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An investigation of some sulfide deposits of the rambler area, Newfoundland

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AN INVESTIGATION OF SOME SULFIDE DEPOSITS

OF THE RAMBLER AREA,

NEWFOUNDLAND

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by

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ABSTRACT

The geology of the Rambler area, Newfoundland, is described. The rocks of the area consist mainly of ultramafic and tholeiitic pillow lavas and associated pyroclastic rocks. Clastic sedimentary rocks, acidic lavas and pyroclastics, and thin units of an acidic 'chert-like' rock are interbanded with the lavas and pyroclastics. Metadolerite dikes intrude all other rocks in the area.

The field and petrographic relationships suggest that the area has undergone at least three deformational and two metamorphic events. The first deformational event was mainly constrictive and produced rock fabrics which locally approach those of L tectonites; mineral and particle lineations are abundant. This deformational event was accompanied by metamorphism to the quartz-albite-epidote-almandine subfacies of the greenschist facies. Structures produced by the first deformational event were folded by at least two later deformations into earlier tight, northeast plunging, isoclinal folds which were followed by development of open recumbant folds. A second metamorphic event which appears to have post-dated the folding, attained conditions of biotite grade greenschist metamorphism.

Major and trace element data are presented for the country rocks. The tholeiitic lavas are chemically similar to present day ocean floor basalts and the ultramafics to rocks described from the Komatii formation in the Barberton Mountain Land, South Africa, by R.P. Viljoen and M.J. Viljoen in 1970. The association of ultramafic lavas, ocean floor type lavas,

basic pyroclastics, 'chert-like' sediments, acidic lavas and low potassium basic intrusives (metadolerites) suggests that the Rambler area represents an ancient ocean floor complex - probably part of an ophiolite complex.

The geology and mineralogy of several of the sulfide deposits are described, their textures being explainable in terms of the deformational and metamorphic events affecting the area. The sulfide deposits have been deformed and metamorphosed during the first constrictive deformation and their textures are the result of recrystallization under conditions of the biotite grade greenschist facies of metamorphism.

Fluid inclusion filling temperatures on the quartz gangue in remobilised sulfide veins gave temperatures (uncorrected for pressure) of crystallization of 145-330°C. The geochemistry of the East Mine ore body is described and the genesis of the sulfide deposits is discussed in the light of the geochemical and petrological data. Although it is difficult to establish clearly the mode of formation of the highly metamorphosed and deformed sulfide deposits the bulk of available information favours a 'syngenetic' rather than an 'epigenetic replacement' mode of formation.

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CHAPTER I

INTRODUCTION

A. Location and accessibility:

The Rambler area is situated on the Burlington Peninsula

in the northeastern part of the province of Newfoundland,

Canada. The center of the area of interest lies, approximately,

at 49°53' latitude and 56°05' longitude. The area can be

reached via the La Scie Road which is joined to the Baie Verte

Highway approximately nine miles to the west of the Rambler area.

Figure 2-2 shows the general location of the Rambler area.

In general, the term Rambler area can be used to refer to

the region surrounding the Rambler and Big Rambler Ponds. In

this thesis the term 'Rambler area' is restricted to that area

included within the boundaries of Plate I.

B. Purpose and method of investigation:

The purpose of this investigation is to determine the

geological setting, history and origin of the sulfide deposits

found in the Rambler area. Several complementary methods of

investigation are employed.

The geological and structural environment of the country

rocks were investigated by systematic geological mapping of the

general area surrounding the sulfide deposits. The geology is

described and an attempt is made to determine the tectonic

history by an analysis of small scale structural features.

The petrography of the country rocks is described and the

textural relationships observed are related to the deformational

and metamorphic events recognized.

Major and trace element analyses were performed on

representative rock units. The geochemical relationships of the different rock units mapped are presented and an attempt is made to establish the origin of the rock on the basis of their field occurrence and geochemistry.

The geology, structure and silicate petrography of the host rocks of the sulfide deposits were investigated by examining diamond drill cores and accessible underground workings. Comparisons are made with the country rocks.

The opaque mineralogy of the sulfide deposits is described and textural relationships are compared with textures observed in the host rocks. The observed textural relationships and the results of geothermometric investigations are considered in terms of the recognizable deformational and metamorphic events.

Major and trace element analyses were performed on representative profiles through one of the sulfide deposits. An attempt is made to determine the nature of the ore forming process utilizing this geochemical data.

Brief comparisons are made with similar rocks and sulfide deposits in other parts of the world. Possible genetic hypotheses supported by the data collected in this investigation are considered.

C. Previous geological investigations:

Attention was first drawn to the mineral potential of the Burlington Peninsula by the discovery of the Tilt Cone copper deposits in 1857. In 1864, Alexander Murray visited parts of

the Burlington Peninsula and in his report (Murray and Howley,
1881) he made general reference to the rocks of the Ming's Bight -
Baie Verte area north of the Rambler area. His geological map,
the earliest geological map of Newfoundland, published in 1873
shows the Burlington Peninsula to be underlain largely by
"Laurentian" rocks, but no further descriptions were given.
J.P. Howley published a geological map (in Murray and Howley,
1918) which showed the Peninsula to be underlain by serpentines,
diorites, dolerites and granite.

Following the pioneering work of Murray and Howley a number
of reports and geological maps have been published on the geology
of the Burlington Peninsula. The majority of these reports are
concerned with regional geology and are of a reconnaissance
nature (Watson, 1947; Baird, 1951; Neale, 1958).

Douglas et al (1940) include the Rambler deposits in a
general account describing the copper deposits in Newfoundland.
Livingston (1942) describes the geology and vein mechanics of
the mineral deposits in the Rambler area. The deposits were
considered to be vein deposits at that time.

Quinn (1945) gives a general description of the geology
and mineral deposits of the Rambler area. He also considers
the economic potential of the prospects.

Watson (1940, 1947) includes the Rambler area in his
description of the geology and mineral deposits of the Baie Verte -
Ming's Bight area. He mapped the greenschist grade volcanic
rocks of the Rambler area as part of the "Baie Verte Formation"
and noted that the rocks were similar to the Ordovician rocks
of the Notre Dame Bay area to the southeast. Watson describes

briefly the 'Rambler Prospect' which later developed into the Rambler Mine.

Although Baird (1951) included the Rambler area in his reconnaissance study of the Burlington Peninsula his geological map is very similar to that produced by Watson (1947) for the Rambler area.

Neale (1958a,1958b)produced one inch to one mile geological maps which cover the Rambler area during systematic geological mapping of the Burlington Peninsula under the auspices of the Geological Survey of Canada.

Recently, detailed structural analysis of the metamorphosed rocks on the Burlington Peninsula have been undertaken (Church, 1965, 1966, 1969; Kennedy, 1967; Neale and Kennedy, 1967; and by graduate students at Memorial University of Newfoundland, the University of Western Ontario and Cambridge University). These studies which are concerned mainly with regional and local problems do not deal specifically with the Rambler area but will, when completed, aid in the interpretation of structural and stratigraphic problems in the Rambler area.

Trace element partition coefficients have been determined for the Rambler Mine as part of a study of several Appalachian sulfide deposits (Ghosh-Dastidar, 1969); the results of this study have recently been published (Ghosh-Dastidar et al., 1970).

Sulfide specimens from the East Mine have been studied by D.J. Bachinski (1967, and personal communication) as part of his Ph.D. studies at Yale University. The results of this study have not been accessable to the writer.

An unpublished company report on the geology of the Rambler

Mine based on a macroscopic study of drill cores (Barrager, 1954) is available.

D. History of mining:

Enos England, a local prospector, discovered outcrops of sulfide mineralization containing gold and copper along the banks of Rambler Brook in 1903. Two years later the property was optioned by Naylor and Company of New York who sank a 65 foot shaft and did some underground development which revealed only low metal values.

In 1936 Enos England and his son William discovered gold, copper and zinc mineralization approximately 600 feet north of the original showing. This new deposit became known as the Rambler vein.

Between 1938 and 1941 the Geological Survey of Newfoundland examined the deposit and carried out diamond drilling on the Rambler Vein which proved the existence of a gold, copper, zinc orebody.

In 1944 the property was optioned by a group of businessmen who formed Rambler Mines Ltd. This company did additional drilling and trenching which increased the known size of the deposit.

Siscoe Gold Mines optioned the property in 1945 and carried out further diamond drilling on the deposit.

Rambridge Mines Ltd. was formed in 1951 when the property was optioned by Falconbridge Nickel Mines Ltd. They increased the size of the known orebody by deeper down dip drilling, but allowed the property to become dormant.

In 1960 the property was expropriated by the Newfoundland Government under Section 3 of the Undeveloped Minerals Act. The

property was leased to M.J. Boylen Engineering Ltd. who formed

Consolidated Rambler Mines Ltd. This company brought the

'Rambler Vein' into production as the Rambler Mine.

From 1961 to 1964 Consolidated Rambler Mines Ltd. carried

out exploratory drilling on a sulfide prospect known as the Norris

showing, approximately one mile East of the Rambler Mine. In 1967

the Norris showing was brought into production as the East Mine.

The Rambler Mine was phased out and finally shut down in 1967.

Consolidated Rambler Mines Ltd. have carried on exploration

programs on other known sulfide deposits in the Rambler area.

One of these, Big Rambler Pond, may eventually be brought into

production on a small scale. An extensive geochemical soil

survey was initiated in 1968. This survey has resulted in the

discovery of a sulfide deposit approximately 2000 feet southwest

of the Rambler Mine known as the New Prospect. Diamond drilling

has been carried out on the New Prospect and although copper

mineralization has been found an economic deposit has not yet

been outlined (M.J. Collins, personal communication, 1970).

Exploration activity is continuing in an effort to extend

the size of the known deposits and also to discover new deposits.

At present the East Mine is producing approximately 1100 tons

of ore a day which averages about 1.5 percent copper and traces

of gold which is recovered from the copper concentrates during

smelting operations.

E. Topography and exposure:

In general the Rambler area is relatively flat with a few

small hills. The mean height above sea level for the Rambler

area is 450 feet. In the southern part of the area approximately

one mile from the Rambler Mine several hills stand 750 feet

above sea level. Except for the extreme southern part of the

map area most of the area lies between the 450 and 550 foot contours.

Rock exposures in the area are generally poor, and seldom reach 5 percent except in the high ground to the south of the area where locally about 10 percent of the bedrock is exposed.

The area has been extensively glaciated and is covered by glacial drift and peat bog. In addition, the area is heavily forested and geological studies can only be carried out satisfactorily along lines cut through the bush for geochemical sampling. Even with lines spaced 200 feet apart it is often impossible to see rock exposures only 50 feet away from the line.

In addition rock exposures are small, generally less than 25 feet in diameter, flat and only rarely can the third dimensions be observed.

F. Acknowledgements:

The writer wishes to thank Professor G.M. Brown for the provision of research facilities in the department and for discussions on the origin of the basic volcanic rocks.

The study would not have been possible without the kind generosity of Mr. M. Trueman, Manager, Consolidated Rambler Mines Ltd., who provided both an opportunity for the writer to study the Rambler area and financial assistance during the course of the field work.

Sincere thanks are due to Mr. R. Phillips for his supervision of this study and for critically reading the manuscript.

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CHAPTER II

REGIONAL AND GENERAL GEOLOGY

A. Regional Setting:

The Appalachian Mountain System, Appalachian Geosyncline, extends for some 2000 miles northeastwards along the Atlantic seaboard from the southeastern United States. The island of Newfoundland forms the northeastern extremity of exposures of this mountain system. Geophysical evidence (Sheridan and Drake, 1968) has shown that the Appalachian System can be traced out into the Atlantic Ocean northeast of the Island. Proponents of the theory of continental drift show that the British Caledonides are a further eastward extension of the Appalachian system (Church, 1965, 1969; Neale and Kennedy, 1967; Dewey, 1969; Bird and Dewey, 1970; see also 'North Atlantic - Geology and Continental Drift' Kay, Ed.).

The general geology of the Canadian Appalachian Mountain System is shown in Figure 2-1.

B. Tectonic Setting:

The Appalachian system in Newfoundland has been divided into three major tectonic units, Figure 2-2, namely: (1) the St. Lawrence Platform; (2) the Acadian Geosyncline; and (3) the Avalon Platform (Poole, 1967). Bird and Dewey (1970) in their application of the theory of plate tectonics to the Appalachian System recognize three tectonic Units which they call Zones A, B and C. The three zones of Bird and Dewey (1970) are superimposed on the divisions of Poole (1967) in Figure 2-2. In this thesis the writer adheres to the nomenclature of Poole (1967).

Williams (1964) was the first to recognize that the Appalachian System in Newfoundland was a two-sided Geosynclinal System with
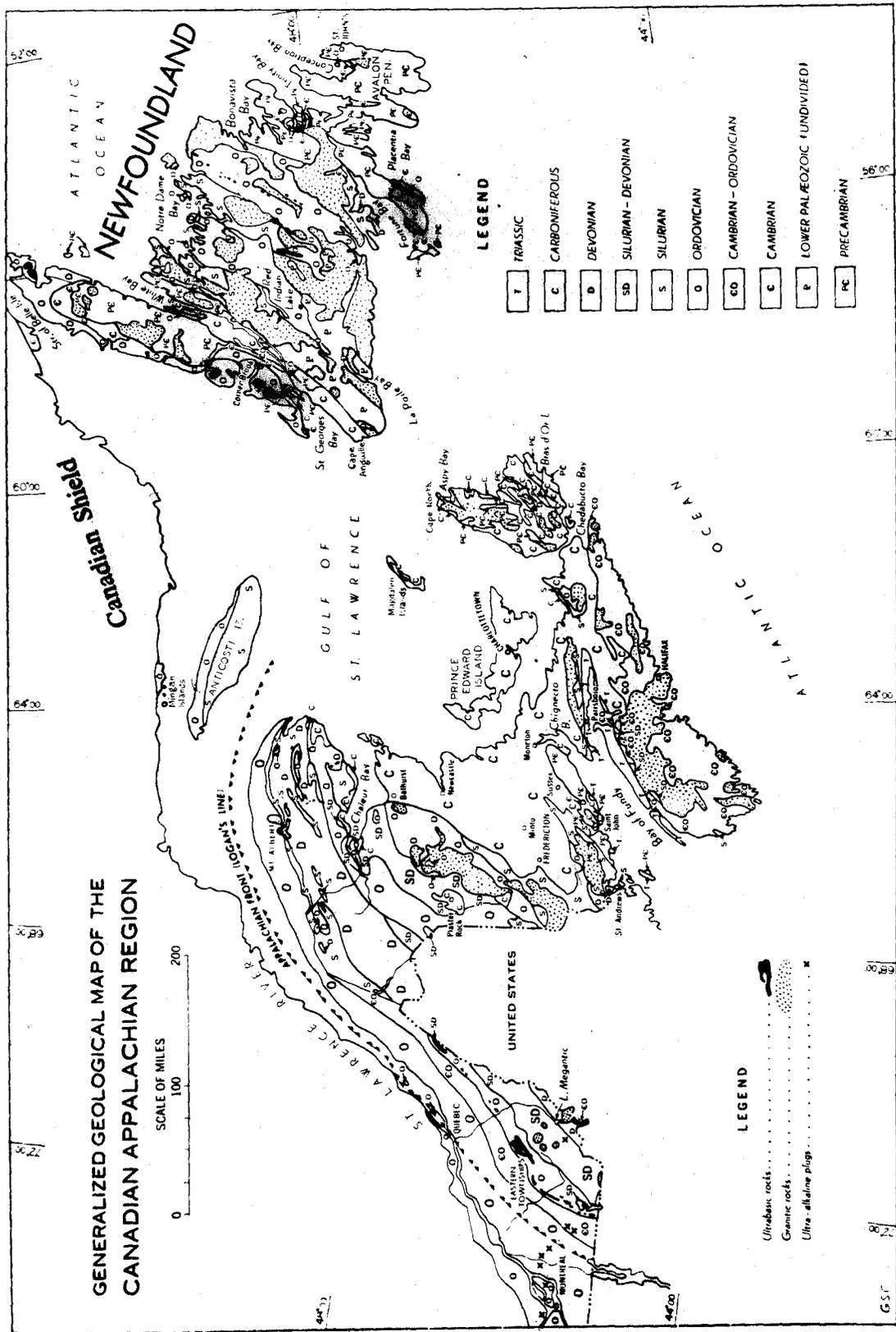
Fig. 2-1   Generalized geologic map of Canadian Appalachian region.
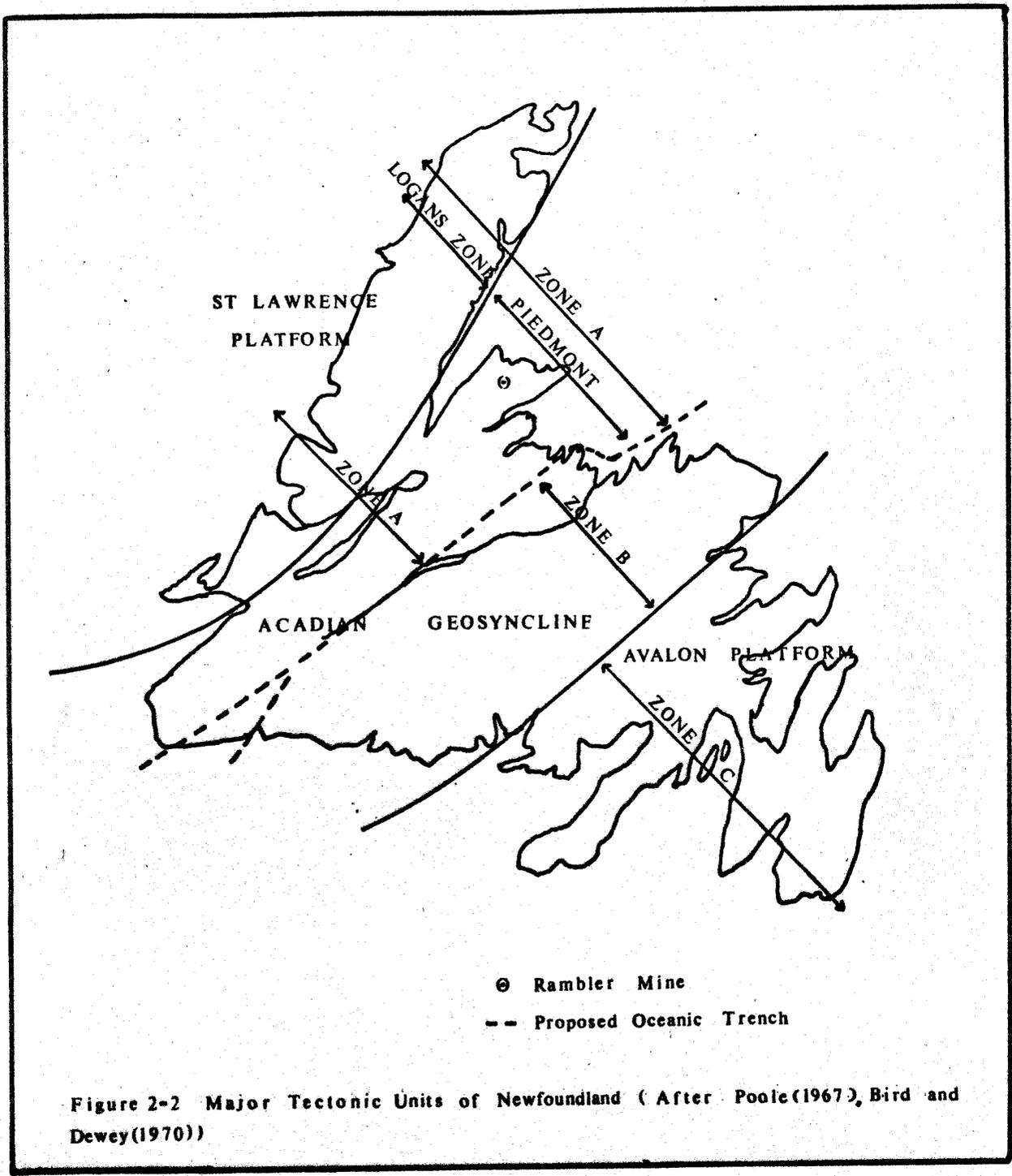
Figure 2-2 Major Tectonic Units of Newfoundland (After Poole(1967), Bird and Dewey(1970))

a 'Central Mobile Belt', the Acadian Geosyncline, flanked by

stable platforms on the west and east.

Lower Palaeozoic miogeoclinal carbonates of the St. Lawrence

Platform rest unconformably upon crystalline rocks of the

Grenville structural province of the Canadian Shield. Inliers

of Precambrian rocks correlateable lithologically and radiomet-

rically (900 m.y.) with those of the Grenville province have been

found in the southwestern and northern parts of the St. Lawrence

Platform in Newfoundland. At the northern tip of Newfoundland

basalts of post-Grenville,Cambrian (?) age underlie the miogeo-

clinal rocks. The miogeoclinal carbonates are disconformably

overlain by thin bedded limestones, shales and greywacke. These

rocks are in turn structurally overlain by the allochthonous

Taconic Klippe in western Newfoundland (Rodgers and Neale, 1963)

and thrust sheets in the northern extremity of the Island (Stevens,

1967). The Klippen and thrust sheets consist of Cambro-Ordovician

and (?)Eocambrian clastic sediments, greywacke, volcanics and

ultramafic-mafic-granitic intrusions and were probably derived

from the Acadian geosyncline (Rogers and Neale, 1963; Bird and

Dewey, 1970). Stevens and Church (1971) have recognized an

ophiolite complex in the Bay of Islands klippe and tentatively

correlated these rocks with similar rocks in the Acadian Geosyncline.

The Avalon Platform forms the eastern border of the Acadian

Geosyncline. This platform consists mainly of folded and faulted

Precambrian volcanic and sedimentary rocks which have been

intruded by late Precambrian, Hadrynian and/or early Cambrian

granitic and mafic rocks. Cambrian and early Ordovician

sedimentary rocks lying unconformably upon the Precambrian are

the youngest rocks on the Avalon Platform which appears to

have been a stable platform prior to the deposition of Cambrian

strata. Devonian granitic rocks have been intruded along the western margins of the Platform.

The Acadian Geosyncline occupies the central mass of the Island. A thick sequence of Eocambrian to Cambrian sedimentary rocks, the Fleur de Lys Group, on the western edge of the Acadian Geosyncline appear to overlie basement rocks (Martin deWit, personal communication). The Fleur de Lys Group are in turn overlain by volcanic and sedimentary rocks of Cambro-Ordovician age. Silurian volcanic and sedimentary rocks unconformably overlie the Cambro-Ordovician rocks. Rocks of the Acadian Geosyncline have been folded, faulted, metamorphosed and intruded by basic and granitic rocks during the Taconic (Ordovician) and Acadian (mid-Devonian) orogenies. The main deformation found in the eastern part of the Acadian Geosyncline, i.e. east of the proposed trench shown on Figure 2-2, was during the Acadian orogeny while both the Taconic and Acadian orogenies have affected the western part of the geosyncline (Bird and Dewey, 1970).

The rocks of the Burlington Peninsula which are the best exposed section of the western part of the Acadian Geosyncline are described briefly below.

C. Geology of the Burlington Peninsula:

The Rambler area is situated in basic volcanic rocks of the western part of the Acadian Geosyncline. Since the relationships of the main rock units are based largely on correlations of lithology and interpretations of the structural geology a brief account of the geology of the Burlington Peninsula is presented here in order to provide the reader with a background to some of the

G Devonian granitic rocks

SILURIAN

△ △ Quartz-feldspar porphyry
and acid pyroclastic rocks

Metamorphosed Cape St. John
group and/or older rocks

Acid and basic volcanics, clastic sediments
SP – Springdale Group
CJ – Cape St. John Group
mm – Mic Mac sequence

ORDOVICIAN OR LATER (?)

Ultrabasic rocks; metadiorite

Baie Verte Group; pillow lavas
and minor sediments

ORDOVICIAN

V V V Pillow lavas; LB – Lushs
Bight Group, SN– Snooks'Arm Gp.

PRE-ORDOVICIAN

+ + Burlington granodiorite

Metamorphosed basic
volcanic rocks

s s s Fleur de Lys Group:
psammitic and pelitic
schists, cg – conglomerate

Miles
4 0 4 8

PARTRIDGE POINT
FLEUR DE LYS
HARBOUR
COACHMANS COVE
BAIE VERTE
KINGS POINT
MIDDLE ARM
White Bay
Bay
Confusion Bay
C. J.
TILT COVE
GRAND COVE
BETTS COVE
SN
LB
LB
NOTRE DAME BAY
Green Bay
SOUTHWEST ARM
Halls Bay
LB
SP
mm
MILE MAC
mm

Newfoundland

Fig. 2-3 Generalized geologic map of Burlington Peninsula, northeastern Newfoundland (after Neale and Kennedy, 1967).

problems encountered in the region as a whole and the Rambler

area in particular.

The general geology of the Burlington Peninsula is presented

in Figure 2-3.

Fleur de Lys Group

Rocks of the Fleur de Lys Group crop out along the western

part of the Burlington Peninsula and in a small area between Ming's

Bight and Pacquet Harbour. These rocks consist of "complexly

folded pelitic and psammitic schists, minor metaconglomerate and

metamorphosed basic sills, and/or flows" (Neale and Kennedy, 1967,

p.143). Betz (1948) and Church (1969) report the presence of

marble units in the extreme western parts of the peninsula.

Church (1966, 1969) describes eclogite boudins in the Fleur de Lys

Group. Metaconglomerates found in the Fleur de Lys have been

described as tilloid by Harland (1969).

Rocks of the Fleur de Lys Group have been ascribed to the

Precambrian and Cambrian by various authors over the past few

years. Age determinations of the unfossiliferous Fleur de Lys

Group have been largely restricted to correlation of lithologies.

Harland (1969) correlates the Fleur de Lys tilloid with Precambrian

tilloids in the Moine-Dalradian rocks of Scotland and rocks of

similar age in Spitzbergen and Greenland. R.K. Stevens (personal

communication in Church, 1969) considers the Birchy Schist division

of the Fleur de Lys to be represented in the Taconic klippen of

northern Newfoundland. According to Church (1969) this would make

the Fleur de Lys rocks

> "ranging in age from early late Proterozoic to early
> Ordovician. Consequently, the writer suggests that
> the Fleur de Lys metamorphic rocks are not Precambrian
> basement rocks of the Archean or early middle Pro-
> terozoic age but represent an early phase of the
> stratigraphic and structural history of the Appalachian
> geosyncline". (p.227).

Church (1969) reports that "Eight types of fold structure different in age and/or geometry are recognized in rocks of the Fleur de Lys, and five phases of deformation in the overlying Baie Verte Group". (p.220). On the other hand Phillips, Kennedy and Dunlop (1969) recognize only five phases of deformation in rocks of the Fleur de Lys Group.

At Pacquet Harbour the Fleur de Lys Group is conformably intercalated with and overlain by rocks of the Pacquet Harbour Group (Church, 1969). The main body of the Fleur de Lys rocks is in fault contact with the Baie Verte Group, Figure 2-3.

Pacquet Harbour Group

The Rambler area is found within a group of rocks which crop out between the Burlington Granodiorite and Pacquet Harbour.

These rocks were originally mapped as the Baie Verte Group by Watson (1947), Baird (1951) and Neale (1958). Church (1969, and personal communication in Neale and Kennedy, 1967) has shown that rocks of the Pacquet Harbour Group are pre-Ordovician on the basis of their structural complexity, metamorphic grade and conformable relationship to the Fleur de Lys rocks at Pacquet Harbour.

The Pacquet Harbour Group consists of a succession of mafic metavolcanic pillow lava, pyroclastics of acidic and mafic composition and minor greywacke.

The relationship between the Pacquet Harbour Group and Baie Verte Group is uncertain. Neale and Kennedy (1967) show the Baie Verte to overly the Pacquet Harbour Group while Church (1969) considers the Baie Verte Group to be in fault contact with the

Pacquet Harbour Group.

Lower amphibolite facies metamorphism has affected most of the Pacquet Harbour Group rocks.

Grand Cove Group

Church (1969) proposed the name "Grand Cove Group" for a succession of predominantly silicic flows and fragmental rocks plus ignimbrites and metasedimentary rocks which crop out in the vicinity of Confusion Bay.

Neale and Kennedy (1967) consider the Grand Cove rocks to be younger than the Fleur de Lys and Pacquet Harbour Groups since their structural history is simpler and they show only partial adjustment to the greenschist facies metamorphism. On the other hand, Church (1969) considers the Grand Cove Group to have undergone the same metamorphic history as the Pacquet Harbour and Fleur de Lys Groups at Pacquet Harbour.

