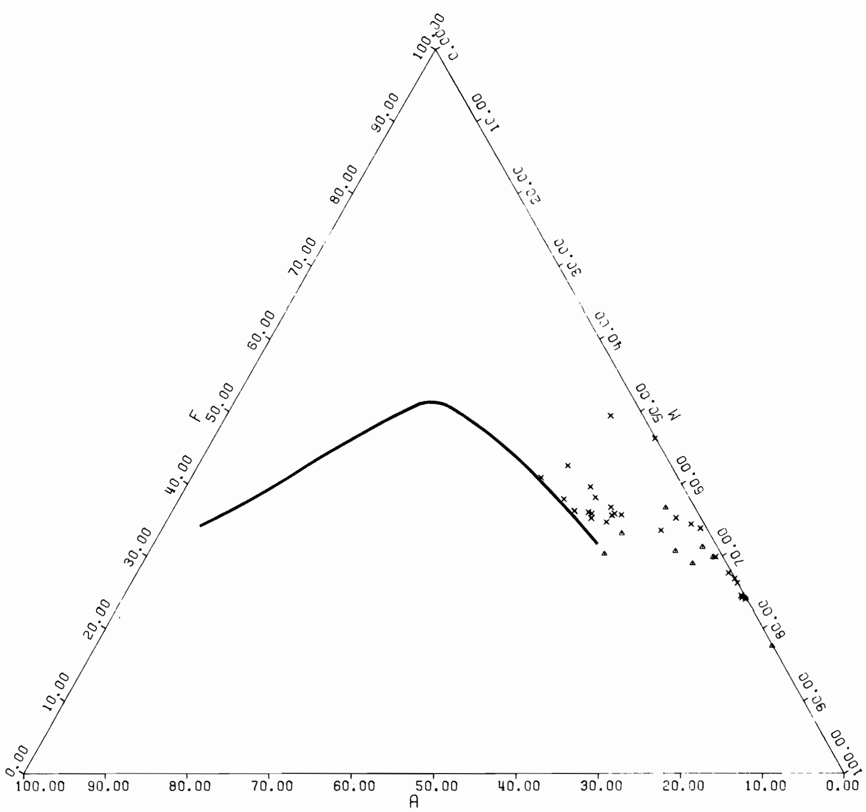


FIGURE 4.3(b): AFM diagram for the "EL" plug. Symbol notation is as for Figure 4.2(b). The alkali-subalkali divide is taken from Irvine and Baragar (1971).

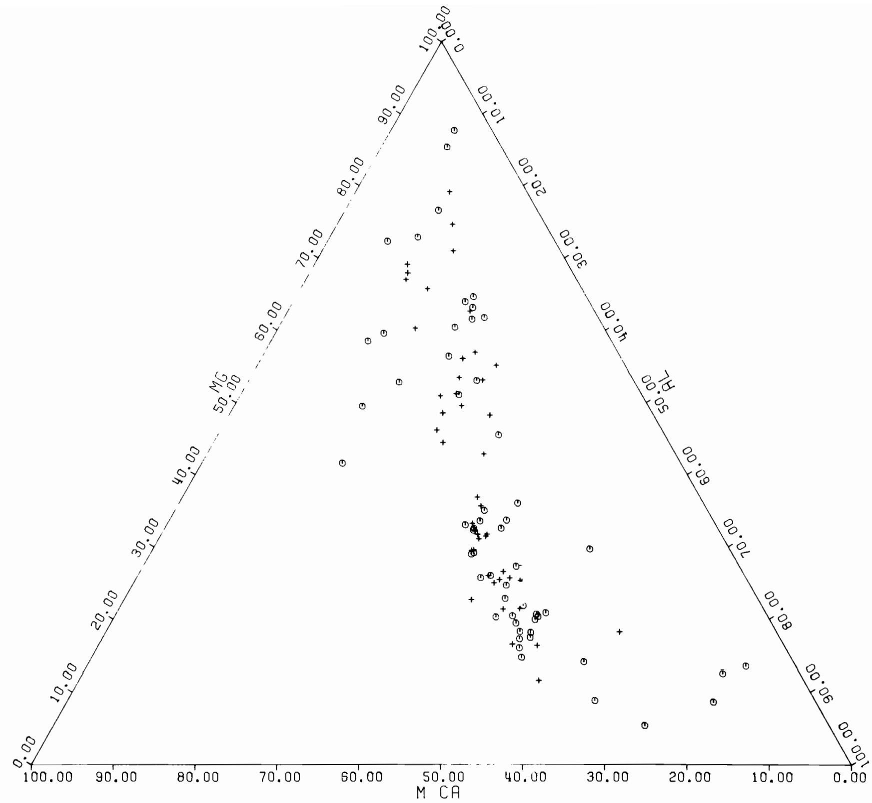


FIGURE 4.4(a): CaO-MgO-Al_2O_3 diagram for "A" plug samples. Symbol notation as for Figure 4.2(a).

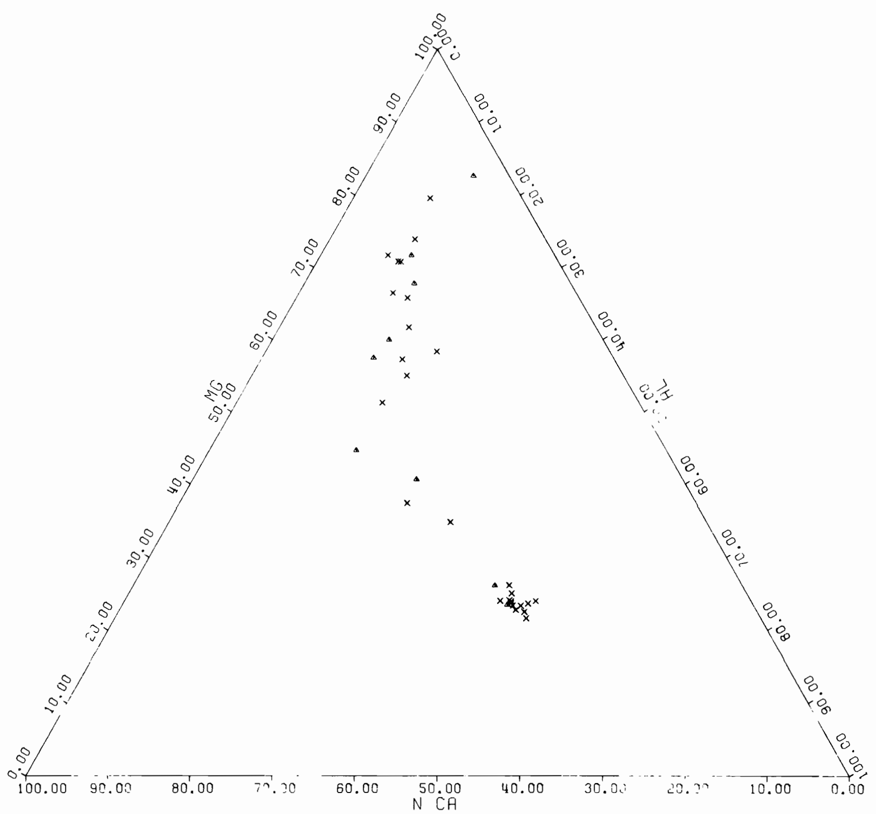


Figure 4.4(b): CaO-MgO-Al_2O_3 diagram for "EL" plug samples. Symbol notation as for Figure 4.2(b).

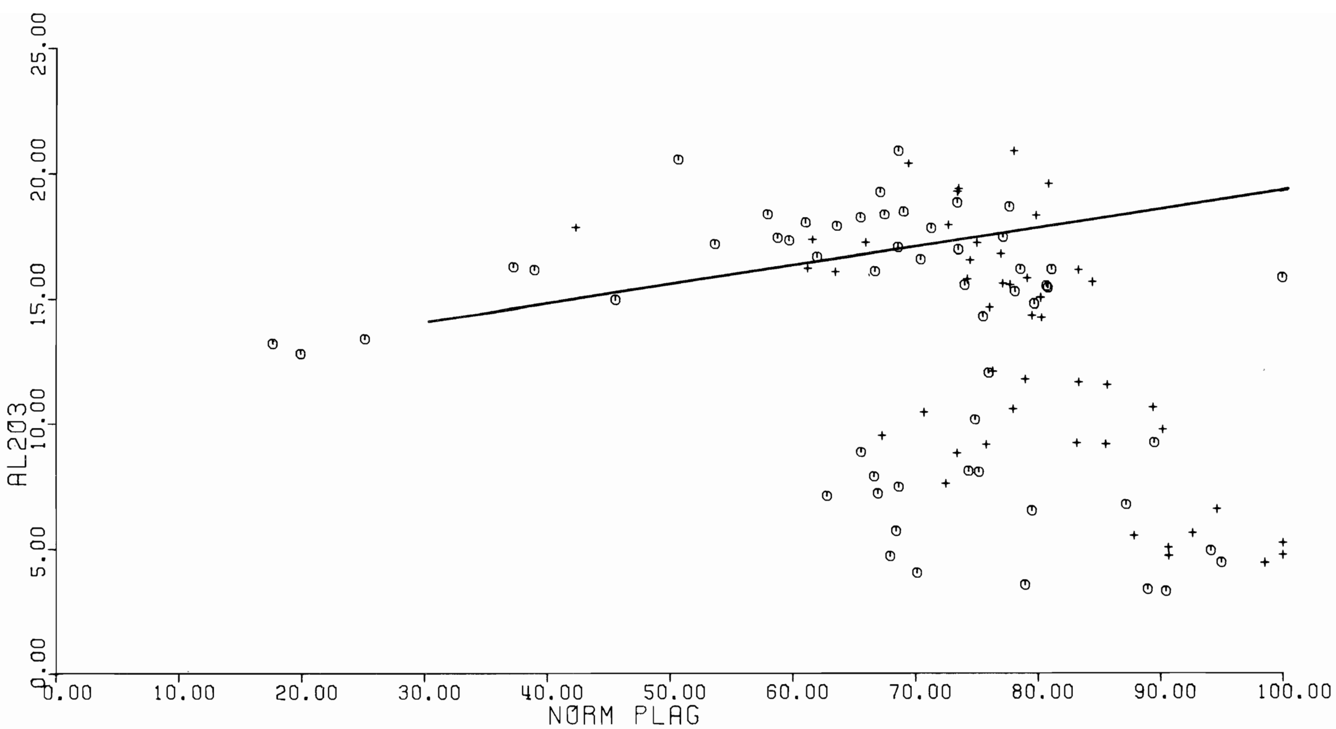


FIGURE 4.5(a): *Al_2O_3 vs Normative Plagioclase diagram for "A" plug samples. Symbol notation as for Figure 4.2(a). The "Calc-alkali"-"Tholeiite" basalt divide is taken from Irvine and Baragar (1971).*

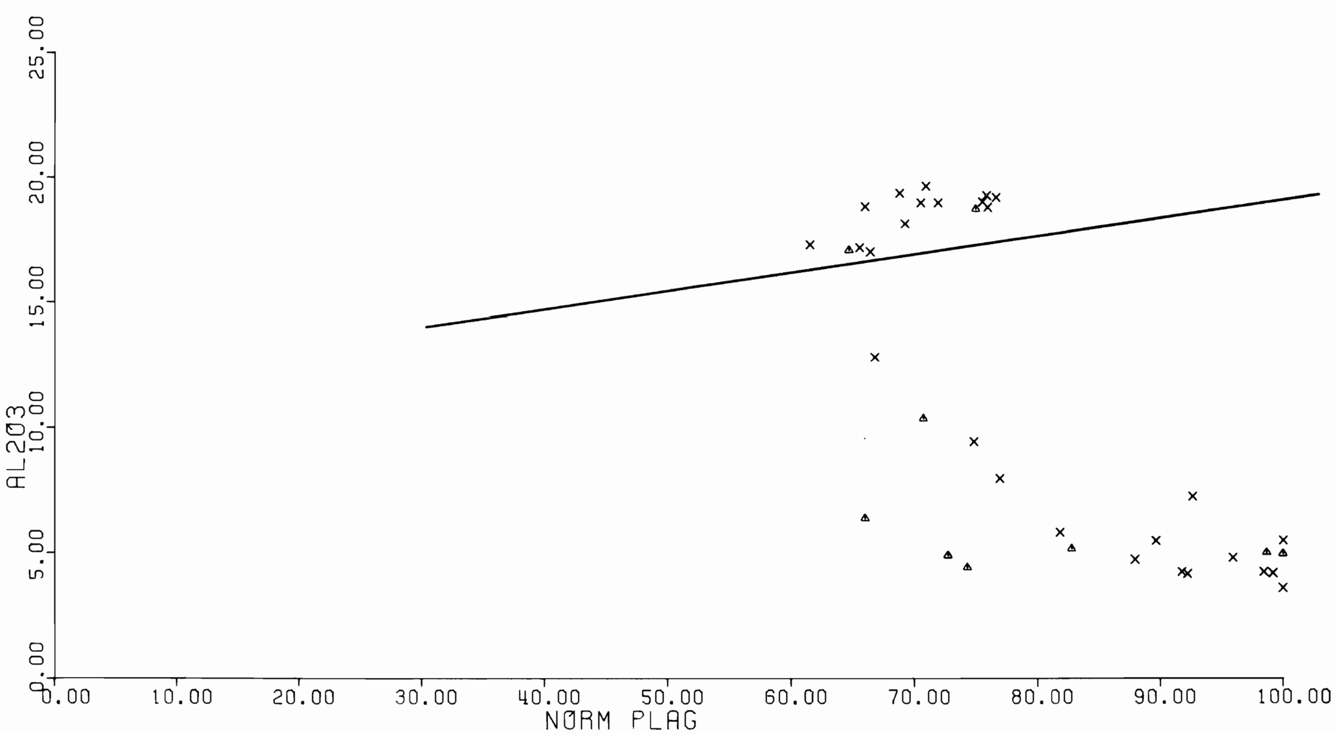


FIGURE 4.5(b): *Al_2O_3 vs Normative Plagioclase diagram for "EL" plug samples. Symbol notation as for Figure 4.2(b). The "Calc-alkali"-"Tholeiite" basalt divide is taken from Irvine and Baragar (1971).*

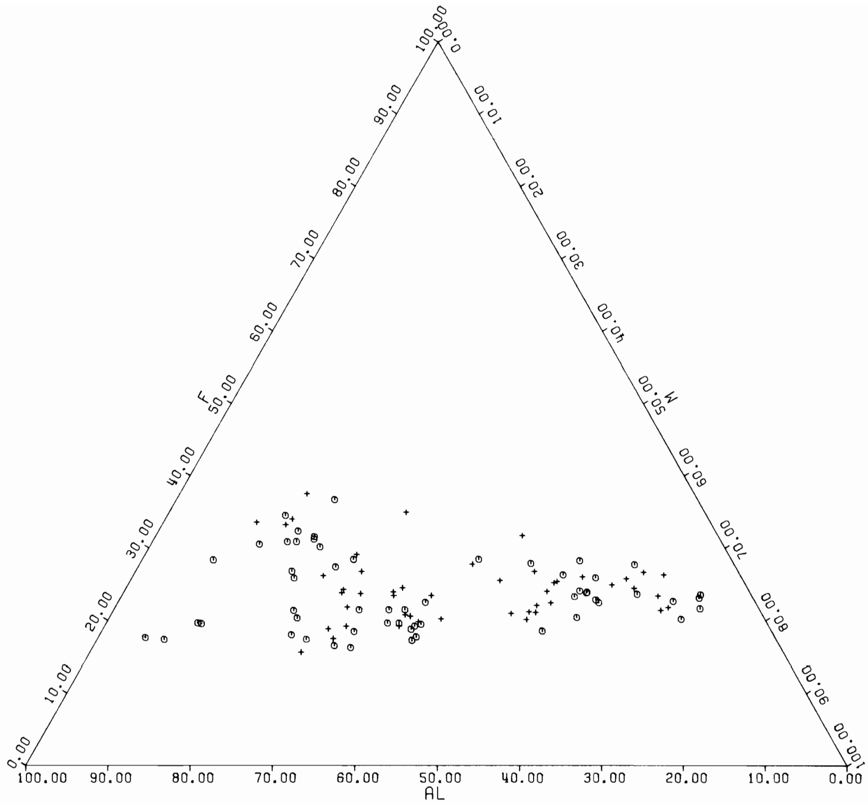


FIGURE 4.6(a): Al_2O_3-FeO-MgO diagram for "A" plug samples. Symbol notation as for Figure 4.2(a).

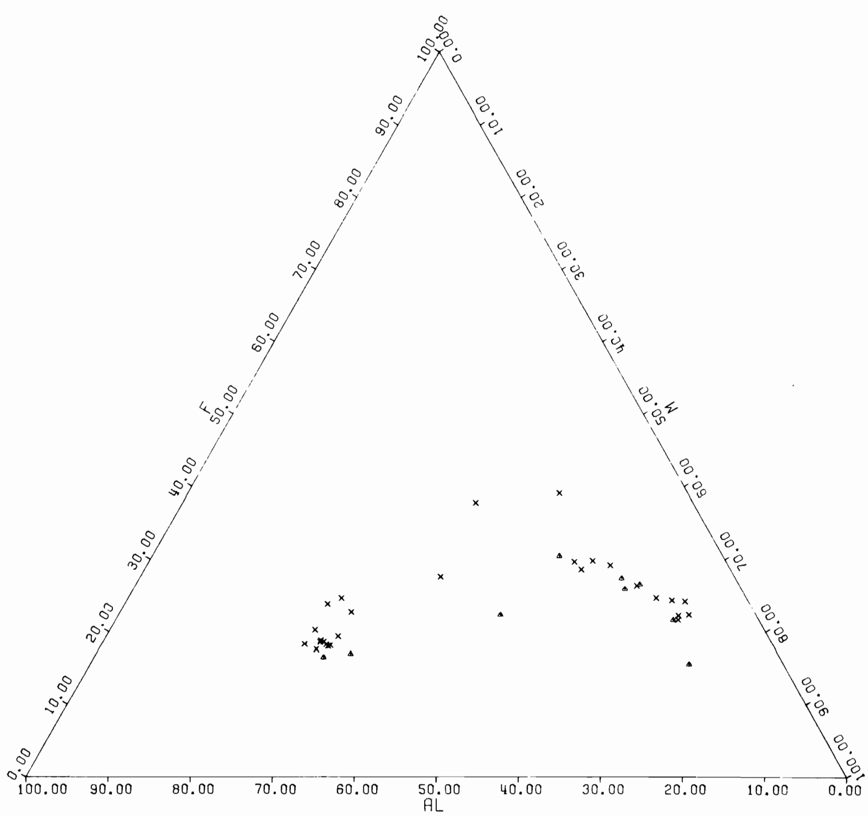


FIGURE 4.6(b): Al_2O_3-FeO-MgO diagram for "EL" plug samples. Symbol notation as for Figure 4.2(b).

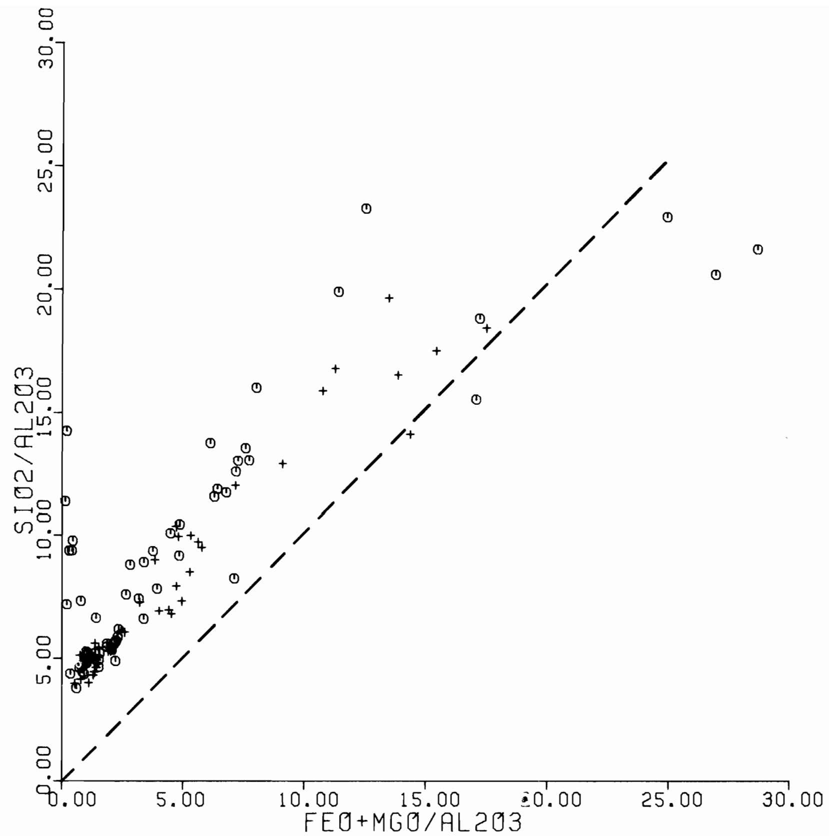


FIGURE 4.7(a): Molar SiO_2/Al_2O_3 vs FeO + MgO/Al_2O_3 diagram for "A" plug samples. Symbol notation as for Figure 4.2(b). Dashed line indicates 1:1 partition ratio.

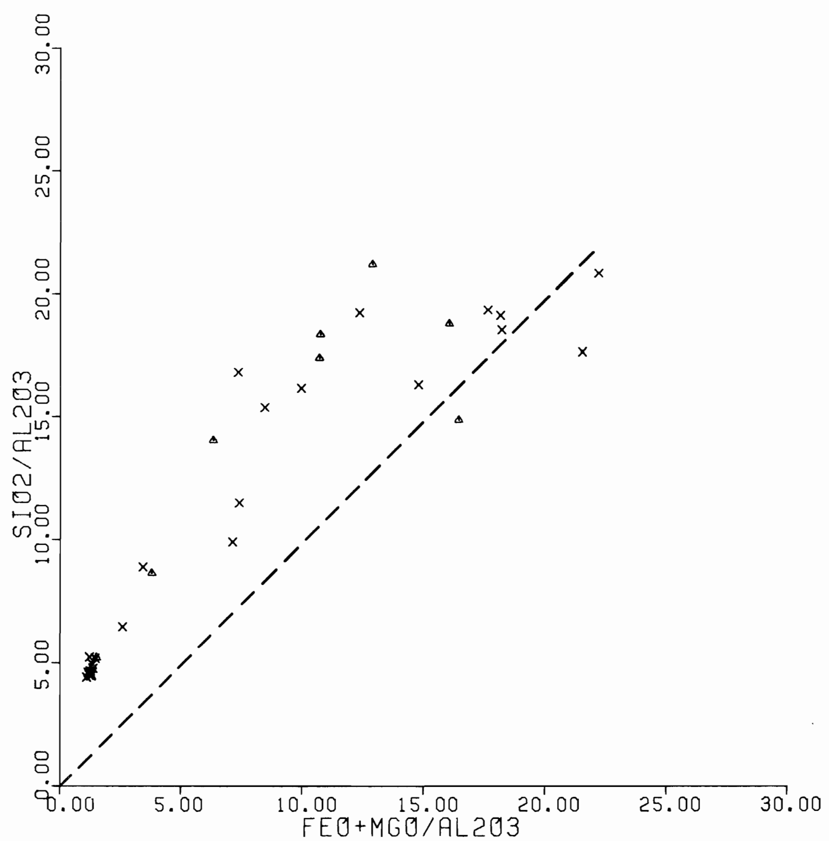


FIGURE 4.7(b): Molar SiO_2/Al_2O_3 vs FeO + MgO/Al_2O_3 diagram for "EL" plug samples. Symbol notation as for Figure 4.2(b). Dashed line indicates 1:1 partition ratio.

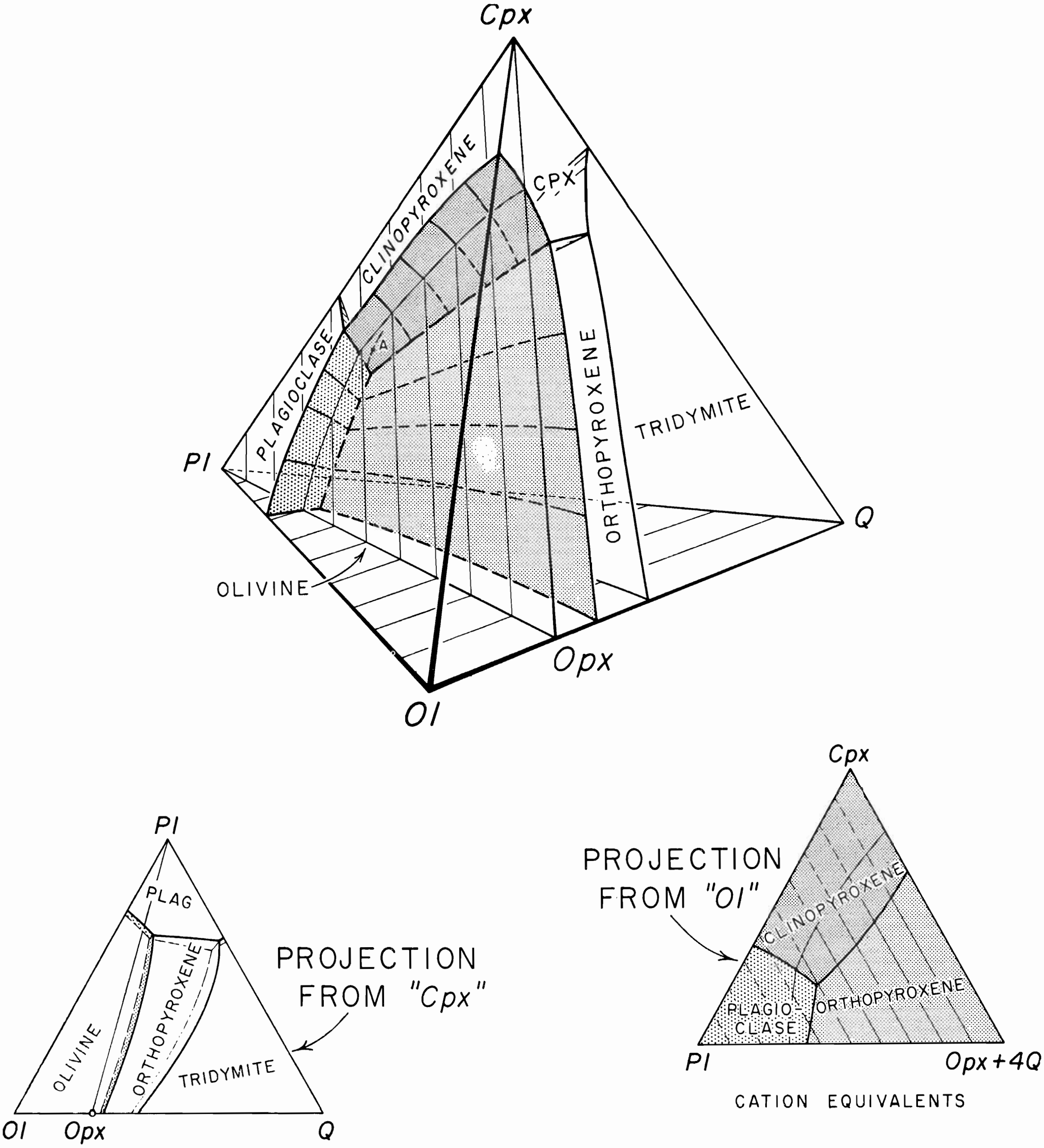


FIGURE 4.8: Phase Diagram Model and Projections of the "System" Ol (Olivine) — Cpx (Clinopyroxene) — Pl (Plagioclase) — Q (Silica), showing liquidus volumes for olivine, clinopyroxene, orthopyroxene and tridymite; taken from Irvine (1970).

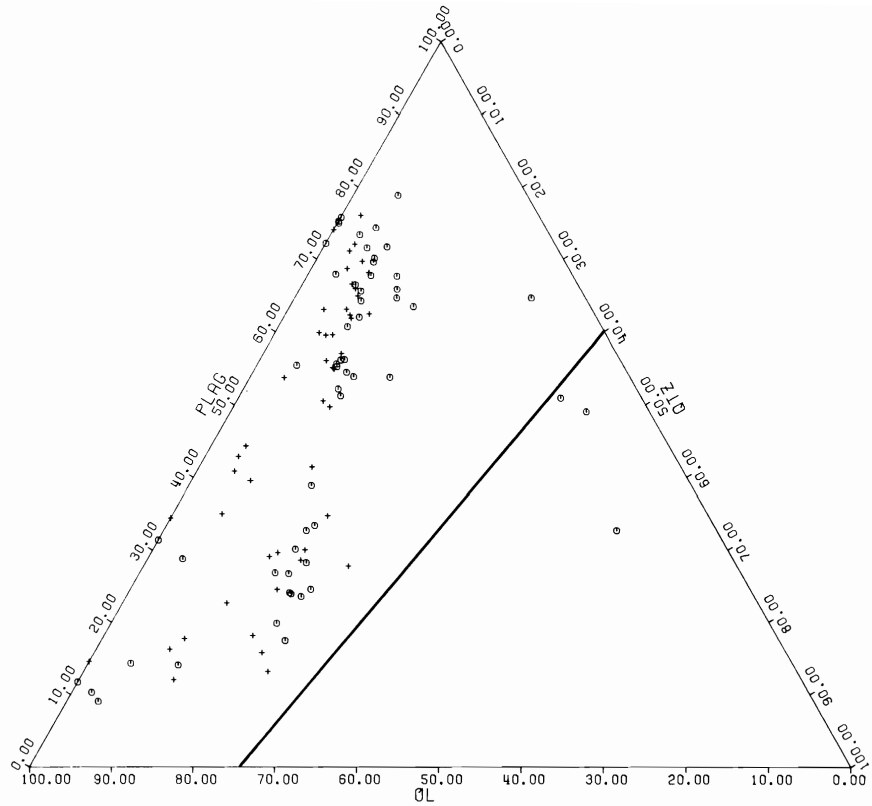


FIGURE 4.9(a): Cation normative Ol — Plag — Qtz diagram for "A" plug samples, showing Plag — Opx tie line: Symbol notation as for Figure 4.2(b).

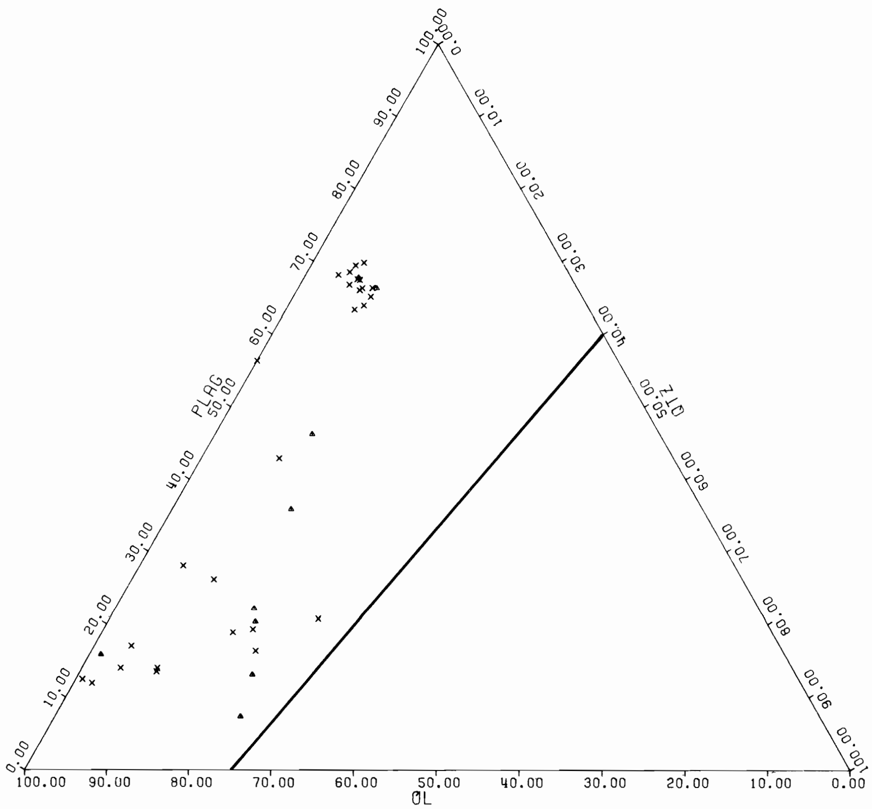


FIGURE 4.9(b): Cation normative Ol — Plag — Qtz diagram for "EL" plug samples, showing Plag — Opx tie line: Symbol notation as for Figure 4.2(b).

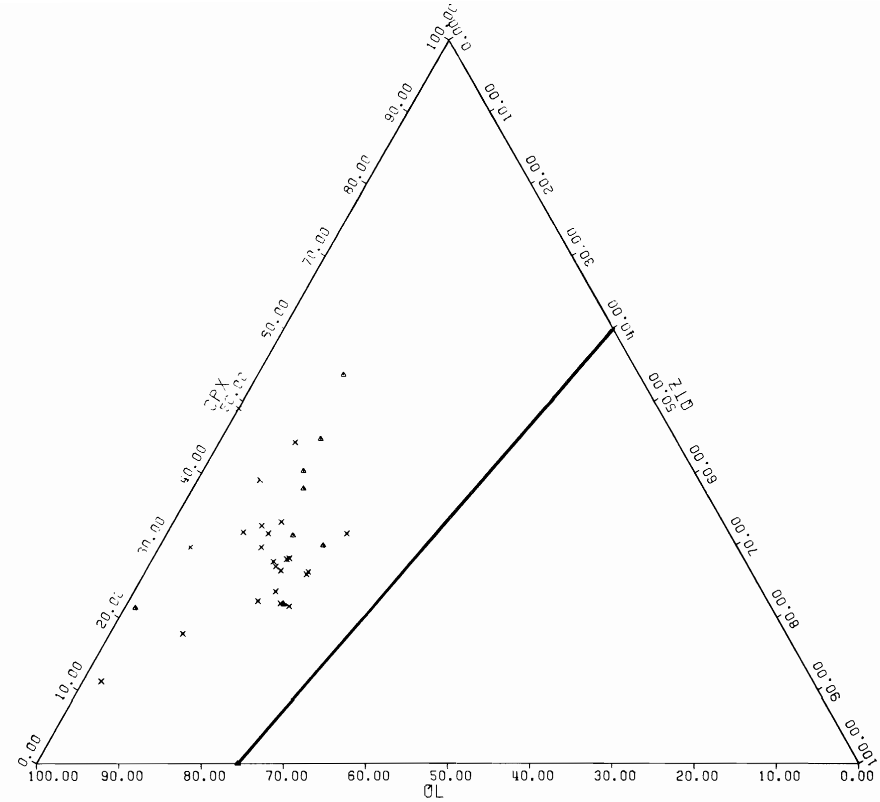


FIGURE 4.10(a): Cation normative Ol — Cpx — Qtz diagram for "A" plug samples, showing Plag — Opx tie line: Symbol notation as for Figure 4.2(b).

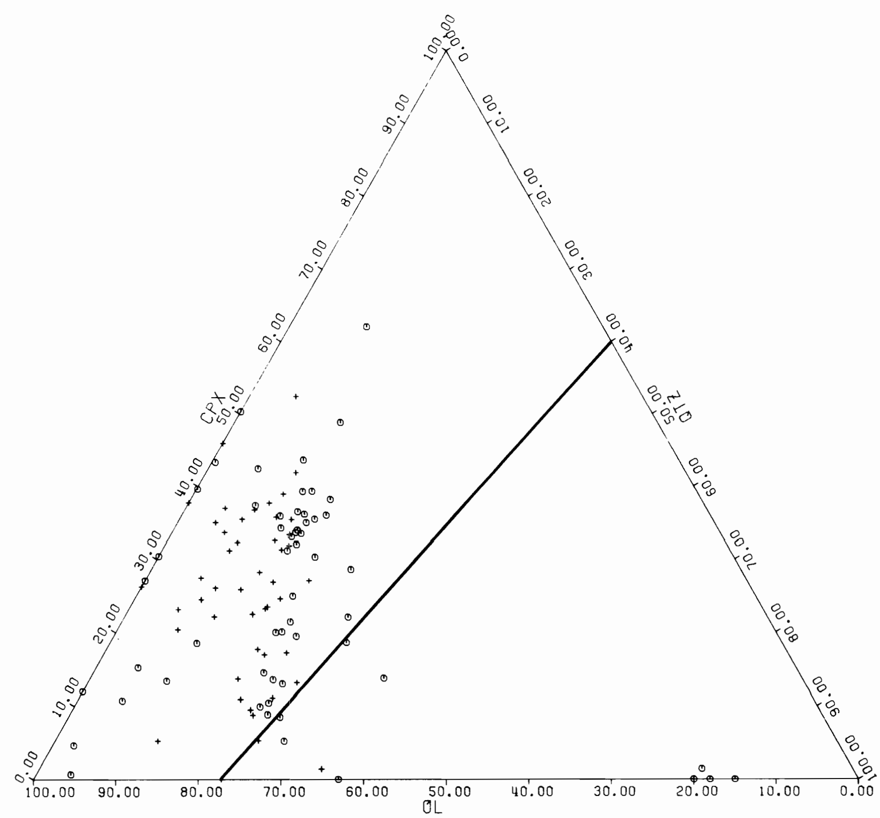


FIGURE 4.10(b): Cation normative Ol — Cpx — Qtz diagram for "EL" plug samples, showing Plag — Opx tie line: Symbol notation as for Figure 4.2(b).

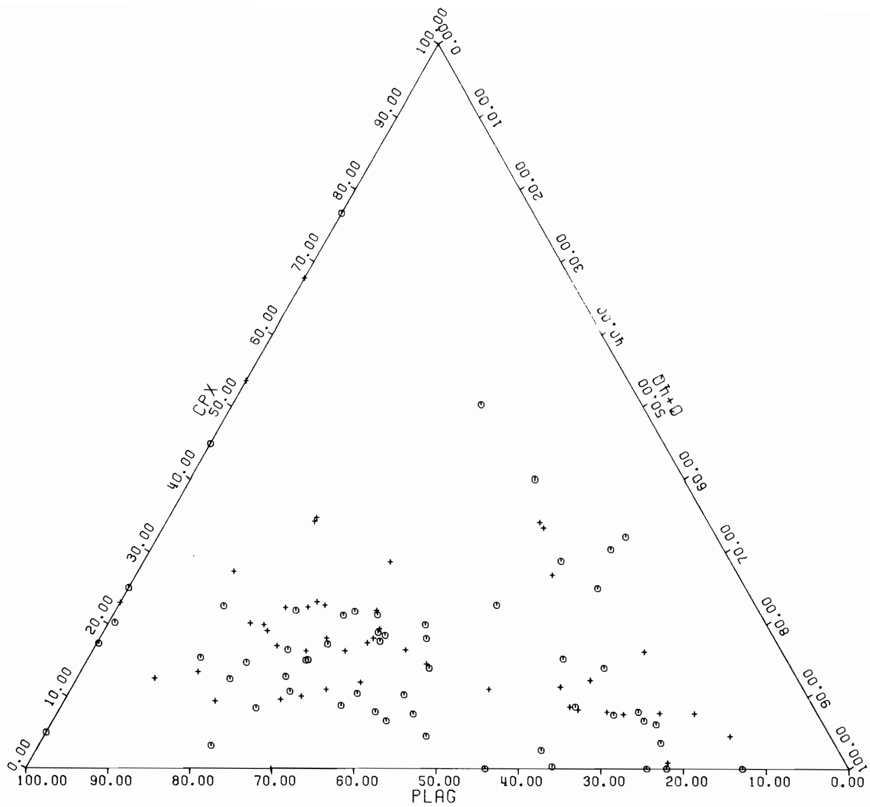


FIGURE 4.11(a): Cation normative Plag — Cpx — (Opx + 4Qtz) diagram for "A" plug samples: Symbol notation as for Figure 4.2(a).

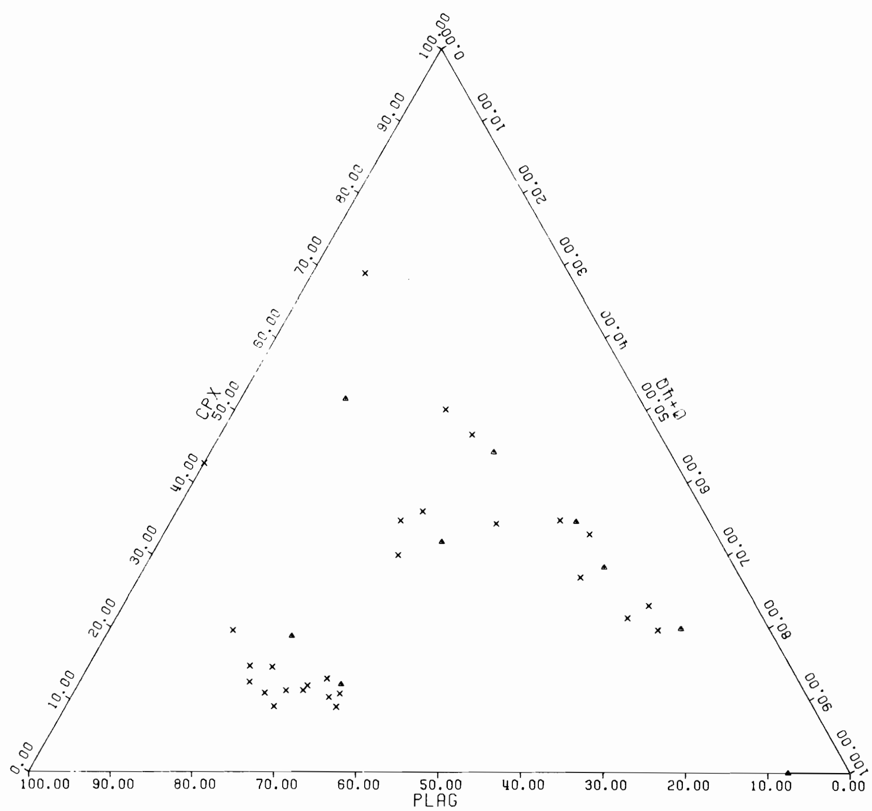


FIGURE 4.11(b): Cation normative Plag — Cpx — (Opx + 4Qtz) diagram for "EL" plug samples: Symbol notation as for Figure 4.2(b).

Chapter V - Ni-Cu Mineralization

5.1 INTRODUCTION

The orebody descriptions in Chapter II and Appendix I show that individual orebodies at Lynn Lake vary considerably in structure and mode of mineralization. The variation, which is primarily a function of mode of emplacement of the Ni-Cu ore, has been aggravated by differential deformation and metamorphism of individual ore pipes and lenses.

The ores have been classified into five ore-types: (1) Disseminated ore, (2) Plutonic breccia ore, (3) Sulphide breccia ore, (4) Massive sulphide vein ore and (5) Siliceous felsite ore, on the basis of texture, morphology and, in the case of ore-type 5, composition.

The ore-types reflect both a magmatic and a hydrothermal origin for the ores. The ore-types are, in part, gradational. Disseminated ores (ore-type 1) grade into plutonic breccia ores (ore-type 2) and liquid sulphide segregation from both has led to the development of sulphide breccia ore (ore-type 3) and massive sulphide vein ore (ore-type 4). Hydrothermal mobilization of the sulphide has caused local dispersion of disseminated ore and apparent concentration of sulphide in recrystallized plutonic breccia ore. Hydrothermal activity is also responsible for mobilization of sulphide into veins in competent mafic rocks ("gabbros", Q.H.D., "diabase") and also for the formation of siliceous felsite veins peripheral to major orebodies ("B", "O"). It may also be responsible for the silica contamination found locally in sulphide breccia and massive sulphide veins and lenses.

Disseminated ores (ore-type 1) occur in amphibolites and "gabbros" in structurally controlled lenses ("B0", "B1", Lower "D", "E-J", "G" and "P"), and in amphibolitized "gabbros" and fresh norites in the cores of mineralized, intrusive ore pipes ("A", "C", "F", "M-N", "O" and "EL"). Plutonic breccia ores (ore-type 2) occur when mineralized norites and amphibolites, in the cores of intrusive pipes, have stoped fragments of the neighbouring host rock "gabbro" ("C", "O", and "EL"). Sulphide breccia ores (ore-type 3) are found either as discrete dykes or veins cutting "A" plug host rock ("B2, "K", Upper "O") or as pipes and lenses within mineralized ore pipes ("A", "C", "O", and "EL"). Massive sulphide veins (ore-type 4) are found, to a lesser or greater extent, in all the orebodies. Siliceous felsite ores (ore-type 5) occur in small amounts often as inclusion material in all the orebodies, but it is particularly abundant in the vicinity of the"B" orebody. It appears to form early veins within and adjacent to ore-types 1, 2 and 3.

5.2 ORE-TYPES

Ore-type 1 (Disseminated ore)

Ores that are predominantly disseminated consist of interstitial crystals of fine grained sulphide, or coarse (0.5 — 1.0 cm) blebs of sulphide, uniformly distributed in structureless amphibolite, feldspathic amphibolite, norite, "gabbro" and, locally, "peridotite". The rock characteristically retains its igneous texture, although it commonly displays a secondary, hydrous mineralogy.

Fresh, anhydrous norites and pyroxenites in the "A" orebody, described by Hunter (1950), resemble similar material found in the "N" orebody during the present study. Both contain irregular, interstitial, sulphide blebs (1-5 mm) which partially envelop and locally enclose subhedral to euhedral crystals of orthopyroxene. The contact between sulphide and the pyroxene is sharp. In both instances the norites and pyroxenites show progressive alteration to amphibolite and feldspathic amphibolite and, as noted by Hunter (1950), some of the sulphide in the finer grained rocks takes an "interlaminate" form, replacing fibrous actinolite and occurring as granules along amphibole cleavages. Recrystallization of the rock is accompanied by partial dispersion of the sulphide.