Recent research in this area by H. Coates, Memorial University of Newfoundland, and G. Cockburn, University of Western Ontario, may help to establish the correct relationships between these rock units.

Baie Verte Group and the Mic Mac sequence

The Baie Verte Group and Mic Mac sequence as now defined by Neale and Kennedy (1967) and Church (1969) are found mainly between the Fleur de Lys Group on the west and the Burlington Granodiorite on the east.

The Baie Verte Group consists chiefly of sediments, acidic to basic tuffs and basic pillow lavas.

Acidic ignimbrites, acidic and basic lavas and clastic

sediments of the Mic Mac sequence are thought to underlie the Baie Verte Group (Neale and Kennedy, 1967). The Mic Mac sequence rests unconformably upon and contains boulders of the Burlington Granodiorite.

Neale and Kennedy (1967) argue that the Mic Mac sequence is lithologically similar to the Cape St. John rocks and therefore must be Silurian since the Cape St. John Group overlies the Lower Ordovician Snooks Arm Group.

Recently Dewey et al (1971) have reported the presence of ophiolites in the Baie Verte Group.

Snooks Arm Group

The Snooks Arm Group consists of three lava formations and two formations of pyroclastic rocks, greywacke, black slates and cherts (Neale, 1957; 1958). The relationship of the Snooks Arm Group to the Burlington Granodiorite is not known.

This Group is dated as Early Ordovician on the basis of a graptolite locality found by Snelgrove (1931).

Lush's Bight Group

The main outcrops of the Lush's Bight Group occur between Green Bay and Halls Bay. The two exposures of Lush's Bight Group, Figure 2-3, on the Burlington Peninsula have recently been considered a separate group, the Nippers Harbour Group, by Bird and Dewey (1970) and Dewey et al (1971) although no evidence in support of the separate classification has yet been forthcoming.

The Lush's Bight Group consists mainly of basic pillow lava and pyroclastic deposits of submarine origin which have

been classified as spilites and tholeiitic basalts on the basis

of petrochemical studies (Papezik and Fleming, 1967) and as a

possible ancient oceanic floor by Smitheringale (in preparation).

A single fossil locality (MacLean, 1947) dates the rocks as

Ordovician.

Dewey et al (1971) have recognized an ophiolite sequence in the

exposure of Lush's Bight, Nippers Harbour Group, rocks on the

northwest side of Green Bay.

Quartz feldspar porphyry and acidic pyroclastic rocks

A wide belt of quartz feldspar "porphyry" with acidic

pyroclastics and flow rocks occur to the east and south of the

Pacquet Harbour Group (Figure 2-3).

With the exception of general descriptions by Baird (1951)

who called these rocks the Cape Brule granite and Neale and

Kennedy (1967) very little has been published on the origin of

these rocks and their relationships to the other rock units.

At Pacquet Harbour the Cape Brule "porphyry" appears to be in

fault contact with the Pacquet Harbour group. The relationship

between the quartz-feldspar "porphyry" and the Pacquet Harbour

Group east of the Rambler area is unknown.

Cape St. John Group

Basic and acidic lavas, acidic tuffs and agglomerates and

clastic sediments in the eastern part of the Burlington Peninsula

were named the St. John Group by Baird (1951). Neale (1957)

considered the Cape St. John Group to be unconformably overlying

the Snooks Arm Group and similar to the Silurian rocks in the

Halls Bay area.

Intrusive Rocks

Basic and ultrabasic rocks, commonly serpentinized, are found intruding most of the rock units on the Burlington Peninsula. Parts of the quartz-feldspar "porphyry" have intrusive relation-ships with the Cape St. John Group and cut the Burlington Granodiorite (Neale and Kennedy, 1967; Baird, 1951).

The Burlington Granodiorite, which ranges in composition from quartz diorite to granite, intrudes the Pacquet Harbour Group along the western margin of the Rambler area.

Small bodies of Devonian granitic rocks are found in several places on the Burlington Peninsula.

D. General Geology of the Rambler Area.

Introduction

It became apparent during the writer's initial visit to the Rambler Area in August 1968 that the existing geological maps were inadequate in that the scarcity of exposure had led to misinterpretation of the stratigraphy and structure. Many new exposures had been produced during mining and exploration activity since the preparation of the latest geological maps. The cutting of grid lines spaced 200 feet apart over much of the area for the purpose of a soil geochemical survey afforded greater accessibility to parts of the area than had previously been possible. Further-more, the recognition of polyphase deformational structures in coastal exposures of the Pacquet Harbour Group (Neale and Kennedy, 1967) indicated that a study of small scale structural features might help to establish stratigraphic and structural relationships

in the Rambler area. Therefore, during the 1969 field season

the writer remapped that part of the area covered by the geo-

chemical grid system and the new exposures. In addition

exposures along the La Scie Road were studied.

A geological map, prepared on a scale of one inch to 400

feet, is presented here on a reduced scale of one inch to 800

feet (Plate I, in pocket).

Some of the outcrops on Plate I are taken from previous

geological maps prepared by J. DeJeoffrey for Consolidated

Rambler Mines Ltd. The lithologies assigned to these outcrops

are based on a correlation of the original field sheets used

by DeJeoffrey with the rock types found in the areas remapped

by the writer. Although it is recognized that some of the out-

crops taken from DeJeoffrey's maps may be inaccurately labelled

their inclusion in the present mapping helps to establish the

general geological setting of the sulfide deposits.

All descriptions and interpretations in this thesis are based

entirely upon the writer's own observations.

An arbitrary grid system has been placed on Plate I in order

to facilitate location of specimens and localities referred to

in the text.

Map Units

The following map units were recognizable on the basis of

field relationships and appearance in hand specimen:

8. Basic intrusives

7. Leucocratic intrusive

6. Burlington Granodiorite

5. Basic sedimentary rocks

4. Acidic volcanic rocks

3. Acidic rocks of uncertain origin

2. Basic pyroclastic rocks

1. Basic lavas.

Basic lavas

Although basic lavas crop out throughout the map area the main exposures are found in the southern part of the area. DeJeoffrey recorded basic lavas in the northern part of the area.

The basic lavas are predominantly pillowed and only rarely can nonpillowed lavas, 'flows', be discerned with any degree of certainty. The lavas, both pillowed and nonpillowed are typical greenstones in that they are very fine to fine grained, light to dark green rocks which often possess a weakly developed schistosity.

The recrystallized "chill margin" on the pillows is a distinct, darker green colour in comparison with the light green to dark green coloured pillow centers. Pillow lavas in the extreme southern part of the map area are commonly amygdaloidal. The average size of amygdales often increases from the amygdale free "chill margins" toward the center of the pillows. The average size of amygdales is approximately 3mm, maximum dimension, with a size range from microscopic up to more than 1 cm. In general the amygdales are elongated parallel to the direction of elongation of the pillows and have a roughly ellipsoidal shape.

Pillows are invariably elongated and have a roughly circular outline in cross sections normal to their long axes. The average pillow dimensions are 1.5 by 2.5 feet. Pillows with a short diameter greater than four feet are extremely rare.

Schistosity planes when present are restricted to the outer few inches of a pillow, are best developed in the inter-pillow matrix, and wrap around the pillows.

In several exposures individual pillows have strongly epidotized cores which give the rock a characteristic yellow green colour which decreases noticeably toward the margins of the pillow which in hand specimen do not exhibit any evidence of epidotization. In general, epidotization visible in hand specimen is restricted to scattered epidote threads and veins, .1 to 1 cm wide.

Nonpillowed basic lavas crop out mainly in areas of predominantly pillow lava. These exposures, which are seldom more than twenty feet in maximum dimension and cannot be traced beyond the immediate outcrop, are considered to be either basic flows or else feeder dikes to overlying pillow lava. These basic 'flows' which rarely contain amygdales are identical in hand specimen to amygdale-free pillow lava.

The nonpillowed lavas presented problems of classification in the field since they could be large pillows or even fine grained intrusives since their relationships to the surrounding pillow lavas are nowhere exposed. However, pillows greater than four feet are rare and rocks definitely identified as fine grained intrusives have a slightly darker colour and a relatively coarser texture in hand specimen. In addition, thin section studies of a number of rocks mapped as nonpillowed lava show them to be texturally and mineralogically similar to the pillow lavas and different from the fine grained intrusives.

Basic pyroclastic rocks

Five divisions of basic pyroclastic rocks are recognized

on the basis of their appearance in hand specimen: a. agglomeratic

rocks; b. tuffaceous rocks; c. agglomeratic rocks with acidic

fragments; d. basic schistose rocks; and e. volcanic sedimentary

rocks.

a. Agglomeratic rocks

These are fragmental basic volcanic rocks with at least

five percent of the fragments greater than one inch in diameter

and in which no acidic volcanic fragments are visible to the

unaided eye.

The agglomeratic rocks are comprised of subangular to oval

shaped blocks of basic lava, often amygdaloidal, embedded in a

matrix of fine grained basic material. The ratio of matrix to

fragments is highly variable, ranging from exposures in which

only five percent by volume of the fragments are greater than

one inch in diameter to those in which more than ninety-five

percent of the fragments are greater than four inches in

diameter.

In some cases the basic agglomeratic exposures resemble

"mini-pillows". Exposures in which the mean minimum diameter

of the fragments is less than six inches are mapped as

agglomerates, otherwise they are mapped as pillow lava.

A number of exposures of agglomeratic rocks which can be

viewed only in two dimensions resemble conglomerates in that

they have nearly circular outlines, however, when these

outcrops are exposed in three dimensions the rock fragments are

seen to be strongly elongated (see Figure 3-7., Ch.3).

The best exposures of agglomeratic rocks are found along the power line in the northwest corner of Plate I and between Witness Stake and Big Rambler Ponds.

b. Tuffaceous rocks

These are fine grained tuffs and lapilli tuffs in which more than ninety-five percent of the rock fragments are less than one inch in diameter. This rock type is easily identified on weathered surfaces where differential weathering delineates the fragmental nature of the rock (Figure 2-4).

c. Basic pyroclastic rocks with acidic fragments

Several outcrops of basic agglomeratic rocks contain fragments of acidic composition. It is not clear whether these blocks are ejectamenta or boulders because of the distortion of the original shapes during deformation, however, the heterogenous distribution in the basic matrix and lack of sorting in the acidic blocks, which have diameters varying from one to twelve inches in sections normal to the direction of elongation, favours a pyroclastic origin.

Exposures of this rock type are widely separated and it is not practical in view of the sparseness of the available data to consider them as one stratigraphic unit.

d. Basic schists

Fine grained, dark green, schistose basic rocks devoid of definite banding and rock fragments visible to the unaided eye are mapped as basic schists. This rock type is often associated with volcanic sediments and other pyroclastic rocks and probably represent waterlain ash bands.

Figure 2-4   Basic tuffaceous rocks.

Top and bottom left: tuffaceous rocks in which

clastic fragments can be discerned on weathered

surfaces.

Top right: basic tuffaceous rock without visible

clastic fragments. Note the absence of a

schistosity and the circular holes left by

weathered material.

Bottom right: basic tuffaceous rock with a weak

schistosity.

Scale.

0   1

inches

e. Volcanic sediments

These are fine grained greyish green to greenish coloured rocks with a discernible banding in which clastic quartz and feldspar grains and occasional rock fragments are found. This rock type is commonly found interbanded with basic schists and tuffaceous rocks, e.g. Big Rambler Pond and at the Rambler Mine.

This rock unit is interpreted as representing short(?) periods of sedimentation during volcanic quiescence.

Acidic rocks of uncertain origin

Exposures of an extremely siliceous rock, previously described as 'veins' by Livingston (1942), are found throughout the predominantly pyroclastic area between Rambler and Big Rambler Ponds (Plate I).

The rock is aphanitic, white to pale brown on weathered surfaces, commonly splintery and is distinguished from the acidic volcanic rocks by the presence of mariposite and the general absence of phenocrysts. Exposures vary from less than six inches to more than fifty feet in width.

At Big Rambler Pond a band of this rock type, 0.5 to 2 feet wide, is interbanded with and parallels the banding in volcanic sediments and can be traced for a distance of approximately 1000 feet along strike.

Locally the presence of mariposite gives the rock a distinct bright green colour.

In overall appearance this rock resembles a metamorphosed chert horizon.

Acidic volcanic rocks

Acidic volcanic rocks crop out mainly in the area north of Rambler Pond. In addition, small exposures are found at the East Mine and east of Namurt Pond.

The main exposure of acidic volcanic rocks contains both lava and fragmental rocks. The flow and fragmental rocks cannot be divided into separate stratigraphic units because of the limited exposure. Although acidic fragmental rocks are present along the southern boundary, they appear to be the dominant acidic rock only in the northern exposures, especially along the La Scie road.

The acidic lavas are grey to greyish white weathering, very fine grained porphyritic rocks with 1 to 2 mm quartz and 1 to 5 mm feldspar phenocrysts.

The rock is generally massive and devoid of igneous structures, however, 1 to 2 mm wide flow banding is present in several of the larger outcrops.

Acidic fragmental rocks consist of blocks of acidic rocks similar to the lavas. The fragments range in size from less than 1 cm up to more than 50 cms in diameter. Within any one exposure the range in fragment size is narrow. In several widely scattered outcrops the acidic fragments are mixed with a basic matrix which rarely exceeds 20 percent by volume of the rock. Acidic fragmental rocks invariably have a well developed particle elongation.

The single outcrop east of Namurt Pond is identical to the porphyritic massive lava of the main body. The small

exposures near the East Mine are fragmental and may be tuffaceous in part.

The acidic volcanics are found in contact with basic agglomerates at 10380N/5140E and 9760N/5600E (Plate I). The power line contact is sharp and parallels the first schistosity at 010/40E (Figure 2-5). Blocks of basic rocks found within several feet of the contact appear to have been caught up in the acidic flow. Unbroken quartz and feldspar phenocrysts are found in the acidic flow within one inch of the contact. The diversion ditch contact (9760N/5600E) occurs in a five foot high rock cut in which basic agglomerates overlie acidic lava.

Basic Sedimentary rocks

The northeastern corner of the Rambler area is comprised predominantly of basic clastic sedimentary rocks. The writer's examination of these rocks has been restricted mainly to road side exposures.

Fine and medium grained (1 to 3 mm) clastic biotitic and biotite-quartz-feldspar sediments are interbanded with fine to medium grained clastic(?) amphibolitic rocks. In addition, a two to three foot wide pebble (0.2 to 3 cm) horizon occurs at 14460N/20100E.

The contact relationship between the basic sediments and the volcanic sedimentary unit is unknown.

Burlington Granodiorite

Several small exposures of the Burlington Granodiorite are included within the Rambler area. The exposures include the only known intrusive contact of the Burlington Granodiorite.

The exposures mapped vary from a dark green, medium grained

(1-3 mm) hornblendic variety at the immediate contact to a greyish variety containing hornblende, feldspar and quartz at a distance of several hundred feet from the contact. West of Plate I pinkish granitic rocks can be seen in roadside exposures.

Leucocratic intrusive

Two exposures of a medium grained leucocratic dike, comprised mainly of feldspar and amphibole, occur in the northwest corner of Plate I.

Basic intrusives

Dark green, fine to medium grained, and fine grained porphyritic basic dikes intrude all other rock types, including the sulfide deposits. Individual dikes vary in width from less than a foot to several hundred feet.

At the Rambler and East Mines thick bodies of medium grained basic rock, subparallel or parallel to the regional schistosity have been outlined by surface mapping and diamond drilling. Barrager (1954) interpreted the Rambler Mine occurrence as a basic sill on the basis of an examination of drill core. A sill-like body at the East Mine can be traced intermittently along strike for a distance of over 2000 feet. However, since the contacts of these bodies are not exposed it is not possible to determine whether these "sills" are intrusives or merely thick volcanic flows.

The age relationship of the different dikes is uncertain. Fine grained and fine grained porphyritic dikes appear to intrude the medium grained dikes, however, the reverse relationship has also been observed.

Figure 2-5 A. Contact between acidic lava and basic

pyroclastics at 10380N/5140E.

B. Basic pillow lava. Roadside exposure

approximately one-quarter mile east of Sacrey's

Mill.

C. Stratiform basic volcanic sediments at

10000N/17660E. Note circular outline of rock

fragments. Photograph taken normal to the

lineation.

Figure 2-6 A. Basic agglomeratic rock at 1240N/9900E.

B. Banded basic agglomeratic rock at

10240N/3200E.

C. Stratiform volcanic sediment at

10020N/17660E. Note weakly deformed quartz veins.

D. Lineated agglomerate at 10200N/3600E.

Exposure in the background is shown in greater

detail in Figure 3-7.

E. Stratiform volcanic sediments at

10640N/16320E. Note weak schistosity near lower

half of pencil.

CHAPTER III

STRUCTURAL GEOLOGY

A. Introduction

Structural interpretation of the Rambler area is difficult due to the small, widely scattered exposures and the lack of a recognized stratigraphy. Although previous structural interpretations by Livingston (1942) and Neale (1958) suggest the presence of a major northeast plunging synform no major fold closures have been found in either the Rambler area or the immediately surrounding areas.

In this chapter minor structures observed in the Rambler area are described. The deformational history of the area is considered and a regional interpretation of the structure is attempted on the basis of the minor structures.

Three major phases of deformation and at least two different fold styles have been recognized in addition to episodes of brittle deformation involving the production of kink bands and fault zones.

The earliest deformational event recorded is that of the main deformation and is referred to as the first deformation. Subsequent deformational events which have deformed structures produced by the main deformation are identified as the second and third deformations. It is noted here that these designations are purely for descriptive purposes since the relative relationship of the second and third types of deformation have not yet been clearly established.

Structural terms and symbols used in this thesis are defined in Table 3-1.

Table 3-1 Definition of structural terminology

D_1, D_2, D_3	First, second and third deformations
S_1	Schistosity produced during D_1
S_2	Cleavage produced during D_2
S_3	Cleavage produced during D_3
F_2	Fold produced during D_2
F_3	Fold produced during D_3
L_1	Mineral or particle lineation produced during D_1
L, L $\gg$ S tectonite	after Flinn (1962, 1965)
X,Y,Z	Major axes of the deformation ellipsoid where Z $\geqslant$ Y $\geqslant$ X, after Flinn (1962, 1965)
a	$= \dfrac{Z}{Y}$
b	$= \dfrac{Y}{X}$
k	$= \dfrac{a-1}{b-1}$, k-value after Flinn (1962)
030/35W	Attitude of a plane striking north 30 degrees east and dipping 35 degrees to the west.

B. Faults, shear zones and kink bands:

A fault zone, up to ten feet in width, is exposed in several small outcrops in the bed of Rambler Brook immediately south of the Rambler Mine. The fault zone is characterized by vertically dipping basic schists which strike parallel to the trace of the fault zone.

The fault zone can be traced eastwards along Rambler Brook as a scarp which rarely exceeds 50 feet in height. It is possible that the relatively straight south shore of Rambler Pond represents the westward extension of the Rambler Brook fault zone. The direction and amount of displacement on the Rambler Brook fault are not known.

Two small shear zones, 12-18 inches wide, found at 9000N/13810E and 9920N/16400E with attitudes of 030/90 could not be traced beyond their immediate outcrops.

Other topographic lineaments, such as England's Brook, may represent unexposed fault zones, however, there is no geological evidence at present to support such a hypothesis.

A ten cm wide kink band in basic sedimentary rocks on the La Scie road, 13920N/15380E, has an attitude of 080/80S.

C. Structures produced by the Third Deformation

Minor recumbant open folds, F_3, can be seen in exposures of basic sedimentary rocks along the La Scie road (Figs.3-1A, 3-1B). They are identified as F_3 because they fold an earlier schistosity, S_1, and possibly refold earlier folds, $F_2(?)$, in a highly disturbed exposure at 14660N/21560E (Fig. 3-1B). A crenulation cleavage, S_3, which is axial planar to these F_3 folds has an

Figure 3-1 A. F_3 minor folds in basic sediments. La

Scie road. Crenulation of the first schistosity

by the nearly flat lying F_3 axial plane cleavage

can be seen immediately below the notebook.

B. F_3 minor folds in basic sediments, La

Scie road.

C. F_2 minor fold in basic sediments. Folds

exposed in small outcrops along a tractor trail

north of Sacrey's Mill.

Figure 3-2 A. Minor open fold in basic pyroclastics.

Probably F_2.

B. F_2 minor fold, Rambler Pond.

C. Crenulation cleavage related to F_3

folding in basic sediments at 14400N/18400E. (X 10)

A

B

C

A
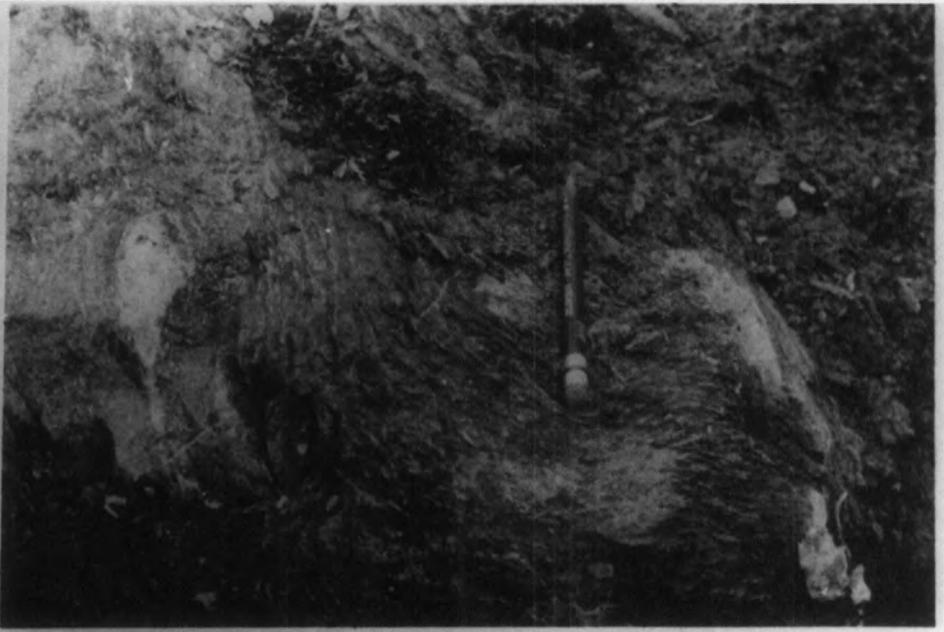
B

C
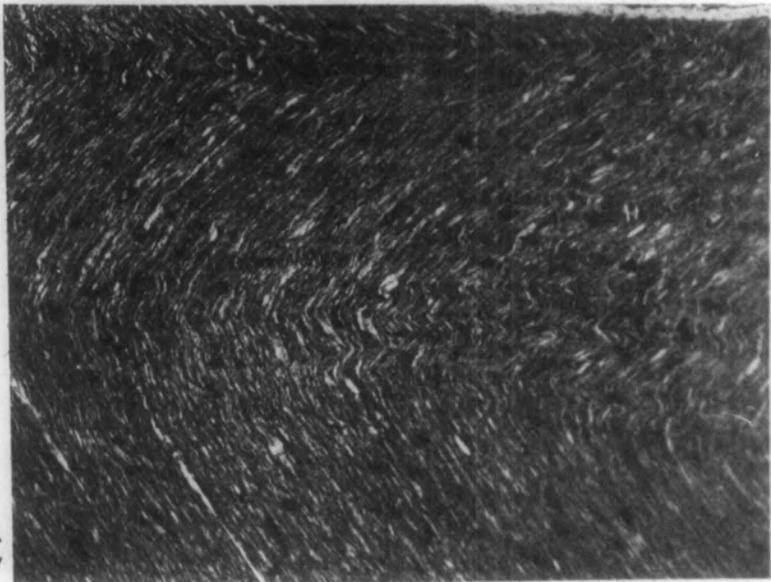
attitude of 090/20S (Fig. 3-2C).

The only other evidence of D_3 was an approximately flat lying crenulation cleavage in several diamond drill cores from the East Mine.

No major F_3 fold closures have been recognized in the Rambler area. The very high angle of intersection between S_3 and S_1 suggests that the F_3 structures are large open recumbent folds. Kennedy (personal communication, 1969) reports that recumbent fold structures have been recognized in coastal exposures east of Pacquet Harbour.

D. Structures produced by the Second Deformation

Minor folds considered to be related to the second deformation because they fold the first schistosity and may themselves be folded by F_3 occur at Big Rambler Pond, Rambler Pond and along a tractor trail north of Sacrey's Mill. In addition, an open fold (Fig. 3-2A) probably belongs to the same deformation.

The F_2 folds of Rambler Pond (Fig. 3-2B) and Big Rambler Pond have vertically dipping axial plane crenulation cleavages which strike N30E. F_2 folds found north of Sacrey's Mill do not have an axial plane cleavage (Fig. 3-1C).

The distribution of F_2 fold axes is shown in Fig. 3-3(ii). The spread in the distribution of the F_2 fold axes may be due either to an original variation in attitude or to modification by a later deformation.

A vertical to nearly vertical cleavage, S_2, with a north to northeast strike is discernible in several places. This cleavage is best developed in acidic rocks of map unit 3 at 7120N/10560E, in acidic lavas north of Rambler Pond and in volcanic sediments at Big Rambler Pond and the East Mine.

When S_2 and S_1 are developed in the same exposure the rock takes on a splintery appearance and breaks easily into pencil shaped fragments (Fig. 3-4).

Figure 3-3(i), a plot of poles to S_2, shows that there is little variation in S_2 within the Rambler area.

E. Structures produced by the First Deformation

Major and minor folds associated with the first deformation have not been recognized in the Rambler area but the existence of this first deformation is proved by the occurrence of a weak schistosity, S_1, and a strong mineral lineation, L_1, which have been deformed by later deformations.

S_1 is best developed in the basic sedimentary rocks and basic schists. L_1 is developed in all rocks of the Rambler area but is most pronounced in basic pillow lavas and pyroclastics, volcanic sediments and acidic pyroclastic rocks (Fig. 3-8).

Mineral lineations consist of elongated and oriented micas, amphiboles, quartz and feldspar. Particle lineations include pillows, rock fragments, amygdales, quartz-feldspar phenocrysts, and quartz segregations in quartz chlorite schists.

A striking feature of particle lineations in the Rambler area is their pronounced cigar-shape. Since mineral lineations are affected by the mineral species, and the presence of a pre-existing shape fabric they are only partly indicative of the deformational processes. On the other hand, particle lineations are a direct result of the finite deformational history of a rock. If the original shape of the deformed object is known then the finite deformational strain can be measured quantitatively.
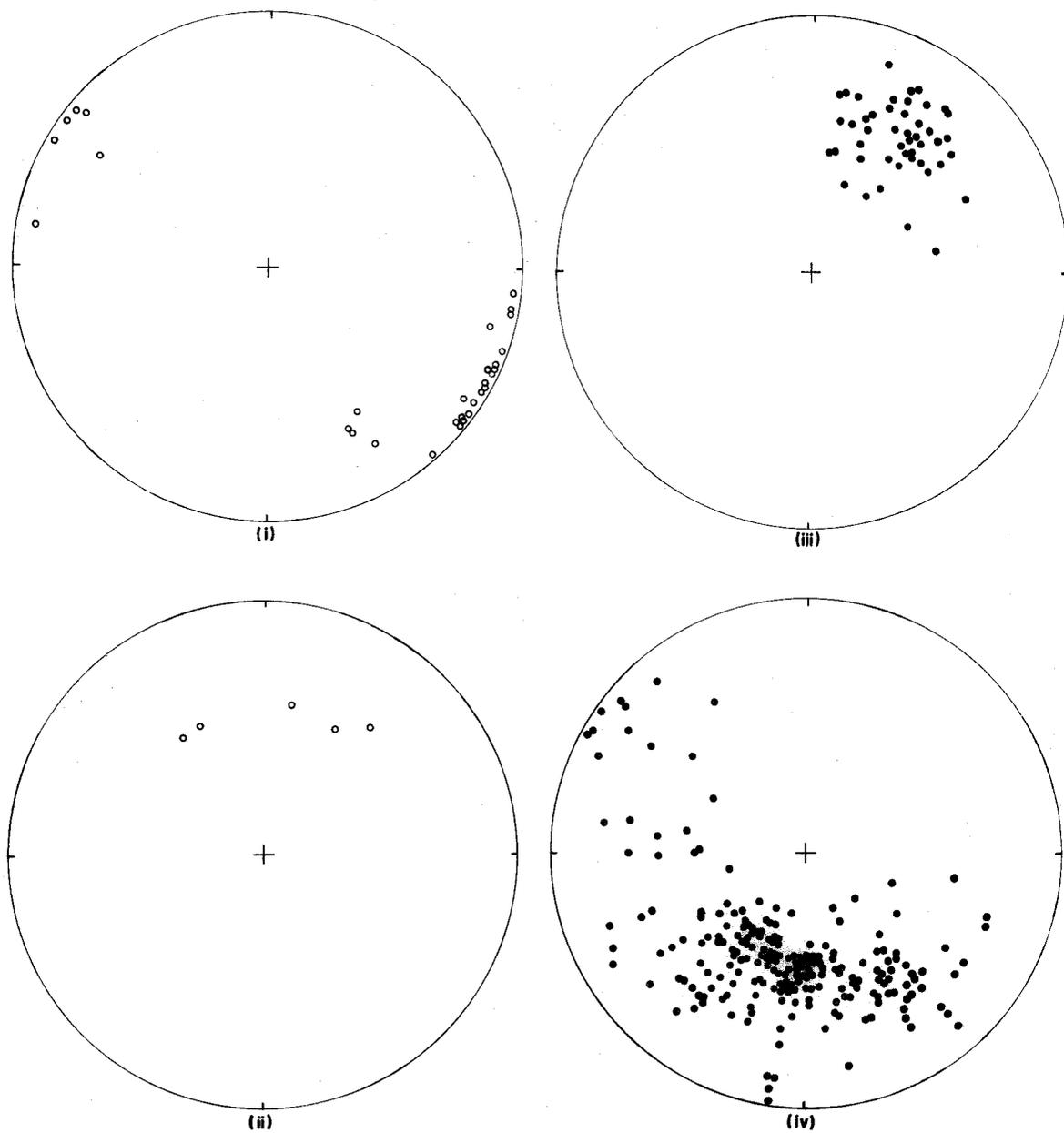
Fig. 3-3   Stereographic projections of minor structures
in the Rambler area.
     (i)   Poles to the second cleavage (S_2)
     (ii) Plunge of minor F_2 fold axes
     (iii) Plunge of lineations (L_1)
     (iv) Poles to the first schistosity (S_1)

Figure 3-4 Pencil shaped fragments formed by intersecting S_1 and S_2.