Sulphide blebs commonly occur in "gabbros" and silicified "gabbroic" rocks inside and peripheral to ore zones. Coarse subhedral to euhedral sulphide blebs, rectangular in section, are associated with interstitial, blue quartz eyes in some localities in the "B", "O" and "N" ore pipes. The blebs appear to be coarse pyrrhotite crystals with exsolved flames and veinlets of pentlandite and peripheral patches of chalcopyrite. Sheared and faulted ores are commonly silicified and some are cut by small veins which are hydrothermal in origin. These include veins of siliceous felsite (ore-type 5) and assemblages of quartz-chlorite-carbonate and sulphide. Veins are particularly abundant in the more "gabbroic" facies of the "B" and "C" orebodies.

Disseminated ores grade into pods and veins of massive sulphide (ore-type 4) through a reticulate, net-textured ore which consists of a poikilitic suspension of amphibole crystals (after pyroxene) in sulphide.

ORE-TYPE 2 (Plutonic breccia ore)

Plutonic breccia ore occurs at the interface between a mineralized intrusive facies within an ore pipe, and the barren host country-rock "gabbro" around it. The breccias are well developed around the margins of the "O" and "EL" ore pipes. Subangular to subrounded (0.1 — 10.0 m) xenoliths of allochthonous, barren diorite, "gabbro", amphibolite and "peridotite" (Plates 5.1, 5.2) and less common inclusions of disseminated ore (ore-type 1) and "siliceous felsite" ore (ore-type 5, Plates 5.3, 5.4) are found in a sulphide-bearing silicate matrix. The matrix ranges from relatively undeformed, mineralized, feldspathic amphibolite or "gabbro" (ore-type 1, above) to a completely recrystallized sulphide silicate assemblage which contains amphibole but no feldspar. In the lower part of the "O" ore pipe, the inclusion material becomes more abundant and the matrix more deformed as one approaches the outer contact of the pipe.

Where the matrix is deformed and recrystallized, the distribution of interstitial sulphide tends to be erratic. Sulphide occurs as disseminated blebs in the matrix and it concentrates into pods and structurally controlled sulphide veins (ore-type 4). The sulphide commonly concentrates around xenolithic fragments in the breccia and some fragments are either veined by sulphide, commonly chalcopyrite, or they consist of two parts, a barren core and a narrow weakly mineralized margin. The degree of contamination appears to be related to rock type. "Gabbroic" rocks are less mineralized than amphibolitic ones. Partially mineralized inclusions of the matrix amphibolite are found in zones of sulphide concentration (Plate 5.5). Ruttan (1955) noted that the grade of mineralization increases in zones of brecciation near faults and contacts and he inferred that the breccia zones channelled hydrothermal, ore-bearing fluids. He described a minor dragfold in amphibolite replaced by sulphide.

ORE-TYPE 3 (Sulphide breccia ore)

Sulphide-cemented breccias are found in pipes, pods and lenses in the "B", "C", "O", "F-K", "O" and "EL" orebodies. The breccias consist of subangular to rounded (0.1 — 10 m) inclusions in a silicate-contaminated sulphide matrix. The size, shape and abundance of the various inclusion types varies from lens to lens, and within a given lens. According to Vellet (1963), the "EL" high-grade breccia zone contains stoped inclusions of plutonic breccia ore (ore-type 2) and many of the inclusions in the sulphide breccia pipe are reworked from the near-surface, plutonic breccia. The size and abundance of the inclusion material decreases with depth. In contrast, the inclusions in the "B2" ore zone increase in size, abundance and angularity between the "B" pit, on surface, and the 2000' level (Vellet, 1963).

The inclusions comprise a variety of recrystallized local rock-types, including diorites, "gabbros", amphibolites, "peridotites", various fine grained mafic rocks, including Q.H.D., and "siliceous felsite" (ore-type 5). The sulphide breccia in the west side of the "B" pit also contains rare pebble-sized fragments of recrystallized quartz and pyrite.

Macauley (1962) examined the "B2" ore lens in a stope wall on the 1910' sublevel. He concluded that the inclusions had distinct preferred orientation, although he was unable to determine whether it was a linear or a planar feature. Blocks of "siliceous felsite" (ore-type 5) are characteristically tabular and they commonly impart a preferred orientation to the breccia. The lens boundaries, which probably control the preferred fabric, are sharp and locally discordant to structure.

Coarse mafic inclusions are commonly partially disaggregated and invaded by sulphide. Round inclusions are surrounded by isolated crystals or clots of amphibole or, in the "EL" orebody, alteration-rimmed pyroxene. The sulphide matrix invariably contains pyroxene pseudomorphs and ragged clots of acicular actinolite. In the "EL" orebody, the sulphide matrix contains euhedral crystals (2-4 mm) of augite and talc-antigorite pseudomorphs after olivine (Vellet, 1963). The Upper "O" ore lens contains abundant ragged amphibole but it is relatively free from larger xenolithic blocks.

The sulphide matrix is locally siliceous and low in Ni content. Vellet (1963) noted that the top of the Upper "O" ore lens was siliceous and that siliceous patches, resembling ore-type 5, occur in the high grade "EL" and "B2" ore zones. According to Vellet, bulges of "siliceous and sulphide breccia" occur above and below narrow, isolated, sheets of dyke material which plugged the ("B2") ore structure during formation. A similar, silicified sulphide matrix was found in material from the "B" pit and in sulphide breccias near the contact between a lens in the "O" orebody (3400' level) and host rock amphibolite.

The sulphide component of the matrix tends to be relatively fine grained and the pyrrhotite is sugary in texture. Pentlandite occurs in exsolved flames in the non-magnetic pyrrhotite and in a network of fine veinlets.

ORE-TYPE 4 (Massive sulphide veins)

Ore-types 1, 2 and 3 are cut by veins and pods of a massive sulphide (ore-type 4) which is characteristically coarser grained and less contaminated by silicate material than the matrix sulphide in sulphide breccia ore (ore-type 3).

The sulphide occurs in isolated pods and anastomosing veins such as those which cut the plutonic breccia ores in the "O" orebody below the 3000' level. These veins appear to display a strong structural control and they are oriented parallel to three, late, high-angle fracture sets (NW-SE, north-south and NE-SW). According to A. de Carle (pers. cormm.), some of the differences in structural orientation observed in the north, central and southern sections of the "A" Plug can be discounted, if one assumes that the plug itself has been folded about its long axis into the present configuration (Fig. 12). One fracture restricted to the south end of the "A" Plug is parallel to the "O" fault which truncates the "O" orebody. The vein contacts are sharp and the sulphide contains angular fragments of locally derived amphibolite. Sulphide veins are most abundant in the most deformed portions of orebodies and local concentrations create "stringer" or "stockwork" ores.

Some structurally controlled sulphide veins cut late acidic and basic igneous dykes (Milligan, 1960). Although few of the larger massive sulphide veins show direct evidence for hydrothermal origin, many of the smaller veins and veinlets are clearly hydrothermal, as they are associated with quartz, carbonate, chlorite and amphibole.

Weakly mineralized amphibolitized norite in the "N" orebody (2600' level) is cut by an irregular dyke of massive sulphide ore. The dyke, which occurs in an undeformed portion of the orebody, is probably mainly magmatic. It consists of a core of coarse (1 cm) pyrrhotite and narrow, finer grained, pyritized margins. The core pyrrhotite crystals are fractu red and mesh veined by stringers of pentlandite and chalcopyrite.

ORE-TYPE 5 (Siliceous felsite ore)

Siliceous felsite ore comprises an assemblage of aphanitic to fine grained quartz and plagioclase with variable amounts of interstitial and ramifying micro-vein sulphide. The rock type was originally known as "chert" in the Mine and as quartz-plagioclase hornfels by Macauley (1962). It commonly occurs as veins (1-20 cm) in "gabbros" peripheral to the "B" and "O" and "N" orebodies, and it less commonly occurs as veins, which cut disseminated and plutonic breccia ores within the "A" (Vellet, 1963) and "O" orebodies.

The matrix to sulphide breccia ore (ore-type 3) is locally siliceous, particularly near host-rock contacts, and the top of the Upper "O" ore lens grades into a vein of near-barren siliceous felsite ore (Vellet, 1963). Similarly the"B2" ore lens appears to merge into siliceous felsite, in veins, on strike to the south.

Siliceous felsite ore is brittle and it occurs as angular inclusions in plutonic and sulphide breccia ores in the "A", "B", "C", "N", "O" and "EL" orebodies. In the "O" orebody it is far more abundant as inclusion material than it is as veins. The inclusions are commonly banded. Gradational bands contain different proportions of silicate and sulphide. The brittle inclusions are much fractured and they are commonly riddled with veinlets of ore from the breccia matrix. Dornian (1950) described fragments of siliceous ore encountered in a body of massive sulphide (sulphide breccia?) on the 1000' level in the "A" orebody. The ore, which appears to be altered, consists of fine grained quartz, carbonate and sphene with abundant interstitial pyrrhotite and small amounts of pentlandite and chalcopyrite. Dornian considered that some of the acid intrusive phases were related to siliceous (felsite) ores.

5.3 ORE COMPOSITION

The Ni-Cu ores at Lynn Lake have been recrystallized and the principal Ni and Cu bearing sulphides (pentlandite and chalcopyrite) show evidence for independent, low temperature ($<350°C$), segregation and mobilization into veins. The ores have therefore lost much of their original homogeneity and visual estimates of pyrrhotite, pentlandite, chaicopyrite and pyrite in hand specimen are not necessarily representative of ore composition.

Some aspects of the ore composition can be determined from a study of ore reserve calculations made by Sherritt Gordon Mines Limited. Table 2.2 is a summary of the metal grades and maximum "ore" tonnages found in the various orebodies in the "A" and "EL" plugs.

The figures, which are mainly estimates made after production, are probably reasonable estimates of the reserves in each orebody. The definition of ore changed throughout the life of the deposit. The cut-off grade for ore was 0.5% Ni in the early stages of development but in the later stages it changed to 0.7% Ni.

The Ni/Cu ratio of the "ore" in each orebody is also given in Table 2.2. This figure is an indirect measure of the relative proportions of pentlandite and chalcopyrite in the ore. The Ni/Cu ratio ranges from 1.37 in the "K" orebody to 2.99 in the "high-grade" portion of the "EL" orebody. The combined tonnage for the "A" plug has a Ni/Cu ratio of 1.85 and the average value for "A" plug orebodies is 1.88. Despite the significant increase in the Ni content of the sulphide breccia ores (ore-type 3) in the "EL" orebody and Cu content in massive sulphide vein and breccia ores (ore-types 3 and 4) in the "K" orebody, the bulk composition of the ore varies within a relatively narrow range.

Macauley (1962) examined the ore in "B" orebody in detail and he concluded, from a study of the Ni and Cu content of sections of mineralized drill core, that it was possible to differentiate between (a) disseminated ores in "gabbro", (b) disseminated ores in amphibolite and (c) sulphide breccia ores on the basis of Ni/Cu ratio. He found that the Ni/Cu ratio of each was consistent, and that "gabbro"-related ores are significantly richer in Cu than amphibolite-related ores. Sulphide breccia ores have an intermediate Ni/Cu ratio, similar to that of the "average" composite orebody.

A similar trace element distribution study of the "N" orebody was conducted by E.S. Santiago at the University of Kansas. He was unable to discriminate between individual ore lenses and he concluded that the orebody was more or less homogeneous, and that there was no correlation between rock type and trace element chemistry in this particular orebody (pers. comm. to A. de Carle).

Vellet (1963) plotted the Ni/Cu ratios of the orebodies developed at that time (1963) with respect to depth. He found that those orebodies characterized by "heterogeneity, high pyrrhotite content and gabbroic composition" ("B", "C", "D", "K") were relatively enriched in Cu (Table 2.2) and chemically homogeneous. Ni-rich ores in orebodies associated with more amphibolitic rock types either display a widely erratic Ni/Cu ratio from level to level ("A", "UD", "EL") or what appears to be a systematic variation. The Ni content of the "J" orebody appears to increase upward, towards the "E-J" fault and it decreases between the base of the "E" orebody, above the fault, and surface. The Ni/Cu variation in some localities may be, in part, a result of differential mobilization of Cu and Ni. The mobility of Cu appears to be appreciably greater than that of Ni.

Vellet (1963) found that the pyrrhotite/Ni ratio of the ore was constant within an orebody and, using assay data available at that time (1963), he determined the ratios shown in Table 5.1. He noted that near-barren siliceous felsite (ore-type 5) is an early phase of both the "B" and "D" orebodies and he concluded that the primary sulphide liquid was relatively Fe-enriched at source, and that it later became progressively enriched in Ni (and Cu).

Although Sherritt Gordon did not assay for Co on a routine basis, company data are available for the "D", "K", "O" and "N" orebodies. The figures are average values for anywhere between 5 m and 50 m of analyzed diamond drill core. They show that the "K" orebody is relatively enriched in Cu and Co and that the "D", "O" and "N" orebodies are relatively depleted in these elements (Fig. 5.1). The Co content of the ore rarely exceeds 10% of the recoverable metal in the ore. The distribution of Co in the ore is not well known, but it appears to be concentrated in 5.8 cm "haloes" of pyrite and chalcopyrite around inclusions in ore-type 3 in the "EL" orebody (Ruttan, 1955).

5.4 ORE MINERALOGY

Various aspects of the mineralogy of the ore have been discussed by several workers, including Allan (1948), Dornian (1950), Macauley (1962), Vellet (1963) and Scott (1977). The petrographic and analytical studies conducted by J.D. Scott at the Canada Centre for Mineral and Energy Technology at Ottawa were done in support of the present study.

The Ni-Cu ores at Lynn Lake, irrespective of ore-type, consist of a primary assemblage of pyrrhotite, pentlandite and chalcopyrite, with small amounts of pyrite and traces of sphalerite, magnetite and ilmenite. This primary assemblage has locally undergone intense supergene alteration, and secondary minerals such as marcasite, violarite, smythite, bravoite, geothite, millerite, and hematite are common in near-surface ores. They are also found along fault structures down to between the 500' and 1000' levels.

a) Pyrrhotite

The bulk of the more massive ore comprises a mosaic of interlocking crystals of fine- to coarse-grained pyrrhotite. The pyrrhotite crystals in the coarse grained ores are smooth edged. They have 120° (V-shaped) triple junctions and strain-free centres (J.D. Scott, pers. comm.) and the fabric appears to be a product of metamorphic crystallization, The pyrrhotite crystals tend to be strongly anisotropic and they display a pronounced 1000 parting (Allan, 1948). They are slightly inhomogeneous (Allan, 1948; Dornian, 1950) and they occur as a mixture of both hexagonal and monoclinic forms. Most of the fresh pyrrhotite analyzed by J.D. Scott (pers. comm.) is monoclinic. Rock textures indicate that primary hexagonal pyrrhotite which is still common in the Lower "O" orebody crystallized after the adjacent silicates and oxides. It later, partially

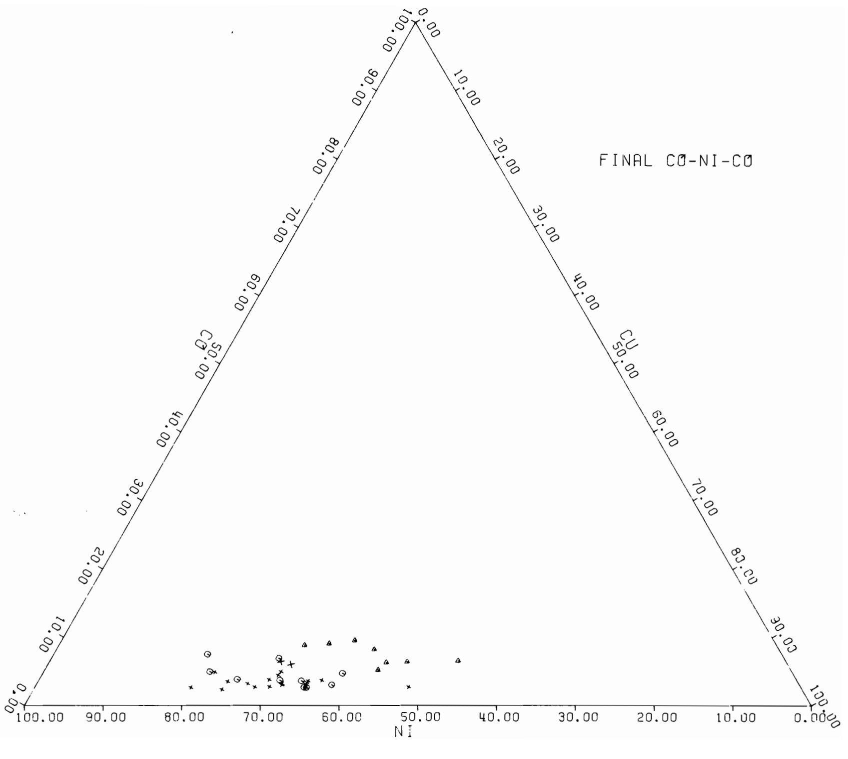


FIGURE 5.1: Portion of a Ni-Co-Cu diagram showing the relative metal contents of sections of mineralized drill core from "D" (X), "K" (▲), "N" (O) and "O" (+) orebodies. Data supplied by Sherritt Gordon Mines Limited.

to completely, inverted to the monoclinic form at a temperature below 254° C. Pyrrhotite crystals locally contain corroded euhedral to anhedral grains of "early" pyrite (1) which may also border large veins of massive ore (ore-type 4). Pyrrhotite crystals in the massive ore are commonly separated by an irregular network of stringers and veinlets of pentlandite veinlets which appear to contain corroded "islands" of pyrrhotite.

TABLE 5.1: PYRRHOTITE/Ni RATIOS IN SELECTED OREBODIES

Orebody	Pyrrhotite/Ni ratio
"A"	10:1
"EL" (low grade)	11 :1
"EL" (high grade)	13:1
"K", "E", "J"	14:1
"B"	19:1
"C"	21 :1
"D" (upper)	25:1
"D" (lower)	40:1

b) Pentlandite

Pentlandite stringers which separate pyrrhotite and veinlets which cut pyrrhotite crystals are usually 1—5 mm wide and relatively short in length (5-30 cm). Some stringers are up to 1 m long (Macauley, 1962), and Ruttan (1955) considered that they were deposited from a pentlandite-rich ore fluid after a period of deformation and fracturing. However, pyrrhotite "islands" in pentlandite veinlets commonly remain in crystallographic continuity with the crystals from which they are derived (Dornian, 1950) which supports a replacement origin for some of the pentlandite. In the disseminated ore (ore-type 1), pentlandite blebs and veinlets are restricted to individual, interstitial, pyrrhotite crystals. They are very rarely separate from pyrrhotite.

Pentlandite also occurs as feathery exsolution "flames" or lamellae in the coarse, granular pyrrhotite found in ore-types 2, 3 and 4. According to Macauley (1962), exsolution is relatively uncommon in the disseminated ores (ore-type 1) in the "B" orebody. In the more massive ores, *en echelon* pentlandite flames in pyrrhotite crystals are commonly cut, or replaced, by younger veinlets of the "remobilized" pentlandite (Scott, 1977).

c) Chalcopyrite

Chalcopyrite occurs as patches and veins segregated within and peripheral to massive and disseminated ores. Chalcopyrite veins cut and replace crystals of early pyrite (pyrite 1), pyrrhotite, and both flame and vein pentlandite (Dornian, 1950; Scott, 1977). Chalcopyrite crystallized late, although it may overlap with the crystallization period of "remobilized" pentlandite. Pentlandite veinlets locally contain corroded islands of chalcopyrite (Dornian, 1970). Chalcopyrite commonly segregates out in veins and patches adjacent to, or within, silicate material in preference to remaining within a body of massive pyrrhotite and pentlandite.

Traces of sphalerite occur with pyrrhotite and chalcopyrite in some of the disseminated ores (Macauley, 1962; Scott, 1977).

Trace quantities of other primary phases have also been recorded. Dornian (1950) identified nickelian cobaltite in the "A" orebody and J.D. Scott (pers. comm.) found cobaltite in the "O" orebody. He also found exsolved blades of native tellurium in a pentlandite vein cross-cutting an interstitial pyrrhotite bleb in a feldspathic amphibolite (Scott, 1977).

Coarse grained sphalerite occurs in an extensive 3 m wide coarse grained vein on the 2000' level, east of the "N" orebody. The vein is attributed to mineralization processes which originated outside the "A" plug,

5.5 SUPERGENE ALTERATION

Ore samples collected in the "B" pit and from the ore dump adjacent to the "B" pit are severely altered. The "primary" sulphide assemblage is partially to cornpletely modified to a "secondary" assemblage. Some minor alteration has been found in ores from other orebodies, at depth in the "A" plug, but nowhere else is the alteration as extreme as in the vicinity of the "B" pit.

Pyrrhotite and pentlandite appear to be particularly susceptible to the alteration, which is partially controlled by late fractures in the "primary" ore. Pentlandite stringers, veinlets and flames are pervasively altered to violarite and minor secondary pyrrhotite. Primary pyrrhotite is altered in two ways. It is either altered to violarite through smythite or it is converted into an assemblage containing late pyrite (pyrite 2) and marcasite. J.D. Scott (pers. comm.) described feathery fronts of smythite invading crystals of monoclinic pyrrhotite along fractures and contacts with altered pentlandite (violarite) veinlets. He also described progressive alteration of massive pyrrhotite to assemblages of pyrite (pyrite 2) and magnetite, followed by marcasite. The pyrite (pyrite 2) shows some alteration to goethite along fractures.

Faults cutting the walls of the "B" pit were found to contain pods and veins of free-growing, cockade marcasite and pyrite (pyrite 2). Interbanded colloform pyrite (pyrite 2) and marcasite occur on a cracked and brecciated pyrite (pyrite 2) base in open veins. The late phase to crystallize in the vein was chalcopyrite (J.D. Scott, pers. comm.), which indicates that this mineral phase is mobile at very low temperatures. Macauley (1962) described a "patch" of pyrite on the 850' level which showed alteration to marcasite and hematite. Marcasite alteration occurs in the vicinity of several faults.

Diamond drill core samples, from the 2000' level in the "O" orebody, were compared with stope samples from the same locality (Fig. 5.2). According to J.D. Scott (pers. comm.) the core from hole D.D.H. U1613, drilled in1962, shows signs of incipient alteration after exposure to the atmosphere for over 15 years. Pentlandite showed signs of incipient violarization along cracks within 0.5 mm of the exposed surface. Pyrrhotite in the core was unaltered. The stope samples show no sign of superficial alteration.

The alteration products resemble those found in pyrrhotite-pentlandite ores from Kambalda in Western Australia (Nickel *et al.*, 1974) and a similar, supergene alteration process is inferred. The ores in and below the "B" pit are thought to have been affected by circulating ground water from the east arm of Lynn Lake, which gained access through a system of faults.

5.6 SULPHIDE COMPOSITIONS

The compositions of "primary" and "secondary" sulphide phases in the Lynn Lake ores have been studied by Arnold and Malik (1974) and J.D. Scott (pers. comm.). Average chemical analyses are shown in Tables 5.2 and 5.3.

Hexagonal pyrrhotite is relatively uncommon in the ore and it was analyzed in only three samples of coarse, blebby, disseminated ore from the "B" pit. The hexagonal pyrrhotite is appreciably richer in Fe than the more common, monoclinic variety. The pyrrhotite analyses given by Arnold and Malik (1974) and J.D. Scott (pers. comm.) are remarkably similar (Table 5.2).

The pentlandite analyses from the two laboratories are also similar (Table 5.2) and there is no apparent difference in composition between flame pentlandite and "remobilized" pentlandite (Scott, 1977). The Ni content of the pentlandite is comparable to that of pentlandites in other assemblages of monoclinic pyrrhotite-pyrite-pentlandite (Misra and Fleet, 1973). The pentlandite contains a significant trace of Co.

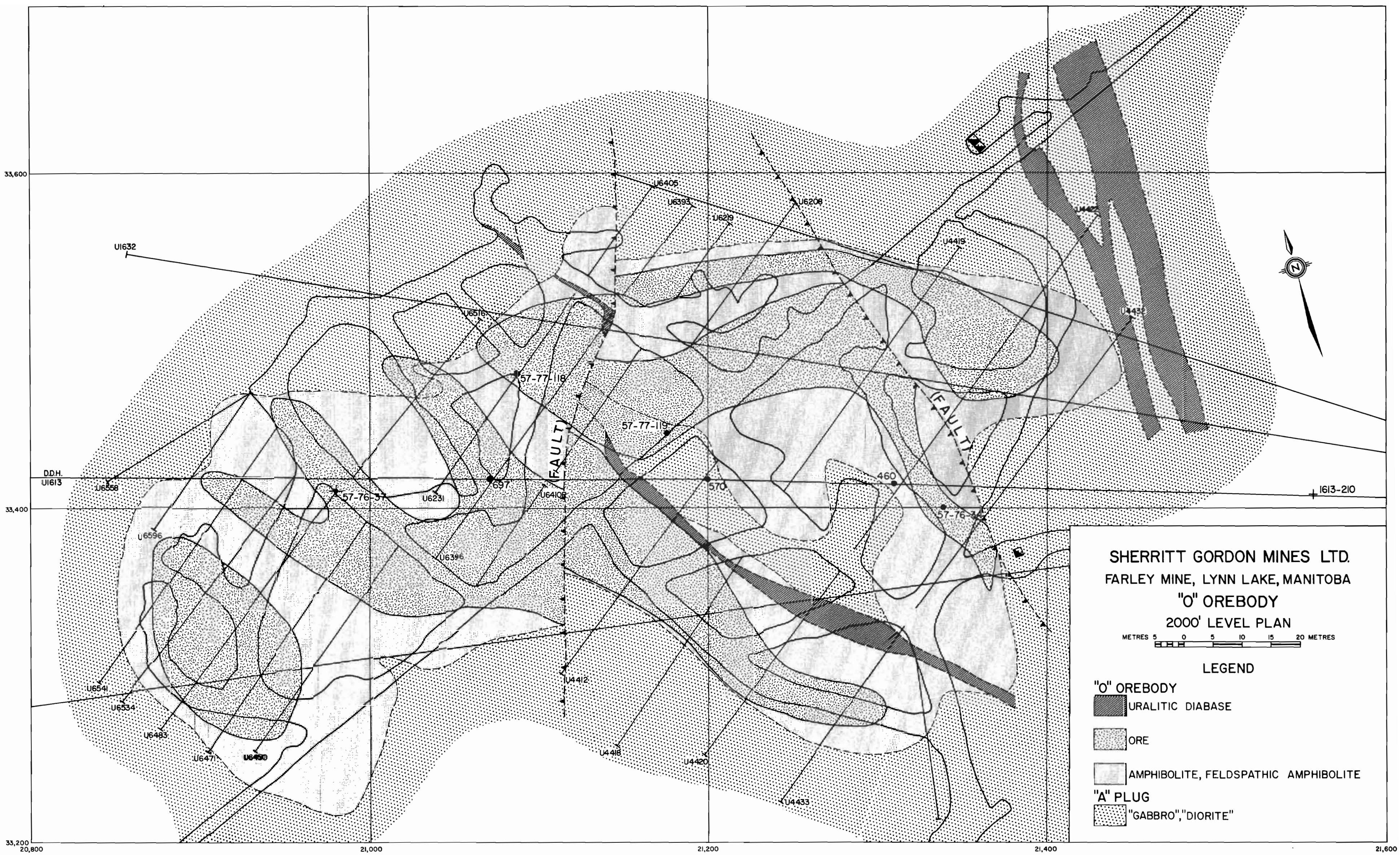


FIGURE 5.2: Plan of the "O" orebody, 2000' Level, showing the location of unaltered stope samples (57-76-34, 57-77-118, 57-77-119) and slightly altered drill core samples (U1613-460', U1613-570', U1613-697') examined for supergene alteration. Samples 57-76-37 and U1613-210 as shown in Plates 3.10 and 3.4.

Scott also analyzed the "primary" sulphide found in relatively unaltered "peridotite" on the 2000' level west of the "B" orebody. Sulphide blebs interstitial to primary olivine (Fo_{81}, 0.28% NiO) consist of an assemblage of troilite with veinlets of exsolved pentlandite. The pentlandite is appreciably richer in Fe and Co than that found in the ore (Table 5.2).

The Co content of texturally "early" pyrite (pyrite 1) appears to be exceedingly variable. Analyses indicate that it contains a trace of Ni and up to 3.24 atomic percent Co (J.D. Scott, pers. comm.). Pyrite (pyrite 2), which is texturally "late" as it replaces pyrrhotite and pentlandite, appears to be richer in Ni (Table 5.3). According to Arnold and Malik (1974), small "secondary" pyrite "inclusions" in pentlandite contain 4.5 + 0.9 atomic percent Ni and 3.4 + 0.3 atomic percent Co.

Arnold and Malik (1974) present data on the composition of mixtures of monoclinic pyrrhotite and "secondary" violarite at Lynn Lake. The mixture has an exceedingly variable composition between end-points (Table 5.3) calculated by linear regression analysis. The secondary marcasite also has a variable composition. J.D. Scott (pers. comm.) found that some replacement marcasite (marcasite 2) was nickeliferous but that the cockade material (marcasite 2) was free from Ni and Co (Table 5.3).

Figures 5.3 and 5.4 show that the pentlandite at Lynn Lake belongs to a single population and that it has a metal to sulphur ratio of 9:8. Figure 5.5 shows that the atomic percent Ni increases sympathetically in pyrrhotite and pentlandite.

The analytical data show that there are no significant differences in composition between the sulphides found in the various ore-types or, on the basis of results from the "B", "O" and "N" orebodies, between the various orebodies. The sulphides in the anhydrous "norites" and in the "N" orebody resemble those of hydrated amphibolites. Mobilization of Fe and Ni during "supergene" alteration has produced a heterogeneous "secondary" sulphide mineralogy near surface.

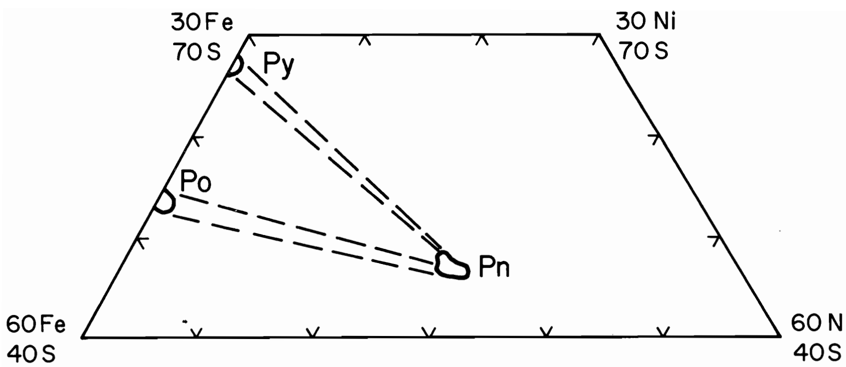


FIGURE 5.3: Portion of an Fe-Ni-S diagram (atomic percent) showing the composition, range of, and the tie-lines joining, coexisting Pyrrhotites (Po), Pentlandites (Pn) and Pyrite (Py). Data supplied by J.D. Scott (pers. comm.).

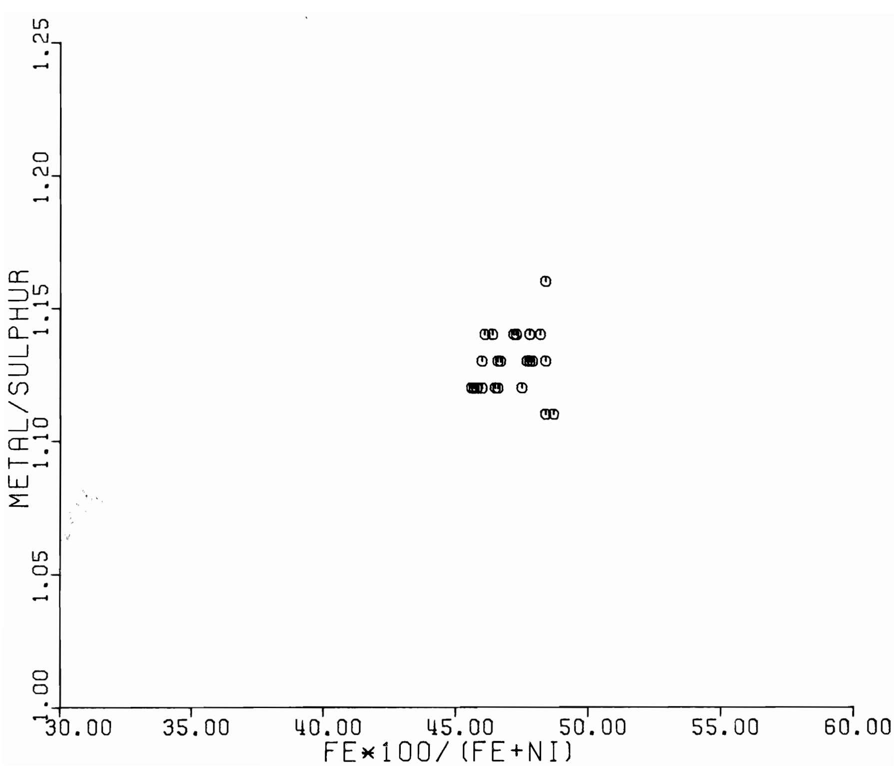


FIGURE 5.4: Metal/S vs Fe x 100/(Fe + Ni) diagram for "A" plug pentlandites. Data supplied by J. D. Scott (pers. comm.).

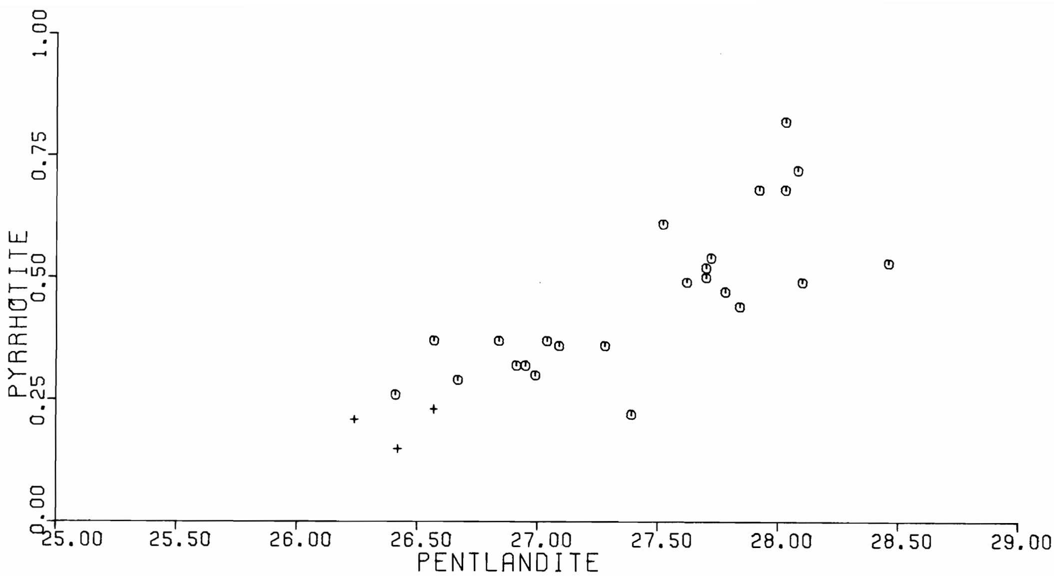


FIGURE 5.5: Ni distribution (atomic percent) in coexisting pyrrhotites and pentlandites in "A" plug ores. Monoclinic pyrrhotites are denoted by open circles (O) and hexagonal pyrrhotites by cross (+). Data supplied by J. D. Scott (pers. comm.).

TABLE 5.2 ANALYSES OF "PRIMARY" SULPHIDES

1) Hexagonal pyrrhotite, monoclinic: pyrrhotite, pyrite, pentlandite assemblage

	No. of samples* or analyses	Fe	Atomic percent Ni	Co	S	Source
Hexagonal: pyrrhotite	(3)	47.37 ± 0.2	0.20 ± 0.05	0.00	52.43 ± 0.2	J.D. Scott (pers. comm.)
Monoclinic: pyrrhotite	(26)	46.26 ± 0.5	0.47 ± 0.3	0.00	53.27 ± 0.3	
Monoclinic: pyrrhotite	60	46.6 ± 0.3	0.4 ± 0.1	0.01	53.0 ± 0.9	Arnold & Malik (1974)
Pentlandite	(28)	24.39 ± 1.0	27.42 ± 1.0	1.18 ± 0.4	47.01 ± 0.5	J.D. Scott (pers. comm.)
Pentlandite	140	24.2 ± 0.3	28.5 ± 0.2	1.3 ± 0.1	46.0 ± 0.2	Arnold & Malik (1974)
Pyrite (1)	(9)	32.18 ± 2.0	0.06 ± 0.5	1.17 ± 2.0	66.59 ± 0.3	J.D. Scott (pers. comm.)

2) Troilite pentlandite assemblage

Troilite	(1)	50.3	0.01	0.08	49.58	J.D. Scott (pers. comm.)
Pentlandite	(10	26.99	23.55	2.71	46.75	J.D. Scott (pers. comm.)

*Number of analyses by J.D. Scott are for individual samples and those of Arnold and Malik (1974) are for crystals or individual point analyses.

TABLE 5.3 ANALYSES OF "SECONDARY" SULPHIDES

1) "Pyrrhotite + Violarite", Pyrite (Marcasite) assemblage

	No. of samples* or analyses	Fe	Ni	Co	S	Source
"Pyrrhotite +		17.01 ± 1.7	18.7 ± 1.0	8.0 ± 0.3	56.3 ± 0.7	Arnold & Malik (1974)
Violarite		44.5 ± 1.7	1.2 ± 1.2	0.1 ± 0.1	54.2 ± 0.7	Arnold & Malik (1974)
Pyrite (2)	(2)	32.38 ± 0.2	0.37 ± 0.2	0.84 ± 0.1	66.42 ± 0.11	J.D. Scott (pers. comm.)
Marcasite (1)	(1)	31.69	1.64	0.00	66.67	J.D. Scott (pers. comm.)
Marcasite (2)	(1)	33.50	0.00	0.00	66.48	J.D. Scott (pers. comm.)

*Number of analyses by J.D. Scott are for individual samples.

PLATE 5.1: Barren feldspathic "gabbro" inclusion in a weakly mineralized noritic amphibolite matrix: Plutonic breccia ore (ore-type 2), 2000' level, "O" orebody.

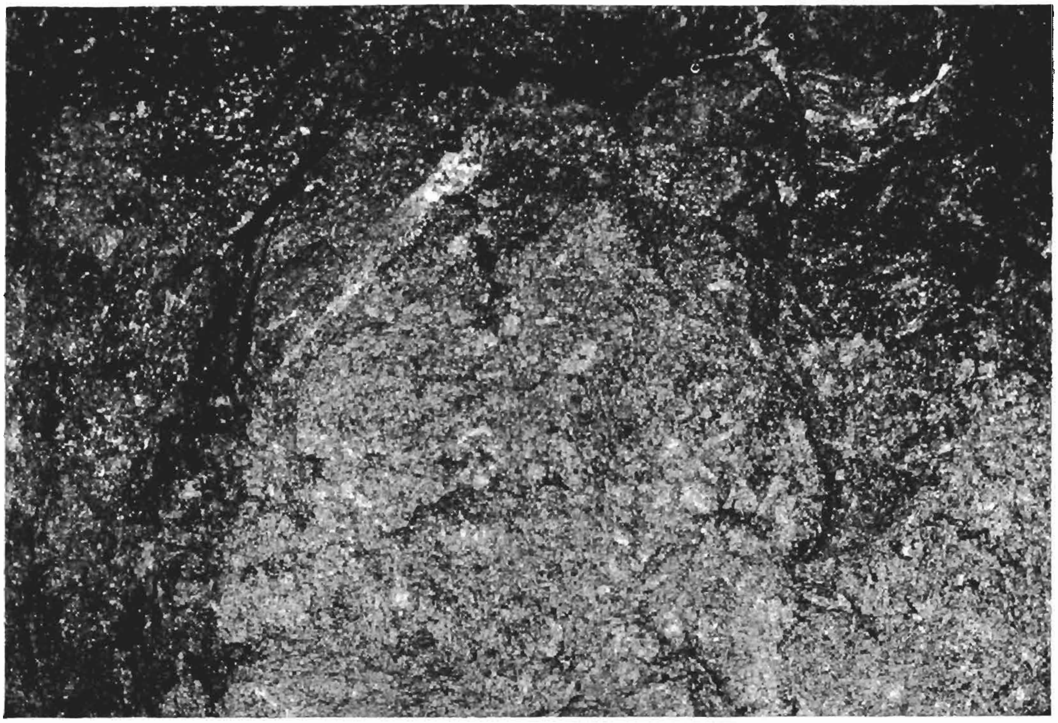


PLATE 5.2: Barren "peridotite" inclusion in a weakly mineralized noritic amphibolite matrix: Plutonic breccia ore (ore-type 2), 2000' sublevel, "O" orebody.

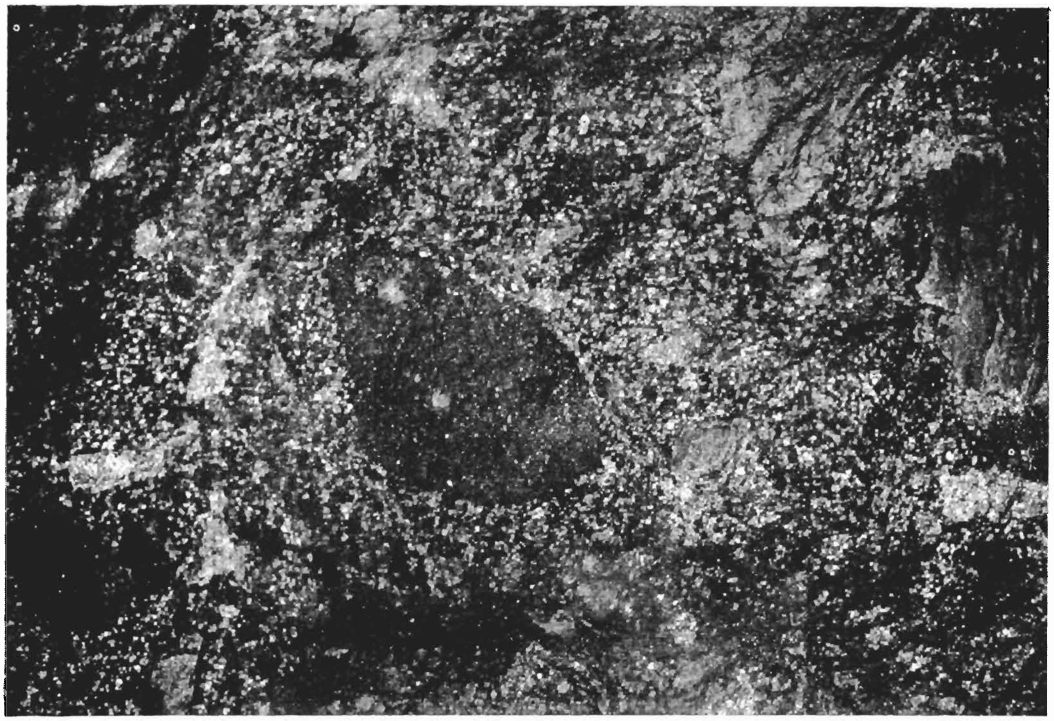


PLATE 5.3: Amphibolite and siliceous felsite ore (ore-type 5) inclusions in a strongly mineralized amphibolite matrix: Plutonic breccia ore (ore-type 2), 3400' level, "O" orebody.

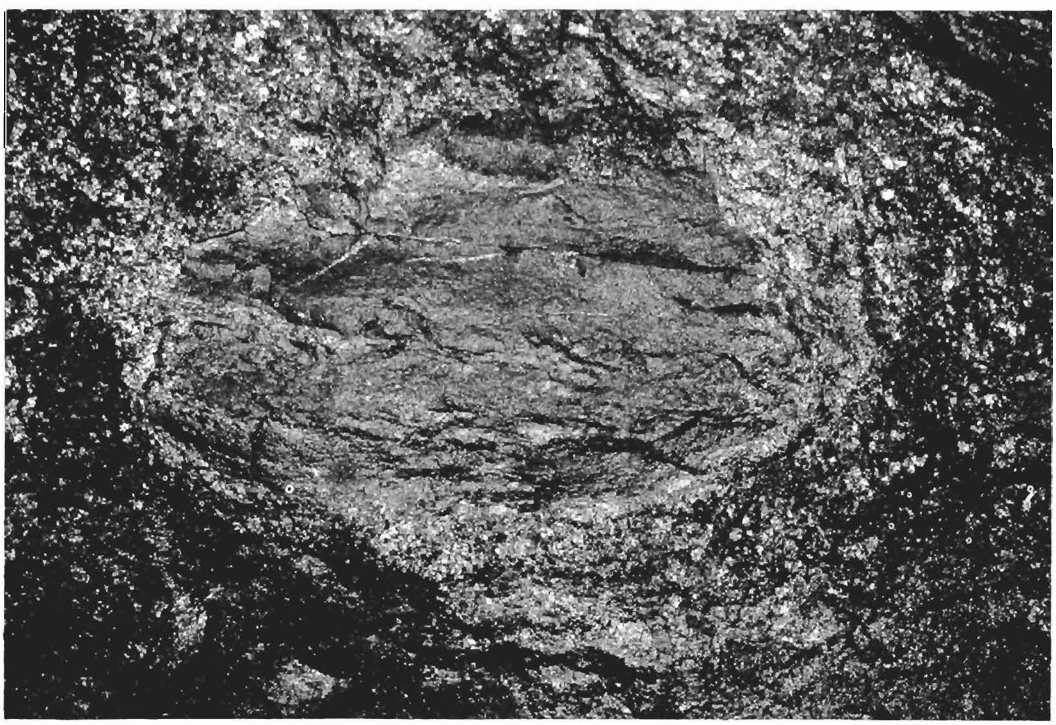


PLATE 5.4: Siliceous felsite ore (ore-type 5) inclusion in a mineralized amphibolite matrix. Plutonic breccia ore (ore-type 2), 3400' level, "O" orebody.

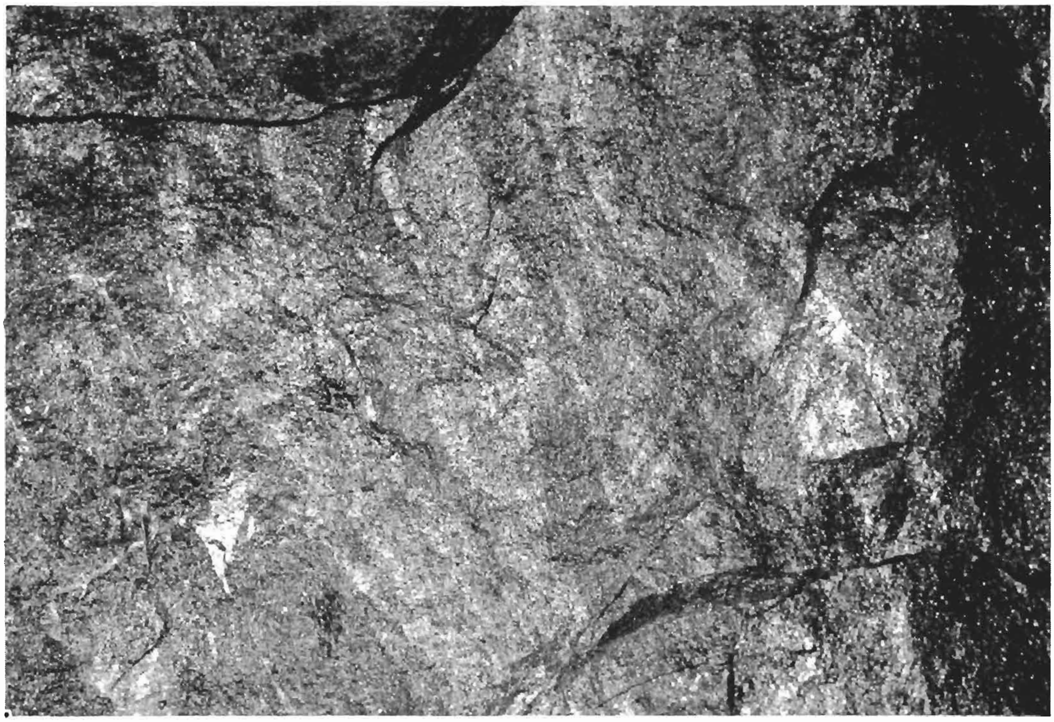


PLATE 5.5: Strongly mineralized amphibolite matrix to plutonic breccia showing sulphide-silicate formation and residual blocks of weakly mineralized amphibolite. Plutonic breccia ore (ore-type 2), 3270' level, "O" orebody.

Chapter VI - Discussion

6.1 ORE DEPOSIT STRUCTURE

The Ni-Cu deposits described in Chapter II and Appendix I occur in two adjacent, but separate, composite igneous plugs. The mineralization occurs in discordant, vertical intrusions emplaced within a succession of Wasekwan Group metavolcanics and metasediments. The composite intrusions appear to result from (a) remobilization of ultramafic ("peridotite") and mafic (amphibolite, norite, "gabbro") cumulate and (b) intrusion and crystallization of mafic to acid igneous magmas.

The range of composition in the "EL" plug "gabbro" is different from that in the "A" plug "gabbro" and there is no evidence to support the contention of Emslie and Moore (1961) that the two plugs are fault-displaced components of a single mineralized body.

The "EL" plug comprises a discrete composite pipe. The margin of the pipe consists of a eutectic composition, Mg-rich, High-alumina "gabbro" and the core consists of a younger intrusion of barren "peridotite", mineralized amphibolite and massive sulphide breccia. The structure of the "EL" pipe clearly indicates that it formed through multiple intrusion and that the mineralization is associated with remobilized mafic (orthopyroxenitic) cumulate. The ore fluid in the" EL" pipe was evidently trapped in an unstable situation, between the cumulate source magma chamber and the intended destination of the magma, and the mineralized cumulate was evidently drawn into the core of the "EL" pipe. The process may have been aided by volcanism above the present level of erosion (Vellet, 1963).

The "A" plug is a more complex intrusion, but it has many features in common with the "EL" plug. Remobilized "gabbro" cumulate (normal "gabbro") appears to be intruded by (a) barren ultramafic ("peridotite"), and (b) barren to weakly mineralized mafic (amphibolite), (c) mineralized norite cumulate and (d) barren basic to acid igneous magmas. The bulk of the mineralization in the "A" plug occurs in discrete ore pipes, which characteristically contain disseminated sulphide-bearing anhydrous norite (or amphibolite derived from norite) and/or plutonic breccia ore found at the pipe interface with host-rock "gabbro". The pipes are extensive, although the mineralization may be localized. The sulphides, locally segregated into a discrete silicate-contaminated ore fluid, either within the source magma chamber, or in transit to the "A" plug, and this liquid, formed "high grade" sulphide pipes and lenses (a) within ore pipes ("EL", "C", "O") and (b) within host-rock "gabbro" and Q.H.D. ("B", "D", "K"). The sulphide liquid evidently remained mobile after the silicate rocks consolidated and it segregated into fractures, both inside and outside individual ore pipes.

Fresh, anhydrous norite appears to be restricted to the cores of the least deformed ore pipes ("A" and "N") in the "A" plug and it is probable that these ore pipes were formed after the main period of pyroxene uralitization. Siliceous felsite ore, which is inferred to be largely hydrothermal vein material, was formed in the vicinity of the "B", "N" and "O" orebodies in advance of the main period of mineralization, and fragments were subsequently caught up in plutonic and sulphide cemented breccias. This observation also favours hydrothermal activity early in the development of the plug. The "A" plug host-rock "gabbros", and most of the silicate rocks in the ore pipes, are completely altered. Much of this alteration is probably deuteric (Vellet, 1963) although some uralitization probably accompanied post-ore metamorphism. The inferred development history of the "A" plug is shown in Table 6.1.

6.2 ORE GENESIS

The deposits have been studied by many geologists since their discovery in 1941. They include Allan (1948, 1950), Hunter (1950), Dornian (1950), Ruttan (1955), Milligan (1960), Emslie and Moore (1961), Macauley, (1962), Vellet (1963) and, in addition, a large number of mine geologists, most notably A. deCarie, employed by Sherritt Gordon Mines Limited. All have contributed substantially to the data available on the deposits and to the present interpretation of the genesis of the deposit type. The published and unpublished descriptions show general agreement on the main features of the deposits but they fail to show any consensus on the genesis of the ore. The authors hold conflicting opinions on (a) the relative

TABLE 6.1 GEOLOGICAL HISTORY OF THE "A" AND "EL" PLUGS

(1) Post-Wasekwan deformation, granite intrusion and metamorphism of Wasekwan Group metasediments and metavolcanics.

(2) Intrusion of "A" and "EL" plug "gabbro".

(3) Faulting(?).

(4) Intrusion of minor phases ("peridotite", "pyroxenite", "quartz-hornblende-diorite", "diorite").

(5) Partial static uralitization of "A" and "EL" plug "gabbro" and formation of siliceous felsite veins (ore-type 5).

(6) Intrusion of mineralized norite (ore-type 1) with (a) formation of contact breccia (ore-type 2) and (b) segregation of sulphide (ore-types 3 and 4).

(7) Further uralitization.

(8) Deformation, with (a) disruption of siliceous felsite veins in plutonic breccia (ore-type 2), (b) further concentration of sulphide in plutonic breccia, (c) concentration of sulphides in fracture sets (ore-type 4) and (d) segregation of granitic fluids into pods and veins.

(9) Intrusion of minor plutons of quartz diorite and granodiorite, and granodioritic batholiths in the axis of the Lynn Lake Greenstone Belt.

(10) Injection of late acid to basic dykes.

(11) Post-mineral faulting.

(12) Completion of hydrothermal activity.

importance of magmatic and hydrothermal processes in localizing the ore, (b) the relative age of the mineralization and (c) the basic structure of the two mineralized plugs,

Allan (1948) was unaware of the presence of anhydrous norite when he examined the petrography of altered "gabbro" found in the vicinity of the "A" orebody. As a result, he concluded that the sulphides formed a "high temperature, hydrothermal, replacement deposit". He evidently thought the "gabbro" and the sulphide were derived from a common magma chamber, and that heat from a later granite intrusion caused remobilization of the sulphide into mineable orebodies.

Hunter (1950) found anhydrous mineralized norites in the "A" orebody and concluded that the sulphide must be magmatic in origin. He envisaged partial to complete segregation of sulphide liquid, at depth, prior to vertical intrusion of the partially consolidated sulphide-silicate assemblage to its present location. He considered that still-liquid norite and sulphide would intrude the more consolidated "gabbro", and that the sulphide would concentrate in breccia zones. He concluded that the hydrothermal effects are relatively insignificant and that uralitization occurred when neighbouring granites were intruded.

Dornian (1950) concurred with Hunter (1950). He suggested that the deposits are "late magmatic injection deposits". He pointed out that the sulphide volume in the "A" plug is disproportionate to its size, and that it must represent sulphide concentrated from a large body of "gabbro".

Ruttan (1955) noted that the grade of mineralization increased near faults and zones of intense brecciation. From this, he concluded that the age of the mineralization must postdate faulting, the intrusion of a suite of acid dykes, and hydrothermal alteration of the "A" plug "gabbros". He attributed mineralization directly or indirectly to the influence of a granite intrusion, and he concluded that geochemical factors must control the localization of the Ni-Cu ores in the "gabbro" plug.

Milligan (1960) also emphasized the hydrothermal aspects of the "A" plug mineralization and he concluded that "... direct magmatic segregation therefore appears unlikely" (Milligan, 1960, p. 179). He also thought that the orebodies were spatially closely related to faults which both displaced the ore and also somehow acted as a factor in localizing the ore. He too recognized that acid and mafic dykes within faults were mineralized and concluded that mineralization must be an extremely late phenomenon. Emslie and Moore (1961) concluded, from a study of petrographic and geochemical data, that the "A" plug is a deformed layered intrusion which differentiated after emplacement into subhorizontal Wasekwan Group strata. They contended that immiscible sulphide concentrated into pools and disseminations in mineralized norite, above an ultramafic basal cumulate layer, and that the entire stratigraphic section was later rotated to its present structural position. They considered that faulting and hydrothermal alteration were late effects which did no more than remobilize magmatic sulphides.

Macauley (1962) restricted his observations to the "B" orebody. He concluded that the main "A" plug "gabbro" was intruded by minor mafic and ultramafic igneous phases prior to a period of faulting, which was followed by intense hydrothermal alteration and local silicification. He envisaged that magmatic, partially consolidated sulphide then 'intruded the fracture zone and partially diffused into the enveloping "gabbro".

Vellet (1963) concluded that the amphibolitization of the "gabbro" was deuteric and that primary pyroxenes reacted with a wet magma. He noted that the mineralization is largely restricted to vertical pipes and lenses and he attributed much of the brecciation observed in the ore pipes to gas expansion and explosive volcanism above the present level of erosion. He seems to have envisaged that volcanism would reduce the pressure above a feeder pipe and allow pulses of partially consolidated barren, and mineralized, cumulate to intrude the overlying "gabbro".

Much of the Ni-Cu mineralization at Lynn Lake occurs in structurally controlled ore pipes. The pipes are magmatic in origin and the occurrence of disseminated sulphide within anhydrous norite, in the cores of several of the ore pipes, suggests that the mineralization is also magmatic in origin. The ore pipes have clearly been influenced by hydrothermal activity, but the overall homogeneity of the ore indicates that it caused local redistribution rather than extensive mobilization.

Rajamani and Naldrett (1978) indicated that the composition of a magmatic ore is controlled by (a) the composition of the silicate magma and (b) partition coefficients during fractionation. They showed a correlation between the Ni content of the ore and the MgO content of the magma. The Lynn Lake Cu/(Cu + Ni) ratios (0.35, "A" plug average and 0.31 "EL" plug average; Table 2.2) indicate a more magnesian parent than that found associated with the ores at Sudbury (Cu/(Cu + Ni) ratio 0.5; Rajamani and Naldrett, 1978). This is in accord with the Mg-rich nature of the intrusive magmas and cumulates which are found at Lynn Lake. Maalo (1979) suggested that "primary" tholeiite liquids may range in composition from 8-9% MgO to 20% MgO. He concluded that the composition of the magma is porportional to depth of mantle segregation and the degree of partial melting.

The composition of the present magma at Lynn Lake is not known but it must have been significantly enriched in MgO in order to have evolved toward "contact-diorite" (9.26% MgO).

The principal characteristics of the mineralized magma-cumulate assemblage at Lynn Lake are (a) Mg and Al enrichment, (b) tholeiitic differentiation trends and (c) orthopyroxene and plagioclase normative assemblages. Besson (1977) noted that the magmas and cumulates associated with this type of Ni-Cu deposit are characteristically Al-rich and he concluded, from a study of published analyses, that the deposit type is associated with calc-alkaline magmatism. The present study shows tholeiitic Fe enrichment in the sample suite from Lynn Lake.

The "A" and "EL" plug silicate and sulphide magmas and cumulates formed in a magma chamber which structurally underlies their present position in the crust. The magma-cumulate assemblage appears to have been deformed and partially remobilized prior to complete consolidation. The deformation process may have led to assimilation of acid metasediments or metavolcanics. Alternatively, some of the magma may have been contaminated by a granitic fluid as the silicified "gabbros" in the "A" plug appear to have a hybrid composition and granite occurs in veins and segregations. Silica contamination of an Mg-rich olivine tholeiite magma would profoundly affect the crystallization of the magma (Irvine, 1970, 1975a) and contamination may have been instrumental in the early segregation of an immiscible sulphide liquid (Irvine, 1975b). Sulphide segregation occurred during the precipitation and accumulation of orthopyroxene in amphibolite and norite. The "peridotites" and "gabbros" are, for the most part, barren. Irvine (1975a) found that granitic contamination of a basaltic magma would enhance the crystallization of orthopyroxene over olivine and plagioclase, which is consistent with the nature of the cumulate.

Green *et al.* (1967) showed that the orthopyroxene crystallization field increases at the expense of olivine between 4.5 and 9.0 k/bars. They suggest that "High-alumina" basalts would be formed by orthopyroxene fractionation in this pressure range. It seems likely that an Mg-rich tholeiite magma was contaminated by silica, in a magma chamber, within or below this maximum pressure range (15-35 km or less). The magma chamber was subsequently deformed and the sulphide and silicate magmas and the cumulates were intruded into shallower levels in the crust.

Hulbert (1978) studied the Fraser Lake "gabbro" complex and concluded that it was a funnel-shaped cumulate body derived from several pulses of "High-alumina" basalt magma. He deduced that the magma equilibrated at 958° — 1 045°C, on the basis of coexisting pyroxene compositions, and estimated a depth of 3.08 km for the top of the magma chamber, on the basis of the mineralogy of hornfelsed blocks near the chamber roof. This suggests that the "A" and "EL" plug assemblages may have equilibrated in a near-surface, possibly sub-volcanic, environment.

The ore is almost completely homogeneous and the sulphide fractionation appears to have been relatively minor. The ore was probably largely liquid when the sulphide-silicate assemblages were emplaced. The pyrrhotite has exsolved two generations of pentlandite: (a) in stringers and (b) in flames. The ores have been metamorphosed and the two forms of pentlandite may reflect periods of exsolution before and after metamorphism. The ores have also been influenced by hydrothermal fluids. Siliceous felsite veins appear to be hydrothermal in origin and chalcopyrite mobility is probably related to hydrothermal activity.

6.3 EXPLORATION SIGNIFICANCE

The Ni-Cu ores at Lynn Lake are found in structurally controlled pipes of remobilized ultramafic ("peridotite") and mafic (amphibolite, norite) cumulate. The ores are magmatic in origin and they intially segregated and concentrated in a magma chamber prior to vertical injection into the ore pipes. The process of remobilization has influenced the distribution of the ore, and the amount of sulphide is not necessarily proportional to the size of the plug in which it occurs. The "EL" plug is small in size but it contains a large, high-grade orebody.

Although the exact location of a narrow diameter (100 m) ore pipe may be hard to find, the composition of the silicate magma and cumulate assemblage associated with it is diagnostic. Despite metamorphism, it should be possible to identify other "gabbroic" bodies which show a similar pattern of differentiation to that found in the "A" and "EL" plugs. Mafic intrusions that contain Mg-rich "High-alumina gabbros", or norites, have ore potential, particularly if they also contain ultramafic ("peridotite") and mafic (amphibolite, norite) cumulate as evidence of early fractionation.

The pipe structure is essentially unstable and the ore in the "EL" plug was presumably drawn into the pipe with cumulate and magma destined for a higher level structure. This structure, which could be a funnel-shaped intrusion similar to that found at Fraser Lake (Hulbert, 1978), would also have potential for Ni-Cu sulphide.

6.4 REGIONAL SIGNIFICANCE

Pinsent (1977b) subdivided some of the "gabbro" bodies in the Lynn Lake Greenstone Belt on the basis of structure, and apparent presence and absence of differentiation. The intrusions examined, and reported on in 1977, occur at the following localities (Fig. 1.1): (1) Lynn Lake "A" plug; (2) Lynn Lake "EL" plug; (3) Fraser Lake, SE plug; (4) Carr Lake; (5) Fraser Lake, Main Sill; (6) Cartwright Lake; (7) Tulune Lake; (8) Snake Lake; (9) Nickel Lake; (10) Larsen Lake; (11) Tow Lake; (12) Sickle Lake; (13) Black Trout Lake.

The distribution of gabbro in the Lynn Lake Greenstone Belt (Fig. 1.1) is after Milligan (1960), Gilbert (1976), Syme (1976) and Zwanzig (1977), with some modifications.

For the purposes of the present study, the intrusions have been divided into two categories. The categories and their descriptions are taken directly from Pinsent (1977b).

Group I: Differentiated Intrusions
- Ia) Differentiated stocks
  - (1) Lynn Lake "A" plug
  - (2) Lynn Lake "EL" plug
  - (3) Fraser Lake, SE plug
  - (4) Carr Lake plug
- Ib) Differentiated sills
  - (5) Fraser Lake, Main sill
  - (6) Cartwright Lake sill

Group II: Undifferentiated Intrusions
- IIa) Undifferentiated stocks
  - (7) Tulune Lake plug
- IIb) Undifferentiated sills (cont'd.)
  - (8) Snake Lake sill
  - (9) Nickel Lake sill
  - (10) Larsen Lake sill
  - (11) Tow Lake sill
  - (12) Sickle Lake sill
  - (13) Black Trout Lake sill

Ia) Differentiated stocks

The mineralized intrusions (Lynn Lake "A", "EL" and Fraser Lake, SE plug) consist of vertical, composite gabbro plutons, elliptical in section, which have intruded with minor discordance into the Wasekwan Group. Characteristically, the principal rock type is a uralitized gabbro (2-5 mm grain size). The pluton is sheared adjacent to the country rock contact, but is otherwise largely undeformed. Pulses of (a) Ni-Cu mineralized norite, (b) peridotite and (c) diorite have intruded the gabbro within structurally controlled pipes. The pipe margins have undergone intense hydrothermal alteration which includes uralitization, silicification and chloritization. Diabase dykes pre-date the pipes, which were subsequently cut by dykes of diabase and quartz-feldspar porphyry.

The Carr Lake mafic plug appears to be a vertical stock surrounded by acid to intermediate intrusions. It consists mainly of an undeformed, coarse (5 mm — 1 cm grain size) feldspathic gabbro or norite with a pronounced feldspar lamination, similar to that displayed by the gabbro in Ib (below). The plug also contains a fine grained (2 mm grain size) norite facies found in the Cartwright Lake intrusion, (Ib, below), and a gabbro of normal texture. The Carr Lake plug is cut by dykes (10 — 20 cm wide) of aphanitic diabase and aplitic granite.

Although the Carr Lake intrusion and a noritic phase of the Fraser Lake SE plug contain rare traces of mineralization, neither pluton appears to display the extensive mineralization found in the "A" and "EL" plugs.

Ib) Differentiated sills

The two differentiated sills at Fraser Lake and Cartwright Lake consist of undeformed and undifferentiated gabbro (1-3 mm grain size) with weak to strong feldspar lamination, overlain by a more feldspathic, noritic unit (1-6 mm grain size), which displays feldspar lamination and compositional banding. The noritic unit includes coarse (5-10 mm) feldspar- and orthopyroxene-rich cumulate layers which very locally contain olivine. A 15 m wide gossan zone in norite near the inferred top of the main sill in the Cartwright Lake intrusion is caused by abundant magnetite.

The Cartwright Lake intrusion appears to be a sill complex which is concordant with the local stratigraphy but discordant in terms of regional structure (Syme, 1976). Although the detailed structure has yet to be resolved, the complex appears to consist of a 700 m wide differentiated intrusion and a suite of related but less differentiated sills, 10-50 m wide. The complex is partially truncated by a younger diorite.

The main body of the Fraser Lake gabbro has been studied in detail by Emslie and Moore (1961) and Hulbert (1978). It consists of a laterally compressed, funnel-shaped, layered intrusion situated in the nose of a major syncline (Gilbert, 1976). The fold axis has been exploited by intrusions ranging from gabbro to granite in composition. The layered intrusion is truncated by diorite which intruded the interface between the gabbro and the country-rock volcanics.

IIa) Undifferentiated stocks

The Tulune plug is a discordant vertical plug, possessing the same weak tectonic fabric as the neighbouring volcanics. It consists of weakly layered, amphibolitized metagabbro (5 mm — 1 cm grain size) cut by 20 cm — 1 m wide dykes of fine grained (2 mm) metadiabase and aplitic granite. The age of the diorite adjacent to the gabbro is uncertain, although Milligan (1960) indicates that it is cut by gabbro dykes.

IIb) Undifferentiated sills

The gabbro sills appear to be stratigraphically concordant but structurally deformed. They are more or less recrystallized and textures range from igneous to metamorphic. The principal rock types range from a uniform sub-ophitic metadiabase (1-3 mm grain size) to a schistose amphibolite (2-4 mm grain size). The schistosity, which may be either penetrative or restricted to shear zones within the intrusion, is commonly concordant to the sill contact; it appears to be discordant in the vicinity of younger fold axes (Zwanzig, pers. comm.). The sills show little evidence of multiple-phase intrusion. They are cut by rare dykes of finer grained metadiabase and more abundant dykes of seemingly unrelated granitic rock. The Tow Lake intrusion was studied in detail by Hunter (1958), who divided the body into three parts but found little evidence for mafic differentiation through crystal settling.

The Black Trout Lake gabbro is anomalous in this group, as it consists of weakly deformed, uralitized, amphibole-phyric (2-6 mm grain size) metadiabase. Its relationship to the Sickle Lake metadiabase is not known.

The differentiated plugs and sills have several features in common. They are relatively undeformed and, although extensively uralitized, they all contain (or are inferred to contain) fresh norite. In most cases they are known to contain mafic to ultramafic cumulates which occur as intrusions in the pipes and layers in the sills. As the plugs and the sills both consist of early gabbro followed by later norite, it is conceivable that the layered sills represent collection chambers structurally above the plugs. To date, however, mineralization has not been found in the sills, and a source for the sulphide and silicate differentiates of the pipes has yet to be identified.

The undifferentiated sills and stocks are more highly deformed than those that are differentiated, and may be older. They are considered to be sub-volcanic intrusions related directly to the Waskwan mafic volcanism. The original intrusions appear to have been more gabbroic than noritic in composition, although Hunter (1958) has shown that much of the Tow Lake intrusion consists of hypersthene-rich gabbro. Despite considerable exploration of these intrusives, no significant sulphides have so far been found within them.

ACKNOWLEDGEMENTS

The writer wishes to thank Sherritt Gordon Mines Limited for access to the Farley Mine and to data relevant to the Lynn Lake Ni-Cu Deposit Study. The assistance of A. deCarie, J. Langelaar and P. Pawliw in the compilation and interpretation of mine data are specifically recognized. A deCarie, J. Langelaar, O.R. Eckstrand and W.D. McRitchie kindly reviewed the manuscript, which was ably prepared by Debbie S. Navitka and B. Thakrar.

The writer also acknowledges the contributions made by the following employees of the Manitoba Department of Mines, Natural Resources and Environment: R. Nembhard, J. Weitzel and W. Lipinsky in the production of wholerock analytical data; H. Ambach in the computer analysis of the data; U. Fraser and C. Sandy in the final production of plates and figures. A. Asham et al. provided thin sections for the study, and detailed optical studies were carried out by J. Peters. J.D. Scott at the Canada Centre for Mineral and Energy Technology in Ottawa provided electron microprobe analyses in support of the study.

The writer thanks P. Theyer, O.R. Eckstrand, H.P. Gilbert, E.C. Syme and other members of both the Manitoba Department of Energy and Mines and the Canada Department of Energy, Mines and Resources for many useful discussions on the subject of the Lynn Lake Ni-Cu deposits.

REFERENCES

Allan, J.D.
1948: Geological Studies of the Lynn Lake Area, Northern Manitoba; *Massachusetts Institute of Technology,* Ph.D. Thesis (unpublished).
1950: The Lynn Lake Nickel Area, Manitoba; *Canadian Institute of Mining and Metallurgy,* Transactions, V.53, pp. 343-348.

Arnold, R.G. and Malik, O.P.
1974: Violarite in some Nickel Ores from Lynn Lake and Thompson, Manitoba, and Sudbury, Ontario, Canada; *Canadian Mineralogist,* V.12, pp. 320-326.

Bateman, J.D.
1942: Geology and Metamorphism in the McVeigh Lake Area, Northern Manitoba; *American Journal of Science,* V.240, pp. 789-808.

Besson, M.
1977: Le Volcanisme Associe aux Gisements Sulfures de Nickel; *Bulletin du B.R.G.M.,* Section II, No.3, pp. 183-207.

Campbell, F.H.A.
1969: Sickle-Wasekwan Contact, Granville Lake; **in** Summary of Geological Fieldwork 1969; *Manitoba Mines Branch,* Geological Paper 4/69.
1972: Stratigraphic and Structural Studies in the Granville Lake-Lynn Lake Region; *Manitoba Mines Branch,* Publication 71-2A.

Dorian, N.
1950: A study of the Sulphides and Oxides of the Nickel-Copper Deposits of Lynn Lake, Manitoba; *University of Manitoba,* M.Sc. Thesis (unpublished).

Emslie, R.R. and Moore, J.M.
1961: Geological Studies of the area between Lynn Lake and Fraser Lake; *Manitoba Mines Branch,* Publication 59-4.

Gilbert, H.P.
1976: Lynn Lake Area (Arbour Lake); **in** Report of Field Activities 1976; *Manitoba Mineral Resources Division.*
1977: Lynn Lake Area (Arbour Lake Project); **in** Report of Field Activities 1977; *Manitoba Mineral Resources Division.*
1978: Lynn Lake Project (Arbour Lake); **in** Report of Field Activities 1978; *Manitoba Mineral Resources Division.*

Green, T.H., Green, D.H. and Ringwood, A.E.
1967: The Origin of High-alumina Basalts and their Relationships to Quartz Tholeiites and Alkali

Basalts; *Earth and Planetary Science Letters,* V.2, pp. 41-51.

Hulbert, L.J.
1978: Geology of the Fraser Lake Gabbro Complex, Manitoba; *University of Regina,* M.Sc. Thesis (unpublished).

Hunter, H.E.
1950: Geological Investigations of the Lynn Lake Basic Intrusive Body, Northern Manitoba; *University of Manitoba,* M.Sc. Thesis (unpublished).
1958: A study of the Tow Lake Gabbro; *Manitoba Mines Branch,* Publication 53-5.

Irvine, T.N.
1970: Crystallization Sequences in the Muskox Intrusion and other Layered Intrusions; *Geological Society of South Africa,* Special Publication 1, pp. 441-476.
1975a: The Silica Immiscibility Effect in Magmas; *Carnegie Institute,* Washington, Annual Report 1974/75, pp. 484-500.
1975b: Crystallization Sequences in the Muskox Intrusion and other Layered Intrusions — II, Origin of Chromite Layers and Similar Deposits of other Magmatic Ores; *Geochimica et Cosmochimica Acta.,* V.39, pp.991-1020.

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, pp. 523-548.

Maalo, S.
1979: Compositional Range of Primary Tholeiitic Magmas from Major-Element Trends; *Lithos,* V.12, pp. 59-72.

Macauley, T.N.
1962: Geology of the Sherritt Gordon "B" Orebody, Lynn Lake, Manitoba; *Michigan College of Mining and Technology,* M.Sc. Thesis (unpublished).

McRitchie, W.D.
1974: The Sickle-Wasekwan Debate: A Review; *Manitoba Mines Branch,* Publication 1/74.

Milligan, G.C.
1960: Geology of the Lynn Lake District; *Manitoba Mines Branch,* Publication 57-1.

Misra, K.C. and Fleet, M.E.
1973: The Chemical Compositions of Synthetic and Natural Pentlandite Assemblages; *Economic Geology,* V.68, pp. 518-539.

Nickel, E.H., Ross, J.R. and Thornber, M.R.
1974: The Supergene Alteration of Pyrrhotite-Pentlandite Ore at Kambalda, Western Australia; *Economic Geology,* V.69, pp. 93-107.

Pearce, T.H.
1970: Chemical Variations in the Palisades Sill; *Journal of Petrology,* V.11, Pt. I, pp. 15-32.

Pinsent, R.H.
1977a: The Lynn Lake Ni-Cu Deposits; **in** Non-Renewable Resource Evaluation Program, Second Annual Report, 1976/77; *Manitoba Mineral Resources Division,* Open File Report 77/1.
1977b: The Lynn Lake Ni-Cu Deposits; **in** Report of Field Activities 1977; *Manitoba Mineral Resources Division.*

Rajamani, V. and Naldrett, A.J.
1978: Partitioning of Fe, Co, Ni, Cu, between Sulphide Liquid and Basaltic Melts and Composition of Ni-Cu Sulphide Deposits; *Economic Geology,* V.73, pp.82-93.

Roy, B.H. and Haugh, I.
1971: Geology: Lynn Lake-Southern Indian Lake Area; **in** Field Excursion A31-C31 Guidebook, *24th International Geological Congress* (Montreal).

Ruttan, G.D.
1955: Geology of Lynn Lake; *Canadian Institute of Mining and Metallurgy* Bulletin, V.48, pp. 339-348; V.II.

Scott, J.D.
1977: Ore Mineralogy (Farley Mine); **in** Non-Renewable Resource Evaluation Program, Second Annual Report, 1976/77; *Manitoba Mineral Resources Division,* Open File Report 77/1.

Syme, E.C.
1976: Geology of the Southern Lynn Lake Greenstone Belt; **in** Report of Field Activities 1976; *Manitoba Mineral Resources Division.*
1977: Sickle Lake-Hughes Lake Area; **in** Report of Field Activities 1977; *Manitoba Mineral Resources Division.*

Vellet, V.
1963: Geology of the Lynn Lake Ni-Cu Deposits; *Sherritt Gordon Mines Limited,* Company Report (unpublished).

Zwanzig, H.V.
1976: Lynn Lake Project; **in** Report of Field Activities 1976; *Manitoba Mineral Resources Division.*
1977: Geology of the Fox Mine Area; **in** Report of Field Activities 1977; *Manitoba Mineral Resources Division.*

APPENDIX I

A.1.1 EXPLORATION AND DEVELOPMENT HISTORY

Austin McVeigh located mineralization associated with the "A" orebody, in outcrop, while prospecting for the source of Ni-Cu mineralized float, in the vicinity of Lynn Lake, in September, 1941. Sherritt Gordon Mines Limited staked the "ELB" Group of 353 contiguous claims over the mineralization in 1945 and, following geophysical prospecting of the area, they located the exact position of the "A" orebody by diamond drilling. The company decided to sink the "A" shaft, adjacent to the "A" orebody, in 1947 following the discovery of the high-grade "EL" orebody. By 1952 development drilling, and the drilling of surface magnetic anomalies, had located the "B", "C", "E", "F" and "G" orebodies. At this time the Company had outlined over 14 million tons of ore, averaging 1.223% Ni and 0.618% Cu. (Sherritt Gordon Mines Limited Annual Report 1952).

Work on the "EL" Shaft got underway in 1952 and by 1954 both the "A" mine and the "EL" mine were in full production. Although the Farley Shaft was collared in 1955, it did not go into production until 1961. During the intervening years the bulk of the mill-feed came from the "A", "C", "E" and "EL" orebodies. The Company undertook an extensive underground exploratory drilling program on the 800', 950' (12th level "A" Mine) and the 2000' levels in the Farley Mine and by 1961 they had also identified the "D", "J", "K" and "N" orebodies, and the subeconomic "H" zone. The Company drove a drift down the axis of the "A" plug on the 2000' level linking the two mines and extended it towards the "EL" plug. Exploratory drilling below the "EL" shaft showed that the mineralization at depth was subeconomic and the "EL" Mine was closed in 1963.

From the onset of the production in the Farley Mine in 1961, to the closure of the "A" Mine in 1969, the centre of activity gradually shifted towards the Farley Shaft and to deeper levels in the "A" plug. The Farley Shaft was deepened to the 3,450' level in 1962 and exploratory drilling was carried out from a drift on the 3000' level. In 1964 the company sunk a winze (No.1 Winze) from the 2000' to the 3000' levels to allow access to the Lower "D" orebody at the north end of the "A" plug and they began mining the Upper "E" orebody. The main production meanwhile continued to come from the"B" and "K" orebodies, adjacent to the Farley Shaft, in the middle of the "A" plug. In 1965 a second winze (No. 2 Winze) was sunk to allow access to the "N" orebody, at the south end of the "A" plug, between the 2000' and 3000' levels, and a major exploratory drilling program was carried out on the "O" orebody.

The "A" Mine was closed in 1969 and production shifted to the lower "B-K" zone, between the "B" and "K" orebodies, and the "N" orebody above the 3000' level. The Farley Shaft was deepened to 3600' level in 1970 and in 1971 a decline was driven to the foot of the "O" orebody on the 3700' level.

Between 1972 and the closure of the Farley Mine in 1976 the Company switched from blast-hole stoping to the more selective cut-and-fill method of ore production. The Upper "O" orebody, which was accessed by a service raise, the "P" orebody on the 3000' level and the lowermost "B-K" ore zone were mined out by 1974, and production had started from the Lower "O" orebody (below 3000' level) and the "N" orebody between the 2000' and 3000' levels.

Some of the orebodies extend to surface and open-pit production from the "A" and "EL" orebodies (1960), the "E" orebody (1963) and the "B" orebody (1966) also contributed to the mill-feed.

For a more detailed account of the development of the Ni-Cu deposits at Lynn Lake the reader is referred to the Manitoba Mineral Inventory cards produced under Project No. NM 7502 during the Non-renewable Resource Evaluation Program (NREP) 1975-1979 (Bamburak, in press).

A.1.2 "A" PLUG GEOLOGY AND STRUCTURE

a) INTRODUCTION

The "A" Plug, which hosts the "A", "B", "C", "D", "E-J", "F-K", "G", "M-N", "O", and "P" Ni-Cu orebodies at Lynn Lake, is a near-vertical composite igneous pluton (3.0 km x 1.5 km). The pluton has intruded Wasekwan Group metasediments and metavolcanics with minor discordance and it is elongated parallel to the regional structural trend of the greenstones (NE-SW). The plug is located (Fig. A.1.1) at the interface between a thick unit of brecciated and massive flow rhyolite and a unit of interlayered tuffs and (porphyritic and aphyric) mafic to intermediate flows and breccias (Gilbert, 1977). The plug contact is, for most part, sheared and the south end of the "A" plug has been cut by the Lynn Lake fault. This fault, which strikes N (true) 45°W and dips 50° NE (Fig. A.1.1), is known to cut diorites and tonalites southeast of the "A" plug. Outcrop over the "A" plug is sporadic, and almost totally restricted to the eastern half of the plug. The western half is covered by thick blanket of overburden and it was originally covered by the east arm of Lynn Lake. In 1965 Sherritt Gordon drained the east arm of the lake, in order to access the top of the "B" orebody. With the exception of the "discovery outcrop", which is located near the crusher house adjacent to the "A" shaft, the Company covered over any outcrop created by open pit mining of "A" and "E" orebodies, and much of the outcrop at the north end of the "A" plug has been covered over by tailings. The surface geology (Fig. A.1.1) is an interpretation based on geophysical data, geological mapping and diamond drill core data compiled by Sherritt Gordon Mines Limited; and personal observation.

Sherritt Gordon systematically drilled the "A" plug on the 12th level (950' level) in the "A" Mine and the 800', 2000' and 3000' levels in the Farley Mine. (Fig. A.1.2, A.1.3, A.1.4, A.1.5), and the following description of the plug is based on an interpretation of the data contained in these plans, and in the detailed orebody descriptions.

b) PETROLOGY

The figures show that the geology of the "A" plug is complex and that the orebodies occur in the west half of the plug, in association with the more mafic to ultramafic ("gabbro", amphibolite, "peridotite") rock types. Mafic to intermediate ("gabbro", diorite) rocks found in the eastern half of the plug appear to be barren. Figures 2.2 and 2.1 show that the orebodies are near-vertical pipes and lenses which (excluding the "D" orebody) project to surface in a belt essentially parallel to the western contact of the "A" plug with Wasekwan country rock. The orebodies occur in three main centres: (1) the "A", "C", "D" and "E-J" orebodies cluster in the vicinity of the "A" shaft at the north end of the plug, (2) the "B" "F-K" and "B-K" ore zones lie west of the Farley Shaft and (3) the "O", "P" and "M-N" orebodies occur near the south end of the IIA" plug.

The "A" plug consists of an assemblage of intermixed amphibolite and "gabbro". which contains irregular bodies of "peridotite", mottled "gabbro" quartz-biotite diorite, fine grained quartz-hornblende-diorite (Q.H.D.) and mineralized rock types associated with discrete ore pipes. According to Hunter (1950), "gabbro" intrudes amphibolite on the 12th level, near the "A" shaft, but, in most instances, the relations between the two are unknown. The "gabbro" is locally layered subparallel to the western contact of the "A" plug with Wasekwan country rock and Vellet (1963) subdivided the "gabbro" into foliated, feldspathic and normal varieties. The proportions of amphibolite and "gabbro" vary from west to east across the plug and from level to level in the plug. The relations are commonly obscured by extensive block faulting.

The "gabbro"-amphibolite assemblage at the north end of the "A" plug is cut by two large bodies of Q.H.D. The western body is a highly irregular vertical mass, variously described as being an inclusion (Emslie and Moore, 1961) or a fine grained, metamorphosed, mafic to intermediate intrusion (Vellet, 1963). The Q.H.D. body, which has been fault disrupted, has apophyses which resemble dykes on the 12th level (Fig. A.1.2) and it extends from surface (Fig. 1.1) down to the 3000' level (Fig. 1.5). The "A" and "C" orebodies both occur on the periphery of the western Q.H.D. mass and, according to Vellet (1963), they cease to be mineable entities where the plunge of the orebearing structure diverges from that of the Q.H.D. body. The emplacement of "C" orebody post dates emplacement of the Q.H.D. mass. The age of the "A" orebody is uncertain.

The eastern Q.H.D. body consists of several partially fused lenses which occur in the "gabbro" subparallel to the eastern contact of the plug. The Q.H.D., which may also be either dyke or country rock inclusion material, is known to extend from the 2000' (Fig. A.1.4) to the 3000' (Fig. A.1.5) levels. There are no known orebodies associated with this Q.H.D. mass.

A major (100 m wide) Q.H.D. dyke complex intrudes "A" plug "gabbros" to the west of the Farley Shaft. The dyke, which appears to be exploiting a major ("B-K") shear zone, in the plug, can be traced as a continuous entity from the 12th level (Fig. A.1.2) to well below the 3000' level (Fig. A.1.5). The dyke extends from the "A" plug — country-rock contact as far south as the "B", "F-K", "B-K" ore zones and, at depth, the lower "K" orebody consists of a sulphide breccia lens within one branch of the Q.H.D. dyke (Fig. A.1.4). The Q.H.D. dyke, the lenses of mineralization and the shear zone all strike NW and dip steeply to the NE. The spatial association between the Q.H.D. dyke complex and the mineralization is maintained above the 2000' level. The upper "K" and "F" ore lenses occur in embayments between two branches of the dyke.

Although amphibolite and "peridotite" are not always differentiated in the mine plans, there would appear to be two "peridotite" bodies in the north end of the "A" plug. One consists of an irregular lens which lies subparallel to the western ("A" plug — country rock) contact of the plug between the contact and the western Q.H.D. mass (Fig. A.1.4). This "peridotite'; body appears to plunge to the east, under the western Q.H.D. mass and also under the "A" and "C" orebodies. Fragments of inferred "peridotite" composition are recorded in both orebodies (Vellet, 1963). The same "peridotite" body structurally overlies the "E-J" orebody south of the "A" shaft (Fig. A.1.2).

The eastern "peridotite" lens occurs towards the centre of the "A" plug northeast of the "A" shaft. The lens, which strikes N 20° E and dips 75°NW, structurally underlies the upper and lower "D" orebodies. The amphibolite "peridotite" lens is known to extend from 12th level (Fig. A.1.2) to the 3000' level. (Fig. A.1.5). It structurally overlies compositionally banded, medium grained, "A" plug "gabbros" and it underlies foliated, fine grained and locally silicified diorites or "gabbros" which host the "D" orebody. Although the data are limited, a break in the surface outline of the "A" plug on strike with the "peridotite" and the difference in plug outline at depth (Fig. A.1.4) may indicate early faulting and structural control of the emplacement of the "peridotite" body.

A large mass of "peridotite" outlined by a ground magnetometer survey (Fig. A.1.1) has been traced across the Lynn Lake fault down to, and below, the 3000' level (Fig. A.1.5). Near surface, the "peridotite" occurs as a lens which strikes NW, parallel to the "B-K" shear zone, but at depth it occurs as a large intrusive plug cored by small amounts of dunite. The limits of "peridotite" and amphibolite distribution should be treated with caution, as intense alteration may have amphibolitized large amounts of "peridotite" and the small patches parallel to the shear zone may have been more extensive. A separate "peridotite" lens occurs to the east of the "N" ore pipe on the 2000' (Fig. A.1.4) and 3000' (Fig. A.1.5) levels. This lens, which appears to be truncated against Wasekwan country rock at the south end of the "A" plug, dips steeply to the west and it appears to cut-out the "N" ore pipe immediately above the "O" fault, at a depth of approximately 1300 m. A discrete "peridotite" lens also intrudes the country rock immediately to the south of the "A" plug (Fig. A.1.4).

Vellet (1963) noted that there was a distinct body of quartz-biotite diorite between the main "peridotite" mass west of the Farley Shaft on the 2000' level (Fig. A.1.4) and the Lynn Lake fault. This unit is inferred to extend from the 800' level (Fig. A.1.3) to the 3000' level (Fig. A.1.5). In addition, he defined a lens of mottled "gabbro" which occurs in the "B-K" shear zone, between the "B", "F-K" and "B-K" mineralization and the footwall "peridotite" (Fig. A.1.4). The extent of this unit is not known.