The original shape of lineated bodies, such as pillows, rock fragments, amygdales and phenocrysts, is not certain. If it is assumed that the amygdales and rock fragments possessed a roughly spherical shape prior to D_1 then the shape of the deformed bodies can be represented in terms of the major axes of the deformation ellipsoid (Flinn, 1962; Ramsay, 1967).

It can be seen from Figure 3-5, a plot of amygdales and rock fragments in specimens typical of the Rambler area, that the deformation ellipsoids not only fall within the field $\infty > K > 1$ but also lie very close to b=1. This indicates that the main deformation was largely constrictive with prolate deformation ellipsoids. Furthermore, Figure 3-5 shows that rocks of the Rambler area have fabrics approaching those of pure L tectonites as defined by Flinn (1962, 1965).

Although a weakly developed schistosity, S_1, is present locally throughout the map area it is often absent even in micaceous volcanic sediments and only approaches a penetrative schistosity in basic schists and basic sedimentary rocks. When S_1 is developed in pillow lavas and pyroclastic rocks it is most pronounced in the matrix between pillows and rock fragments and wraps around pillows, rock fragments and phenocrysts.

When S_1 and L_1 can be determined in the same exposure the Z axis of L_1 invariably lies within the ZY plane of the fabric ellipsoid as defined by Flinn (1965). The ZY plane of lineated micaceous minerals in such outcrops lie within or close to the S_1 plane and impart a step-like "ragged" appearance to the schistosity surface.
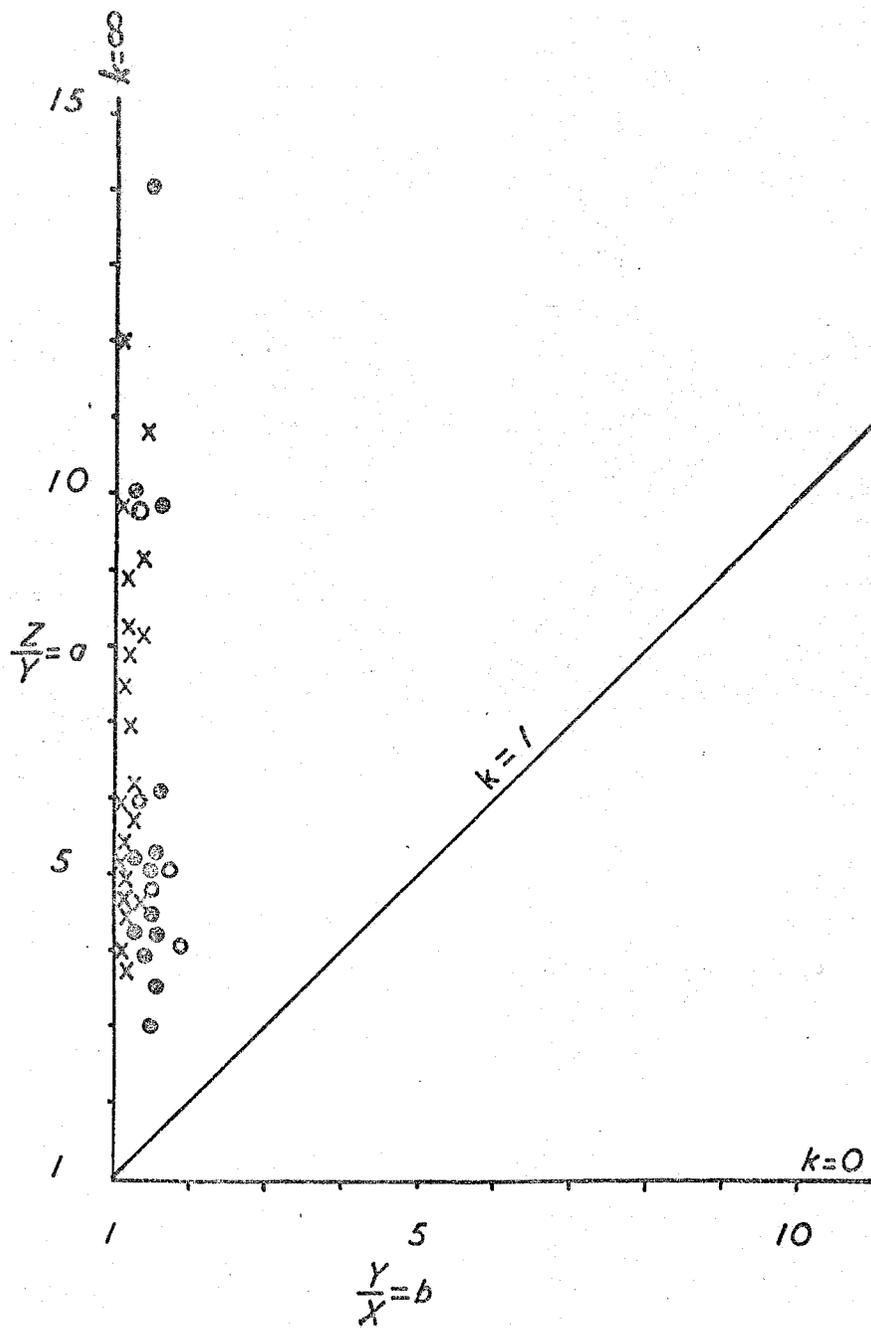
Fig. 3-5 Plot of deformation ellipsoid for vesicles, x; amygdales, ⊙; and agglomerate, o.

In the basic sedimentary rocks where S_1 is best developed and has a relatively smooth surface microscopic examination of the biotites reveals that they are elongated with their Z (long) axes oriented parallel to the Z axes of particle lineations and define a strong mineral lineation within S_1. However, the ZY planes of individual biotites show some variation in attitude but not as much variation as in rocks with a poorly developed cleavage.

The distributions of L_1 and S_1 in the Rambler area are presented in Figs. 3-3(iii) and 3-3(iv).

F. Discussion

The presence of a schistosity wrapping around particle and mineral lineations is not evidence for a post-L_1 deformation producing S_1. S_1 and L_1 always occupy the same plane, the ZY plane of the fabric ellipsoid, and furthermore there is no evidence that S_1 cuts L_1. Flinn (1965) reports that a fabric in which lineation and schistosity are not independent structures but a single structure produced by the same deformation is most common in L-S tectonites where L $\gg$ S. It is concluded that the first deformation in the Rambler area was mainly constrictive and resulted in the development of L and L $\gg$ S tectonites.

It is apparent from Plate II that there is no significant variation in the orientation of minor structures between individual subareas.

The minor F_2 fold axes fall within or close to the lineation field, cf. Figs. 3-3(ii) and 3-3(iii). This suggests a coaxial

relationship between F_2 folding and L_1. A coaxial relationship between D_2 folding and D_1 lineations would account for the relatively small spread of L_1 attitudes produced during the second deformation.

The strike of F_2 minor folds which varies from northwest to northeast is correlateable with a major synform shown by Church (1969, Fig.2) to have a roughly northward striking axis.

Structural events affecting the Rambler area are:

(1) An intensely constrictive deformation produced L and L $\gg$ S tectonites.

(2) A second deformation produced minor folds, with a near vertical cleavage which is axial planar to the minor folds.

(3) Large open recumbent folds refolded the basic sedimentary rocks but does not appear to have greatly affected the remainder of the area.

(4) Kink bands were produced during a late episode of brittle deformation.

Further interpretations of the structure of the Rambler area may become apparent as a result of detailed structural studies now being carried out by M.J. Kennedy and associates at Memorial University.

Figure 3-6 A and B. Lineated amygdales in basic lava.

Hammer in same position on both photographs.

C. Second cleavage (vertical) in volcanic

sediments. Big Rambler Pond.

Figure 3-7 A and B. Lineated agglomerate at 10200N/

3600E.

C. Lineated amygdales in basic agglomerate.

A
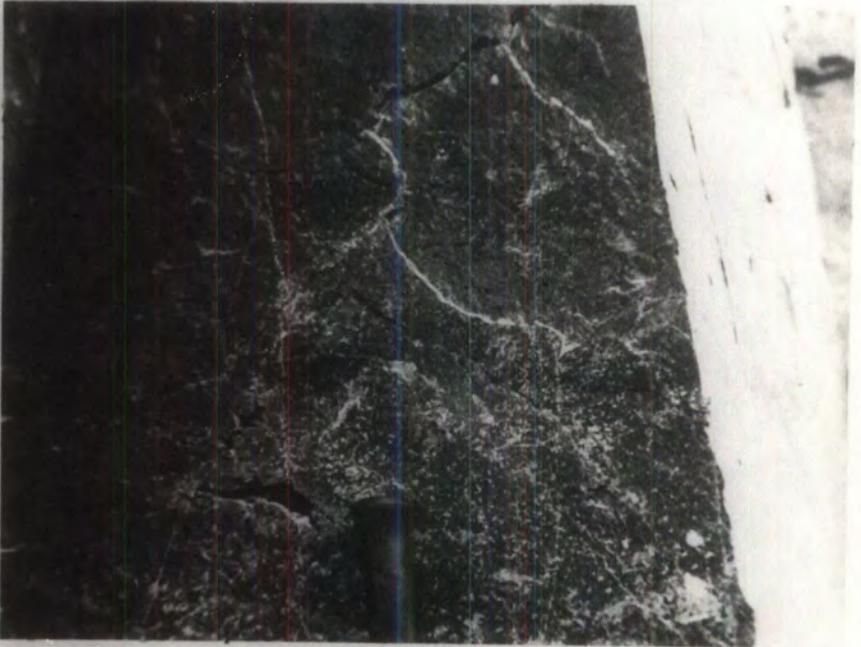
B

C

A

B

C
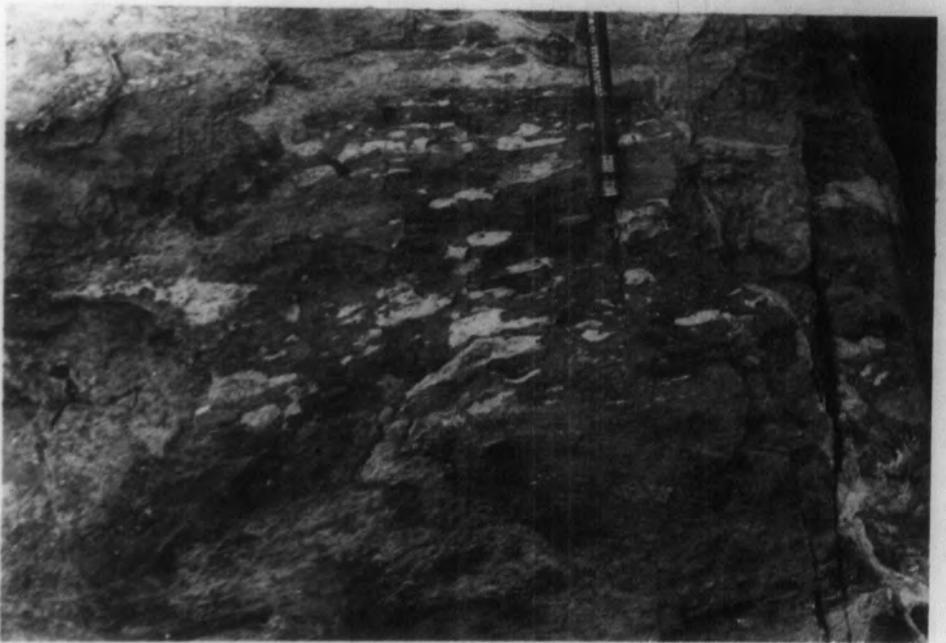
Figure 3-8   Lineations in rocks from the Rambler area.

9989 - acidic block in basic agglomerate.

99186 - lineated amygdales in basic agglomerate.

98223 - amphibolite.

96122 - lineated amygdaloidal agglomerate.

91810 - lineated acidic pyroclastic.

99189 - lineated acidic pyroclastic with basic clasts.

Scale.
0   1
inches

9989

9822-3

962-2

9822-3

9612-2

998-9

918-10

9-8166

9918-9

9918-9
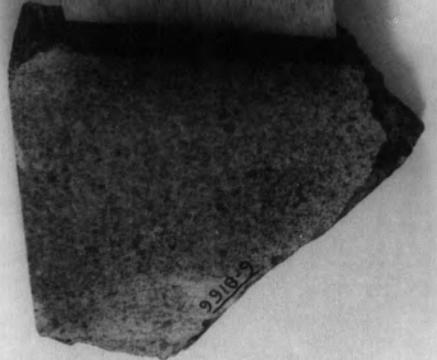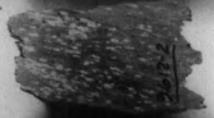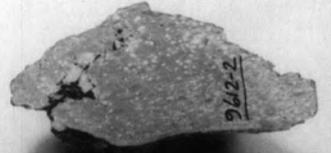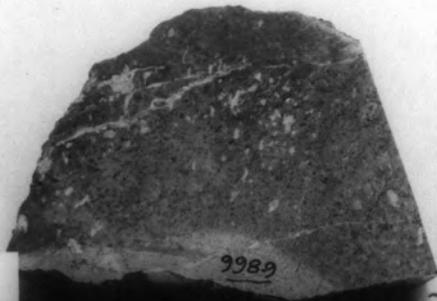
CHAPTER IV

PETROGRAPHY AND METAMORPHISM OF THE COUNTRY ROCKS

A. Introduction

The petrography of the country rocks is described and the observed textures are related to the deformational and metamorphic events affecting the area.

This account of the petrography is not intended to be an exhaustive one since this is not the primary aim of this thesis.

With the exception of some of the basic intrusives, rocks of the Rambler area consist of metamorphic assemblages in which primary igneous textures are rarely observed.

B. Basic volcanic lavas

Pillowed and nonpillowed basic lavas are mineralogically and texturally very similar. The mineral assemblage, actinolite-albite-epidote $\pm$ chlorite $\pm$ quartz, and mineral lineations indicate that the basic lavas have recrystallized during metamorphism and deformation. Deformed plagioclase phenocrysts and amygdales are the only original igneous textures remaining in the majority of the basic lavas. Several small outcrops of pillow lava at 8900N/13280E, near the Rambler Mine, contain relict plagioclase microlites in addition to plagioclase phenocrysts. These microlites are anomalous since the groundmass of the basic lavas is generally completely recrystallized, e.g. Figure 4-1A.

Actinolite, plagioclase, epidote and clinozoisite are the most common minerals. Hornblende, chlorite, zoisite, biotite, calcite and quartz are minor constituents in some thin sections.

The predominant mineral in all basic lavas is a pale green

slightly pleochroic actinolite. Actinolite occurs as: a matte

of interlocking laths, 0.1 x 0.5 mm; porphyroblasts, 0.3 x 0.5 mm

in a felt-like matrix of actinolite crystals with maximum

dimensions of 50 microns; and as acicular anhedral crystals with

roughly equidimensional end sections, 0.1 to 0.3 mm, and lengths

five to ten times the diameter of the end sections. Actinolite

crystals generally have fibrous terminations and euhedral grain

boundaries are extremely rare. Porphyroblastic actinolites are

commonly twinned. (see Figs. 4-4D,4-5A)

The Pillow lavas at 8900N/13200E contain, in addition to

actinolite, a blue green hornblende with a pale yellow green (α)

to blue green (β) pleochroism.

Electron microprobe analyses of actinolites in specimens

96203 (5540N/16000E) and 96273 (5160N/15400E) are presented in

Table 4-1. The method of recalculation of the analyses is given

in Appendix A .

According to the classification scheme of Phillips and Layton

(1964) the basic formula of the mineral is Tremolite S.E.

In addition to the plagioclase microlites mentioned above,

plagioclase occurs as: relict phenocrysts; polycrystalline

aggregates in amygdales; and in late stage quartz veins.

Subhedral to euhedral plagioclase phenocrysts, 0.5 x 1.0 mm,

generally show some alteration to epidote or clinozoisite. In

several instances the centres of the phenocrysts have been

completely replaced and only a narrow outer rim of plagioclase

remains unaltered. In other instances the plagioclase has been

replaced by acicular actinolite.

Some of the plagioclase phenocrysts appear to have been

overgrown by plagioclase during metamorphism. In Figure 4-1B

an untwinned core of plagioclase is surrounded by a rim of

plagioclase with albite twinning.

Plagioclase microlites, 0.02 x 0.2 mm, found in the

groundmass of pillow lavas east of the Rambler Mine have albite

and carlsbad twinning and are partly altered to clinozoisite

and actinolite.

Subhedral to euhedral plagioclase crystals are found at

the margins of quartz-epidote veins, several mms wide; these

plagioclase crystals have albite and chessboard twinning and

do not exhibit any evidence of alteration or deformation.

Plagioclase is the main constituent of amygdales in the

basic lavas. Individual amygdales consist of several anhedral

to subhedral plagioclase crystals with sutured boundaries and

combined carlsbad and albite twin lamellae. The average size

of individual plagioclase crystals is approximately 0.2 x 0.3 mm.

Several of the amygdales have an unusual texture in which an

outer ring of plagioclase surrounds a core of radiating wedge

shaped plagioclase crystals (see Figs. 4-1C and 4-1D). Plagio-

clase crystals in the amygdales generally show some alteration

to epidote, clinozoisite and actinolite.

The original constituents of the amygdales are unknown

but it is not unreasonable to assume that they consisted mainly

of minerals of the zeolite group since they have recrystallized

mainly to plagioclase.(Figs. 4-4A,4-4B).

Plagioclase crystals in amygdales and phenocrysts from

specimen 96203 were analysed for Na and Ca by electron micro-

probe techniques. The analyses, tabulated in Table 4-2, give

a range of compositions from An_5 to An_{10}. No significant

difference could be established between plagioclase present as

phenocrysts and that present in the amygdales. Zoning of

plagioclase in both phenocrysts and amygdales was looked for

but none was found.

Granular epidote is found as an alteration product of

plagioclase and distributed throughout the actinolitic matrix.

Clinozoisite and zoisite are found only as alteration products

of plagioclase. The average grain size of these minerals is

approximately 0.1 mm. Locally, where intensive epidotization

has taken place, epidote constitutes about 75 percent of the

rock. In general, the combined volume of epidote and clino-

zoisite is less than 5 percent.

Quartz occurs mainly in veins, several mms wide, cutting

across the other minerals and occasionally it is found filling

amygdales. Traces of reddish brown biotite, replacing actinolite

are found in several thin sections. Chlorite and calcite are

found only in quartz veins.

C. Basic pyroclastic rocks

Basic agglomeratic and tuffaceous rocks

The agglomeratic and tuffaceous rocks are petrographically

similar and will be described together. The petrography of the

acidic blocks in map unit 2C - agglomeratic rocks with acidic

fragments - will be considered separately.

In general, the lava fragments are mineralogically identical

to their enclosing matrix. The main textural difference between

the lava fragments and their matrix is the more pronounced

mineral lineation in the matrix material.

Actinolite, hornblende, quartz, plagioclase, chlorite

and epidote are the predominant minerals. Clinozoisite, zoisite

and biotite are minor constituents in many of the thin sections.

Actinolite, the most common amphibole, is found in nearly

all of the thin sections. It occurs as: very fine grained,

0.01 x 0.1 mm acicular crystals; fibrous terminating laths,

0.1 x 0.5 mm; and, porphyroblasts, 0.3 x 1 mm. The actinolites

generally define a mineral lineation which is always parallel to

the long axes of the rock fragments.

Poikiloblastic blue green hornblende crystals, up to 1 x 3

mm, enclosing acicular actinolites occur in the basic pyroclastic

rocks cropping out between the main body of acidic volcanics and

the Burlington Granodiorite in the northwestern corner of Plate I.

The amphibole in basic pyroclastic rocks cropping out along

the La Scie road east of the Rambler road is a blue green hornblende

optically similar to the hornblende occurring in basic pillow

lavas east of the Rambler Mine. These hornblendes, generally

euhedral and acicular, define a strong mineral lineation in the

rocks in which they occur. In an exposure at 13780N/14580E several

of the hornblende crystals are randomly oriented and have grown

over lineated hornblendes.

The presence of poikiloblastic and randomly oriented horn-

blendes in rocks with a mineral lineation indicate that some

recrystallization took place after deformation had ceased.

Electron microprobe analysis of hornblendes in specimen

98225 (13780N/14580E) is presented in Table 4-1. According to

the classification of Phillips and Layton (1964) the basic

formula of the mineral is pargasite S.E.

Quartz varying from less than 5 to approximately 50 percent

is present in almost all thin sections examined. Quartz grains

generally have irregular outlines and seldom have straight grain

boundaries. The size of quartz grains ranges from 0.05 to 0.1 mm

with scattered quartz porphyroblasts 0.5 mm in diameter present

in some thin sections. Although undulatory extinction is not

common in the smaller grain size the quartz porphyroblasts have

undulose extinction. The long axes of lineated quartz grains

parallel the long axes of other lineated minerals.

Subhedral to euhedral plagioclase phenocrysts, 0.3 x 0.7 mm,

showing various stages of alteration to clinozoisite, epidote and

zoidite are present in nearly all rock fragments but are seldom

present in the enclosing matrix material.

Plagioclases occurring in amygdales of rock fragments and

in quartz veins are identical to those occurring in basic lavas

and are not described further.

One or more of the minerals epidote, clinozoisite and zoisite

have been identified optically in all thin sections of basic

pyroclastic rocks. In addition to their occurrence as an alteration

product of plagioclase, clinozoisite and epidote occur as granules

up to 0.5 mm in diameter scattered throughout the rock. Locally

extremely fine grained granular epidote and/or clinozoisite are

present as a cloudy alteration pervading the whole rock.

Clinozoisite and zoisite are rarely found in quartz and epidote

veins.

In the central part of the Rambler area, i.e. north of
Rambler brook and between the East Mine and the Rambler Mine,
chlorite is the predominant iron-magnesium silicate in the basic
pyroclastic rocks and locally it constitutes up to 50 percent of
the rock. Outside of this area the chlorite occurs mainly as a
minor constituent and rarely exceeds 5 percent by volume.

Where chlorite is a minor constituent it occurs mainly as
unoriented crystals of green chlorite in patches, 0.5 to 1 mm
in diameter, irregularly distributed throughout the section.
In thin sections with more than approximately two percent chlorite
the mineral occurs mainly as elongated crystals in which the long
axes (Z) have a well developed preferred orientation and the inter-
mediate axes (Y) have either a poorly developed planar orientation
in which case the mineral defines a weak schistosity or more
commonly a random orientation whereby the mineral defines a
lineation rather than a schistosity.

Two varieties of chlorite have been recognized on the basis
of their optical properties. The most common variety is identified
as prochlorite on the basis of its green colour, faint pleochroism,
very weak birefringence and parallel extinction. The second
variety, clinochlore, is distinctly pleochroic from pale green
to green, and has a low birefringence and inclined extinction.
Both varieties may occur together or separately.

In several specimens several hundred feet northwest of
Namurt Pond clinochlore was observed to partly replace actinolite
porphyroblasts (Fig. 4-2A).

Biotite occurs as an intergrowth with chlorite in some sections
and as randomly oriented porphyroblasts up to 1 mm in diameter.

Biotite rarely constitutes one percent of the rocks and is not present in the majority of thin sections studied.

Basic schists and stratiform volcanic sediments

Basic schists are fine grained rocks, 0.1 to 0.5 mm grain size, comprised mainly of actinolite, chlorite and quartz. Epidote and calcite are minor constituents. Both actinolite and chlorite are lineated. The schistosity is defined by a planar orientation of the lineated chlorite.

The volcanic sediments are comprised mainly of quartz, chlorite, plagioclase and actinolite. Epidote, clinozoisite, zoisite and calcite are minor constituents in some specimens. Rutile needles were identified in one thin section.

Rocks mapped as volcanic sediments have an extremely variable mineralogy and include: (1) rocks consisting mainly of quartz and chlorite; (2) rocks consisting mainly of quartz, plagioclase and actinolite; (3) rocks consisting mainly of plagioclase and chlorite; and (4) various combinations of the above.

In general the volcanic sediments have a strong linear fabric due to elongated chlorite, actinolite, quartz and plagioclase. At the East Mine and Big Rambler Pond the fabric is extremely linear and approaches the L tectonite type of fabric described by Flinn (1965), e.g. cf. Figures 4-2B and 4-2C.

D. Acidic rocks of uncertain origin

These acidic rocks are composed mainly of quartz. Minor amounts of mariposite, clinozoisite, feldspar and calcite are found locally in addition to the sulfide minerals which are mentioned in a separate chapter (P. 93).

Quartz accounts for more than 95 percent of the minerals present. Quartz porphyroblasts, 0.1 mm in diameter, are scattered throughout extremely fine grained, 0.03 mm, quartz groundmass. Both the groundmass quartz and the porphyroblasts rarely show polygonal outlines. Undulatory extinction is common in the porphyroblasts but is difficult to determine in the groundmass quartz due to its fine grain size.

A number of quartz veins, less than 1 cm wide, which formed after the main deformation, show crystals with regular polygonal outlines which meet in triple point junctions that are close to 120°. Undulatory extinction is not found in this quartz.

Anhedral plagioclase, 0.05 x 0.1 mm, comprises about 2 percent of the rock. A composition of oligioclase (An_{16}) was obtained (Michel-Levey method) from measurements made on ten grains.

The bright green mica which generally constitutes about 2 percent of the rock by volume resembles pale green sericite in thin section. X-ray diffraction patterns are identical to those of muscovite. XRF analysis of a specimen containing approximately 3 percent of the mica gave 0.10 percent Cr_2O_3. Chromian muscovites with more than 1 percent Cr_2O_3 are called mariposite or fuchsite (Deer et al., 1962). The mineral defines a strong mineral lineation in the rock.

E. Acidic volcanic rocks

Acidic lavas

The acidic lavas have quartz and plagioclase phenocrysts in a very fine grained, less than 0.02 mm, quartz-rich groundmass which may contain up to 5 percent biotite and minor amounts of

sericite, chlorite, actinolite, epidote and clinozoisite.

The dominant texture in the acidic lavas, as in other rocks of the Rambler area, is the well developed mineral lineation.

Subhedral to euhedral plagioclase phenocrysts, 0.5 x 1.5 mm, were found in all thin sections of acidic lava studied. The phenocrysts generally have their long axes parallel to the long axes of other lineated minerals. In sections parallel to the long axes the phenocrysts commonly exhibit boudinage structures.

Some of the plagioclase phenocrysts are relatively free of inclusions while others in the same section have a dusty appearance due to an incipient alteration. Granular clinozoisite and zoisite are rarely observed as an alteration product of plagioclase in these rocks.