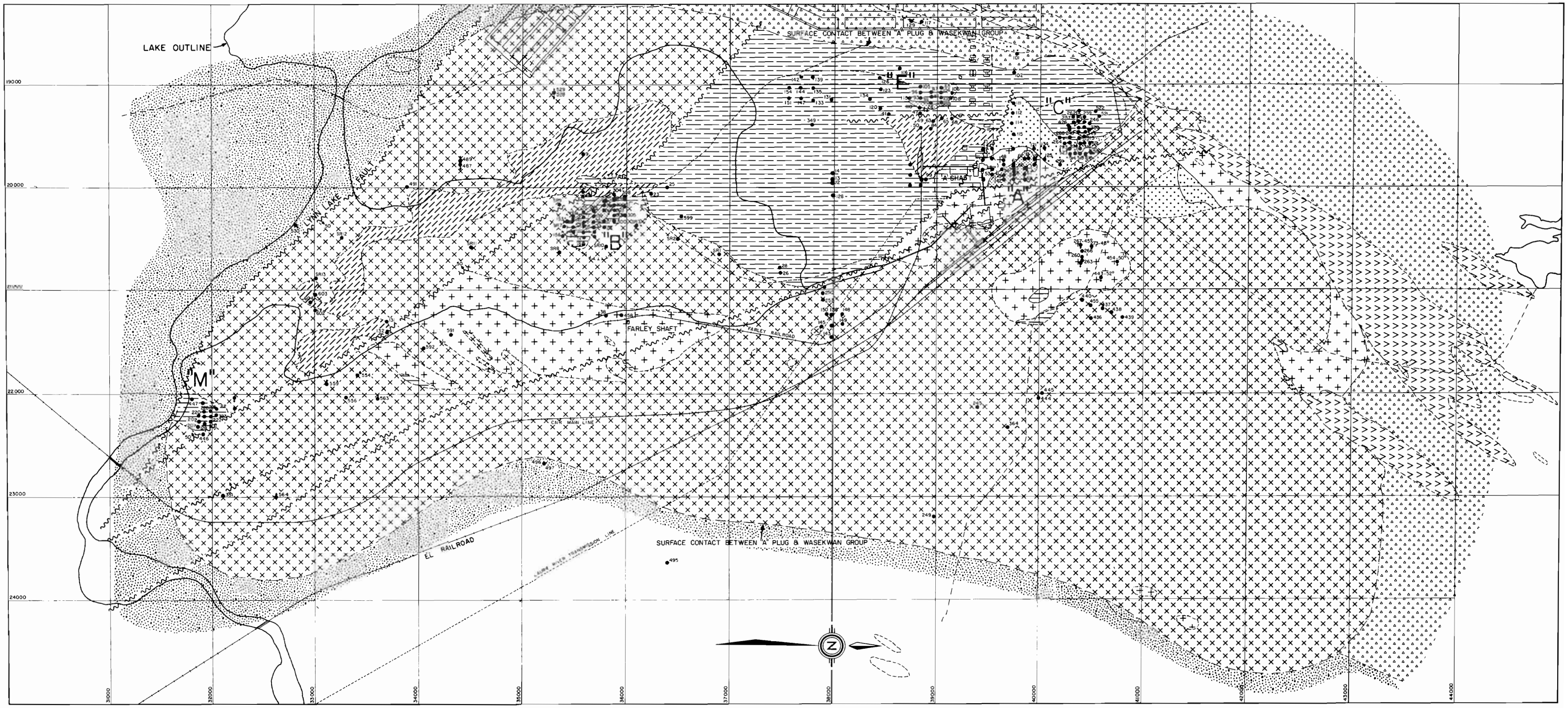
c) STRUCTURE

The "O" and "N" orebodies, which occur in near-vertical ore pipes intruded into amphibolites and "gabbros" at the south end of the plug, are disrupted and offset by movements on two major reverse faults. The Lynn Lake fault (Griffith Shear) and the "O" fault strike NW and dip at a moderate to steep angle to the NE. Reverse movement on the lower, "O", fault has caused sections of the "O" and "N" ore pipes to be thrust southwest over Wasekwan country rock below the 3500' level. The footwall extension of the two ore pipes in the "A" plug below the fault, were not located. A similar sense of movement on the upper, Lynn Lake, fault also thrust near-surface portions of the "O" and "N" ore pipes to the southwest over Wasekwan country rock. The mineable portions of each occur between the two faults which cut the ore pipes on the 1600' and 3500' levels. Although neither ore pipe was identified in the fault-gap on the 800' level (Fig. A.1.3), mineralization was encountered in the "M" zone between the surface and the Lynn Lake fault on the 500' level at the south end of the "A" plug. If the "M" zone is the hanging wall extension of the "N" ore pipe, the net slip on the Lynn Lake fault must be in the order of 570 m. The hanging wall extension of the "O" ore pipe was not located. Either the pipe was missed by surface drilling under the east arm of Lynn Lake, or the mineralized zone was thrust sufficiently far to the southwest that it was elevated above the present level of erosion.

The Lynn Lake fault defines the southwest contact of the "A" plug on surface (Figs. 1.2 and A.1.1). However, although it has a moderate (45° — 50°) dip to the NE from surface down to the 1600' level, there is no evidence to indicate that it intersects or truncates the "B", "K" and "B-K" ore zones. The fault cuts the "peridotite" body, which defines the footwall of the central block, below the 800' level (Fig. A.1.3), and it presumably steepens into the plane of the shear and underlies the Q.H.D. body which hosts the"B", "K" and "B-K" ore lenses below the 2000' level. The "O" fault also dips to the NE under the "B", "K" and "B-K" ore zones but it has not been traced to depth.

At the north end of the "A" plug, movements on the footwall "A" fault, which strikes west of north and dips to the east, has pushed the "A" orebody westward, structurally over a "peridotite" body on the 15th — 18th levels in the "A" mine. A similar sense of movement on the related "contact 'C'" fault defines the base of the "C" orebody on the 14th level, and it may also off-set the "E" ore lens from the "J" ore lens above and below the 12th level (Fig. A.1.2). According to Vellet (1963), the "contact 'C'" and the "E-J" faults may be the same. Movement on the "E-J" fault has thrust "peridotite" westward over the "J" ore lens. Easterly dipping reverse faults appear to be few in number but they characteristically show appreciable movement. Westerly dipping, imbricate, reverse faults are more abundant but they cause minor deformation and little dislocation of individual orebodies.

The orebody descriptions show that the westerly dipping faults strike anywhere from NW to NE and they dip moderately to steeply to the west. All the orebodies appear to be affected by the faulting,



LEGEND

Wasekwan Group

- Arkosic wacke, rhyolite breccia and quartz-plagioclase porphyry
- Pyroclastic, tuff, volcanic breccia and recrystallized volcanic rock
- Tuff with interbedded sediment

"A" Plug

- "Peridotite" with minor amphibolite
- Amphibolite with minor "Gabbro"
- Undifferentiated "Gabbro" and diorite
- Diorite with minor "Gabbro"

"A" Plug

- Quartz-hornblende diorite
- Quartz-feldspar porphyry
- Ore

FIGURE A1.1: Geological plan of the "A" plug, surface

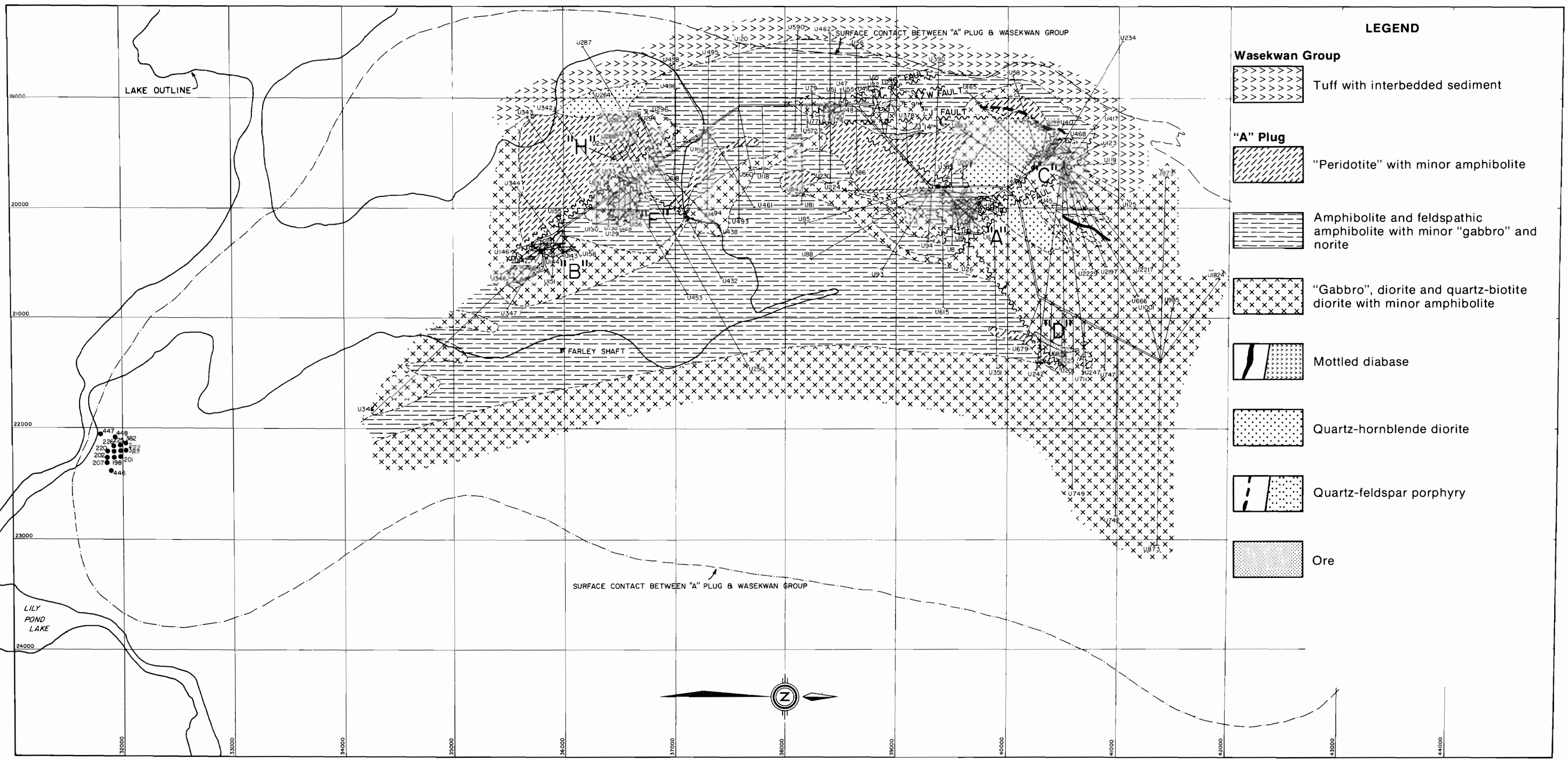


FIGURE A1.2: *Geological plan of the "A" plug, North end; 950' level*

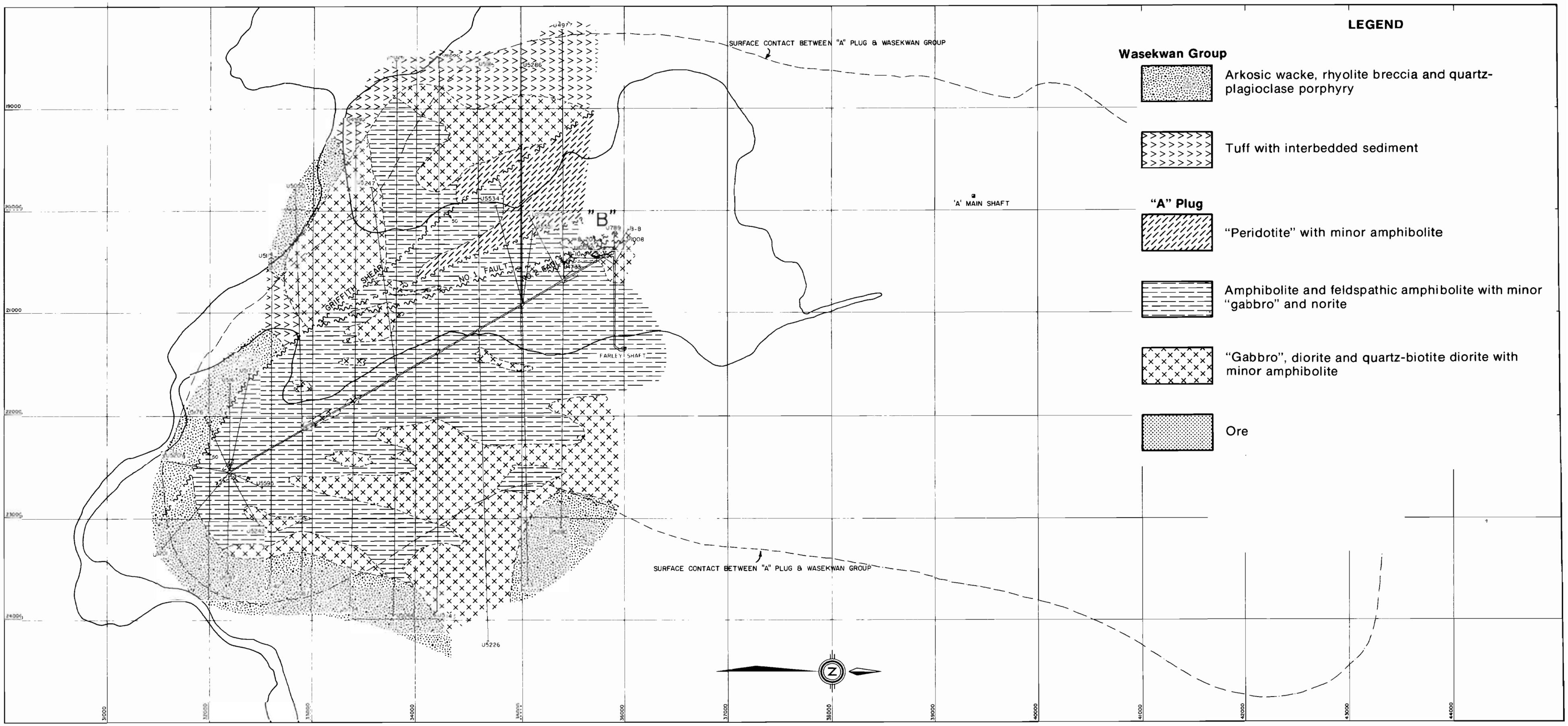


FIGURE A1.3: Geological plan of the "A" plug, South end; 800' level

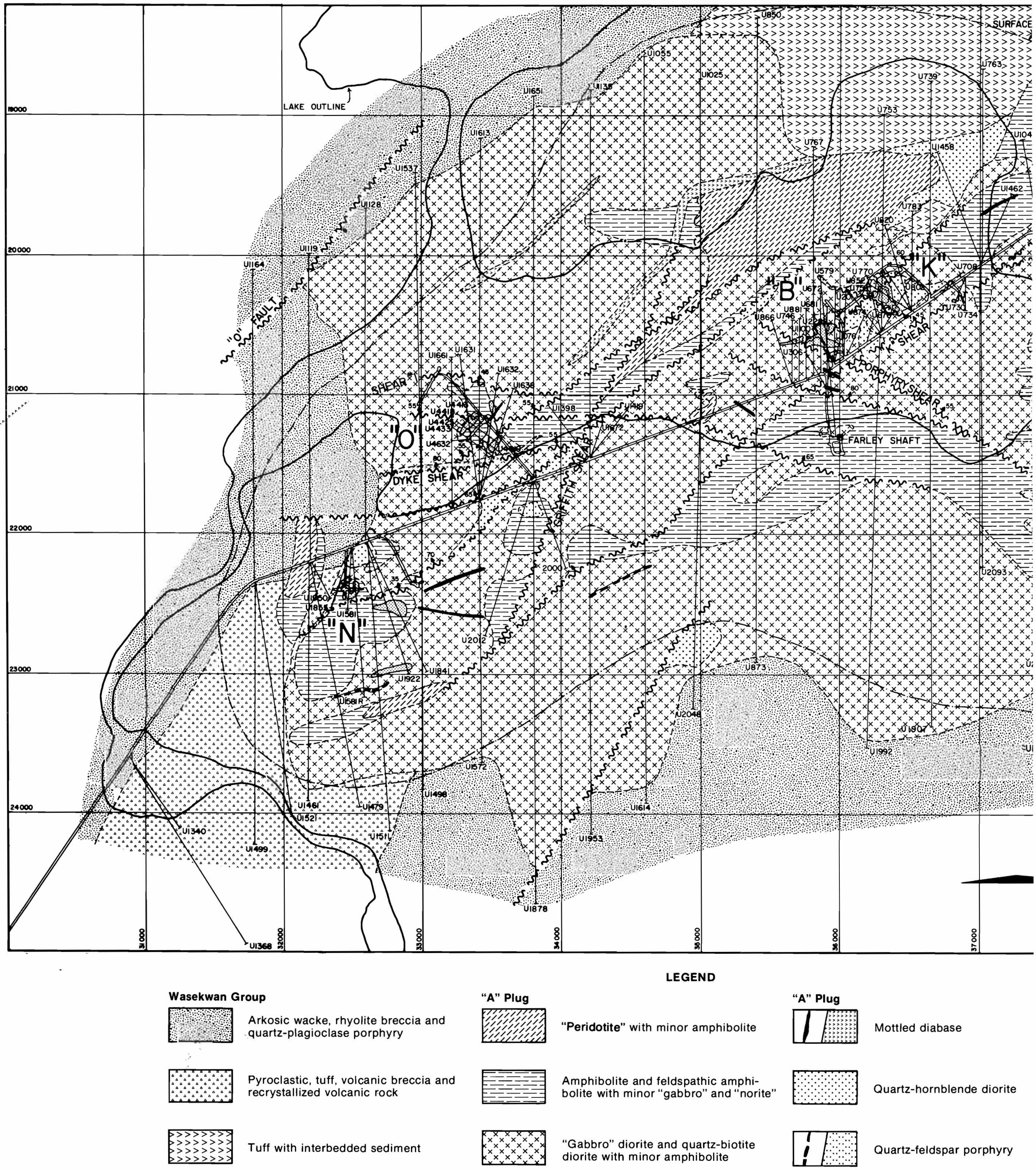
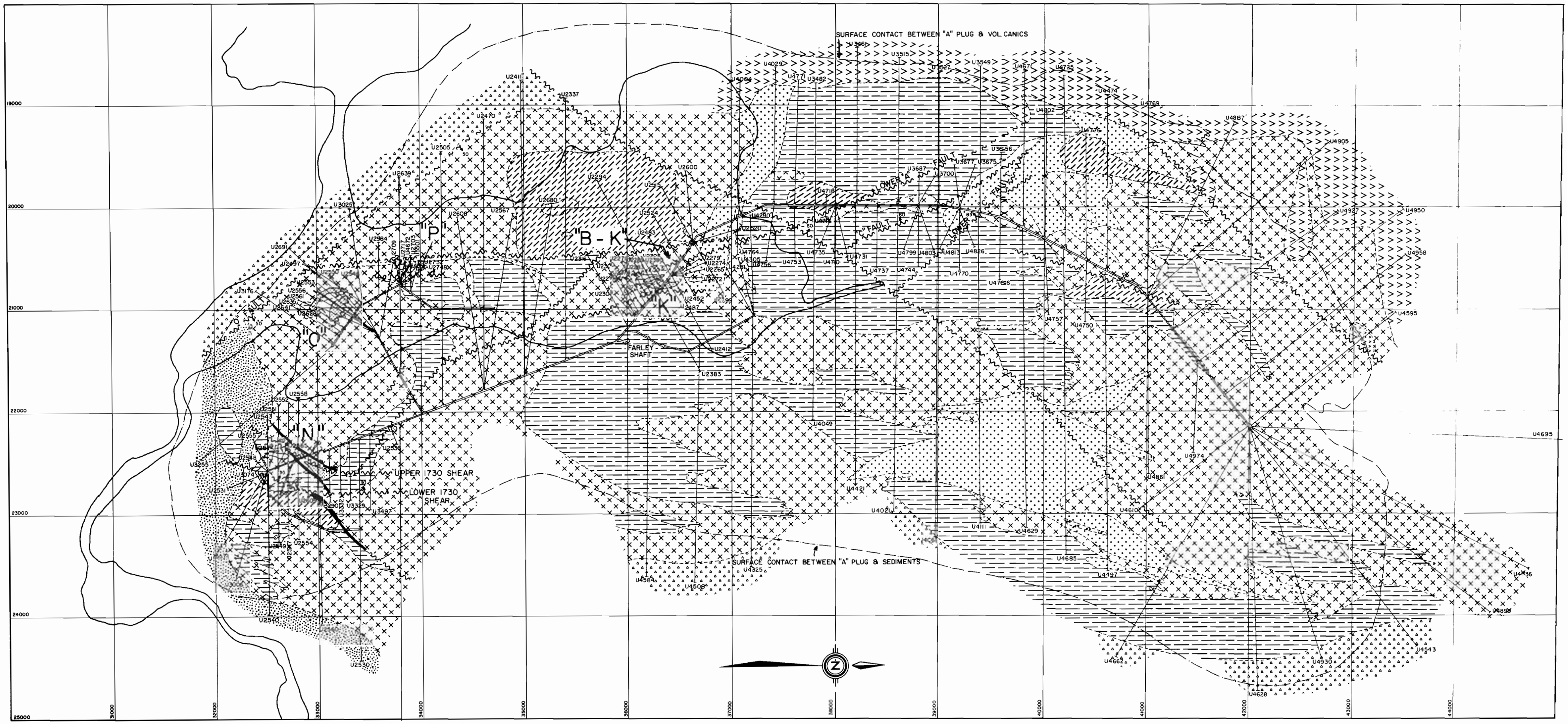


FIGURE A1.4: Geological plan of the "A" plug, 2000′ level

A complete version of Figure A1.4 is included at the end of this file.



LEGEND

Wasekwan Group

- Arkosic wacke, rhyolite breccia and quartz-plagioclase porphyry
- Pyroclastic, tuff, volcanic breccia and recrystallized volcanic rock
- Tuff with interbedded sediment

"A" Plug

- "Peridotite" with minor amphibolite
- Amphibolite and feldspathic amphibolite with minor "gabbro" and "norite"
- "Gabbro" diorite and quartz-biotite diorite with minor amphibolite
- Mottled diabase

"A" Plug

- Quartz-hornblende diorite
- Quartz-feldspar porphyry
- Ore

FIGURE A1.5: Geological plan of the "A" plug, 3000' level which is particularly intense adjacent to bodies of "peridotite" and Q.H.D. Fault movement has caused successively higher sections of the "A", "C", "E" and "J" orebodies to be thrust to the east and this has caused steepening of easterly plunging ore pipes and lenses. Many of the faults have been the locus of intrusion of quartz feldspar prophyry (Q.F.P.) and diabase dykes, ("porphyry" shear, "B", 2100' level and "dyke" shear, "O" 2800' level) and some appear to have localized sulphide mineralization. Massive sulphide veins in the Lower "O" orebody (Pinsent, 1977) and sulphide breccia lenses in the Upper "D", Upper "O" and the "B" orebodies are clearly structurally controlled.

The age of the faulting is uncertain and it probably continued throughout the evolution of the plug. With the possible exceptions of the "B-K" shear west of the Farley Shaft and the "D" "peridotite" structure, all the known faults post-date the onset of mineralization. However, deformation occurred in the ore pipes (eg: "O") prior to emplacement of structurally controlled, sulphide-cemented breccias and massive sulphide veins. The easterly dipping faults may pre-date those with a westerly dip, but relations are uncertain for all but the Footwall "A" fault, which pre-dates movement on the Lower "A" fault.

Mafic dykes, which occupy the faults, are metamorphosed and the principal period of deformation is inferred to pre-date final, metamorphic equilibration.

A.1.3 "A" PLUG OREBODIES:

INTRODUCTION

The "A" plug contains ten economic ore zones: "A", "B", "C", "D", (Upper and Lower) "E-J', "F-K", "G", "M-N", "O" and "P", and several areas of subeconomic mineralization. The "M", Lower "N", Lower "D", Upper "G" and "H" ore zones were subeconomic at the time of mine closure and remain either undeveloped or selectively mined. There are no mineralized zones designated "L" or "I" in the "A" plug.

"A" OREBODY

The "A" orebody is located 92 m NE of the "A" shaft in the NW sector of the "A" plug (Fig. 2.1). The orebody extends from surface to the 2000' level as a mineable entity (Fig. 2.2) and it was accessed from all levels between 1st and 23rd, from the 14th Diesel Haulage level and from the Farley Mine 2000' level (Fig. A.1.6). The "A" orebody consists of disseminated sulphide mineralization concentrated into ore grade lenses within a faulted pipe of amphibolite, adjacent to a large mass of quartz-hornblende diorite (Q.H.D.).

The "A" orebody consists of two ore lenses located within an amphibolite pipe which narrows with depth. The eastern or "hanging wall" lens can be traced from surface, through a series of fault blocks, to the 23rd level and the western or "footwall" lens develops into ore between 8th and 23rd levels (Fig. A.1.6). Below this level the mineralized "amphibolite" pipe appears to die out.

The "footwall" and "hanging wall" lenses appear to be separated by subeconomic to barren amphibolite, minor gabbro and an irregular, complex body of Q.H.D. The Q.H.D. can be traced from the footwall of the Upper "A" fault on the 5th level to the 2000' level. It has the form of a discontinuous dyke which protrudes from a large mass of Q.H.D. located immediately to the north of the orebody and it partially envelopes the ore pipe to the west and east. (Fig. A.1.7, A.1.8). The ore lenses may represent two discrete mineralized intrusions into the Q.H.D. body or, alternatively, a single ore pipe may have been split by a Q.H.D. dyke complex intruded at a later date.

The "A" orebody (Fig. A.1.6) is cut by the following six faults Vellet (1963):

	Strik	Dip	Net Slip	Level
1) Upper 'A'	N 12° W	45°W	138 m	2-1 SL
2) '1984'	N 15° E	80°W	46 m	7th L
3) Lower 'A'	N 30° W	60°-80°W	92 m	13th-15th L
4) Footwall 'A'	N 50° W	40° E	?	15th-18th L
5) 'C'	N 30° W	50°W	107 m	18th-22nd L
6) 2000° L	N 20° E	45°W	107 m	23rd-2000' L

The "A" ore pipe was thrust to the SW over a large mass of "peridotite" by movement on the "Footwall 'A'" fault (Fig. A.1.6) and a series of westerly dipping reverse faults later pushed successively higher blocks of the ore pipe towards the NE, causing the ore pipe to steepen from a plunge of 50° NE (observed within individual blocks) to an apparent combined plunge of 70° — 80° NE.

The Upper "A" (U "A") orebody is offset from the main body of the ore pipe by the Upper "A" fault. The Upper "A" orebody correlates with the main, "hanging wall" lens below the fault. It is 154 m x 62 m in subsurface plan, it trends N40°W and it displays a slight plunge to the SE.

The main body of the "A" ore pipe occurs between Upper "A" fault on the 3rd Level and the intersection of the Footwall "A" and Lower "A" faults on the 18th level, where both "footwall" and "hanging wall' ore lenses and the underlying footwall "A" fault are offset by movement on the Lower "A" fault. This fault offsets the hanging wall lens (L "A") from the 13th to the 16th levels and the footwall lens (FW "A") from the 18th to the 21st levels.

The footwall "A" lens is subeconomic above the 8th level (Fig. A.1.8). Below this level it expands to depth until it becomes sheared into the plane of the footwall "A" fault below the 18th level (Fig. A.1.9). The "hanging wall" lens, separated from it by 46 m of barren amphibolite and gabbro (which strikes N45°W and dips 55° NE) is a continuous mineable entity between the Upper and Lower "A" faults. It has a crudely circular outline in plan section (roughly 62 m diameter on the 5th level) and it is partially enveloped by offshoots from the large mass of Q.H.D. located to the north. The Q.H.D. body is particularly well developed between the two ore lenses and along the eastern flank of the "hanging wall" lens (Fig. A.1.8).

The central portion of the "A" orebody between the Upper and Lower "A" faults (L "A" and FW "A") is cut by the "1984" fault (Fig. A.1.7). This fault strikes N15°E and dips 80° W. It causes only minor dislocation of the ore lenses between 5th and 12th levels at the south end of the orebody, but it is responsible for more severe, but incomplete, offset at the north end.

Below the Lower "A" fault the orebody is cut by two imbricate reverse faults (the "C" and 2000' faults) which, like the Lower "A" fault, splay from the contact between the amphibolite or the ore pipe and "peridotite" brought in by earlier movement on the footwall "A" fault (Fig. A.1.6, A.1.9). These faults isolate progressively smaller blocks of ore (LL "A", LLL "A", FW "A" offset) and ore grade mineralization appears to die out above the fault on the 2000' level.

The "A" orebody consists of one or more pipes of mineralized amphibolite adjacent to a body of Q.H.D. in an area of "A" plug amphibolite. The contact between the two types of amphibolite appears to be gradational and the orebody has an irregular, ill defined contact. Ore distribution within the "A" ore pipe tends to be erratic, although zones of "better" grade ore do occur, particularly parallel to the Q.H.D. partition between "hanging" and "footwall" sections of the "A" orebody in the L. "A" ore lens, and in the vicinity of faults and contacts.

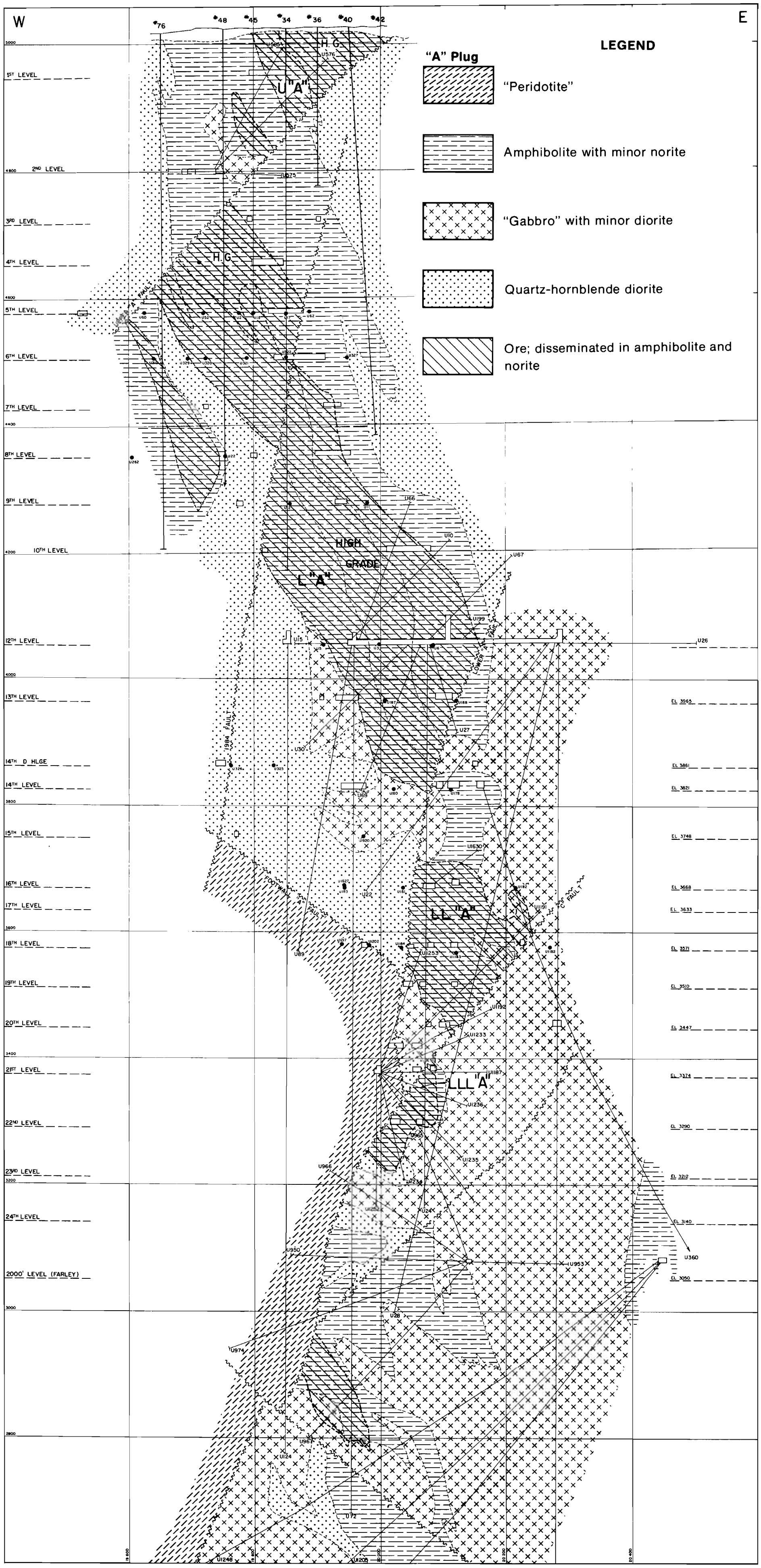


FIGURE A1.6 "A" orebody, W39650E cross-section

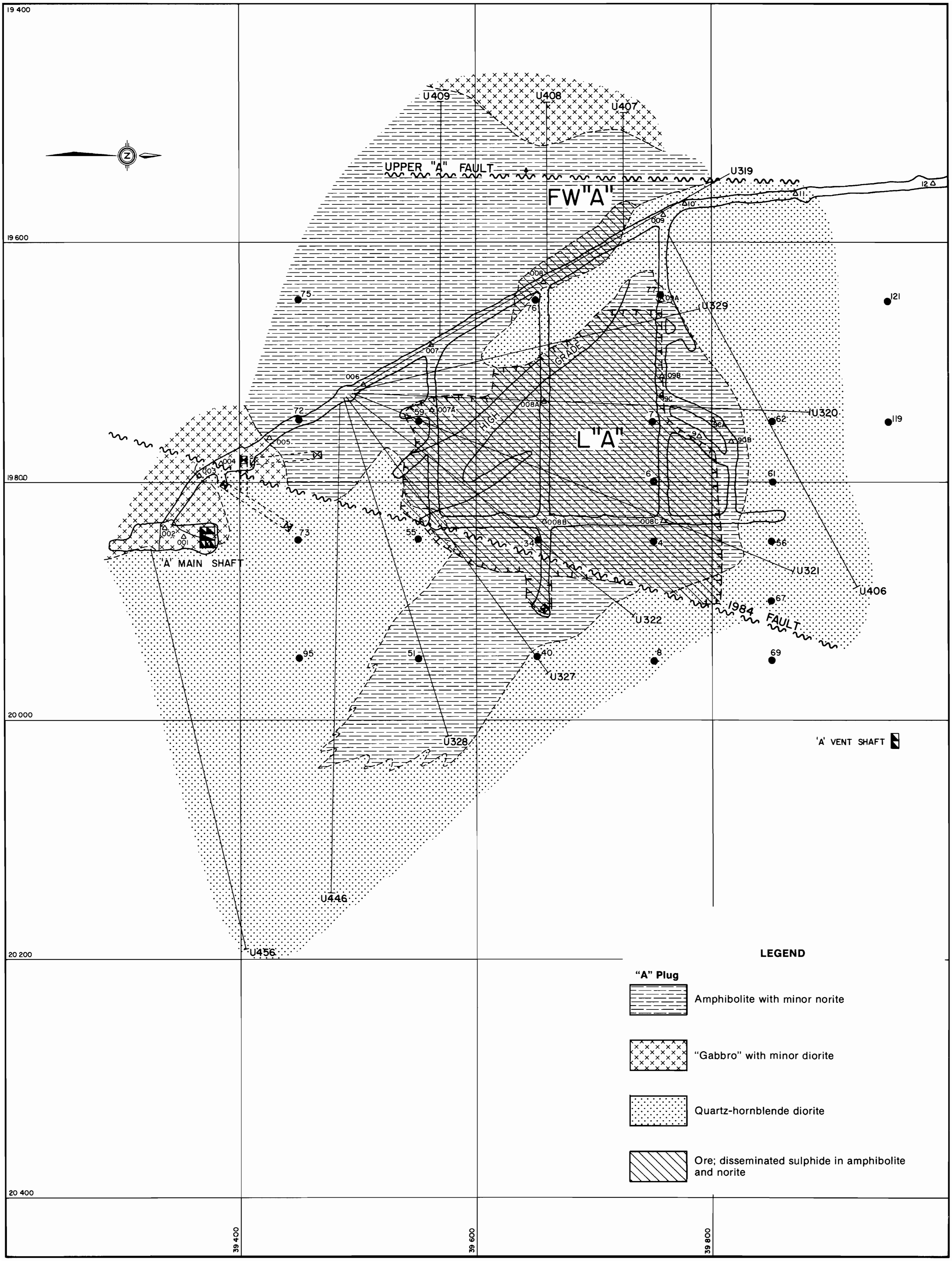


FIGURE A1.7 "A" orebody, 6th level

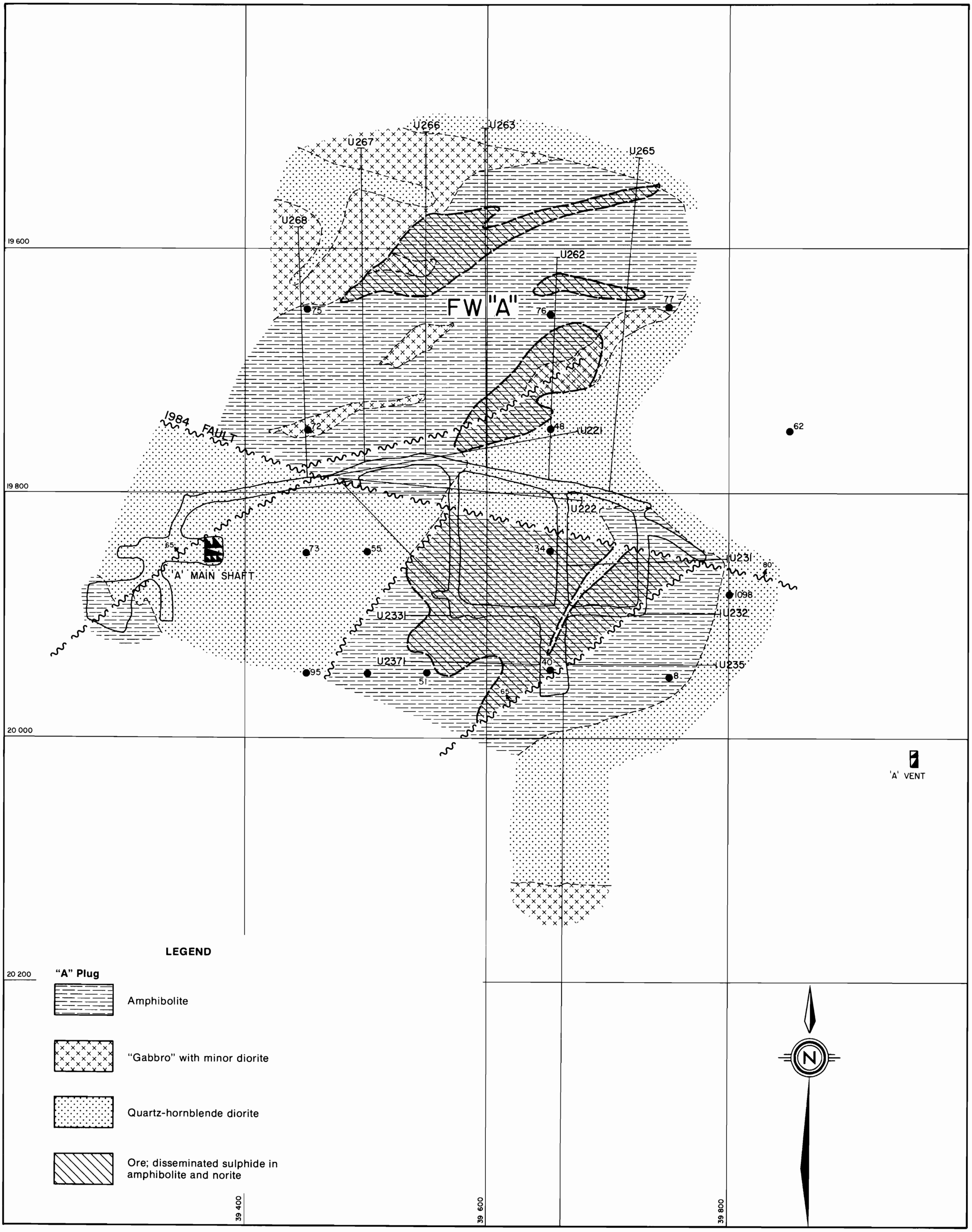


FIGURE A1.8 "A" orebody, 8th level

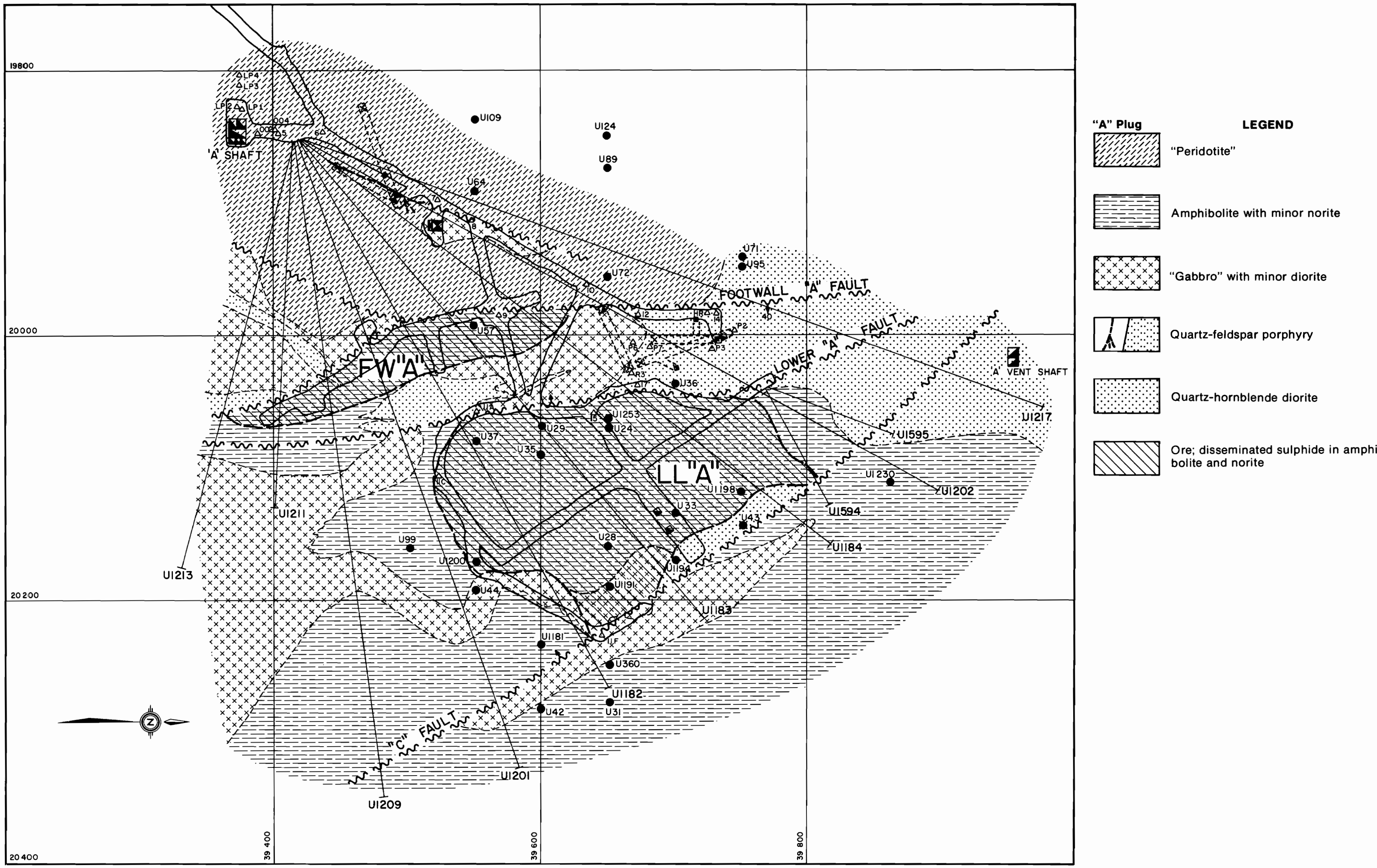


FIGURE A1.9 "A" orebody, 18th level

The mineralized amphibolite in the Upper "A" orebody, above the Upper "A" fault, contains (0.3 m — 1 m) inclusions of talcose peridotite, although the nearest body of peridotite is that brought in by the footwall "A" fault on the 18th level (Fig. A.1.9). Vellet (1963) used the presence of these inclusions as evidence for forcible intrusion of the mineralized amphibolites in the "A" pipe. According to Vellet (1963), patches of fresh, anhydrous norite were found "on some of the lower levels", and between the Upper "A" and the 1984 faults (3rd and 6th) levels in the "hanging wall" orebody (L. "A"). Fresh norite, enveloped by amphibolite, forms an anhydrous core to the L. "A" ore lens on the 5th level. Hunter (1950) noted that the norite grades into "gabbro" through progressive alteration of the pyroxene to actinolite and he proposed that much of the rnineralized amphibolite in the "A" orebody was originally derived from pyroxenite.

The sulphide content of the amphibolite varies considerably and there is a complete gradation from barren amphibolite through disseminated sulphide mineralization in amphibolite (ore-type 1) to silicate contamination of massive sulphide pods and lenses in amphibolite (ore-type 3). According to Vellet (1963) the sulphide breccia ore (sulphide — silicate ore) in the "A" orebody contains relict euhedral to subhedral crystals of amphibolite, apatite and quartz. Vellet records a single vein of siliceous felsite ore (ore-type 5) which cuts mineralized amphibolites in the "A" orebody.

Ruttan (1955) noted that the grade of mineralization increased in zones of brecciation in the vicinity of faults and he described a minor dragfold in amphibolite which was replaced by sulphide. Vellet (1963) found that the mineralization in faults cutting the "A" orebody does not extend for any great distance beyond the confines of the ore pipe and that most of the faults clearly post date emplacement of the ore.

"B" OREBODY

The 'B" orebody, which is located 230 m west of the Farley Shaft, (Fig. 2.1), was accessed from the '8' pit, the 500', 650', 800', 950' (12th level 'A' Mine), 1080' (diesel haulage), 1250', 1550', 1850', 2000', 2100', 2200' and 2300' levels, and the 350', 750', 885', 1060', 1150', 1350',1450',1665',1700',1775',1910',1950', 2060', 2420' and 2500' sublevels in the Farley Mine.

The mineralization extends from subsurface outcrop to below the 3000' (Fig. 2.2) level as a series of discrete, faulted, ore lenses which have an overall northwesterly strike and a steep dip to the NE. The mineralized lenses lie subparallel and adjacent to a large continuous body of "peridotite", which underlies the "footwall" of the "B", "B-K", "F" and "K" orebodies. The lenses occur *en echelon*, and they are separated by barren or weakly mineralized fedspathic "gabbro". They are irregular in outline but they have an average length of 100 m and width of 25 m. The lenses intersect the "peridotite" body in the northwest corner of the "B" pit but diverge from it and at depth (2000' level); they are separated from it by up to 184 m of barren, mottled, "gabbro".

The "B" orebody has been cut by seven major reverse faults and a large number of imbricate splays. The main faults are:

	Strike	Dip	Inter-section
1) Footwall "B"	N15°W	70°E	250-350′ L
2) Upper "B"	N30°W	35°W	350′ L
3) No. 1	N30°W	70°W	250-725′ L'
4) No. 2	N30′W	50′W	775′ L
5) No. 3	N25°W	55°E	775′ L
6) No. 4	N20°W	50°W	1450′ L
7) Porphyry Shear	N30°E	60°W	2100° L

The Upper "B" orebody extends from subsurface outcrop down to the No.1 fault on the 500' level (Fig. A.1.1 0). The orebody consists of two parallel zones of mineral ization separated by 23 m of barren feldspathic "gabbro". The lenses strike N40°W and display a steep but irregular (70°) dip to the northeast. The "hanging wall" (81) lens located on the NE flank of the "B" pit consists of disseminated sulphide (ore-type 1) in an amphibolite lens 150 m long and 30 m wide. The "footwall" (82) lens, to the SW, is approximately 150 m long and 23 m wide. The footwall lens consists largely of sulphide-cemented breccia (ore-type 3). The "footwall" and "hanging wall" lenses were mined to an elevation of 4730' (equivalent ot the 300' level) in the "B" pit.

The Lower "B" orebody is complexly faulted between the 500' and (Macauley, 1962; Vellet, 1963) 850' levels (Fig. A.1.10, A.1.12). Equal movement on the No. 2 and No. 3 faults has, nevertheless, retained the axis position of the "B1" and "B2" ore lenses and vertical continuity of the "B2" ore lens is maintained (Fig. A.10). The "B1" and "B2" ore lenses occur *en echelon* and they are separated by 15 m — 30 m of barren to weakly mineralized "gabbro" below the 775' level. The 81 lens is located to the northeast of the 82 lens. The shape of the 81 lens is influenced by the No.3 fault down to the 1080' level, where it broadens into a pipe of disseminated sulphide and plutonic breccia ore 40 m in diameter. The B2 lens (which is 80 m x 15 m on the 950' level) extends down-dip (strike N20°W, dip 70° NE) to the No.4 fault, below the 1350' level.

The B1 and B2 ore lenses are offset by movement on the No. 4 fault between the 1300' and 1500' levels (Fig. A.1.11). The B2 lens in the "hanging wall" of the fault (HW B2) has been thrust onto the footwall portion of the B1 lens (FW B1) below the fault. The "hanging wall B1 lens (HW B1) has, in turn, been thrust to the northeast over the 80 lens (FW B0) below the fault The B0 lens occurs *en echelon* northeast of the B1 lens, below the No.4 fault. It has a very limited expression above the fault (Fig. A.1.11). The FW B0 lens consists of a distorted oval pipe of disseminated and plutonic breccia ore (60 m x 50 m). The pipe appears to constrict with depth to a narrow lens (80 m x 15 m) on the 1850' level. The FW B1 and FW B2 lenses have a similar shape and orientation (N20°W) below the No. 4 fault.

The NE (FW 81) and SW (FW B2) lenses partially coalesce below the 1850' level and they appear to cross-over on the 1910' level. Disseminated sulphide mineralization (ore-type 1) occurs in the SW lobe and massive sulphide breccia ores (ore-types 4 and 3) occur in the NE lobe of the composite orebody on the 2000' level. The cross-over is incomplete and the two lenses are partially joined. The SW lens (FW 81) is oriented N30°W and the NE lens (FW B2) is oriented N-S.

A fourth lens (B3) occurs *en echelon* SW of the FW B2 lens, below the 1550' level (Fig. A.1.13). The B3 lens, which consists largely of disseminated ore (ore-type 1), is a minor lens (oriented N60°W) which appears to be an offshoot from the south end of the FW B2 lens. On the 1850' level, the B3 lens is a discrete body (Fig. A.1.14).

The B3 and FW B0 lenses, which are controlled by W-E and N-S structures respectively, on the 1850' level, diverge from the core of the "B" orebody (the FW B1 and FW B2 lenses) and they are reduced to isolated pods of ore above the porphyry shear, on the 2100' level.

The character of the "B" orebody changes below the Porphyry Shear (Fig. A.1.15). The complex ore lenses found above the fault are replaced by a single pod (40 m x 15 m) of massive sulphide and sulphide breccia ore (ore-types 4 and 3) oriented N60°W. The B5 lens dies out as a continuous entity below the 2400' level, but it continues to the 3000' level as a series of discontinuous ore lenses. These occur in an orientation N20°W and plunge towards the NE, towards the base of the "B-K" zone (Fig. A.1.16).

There is a considerable development of disseminated sulphide along the plane of the porphyry shear between the 2060' and 2200' levels, and weak mineralization occurs in the "gabbro" which envelopes the B5 lens.

The Upper "B" orebody consists of two main ore lenses in a body of barren to weakly mineralized amphibolite and "gabbro". The "B" pit contains a "footwall" lens (B2), which is composed of sulphide cemented breccia ore (ore-type 3), and a "hanging wall" lens of disseminated sulphide ore (ore-type 1) in amphibolite and amphibolitic "gabbro".

The B1 (disseminated) and B2 (sulphide breccia) lenses separate between the Nos. 2 and 3 and No.4 faults, and there is the weak development of a subsidiary disseminated ore lens (B0) below the No. 3 fault. Below the No. 4 fault, there are two lenses of disseminated sulphide in "gabbro' (B1 and B0) and one of disseminated sulphide in amphibolite. Mineralized amphibolites and amphibolitic "gabbros" display abrupt lateral contacts with "A" plug host "gabbros" in the upper levels but, at depth, the more feldspathic "gabbros" show more sporadic mineralization and the ore cut-off is less distinct (Vellet, 1963).

The B1 and B0 orebodies are fairly homogeneous, although a major sulphide vein is found in the "hanging wall" of the B0 lens. The two ore lenses contain silicified patches and zones of microstockwork vein development. The mineralization in B3 is similar, but the rock type is amphibolite.

The B2 ore lens is highly heterogeneous. It contains sulphide cemented breccias, veins of massive sulphide, siliceous felsite veins, disseminated sulphide ore and barren inclusion material. The main ore-type is sulphide breccia ore (ore-type 3), which occurs in an irregular system of dyke-like pods and lenses that have abrupt contacts with barren and/or weakly mineralized "gabbro". The sulphide breccias contain pods of mineralized siliceous felsite (ore-type 5) and they are cut by veins of massive sulphide (ore-type 4). The sulphide breccia, near surface, contains a heterogeneous assemblage of different rock types as subrounded to rounded pebble to cobble sized inclusions. The inclusions appear to become larger and more angular with depth (Vellet, 1963) and the percentage of the inclusion material in the breccia appears to increase below the 1850' level.

The sulphide breccia ore was examined in detail by Macauley (1962). He found that a stope wall (3 m x 2 m) on the 1910' level contained over 50% inclusion material as isolated subangular to subrounded heterogeneous fragments cemented by massive sulphide. The inclusions ranged in size from fragments a few centimetres in length and width to blocks 2 m long and 1 m wide. Vellet records fragments of up to 15' (4.6 m) in length. Macauley (1962) found a distinct preferred orientation to the fragments, although he was unable to determine whether it was a linear or a planar orientation. The inclusion contacts tend to be sharp, although some fragments appear to be in the process of disintegration. Gabbroic samples locally display a barren core which grades outward into an envelope of "gabbro", which contains disseminated sulphide and is itself enveloped by a fringe of sulphide enriched in disaggregated crystals of feldspar and amphibole.

According to Macauley (1962) the breccia inclusions consist of several distinct rock types. These include fine and medium grained amphibolitic "gabbro" with interstitial blue quartz eyes, fine and medium grained amphibolites. leucocratic and melanocratic metadiabase, quartz-biotite diorite and quartz-plagioclase hornfels (siliceous felsite).

"B-K" OREBODY

The "B-K" orebody consists of a series of discontinuous, structurally controlled ore lenses located between the "B" and "K" orebodies. The "B-K" ore lenses extend from the 2100' level to the 3500' level. The "B-K" orebody was accessed from the 2100', 2200', 2300', 2600', 3000' and 3150' levels, and the 2420', 2500', 2800' and 2950' sublevels in the Farley Mine.

The "B-K" ore zone strikes N45°W and dips 50° NE. It is approximately 60 m wide and it is flanked on either side by offshoots from the mass of Q.H.D. which separates the "B" and "K" orebodies on the 2000' level and controls the "footwall", and to a large extent, the "hanging wall", of the Lower "K" orebody.

The extent of the ore is partially controlled by the separation of the two parallel dykes of Q.H.D. on either side of the ore zone. The "B-K" and "K" ore lenses, on the 2300' level, are controlled by the same structure and they are partially separated by a constriction in the Q.H.D. dyke system. (Fig. A.1.15). The two ore lenses are joined by a 1.5 m to 3.0 m channel of mineralized amphibolite between the two controlling dykes.

The "B-K" zone dies out above the "K" shear in a complex body of Q.H.D. which separates the "B" and "K" orebodies on the 2100' level. The "B-K" zone is cut by the porphyry shear between the 2300' and 2400' levels.

The ore lenses consist of disseminated clots and blebs of sulphide (ore-type 1) in narrow lenses of amphibolite within mottled "gabbro" between the containing Q.H.D. dykes. The Lower "K", "B-K" and Lower "B" (below the porphyry shear) ore lenses all project towards a common source below the intermediate "B-K" zone (Fig. A.1.6).

"C" OREBODY

The "C" orebody is located 340 m NNW of the "A" shaft on the 12th level (Fig. A.1.2). The orebody consists of an irregular faulted ore pipe which extends from 14th level to subsurface outcrop (Fig. A.1.17). The pipe is located adjacent to a large mass of Q.H.D. in a mixed assemblage of "A" plug rock types. The orebody was accessed from 2nd, 3rd, 4th, 6th, 7th, 9th, 10th, 11th and 12th levels, and 1st and 5th sublevels.

The "C" ore pipe is cut by two main northerly striking reverse faults (Fig. A.1.17) which divide the pipe into upper, middle and lower sections. The Upper "C" orebody overlies the (compound) Upper "A" fault on the 7½ level (Fig. A.1.19). The fault strikes north and dips 60° west. The "C" fault, which strikes NW and dips 60° SW, moves up-section from the 12th level in the south of the "C" orebody to the 9th level in the north, and the Middle "C" orebody is reduced at the expense of the Lower "C" portion. Movement on the Upper "A" and "C" faults has caused successively higher sections of the orebody to be thrust 20 — 60 m to the east. At the south end of the "C" ore pipe, the three sections show a steep (60°) easterly plunge. At the north end, movement on the faults and extensive shearing have progressively rotated the middle and upper sections into a more westerly orientation. The uppermost part of the "C" orebody shows a shallow plunge to the east.

The "C" orebody is cut out by the "C-contact" fault at the 14th level (Fig. A.1.17). This fault, which strikes north and dips 30° east, may be related to the "E-J" fault to the south (Vellet, 1963). The footwall extension of the "C" ore pipe below the "C-contact" fault has not been found.

The south end of the "C" orebody abuts against a large (faulted) mass of Q.H.D. which is known to extend from surface to below the 3000' level. The Q.H.D. mass that separates the "C" orebody from the "A" orebody, located 185 m SE, splits into numerous near-vertical, N-S dykes, one of which is located in the east wall of the "C" orebody. A structural section at the south end of the orebody shows that mineralized amphibolite lenses penetrate into the main Q.H.D. mass.

The lower "C" orebody extends from the "C-contact" fault to the "C" fault. The ore on the 14th level consists largely of disseminated sulphide blotches and sulphide veins in amphibolite and "gabbro". On the 13th level the "C" orebody splits into two discrete ore lenses ("hanging wall" and "footwall") which are separated by a weakly mineralized "hybrid" gabbro (Vellet, 1963). The eastern, "hanging wall" lens consists of disseminated sulphide in amphibolite (ore-type 1) and the western, "footwall" lens consists of sulphide-

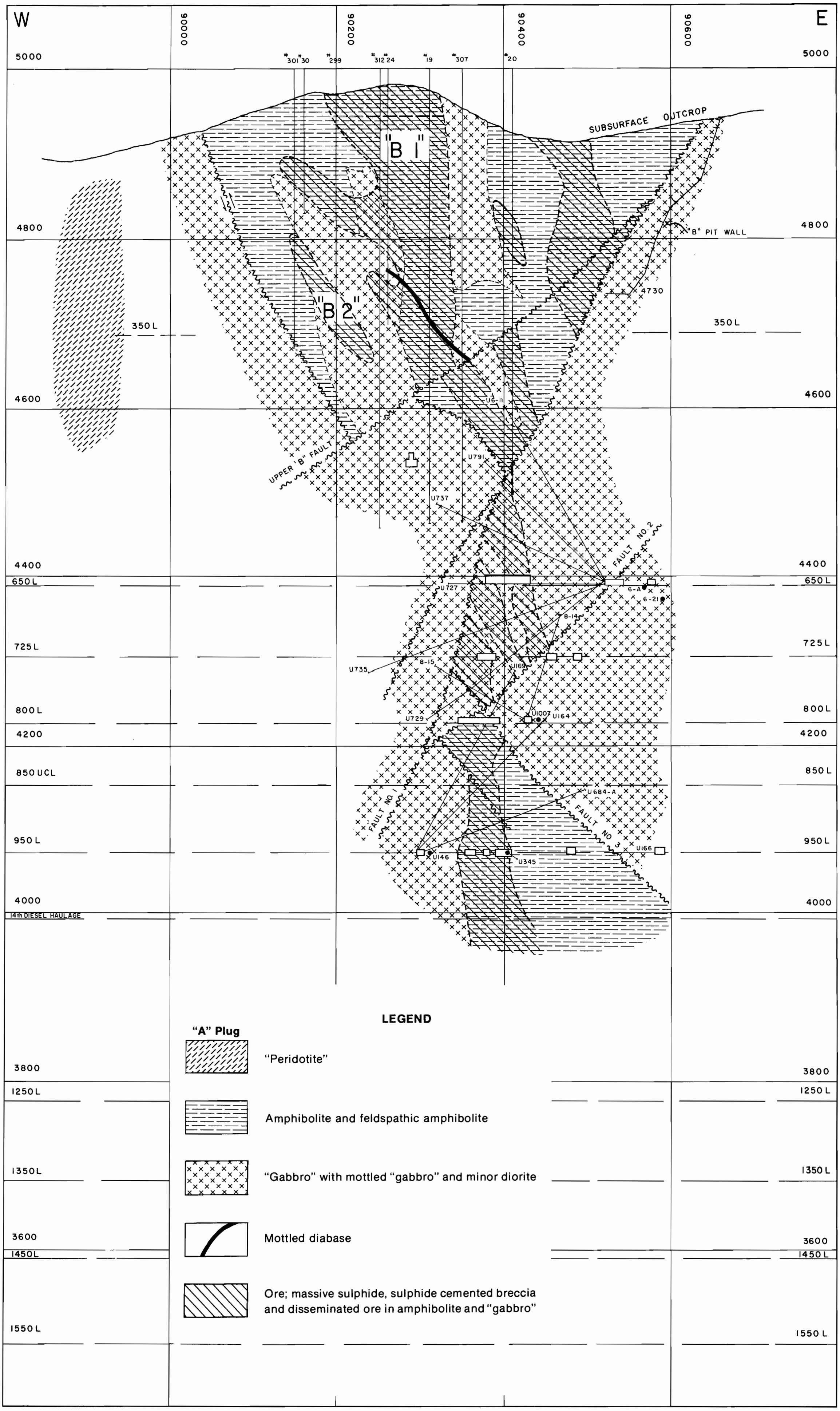


FIGURE A1.10 Upper "B" orebody, W35800E cross-section

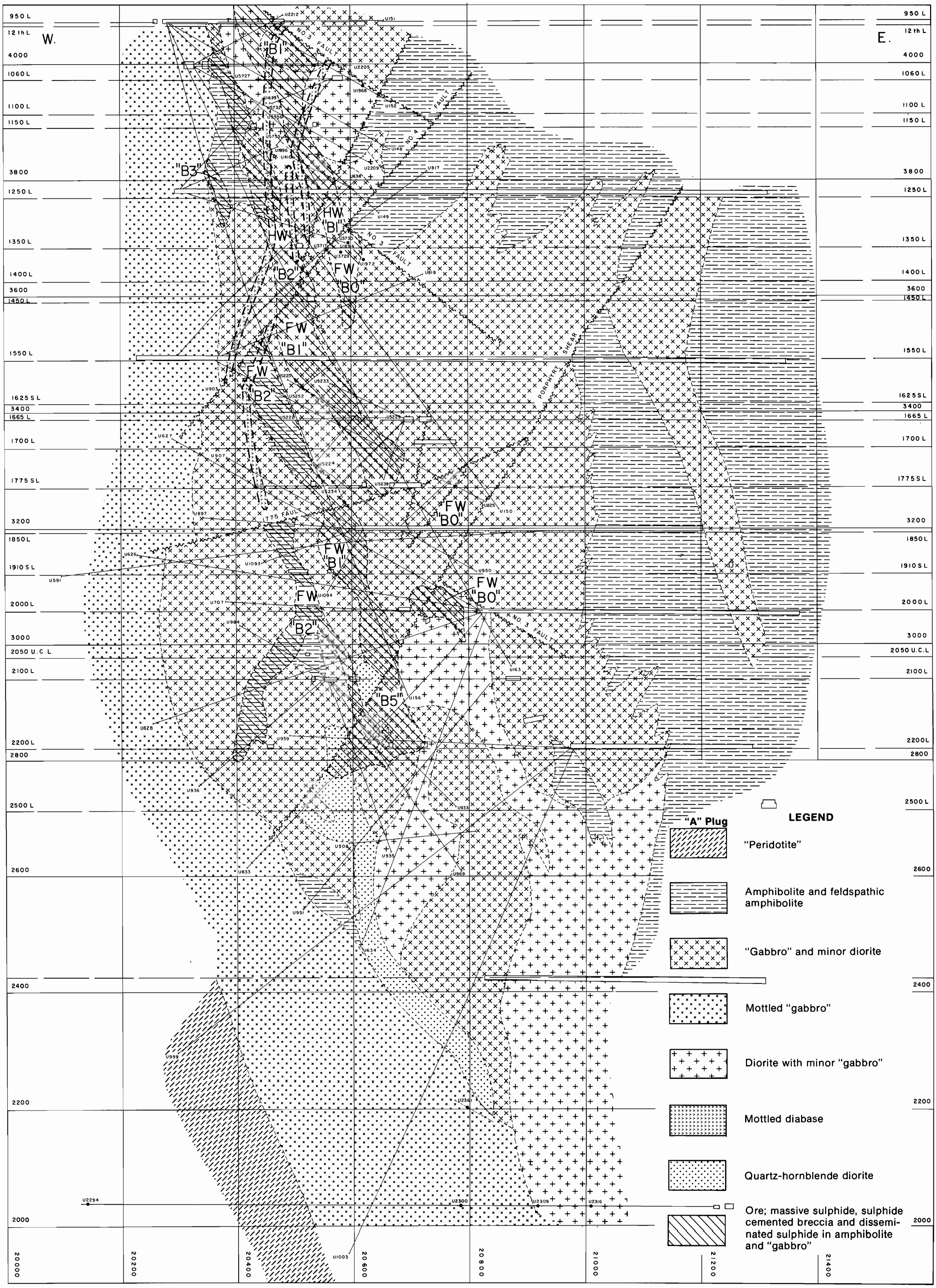


FIGURE A1.11 Lower "B" orebody, W35900E cross-section

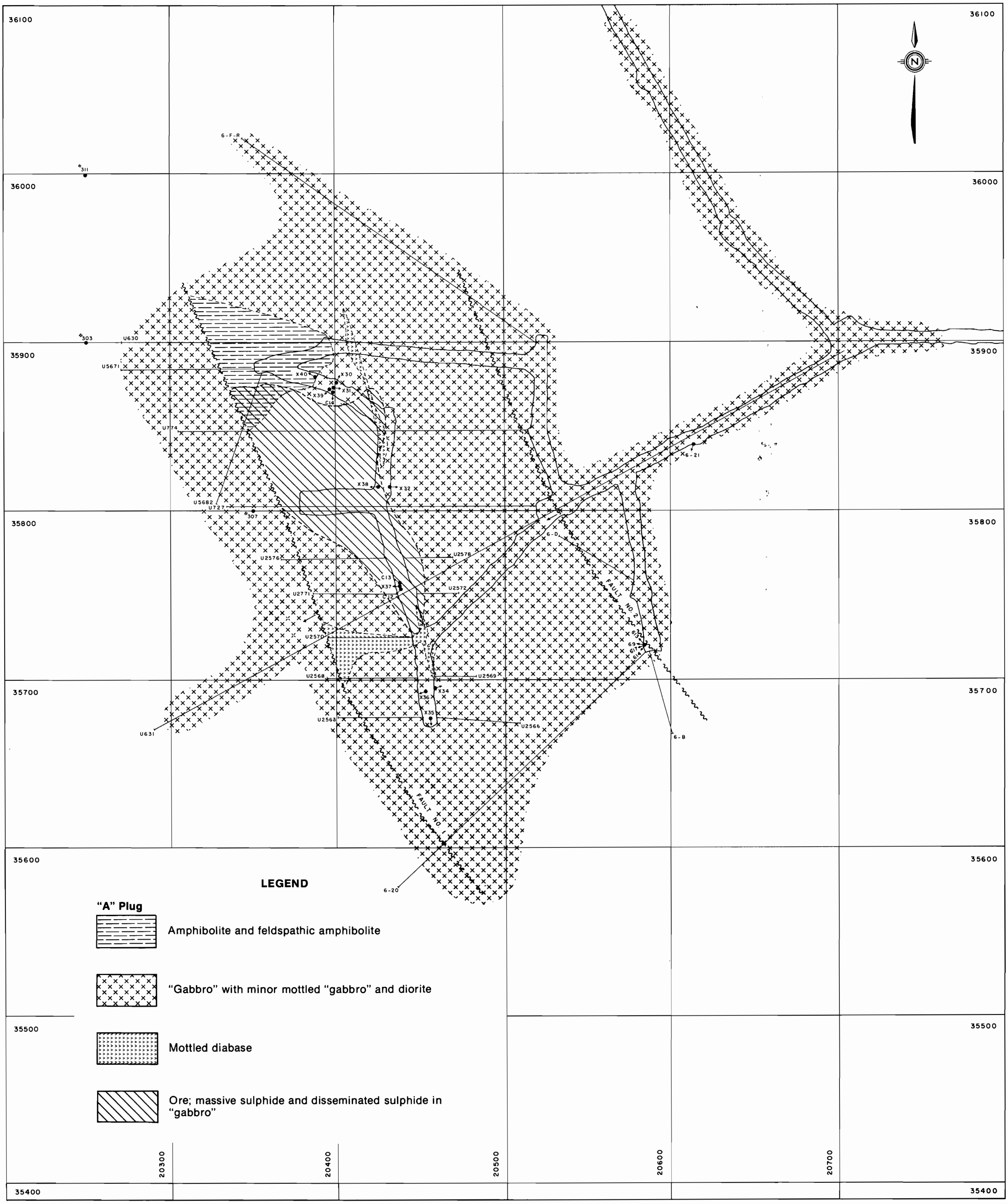


FIGURE A1.12 "B" orebody, 650' level

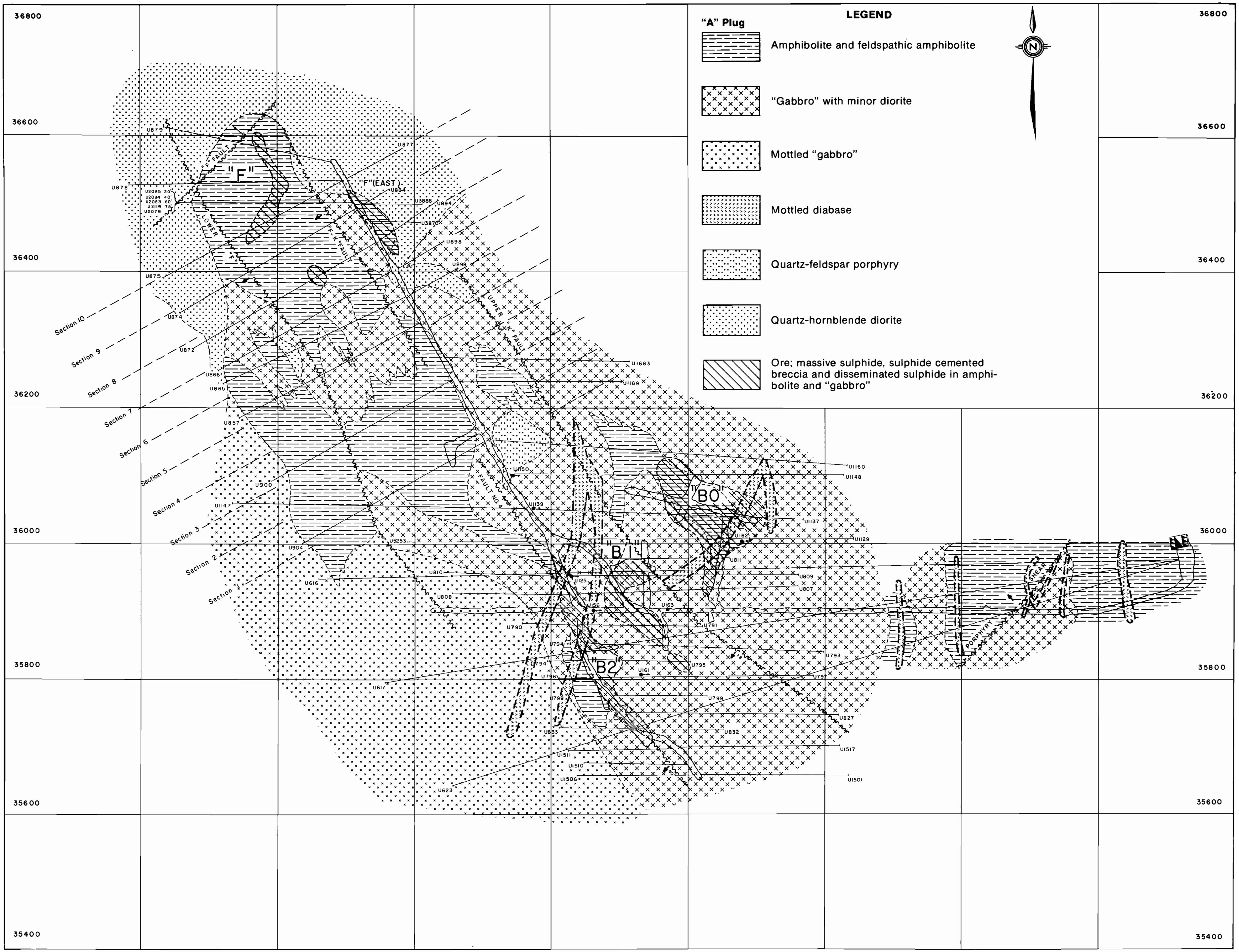


FIGURE A1.13 "B" orebody, 1550' level

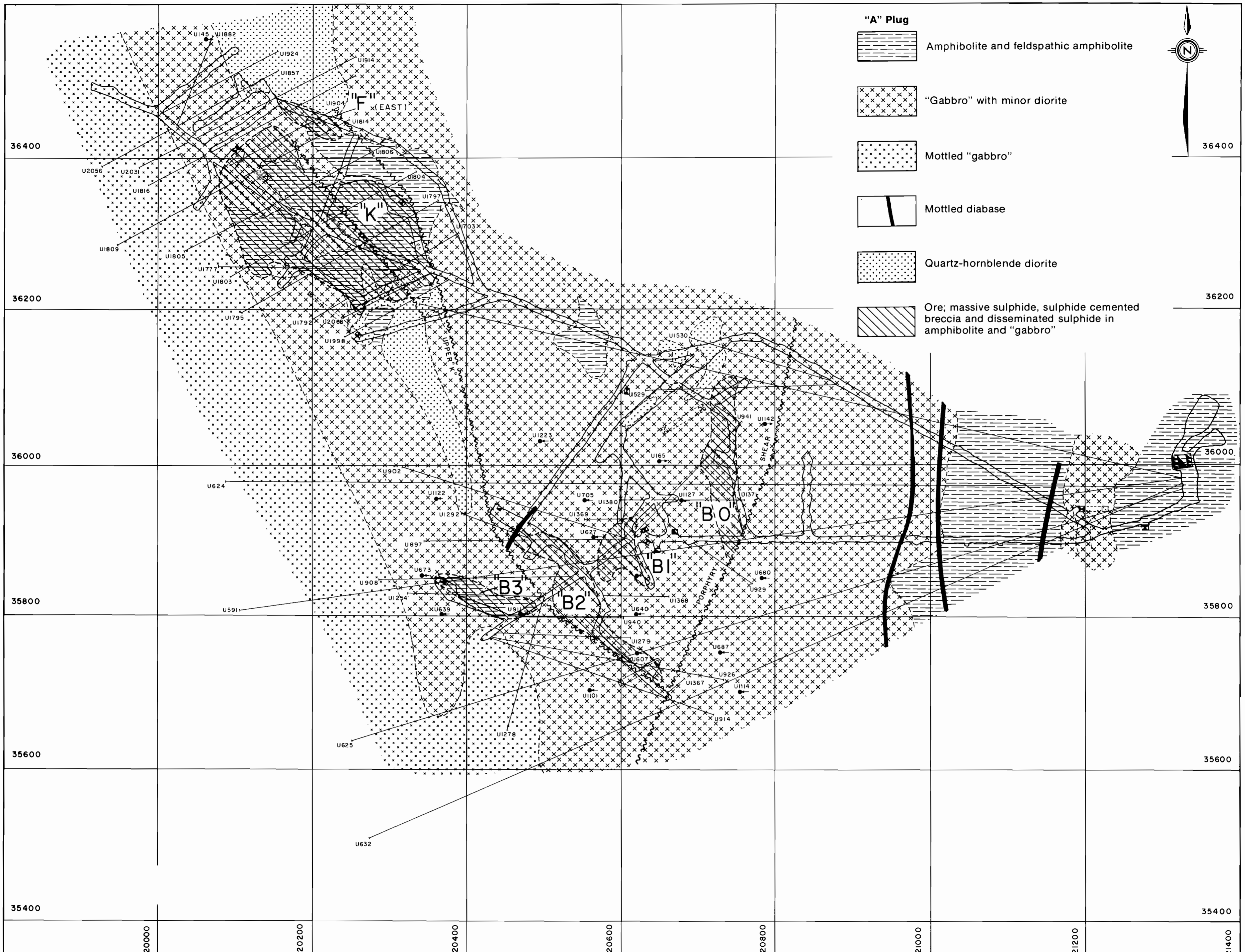


FIGURE A1.14 "B" and "K" orebodies, 1800' level

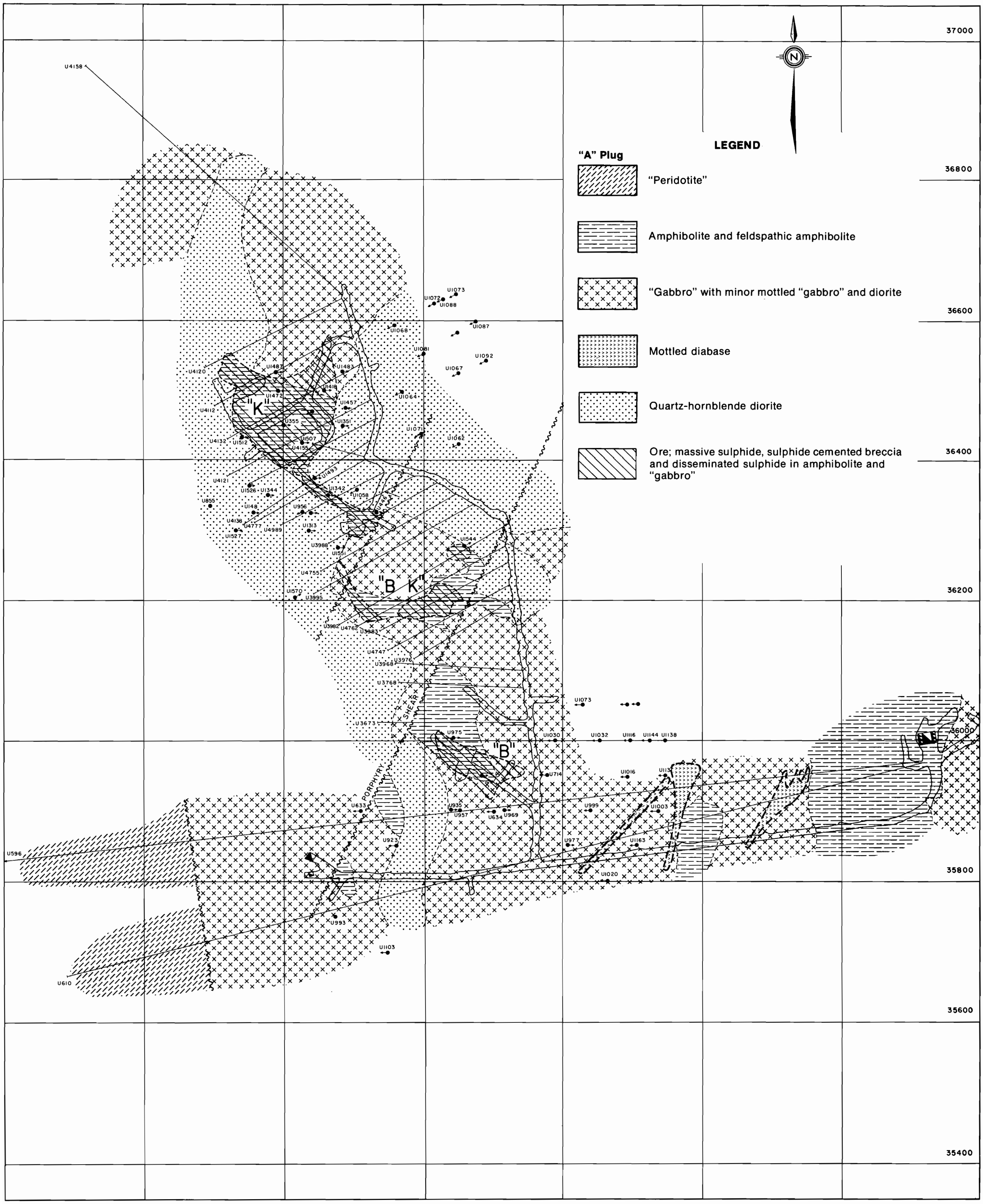


FIGURE A1.15 "B", "B-K" and "K" orebodies, 2300' level

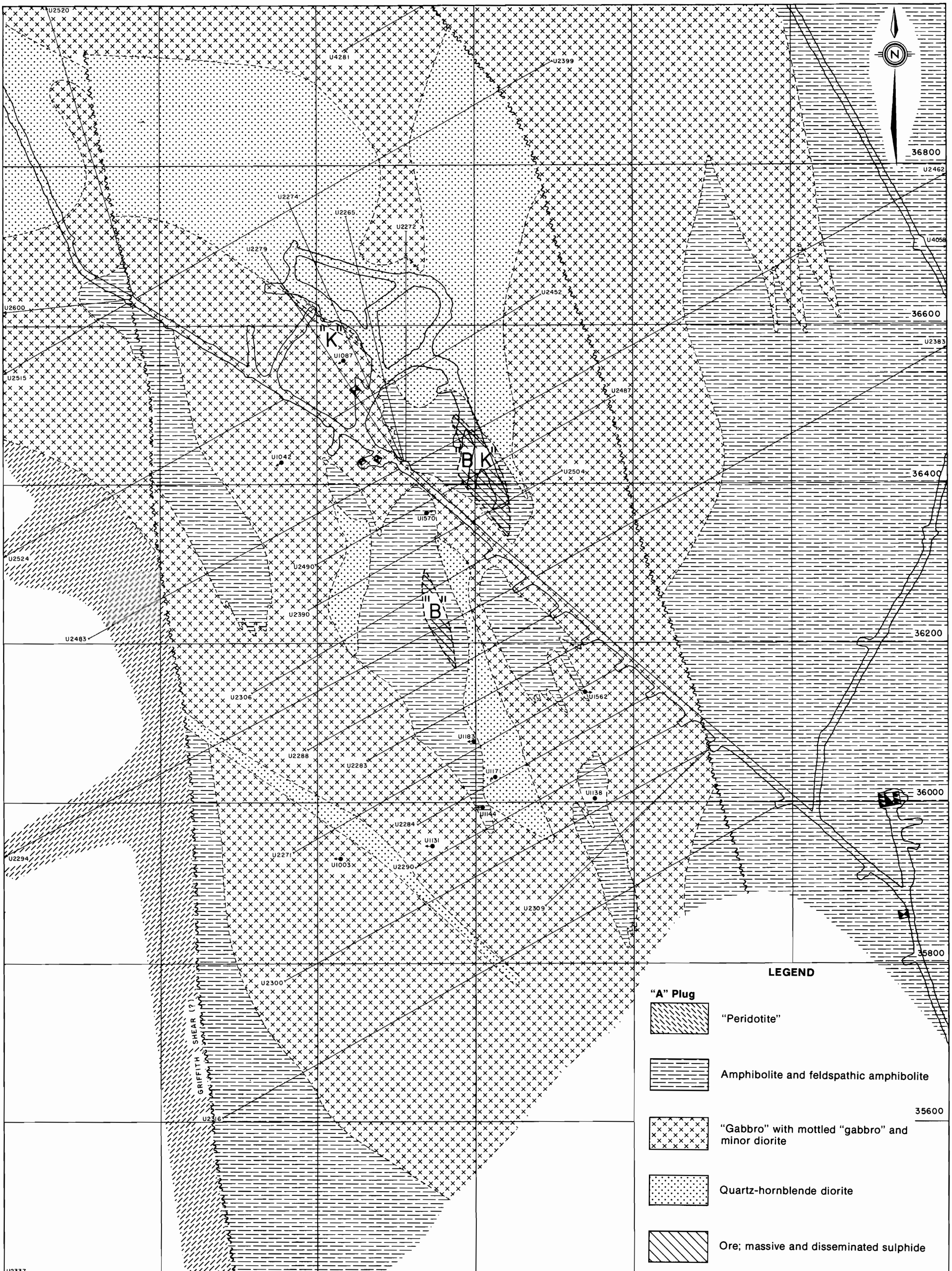


FIGURE A1.16 "B", "B-K" and "K" orebodies, 3000' level cemented breccia (ore-type 3). Both lenses extend to the Upper "A" fault (Fig. A.1.17).

The weakly mineralized "hybrid" consists of fine grained "gabbro" with variable quantities of coarse grained "gabbro" as spots and inclusions. The hybrid "gabbro" contains disseminated specks and clots of sulphide and it locally reaches ore grade. Vellet (1963) records examples of "double inclusions" in the "gabbro". Inclusions of barren, coarse grained diorite occur within the mineralized, fine grained "gabbro" and in inclusions in weakly mineralized, coarse grained "gabbro" which are themselves caught up in the fine grained "hybrid". According to Vellet, the hybrid "gabbro" contains rounded inclusions of porphyritic amphibolite and large areas (inclusions?) of near barren "gabbro". He noted that the amphibolite inclusions tended to be sheared.

The western, "footwall" lens consists of sulphide breccia (ore-type 3). The breccia contains rounded fragments of barren, "host" rock-types such as Q.H.D., porphyritic amphibolite, coarse grained "gabbro", diorite and (?) granite (Vellet, 1963). The sulphide-cemented breccia also contains fist sized inclusions of siliceous felsite which are riddled with fine grained ore veinlets (Vellet, 1963). Vellet noted that there was a conspicuous biotite-chlorite reaction between porphyritic amphibolite and sulphide, and that clots of chlorite occur as inclusions throughout the sulphide breccia. The sulphide breccia lenses are well developed at the south end of the "G" orebody along the irregular Q.H.D. contact (Vellet, 1963) and he records that, at one locality (on the 7½ level), the contact between the two is horizontal. He concluded that this was evidence for the intrusive nature of the sulphide-breccia ore.

The eastern, "hanging wall" lens consists of low-grade disseminated sulphide' mineralization in amphibolite (ore-type 1). The amphibolite locally contains inclusions of "A" plug wall rock and a single, sheet-like inclusion of "peridotite" was found on the 12th level (Vellet, 1963). Above the 9th level the "hanging wall" lens splits into two discrete lenses.

The Upper portion of the "G" orebody continues to surface as poorly defined but discrete disseminated ore lenses in amphibolite and "gabbros". The western ore lens flattens considerably to the west and it dips at 10° — 30° to the east above the 1st level. The reason for this change in orientation is uncertain, but it may be partially controlled by the presence of a lens of "peridotite" which dips at a shallow angle to the east in the vicinity of the mineralized lens (Fig. A.1.17).

The "G" orebody and the neighbouring country rock are cut by several inter-related dykes of quartz-feldspar porphyry (Q.F.P.). The dykes strike N25° E and dip at approximately 60° west. A Q.F.P. dyke complex cuts the upper "G" orebody near surface (Figs. A. 1.17 and A.1.18). The dyke complex intercepts the compound Upper "A" fault at the north end of the orebody. According to Vellet (1963) the Q.F.P. dyke exploits and trails one fault and cuts a second. The Q.F.P. exploits the faulted top of the Middle "G" orebody from the 5th to the 7th levels.

"D" OREBOOY

The "D" orebody consists of two distinct ore lenses ("Upper" and "Lower") which lie within the same structural plane. The two lenses are separated by approximately 77 m of barren fine grained diorite. They are located subparallel to, and 15 m — 61 m NW from, a lens of "peridotite" and amphibolite. The two ore lenses lie in a plane which strikes N20° E and dips 75°NW.

The Upper "D" orebody is located approximately 554 m NE of the 'A' shaft (Fig. 2.1). The ore lens was accessed from the 12th, 15th, 17th ("20th U/G") and 18th (drawpoint) levels and from the 9½, 13½, 14th and and 16th levels (Fig. A.1.20).

The Lower "D" ore lens is located approximately 500 m N50° E of the "A" shaft on the 2000' level. The orebody was accessed from the 2000' level in the Farley Mine and from a winze (No.1 Winze) sunk from the 2000' level to the 2580' level. The winze gave access to levels at 2150', 2300', 2450' and 2580' (drawpoints) (Fig. A.1.21). The ore was sent through an ore pass to a draft on the 3000' level where it was transported to the 3150' crusher.

The Upper "D" orebody consists of a tabular body of heavily disseminated, semi-massive and massive sulphide in fine grained diorite. According to Vellet (1963) the ore becomes siliceous and low in Ni at the contact at the top of the lens and it passes into subeconomic disseminated ore below the ore lens. The upper "D" ore lens can be subdivided into two distinct, but partially connected, sublenses by the Upper "D" fault (Fig. 1.22), which is thought to strike N45°W and dip 50° NW. The northern sublens, above the fault, extends from the 13th to the 18th level and it lies in the dominant regional structural plane. The southern sublens extends from 9½ sublevel to the 17th level. It follows a N40°W trend at depth, below the fault, but rotates into the regional trend on the 15th level above the fault. The two lenses are separated by barren fine grained diorite below the 15th level but they join to form a single lens approximately 138 m long and 15 m wide above the fault. The lens displays a steep (60°) overall plunge to the northwest.

The Lower "D" ore lens consists of fine grained diorite with weak disseminated sulphide mineralization. The lens reaches its maximum extent (260 m x 23 m) on the 2300' level and extends from the 1900' to the 2500' levels. The Lower "D" ore lens lies down dip from the Upper "D" ore lens and it is separated from it by 60 m of barren fine grained diorite.

The Lower "D" ore lens is cut by the 2150' (Lower "D") fault, which strikes N35°W and dips 30° SW and offsets the "hanging wall" portion of the orebody 15 m — 30 m to the NE with respect to the "footwall" portion (Fig. A.1.4).

According to Vellet (1963) the "D" ore lens is confined to a zone of cleavage in the diorite subparallel to a major lens of "peridotite" and amphibolite, and the sulphide content decreases where the deformation becomes constricted. He considered that the disseminated Lower "D" ore lens marks the passageway of an intrusive ore dyke represented by the Upper "D" ore lens.

The SE contact of the Lower "D" ore lens is sharp and the NW margin grades into subeconomic disseminated sulphide mineralization in fine grained diorite. Similar subeconomic mineralization can be traced along strike to the southwest, where it follows the "peridotite"-diorite contact. The fine-grained diorite adjacent to the Lower "D" ore lens is commonly cut by narrow (2-10 m) veins of siliceous felsite which parallels the regional structure.

The fine grained diorite is cut by (a) quartz-hornblende diorite (Q.H.D.), (b) dykes of younger mafic material and (c) quartz-feldspar porphyry (Q.F.P.). The ore lens appears to cut mafic dyke material (Q.H.D.?) on the 9½ and 12th levels and it appears to be cut by dykes of mottled diabase and Q.F.P. on all levels. The latter dykes both exploit the Upper "D" fault on the 15th level. Dyke orientations vary considerably, but mafic dykes are commonly parallel to the regional structural trend and the younger Q.F.P. dykes are commonly oriented approximately E-W, discordant to the regional trend.