Quartz phenocrysts and aggregates of quartz grains have mean diameters of approximately 1 mm. Quartz phenocrysts generally have rectangular outlines and exhibit undulose extinction while aggregates of quartz grains have irregular serrated boundaries and seldom exhibit any evidence of strain. Occasionally quartz phenocrysts have pressure fringes of granular quartz which give the phenocrysts a lineated appearance. Aggregates of quartz grains, 0.2 mm in diameter, in lenses several mms in diameter are distinctly elongated and probably represent recrystallization of quartz phenocrysts or the crystallization of quartz during deformation and metamorphism. In sections parallel to the lineation micaceous minerals wrap around quartz phenocrysts.

Very fine grained quartz, less than 0.02 mm, is the main constituent of the acidic lavas. In sections normal to the lineation in the rock the quartz has a granular appearance but

rarely exhibits polygonal outlines or undulose extinction. Sections parallel to the lineation are generally granular with some sections having elongated grains in which the length is approximately twice the width.

Biotite which seldom constitutes more than 5 percent of the rock occurs mainly as elongated crystals which define a strong linear fabric in most of the acidic rocks. Porphyroblastic, randomly oriented biotites enclose lineated quartz and cut across the earlier first deformation lineation.

Minor constituents of the acidic lavas are clinozoisite, epidote, chlorite and acicular actinolite.

Acidic pyroclastic rocks

Fragments of acidic rocks are mineralogically and texturally identical to the acidic lavas. In addition fragments of basic material are found throughout the groundmass. The basic fragments consist mainly of lineated actinolite and/or chlorite with minor quartz. Traces of a very fine grained colourless mica, probably muscovite, are present in several thin sections.

Acidic fragments in basic agglomerates

Acidic fragments in basic agglomerates, map unit 2C (Plate I), are mineralogically and texturally similar to the acid lavas. The rock has a strong mineral lineation and consists of quartz and feldspar phenocrysts in a quartz rich groundmass with approximately 5 percent biotite. Epidote and calcite are minor constituents.

F. Basic sedimentary rocks

The predominant rock type found in the roadside exposures consists of clastic quartz and feldspar, 0.1 to 1.0 mm in diameter,

in a quartz-biotite groundmass. Lineated biotites and hornblendes

defining the first schistosity have been crenulated by the third

cleavage. Approximately 50 percent of the rock consists of

granular quartz less than 0.01 mm in diameter.

Amphibolitic rocks interbanded with the quartz-biotite clastic

sediments contain predominantly lineated blue green hornblende and

approximately 15 percent quartz and feldspar.

An unusually quartz rich rock at 14300N/18280E contains 10-15

percent chlorite with an anomalous blue birefringence (penninite?)

and euhedral syn- or post-deformation (D_1) garnets (Fig. 4-3A).

G. Intrusive rocks

Burlington Granodiorite

Livingston (1942) and Baird (1951) describe the petrography

of the "Burlington Granodiorite". Livingston (1942) describes

rocks of the Burlington Granodiorite immediately west of the

Rambler area as:

> "In thin section the rock is seen to consist of albite,
> quartz, hornblende, biotite, and microcline. Accessory
> minerals are apatite, titanite, zircon, and pyrite
> altered in part to limonite. Clinozoisite-epidote and
> sericite are·secondary.

> Albite is the most abundant mineral and makes up about
> 65% of the rock. Biotite and hornblende together make
> up about 15%, quartz about 14% and microcline about 5%.
> The albite is saussuritized, sericitized, and in part
> replaced with microcline......" (p.17).

A thin section of the intrusive 18 inches away from its

contact contains approximately 70 percent blue green hornblende

and 30 percent altered plagioclase feldspar. Biotite, clinozoisite

and pyrite are acesssory minerals.

The medium grained, 1-2 mm, hornblende and plagioclase are

lineated.

Figure 4-1 A.   Plagioclase microlites in pillow lava

near the Rambler Mine. Crossed polars. (X 200)

B.   Untwinned plagioclase core surrounded

by a rim of twinned plagioclase. Crossed

polars (upper) and uncrossed polars (lower).

(X 80)

C.   Radiating plagioclase crystals in an

amygdale surrounded by actinolite. Crossed

polars. (X 40)

D.   Radiating plagioclase crystals in an

amygdale. Same specimen as C. (X 80)

Figure 4-2 A.   Actinolite porphyroblast partly

altered to chlorite (black). Crossed polars.

(X 80)

B.   Lineated volcanic sediment. Section

cut normal to lineation. Quartz, chlorite and

pyrite. Partly crossed polars. (X 80)

C.   Lineated volcanic sediment. Same

specimen as B with section cut parallel to

lineation. Crossed polars. (X 80)

D.   Lineated tuffaceous rock. Quartz,

actinolite and chlorite (black). Partly

crossed polars. (X 80)

A
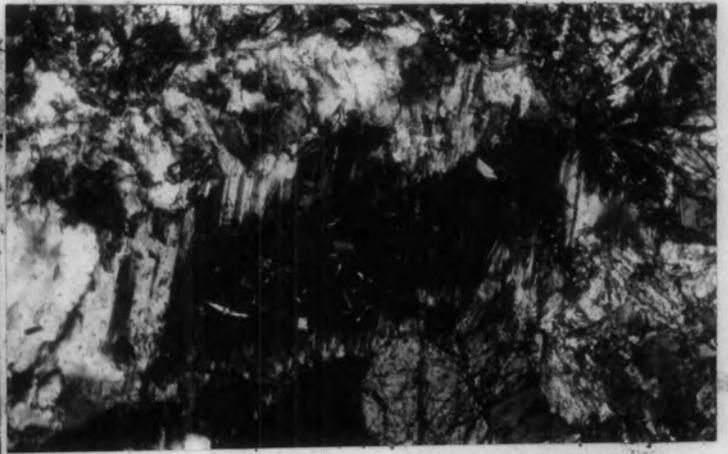
B
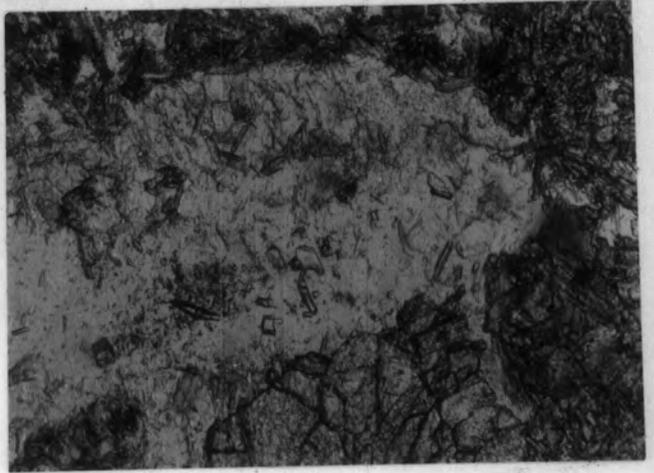
C

D
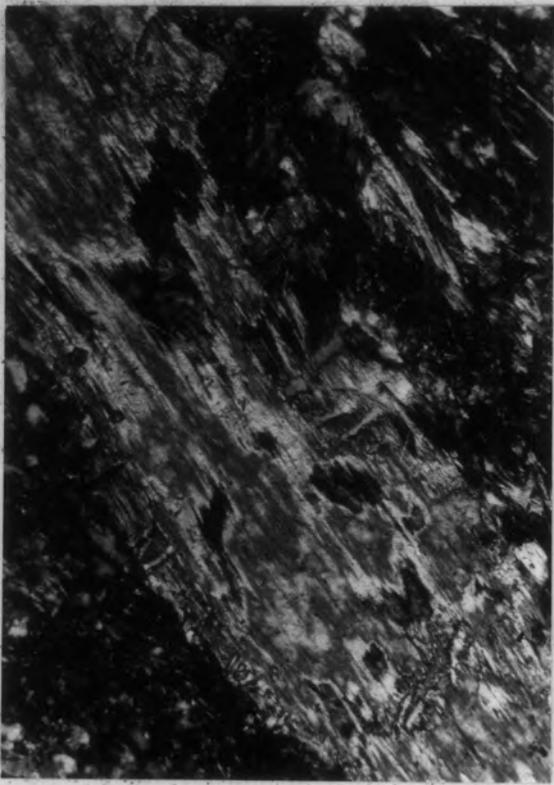
A

B

C

D

Figure 4-3 A. Garnet porphyroblast. Quartz, chlorite, and garnet. Uncrossed polars. (X 200)

B. Stratiform volcanic sediment. Section normal to the lineation. Plagioclase, quartz and chlorite. Crossed polars. (X 80)

C. Boudinaged plagioclase in stratiform volcanic sediment. Plagioclase, quartz and chlorite. Crossed polars. (X 80)

D. Porphyroblastic biotite enclosing grains of pyrite and quartz in quartz-chlorite schist. Quartz, chlorite, pyrite and biotite. Uncrossed polars. (X 80)

Figure 4-4 A. Amygdale in basic pillow lava. The amygdale is filled with plagioclase which is partly overgrown by actinolite. The groundmass mineral is actinolite. Uncrossed polars. (X 40)

B. Amygdale in basic pillow lava. Crossed polars. (X 40)

C. Deformed plagioclase phenocryst. The groundmass mineral and the acicular minerals in the plagioclase is actinolite. Crossed polars. (X 80)

D. Lath shaped actinolite in basic pillow lava. Crossed polars. (X 200)
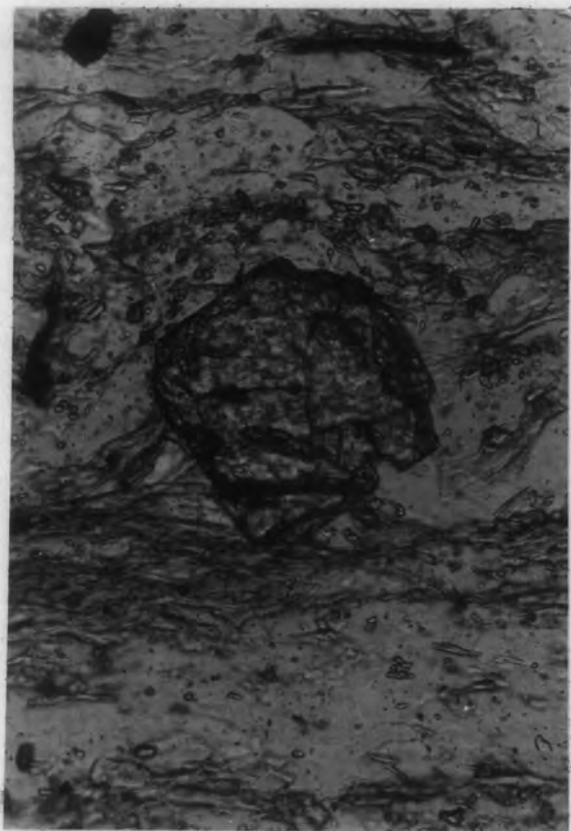
A
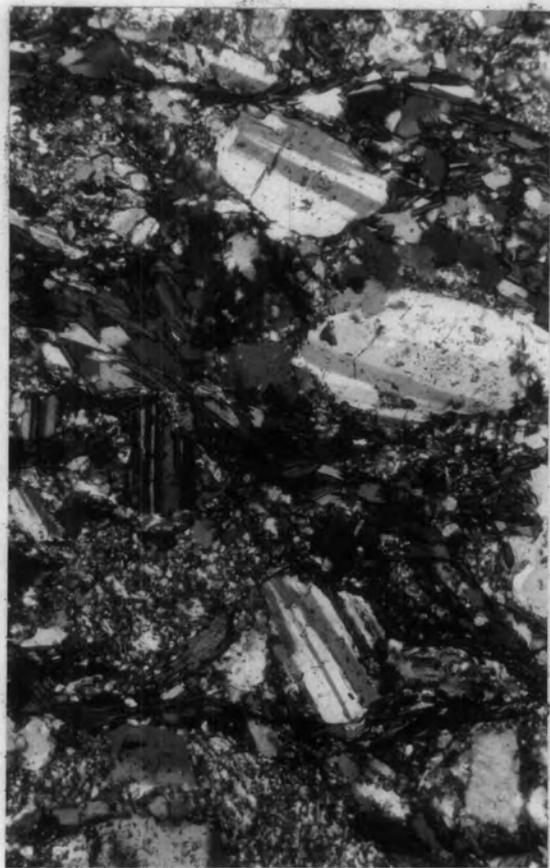
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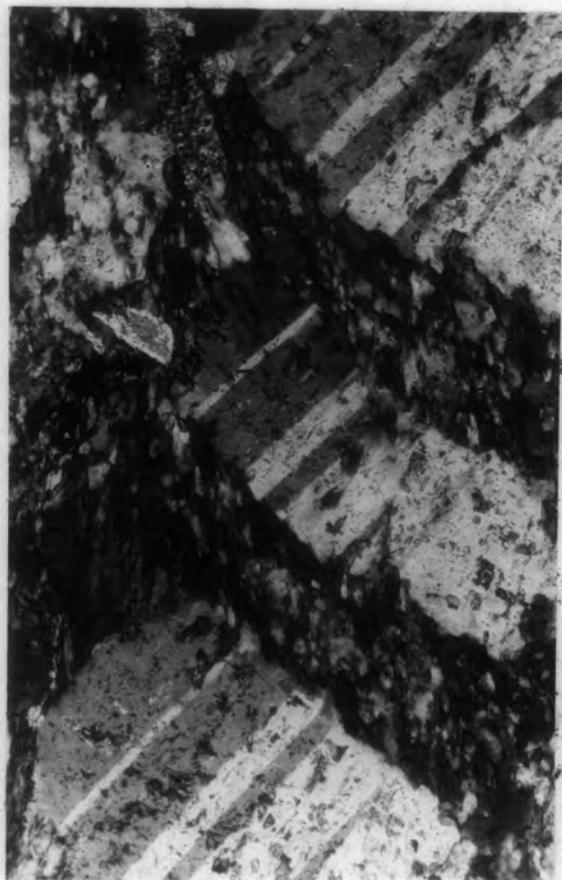
C
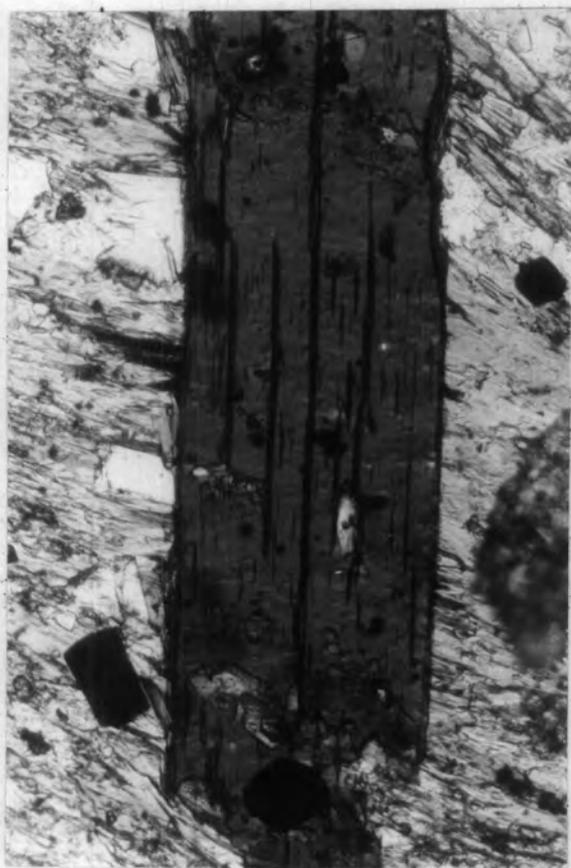
D
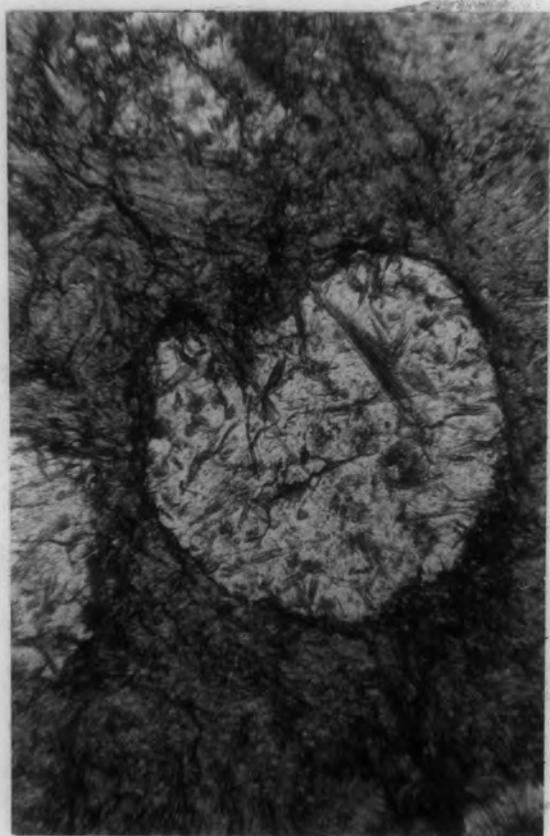
A

B

C

D

Figure 4-5 A. Lineated actinolite porphyroblasts in
a very fine grained matrix of acicular actinolite
(black). Crossed polars. (X 80)

B. Plagioclase phenocrysts in acidic lava.
Section cut parallel to lineation. Crossed
polars. Quartz, biotite and plagioclase. (X 80)

C. Quartz phenocryst in acidic lava.
Section cut normal to lineation. Quartz and
biotite. Uncrossed polars. (X 80)

D. Quartz and plagioclase phenocrysts in
acidic lava. Same specimen as C with section
cut parallel to lineation. Quartz, biotite and
plagioclase. Crossed polars. (X 80)

Figure 4-6 A. Fine grained basic dike. Plagioclase
and hornblende. Crossed polars. (X 80)

B. Fine grained basic dike. Plagioclase,
hornblende and epidote. Crossed polars. (X 80)

C. Lineated hornblende in fine grained
basic dike. Hornblende, plagioclase and epidote.
Section cut parallel to lineation. Crossed
polars. (X 80)

D. Lineated amphibolite. Section cut
normal to lineation. Uncrossed polars. (X 80)
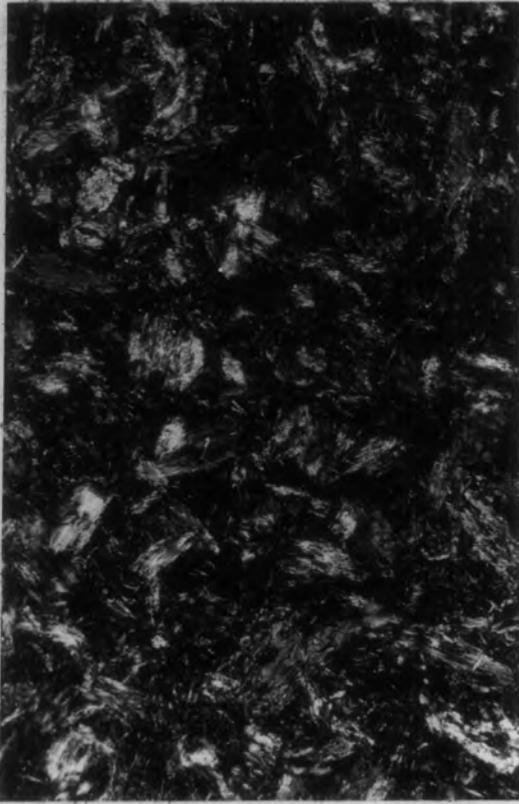
A

B
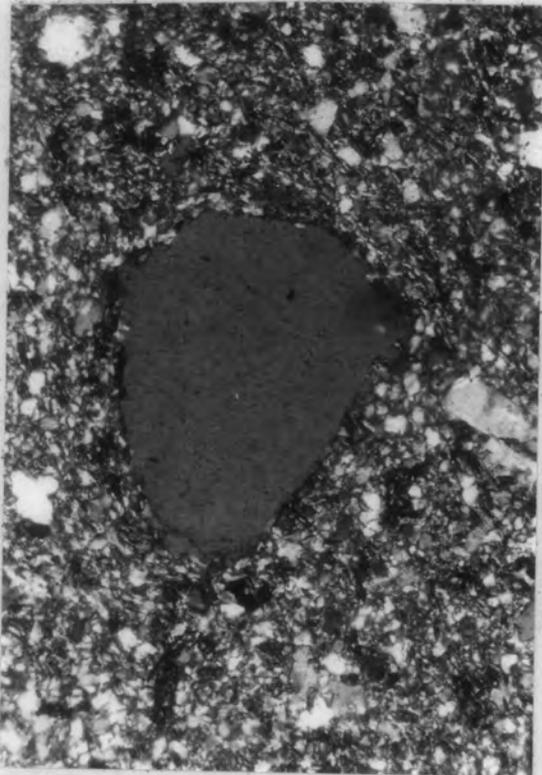
C
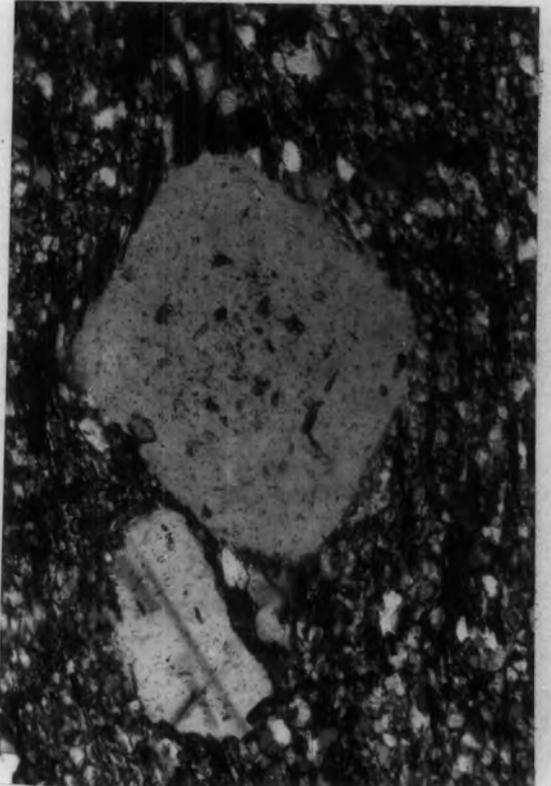
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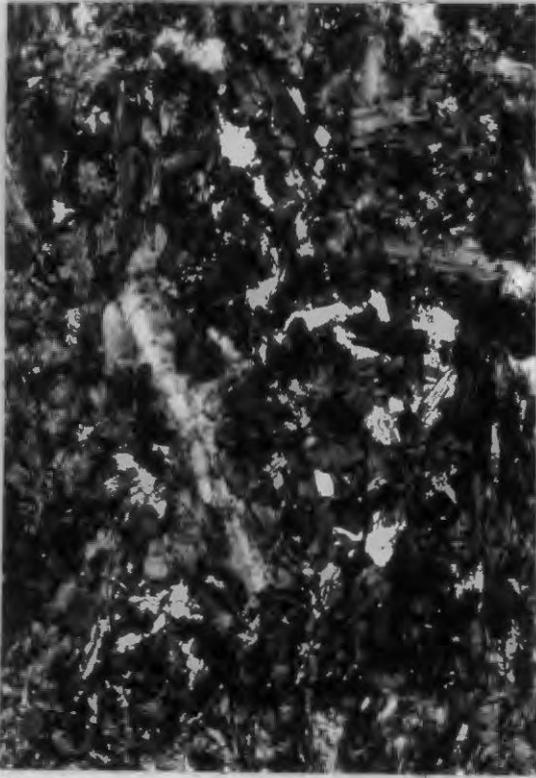
A

B
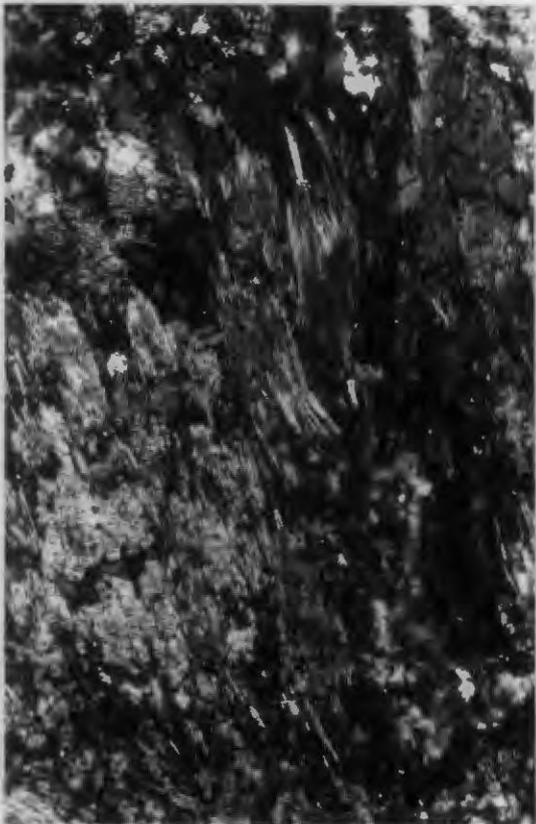
C

D

A specimen of the intrusive collected approximately 500 feet from the contact contains approximately 40 percent hornblende and 60 percent plagioclase. Minor constituents are biotite, quartz and clinozoisite.

Leucocratic intrusive

This rock is comprised of green porphyroblastic hornblende, 1 x 3 mm, and epidotized plagioclase 0.5 x 1.0 mm. Approximately 95 percent of the original plagioclase has been altered to granular clinozoisite. Scattered plagioclase laths, .05 x 0.2 mm, remain in a relatively unaltered state.

Basic intrusives

There is no significant mineralogical difference between fine grained, fine grained porphyritic and medium grained basic intrusives. The main textural difference in these rocks is the difference in grain sizes.

The basic intrusives consist mainly of plagioclase and a green hornblende. The total content of epidote, clinozoisite and zoisite varies from trace amounts to approximately 30 percent. Biotite, chlorite, titania and quartz are minor constituents.

A pale green to green hornblende is present in all basic intrusives. The mineral ranges in grain size from needles, 0.01 x 0.05 mm, up to short stubby crystals 1 x 2 mm. Euhedral grains are extremely rare. The most common grain boundary is fibrous and the hornblende is intergrown with plagioclase.

Euhedral plagioclase phenocrysts up to 4 mm in length are present in fine grained porphyritic intrusives. The plagioclase phenocrysts are generally completely altered to zoisite, clino-zoisite and rarely epidote. The original nature of the phenocrysts

is only recognizeable on the basis of the rectangular outline of

the epidotized masses. The epidotization of plagioclase varies

from intrusives in which the plagioclase contains only scattered

minerals of the epidote group to those in which all of the

plagioclase has been replaced by either epidote, clinozoisite or

zoisite. Deformational textures in plagioclase include boudined

crystals and undulatory extinction.

Biotite and chlorite are present in late stage veins cutting

the intrusives and also as an incipient alteration of hornblende

in specimens where the plagioclase has been completely altered.

In some of the basic intrusives there is a definite mineral

(hornblende) lineation, however, in others the only evidence of

deformation is the undulose extinction in plagioclase(Fig.4-6C).

H. Metamorphism of the Rambler Area

The earliest metamorphic event recognized in the Rambler

area is that accompanying the first deformation during which

chlorite, actinolite, hornblende and quartz crystallized with

L and L $\gg$ S fabrics (Flinn, 1965). The original constituents of

amygdales must have recrystallized to plagioclase during this

metamorphism since plagioclase crystals in lineated amygdales

are overgrown by actinolite.

The presence of hornblende and actinolite porphyroblasts

with a random orientation overgrowing oriented amphiboles

indicates that recrystallization continued in a stress free

environment after the main deformation had ceased.

If a metamorphic event accompanied the second deformation

which produced isoclinal folding then it must have been of very

low grade since chlorites crenulated by the second cleavage did not recrystallize parallel to the crenulation cleavage, S_2.

Biotite grade greenschist conditions of metamorphism probably prevailed at the time of the third deformation when the open recumbent folds were formed since fine grained biotites have crystallized parallel to the axial plane crenulation cleavage, S_3, in some of basic sedimentary rocks.

The presence of porphyroblastic biotite and books of biotite sometimes poikiloblasticly enclosing lineated quartz produced during the first metamorphic event and the occurrence of biotite intergrown with chlorite and replacing actinolite in several thin sections indicate that a second metamorphic event has affected the Rambler area. It must be noted here that this biotite is later than the biotite forming the L and L $\gg$ S fabrics produced during the first metamorphism in the basic sedimentary and acidic rocks. Since the biotite porphyroblasts are randomly oriented and therefore cannot be related to any of the recognized structural events affecting the Rambler area the time of this metamorphic event is known only as taking place after the first metamorphism and not taking place at the same time as the second or third deformations. On the other hand, the growth of the biotite porphyroblasts may have taken place either immediately after the first metamorphism or after either of the second or third deformations.

The metamorphic conditions affecting the Rambler area are considered in the light of the mineral assemblages observed in thin section and the mineral analyses presented in Table 4-1 and 4-2.

Mineral assemblages produced during the first metamorphism are:

1. Actinolite + albite $\pm$ epidote $\pm$ quartz in basic lavas in the southern part of the area.

2. Actinolite + albite + quartz + epidote $\pm$ chlorite in basic pyroclastic rocks.

3. Actinolite + hornblende + albite + epidote $\pm$ quartz $\pm$ chlorite in basic lavas east of the Rambler mine.

4. Hornblende + albite $\pm$ chlorite $\pm$ epidote in basic pyroclastic rocks along the La Scie Road in the northern part of the area.

Assemblage No.4 is the typical assemblage of the 'Quartz-albite-epidote-almandine' subfacies of the greenschist facies (Winkler, 1967). The presence of albite (An_2) in association with hornblende (specimen 98225, Tables 4-1 and 4-2) indicates that the metamorphic conditions have not reached those of the almandine amphibolite facies since the stable plagioclase in that assemblage contains more than 15 percent of the anorthite molecule when it is in equilibrium with hornblende (Winkler, 1967).

Winkler (1967) considers the replacement, in basic rocks, of actinolite by hornblende in the presence of albite evidence for the appearance of the 'quartz-albite-epidote-almandine' subfacies.

In mineral assemblages Nos. 1 and 2 presented above, biotite is conspicuously absent from the minerals formed during the first metamorphic event in the basic volcanic rocks. On the basis of the mineral assemblages it is equally plausible to assign these rocks to either the 'quartz-albite-muscovite-chlorite' subfacies or the 'quartz-albite-epidote-biotite' subfacies of the greenschist

Table 4-1   Electron microprobe analyses of amphiboles.

Oxide	1	2	3
SiO_2	52.36	54.00	44.43
Al_2O_3	4.35	5.40	11.93
Fe_2O_3	11.91	11.59	19.55
MgO	15.84	15.84	8.14
CaO	13.10	13.33	12.09
Na_2O	0.49	0.35	1.45
K_2O	0.06	0.15	0.43
MnO	0.27	0.23	0.40
Total	98.39	100.89	98.42

1. Actinolite, specimen 96203

2. Actinolite, specimen 96273

3. Blue green hornblende, specimen 98225

Table 4-2   Electron microprobe analyses of plagioclase.

Sample	Type of Feldspar	Location	% Na$_2$O	% CaO	% An
96203	Amygdale	center	11.30	1.22	6
	"	"	11.03	1.16	5
	"	rim	10.71	1.77	8
	"	"	10.55	1.72	8
	"	center	10.43	1.89	9
	"	"	11.29	1.07	5
	"	"	11.02	1.16	5
	"	rim	10.06	1.19	5
	Phenocryst	center	10.91	1.58	7
	"	rim	10.82	1.62	8
	Amygdale	center	10.73	1.93	9
	"	"	10.75	1.94	9
	"	rim	10.31	2.18	10
96273	Phenocryst	center	10.12	1.55	7
	"	rim	10.53	2.04	10
	"	"	11.17	1.03	5
991810	Phenocryst	center	11.25	0.46	2
	"	rim	11.42	0.48	2
	"	rim	11.28	0.50	2
	"	center	11.16	0.52	2
	"	"	11.74	0.40	2
	"	rim	11.46	0.54	3
	"	center	11.73	0.58	3
9822-5	Phenocryst	center	11.14	0.40	2

facies. However, several aspects of the mineralogy appear to indicate that metamorphic conditions of the biotite grade rather than the chlorite grade prevailed over most of the Rambler area, namely: chlorite is only a minor constituent in the basic lavas; the albite compositions of An_{5-10} in the presence of a calciferous mineral, actinolite, includes and exceeds the upper limit of An_7 for plagioclase stable within the greenschist facies (Winkler, 1967); and the presence of both actinolite and hornblende in assemblage No.3 represents a transition between assemblage No.4 and assemblages No.1 and No.2. It is not unreasonable to assume that since the metamorphism was prograde then the transition is between 'Quartz-albite-epidote-almandine' and 'Quartz-albite-epidote-biotite' subfacies rather than the 'Quartz-albite-muscovite-chlorite' subfacies which is characteristic of lower temperature and pressure conditions than the 'Quartz-albite-epidote-biotite' subfacies.

On the basis of the foregoing discussion it is concluded that metamorphic conditions of the 'Quartz-albite-epidote-almandine' subfacies existed in the northern part while conditions of the 'Quartz-albite-epidote-biotite' subfacies existed in the southern part of the Rambler area during the first metamorphic event.

The appearance of biotite and amphibole prophyroblasts unrelated to any particular deformational episode indicates that metamorphic conditions of the 'Quartz-albite-epidote-biotite' subfacies affected the area some time after the first metamorphic event ceased. It is not known whether this thermal

event is related to a hidden intrusive or to a post-
deformational regional metamorphism.

CHAPTER V

CHEMISTRY OF THE COUNTRY ROCKS

A. Introduction

In the course of the laboratory work, representative samples of the country rocks were analysed by XRF. A brief description of the analytical procedure and a list of the operating conditions are given in Appendix A. The major and trace element analyses are presented in Appendix C.

Since FeO values are required in the calculation of normative mineralogy and FeO determinations were not made, it was necessary to adjust the analyses prior to calculation of C.I.P.W. norms. The procedure of Irvine and Barrager (1970) was followed and for allocation to the Fe-Ti oxides, the percent Fe_2O_3 was taken as percent TiO_2 + 1.5. The remainder of the Fe_2O_3 in each analysis was then recalculated as FeO. The C.I.P.W. norms are presented as Appendix E.

B. Chemistry of the basic volcanic rocks

An examination of the analyses of basic pillow lavas, analyses 31 to 42 of Appendix C, reveals the presence of two chemically distinct rock types.

The pillow lavas represented by analyses 40 to 42 have higher Al_2O_3 and TiO_2 but lower MgO than the pillow lavas represented by analyses 31 to 39. Furthermore, the trace elements Zr, Y, Ni and La are distinctly different for the two groups. The mean analysis of each group is presented in Table 5-1, columns 1 and 2.

The group of pillow lavas with the higher TiO_2 values are chemically similar to tholeiite basalts and will be referred to as tholeiites in the following discussion. The low TiO_2 pillow

Table 5-1 Comparison of Rambler pillow lavas
with rocks from other parts of the world.

	1	2	3	4	5
SiO_2	52.83	49.07	49.61	52.80	53.35
Al_2O_3	9.49	15.39	16.01	6.05	10.13
Fe_2O_3	10.71	12.18	12.63	11.25	11.12
MgO	14.21	7.84	7.84	13.99	11.73
CaO	10.22	9.70	11.32	11.92	7.35
Na_2O	2.00	3.61	2.76	1.02	1.46
K_2O	0.12	0.09	0.22	0.13	0.10
TiO_2	0.16	1.68	1.43	0.66	0.46
MnO	0.17	0.11	0.18	0.23	-
S	0.02	0.09	-	-	-
P_2O_5	0.07	0.18	0.14	-	0.06
Ba	33	12	14	-	-
Nb	2	4	30	-	-
Zr	14	149	95	-	-
Y	3	29	28	-	-
Sr	136	239	130	-	-
Rb	3	2	1	-	-
Zn	70	100	-	-	-
Cu	14	65	77	-	-
Ni	330	43	97	-	-
La	1	6	2	-	-

1. Mean of 9 ultramafic pillow lavas, Rambler.

2. Mean of 3 tholeiitic pillow lavas, Rambler.

3. Mean oceanic tholeiite (Major elements after Cann, 1971; La and Y from Schilling, 1969; other trace elements after Engel et al., 1965).

4, 5. Basaltic komatiites (Viljoen and Viljoen, 1970b).

- not determined.

lavas have an unusual chemical composition in that they have Al_2O_3 and MgO contents that are representative of ultramafic rocks and hence will be referred to as 'ultramafic lavas' in order to distinguish them from the other, tholeiitic basic lavas.

In Figures 5-1 and 5-2 some of the major oxides and trace elements are plotted against SiO_2. Basic rocks with more than 1.0 percent TiO_2 belong to the tholeiitic group and are indicated by solid symbols in Figures 5-1 and 5-2.

The chemical differences between the tholeiitic (closed triangles) and the ultramafic pillow lavas (open triangles) are readily apparent in the variation diagrams. The ultramafic pillow lavas have lower TiO_2, Al_2O_3, Na_2O, Zr, Y and Sr, and higher SiO_2 MgO and Ni than the tholeiitic pillow lavas.

One of the striking features of the normative mineralogy is the presence of high normative hypersthene in the ultramafic pillow lavas in contrast to the olivine normative, tholeiitic pillow lavas.

Non-pillowed basic lavas and agglomeratic basic rocks contain up to 62 percent SiO_2. Two of the non-pillowed lavas, Nos. 43 and 60, are tholeiitic in composition. The remainder of the basic lavas and agglomeratic rocks resemble the ultramafic pillow lavas in their range of TiO_2, Al_2O_3, Zr and Y values.

Tuffaceous rocks that are chemically similar to the tholeiitic rocks have been found at two localities adjacent to exposures of the tholeiitic lavas. Analyses 64 and 65 are of basic tuffaceous rocks cropping out near the exposures of tholeiitic pillow lava immediately east of the Rambler Mine at S890N/13260E, and analyses 61 to 63 are of stratiform volcanic sediments cropping out near an exposure of tholeiitic lava on the La Scie road at 13700N/14140E.

Although analyses of the tuffaceous and stratiform volcanic sediments (analyses 61-65) have not been plotted on the variation diagrams, because of the possibility of modification of the original composition by depositional processes, the analyses would not alter the variations shown in Figures 5-1 and 5-2. The relationship of the tuffaceous rocks (analyses 61-65) to the tholeiitic pillow lavas is apparent from the analyses since all have higher TiO_2, Al_2O_3, Zr and Y than the ultramafic lavas and pyroclastics. This relationship is reinforced when the analyses (61 to 65, appendix C) are compared with the analysis (No.66) of a tuffaceous rock from the southwestern part of the Rambler area where the pillow lavas and agglomeratic rocks are all ultramafic in composition.

Other interesting features of the basic volcanic rocks, and indeed of almost all rocks of the Rambler area, are the low potassium and rubidium contents. Although the rubidium values obtained for some of the basic rocks are close to the limits of detection of the method used (1 ppm) and some of the K/Rb ratios are therefore suspect, the K/Rb ratios (see Figure 5-3) fall mainly in the fields for ultramafic rocks, and eclogitic inclusions in ultramafic rocks, as defined by Murthy and Stueber (1967). In view of the possibility of some of the data being unreliable, one cannot draw any definite conclusions from the data. However, they tentatively suggest that the rocks have been derived from a primitive magmatic source. A further refinement of these data is anticipated in the near future, in order to determine whether this relationship is true.

Flat rare earth abundance patterns, parallel but enriched relative to chondrites, are thought to characterize unambiguously

the ocean floor basalts of the mid-ocean ridges (Schilling, 1969;

Frey et al., 1968; Gast, 1968). Jakeš and Gill (1970) have noted

similar rare earth patterns in island arc tholeiites.

Rare earth values obtained for the tholeiitic pillow lavas

of the Rambler area are similar to those obtained for basalts

from the ocean floor by Jakeš and Gill (1970) and Schilling (1969)

(cf. Columns 2 and 3, Table 5-1). However, the rare earth values

obtained for the ultramafic pillow lavas are distinctly different

from any of the values obtained for basaltic rocks (Jakeš and Gill,

1970).

It should be noted that the mean Y value of 3 ppm obtained for

the ultramafic pillow lavas is comparable with the values of 3 ppm

obtained on the U.S.G.S. standard rocks DTS-1 and PCC-1 by

Carmichael et al. (1968).

The mean analyses of the ultramafic and tholeiitic pillow

lavas of the Rambler area are compared with analyses of chemically

similar rocks from other parts of the world in Table 5-1. A

comparison of columns 2 and 3 of Table 5-1 shows that a remarkable

similarity in major element and trace element chemistry exists

between the tholeiitic pillow lavas of the Rambler area and the

ocean floor basalts.

Although an intensive search was made of the literature, the

writer was able to find only one publication containing analyses

of rocks with a chemistry similar to the ultramafic pillow lavas

of the Rambler area. Analyses 4 and 5 of Table 5-1 are of ultra-

mafic extrusive rocks from the Barberton Mountain Land area of

the South African shield (Viljoen and Viljoen, 1970b). Although

the publication describing the geochemistry of the rocks from the

Komati formation was not available to the author, the field

descriptions given by Viljoen and Viljoen (1970a) and the analyses given in Viljoen and Viljoen (1970b) indicate that the rocks which they call 'komatiites' have an identical geological setting and a chemistry similar to the ultramafic pillow lavas of the Rambler area. These authors (1970b) indicate that the basaltic komatiites of the Kaapmuiden area of South Africa are closely associated with layered ultramafic bodies.

Although a definite correlation between the komatiites and the Rambler ultramafic rocks is not possible until the results on the geochemistry of the Komati formation are available to the writer, it is tentatively suggested that the ultramafic rocks of the Rambler area are "komatiites".

C. Chemistry of the acidic rocks of uncertain origin

The mean of three analyses (Nos. 79, 80 and 81, appendix C) of the chert-like acidic rocks is given in column 3, Table 5-2. These rocks, like two of the pyroclastic acidic volcanic rocks, have an unusual chemistry for rocks of the Rambler area in that they contain more than 1 percent K_2O. These high K_2O values suggest that the rocks are not simply very fine grained acidic tuffs - the acidic pyroclastics with more than 1.0 percent K_2O have basic sedimentary (?) material mixed with the blocks of acidic rock. Although the geochemistry does not prove the origin of these rocks, it does support the earlier suggestion (Chapter IV) that they are recrystallized chert bands. The relatively high K_2O can then be attributed to the precipitation of K-rich clay minerals which have later recrystallized to muscovite.

Table 5-2 Analyses of Rambler acidic rocks compared
with quartz-albite porphyry from Troodos, Cyprus.

	1	2	3
SiO_2	76.52	77.04	82.75
Al_2O_3	11.40	10.95	8.53
Fe_2O_3	3.11	3.00	2.38
MgO	2.33	0.70	1.05
CaO	1.52	1.86	0.67
Na_2O	5.21	4.63	1.14
K_2O	0.36	0.18	1.83
TiO_2	0.26	0.20	0.08
MnO	0.03	0.05	-
S	0.06	-	1.48
P_2O_5	0.08	0.05	0.03
Cr_2O_3	-	-	0.09

1. Mean of 6 analyses of acidic lavas.

2. Quartz-albite porphyry, Troodos, Cyprus (Moores and
   Vine, 1970).

3. Mean of 3 analyses of acidic rocks (cherts).

- not determined.

Figure 5-1   Harker variation diagrams of some major

    oxides for country rocks.   Pillow lavas are in-

    dicated by triangles.   Non pillowed lavas and

    agglomeratic rocks are indicated by circles.

    Solid symbols indicate rocks of tholeiitic

    composition.

Figure 5-2   Variation diagrams of some trace elements.

    Symbols as in Fig. 5-1.
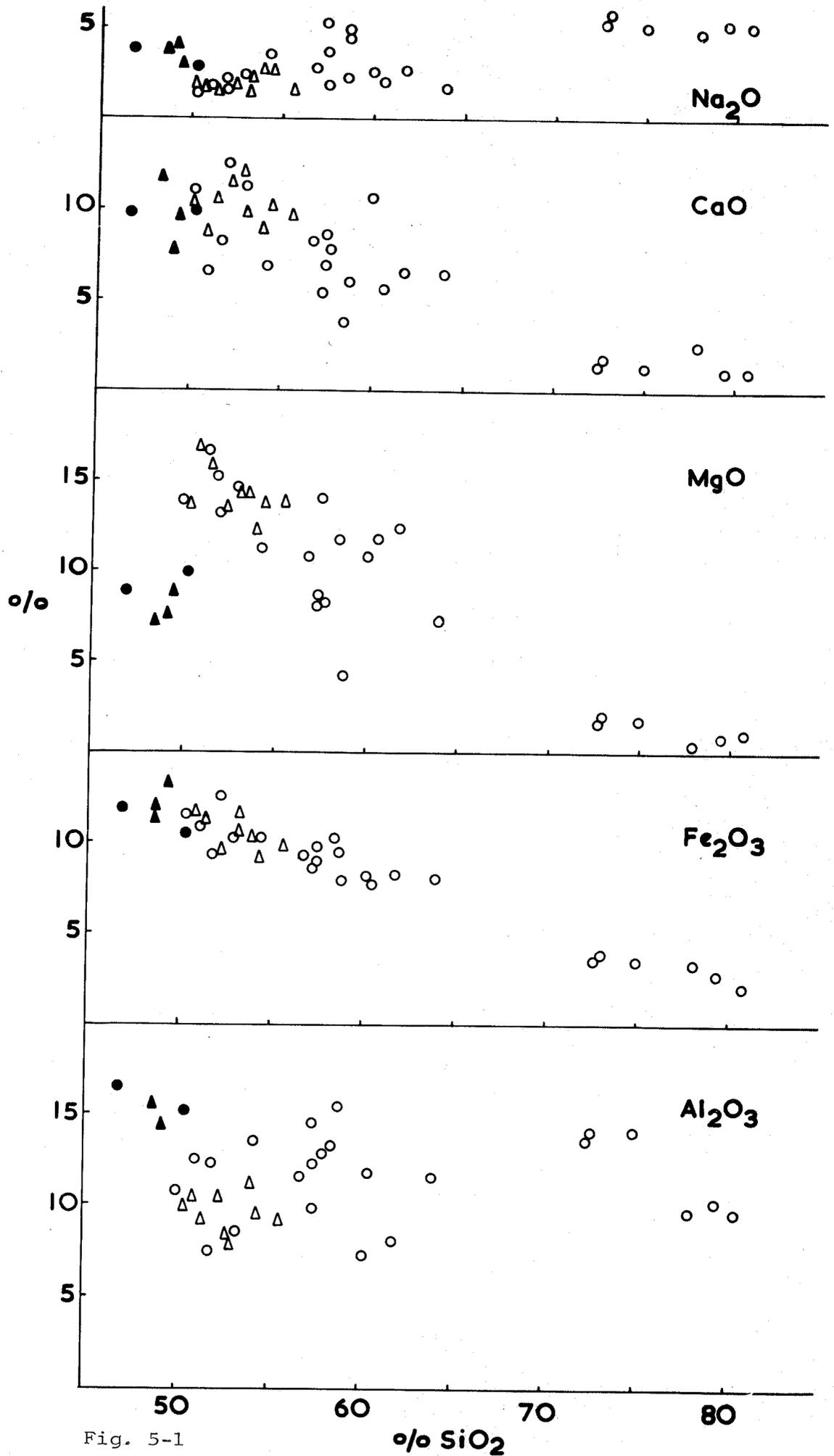
Fig. 5-1
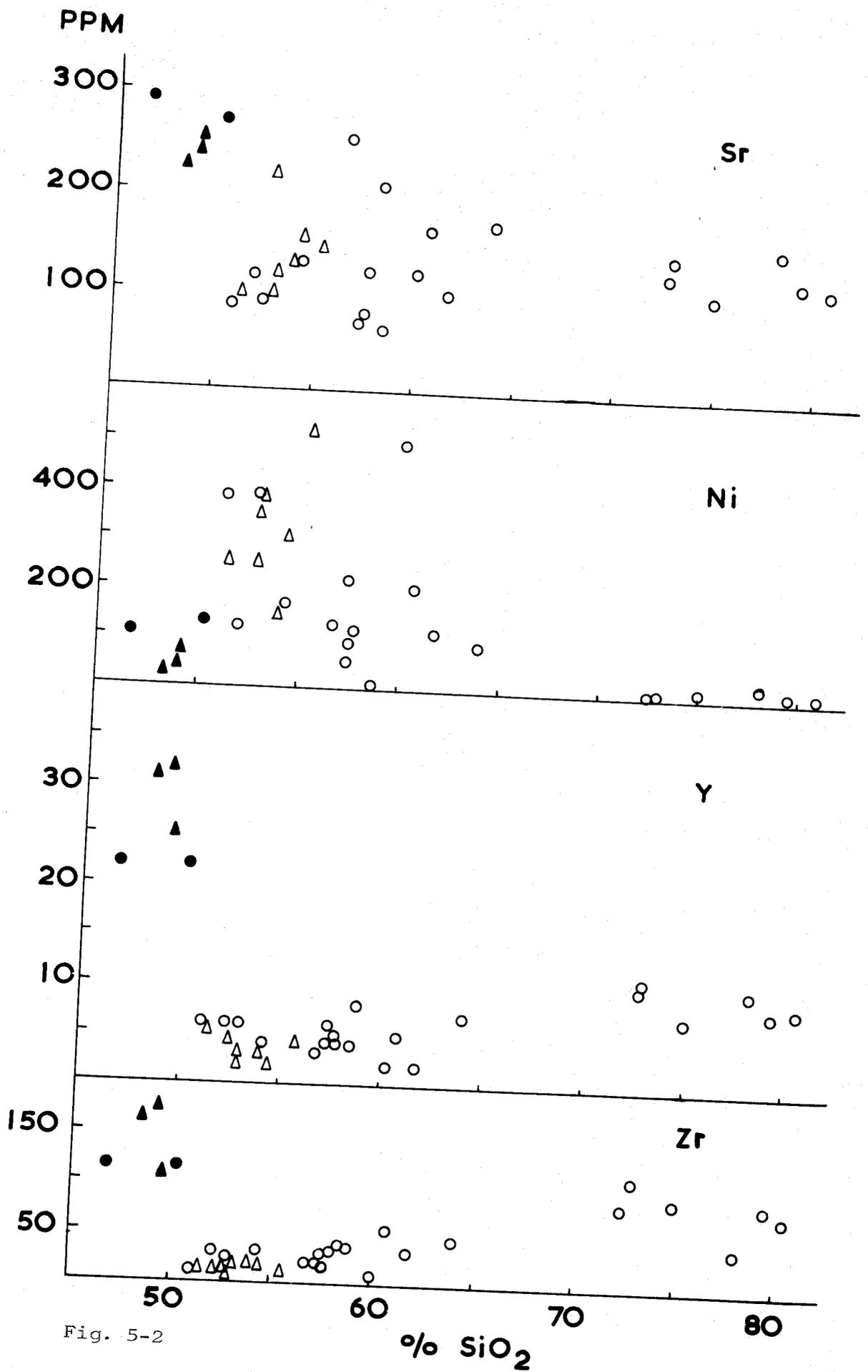
Fig. 5-2

D. Chemistry of the acidic volcanic rocks

Rocks mapped as acidic volcanics have a range of SiO_2 from 64.09 to 80.76 percent (analyses 67 to 77, appendix C). Acidic rocks with 64-70 percent SiO_2 are, with one exception, pyroclastic. The exception, analysis 68, is from a small exposure that may be part of an intermediate flow.

Two of the pyroclastic rocks contain more than 1 percent K_2O, which may be due to mixing of the acidic rock fragments with a K-rich mud on the sea floor.

Analyses of the rock identified as acidic flows (analyses 72 to 77, appendix C) are plotted in Figures 5-1 and 5-2, and the mean analysis is given in Table 5-2, column 1. The acidic lavas are similar to the other volcanic rocks in the Rambler area in that they have low potassium contents. It is not clear from the variation diagrams whether the acidic lavas have differentiated along the same path as the komatiites or the tholeiitic lavas. With the exception of MgO, the mean analysis of the acidic lavas is comparable with the analysis of a quartz-albite porphyry from the Troodos complex in Cyprus (Moores and Vine, 1970).

Analysis 78 is from a block of acidic rock embedded in a basic pyroclastic matrix. The analysis is comparable with analysis 77, an acidic lava, except for higher CaO which is probably the result of calcium migration from the basic matrix during metamorphism.

E. Chemistry of the intrusive rocks

Basic Intrusives

The major and trace element contents of 26 basic dikes are given in Appendix C (analyses 1 to 8, 12 to 29).

When the dikes are plotted on the Al_2O_3 - (Na_2O + K_2O) diagram

proposed by Kuno (1960), all fall in the tholeiitic field. All of the dikes fall within or close to the tholeiitic field defined by MacDonald and Katsura (1964) when plotted on the SiO_2 - $(Na_2O + K_2O)$ diagram (Fig. 5-4). On an AFM diagram (Fig. 5-5), the basic dikes show a trend similar to that of the Hawaiian tholeiites.

Variation diagrams in which the oxides are plotted against the Solidification Index (Kuno et al., 1957) are presented in Figure 5-6. The diagrams show decreasing Al_2O_3 and MgO and increases in Na_2O and Fe_2O_3 with decreases in the solidification index. CaO, and the major oxides not plotted on the variation diagram, do not show any definite trend with differentiation.

The composition of the basic dikes is compared with the compositions of other basaltic rocks in Table 5-3. The data suggest that the basic dikes are similar to oceanic tholeiites in their major element chemistry. The low K_2O and high MgO distinctly set the basic dikes apart from continental, island arc and island tholeiites.

With the exception of higher Sr, the trace element data for the basic dikes are similar to those of oceanic tholeiites rather than to other tholeiites, especially in regard to SiO_2, MgO, Na_2O, K_2O and TiO_2. Cann (1970) reports Y values of 16 to 40 ppm and Nb values of 1 to 19 ppm for ocean floor basalts that are comparable with the Y and Nb values of basic dikes from the Rambler area.

Both the major and the trace element data indicate chemical similarity between the basic dikes of the Rambler area and ocean floor tholeiites. In addition, the dikes are chemically similar to the tholeiitic pillow lavas found within the Rambler area

Table 5-3 Composition of the Rambler
intrusive rocks, with comparisons.

	1	2	3	4	5	6	7
SiO_2	48.76	49.0	51.3	49.61	50.58	48.11	49.19
Al_2O_3	12.97	12.7	14.2	16.01	17.32	13.32	19.83
Fe_2O_3	12.19	15.0	12.9	12.63	6.88	12.70	7.07
MgO	9.00	7.07	6.4	7.84	10.15	6.84	8.69
CaO	9.95	9.43	10.5	11.32	9.95	14.68	10.75
Na_2O	2.84	2.18	2.25	2.76	3.17	2.01	2.64
K_2O	0.19	0.95	0.85	0.22	1.04	0.25	0.78
TiO_2	1.58	1.44	2.05	1.43	0.69	1.65	0.78
MnO	0.17	0.15	0.2	0.18	-	0.18	0.16
S	0.11	-	-	-	0.02	0.04	0.05
P_2O_5	0.21	-	0.25	0.14	0.18	0.21	0.08

1. Mean of 26 metadolerites, Rambler area.

2. Mean of 45 Precambrian diabase dikes (Condie and Barsky, 1969)

3. Mean tholeiitic basalt and dolerite (Nockolds, 1954).

4. Mean ocean floor tholeiite (Cann, 1971).

5. Specimen 99181, Rambler ("Burlington Granodiorite").

6. Specimen 99182, Rambler ("Burlington Granodiorite").

7. Specimen 99105, Rambler.

- not determined.

Figure 5-3   K/Rb ratios in rocks and meteorites.

(after Murthy and Stueber, 1967).