On the 2000' level (Fig. A.1.4) the "D" ore lens projects into what appears to be a broken fold nose, defined by a "peridotite" body which curls around the south end of the ore lens, on strike to the southwest. The fine-grained diorite, between the ore lens and the axis of the fold, contains weak disseminated sulphide, and veins of sulphide occur, on strike, on both sides of the "peridotite" body. It is not known if the mineralization occurs in the "peridotite".

"E-J" OREBODIES

The "E" and "J" ore lenses (Figs. A.1.23 and A.1.24) are thought to be faulted counterparts of the same ore lens (Vellet, 1963) which were separated by south westerly movement of the hanging wall "E" orebody on the "E-J" fault (strike N30°W, dip 50° E).

The "E" orebody is located approximately 277 m SW of the "A" shaft, at the N end of the "A" plug (Fig. A.1.2). The orebody consists of a fault-controlled lens approximately 123 m long and 12 m wide.

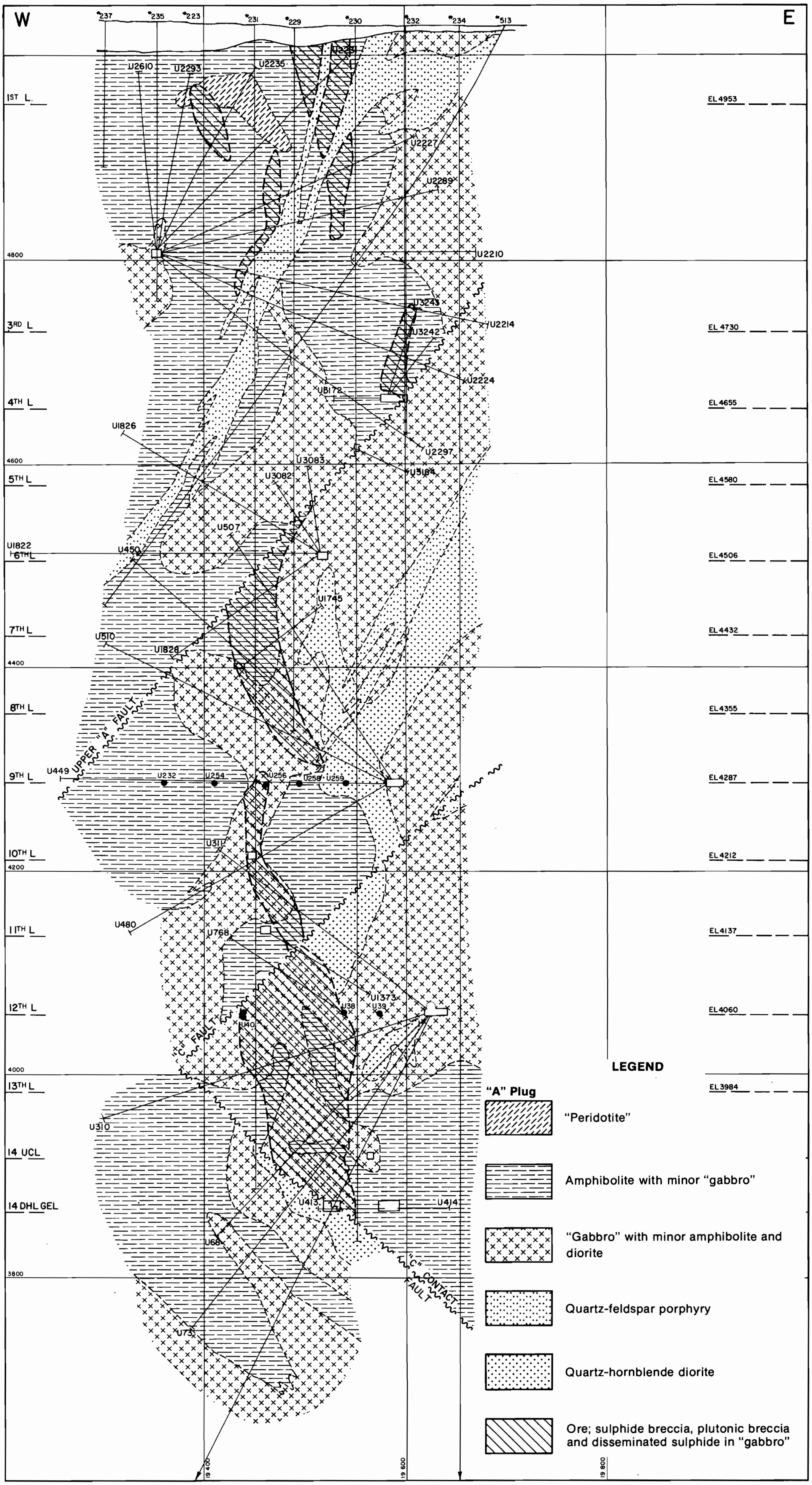


FIGURE A1.17 "C" orebody, W40400E cross-section

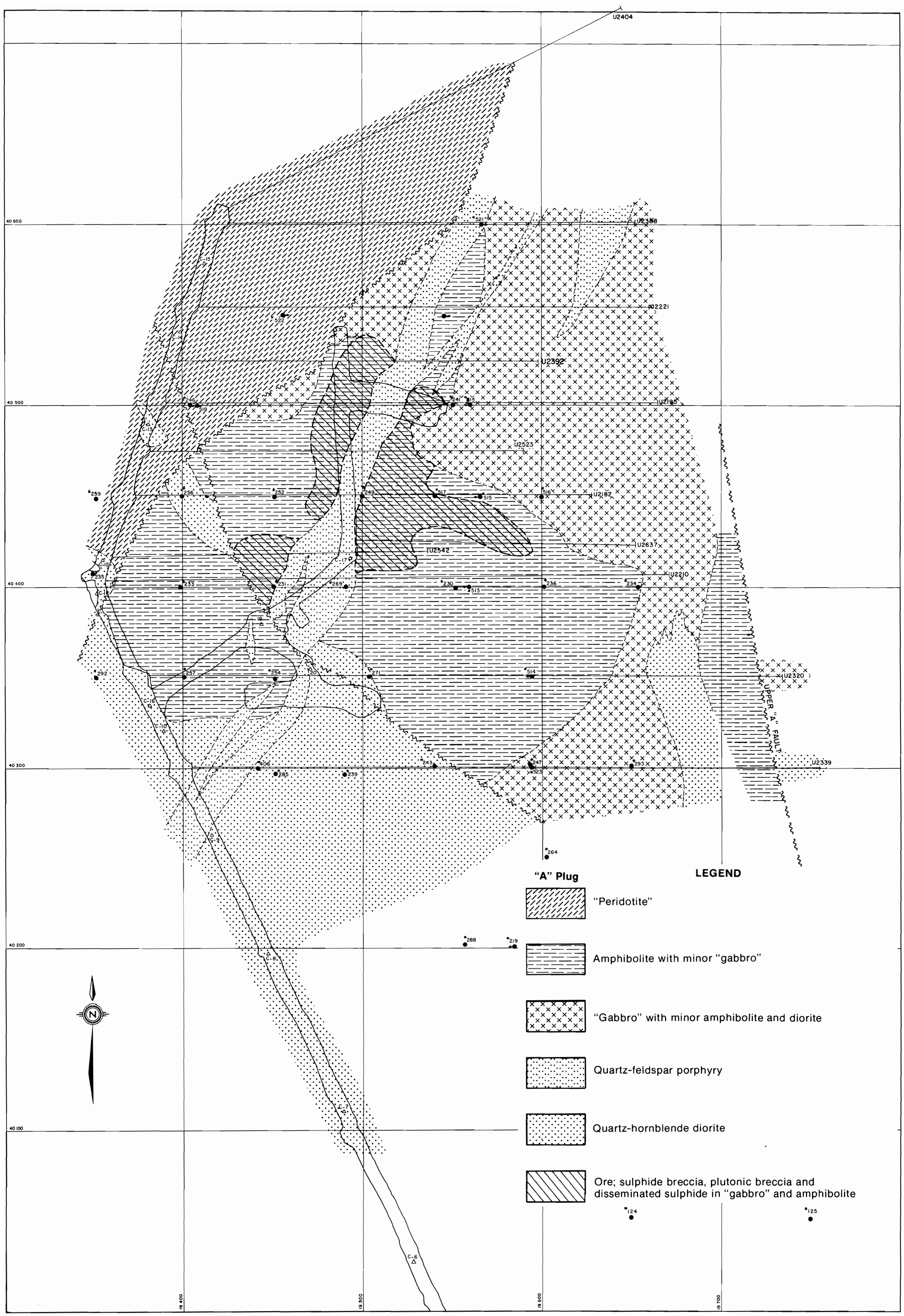


FIGURE A1.18 "C" orebody, 2nd level

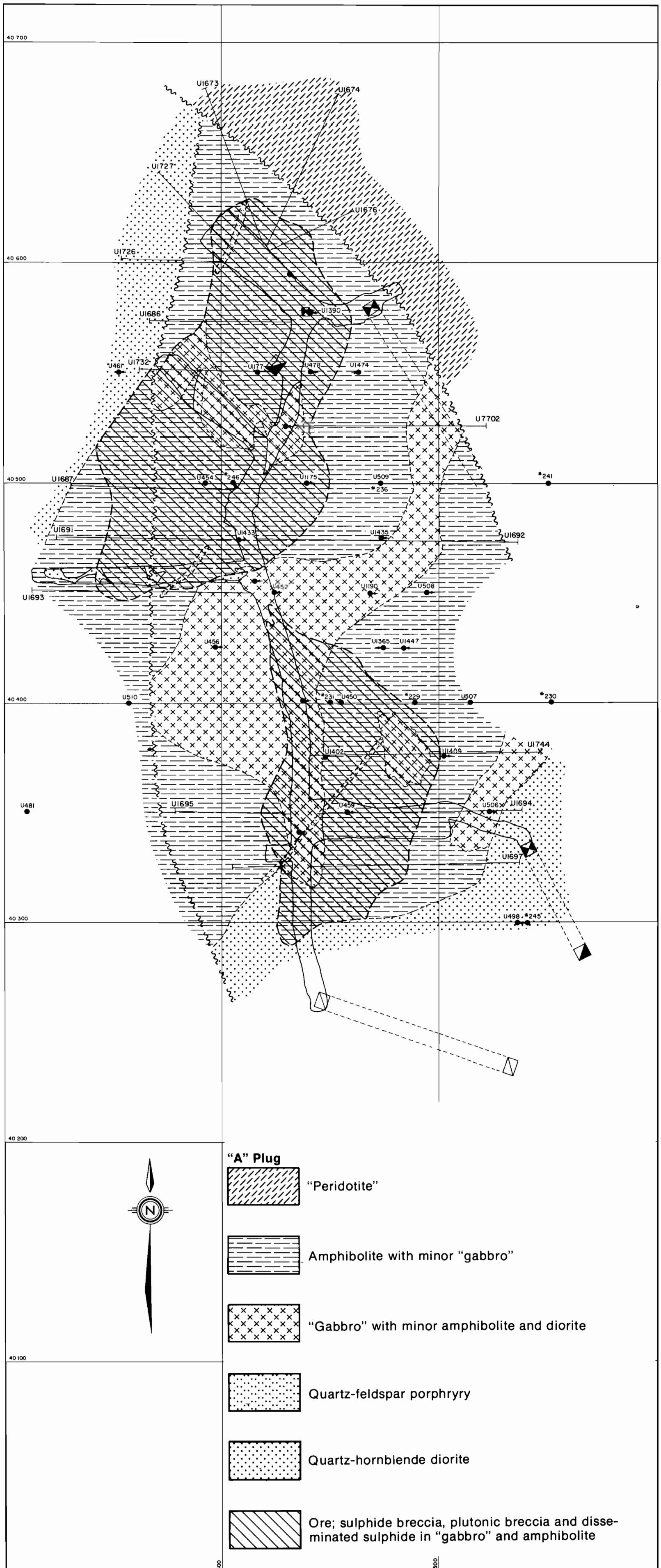


FIGURE A1.19 "C" orebody, 7-1/2 level

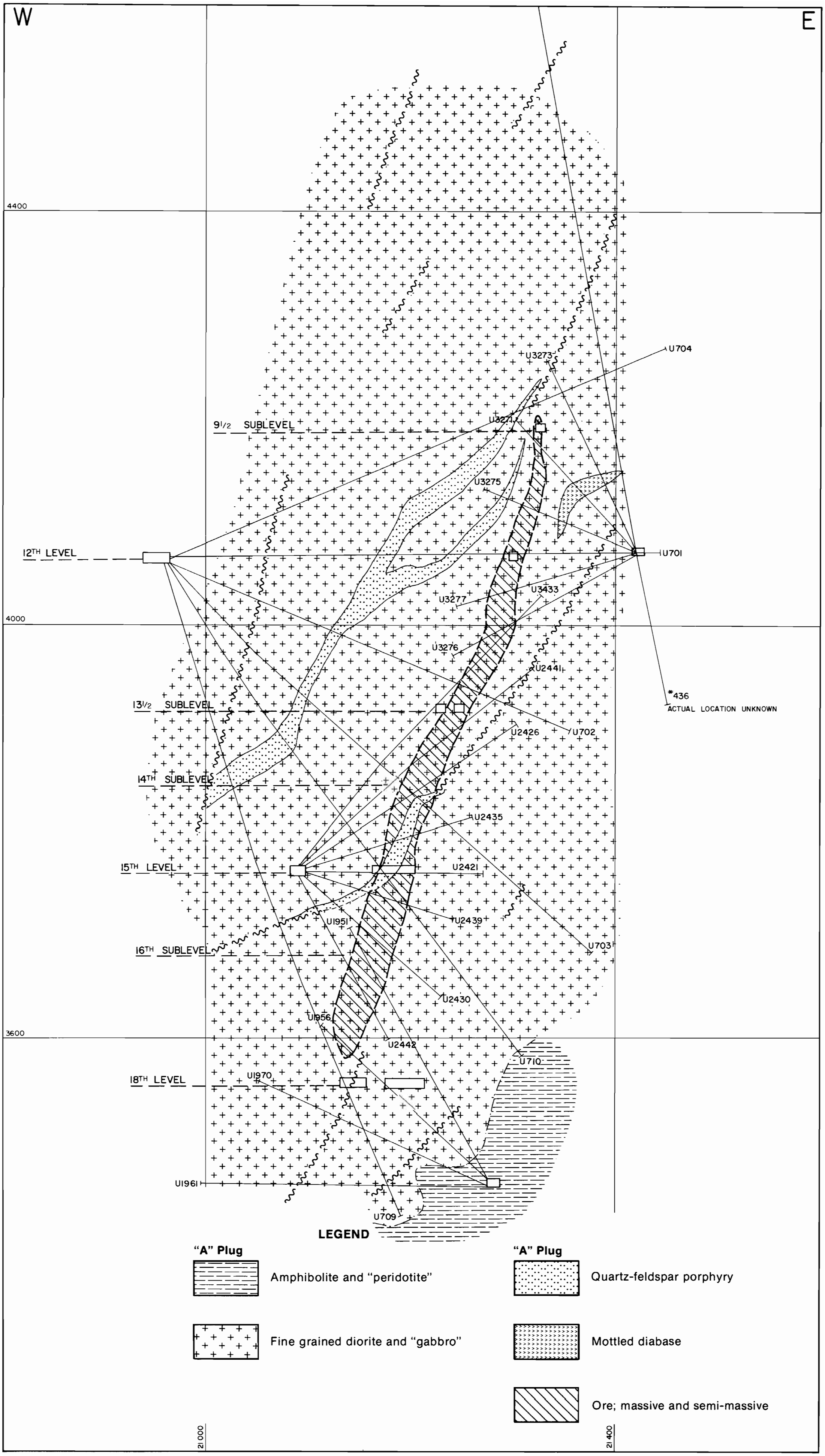


FIGURE A1.20 Upper "D" orebody, W40500E cross-section

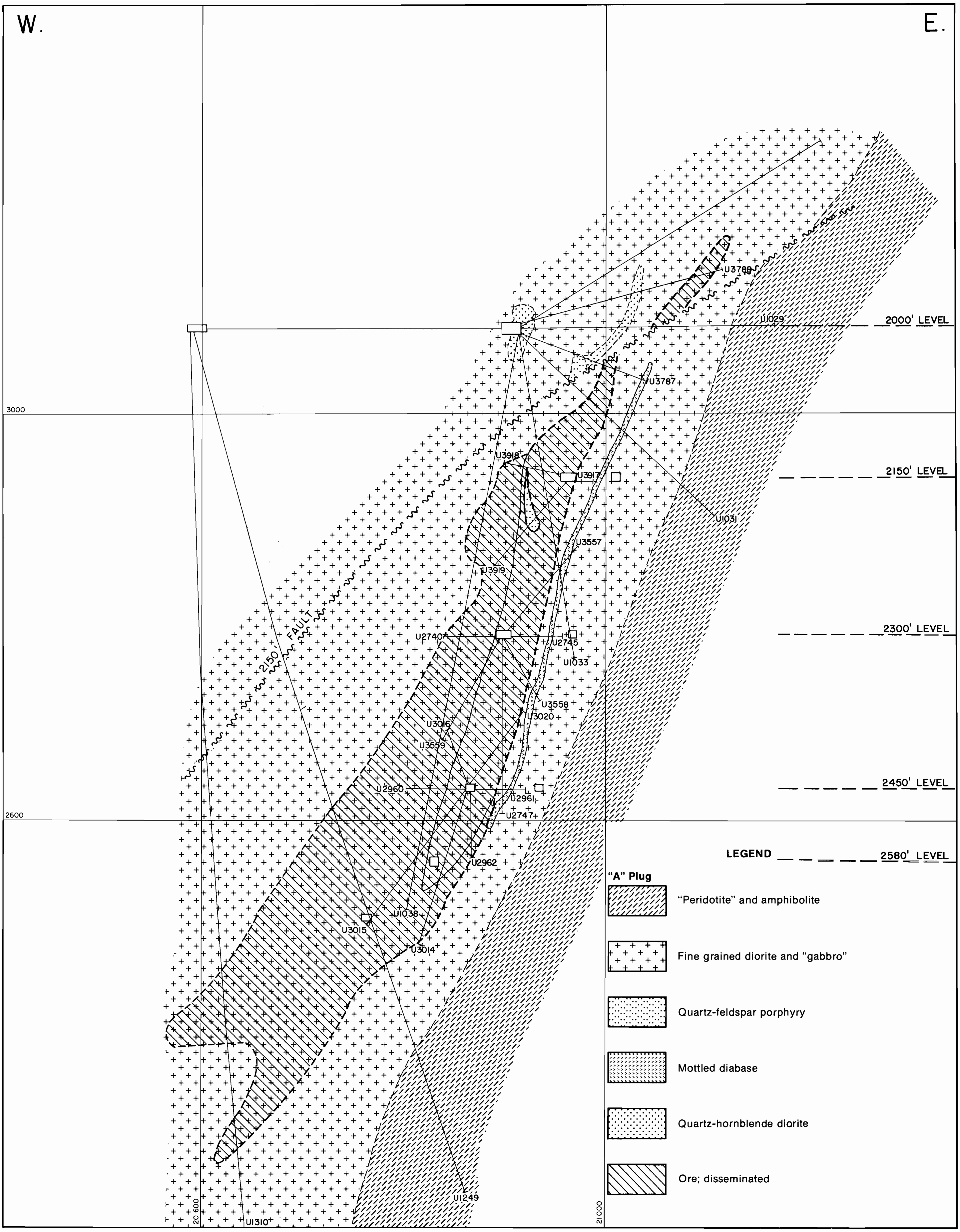


FIGURE A1.21 Lower "D" orebody, W40700E cross-section

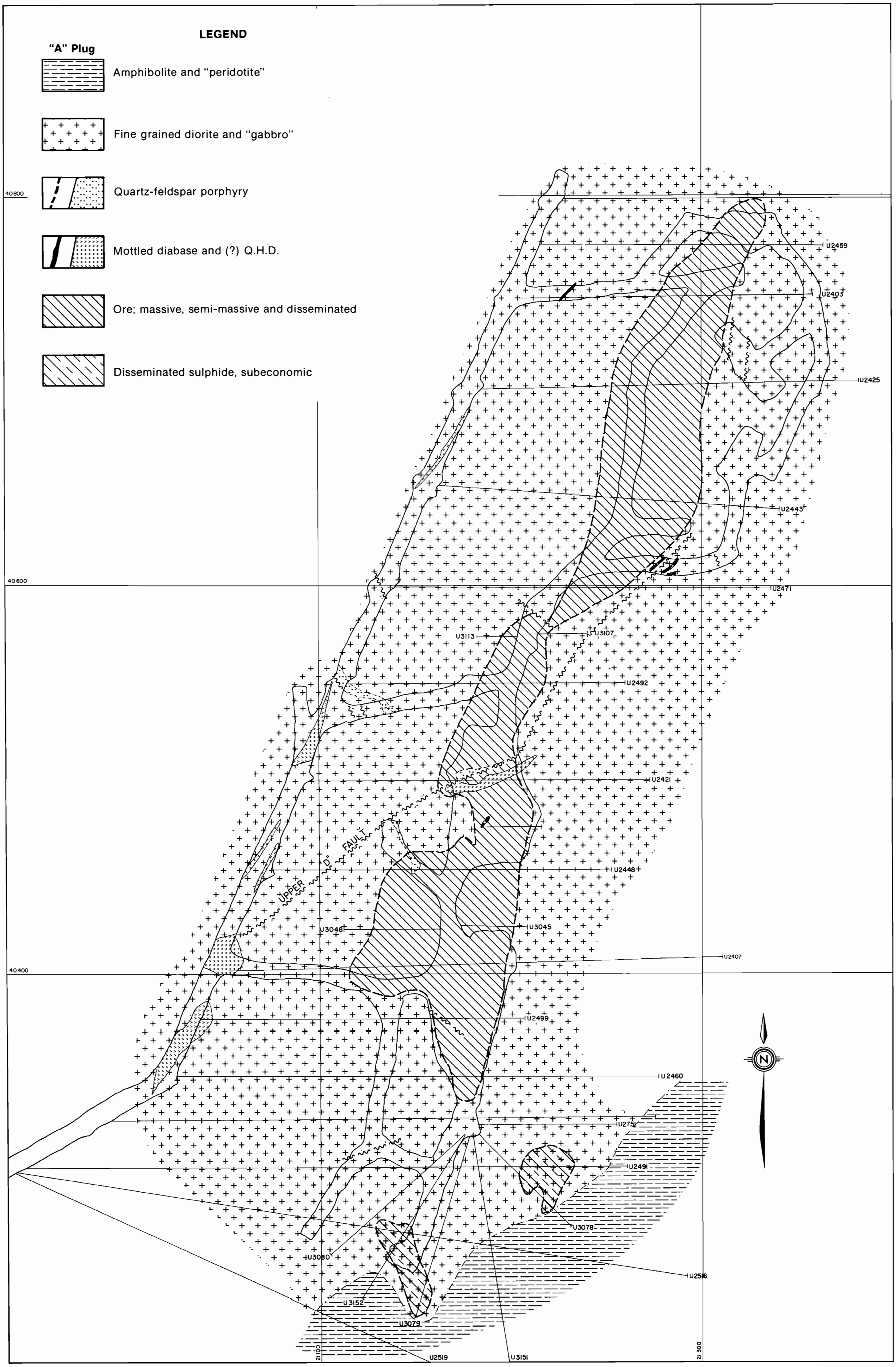


FIGURE A1.22 Upper "D" orebody, 15th level

The lens strikes N10° — 30°W and dips vertically for approximately 277 m. The orebody was accessed from the 1st, U/C, Scram, 2nd, 3½, 5th, 6th, 7th, 8th, 9th, 10th and 12th levels. The orebody consists of disseminated sulphide in "talcose amphibolite" and "peridotite", separated from the western contact of the "A" Plug by approximately 123 m of barren "amphibolite" and "gabbro".

The "J" orebody is located approximately 195 m SW of the "A" shaft on the 12th level (Fig. A.1.2). It extends from the 13th level to the 2000' level and it is accessed from the 14th (diesel haulage), 18th, 21st, U/C, and 2000' (drawpoint) levels, and the 13th, 14th, 16th, 17th, 19th and 23rd sublevels. The "J" orebody consists of a lens of mineralized amphibolite which strikes 10° — 30° W and dips 60° East. The orebody has its greatest strike length, 100 m, on the 14th level.

The "E" orebody is cut by the "Upper E fault", which intercepts the "E" orebody between the 1st and 4th levels. The upper portion of the "E" orebody, above the fault, has been offset 31 m to the northeast with respect to the main ore lens. A similar reverse fault, which either cuts or splays from the "Upper "E" fault" ("Contact" fault) intercepts the ore lens from 4th to 7th levels and proceeds to define the western contact of the ore lens at greater depths. A parallel fault ("Footwall" fault) defines the eastern contact of the ore lens from 7th to 11th levels, where both appear to be truncated by the "E-J" fault.

The "E-J" fault, which strikes N30°W and dips approximately 50° E, separates the "E" orebody from the "J" orebody, located *en echelon* 92 m to the NE (Fig. 2.1). The two orebodies are separated by approximately 100 m of barren amphibolite and "gabbro". According to Vellet (1963) the "J" fault is hard to trace in the "gabbro" but it occurs as a dominant shear at the base of the "E" and the top of the "J" orebodies.

The "J" orebody, which has a generally easterly dip, is cut by a reverse fault which strikes N40°E and dips 55°SW between 14th sublevel and 19th level. The fault off-sets the upper part of the "J" orebody approximately 30 m to the east of the lower portion. The Upper "J" ore lens, above the fault, is sheared against"peridotite" by movement on the "E-J" fault. The orebody is faulted out against "peridotite" in the hanging wall of the fault, and "peridotite" controls the eastern contact of the orebody in the upper levels of the "J" orebody (Fig. A.1.24). The western contact of the "J" ore lens, above and below the reverse fault, is partially controlled by an irregular body, or dyke, of Q.H.D.

The lower portion of the "J" orebody, below the reverse fault, consists of an easterly dipping lens of mineralized amphibolite in a mixed assemblage of barren amphibolite and "gabbro" which can be traced from the 14th level to the 2000' level.

The western contact of the "E" orebody is partially controlled by a body of diabase or Q.H.D., which is sheared along the "contact fault". According to Vellet (1963), the dyke intruded the "A" plug and was sheared prior to "emplacement of the (ore) lenses", and was subsequently disrupted by later movement which also deformed the "E" orebody. Similar dyke material in the "J" orebody also pre-dates mineralization, as Q.H.D. fragments occur in pods of sulphide breccia ore (Vellet, 1963). However, its distribution below the 18th level, in the lower portion of the "J" orebody, suggests that it inter-fingers with mineralized amphibolite and that branches cut the orebody. The "E" and "J" orebodies are both cut by dykes of uralitized mottled diabase, and the distinction between Q.H.D. and younger mafic dyke material is difficult. The two rock types may be locally mixed in the mine plans. The orebodies are also cut by veins of quartz-feldspar porphyry (Q.F.P.).

The ore in the "E-J" ore zone consists largely of fine disseminated sulphide in "amphibolite" and "gabbro". According to Vellet (1963) the disseminated sulphide concentration increases in the core of the "E" ore lens and occasional massive sulphide lenses occur along the west wall. The two ore types are gradational.

Early mine plans show that the core of the main body of the "E" orebody consists of a lens of altered "peridotite" enveloped by talcose amphibolite. "Peridotite" was not identified in drill core during the present study. Vellet (1963) concluded that the "E" orebody was a deformed lens of ore-bearing intrusive pyroxenite which may have had a "peridotite" core. He considered that the "E" orebody was probably developed late in the history of the "A" plug, in view of its close association with dykes and faults. The "J" orebody is similar. It contains disseminated sulphide in amphibolite with local concentration of massive sulphide and sulphide breccia near lens contacts.

The "E-J" orebody is intimately associated with an irregular body of "A" plug "gabbro" or diorite which appears to intrude host amphibolite between the western contact of the "A" plug and the large mass of "peridotite" which lies immediately east of the "E" orebody (Fig. 3.1) above the "E-J" fault. The nature of the "peridotite" contact with amphibolite is uncertain. Although shearing has occurred along its length, the talcose nature of the adjacent amphibolite suggests an affinity with the "peridotite".

"F-K" OREBODIES

The "F" and "K" orebodies are two fault-disjointed components of a single ore pipe.

The "F" orebody is located 430 m NW of the Farley Shaft and 860 m due south of the "A" shaft (Fig. 2.1). The orebody was accessed from the 950' (12th level) and the 1250' (draw point) levels in the Farley Mine and sublevels at 850',1050' and 1150'. The"F" orebody extends from the No.1 fault on the 950' level to the "F-K" fault on the 1700' level. It is probably the uppermost section of the "K" orebody, and the "F" (east) lens is a vertical ore shoot from the underlying "K" orebody, accessed from the 1700' and 1850' levels and the 1470',1626' and 1775' sublevels in the Farley Mine.

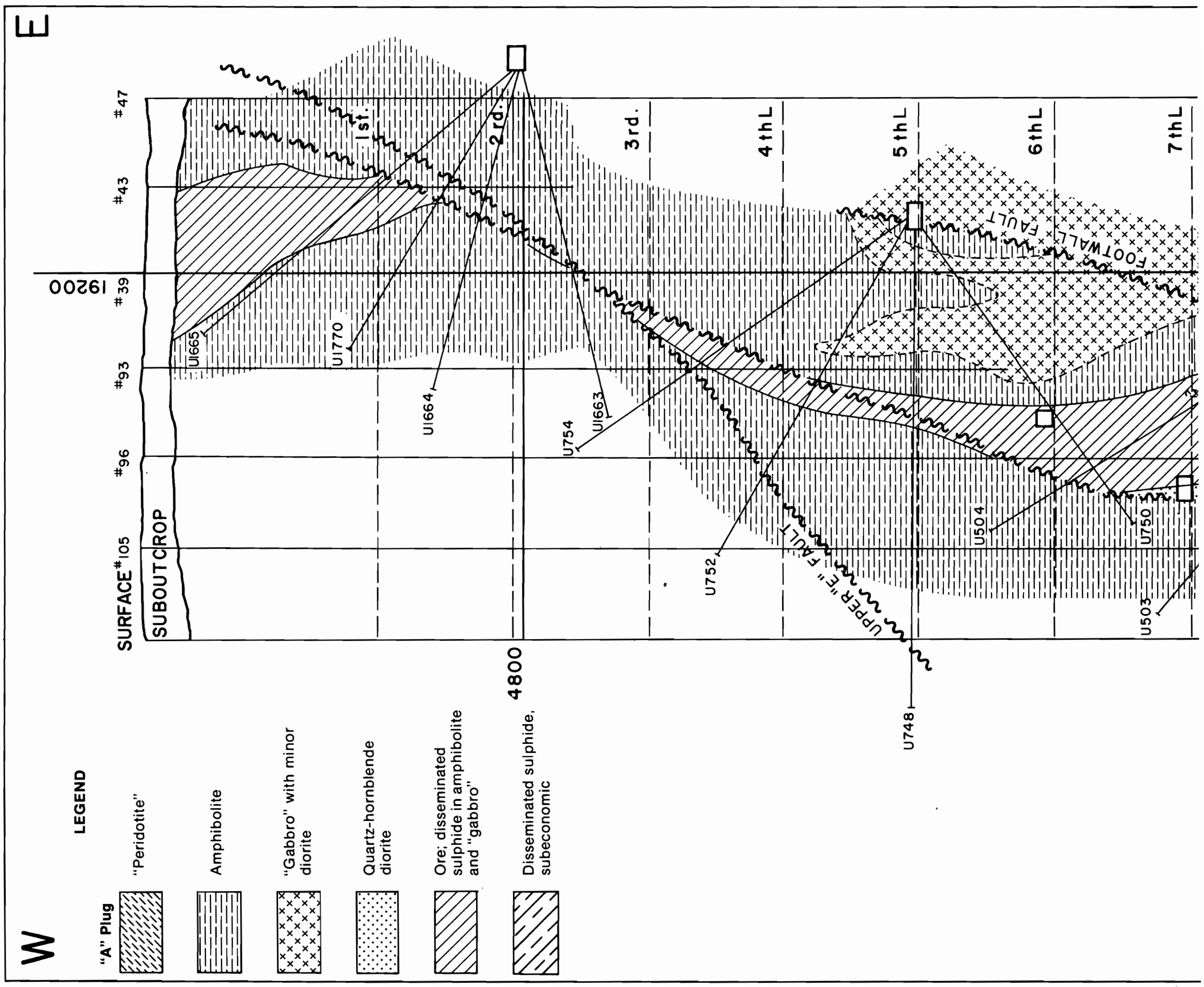
The "K" orebody is located approximately 340 m west of the Farley Shaft and 1000 m south of the "A" shaft. The orebody extends from the "F-K" fault on the 1550' level to the 3000' level. It was accessed from the 1550', 1850', 2000', 2100', 2200', 2300', 2600' and 3000' levels, and the 1700', 1775', 1910', 2520', 2700' and 2880' sublevels of the Farley Mine.

The orebody consists of two parts: the Upper "K" orebody, between the "F-K" fault on the 1550' level, and the "K" shear on the 3000' level.

The zone of economic mineralization which comprises the main "F" orebody is located in a pipe (80 m in diameter on the 950' level) of weakly mineralized amphibolite and "gabbro". The "F" ore pipe trends S35°E and plunges to the SE at approximately 50°. It lies within an embayment between two limbs of a large body of Q.H.D. The limbs strike NW and dip towards the NE. They coalesce at the north end of the orebody and Q.H.D. underlies the ore pipe down to the 1550' level (Fig. A.1.13). A similar relationship occurs in the underlying "K" orebody. The "F" orebody is cut by high-angle reverse faults and the ore occurs in discontinuous lenses between the faults (Fig. A.1.25, A.1.26).

The No.1 fault and related splays, which strike N35°W and dip 60° SW, thrust Q.H.D. and "peridotite" over the main ore zone (Fig. A.1.25). The "F" orebody was not mined above the No.1 fault and there is no record of the "F" orebody on the surface plan (Fig. A.1.1). The dip and strike of the "peridotite" body located to the west of the "B", "B-K", and "F-K" ore zone is discordant to the SE plunge of the "F" orebody and the two are inferred to intersect above the No. 1 fault. It is not entirely clear whether this "peridotite" body pre- or post-dates mineralization, but it may cut out the upper "F" orebody above the No. 1 fault. The weak mineralization found in the "peridotite" body above the No. 1 fault on the 950' level ("H" zone) is probably secondary in origin.

The "F" orebody is cut by several imbricate faults, which are parallel to No. 1 fault, and by faults that are related to the "porphyry shear", a major fault which intersects the "B" orebody to the south.



A complete version of Figure A1.23 is included at the end of this file.

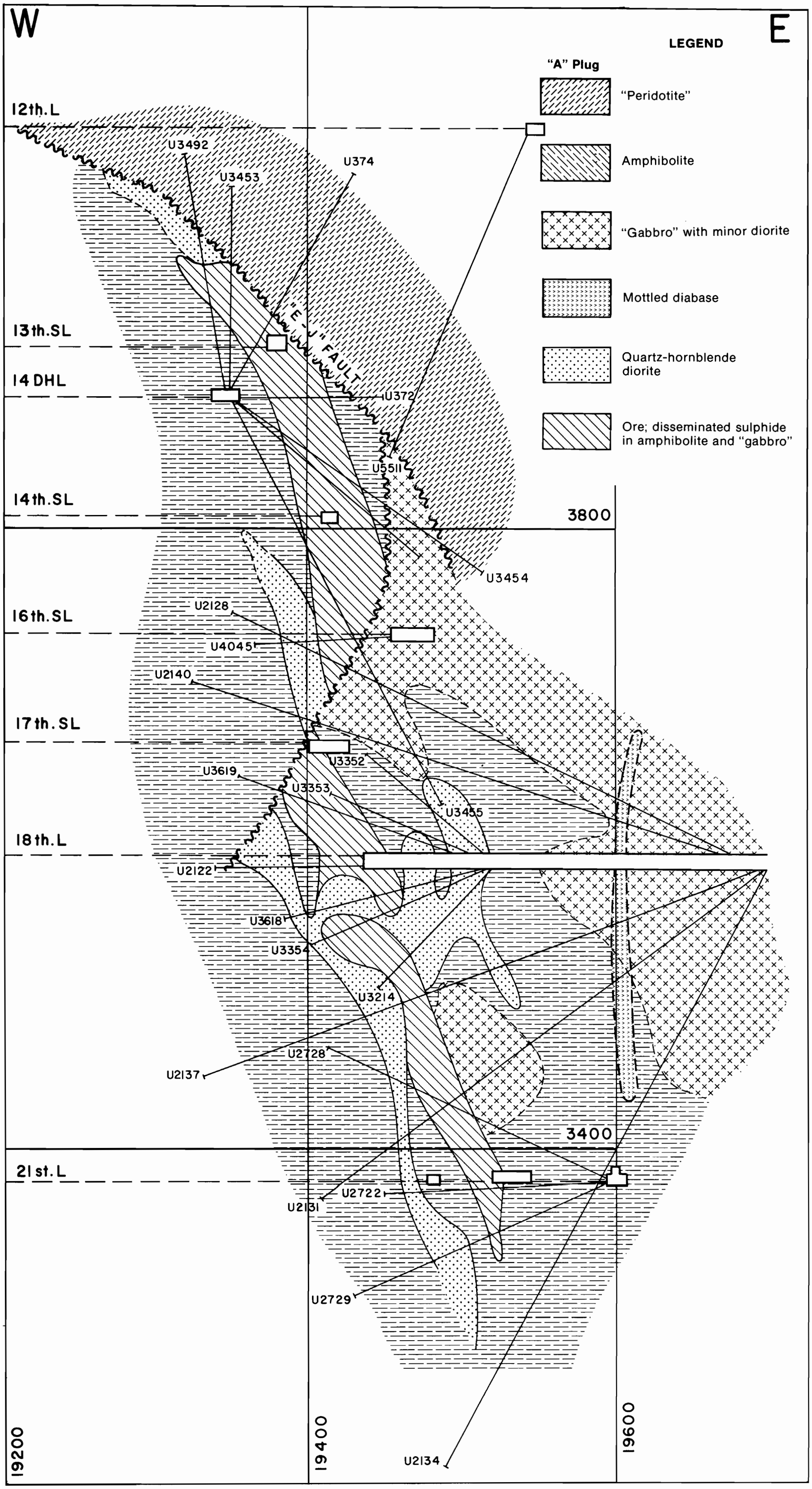


FIGURE A1.24 "J" orebody, W39050E cross-section

The imbricate faults strike approximately N30°W and dip 50° — 70° SW. They are probably also related to faults which cut the "B" orebody. The Lower "F" fault zone cuts the "F" orebody between the 1250' level and the 1550' level, and the "F-K" fault, which is a possible equivalent to fault No.4, cuts the ore pipe between the 1550' level and the 1850' level (Fig. A.1.26).

The orebody is also cut by the "F" fault, which strikes N30° E and dips 70° NW. This fault undercuts the "F" ore pipe from the 950' level to the 1550' level. Combined movement on the two fault systems caused a partial fault-gap between the main body of the "F" orebody above the "F" fault and the "K" orebody below the "F-K" fault. The orebody is much reduced between these levels.

The Upper "K" orebody consists of a mineralized pipe, approximately 45 m in diameter, which plunges to the SE (Fig. A.1.27). The pipe intrudes "gabbros" and amphibolites adjacent to a large mass of "peridotite" and it is located between two dykes of Q.H.D. The Q.H.D. dykes coalesce to form one body which strikes N30°W immediately to the north of the orebody and the ore pipe is located at this junction on the 1500' level. The ore pipe is weakly mineralized on the 1550' level. The ore occurs in lenses which parallel both the regional structural trend (N30°W) and the trend of a secondary structural feature analogous to the "F" fault and the porphyry shear (N45°W). The "F" east lens is located on the interface between barren "gabbro" and the NE limits of the Q.H.D. body. This lens is vertical (31 m x 6 m) and it can be traced downward to the 1920' level where it appears to merge with the main body of the "K" orebody. The Upper "K" orebody and the "F" east lens project upward to the "F-K" fault which strikes N30°W and dips 60° SW.

The Upper "K" orebody appears to plunge SE and it occurs as a SE elongate lens in plan section. The lens is 125 m x 50 m between the 1700' and 1775' levels. The Upper "K" orebody is cut by a fault which is parallel to the overlying "F-K" fault and the underlying "K" Shear, below the 1850' level. The Upper "K" strikes N30°W and dips 60° SW. The fault cuts the orebody on the 1920' and 2000' levels. Below the fault, on the 2100' level, the pipe retains its circular outline and 40 m diameter in the hanging wall of the "K" shear.

The Upper "K" orebody is a rnineralized pipe with a steep SE plunge that has been cut by a series of NW trending faults and has been thrust, in slices, to the NE. The pipe contains disseminated sulphide in amphibolite and gabbro, plutonic breccia and sulpide breccia ore, and veins of massive sulphide. The ore types are distributed irregularly within the pipe. It appears that the sulphide veining parallels the regional trend (N30°W) and occurs around the pipe contacts. The ore lens is intimately related with a body of Q.H.D. on the 2000' level and mineralization invades Q.H.D. along fractures. Q.H.D. contributes to plutonic and sulphide breccias.

The SE contact of the body on the 2000' level may be controlled by a fault similar to the porphyry shear. The Q.H.D. is steeply veined by quartz parallel to N45°E. No faulting was observed on the 2100' level.

The Upper "K" orebody is thrust to the NE on the "K" shear, which strikes N30°W and dips 60° SW. Below the "K" shear, the Lower "K" orebody constricts with depth and is funneled into a narrow lens between two Q.H.D. dykes. On the 2200' and 2300' levels the ore lenses lie along the dyke contacts. The orebody is reduced to a lens 50 m x 20 m on the 2450' level. The lens strikes N45°W and dips 60° NE. It projects down dip to the 2540' level where there is a flexure in the ore lens (Fig. 1.27). The flexure occurs where the SW and NE Q.H.D. dykes coalesce. The sulphide continues at depth as a sulphide breccia lens which is entirely enclosed by Q.H.D. The lens is 60 m long and 12 m wide on the 2700' level. It strikes parallel to the dyke which encloses it (N45°W), and it has a vertical dip. The sulphide breccia lens reduces to a sulphide vein parallel to the interface between a Q.H.D. body and host "gabbro" on the 3000' level (A.1.16). The Q.H.D. on the 3000' level contains "acid" varieties, aphanitic varieties and a "gabbroic" variety. The dyke continues at depth.

Below the "K" shear, the Lower "K" orebody is controlled by a prominent structure that strikes N45°W and dips 60° NE. The structure is defined by the NE contact of a Q.H.D. dyke and "gabbro". The Lower "K" orebody is reduced to a 1.5 m wide channel between the two dykes immediately to the SE of the orebody on the 2300' level. The channel joins the Lower "K" orebody to the "B-K" zone (Fig. A.1.15).

"G" OREBODY

The "G" orebody is located approximately 100 m south of the "E" orebody. It consists of narrow (15 m) lenses of moderate to low-grade Ni-Cu mineralization in "gabbro" and "amphibolite". The mineralization occurs in faulted, subeconomic lenses which strike N10° — 30° W and dip approximately 50° NE. The lenses are dislocated by a series of faults which have similar strike and a steep (70°) westerly dip. Mineralization extends from the 12th level, below the "E-J" fault, to the "porphyry shear" below the 3000' level. The mineralization displays an overall plunge towards the south.

The mineralized lenses are found in a mixed assemblage of "gabbro" and amphibolite which dips steeply to the east from the "E-J" fault to the 3000' level. The "gabbro" locally forms mineralized breccia zones in amphibolite, and weakly mineralized amphibolite extends from the 2000' level to the 3000' level. Barren "gabbro" is found with the amphibolite on the 2000' and 3000' levels. "Peridotite" occurs in the "hanging wall" of the "E-J" fault, above the "J" orebody, and as blocks or patches in the amphibolite found below the 3000' level. Traces of mineralization occur sporadically in amphibolites below the 3000' level. The base of the "G" orebody, which is down dip from the "J" orebody, has been drilled to a depth of 4500'. A lens of ore-grade amphibolite (Lower "G") occurs immediately to the east of the main 3000' level drift. The lens (75 m x 30 m) extends down dip for 100 m. It strikes N45°E and dips steeply (80°) NW. The lens is block faulted and structurally controlled. It is cut by shallow faults which strike N30°W and dip 30° NE, and it bottoms out on the "porphyry-shear".

"M-N" OREBODIES

The subeconomic "M" pipe and the "N" ore pipes are probably fault-disrupted counterparts of a single ore pipe which extends from the "O" fault, on the 4500' level, to subsurface outcrop. The "M" and "N" ore zones appear to lie above and below the Lynn Lake fault, which is known as the "Griffith Shear" in mine terminology (Fig. A.1.3).

The "M" zone is located approximately 1300 m SE of the Farley Shaft, close to the contact between "A" plug "gabbro" and country-rock Wasekwan volcanics. It is comprised of a 100 m diameter pipe of weakly mineralized amphibolite which cuts "A" plug "gabbro".