Figure 5-4   Variation diagram of SiO_2 - (Na_2O + K_2O)

for basic intrusives. Solid symbols represent

specimens 99181, 99182 and 99185 which are

labelled as 1, 2 and 5, respectively. The solid

line is MacDonald and Katsura's (1964) dividing

line between Hawaiian tholeiitic and alkaline

rocks.
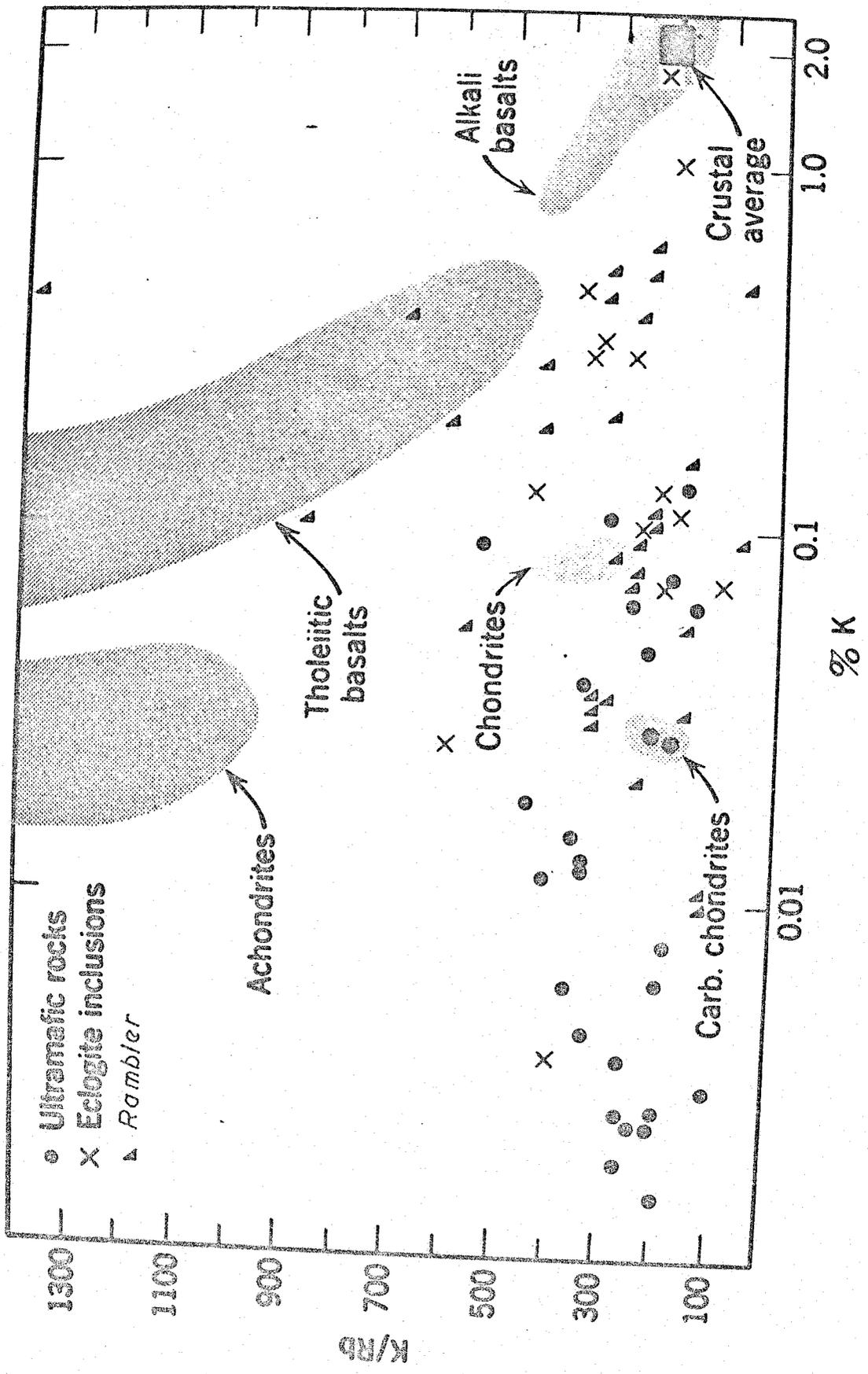
Fig. 5-3. K/Rb ratios in rocks and meteorites.
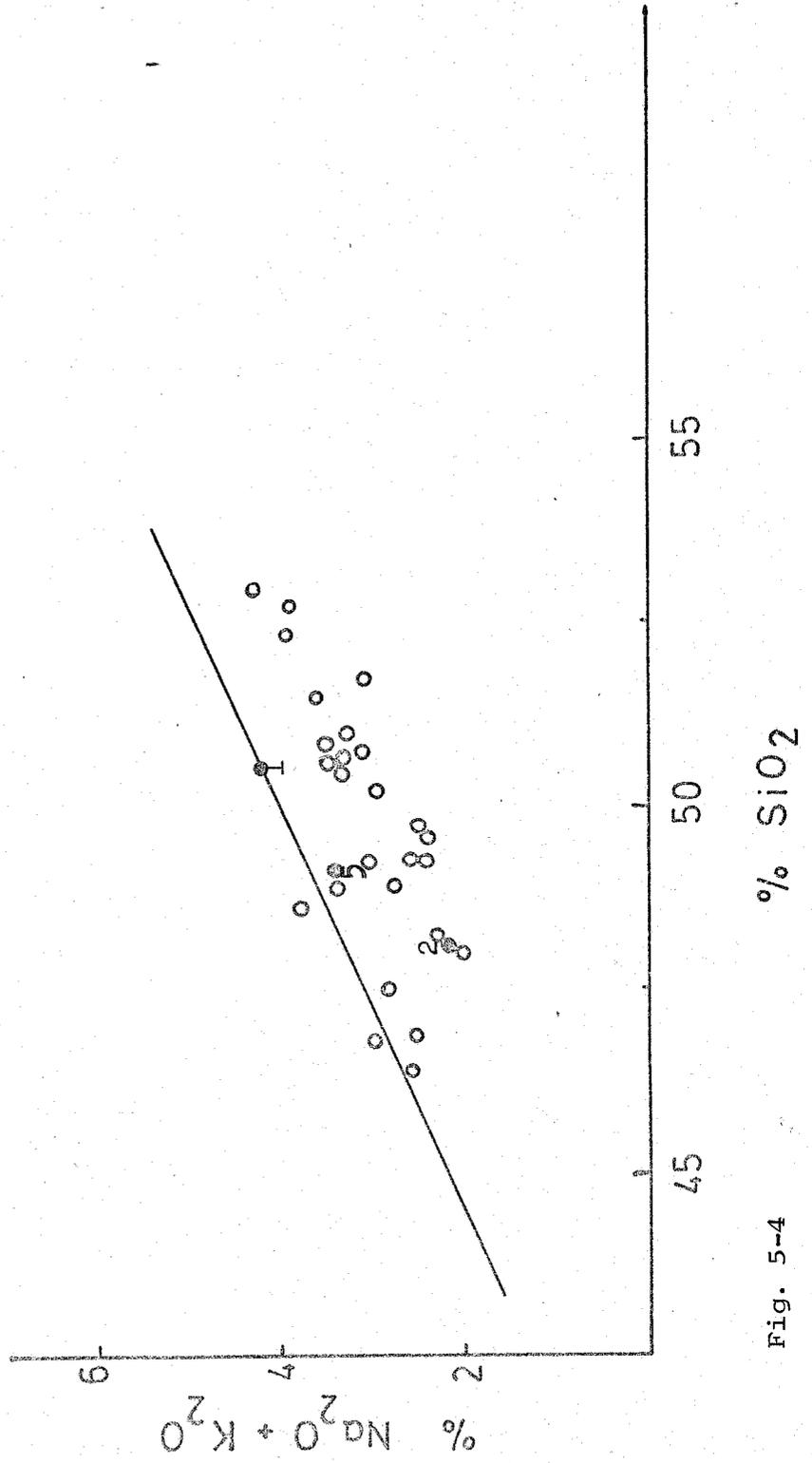
Fig. 5-4

Figure 5-5   Ternary diagram of $(Na_2O + K_2O) - Fe_2O_3$ as

total Fe - MgO.

A.   Basic intrusives.   The numbered points

1, 2 and 5 refer to specimens 99181, 99182 and

99185, respectively.   The solid line represents

the trend of Hawaiian tholeiites (MacDonald and

Katsura, 1964).

B.   Pillow lava.   Solid symbols represent

tholeiitic lavas.

C.   Lavas and agglomeratic rocks.   Solid

symbols represent tholeiitic lavas.

Figure 5-6   Variation diagram of Solidification

Index (SI) vs some major oxides for basic

intrusives.   The numbered solid symbols 1, 2 and

5, represent specimens 99181, 99182 and 99185,

respectively.
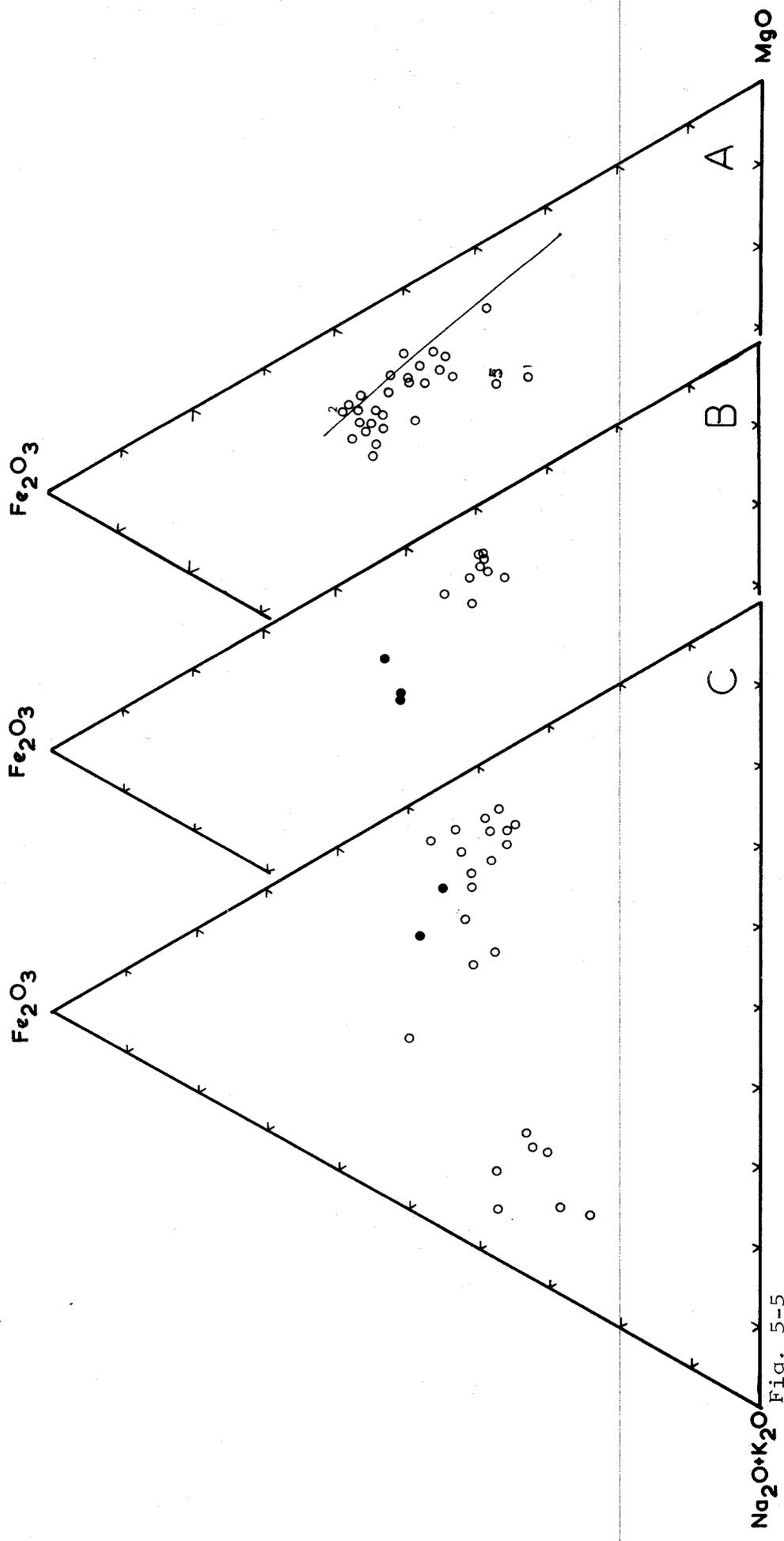
Fig. 5-5
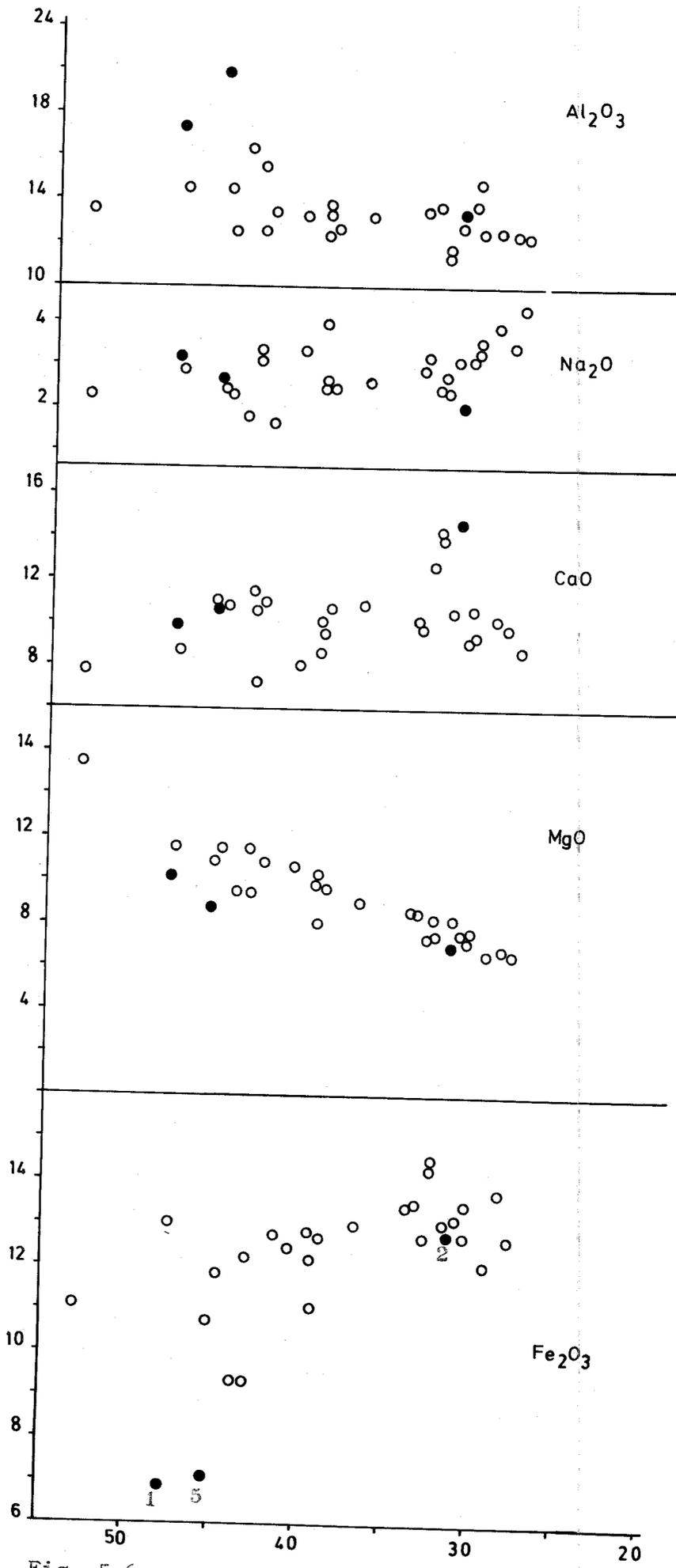
Fig. 5-6 $SI = MgO \times 100 / Fe_2O_3 + MgO + Na_2O + K_2O$

(cf. column 2, Table 5-1 and column 1, Table 5-3). Later in this chapter it is shown that there is also a chemical similarity between the dikes and the contact zone of the 'Burlington Granodiorite'.

a. Nomenclature of the basic dikes

The fine to medium-grained basic dikes have been classified as diorite or meta-diorite, on the basis of their appearance in hand specimen and thin sections, by Barrager (1954) and Livingston (1942). Daly (1933) gives a mean SiO_2 content of 59.67 percent for diorites; a figure that is well outside the range of SiO_2 (46.43 to 53.02 percent) obtained for these basic dikes.

The basic dikes consist mainly of plagioclase (albite) and hornblende and therefore may be classified as meta-diorites on the basis of their mineralogy (Hatch et al., 1961). Since it was pointed out in Chapter IV that the present mineralogy of the dikes is the product of regional metamorphism, a classification based only on mineralogy is not suitable for identification of these rocks.

The rocks are of basaltic composition and thus can be classified as dolerites on the basis of their chemistry. However, according to Hatch et al. (1961), dolerites contain calcic plagioclase and pyroxene.

The term diabase, as originally used by British geologists to describe rocks of doleritic composition in which the original mineralogy has been destroyed, is considered unsuitable by the writer because diabase is used as a synonym for dolerite by American geologists.

According to Flett (1946), Von Gumbel in 1874 coined the

term 'Epidiorite' for a doleritic or basaltic rock in which the augite had undergone alteration to hornblende and the rock approached the composition (mineralogically) of a diorite. Although the term has found acceptance by British geologists (e.g. Wiseman, 1934) it has not found acceptance with North American geologists.

The only terminology which will best accomodate both the chemistry and mineralogy of the basic dikes is 'metadolerite'.

Burlington Granodiorite

Two specimens of the 'Burlington Granodiorite' (99181 and 99182) were analysed for major elements and one of these (99182) was analysed for trace elements (analyses No.10 and 11, Appendix C). The major element analyses are presented in Table 5-3 to facilitate comparison with the other intrusive rocks.

Specimen 99181, collected from the 'Granodiorite' approximately 500 feet from its known contact with basic volcanic rocks, has a gabbroic composition. Specimen 99182, collected approximately 1.5 feet from the contact, is chemically similar to the metadolerites. The greatest difference between the major element composition of specimen 99182 and the mean composition of the metadolerites is in its high (14.68 percent) CaO value in contrast to a mean value of 9.95 percent in the metadolerites. However, this seemingly high value is comparable with the highest CaO content (14.51 percent) of a single metadolerite.

In general, the trace element contents of specimen 99182 are similar to those of the metadolerites. However, the Sr content of 99182 is several orders of magnitude greater than the mean

Sr content of the metadolerites.

a. Consideration of the relationship between 'Burlington

  Granodiorite' and the basic volcanic rocks.

In view of the remarkable similarity between the composition

of the metadolerite dikes and the rock considered to be part of

the 'Burlington Granodiorite' (specimen 99182) it is necessary

to reconsider the nature of the contact.

The 'Burlington Granodiorite' includes not only 'quartz

diorite to granitic rocks' (Baird, 1951) but also rocks of

basaltic composition (specimen 99182). Therefore it is possible

that metadolerite dikes in the Rambler area crystallized from

the same parent magma as the 'Burlington Granodiorite'.

The compositional similarity between the metadolerite dikes

and specimen 99182 may be explained in at least two ways: (1) the

'contact' between the 'Burlington Granodiorite' and the basic

volcanic rocks is not that of the large plutonic mass but merely

the contact of a metadolerite dike intruded between the

'Granodiorite' mass and the basic volcanic rocks; (2) the contact

represents the recrystallized chilled margin of the 'Granodiorite'

parent magma which continued to crystallize and differentiate

to produce the rocks represented by specimen 99181.

The second hypothesis would account for the lower Na_2O,

K_2O and Al_2O_3 and the higher TiO_2 in specimen 99182, collected

at the margin of the plutonic mass, than in specimen 99181. Such

an hypothesis is open to serious question since the MgO content

generally decreases with differentiation whereas in this case

the MgO content of the postulated contact zone is less than the

supposedly more differentiated rock (99181).

If the first hypothesis is correct, and further work shows

that the metadolerite dikes are unrelated to the 'Granodiorite'

mass, then the age and contact relationships of the 'Granodiorite'

and the other rocks in the Rambler area will still be in doubt.

Alternatively, if the first hypothesis is true and the

metadolerites can be shown to be related to the 'Granodiorite'

by way of a common parent magma, then it will confirm the

presently accepted pre 'Granodiorite' age for the non-intrusive

rocks.

If the second hypothesis is correct then we shall not only

have conclusive evidence for the relative age relationships between

the 'Granodiorite' and the other rocks in the Rambler area, but

will be able to establish the parentage of the metadolerite dikes.

Leucocratic intrusive

One specimen (99185) of this extremely light coloured rock

was analysed for major and trace elements (analysis No.9, Appendix

C). Both the major and trace element contents are similar to those

found in the 'Granodiorite' (analyses 10 and 11, Appendix C).

Since the mineralogy of the Leucocratic intrusive is similar

to that of the specimen (99181) of gabbroic rock from the

'Granodiorite' mass (i.e. both consist mainly of altered

plagioclase and hornblende) and the chemical compositions of the

two specimens are similar, the 'Leucocratic intrusive' is considered

to represent a small offshoot of the 'Burlington Granodiorite'.

The compositional relationships of the 'Granodiorite' specimens

(99181, 99182 and 99185) and the metadolerites can be seen in

Figures 5-4 to 5-6, where the 'Granodiorite' specimens are shown

with solid symbols.

CHAPTER VI

GEOLOGY OF THE MINERAL DEPOSITS

A. The Rambler Mine

The Rambler Mine is located in the central part of the map area at map coordinates 8000N/12000E. The history of the deposit has been given in Chapter I.

Mining activity had ceased at the Rambler Mine when the writer commenced the present investigation. The following description is based mainly on company reports, drill logs, underground geological maps and a study of hand specimens of ore and wallrocks from the mine collection. In addition, the writer was able to study the core from one surface drill hole, No.353-5, and a number of underground drill holes.

Description of the ore body

The Rambler Mine ore body was exposed by trenching in the initial stages of its exploration. The present surface exposure is a quartz-sericite schist containing disseminated and vein pyrite. Quartz and pyrite mineral lineations in the surface exposure are oriented parallel to the plunge of the ore body.

The ore body is 100 to 300 feet wide, seldom exceeds 50 feet in thickness, and has been traced by surface diamond drilling for a distance of approximately 2500 feet down dip from its surface exposures. The ore has been exploited to a depth of 775 feet below the surface which corresponds to a distance of about 1500 feet down the dip.

The general outline of the ore body can be seen from a comparison of Figures 6-1 and 6-3 to be ruler shaped.

The main mineralization is a band of massive sulfide
comprised mainly of pyrite with zones of sphalerite and
chalcopyrite. In addition the deposits contain minor galena
and recoverable gold and silver. Several pyritic parts of
the ore body contained sufficient gold to warrant mining for
that metal alone. Disseminated sulfides, mainly pyrite with
traces of chalcopyrite, are found in the footwall for distances
of up to 100 feet below the massive sulfide horizon, but
cannot be profitably extracted at this time.

The massive sulfide horizon exhibits a remarkable continuity
with an horizon of 'magnetite tuff' and a quartzite band,
when present, in both plan and cross section. Thus the
deposit is similar to other massive sulfide deposits of the
world that are conformable with their enclosing country rocks -
Norway (Vokes, 1968; Waltham, 1968), Spain (Williams, 1934, 1962).

Geology of the Rambler Mine

The only detailed description of the Rambler Mine is
contained in an unpublished report by W.R.A. Barrager based
on a study of diamond drill cores available in 1954. Barrager's
report has been drawn on extensively in the following
description.

For the purposes of the following discussion the rocks of
the Rambler Mine are assumed to be "right way up".

The general geological relationships of the Rambler Mine
are shown in Figure 6-3, a longitudinal cross section, and
Plate III, a geological plan of the 400 level.

a. Hanging Wall

The immediate hanging wall of the mineralization in most

places is a band of 'magnetite tuff' described as "siliceous

magnetite bearing siltstones, probably tuffs, varying to

purplish sugary-textured quartzitic rock" (Barrager, 1954).

This layer which may be up to ten feet thick, is present

throughout much of the mineralized zone. However, where

it is absent the massive sulfides are in direct contact with

quartz-chlorite schists or quartz-chlorite-sericite schists.

In thin section the 'purplish sugary-textured' rock consists

mainly of quartz grains, 0.25 mm in diameter, with polygonal

outlines which occasionally meet in 120 degree triple point

junctions. Locally the magnetite-rich parts of this horizon

consist entirely of lineated magnetite with less than one

percent silicate.

The 'magnetite tuff' horizon passes upward into fine

grained chloritic rocks which Barrager (1954) called "streaked

and mottled chlorite schists" and described as "dark green

chlorite schists streaked and banded with light blue-grey

material or mottled with irregular, vaguely outlined, blue-

grey patches. They are probably intensely sheared fragmental

rocks.....". Recently exposed hanging wall rocks at 7200N/12000E

are deformed basic agglomerates with occasional fragments of

acidic rocks and fit Barrager's description of "streaked and

mottled chlorite schists". Barrager found that well defined

bands of acidic fragmental rocks graded into the chlorite

schists in several drill holes. In addition he observed

sections of acidic material up to two feet in length which he

considered to be either large fragments or thin flows. New

exposures of basic agglomerate with acidic blocks at 8400N/12240E

contain elongated blocks of acidic rock up to 12 inches in

diameter and several feet in length. Since none of Barrager's

larger intersections of acidic rock could be correlated

between drill holes, they probably represent intersections of

large blocks of acidic rock.

The blocks of acidic material are petrographically and

chemically similar to the porphyritic acidic lavas found

northwest of the Rambler Mine (Chapter V).

A band of acidic rocks overlie the chloritic schists and

underlie an horizon of fragmental acidic rocks. The acidic

rocks are porphyritic with 1 to 2 mm quartz and feldspar

phenocrysts in a greyish to pink aphanitic groundmass and

are similar to the acidic lavas exposed northwest of the

Rambler Mine.

The fragments of acidic rock are similar to the acidic

flow which they overlie. The pyroclastics are unsorted,

lineated and occasionally the fragments are embedded in a

fine grained matrix of basic material.

An horizon of fine grained sedimentary rocks overlies

the acidic pyroclastics. These rocks have a pronounced

banding and a distinct brown colour due to an abundance of

biotite. These rocks are not known to crop out at the surface.

The uppermost rock unit in Figure 6-3 is basic pillow

lava. These rocks crop out along the road to the East Mine

and form the main occurrence of tholeiitic lavas within the

Rambler map area.

b. Footwall

The ore zone and immediate footwall rocks are mainly

quartz-sericite and chloritic schists. Barrager describes

the quartz-sericite schist as forming a vaguely defined layer in the upper portion of the ore zone and varying in thickness as it interfingered laterally with the chlorite schist in the lower portions of the ore zone. The two rock types normally have gradational contacts, however, in places they are separated by zones of quartz-chlorite-sericite schist. Barrager observed that the quartz-sericite schist horizon thins and becomes more massive as it is traced along strike to the margins of the drilled area where it is similar to aphanitic acidic rocks.

Since none of the drill core logged by Barrager has been preserved it is not possible to correlate the aphanitic acidic rocks he describes with other acidic rocks found in the map area. It would appear from Barrager's description of these rocks that they are analogous with the cherty rocks which the writer has mapped as 'leucocratic rocks of uncertain origin'.

The most common footwall rock, chlorite schist, underlies the rock types described above. This chlorite schist, consisting of stratiform sedimentary rocks and basic agglomerates, crops out in the bed of Rambler brook. These chlorite schists are in turn underlain by basic lavas.