The "N" orebody is also located at the contact of the "A" plug and the Wasekwan country rock, 1100 m SE of the Farley Shaft. The "N" orebody extends from the "G riffith Shear" (on the 1600' level) to the "O" fault (on the 4500' level). It accessed from a winze (No.2 winze) sunk between the 2000' and 3000' levels in the Farley Mine. Drawpoints on the 2910' level were developed from an inclined drift from the 3000' level. The winze gave access to the Upper "N" orebody on the 2200', 2400', 2600' and 2800' levels and the 2500', 2700' and 2850' sublevels. The orebody was drilled off on the 1600' level (immediately below the "Griffith Shear") from a drift cut from the "O" orebody Alitrolley Service Raise. The Lower "N" orebody, below the 3000' level, was considered su beconomic at time of closure and it has not been mined. The Lower "N" orebody was drilled-off from a drift on the 3000' level, and a drift cut from the decline at the base of the "O" orebody on the 3530' level.

The Lynn Lake fault, or "Griffith Shear", defines the SW contact of the "A" plug on surface (Fig. A.1.1) and it controls the extent of the "M" pipe. The fault strikes N60°W and dips 50° NE, under the weakly mineralized "M" pipe (Fig. A.1.1). Mineralized amphibolite in the ore pipe appears to be thrust SW over Wasekwan country rock by

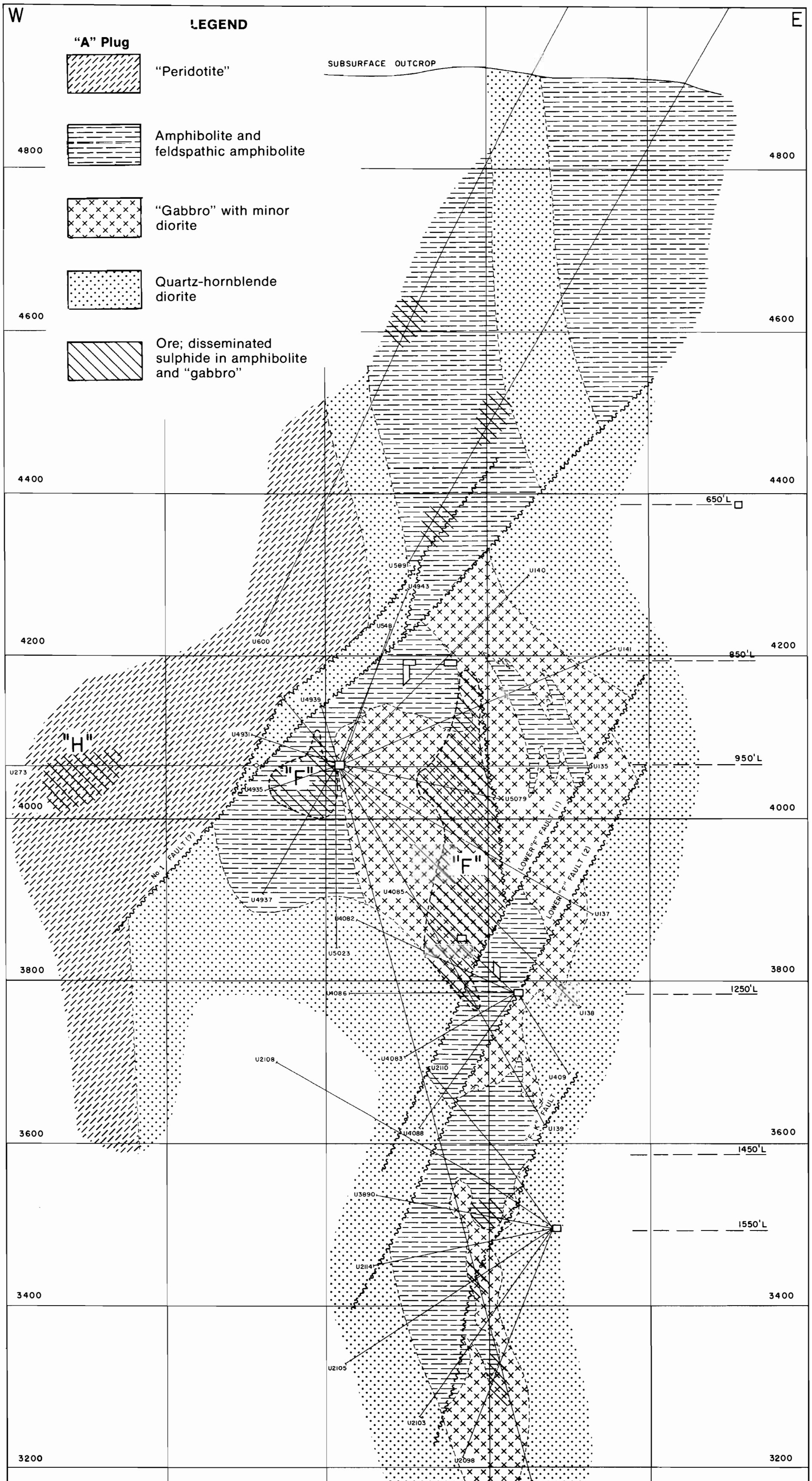


FIGURE A1.25 "F" orebody, W36550E cross-section

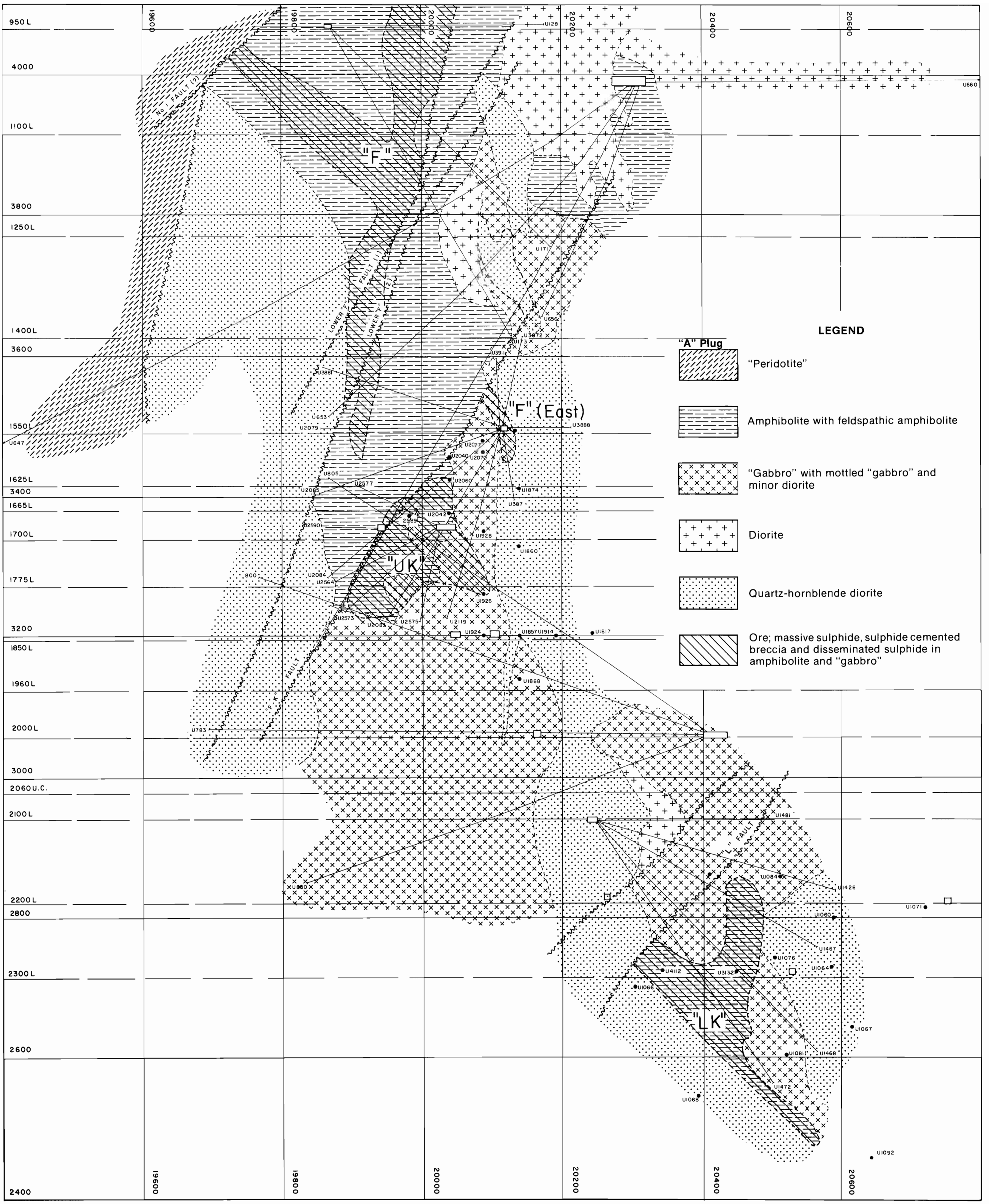


FIGURE A1.26 "F" and "K" orebodies, W36500E cross-section

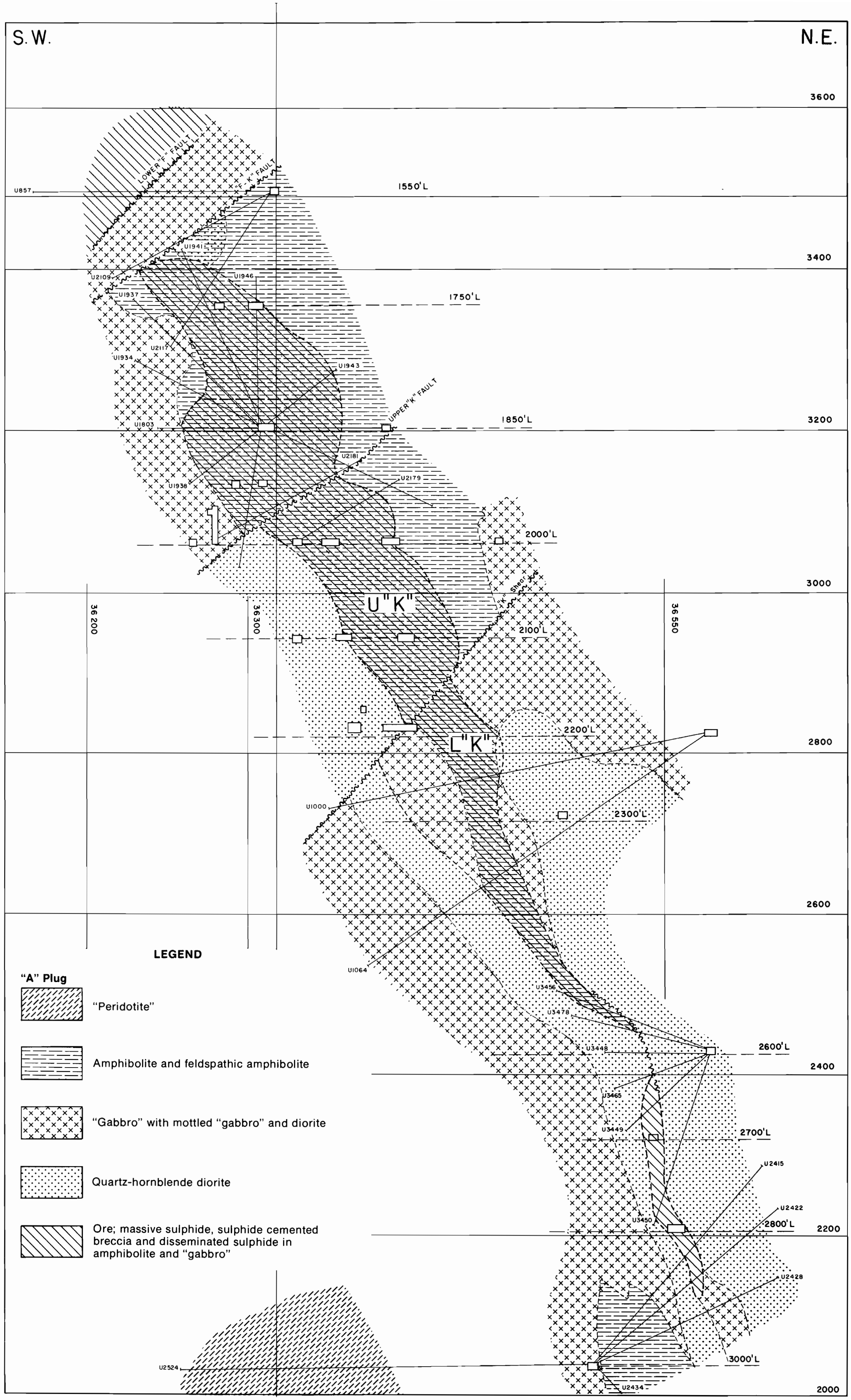


FIGURE A1.27 "K" orebody, No. 5-N61° W cross-section movement on the fault and the "M" pipe is truncated against country rock at a depth of 150 m.

Disseminated mineralization occurs in a lens of talcose amphibolite where "M-N" ore pipe comes in contact with "amphibolite" host "A" plug "gabbro". The "M" pipe contact is cut by a minor SW dipping thrust fault (strike N35°W, dip 50° SW) which has caused minor displacement of the "M" zone towards the NE. This minor thrust appears to be truncated by the "Griffith Shear". The "Griffith Shear" cuts country rock on the 800' level (Fig. A.1.3) and it appears to cut the vertical contact between country rock and "A" plug "gabbro" slightly above the 1600' level.

Weakly mineralized amphibolite and "gabbro" belonging to the "N" orebody are found in the "footwall" of a fault (N40°W, dip 45°NE), inferred to be the "Griffith Shear", 80 m NE of the "A" plug contact with the country rock. The "M" and "N" ore zones are probably faulted counterparts of the same pipe separated by approximately 550 m of southwesterly thrust, equivalent to approximately 400 m of horizontal displacement.

The "N" orebody consists of several discrete ore lenses in a pipe of norite, "amphibolite" and "gabbro". The pipe is cut by a large body of "peridotite" and a number of thrust faults and it is ill defined on all but the 2000' level, where it is crudely circular and approximately 250 m in diameter.

The "N" orebody has been cut by several thrust faults which strike N30° E and dip 30° NW. Movement on these thrusts displaces successively higher blocks of ore pipe to the SE. The thrust faulting post-dates intrusion of a major body of "peridotite" and a suite of mafic dykes, but it appears to predate movement on the overlying "Griffith Shear" and the underlying "O" fault. Movement to the SW on these two major faults has isolated the "N" orebody within a discrete thrust sheet.

Two minor NW dipping thrusts (50 m — 60 m apart) cut the "N" pipe between the 2600' — 3000' levels and the 2800' — 3200' levels, respectively (Figs. A.1.28, A.1.29 and A.1.30). These two faults, the "Upper 1730 shear" and the "Lower 1730 shear", separate the Upper and Lower "N" orebodies. The structure of the ore pipe differs considerably above and below the Upper 1730 shear.

The Lower "N" orebody (below the Upper 1730 shear) is cut by a 30 m — 60 m wide dyke or lens of "peridotite" which strikes N40° E and dips 70° NW. The dyke cuts diagonally across the "N" pipe and isolates a lens of mineralized amphibolite in its footwall (Fig. A.1.28). The mineralized amphibolite lenses below the "peridotite" have the same orientation as the lens itself. Weak mineralization occurs along the hanging wall contact of the "peridotite" lens (which has also been exploited by a mafic dyke) and it develops into the "N2" ore lens at the north end of the ore zone. The "N2" ore lens has a more vertical inclination than the "peridotite" dyke and it can be traced through the Upper and Lower shears into the Upper "N" orebody.

A second ore lens is cut out by the Upper 1730 shear, above the 3000' level. The "N1" ore lens is a complex zone of mineralization which strikes N45° E and dips 75° SE, the same orientation as 3 m — 5 m wide mafic dykes which occur on either side of the ore lens. The two sections of the ore lens found on the 3000' level are reduced to a single lens on the 3530' level and the mineralization was traced downward to the 4200' level, where it was cut out by the "peridotite" dyke. Both the dyke and the ore lens are cut by the "O" fault on the 4500' level (Fig. A.1.29). Mafic dykes cut the ore lens and the "peridotite" body, and all appear to be discordant to the country rock contact.

The Upper 1730' shear, which cuts the "N" orebody above the "N1" and "N2" drawpoints on the 2910' level, marks the lower limit of mining in the "N" orebody. Above the shear, the "N" ore lenses occur in a faulted, subcircular, pipe approximately 215 m in diameter. The eastern limit of the pipe is ill defined on the lower levels but, by the 2000' level, the "peridotite" dyke has cut through the "N" pipe into "A" plug "gabbro" and amphibolite, where it strikes N30°W and dips 75°SW. Faulting has strongly modified the orientation of both the "peridotite" and the mafic dykes which cut the "N" ore pipe. Both show considerable rotation from a northeasterly to a northwesterly strike, possibly as a result of curvature on the controlling faults.

The "N1" ore lens consists of a large body of disseminated sulphide in uniform feldspathic amphibolite on the 2800' level (Fig. A.1.32). The lens strikes NW and it passes into patches of subeconomic, weakly mineralized amphibolite and gabbro which can be traced into the "N2" lens which, on this level, is partially dislocated by the Lower 1730 shear. The core of the "N" pipe between the "N1" and "N2" lenses is composed of amphibolite and a large amount of "gabbro". The "N1" zone is much expanded on the 2600' level (Fig. A.1.31) and it consists of a western zone ("N1" [W]), which is an extension of the above SW dipping lens, and an eastern zone ("N1" [E]), which dips to the NE. The two zones are partially joined in the south and they represent portions of a single ore lens "rolled" over the top of the intervening body of "gabbro" in the core of the "N" pipe (Fig. A.1.28). The two lenses coalesce into a flat or weakly SW dipping lens of ore between the 2600' and 2400' levels (Fig. A.1.28). The "N1"(E) is probably connected to the "N2" lens, although deformation in the eastern section of the orebody is intense and its relationship is obscure. Above the 2400' level the combined "N1" lenses project upward to the NE to join the "N2" lens in a single ore lens ("N4") on the 2000' level. This lens (60 m x 30 m) can be traced across a number of steep thrusts to the 1600' level, where it is cut out by the Griffith Shear. The "N4" lens, on the 2000' level, is an isolated mineralized lens in a body of barren amphibolite and pyroxenite.

"O" OREBODY

The "O" orebody is located 770 m SW of the Farley Shaft (Fig. 2.1) within a pipe of barren and mineralized amphibolite and feldspathic amphibolite (Pinsent, 1977a) intruded into normal "A" plug "gabbro". The pipe, which contains the orebody, has been traced from the "O" fault on the 3550' level to the Griffith shear on the 1600' level. The ore pipe has been faulted into two discrete ("Upper" and "Lower") portions by movement on the "Dyke Shear" (Fig. A.1.33).

The Upper "O" orebody was accessed on the 1600', 1740' and 1860' levels by alitrolley lift from the 2000' in the Farley Mine. It was also accessed by means of a drift cut from the No. 2 Winze on the 2400' level, and a sublevel at 2200'.

The Lower "O" orebody was also accessed from the No. 2 Winze on the 2800' level and the 3000' level in the Farley Mine. A decline was driven from the 3150' level, at the foot of the Farley shaft, to the lowermost stope on the 3550' level and the "O" crusher on the 3700' level. An incline was cut from the 3000' level to drawpoints on the 2950' level. The "U500", a lift between the 3000' and 3550' levels, gave access to the 3140', 3270' and 3400' levels. Sublevels were put in at 2700' and 3060'.

The Upper "O" orebody extends from the intersection, slightly above the 1600' level, of a westerly dipping reverse fault (No.1 shear) and a splay from the easterly dipping Griffith shear (Griffith splay). The two faults, which strike approximately 50°W, define an ore lens (154 m x 31 m) which extends down to the No. 4 shear slightly above 1860' level (Fig. A.1.33). The hanging wall extension of the "O" orebody, above the Griffith Shear, has not been located. A possible correlation of dyke material indicates hanging wall movement of approximately 370 m towards the SW.

The Upper "O" ore pipe appears to consist of two subcircular pipes (approximate diameter 77 m) below the No.4 shear, between the 1860' and 2200' levels. The pipes are joined about an axis oriented NE-SW, perpendicular to the main fault trend (Pinsent, 1977a). The orebody appears as a single pipe (diameter 92 m) in the hanging wall of the "Dyke Shear" on the 2400' level, as the eastern pipe is cut out by movement on the fault. The structure of the "O" ore pipe is complicated by a number of reverse faults which cut the pipe between 1860' and 2400' level. (Fig. A.1.33). The main shears (No. 2, 3 and 5) are minor faults which appear to be curved splays from the underlying "dyke shear". They strike roughtly N-S and they dip to the west. The dip, which is approximately 45° in the ore pipe, appears to steepen considerably in the host gabbro to the east of the ore pipe, possibly in response to drag caused by movement on the overlying Griffith Shear. Movement caused hanging wall ore blocks to be thrust NE with respect to footwall ore blocks.

The composite "O" pipe plunges steeply to the SE and intercepts the "dyke shear" between the 2100' and 2800' levels. The "dyke shear" is a complex post-ore fault zone (strike N-S and dip 40° west) which has been exploited by two aphanitic mafic dykes. Both the dykes and the shear are steepened to near-vertical in the footwall of the Griffith Shear, east of the orebody.

The Lower "O" pipe is separated from the Upper "O" by approximately 92 m of slip on the "dyke shear". The Lower "O" pipe is a single, crudely circular (107 m diameter) pipe (Fig. A.1.34) which maintains a steep SE plunge between the footwall of the dyke shear, on the 2800' level, and the hanging wall of the "O" fault, on the 3550' level. The NE contact of the ore pipe is strongly sheared and it is probably controlled by the Footwall "O" fault (Fig. A.1.33) which merges into the dyke shear above 2400' level. The pipe is cut out by the "O" fault below the 3550' level.

The Upper "O" ore pipe contains several mineralized lenses. These consist of disseminated sulphide ores (ore-type 1), plutonic breccia ores (ore-type 2), sulphide breccia ores (ore-type 3) and veins of massive sulphide (ore-type 4). Plutonic breccia ore is the most abundant ore-type on the 2000' levels. Ore-grade lenses can be traced through the thrusted fault blocks from the 1860' to the 2400' levels. Mineralized lenses in the amphibolite pipe appear to be controlled by the contacts of the ore pipe with "A" plug host "gabbro" and by a NW-SE fracture set. The ore lenses in the main, easterly pipe are controlled by the west and east contacts of the pipe with "A" plug "gabbro" on the 2000' level. The two lenses are separated by subeconomic amphibolites and "gabbros". The lenses in the westerly pipe on the 2000' level are partially controlled by a NW-SE trending structure. They are probably part of a weakly mineralized offshoot from the main, easterly pipe. Mineralized amphibolite is cut by narrow off-shoots from a mafic dyke in the "dyke shear" on the 2000' and 2200' levels.

The Lower "O" orebody, below the "dyke shear", consists of lenses of plutonic breccia and disseminated sulphide ore concentrically oriented with respect to the interface between the "O" ore-pipe and the "gabbro" host contact. Economic mineralization is restricted to two ore lenses on the NW and NE interface between host "gabbro" and ore pipe amphibolite. The situation on the 3270' level is complicated by a minor fault which offsets the pipe, and a disrupted dyke of granite or "hybrid" (strike N20°W, dip 50° NE) sub-parallel to the underlying "O" fault. The "hybrid" dyke was also found on the 3400' level. The main body of the pipe on this level consists of weakly mineralized amphibolite and plutonic breccia. Ore-grade mineralization is restricted to the pipe contact. The lower grade western lens and the higher grade eastern lens, found at higher levels in the pipe, appear to coelesce at around the 3400' level and the 3550' level stope is composite. The "O" fault cuts the SW corner of the ore pipe on the 3400' level. It strikes N45°W and dips 45° NE, under the 3550' level stope.

The "N3" lens is structurally distinct, and it may occur within a satellite pipe adjacent to the main "N" pipe, rather than within the pipe itself. The "N3" lens is an off-shoot from the "N1" (W) lens on the 2800' level. It is comprised of a circular pipe of mineralized amphibolite (30 m — 60 m in diameter) located immediately adjacent to the country rock. The pipe projects vertically to the 2000' level. The "N3" pipe is separated from the "N1" (W) lens by barren amphibolite and a silicified "gabbro". The ore lens is cut, and partially enveloped by, hybrid material and Q.H.D.

"P" OREBODY

The "P" orebody is located 680 m SW of the Farley Shaft and 185 m NW of the Lower "O" orebody on the 3000' level. The "P" orebody was mined between the 2800' and 3000' levels and it was accessed from the Farley Shaft on the 3000' level and the 2nd Winze on the 2800' level.

The "P" orebody extends from a splay from the "dyke shear", on the 2800' level, through a series of imbricate faults related to the "dyke shear" into a body of weakly mineralized "gabbro" on the 3500' level. Mineralization appears to terminate 50 m above the "O" fault (Fig. A.1.35). The orebody is cut by a suite of mafic dykes which strike N10° E and dip 60° W. The dykes are probably off-shoots from the "dyke shear" diabase dyke. The "P" ore lens, which is approximately 100 m long and 30 m wide, has been disrupted by a variety of faults and it appears to die out above the 2800' level. The relationship between the "O" and "P" ore zones remains unclear.

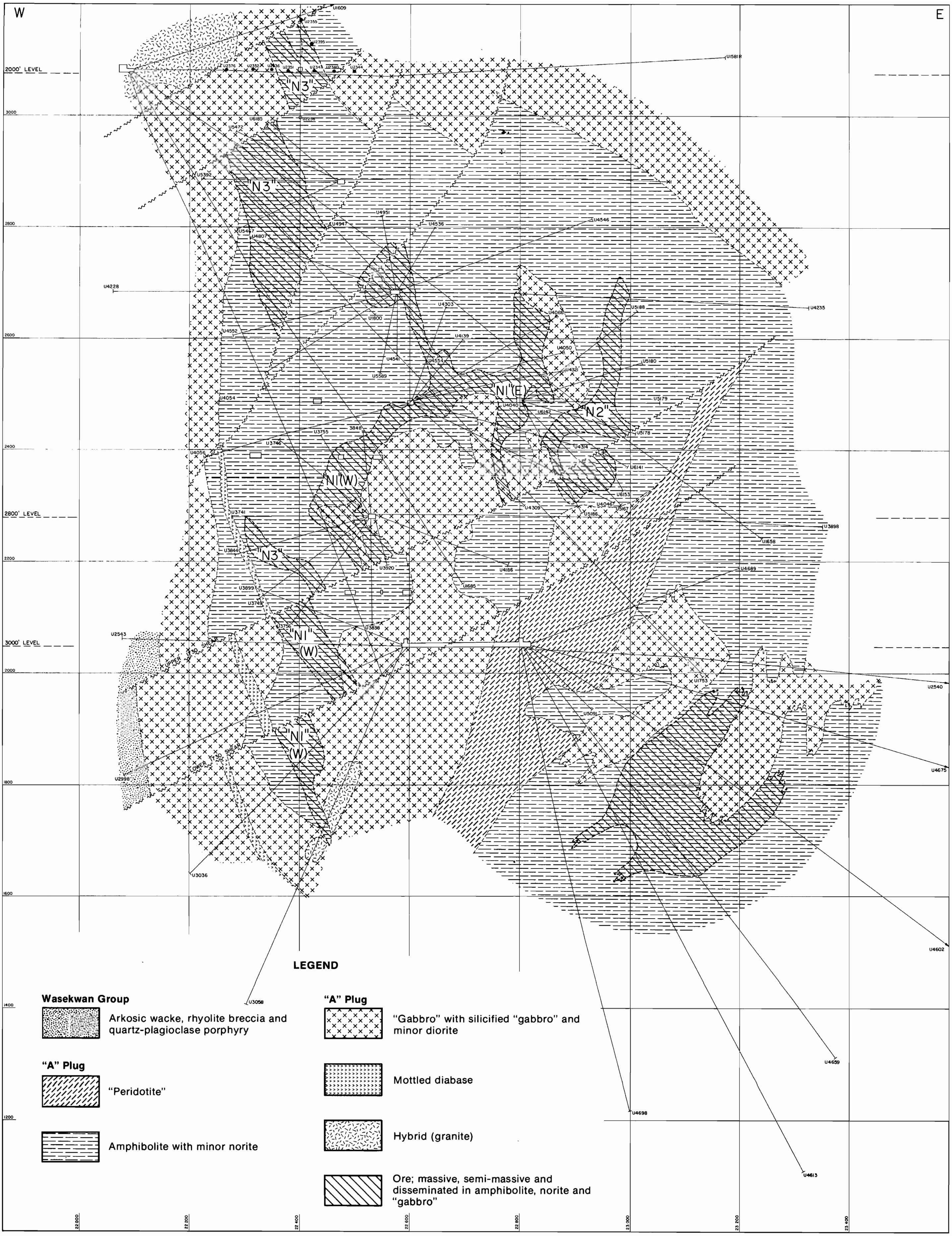


FIGURE A1.28 "N" orebody, W32500E cross-section

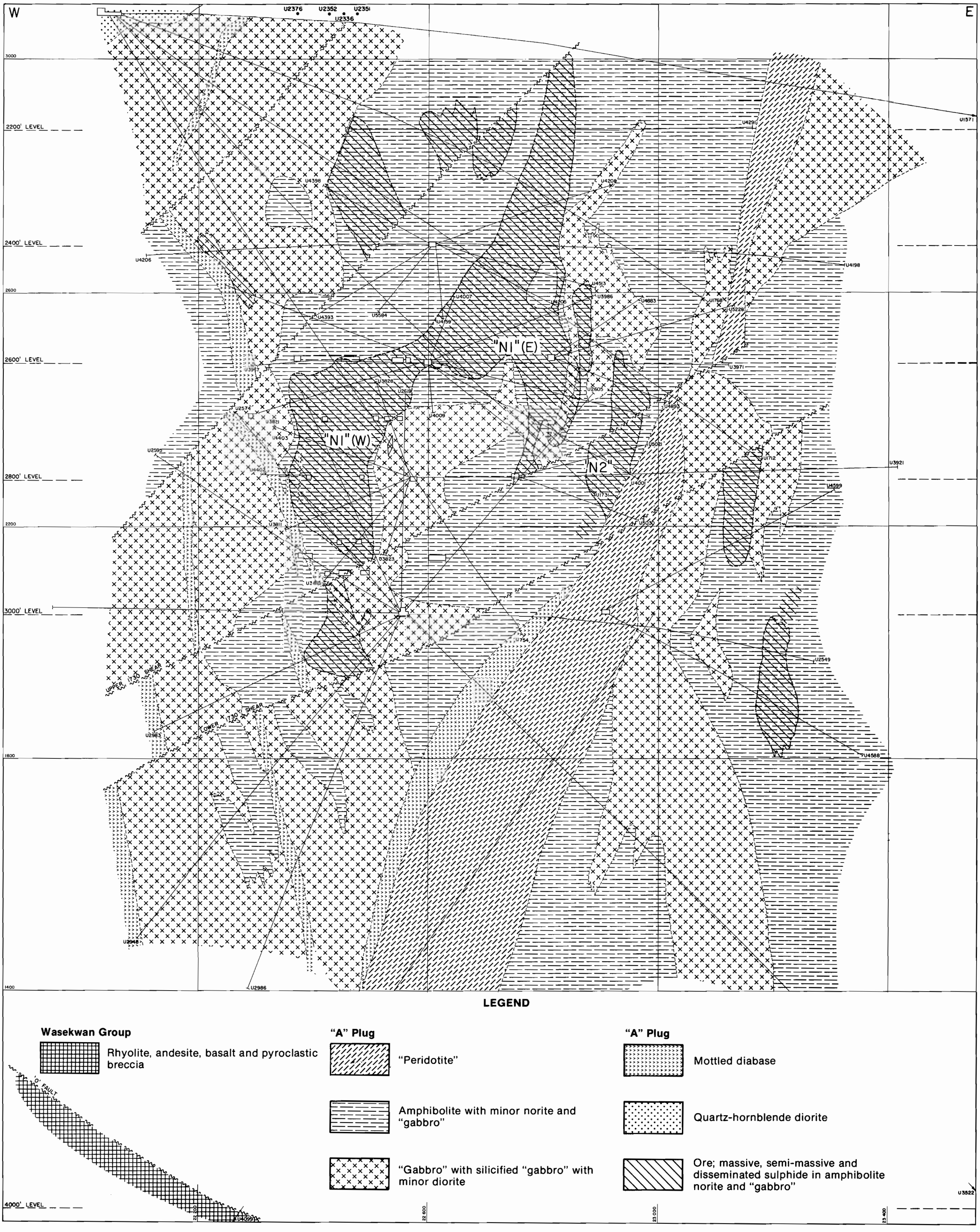


FIGURE A1.29 "N" orebody, W32600E cross-section

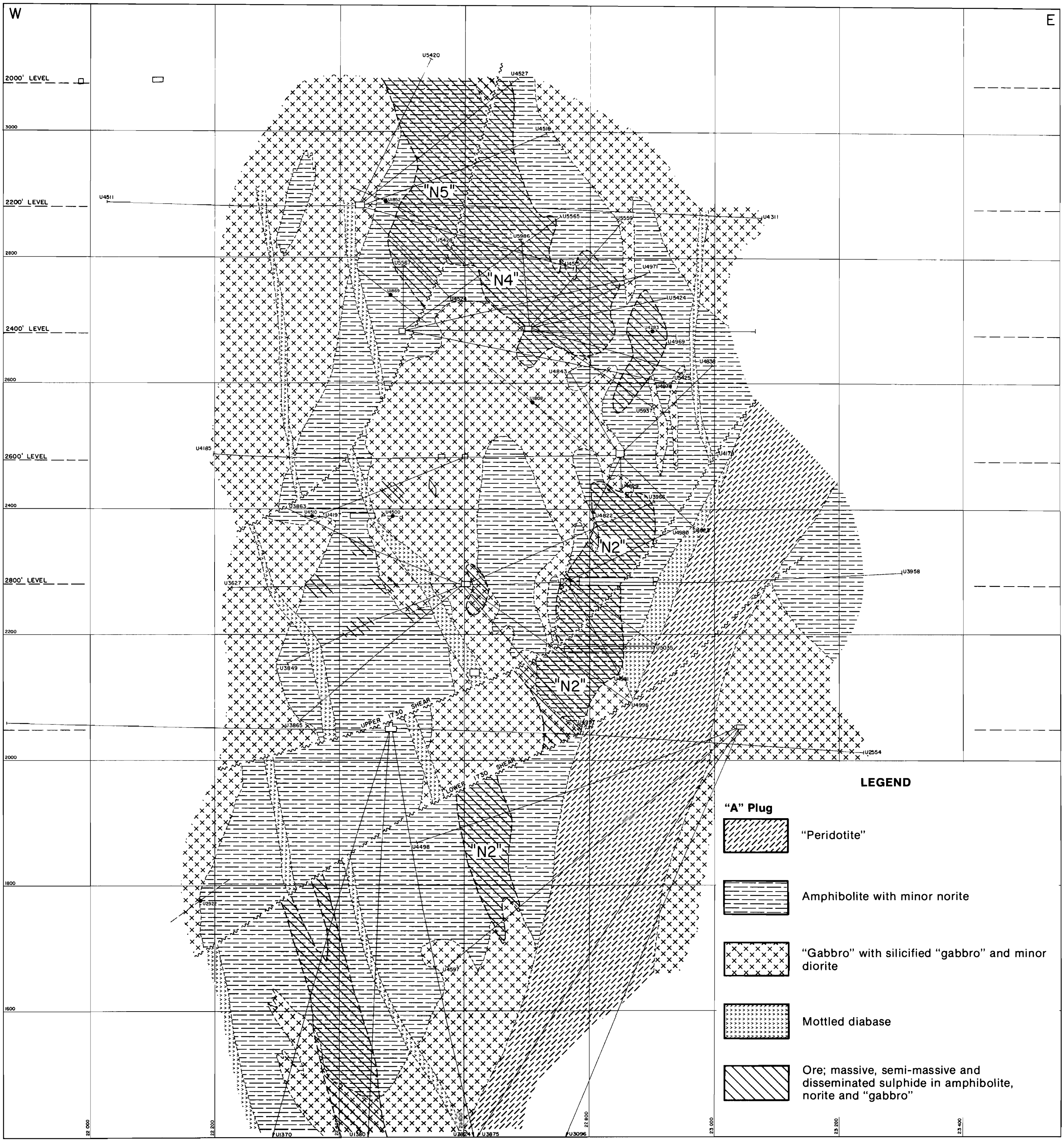


FIGURE A1.30 "N" orebody, W32800E cross-section

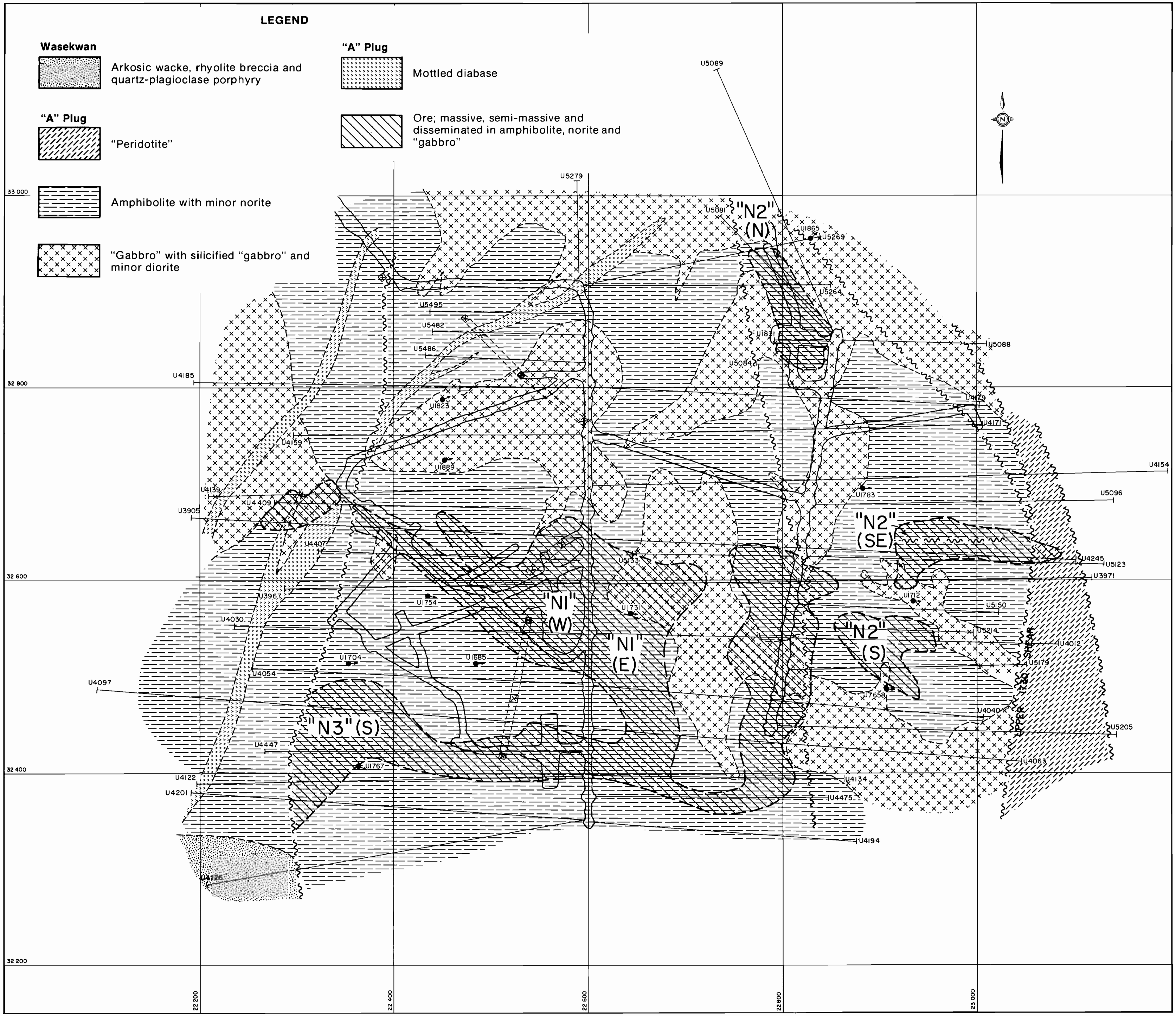


FIGURE A1.31 "N" orebody, 2600' level

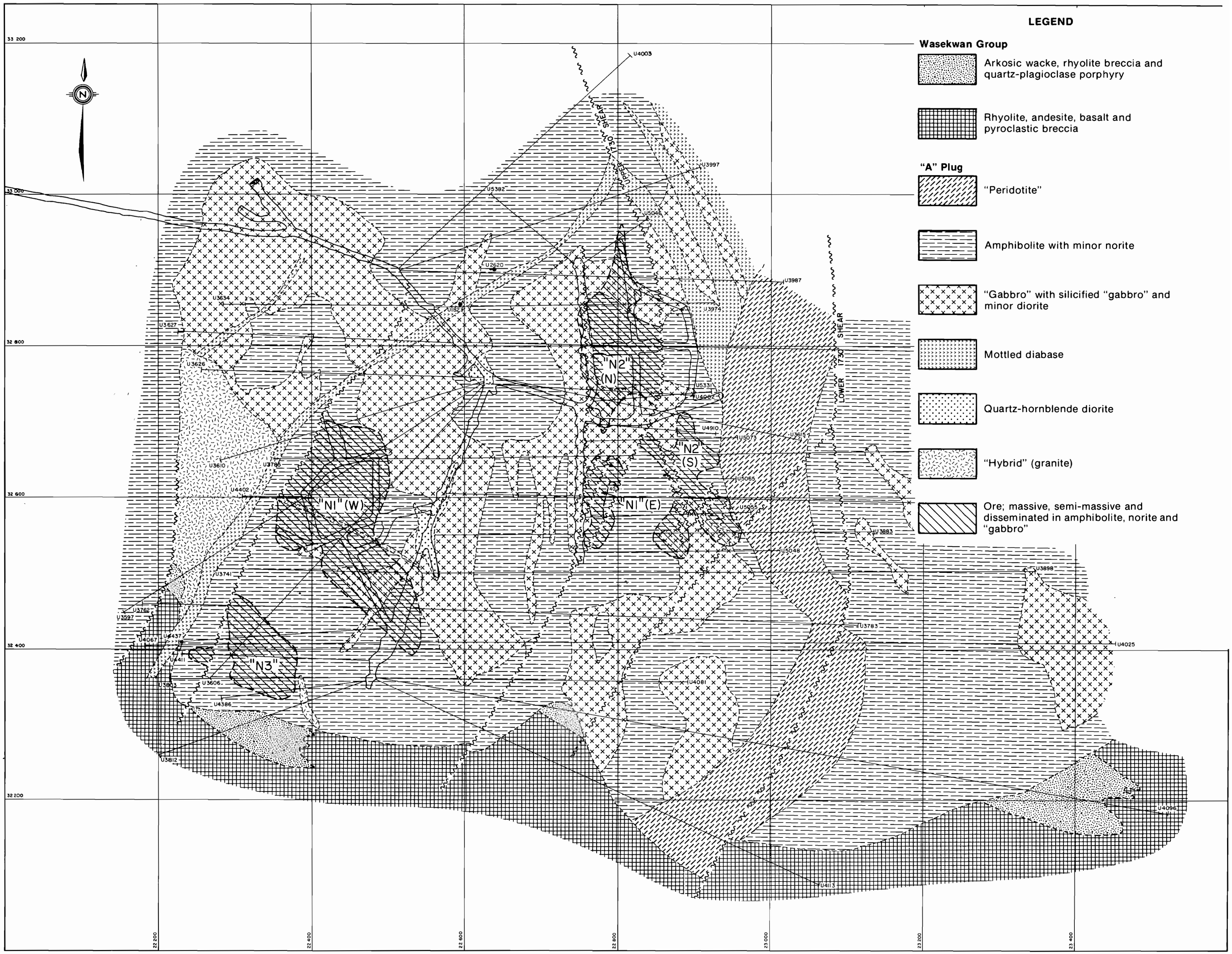


FIGURE A1.32 "N" orebody, 2800' level

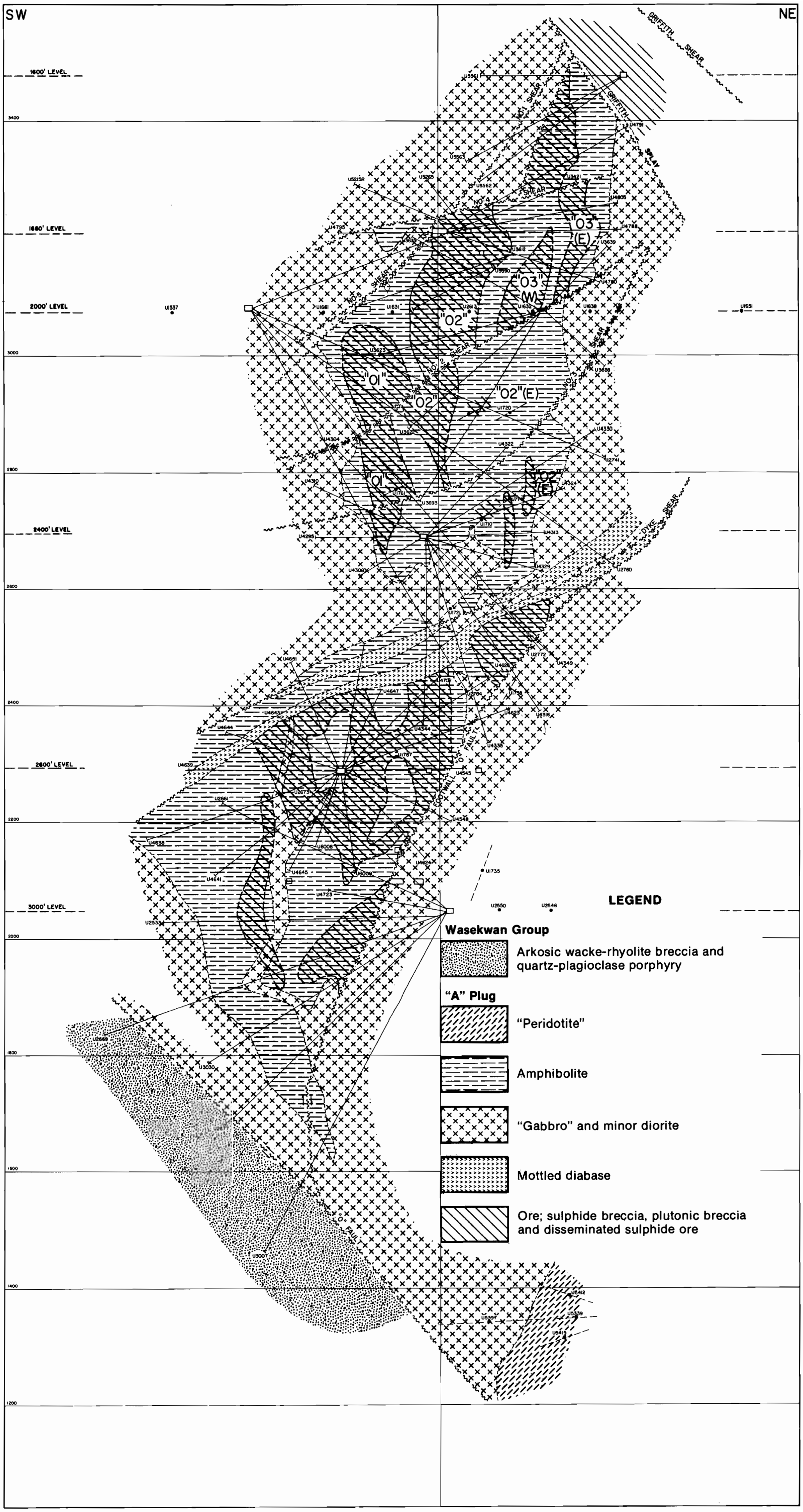


FIGURE A1.33 "O" orebody, No. 22-N55° W cross-section

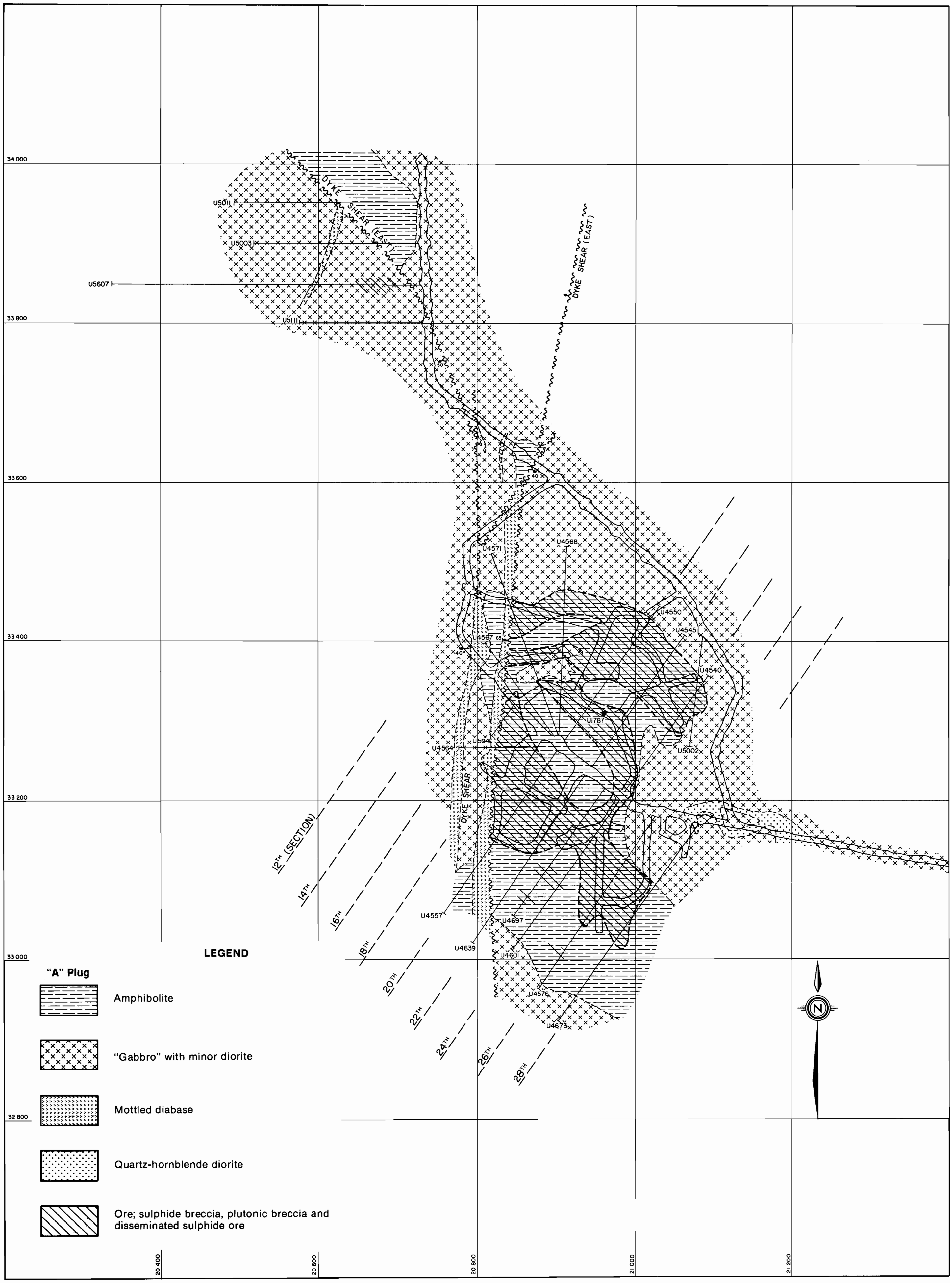


FIGURE A1.34 "O" orebody, 2800' level

FIGURE A1.35 "P" orebody, W33900E cross-section

APPENDIX 2
Analytical Data, Lynn Lake Samples

2.2 Raw Data — oxide weight percent
2.3 Normalized Data — CIPW norms.

RAW

		X657 57-77- 17	X658 57-77- 28	X659 57-77- 33	X660 57-77- 39	X661 57-77- 43
	SIO2	45.95	72.40	72.85	46.50	46.25
	AL2O3	13.65	12.56	13.20	16.13	10.01
	FE2O3	12.36	0.84	0.45	0.69	14.58
	FEO	0.0	3.00	2.92	6.94	0.0
	CAO	10.22	0.96	2.09	8.82	6.61
	MGO	12.04	2.12	1.45	14.05	15.52
	NA2O	1.00	2.02	3.43	1.45	1.28
	K2O	0.34	3.76	1.82	0.51	0.28
	TIO2	0.22	0.26	0.25	0.20	0.22
	P2O5	0.04	0.03	0.0	0.01	0.03
	MNO	0.14	0.14	0.08	0.14	0.17
	NIO	0.65	0.0	0.0	0.03	0.47
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	2.89	1.37	1.14	4.11	4.37
	S	3.10	0.09	0.12	0.21	3.10
	CO2	0.10	0.32	0.20	0.07	0.07
	CUO	0.25	0.01	0.01	0.02	0.28
	TOTAL	102.95	99.88	100.01	99.88	103.24
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

RAW

		X662 57-77- 51	X663 57-77- 73	X664 57-77- 74	X665 57-77- 81	X666 57-77- 91
	SIO2	47.55	48.40	47.35	57.35	64.10
	AL2O3	5.87	5.13	7.69	14.66	9.56
	FE2O3	12.79	13.18	17.41	0.45	13.68
	FEO	0.0	0.0	0.0	9.14	0.0
	CAO	14.03	11.39	6.44	4.68	4.42
	MGO	14.14	16.17	14.75	8.17	0.55
	NA2O	0.40	0.58	0.90	3.09	1.38
	K2O	0.16	0.08	0.55	0.55	0.45
	TIO2	0.41	0.32	0.30	0.15	0.26
	P2O5	0.02	0.03	0.03	0.0	0.05
	MNO	0.15	0.16	0.23	0.25	0.02
	NIO	0.41	0.43	0.66	0.02	0.84
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	2.80	2.69	2.44	1.16	1.01
	S	2.40	2.40	3.80	0.26	6.20
	CO2	3.22	2.91	3.35	0.18	6.37
	CUO	0.18	0.11	0.18	0.01	0.33
	TOTAL	104.53	103.98	106.08	100.12	109.22
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

		X667 57-77- 98	X668 57-77- 100	X669 57-77- 104	X670 57-77- 120	X671 57-77- 123
	SIO2	67.10	42.60	43.80	67.55	64.65
	AL2O3	15.84	7.87	6.42	8.05	14.95
	FE2O3	1.13	19.75	19.83	14.66	0.81
	FEO	3.18	0.0	0.0	0.0	2.83
	CAO	4.93	5.41	5.89	2.46	4.74
	MGO	1.19	15.02	15.92	0.64	4.56
	NA2O	4.07	0.67	0.55	2.01	3.93
	K2O	0.55	0.23	0.30	0.23	0.57
	TIO2	0.48	0.19	0.25	0.21	0.44
	P2O5	0.08	0.03	0.06	0.07	0.14
	MNO	0.06	0.16	0.18	0.01	0.06
	NIO	0.0	1.68	1.69	1.09	0.05
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	0.63	0.63	0.88	0.43	0.97
	S	0.28	7.20	6.80	6.80	0.50
	CO2	0.35	5.54	5.76	6.35	1.03
	CUO	0.01	1.04	0.55	0.46	0.19
	TOTAL	99.88	108.02	108.88	111.02	100.42
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

RAW

		X672 U1685- 108	X673 U1685- 205	X674 U1685- 258	X675 U1685- 322	X676 U1685- 411
	SIO2	52.75	55.20	55.95	56.65	50.35
	AL2O3	12.05	9.28	10.15	10.81	7.19
	FE2O3	0.88	0.74	0.78	0.57	16.09
	FEO	5.72	7.00	5.94	8.28	0.0
	CAO	8.15	5.32	6.21	4.29	4.08
	MGO	15.11	16.42	15.00	14.41	18.19
	NA2O	1.16	0.83	0.92	0.80	0.58
	K2O	0.43	1.51	1.00	1.80	0.44
	TIO2	0.20	0.34	0.19	0.15	0.15
	P2O5	0.01	0.12	0.0	0.0	0.01
	MNO	0.14	0.17	0.16	0.26	0.19
	NIO	0.02	0.03	0.03	0.02	0.92
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	3.52	2.98	3.42	2.32	1.02
	S	0.05	0.11	0.04	0.02	3.80
	CO2	0.05	0.32	0.22	0.17	3.15
	CUO	0.01	0.01	0.01	0.01	0.30
	TOTAL	100.25	100.38	100.02	100.56	106.46
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

RAW

	X677 U1685-524	X678 U1685- 621	X679 U1685- 666	X680 U1685- 751	X681 U1685- 862
SIO2	48.65	52.80	53.15	55.25	52.95
AL2O3	6.55	7.64	6.91	6.92	11.82
FE2O3	15.72	0.88	0.68	0.15	11.54
FEO	0.0	8.20	7.60	8.20	0.0
CAO	4.29	5.14	4.98	4.41	4.61
MGO	18.54	20.40	21.03	20.67	12.36
NA2O	0.68	0.90	0.79	0.89	1.16
K2O	0.53	0.23	0.34	0.50	1.41
TIO2	0.23	0.31	0.34	0.18	0.33
P2O5	0.08	0.03	0.09	0.05	0.05
MNO	0.18	0.18	0.16	0.18	0.20
NIO	0.80	0.01	0.01	0.02	0.28
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	2.69	2.73	3.15	1.77	2.02
S	3.60	0.05	0.07	0.09	1.90
CO2	2.14	0.17	0.07	0.27	0.73
CUO	0.58	0.01	0.01	0.01	1.09
TOTAL	105.26	99.68	99.38	99.56	102.45
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

RAW

	X682 U1685- 970	X683 U840- 600	X684 U840- 600	X685 U1878-1400	X686 U1878-2000
SIO2	57.20	53.40	52.55	49.95	49.85
AL2O3	11.04	3.89	4.48	15.19	15.49
FE2O3	0.69	0.91	1.05	0.94	0.80
FEO	5.72	8.34	7.14	6.50	6.06
CAO	6.55	9.71	9.19	12.10	12.56
MGO	12.27	19.17	20.12	11.22	11.44
NA2O	1.18	0.37	0.47	1.37	1.19
K2O	1.37	0.43	0.42	0.10	0.14
TIO2	0.27	0.28	0.26	0.23	0.32
P2O5	0.05	0.05	0.05	0.03	0.03
MNO	0.15	0.20	0.19	0.16	0.15
NIO	0.04	0.02	0.02	0.01	0.01
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	2.73	2.40	3.30	1.89	1.18
S	0.11	0.18	0.25	0.07	0.11
CO2	0.20	0.19	0.20	0.17	0.12
CUO	0.05	0.01	0.01	0.0	0.01
TOTAL	99.62	99.55	99.70	99.93	99.46
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

RAW

		X687 U1614- 0	X688 U1614- 2[illegible]	X689 U767- 690	X690 U767- 756	X691 U850- 1775
	SIO2	49.70	49.70	49.30	49.65	52.15
	AL2O3	14.42	15.04	16.68	17.66	16.42
	FE2O3	1.00	0.73	1.56	1.90	0.66
	FEO	5.80	5.92	8.22	7.04	6.78
	CAO	12.08	11.90	11.05	10.20	10.20
	MGO	13.06	12.84	8.20	6.17	7.11
	NA2O	0.99	0.97	1.88	2.58	1.67
	K2O	0.06	0.06	0.08	0.12	0.53
	TIO2	0.18	0.16	0.82	2.06	0.33
	P2O5	0.03	0.02	0.08	0.24	0.09
	MNO	0.14	0.14	0.18	0.16	0.15
	NIO	0.01	0.01	0.01	0.0	0.02
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	2.45	2.55	1.34	1.24	1.54
	S	0.03	0.07	0.13	0.02	0.32
	CO2	0.12	0.08	0.17	0.12	0.27
	CUO	0.0	0.01	0.01	0.0	0.01
	TOTAL	100.07	100.20	99.71	99.16	100.45
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

		X692 U850- 2198	X693 U850- 1212	X694 U850- 1312	X695 U850- 1471	X696 U850- 1481
	SIO2	54.55	40.50	41.05	41.45	39.90
	AL2O3	18.11	3.18	3.38	4.53	2.95
	FE2O3	0.76	1.09	0.87	2.74	2.03
	FEO	5.00	11.22	11.18	8.04	7.16
	CAO	9.25	1.89	2.79	4.79	8.18
	MGO	7.19	35.90	35.90	30.50	29.00
	NA2O	1.95	0.12	0.24	0.09	0.16
	K2O	0.61	0.0	0.03	0.01	0.04
	TIO2	0.43	0.08	0.10	0.16	0.17
	P2O5	0.08	0.06	0.05	0.05	0.05
	MNO	0.12	0.19	0.18	0.18	0.18
	NIO	0.01	0.10	0.10	0.07	0.06
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	1.78	4.39	3.66	5.86	4.37
	S	0.06	0.11	0.12	0.15	0.11
	CO2	0.08	0.51	0.29	1.26	5.60
	CUO	0.01	0.01	0.01	0.01	0.01
	TOTAL	99.99	99.35	99.95	99.89	99.97
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

RAW

	X697 U850- 1490	X698 EL-U 10-8	X699 EL-U10-128	X700 EL-U 11-20	X701 EL-U 11-84
SIO2	45.05	35.25	48.20	47.70	47.90
AL2O3	4.07	4.02	4.70	5.77	9.41
FE2O3	2.70	12.42	2.76	4.51	3.88
FEO	5.80	0.0	9.22	8.88	7.42
CAO	6.23	6.30	8.57	12.10	11.16
MGO	27.60	26.10	19.85	14.39	14.07
NA2O	0.07	0.02	0.27	0.70	0.96
K2O	0.0	0.0	0.09	0.16	0.22
TIO2	0.17	0.16	0.31	0.39	0.20
P2O5	0.06	0.07	0.06	0.04	0.02
MNO	0.11	0.15	0.23	0.20	0.18
NIO	0.05	0.41	0.45	0.55	0.76
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	6.54	5.46	3.80	2.41	2.45
S	0.13	1.60	1.80	2.40	2.40
CO2	1.69	9.03	1.19	1.91	1.89
CUO	0.01	0.10	0.28	0.48	0.25
TOTAL	100.28	101.09	101.78	102.59	103.17
GROUP	M	N	N	N	N
SYMBOL	1	2	2	2	2

RAW

	X702 EL-U11-157	X703 EL-U190-62	X704 EL-U190316	X705 EL-U190613	X706 EL-U190650
SIO2	47.40	50.75	52.85	46.60	50.55
AL2O3	15.43	16.22	4.23	4.21	4.68
FE2O3	3.97	0.65	0.44	3.85	1.23
FEO	5.66	5.06	8.96	6.72	8.62
CAO	10.55	11.63	6.00	1.39	10.00
MGO	9.20	9.17	21.52	26.68	19.82
NA2O	1.96	1.57	0.28	0.0	0.44
K2O	0.40	0.17	1.05	0.02	0.09
TIO2	0.22	0.26	0.23	0.26	0.35
P2O5	0.04	0.03	0.02	0.06	0.04
MNO	0.12	0.12	0.18	0.06	0.19
NIO	0.47	0.02	0.04	0.36	0.10
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	1.97	1.94	3.30	6.31	3.20
S	2.60	0.13	0.04	2.70	0.32
CO2	0.96	0.17	0.14	1.94	0.40
CUO	0.98	0.02	0.02	0.93	0.15
TOTAL	101.93	99.91	99.30	102.09	100.18
GROUP	N	N	N	N	N
SYMBOL	2	2	2	2	2

RAW

		X879 U753-115	X880 U753-198	X881 U753-553	X882 U753-1171	X883 U739-179
	SIO2	50.35	45.40	50.05	45.15	46.95
	AL2O3	13.84	20.44	16.35	11.61	17.33
	FE2O3	1.58	3.36	2.16	2.35	3.60
	FEO	6.52	8.09	8.37	8.60	9.00
	CAO	9.97	8.63	10.45	6.84	10.82
	MGO	12.83	4.78	6.87	15.37	4.86
	NA2O	1.17	2.97	2.29	1.98	1.68
	K2O	0.12	2.08	0.29	3.21	0.83
	TIO2	0.34	1.39	1.22	0.75	2.14
	P2O5	0.06	0.46	0.15	0.43	0.44
	MNO	0.16	0.16	0.19	0.14	0.21
	NIO	0.02	0.0	0.01	0.04	0.0
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	3.21	1.61	1.42	3.12	1.75
	S	0.12	0.03	0.16	0.01	0.29
	CO2	0.15	0.07	0.15	0.16	0.0
	CUO	0.02	0.03	0.01	0.0	0.01
	TOTAL	100.46	99.50	100.14	99.76	99.91
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

RAW

	X884 U767-498	X885 U767-811	X886 U850-4	X887 U850-298	X888 U850-492
SIO2	48.80	46.35	50.00	48.45	46.70
AL2O3	17.60	17.77	15.07	18.85	16.98
FE2O3	2.01	2.05	1.03	1.48	1.58
FEO	8.84	10.52	5.08	8.01	8.84
CAO	10.97	10.34	11.84	11.64	10.67
MGO	5.97	5.95	12.96	6.82	5.28
NA2O	2.35	2.84	0.98	2.24	2.59
K2O	0.26	0.22	0.08	0.14	0.56
TIO2	1.19	1.46	0.14	0.46	3.06
P2O5	0.24	0.04	0.0	0.03	1.10
MNO	0.20	0.17	0.13	0.17	0.19
NIO	0.0	0.02	0.02	0.0	0.0
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	1.19	1.59	2.69	1.42	1.29
S	0.07	0.59	0.09	0.21	0.17
CO2	0.10	0.11	0.12	0.14	0.12
CUO	0.0	0.15	0.01	0.01	0.01
TOTAL	99.79	100.17	100.24	100.07	99.14
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

RAW

	X889 U850-582	X890 U850-1385	X891 U850-1873	X892 U920-450	X893 U947-285
SIO2	50.00	49.45	53.00	45.80	47.45
AL2O3	6.51	15.95	17.95	15.49	16.77
FE2O3	1.38	2.04	0.70	2.90	1.76
FEO	8.64	8.37	6.10	10.78	9.55
CAO	10.10	8.62	9.80	11.01	10.56
MGO	18.60	6.28	7.21	6.74	6.59
NA2O	0.27	5.08	2.04	1.83	3.01
K2O	0.02	0.52	0.66	0.39	0.37
TIO2	0.49	1.40	0.30	1.66	1.40
P2O5	0.08	0.32	0.05	0.03	0.40
MNO	0.22	0.17	0.14	0.20	0.17
NIO	0.02	0.0	0.01	0.01	0.01
CR2O3	0.0	0.0	0.06	0.0	0.0
H2O	3.60	1.28	1.57	2.04	1.49
S	0.01	0.07	0.16	0.29	0.18
CO2	0.09	0.07	0.07	1.13	0.15
CUO	0.0	0.01	0.01	0.04	0.01
TOTAL	100.03	99.63	99.83	100.34	99.85
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

RAW

		X894 U958-268	X895 57-77-2	X896 57-77-11	X897 57-77-13	X898 57-77-21
	SIO2	49.85	49.55	41.20	42.55	39.65
	AL2O3	16.23	18.08	8.47	14.58	12.58
	FE2O3	1.10	0.02	5.96	16.57	21.72
	FEO	6.18	6.18	5.48	0.0	0.0
	CAO	12.47	10.80	7.14	10.46	7.68
	MGO	9.92	10.83	23.80	8.79	10.28
	NA2O	1.71	1.38	0.29	1.13	0.60
	K2O	0.05	0.08	0.02	0.17	0.04
	TIO2	0.30	0.16	0.17	0.17	0.11
	P2O5	0.01	0.0	0.02	0.03	0.02
	MNO	0.15	0.13	0.12	0.14	0.14
	NIO	0.0	0.08	0.12	1.08	1.78
	CR2O3	0.0	0.0	0.36	0.06	0.10
	H2O	1.46	1.88	6.51	1.85	2.16
	S	0.02	0.34	0.43	5.42	7.40
	CO2	0.11	0.22	0.08	4.75	5.11
	CUO	0.01	0.06	0.03	0.68	0.44
	TOTAL	99.57	99.79	100.20	108.43	110.01
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

RAW

	X899 57-77-22	X900 57-77-32	X901 57-77-41	X902 57-77-83	X903 57-77-126
SIO2	44.30	50.20	71.65	52.70	52.10
AL2O3	13.88	16.42	12.97	17.75	20.22
FE2O3	15.30	1.88	0.94	0.70	2.52
FEO	0.0	5.21	3.00	5.45	6.87
CAO	8.92	10.67	1.56	10.48	8.41
MGO	10.99	8.85	2.08	7.88	2.78
NA2O	1.01	2.48	3.99	2.22	3.97
K2O	0.10	0.25	1.57	0.21	0.27
TIO2	0.15	0.42	0.28	0.19	0.92
P2O5	0.02	0.15	0.01	0.04	0.20
MNO	0.14	0.13	0.08	0.13	0.16
NIO	0.99	0.13	0.0	0.04	0.0
CR2O3	0.11	0.05	0.0	0.09	0.0
H2O	2.22	1.68	1.13	1.39	1.12
S	4.28	1.07	0.08	0.36	0.02
CO2	3.86	0.58	0.07	0.41	0.18
CUO	0.28	0.20	0.0	0.02	0.0
TOTAL	106.55	100.37	99.41	100.06	99.74
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X657 57-77- 17	X658 57-77- 28	X659 57-77- 33	X660 57-77- 39	X661 57-77- 43
SIO2	47.44	73.80	73.92	48.70	48.33
AL2O3	14.09	12.80	13.39	16.89	10.46
FE2O3	12.76	0.86	0.46	0.72	15.24
FEO	0.0	3.06	2.96	7.27	0.0
CAO	10.55	0.98	2.12	9.24	6.91
MGO	12.43	2.16	1.47	14.71	16.22
NA2O	1.03	2.06	3.48	1.52	1.34
K2O	0.35	3.83	1.85	0.53	0.29
TIO2	0.23	0.27	0.25	0.21	0.23
P2O5	0.04	0.03	0.0	0.01	0.03
MNO	0.14	0.14	0.08	0.15	0.18
NIO	0.67	0.0	0.0	0.03	0.49
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.26	0.01	0.01	0.02	0.29
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X662 57-77- 51	X663 57-77- 73	X664 57-77- 74	X665 57-77- 81	X666 57-77- 91
SIO2	49.47	50.43	49.07	58.21	67.02
AL2O3	6.11	5.34	7.97	14.88	10.00
FE2O3	13.31	13.73	18.04	0.46	14.30
FEO	0.0	0.0	0.0	9.28	0.0
CAO	14.60	11.87	6.67	4.75	4.62
MGO	14.71	16.85	15.29	8.29	0.58
NA2O	0.42	0.60	0.93	3.14	1.44
K2O	0.17	0.08	0.57	0.56	0.47
TIO2	0.43	0.33	0.31	0.15	0.27
P2O5	0.02	0.03	0.03	0.0	0.05
MNO	0.16	0.17	0.24	0.25	0.02
NIO	0.43	0.45	0.68	0.02	0.88
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.19	0.11	0.19	0.01	0.35
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X667 57-77- 98	X668 57-77- 100	X669 57-77- 104	X670 57-77- 120	X671 57-77- 123
SIO2	68.04	45.01	45.89	69.32	66.02
AL2O3	16.06	8.31	6.73	8.26	15.27
FE2O3	1.15	20.87	20.78	15.05	0.83
FEO	3.22	0.0	0.0	0.0	2.89
CAO	5.00	5.72	6.17	2.52	4.84
MGO	1.21	15.87	16.68	0.66	4.66
NA2O	4.13	0.71	0.58	2.06	4.01
K2O	0.56	0.24	0.31	0.24	0.58
TIO2	0.49	0.20	0.26	0.22	0.45
P2O5	0.08	0.03	0.06	0.07	0.14
MNO	0.06	0.17	0.19	0.01	0.06
NIO	0.0	1.77	1.77	1.12	0.05
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.01	1.10	0.58	0.47	0.19
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

		X672 U1685- 108	X673 U1685- 205	X674 U1685- 258	X675 U1685- 322	X676 U1685- 411
	SIO2	54.59	56.92	58.08	57.78	51.12
	AL2O3	12.47	9.57	10.54	11.02	7.30
	FE2O3	0.91	0.76	0.81	0.58	16.34
	FEO	5.92	7.22	6.17	8.44	0.0
	CAO	8.43	5.49	6.45	4.38	4.14
	MGO	15.64	16.93	15.57	14.70	18.47
	NA2O	1.20	0.86	0.95	0.82	0.59
	K2O	0.44	1.56	1.04	1.84	0.45
	TIO2	0.21	0.35	0.20	0.15	0.15
	P2O5	0.01	0.12	0.0	0.0	0.01
	MNO	0.14	0.18	0.17	0.27	0.19
	NIO	0.02	0.03	0.03	0.02	0.93
	CR2O3	0.0	0.0	0.0	0.0	0.0
	H2O	0.0	0.0	0.0	0.0	0.0
	S	0.0	0.0	0.0	0.0	0.0
	CO2	0.0	0.0	0.0	0.0	0.0
	CUO	0.01	0.01	0.01	0.01	0.30
	TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

NORMALIZED

	X677 U1685-524	X678 U1685- 621	X679 U1685- 666	X680 U1685- 751	X681 U1685- 862
SIO2	50.24	54.58	55.31	56.71	54.14
AL2O3	6.76	7.90	7.19	7.10	12.09
FE2O3	16.23	0.91	0.71	0.15	11.80
FEO	0.0	8.48	7.91	8.42	0.0
CAO	4.43	5.31	5.18	4.53	4.71
MGO	19.15	21.09	21.89	21.22	12.64
NA2O	0.70	0.93	0.82	0.91	1.19
K2O	0.55	0.24	0.35	0.51	1.44
TIO2	0.24	0.32	0.35	0.18	0.34
P2O5	0.08	0.03	0.09	0.05	0.05
MNO	0.19	0.19	0.17	0.18	0.20
NIO	0.63	0.01	0.01	0.02	0.29
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.60	0.01	0.01	0.01	1.11
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X682 U1685- 970	X683 U840- 600	X684 U840- 800	X685 U1878-1400	X686 U1878-2000
SIO2	59.23	55.16	54.77	51.07	50.54
AL2O3	11.43	4.02	4.67	15.53	15.80
FE2O3	0.71	0.94	1.09	0.96	0.82
FEO	5.92	8.62	7.44	6.65	6.15
CAO	6.78	10.03	9.58	12.37	12.81
MGO	12.70	19.81	20.97	11.47	11.67
NA2O	1.22	0.38	0.49	1.40	1.21
K2O	1.42	0.44	0.44	0.10	0.14
TIO2	0.28	0.29	0.27	0.24	0.33
P2O5	0.05	0.05	0.05	0.03	0.03
MNO	0.16	0.21	0.20	0.16	0.15
NIO	0.04	0.02	0.02	0.01	0.01
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.05	0.01	0.01	0.0	0.01
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X667 U1614- 0	X688 U1614- 200	X689 U767- 690	X690 U767- 756	X691 U850- 1775
SIO2	50.99	50.97	50.27	50.78	53.04
AL2O3	14.79	15.43	17.01	18.06	18.73
FE2O3	1.03	0.75	1.59	1.94	0.87
FEO	5.95	6.07	8.38	7.20	6.90
CAO	12.39	12.21	11.27	10.43	10.37
MGO	13.40	13.17	8.36	6.31	7.23
NA2O	1.02	0.99	1.92	2.64	1.70
K2O	0.06	0.06	0.08	0.12	0.54
TIO2	0.18	0.16	0.84	2.11	0.34
P2O5	0.03	0.02	0.08	0.25	0.09
MNO	0.14	0.14	0.18	0.16	0.15
NIO	0.01	0.01	0.01	0.0	0.02
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.0	0.01	0.01	0.0	0.01
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X692 U850- 2196	X693 U850- 1212	X694 U850- 1312	X695 U850- 1471	X696 U850- 1481
SIO2	55.62	42.93	42.81	44.75	44.39
AL2O3	18.47	3.37	3.53	4.89	3.28
FE2O3	0.77	1.16	0.91	2.96	2.26
FEO	5.10	11.89	11.66	8.68	7.97
CAO	9.43	2.00	2.91	5.17	9.10
MGO	7.33	38.05	37.44	32.93	32.26
NA2O	1.99	0.13	0.25	0.10	0.19
K2O	0.62	0.0	0.03	0.01	0.04
TIO2	0.44	0.08	0.10	0.17	0.19
P2O5	0.08	0.06	0.05	0.05	0.06
MNO	0.12	0.20	0.19	0.19	0.20
NIO	0.01	0.11	0.10	0.08	0.07
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.01	0.01	0.01	0.01	0.01
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X697	X698	X699	X700	X701
	U850- 1490	EL-U 10-8	EL-U10-128	EL-U 11-20	EL-U 11-84
SIO2	49.01	41.47	50.74	49.75	49.67
AL2O3	4.43	4.73	4.95	6.02	9.76
FE2O3	2.94	14.61	2.91	4.70	4.02
FEO	6.31	0.0	9.71	9.26	7.69
CAO	6.78	7.41	9.02	12.62	11.57
MGO	30.03	30.71	20.90	15.01	14.59
NA2O	0.08	0.02	0.28	0.73	1.00
K2O	0.0	0.0	0.09	0.17	0.23
TIO2	0.18	0.19	0.33	0.41	0.21
P2O5	0.07	0.08	0.06	0.04	0.02
MNO	0.12	0.18	0.24	0.21	0.19
NIO	0.05	0.48	0.47	0.57	0.79
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.01	0.12	0.29	0.50	0.26
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	N	N	N	N
SYMBOL	1	2	2	2	2

NORMALIZED

	X702 EL-U11-157	X703 EL-U190-62	X704 EL-U190316	X705 EL-U190613	X706 EL-U190650
SIO2	49.17	51.96	55.16	51.13	52.51
AL2O3	16.01	18.65	4.41	4.62	4.86
FE2O3	4.12	0.67	0.46	4.22	1.28
FEO	5.87	5.18	9.35	7.37	8.95
CAO	10.94	11.91	6.26	1.53	10.39
MGO	9.54	9.39	22.46	29.27	20.59
NA2O	2.03	1.61	0.29	0.0	0.46
K2O	0.41	0.17	1.10	0.02	0.09
TIO2	0.23	0.27	0.24	0.29	0.36
P2O5	0.04	0.03	0.02	0.07	0.04
MNO	0.12	0.12	0.19	0.07	0.20
NIO	0.49	0.02	0.04	0.39	0.10
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	1.02	0.02	0.02	1.02	0.16
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	N	N	N	N	N
SYMBOL	2	2	2	2	2

NORMALIZED

	X879 U753-115	X880 U753-196	X881 U753-553	X882 U753-1171	X883 U739-179
SIO2	51.92	46.43	50.86	46.80	47.97
AL2O3	14.27	20.90	16.61	12.03	17.71
FE2O3	1.63	3.44	2.19	2.44	3.68
FEO	6.72	8.27	8.51	8.91	9.20
CAO	10.28	8.83	10.62	7.09	11.06
MGO	13.23	4.89	6.98	15.93	4.97
NA2O	1.21	3.04	2.33	2.05	1.72
K2O	0.12	2.13	0.29	3.33	0.85
TIO2	0.35	1.42	1.24	0.78	2.19
P2O5	0.06	0.47	0.15	0.45	0.45
MNO	0.16	0.16	0.19	0.15	0.21
NIO	0.02	0.0	0.01	0.04	0.0
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.02	0.03	0.01	0.0	0.01
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X884 U767-498	X885 U767-811	X886 U850-4	X887 U850-298	X888 U850-492
SIO2	49.58	47.35	51.37	49.29	47.87
AL2O3	17.88	16.15	15.48	19.18	17.40
FE2O3	2.04	2.09	1.06	1.51	1.62
FEO	8.98	10.75	5.22	8.15	9.06
CAO	11.14	10.56	12.16	11.84	10.94
MGO	6.07	6.08	13.31	6.94	5.41
NA2O	2.39	2.90	1.01	2.28	2.65
K2O	0.26	0.22	0.08	0.14	0.57
TIO2	1.21	1.49	0.14	0.47	3.14
P2O5	0.24	0.04	0.0	0.03	1.13
MNO	0.20	0.17	0.13	0.17	0.19
NIO	0.0	0.02	0.02	0.0	0.0
CR2O3	0.0	0.0	0.0	0.0	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.0	0.15	0.01	0.01	0.01
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

		X889 U850-582	X890 U850-1385	X891 U850-1873	X892 U920-450	X893 U947-285
	SIO2	51.90	50.35	54.07	47.28	48.40
	AL2O3	6.76	16.24	18.31	15.99	17.11
	FE2O3	1.43	2.08	0.71	2.99	1.80
	FEO	8.97	8.52	6.22	11.13	9.72
	CAO	10.48	8.78	10.00	11.36	10.77
	MGO	19.31	6.39	7.35	6.96	6.72
	NA2O	0.28	5.17	2.08	1.89	3.07
	K2O	0.02	0.53	0.67	0.40	0.38
	TIO2	0.51	1.43	0.31	1.71	1.43
	P2O5	0.08	0.33	0.05	0.03	0.41
	MNO	0.23	0.17	0.14	0.21	0.17
	NIO	0.02	0.0	0.01	0.01	0.01
	CR2O3	0.0	0.0	0.06	0.0	0.0
	H2O	0.0	0.0	0.0	0.0	0.0
	S	0.0	0.0	0.0	0.0	0.0
	CO2	0.0	0.0	0.0	0.0	0.0
	CUO	0.0	0.01	0.01	0.04	0.01
	TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP		M	M	M	M	M
SYMBOL		1	1	1	1	1

NORMALIZED

	X894 U958-268	X895 57-77-2	X896 57-77-11	X897 57-77-13	X898 57-77-21
SIO2	50.88	50.90	44.22	44.13	41.59
AL2O3	16.56	18.57	9.09	15.12	13.19
FE2O3	1.12	0.02	6.40	17.19	22.78
FEO	6.31	6.35	5.68	0.0	0.0
CAO	12.73	11.09	7.66	10.85	8.06
MGO	10.12	11.12	25.54	9.12	10.78
NA2O	1.75	1.42	0.31	1.17	0.84
K2O	0.05	0.08	0.02	0.18	0.04
TIO2	0.31	0.16	0.18	0.18	0.12
P2O5	0.01	0.0	0.02	0.03	0.02
MNO	0.15	0.13	0.13	0.15	0.15
NIO	0.0	0.08	0.13	1.12	1.87
CR2O3	0.0	0.0	0.39	0.06	0.10
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.01	0.06	0.03	0.71	0.46
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

NORMALIZED

	X899 57-77-22	X900 57-77-32	X901 57-77-41	X902 57-77-63	X903 57-77-126
SIO2	46.05	51.73	73.02	53.83	52.94
AL2O3	14.43	16.92	13.22	18.13	20.54
FE2O3	15.91	1.94	0.96	0.72	2.56
FEO	0.0	5.37	3.06	5.57	6.98
CAO	9.27	11.00	1.59	10.70	8.55
MGO	11.43	9.12	2.12	8.05	2.82
NA2O	1.05	2.56	4.07	2.27	4.03
K2O	0.10	0.26	1.60	0.21	0.27
TIO2	0.16	0.43	0.29	0.19	0.93
P2O5	0.02	0.15	0.01	0.04	0.20
MNO	0.15	0.13	0.08	0.13	0.16
NIO	1.03	0.13	0.0	0.04	0.0
CR2O3	0.11	0.05	0.0	0.09	0.0
H2O	0.0	0.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0
CUO	0.29	0.21	0.0	0.02	0.0
TOTAL	100.00	100.00	100.00	100.00	100.00
GROUP	M	M	M	M	M
SYMBOL	1	1	1	1	1

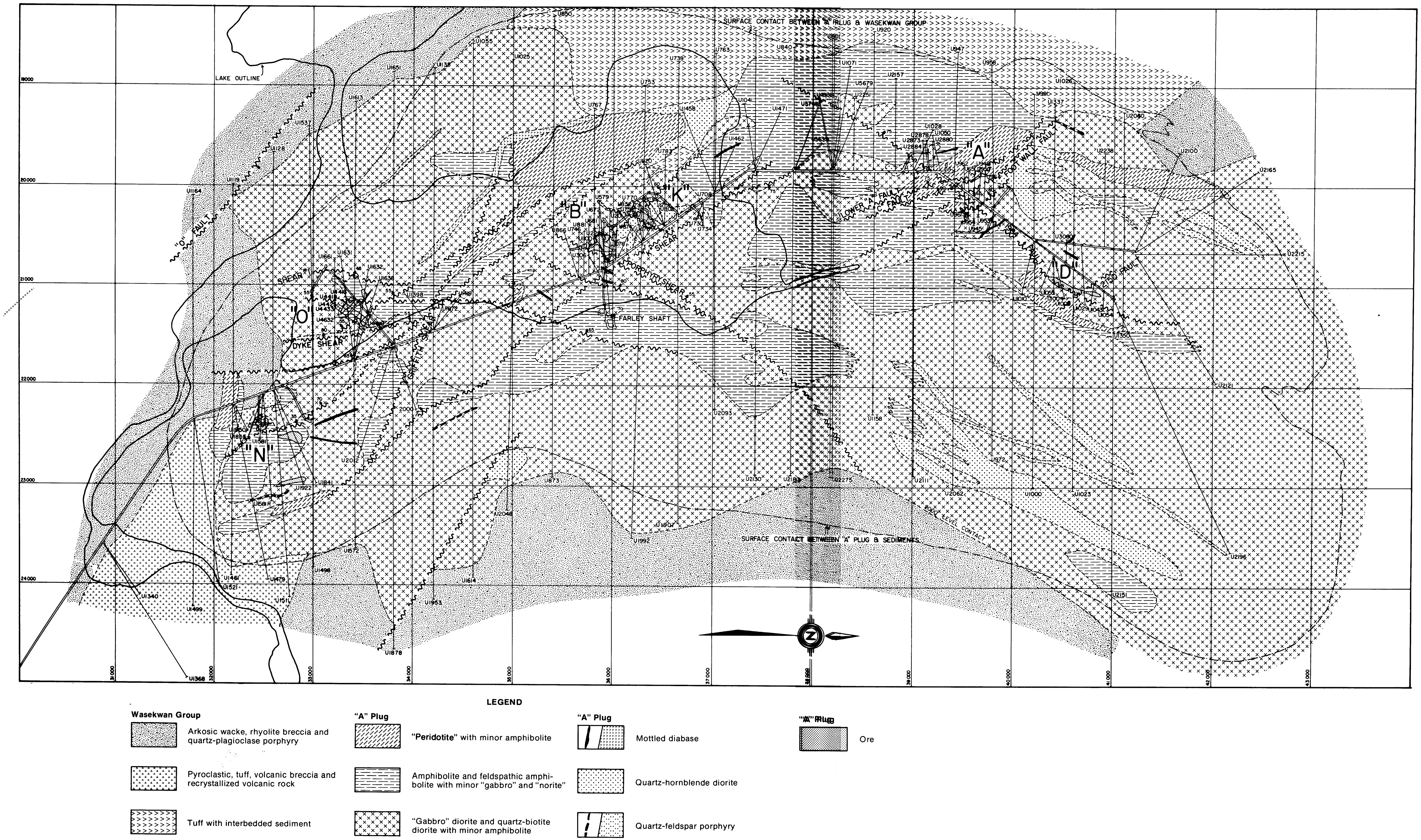


FIGURE A1.4: Geological plan of the "A" plug, 2000' level

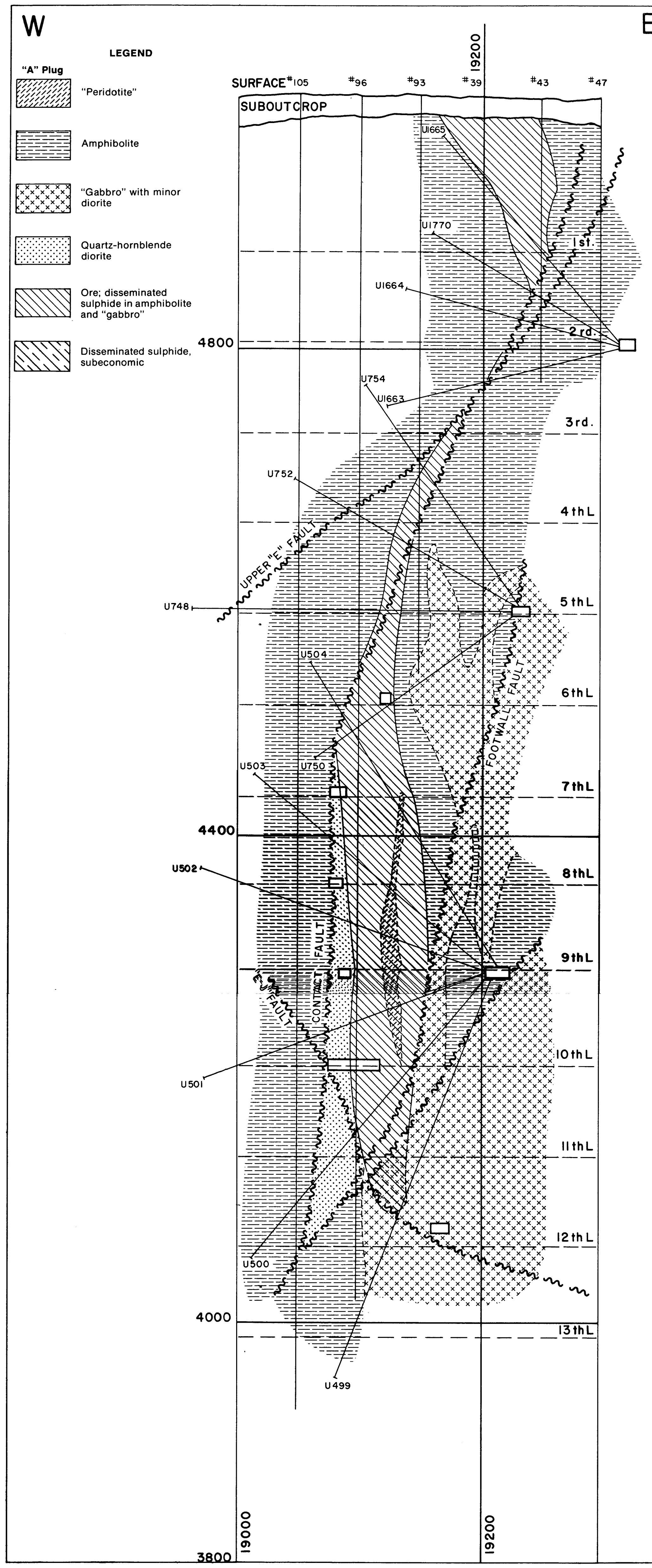


FIGURE A1.23 "E" orebody, W38850E cross-section