Basic dikes and sills intrude the other rocks. Barrager was able to separate a large sill-like body into an upper medium to coarse grained member and a lower lighter coloured fine grained member. This major intrusive has been intruded by younger fine grained dikes. It was shown earlier (Chapter V) that these intrusives are metadolerites.
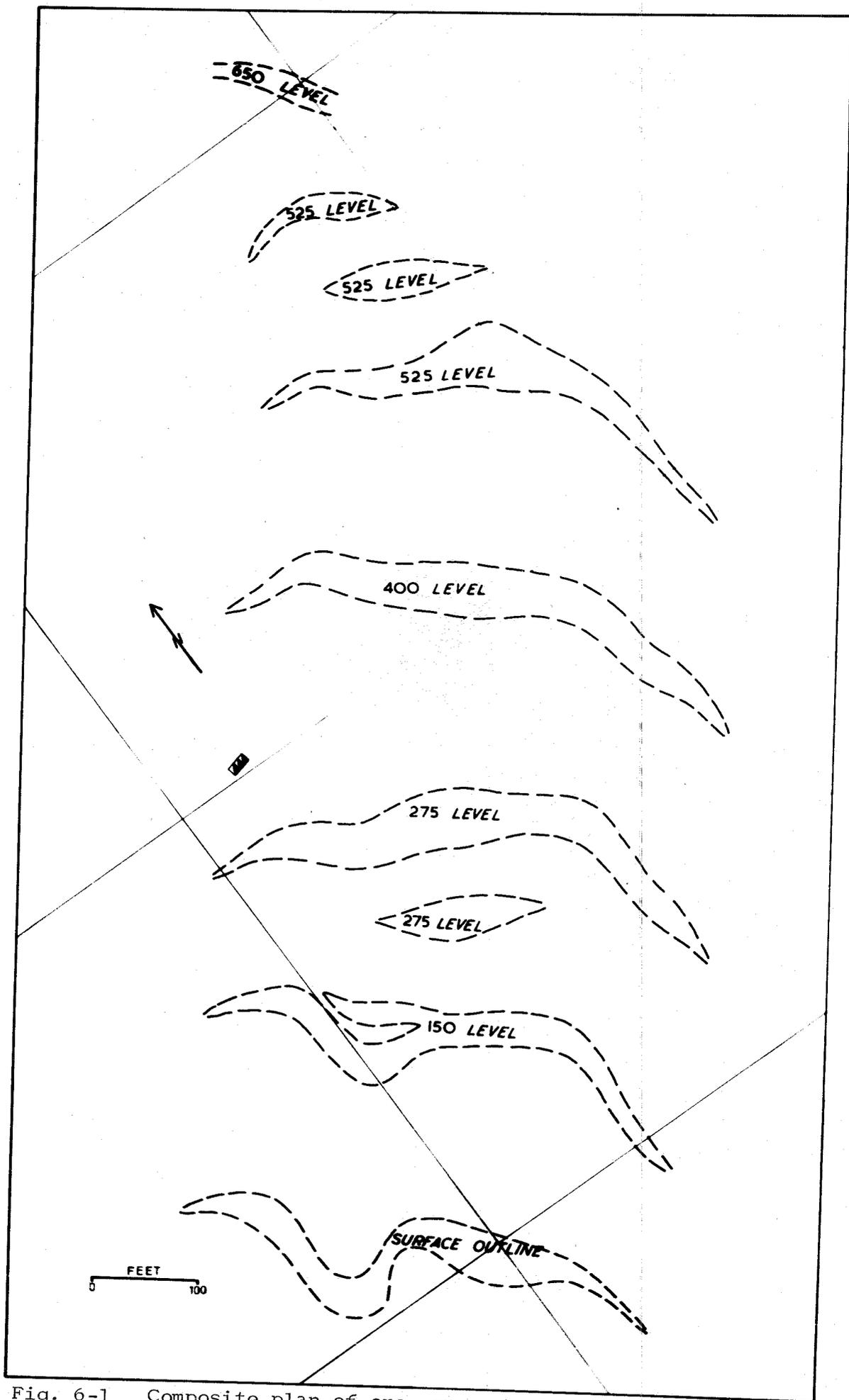
Fig. 6-1   Composite plan of ore zones, Rambler Mine.
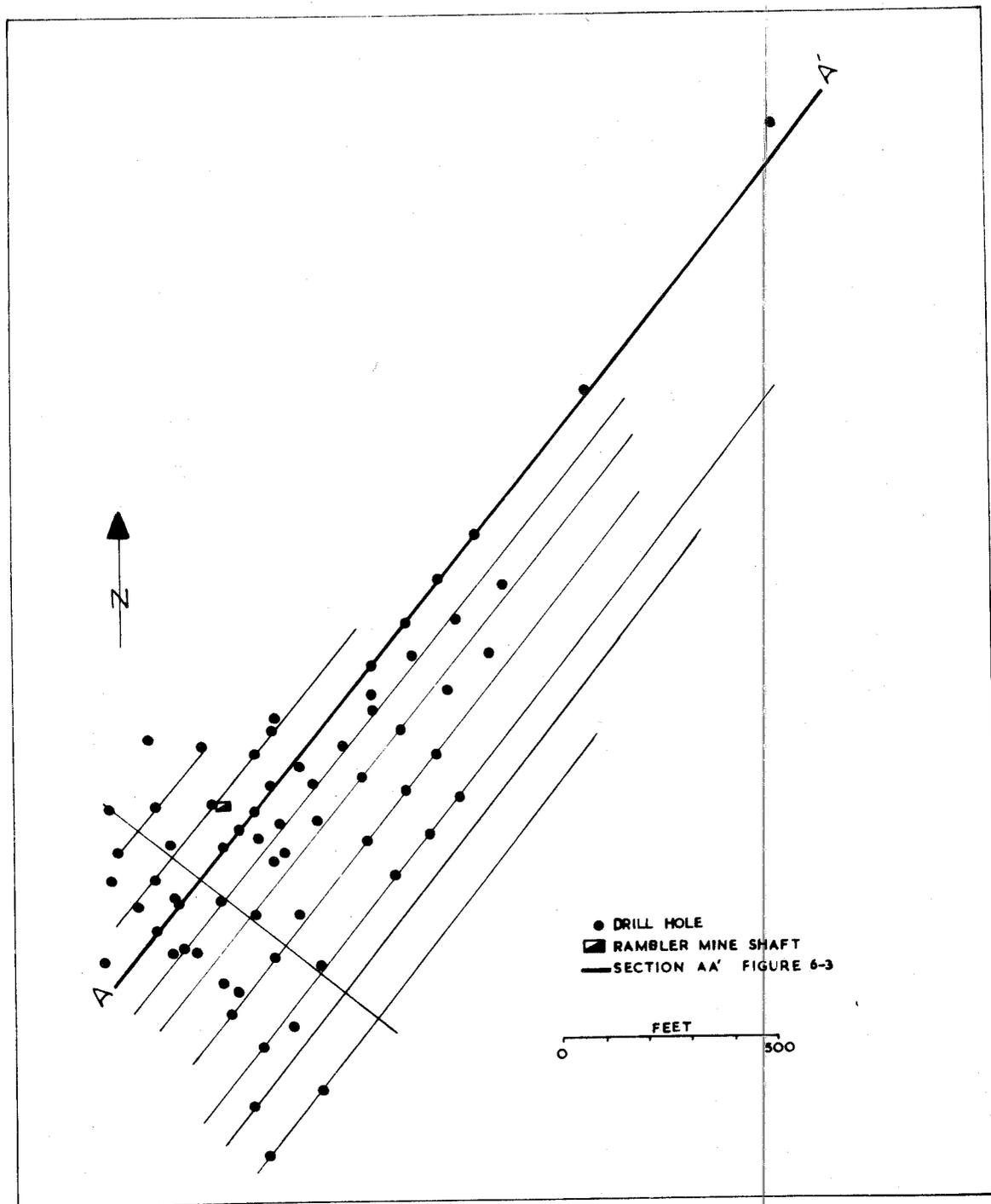
Fig. 6-2   Plan of drill hole locations Rambler Mine
showing location of section shown on Fig. 6-3

Figure 6-3   Longitudinal section, Rambler Mine.

LEGEND[*]

13   Dolerite.

12   Diorite porphyry.

11   Porphyritic diorite.

10   Diorite with acicular hornblende and lath-like
      plagioclase crystals.

9   Diorite with equidimensional feldspar and
      hornblende crystals.

8   Greywacke and siltstones, probably tuffs.

7   Rhyolite porphyry.

6   Coarse fragmentals composed largely of well
      defined acidic and intermediate volcanics.

5   Streaked and mottled chlorite schists grading
      into and apparently derived from, and containing
      in places, short sections of massive felsite.

4   Siliceous magnetite-bearing siltstones, probably
      tuffs, varying to purplish sugary-textured
      quartzitic rock adjacent to the ore zone.

3   Chlorite schist of uncertain origin.

2   Quartz-sericite schist.

1   Basic lava.

[*] After Barrager (1954)
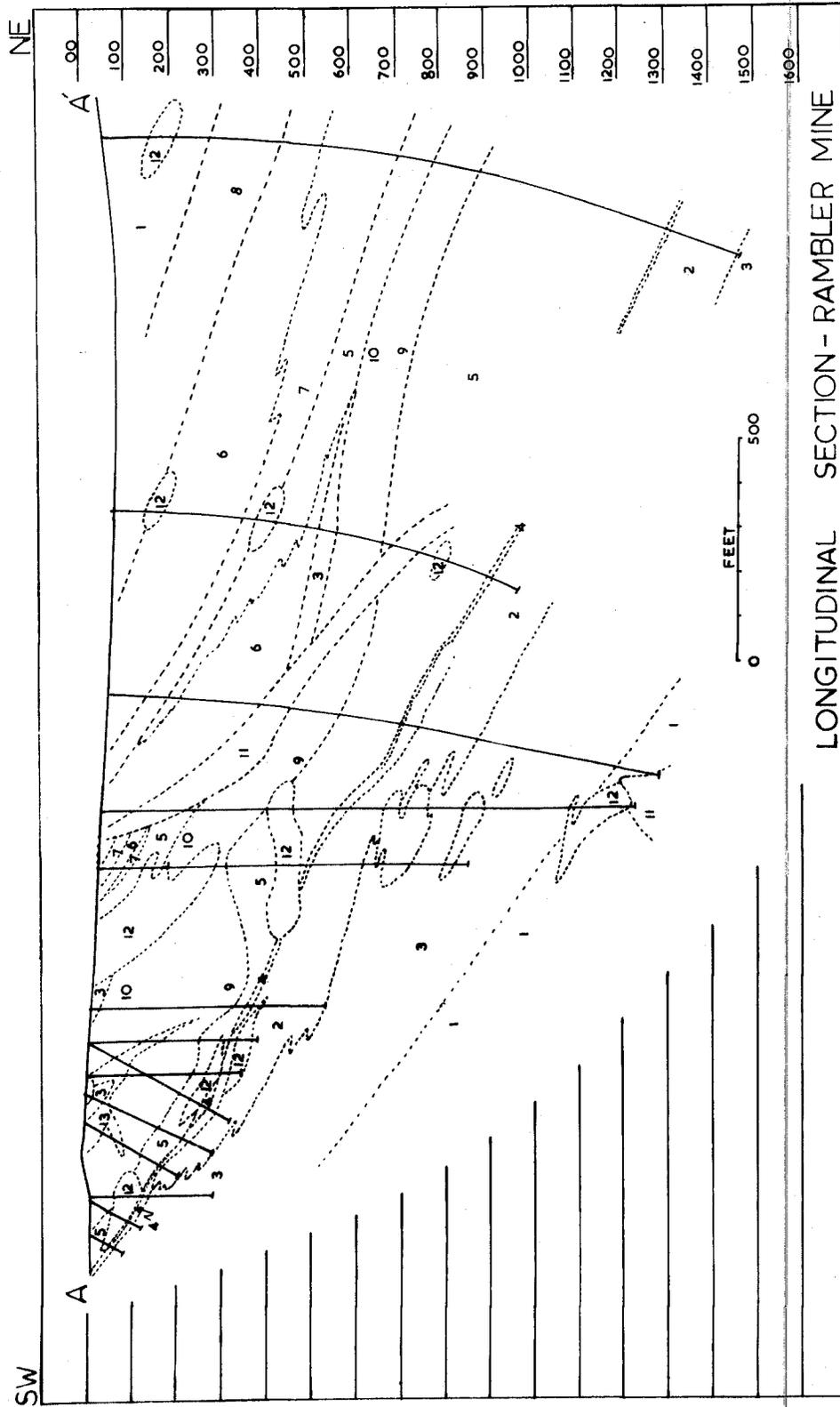
LONGITUDINAL SECTION – RAMBLER MINE

Fig. 6-3

Mineralization

The main sulfide minerals are pyrite, sphalerite and chalcopyrite with pyrite being the most abundant and widespread sulfide. Minor galena and pyrrhotite are visible in some hand specimens. Pyrrhotite occurs in association with chalco-pyrite which is found mainly in the uppermost part of the massive sulfide horizon.

The sulfides vary from massive to weakly disseminated. Near the top of the ore zone sections of massive sulfide 15 to 20 feet thick were commonly encountered. Narrow bands of massive sulfide up to one foot thick occur below the main massive sulfide horizon. In addition to the massive sulfides chalcopyrite, pyrrhotite and pyrite occur in veins up to several cms in width, cutting across and paralleling the schistosity and as disseminations in the footwall schists.

Fine grained glassy quartz is often found in the sulphide veins.

Structural geology of the Rambler Mine ore body

The writer has no first hand knowledge of structures within the Rambler Mine, however, detailed level plans prepared by mine geologists have been interpreted in the light of the regional structural studies.

As mentioned earlier, the overall shape of the Rambler Mine resembles that of a thin ruler. The composite level plan, Figure 6-1, indicates the approximate shape of the ore zone as determined from diamond drilling and mining. It appears from Figure 6-1 that the mineralization is located on the hinge line of a northeastward plunging fold. Since mining and diamond drilling

were not extended beyond the limits of economic mineralization,
the apparent tapering of the ends of the ore zone could be
merely local features and not due to thinning on fold limbs.
Several of the mine plans do show a definite change in the
strike of the first schistosity at the margins of the ore zone.

The plunge of the ore body, 030/35NE, approximates the
plunge of a minor F_2 fold axis (035/35NE) at Rambler Pond 2000
feet west of the mine.

Although it cannot be conclusively proven, it appears as
if the ore body lies along the axis of a northeastward plunging
fold.

Macroscopic deformation of the ore

Approximately 30 hand specimens of massive sulfides from
several levels of the ore body were sawn and examined for
macroscopic deformational features. Microfolding of sulfide
and silicates was observed in two specimens. Compositional
banding and mineral lineations were found in about half of the
massive sulfide specimens.

A conspicuous feature of some of the sulfide specimens is
the separation of sphalerite-pyrite ores and pyrite-chalcopyrite
ores into nearly monomineralic bands (Fig. 6-4). In specimens of
banded sulfides which have inclusions of the host rock, the
banding in the sulfides is parallel to the weak schistosity in
the silicate inclusions.

Rock fragments enclosed in the massive sulfides have their
long axes parallel to the long axes of lineated minerals in the
fragments.

Lineated sulfide minerals are not as common as lineated

silicate minerals. Several specimens do however contain

lineated pyrite crystals and locally have typical L-tectonite

fabrics.

The presence of mineral lineations in the sulfide ores

indicate that the ore was deformed during the main deformation

affecting the Rambler area.

Continuation of the ore body

Diamond drilling of the Rambler ore body to date has been

designed to outline the limits of the known economic mineral-

ization by exploring the down dip extension of the mineral-

ization. Subsequently, little is known about the lateral

continuation of the sulfide zone beyond the limits of the known

economic mineralization and it is difficult to assess if the

mineralized horizon does continue laterally.

Although the grade of ore was decreasing in the lower

levels when mining was discontinued, the limits of the

mineralization had not been reached by either mining or diamond

drilling.

It has been shown above that the Rambler ore body is

stratigraphically bounded by a 'magnetite-tuff-quartzite' horizon

over much of its known area and that the ore zone host rock is

probably analogous with a cherty horizon. In addition the

sulfide minerals and their enclosing rocks have undergone the

first deformational event recorded in the Rambler country rocks.

The recognition of the Rambler ore body as a strata-bound

sulfide deposit opens up new possibilities for future exploration.

If the deposit is a pre-deformation replacement type then

exploration of the down dip extension of the known mineralization

may reveal other lenses of sulfides deposited during the same period of mineralization as that forming the presently known deposits. In addition, exploration for blind ore bodies in stratigraphically similar environments is also warranted.

If the deposit is a sedimentary - volcanogenic type then both lateral and down dip exploration of the presently known deposit may reveal other ore deposits at the same stratigraphic horizon.

B. The East Mine

The East Mine shaft is situated approximately one mile northeast of the Rambler Mine at 10100N/16800E. The deposit, originally known as the 'Norris showing', was discovered by trenching an oxidized zone. Appreciable copper mineralization was discovered as a result of surface diamond drilling.

The property was brought into production in 1968 and has a current daily output of approximately 1200 tons of ore containing an average copper content of 1.5 percent.

Geological investigation of the ore deposit is restricted by the method of mining employed. The ore is broken by longhole blasting methods and the actual stopes and working faces are inaccessible for direct geological observations. Furthermore, the drifts are designed to provide haulage ways for the ore and very little exploration drifting is done. Once mining has commenced it is difficult to carry out geological studies on a particular level without interrupting mining activity.

Description of the ore body

The East Mine ore body crops out in a zone of pyritized stratifrom quartz-chlorite schists approximately 600 feet

southwest of the East Mine shaft. The surface exposures

contain less than 30 percent pyrite as disseminations and

occasional veins, 1-2 cms in width. Widely scattered chalco-

pyrite-pyrite-pyrrhotite veins, less than 1 cm in width, cut

across the pyrite mineralization.

The East Mine ore body is mainly a disseminated sulfide

deposit and unlike the Rambler Mine it does not contain

horizons of massive sulfides. The main sulfide minerals are

pyrite, chalcopyrite and pyrrhotite. Above the 500 level the

mineralization consists mainly of pyrite which locally may

constitute 75 percent of the rock. The average pyrite content

of the upper levels of the mine is approximately 30 percent

whereas chalcopyrite rarely constitutes more than one percent.

The pyrite content decreases below the 500 level and the lower

levels of the mine, 850 and 1000 levels, contain approximately

equal volumes of chalcopyrite and pyrite which together seldom

amount to more than 15 percent of the rock.

The limits of the ore body are defined by copper assay

values. The sulfide deposit is roughly ruler shaped with a

width of about 400 feet and a thickness that is generally less

than 100 feet. The deposit has been traced by diamond drilling

for a distance of about 3000 feet down dip from its surface

exposures. Mining has been carried out to a depth of approxim-

ately 1000 feet below the surface.

The approximate shape of the economic copper mineralization,

compiled from surface drill core assays, is shown in Figure 6-5.

Geology of the East Mine

a. Surface exposures

The quartz-chlorite schists southwest of the East Mine shaft are probably sedimentary in origin since they are poorly banded and contain clastic fragments of basic volcanic material which exhibit a rough graded bedding suggesting that the rocks are the right way up. The quartz-chlorite schists sometimes contain a very weak first schistosity and always contain strong mineral and particle lineations. The lineations are parallel to the plunge of the ore body at 035/40NE.

Chlorite schists are interbanded with quartz-chlorite schists in several places. A two foot wide band of aphanitic tuffaceous acidic rock can be traced for a distance of 25 feet in one exposure. The strike of the acidic band is parallel to the weak schistosity in the quartz-chlorite schists.

The quartz-chlorite schists and the mineralized zone are intruded by pre-deformation fine grained and fine grained porphyritic metadolerite dikes.

b. Hanging wall

Although extensive drilling has been carried out during exploration and development of the East Mine ore body, relatively little information exists on the geology of the hanging wall rocks. Most of the drill core from the hanging wall has been logged as 'diorite' and the unmineralized cores have been discarded.

The core from one of the few remaining drill holes, No.61, has been studied by the writer in some detail in order to establish the main rock types present in the hanging wall. A profile of this drill hole is presented in Appendix F.

The hanging wall rocks consist of basic agglomeratic and tuffaceous rocks, basic flows and/or sills, metadolerite dikes and acidic tuffaceous rocks. The hanging wall rocks are mineralogically and texturally similar to rocks found elsewhere in the Rambler area.

The immediate hanging wall of most of the East Mine ore body is an aphanitic light buff to chocolate coloured acidic rock which separates unmineralized quartz-chlorite schists above from mineralized quartz chlorite schists below. The acidic rock consists of 0.1 to 0.5 mm feldspars phenocrysts in a matrix of recrystallized quartz grains with a mean diameter of 0.05 mm. One mm books of porphyroblastic biotite and 1-2 mm pyrite cubes are found in some cores of this rock. Locally, the fragmental nature of the rock suggests that it is an acidic tuff.

The acidic tuff appears to represent a stratigraphic unit since it can be traced intermittently in drill cores for a distance of some 2000 feet down dip and for distances of 300 to 500 feet along strike. The thickness of the unit varies from several feet to more than twenty feet.

In several places on the 375 and 500 levels a light grey quartz-sericite schistose rock with 5-15 percent disseminated pyrite appears to have formed by alteration of the acidic tuff described above. The quartz-sericite schist is sometimes interbanded with quartz-sericite-chlorite schists and is generally continuous with the acidic tuff.

c. Footwall

The footwall rocks are exposed in drifts on all of the

mine levels, however, it is most extensively exposed in the

deepest mine level, the 1000 level.

The dominant rock type in the footwall is quartz-chlorite

schist which is commonly interbanded with 'quartz-eye' chlorite

schists, biotitic schists and actinolitic schists. These

schists are intruded by fine grained, often porphyritic, and

medium grained metadolerite dikes and aphanitic basic dikes.

Quartz-chlorite schists often grade into 'quartz-eye'

chlorite schists. The quartz-chlorite schist is a fine grained

dark green rock with a weak schistosity and a strong mineral

lineation defined by lineated chlorite, quartz and actinolite

when present. The rock often contains ellipsoidal bodies of

quartz which define a particle lineation parallel to the mineral

lineation. Where the 'quartz-eyes' constitute more than ten

percent of the rock by volume it is referred to as a 'quartz-

eye' chlorite schist. 'Quartz-eyes' seldom constitute more than

50 percent of the rock by volume (see Figure 6-7).

The 'quartz-eyes' are polycrystalline aggregates of quartz

in which the quartz grains are several orders of magnitude

larger than in the enclosing matrix where the quartz grains

seldom exceed .05 mm maximum. The 'quartz-eyes' are

invariably elongated and are circular to slightly flattened

in sections normal to their long axes. The short diameters

usually range from 1 to 5 mm.

The 'quartz-eyes' sometimes have a core of pyrite (Fig. 6-7).

The 'quartz-eyes' often have an envelope of chlorite surrounding

them which suggests that they probably formed by recrystalliz-

ation of the matrix either by expulsion of chlorite to the

margins of the growing body or else by migration of quartz

into the metacryst and concentration of chlorite at the borders of the enlarging metacryst as a result of the depletion of quartz at the borders.

Mineralogically and texturally the footwall quartz-chlorite schists and 'quartz-eye' schists are a monotonous sequence of quartz and chlorite with minor actinolite, epidote and feldspar similar to the stratiform volcanic sediments described in Chapter IV. Porphyroblastic biotite books are present in both mineralized and unmineralized schists.

Occasionally quartz veins up to 1 cm in width can be recognized in the quartz-chlorite schist and the 'quartz-eye' schist. The quartz veins are folded and boudined so that they form discontinuous quartz lenses from which the original fold structure can only be deduced on sawn surfaces.

Bands of biotitic schists, up to 4 feet in width, are concordant with the banding in the quartz-chlorite schists with which they are interbanded. These rocks consist mainly of biotite, quartz, epidote and minor chlorite and frequently grade into quartz-chlorite schists. Individual bands can be traced for distances of several hundred feet in diamond drill cores. Since thin sections of these rocks do not show any evidence of relict igneous textures, such as phenocrysts, these rocks are interpreted as recrystallized sedimentary units rather than concordant dikes.

A fine grained dark green rock, in which lineated actinolite is the most abundant mineral and quartz and chlorite are minor constituents, was noted in a number of drill holes and at several places in drifts on the 1000 level. The rock is concordant with the weak schistosity and banding, when present,

in the quartz-chlorite schists. The thickness of this unit
varies from 0.5 to 2 feet. It is not certain whether this
rock represents a basic tuff horizon or a recrystallized basic
dike.

A distinctive pale green rock with acicular porphyroblastic
actinolites, 0.5 x 10 mm, in a calcareous groundmass was
observed in a number of drill cores and is well exposed on the
west wall of the 1000 level drift approximately 80 feet from
the mine shaft (Fig. 6-8A). The rock probably represents a
recrystallized dolomitic sediment (an analysis of this rock
is given in Appendix D).

Fine grained, fine grained porphyritic and medium grained
metadolerite dikes intrude the wall rocks and the ore zone.
Two nearly vertical dikes, up to 50 feet thick, intruding
the ore body can be traced on the 500, 625, 750 (see Plate IV),
875 and 1000 levels. In general the metadolerites have a more
varied strike than the two major dikes shown in Plate IV and
also pinch and swell along strike.

A number of aphanitic basic dikes, seldom more than one
foot wide, were observed during underground mapping. These
dikes post-date the weak schistosity which they cut and have
chilled margins.

Mineralization

The main sulfide minerals are pyrite, chalcopyrite and
pyrrhotite. In contrast to the Rambler Mine, sphalerite and
gold are present in only trace amounts. Sphalerite is rarely
seen in hand specimen and gold is recovered as a by-product
during smelting the chalcopyrite concentrates.

The East Mine sulfide deposit exhibits a broad zonal
pattern. Between the 375 level and the surface pyrite is the
dominant sulfide and economic concentrations of chalcopyrite
are rare. Below the 500 level the ratio of pyrite to
chalcopyrite decreases rapidly and below the 750 level the
volume of chalcopyrite and pyrrhotite equals or exceeds the
volume of pyrite.

Above the 500 level pyrite may constitute more than 75
percent of the rock although the average pyrite content is less
than 30 percent. The pyrite occurs mainly as disseminated to
nearly massive lenses in quartz-chlorite and quartz-sericite
schists. In addition pyrite occurs as veins up to six inches
in width cutting across the pyritized and nonpyritized rocks.
Chalcopyrite occurs as scattered blebs, 1-2 mm in length, in
the disseminated pyrite and in chalcopyrite-pyrrhotite veins
several cms wide.

Below the 625 level pyrite rarely constitutes more than
10 percent of the rock. The pyrite occurs mainly as disseminated
porphyroblasts, 1-2 mm in diameter. Pyrite veins, several cms
in width, may contain chalcopyrite and pyrrhotite. The writer's
investigation of this deposit is based on a brief study of the
500 and 1000 levels on which mining was not being carried out
and a study of diamond drill cores.

The main chalcopyrite mineralization occurs between the 500
and 1000 levels. The chalcopyrite mineralization occurs mainly
as disseminated blebs and as chalcopyrite-pyrrhotite veins.

Disseminated chalcopyrite-pyrrhotite mineralization consists
of oriented blebs of chalcopyrite with variable, generally
minor, amounts of pyrrhotite scattered throughout quartz-chlorite

and 'quartz-eye' schists. The concentration of sulfide blebs

is quite variable but rarely exceeds 15 percent of the rock

by volume.

Individual sulfide blebs range in size from barely visible

with a 10X hand lens up to slightly more than 1 x 2 cms. The

sulfide blebs resemble the 'quartz-eyes' in their roughly

ellipsoidal shape. The long axes of the sulfide blebs parallel

the long axes of mineral and particle lineations in their host

rock. Sulfide blebs in 'quartz-eye' chlorite schists have long

axes parallel to the long axes of the quartz bodies.

Although pyrite is present in the disseminated ore it is a

minor constituent of the rock and occurs mainly as either

ellipsoidal aggregates or porphyroblasts of pyrite outside the

chalcopyrite-pyrrhotite blebs.

The disseminated chalcopyrite-pyrrhotite exposed on the

1000 level (Fig. 6-8B) appears to be restricted to definite

stratigraphic horizons which can be traced across the drift.

The contacts of the disseminated chalcopyrite-pyrrhotite

mineralization are generally diffuse and often grade into

disseminated pyrite mineralization.

It has not been definitely established that the disseminated

chalcopyrite-pyrrhotite mineralization represents stratigraphic

horizons since mineralized and unmineralized quartz-chlorite

schists are identical except for their sulfide content.

Furthermore no systematic attempt has been made to trace

individual horizons of chalcopyrite-pyrrhotite mineralization

in diamond drill cores and between mine levels. An examination

of several drill cores indicates that the disseminated ore can

Figure 6-4 A. Banded massive pyrite-chalcopyrite ore,

Rambler Mine. Very dark grey mineral is

chalcopyrite. (X 1)

      B. Lineated massive pyrite-sphalerit e

ore, Rambler Mine. Specimen cut normal to the

lineation (upper) and parallel to the lineation

(lower). (X 0.75)

      C. Lineated pyrite. Rambler Mine. (X 1)

A

B
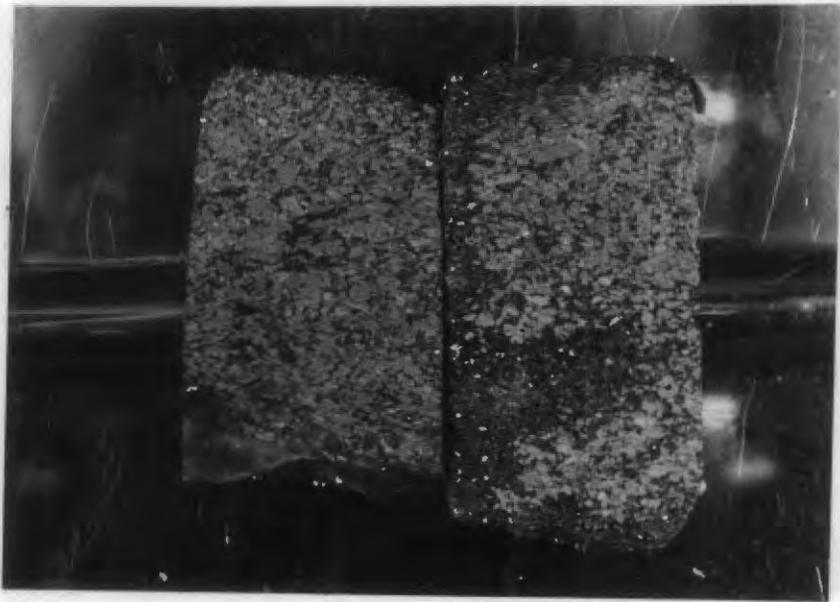
C
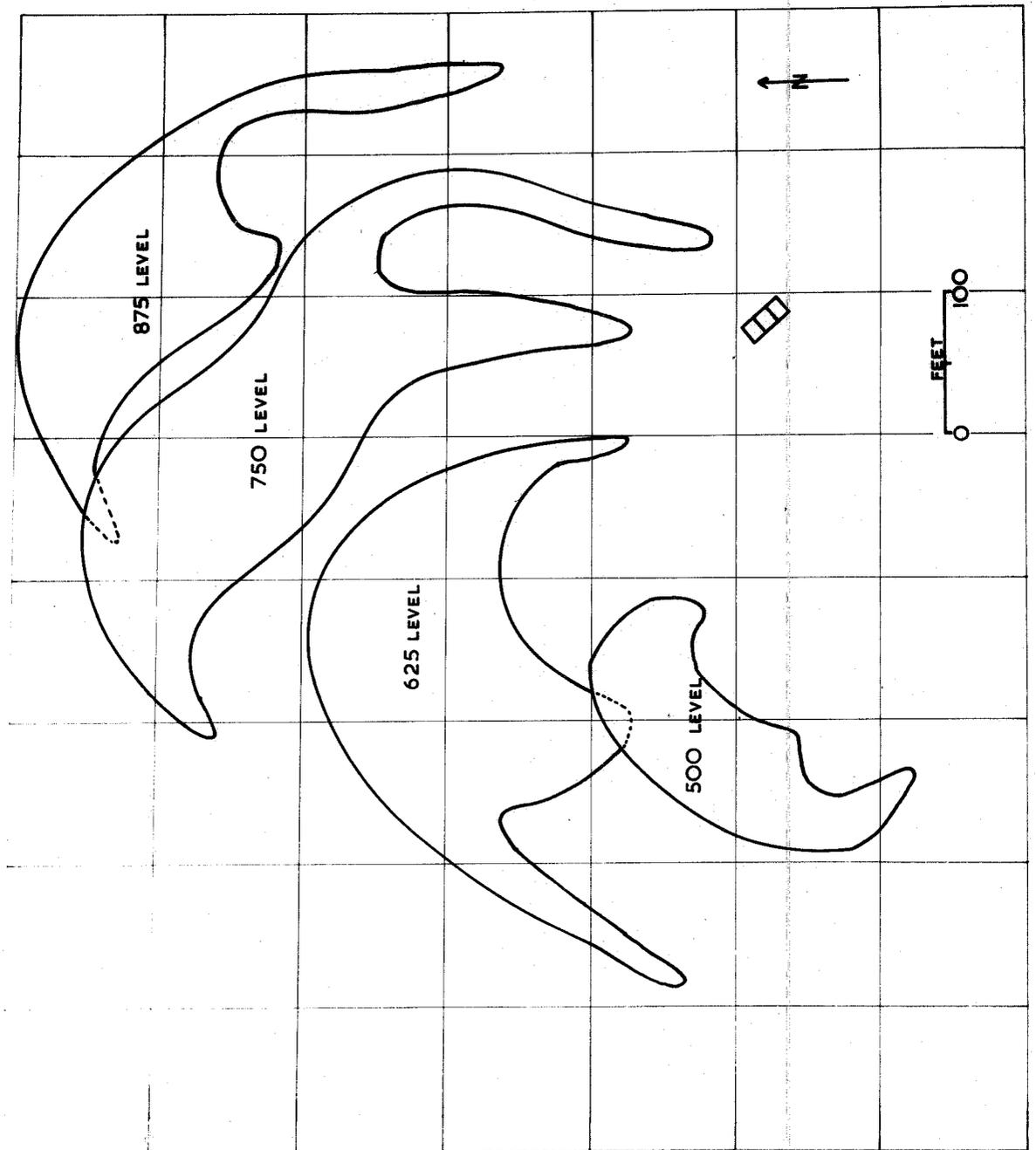
Fig. 6-5   Composite plan of mineralized zone, East Mine.
  Outlines determined from surface drilling.

Figure 6-6 A. Lineated pyrrhotite, East Mine. (X 1)

B. Lineated chalcopyrite-pyrrhotite ore, East Mine. (X 1)

C. Chalcopyrite-pyrrhotite vein in quartz-chlorite schist, East Mine. Pyrrhotite (medium grey), silicate (dark grey and black) and chalcopyrite (light grey). (X 1)

D. Chalcopyrite in pressure fringes around pyrite. (X 10)

Figure 6-7 A. Basic dike cutting quartz-chlorite schist. The dike contacts parallel the schistosity. Sulfide veins near the upper end of the pencil penetrate the dike for several inches.

B. Basic dike intruding quartz-chlorite schist containing disseminated chalcopyrite-pyrrhotite mineralization. Veins in the quartz chlorite schist are filled with chalcopyrite and pyrrhotite, those in the dike are filled with white quartz.

C. 'Quartz-eyes' in quartz-chlorite schist and 'quartz-eye' chlorite schist. The 'quartz-eyes' in the left hand specimen contain pyrite nucleii. (X 0.5)

A

B

C
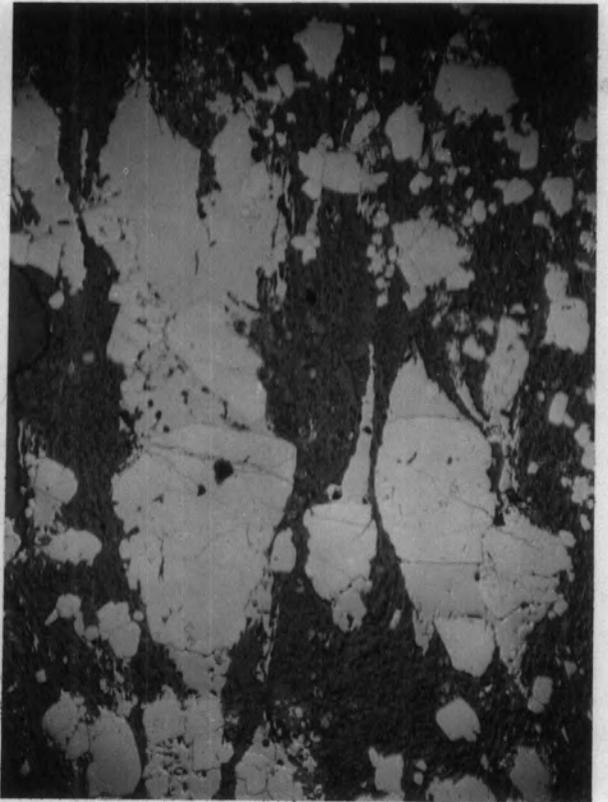
D
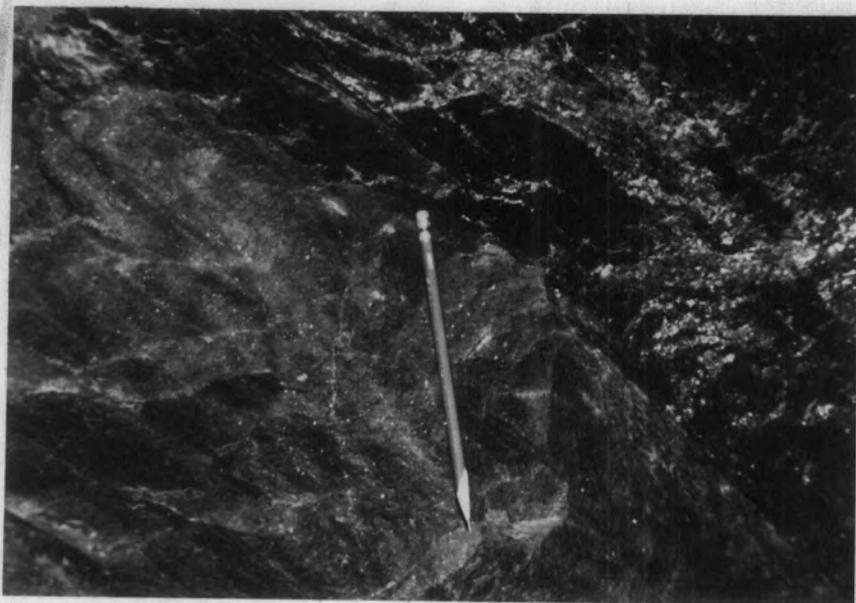
A

B
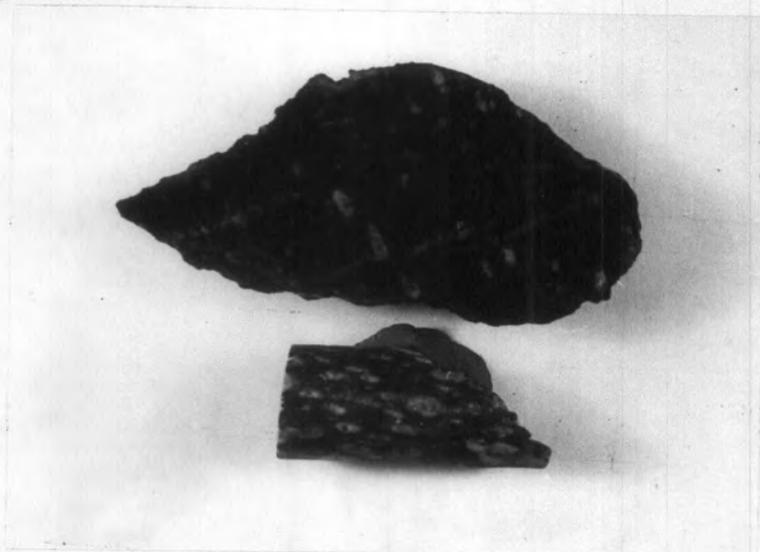
C

Figure 6-8 A. Amphibolitic band in quartz-chlorite

schist. 1000 level, East Mine.

B. Disseminated chalcopyrite-pyrrhotite

blebs in quartz-chlorite schist. 1000 level,

East Mine.

C. Pyrite-chalcopyrite veins cutting across

the schistosity. 1000 level, East Mine.

D. Chalcopyrite-pyrrhotite veins parallel

to the schistosity in quartz-chlorite schist.

1000 level, East Mine.

Figure 6-9 A. Lineated chalcopyrite ore in quartz-

chlorite schist, East Mine. Section cut normal

to lineation. (X 10)

B. Same specimen as A. Section cut

parallel to the lineation. (X 10)

C. Pyrite porphyroblasts with biotite

pressure fringes in acidic tuff, East Mine.

Normal (left) and parallel (right) to the

lineation. (X 1)

A

B

C

D
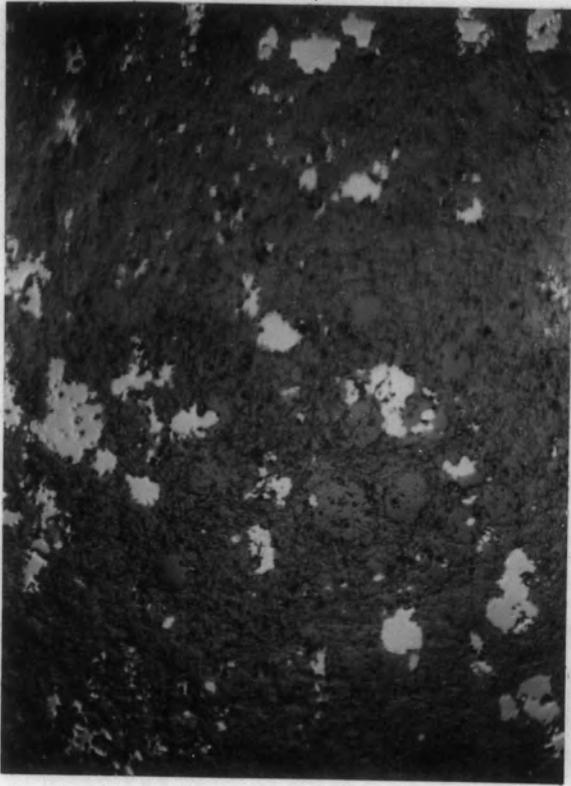
A

B

C

be traced for distances of several hundred feet along the
strike and dip of the ore body and appears to parallel other
stratigraphic units, such as the biotitic schists.

Sulfide veins are common throughout the East Mine ore
body. The proportion of sulfide occurring in the veins is
difficult to assess due to relatively small exposures of the
ore body in the underground workings and the inaccessibility
of the stopes for direct observations. In some parts of the
1000 level the sulfides are found entirely in veins and in
other parts veins 2 cm wide are several feet apart. In
general the sulfides occur as a combination of both vein
and disseminated ore.

The sulfide veins vary from 1 mm to about 10 cm in width,
with an average width of less than 3 cms. The veins may be
parallel to the schistosity (Figure 6-8D), or cut across the
schistosity as in Figures 6-7B and 6-8C. In some cases a
vein cuts across the schistosity for short sections and then
continues parallel to the schistosity for several feet before
cutting across the schistosity again. No definite orientation
of veins could be determined from measurements made on the
1000 level.

In general the veins consist either of chalcopyrite and
pyrrhotite with traces of pyrite or of pyrite with traces of
chalcopyrite and pyrrhotite. Veins with equal proportions of
chalcopyrite and pyrite are rarely found.

Pyrrhotite is generally found only in the chalcopyrite-
pyrrhotite veins. In veins less than 2 cms wide the pyrrhotite
generally occurs as stringers at the margins of the chalcopyrite

and seldom constitutes more than 25 percent of the total sulfides. In the larger veins, such as the one shown in Figure 6-6, a band of pyrrhotite, usually discontinuous, occupies the central part of the vein and appears to be veining the chalcopyrite. Other veins have pyrrhotite-rich sections in which the chalcopyrite appears to vein the pyrrhotite.

Euhedral 1 to 2 mm pyrite cubes and pyritohedrons, are common in the chalcopyrite-pyrrhotite veins.

Sulfide veins are rarely truncated by the metadolerite dikes and yet the dikes are rarely cut by sulfide veins. In general, the sulfide veins either change their direction of strike and parallel the dike contact as they approach a dike or pinch out 10 to 15 cms within the dike.

In the 10-01 drift on the 1000 level a porphyritic metadolerite dike cuts disseminated chalcopyrite-pyrrhotite ore in a quartz-chlorite schist. Vertical post-tectonic veins cutting across the disseminated ore are filled with chalcopyrite, pyrrhotite and minor white quartz. Most of the veins pinch out about 5 cms inside the dike. One of the veins is continuous across the dike but contains only white quartz inside the dike.

Biotitic and actinolitic schists may occasionally be cut by sulfide veins. These rocks generally contain 1 to 2 percent porphyroblastic pyrite but none were observed to contain chalcopyrite-pyrrhotite blebs.

Lenses of white quartz up to 20 feet in diameter are found in several places on the 1000 level and in drill holes

from other parts of the Mine. These bodies are later than
the first schistosity since they cut across it and enclose
randomly oriented blocks of lineated quartz-chlorite schist.
These quartz bodies sometimes contain small patches of
chalcopyrite and pyrrhotite which have unusually smooth
contacts with the enclosing quartz. The chalcopyrite is
separated from the quartz by pyrrhotite which forms a rim
surrounding the chalcopyrite.

Structural geology of the East Mine

The ruler-like shape of the ore body can be seen by
comparing Figures 6-5 and Plate V. The ore body is broadly
concordant with the regional stratigraphy, i.e. the acidic
tuffs, and its long axis lies parallel to the mineral and
particle lineations in the host rocks.

No major fold structures have been recognized to date in
the East Mine. Figure 6-5, a construction of the extent of
the economic mineralization based on surface drilling results,
indicates that the hanging wall of the ore body has an arcuate
fold-like configuration. The copper assay values obtained
from underground drilling on each mine level were contoured to
determine if the ore body did have an arcuate hanging wall.
Plate IV, the contoured assay plan for the 750 level, is
representative and clearly does not support a fold-like
structure for the economic mineralization. Furthermore, an
examination of the drill logs does not support a fold like
structure for the sulfide mineralization or the hanging wall
acidic tuff horizon.

Several minor folds have been noted in deformed quartz

veins in quartz-chlorite schist and 'quartz-eye' chlorite schist. The attitude of the hinges of these folds could not be ascertained.

The main structural features of the East Mine are the mineral and particle lineations, L_1, produced by the first deformation. The most common particle lineations are rock fragments, 'quartz-eyes' and sulfide blebs (see Figure 6-6). Particle and mineral lineations measured on oriented hand specimens have a mean orientation of 035/35NE.

Chlorite, chlorite and quartz and quartz pressure fringes around a nucleus of pyrite or chalcopyrite are common in the ore zone and footwall rocks. Both straight and curved varieties are present. Spry (1969) indicates that straight pressure fringes are due to non-rotational movements while curved pressure fringes are due to rotation of the nucleus during growth.

Macroscopic deformation of the ore

The most obvious deformational feature of the East Mine ore is the lineated sulfide blebs.

Pyrite rich specimens from the 375 and 500 levels of the Mine exhibit a distinct banding on surfaces sawn parallel to the silicate mineral lineations, however, banding is not present on surfaces cut normal to the silicate lineation.

Although lineated pyrite crystals are not visible in hand specimens, the banding represents an elongated pyrite lense.

Origin of the 'quartz-eyes', sulfide blebs, and sulfide veins.

Metamorphic differentiation by means of chemical diffusion is a well established geological process. Mineral segregations (Morton, 1971) and porphyroblasts (Spry, 1969) are considered to form by this process.

Several factors indicate a syn-deformational age for the 'quartz-eyes' and sulfide blebs of the East Mine: (1) the long axes of the 'quartz-eyes' and the sulfide blebs have the same orientation as the mineral lineations in the enclosing rock; (2) individual 'quartz-eyes' and sulfide blebs do not appear to be connected to adjacent bodies; and (3) envelopes of chlorite surrounding 'quartz-eyes' indicate 'in situ' growth of the quartz bodies.

The 'quartz-eyes' and the sulfide blebs are considered to have formed during the first metamorphism and deformation by means of chemical diffusion.

The presence of abundant sulfide veins in the East Mine, and also in the Rambler Mine, suggests that a second episode of mineralization may have affected the Rambler area after the main deformation. Such an hypothesis must account for the remarkable coincidence in both the East and the Rambler Mines of pre- and post-deformation mineralizations and also for the absence of known post-deformational mineralization by itself. It is highly unlikely that pre-deformation conduits would have remained open after the intense first deformation affecting the Rambler Area. Furthermore, although the lack of alteration products does not rule out the possibilities of an epigenetic mineralization, on the other hand it does not support a hypothesis of epigenetic mineralization.

The association of sulfide blebs of pre-deformation age and sulfide veins of post-deformation age with identical mineralogy could be due to the migration of sulfides from the surrounding mineralized rock into post-deformation fractures during a later tectonic or metamorphic event. Similarly the sulfide veins outside the disseminated sulfide bands could have formed by migration of sulfides along fractures - a phenomenon long advocated by supporters of the theory of lateral secretion (Sandberger, 1885; Boyle, 1961; Amstutz, 1967, 1969; and others).

The geological literature contains many examples of remobilized sulfides, several of which are described in the symposium volumes edited by James (1969) and Zuffardi (1969).

Continuation of the ore body

Very little exploration has been carried out to trace the lateral extent of the mineralized zone. A number of surface drill holes prove that the mineralization continues for at least 1200 feet beyond the 1000 level (Plate V). Although ore grade mineralization, greater than one percent copper, occurs below the present level of mining, the deposit appears to decrease in size and mineable zones have not been outlined to date.

An interesting feature of the mineralization in the deepest drill holes is that it still occurs adjacent to and below an acidic horizon similar to the acidic tuff hanging wall in the areas now being mined. In addition the mineralization in the deep drill holes is mainly chalcopyrite and pyrrhotite with minor pyrite similar to that found on the 1000 level of the Mine.

C. Other Sulfide Deposits

Big Rambler Pond

A small deposit of sulfides occurs approximately 200 feet south of Big Rambler Pond at 2750N/9000E. Approximately 50,000 tons of ore with an average copper content of two percent in a pipe-like lense has been outlined by surface diamond drilling.

The sulfides are found in stratiform volcanic sediments that are mostly quartz-chlorite schists. The immediate hanging wall rocks are folded by similar F_2 folds. The rocks have a weak schistosity and a good mineral lineation. The plunge of the mineralization parallels the mineral lineation of the host rocks.

The mineralization consists mainly of disseminated pyrite, chalcopyrite and pyrrhotite in addition to chalcopyrite-pyrrhotite veins.

The writer's examination of this deposit has been restricted to an examination of polished sections of selected grab samples from the diamond drill cores.

The New Prospect

During the 1969 field season a soil geochemical survey revealed anomalous copper concentrations in an area to the southwest of Rambler Brook between map coordinates 6800N/11000E and 6600N/11000E. Pyrite, chalcopyrite and pyrrhotite mineralization in quartz-chlorite schists was revealed by surface trenching and diamond drilling but no exploitable deposit has been outlined to date.

The configuration of this deposit has not yet been determined.

An examination of core from one drill hole reveals that
the sulfides are lineated parallel to lineations in the host
rock and some of the chalcopyrite and pyrrhotite occurs in
post-deformation veins.

Other occurrences

Several other small sulfide occurrences are known in the
Rambler area. The majority of these consist mainly of
disseminated pyrite and traces of chalcopyrite in the chert-
like rocks of unit 3 (Plate I).

CHAPTER VII

SULFIDE MINERALOGY AND GEOTHERMOMETRY

The opaque minerals of the main sulfide deposits are described and an attempt is made to interpret the textures observed in terms of the deformational and metamorphic history of the Rambler area. The temperatures of formation of the deposit are discussed in relation to the sulfide phase relationships and fluid inclusion studies.

A. The Rambler Mine

Twenty polished sections and 25 polished thin sections from 30 specimens of sulfide ore from the Rambler Mine were studied. The minerals identified are, in order of abundance, pyrite, sphalerite, chalcopyrite, pyrrhotite, galena, mackinawite and cubanite. Magnetite was found only in specimens of the 'magnetite tuff' horizon.

Pyrite, FeS_2:

Pyrite, found in all specimens examined, is the dominant sulfide in most of the specimens. The average grain size of pyrite in massive pyrite specimens and in the pyritic bands of banded sulfides is approximately 0.5 mm. In sections where sphalerite or chalcopyrite is the most abundant mineral, the average size of the pyrite grains is 0.2 mm but the range in grain size is much greater than in pyrite dominant sections with many of the crystals being more than 1 mm in diameter.

Pyrite grain shapes vary from anhedral to euhedral with the majority having subhedral outlines. Cataclastic deformation is rare except in porphyroblasts more than 1 mm in diameter. Triple point junctions which rarely attain 120 degrees are most common in

pyrite dominant sections (Fig. 7-1A) and are seldom found in

pyrites embedded in a chalcopyrite or sphalerite matrix. Lineated

pyrites, found in only a few pyrite dominant sections (Fig. 7-1C)

have their long axes parallel to the silicate lineations in the

same specimen.

Disseminated pyrite grains in sphalerite are commonly euhedral

whereas disseminated pyrite in a chalcopyrite matrix are commonly

anhedral with rounded grain outlines. Inclusions are common in

pyrite and consist mainly of silicate, sphalerite and chalcopyrite.

Sphalerite, (Zn,Fe)S:

Sphalerite is present in all of the sections studied and is

the dominant sulfide in approximately one-quarter of the sections.

Sphalerite occurs in monomineralic bands, intergrown with and

filling interstices between pyrite grains and as inclusions in

pyrite grains in the massive pyrite-sphalerite and pyrite ores.

Anhedral grains, stringers and stars of sphalerite are found in

the chalcopyrite bands of massive sulfides and in chalcopyrite-

pyrrhotite veins.

The shape, which varies from anhedral to euhedral, and the

size of sphalerite grains are largely controlled by the other

sulfides present and their relative proportions to each other and

to the sphalerite. In specimens of massive pyrite the sphalerite

grain size seldom exceeds 0.5 mm whereas in massive sphalerite

specimens the average grain size is often more than 1 mm and

individual grains often attain maximum dimensions of 3 mm.

Although lineated lenses of sphalerite were observed in hand

specimens of pyrite-sphalerite ore, lineated sphalerite grains

were observed in only one polished section. The sphalerite grains

are generally twinned with multiple straight twin lamellae which are

Table 7-1. ELECTRON MICROPROBE ANALYSES OF SPHALERITE
COEXISTING WITH PYRITE, RAMBLER MINE.

Each analysis is the mean of at least 3
points on each specimen.

No.	wt. % S	wt. % Fe	wt. % Zn	Total
1	32.60	5.23	ND*	-
2	32.90	5.27	ND*	-
3	33.42	5.12	ND*	-
4	33.44	4.40	63.99	101.83
5	32.67	4.37	63.77	100.81
6	32.68	4.32	63.71	100.70
7	32.97	4.42	63.70	101.09
8	32.59	4.48	64.11	101.18
9	32.78	4.37	63.77	100.93
10	32.67	4.39	63.49	100.56

* For purposes of correcting the raw probe data the

weight percent zinc was taken as:

wt. % Zn = 100 - (wt. % S + wt. % Fe).

visible on unetched polished surfaces. Twinning was not observed in sphalerites enclosed in a chalcopyrite matrix.

Electron microprobe analyses of sphalerites from ten specimens are given in Table 7-1. All of the sphalerites analysed coexist with pyrite. Sphalerites in massive sphalerite bands have an iron content identical to that of sphalerites in actual contact with pyrite. Zoning of sphalerite was looked for in two specimens by analysing for iron and sulfur along traverses across several mineral grains, however, no detectable differences were found.

Chalcopyrite, $CuFeS_2$:

Chalcopyrite occurs in approximately half of the specimens studied. The mineral occurs mainly in chalcopyrite-rich bands in massive pyrite-chalcopyrite ore and in chalcopyrite-pyrrhotite veins. In addition, it is a minor constituent in some massive pyrite and massive pyrite-sphalerite ores where it occurs as inclusions in pyrite, filling fractures in pyrite or filling inter-stices between the other sulfide minerals.

Chalcopyrite is commonly associated with pyrrhotite against which it exhibits mutual boundary textures. When chalcopyrite is the dominant mineral in a section, such as in the chalcopyrite bands of massive sulfide ore and in the chalcopyrite-pyrrhotite veins, it is relatively coarse grained with grain sizes reaching maximum dimensions of 1 mm.

Chalcopyrite is invariably twinned with lanceolate and 'oleander-leaf' twin lamellae which are indicative of inversion from a high-temperature form (Ramdohr, 1969). Straight edged rectangular deformation twin laths are common in some specimens. Stringers, blebs and stars of sphalerite, stringers of pyrrhotite, threads of mackinawite and laths of cubanite are commonly exsolved

from the chalcopyrite.

Pyrrhotite, $Fe_{1-x}S$:

Pyrrhotite is nearly always associated with chalcopyrite, the exception is the association with pyrite when pyrrhotite fills fractures in and replaces pyrite porphyroblasts. Four specimens of pyrrhotite were analysed for their total metal content by the X-ray diffraction method of Arnold and Reichen (1962). The analyses are given in Table 7-3. Etching with chromic acid, as described by Arnold (1966), revealed that all of the pyrrhotites consisted of both the hexagonal and monoclinic phases even though the hexagonal phase could not be detected in some specimens by the XRD method.

Galena, PbS:

Galena was found in only three of the sections studied. Galena occurs as irregular grains, up to 0.2 mm in diameter, filling interstices between pyrite and sphalerite. In two of the sections it is widely scattered and constitutes less than 1 percent of the total sulfides while in the third it constitutes about 3 percent of the total sulfides present.

Mackinawite, FeS:

Irregular blebs, platelets and threads of mackinawite occur as exsolutions in chalcopyrite. Individual bodies seldom exceed 20 x 100 microns and are generally oriented in that the mackinawites in a single chalcopyrite grain extinguish at the same time under crossed polars. The mineral has been identified on the basis of its high bireflectance and similarity to analysed material from the East Mine.

Cubanite, $CuFe_2S_3$:

Several laths of cubanite, 30 x 200 microns, were recognized in one section.

Other opaques:

Magnetite is the principal constituent of the 'magnetite-tuff' horizon. Magnetite was looked for but was not found in the sulfide specimens.

Gangue:

Quartz, chlorite, sericite, plagioclase and actinolite are the main gangue minerals identified. Rutile needles and tourmaline were observed in one polished thin section.

B.   The East Mine

Approximately 75 polished sections and 25 polished thin sections of sulfide bearing rocks from the East Mine have been studied. Pyrite, chalcopyrite, pyrrhotite, sphalerite, mackinawite, cubanite, ilmenite and magnetite were identified.

Sphalerite, (Zn, Fe)S:

Sphalerite, a minor phase in the East Mine, seldom constitutes more than 2 percent of the total sulfides in any section. Sphalerite occurs as inclusions in porphyroblastic pyrite and as discrete grains between pyrite grains. However, it is most commonly found as blebs, strings of blebs and as stars in chalcopyrite and as blebs in pyrrhotite. Several of the sphalerite blebs in pyrrhotite contain exsolved chalcopyrite.

Sphalerite stars in chalcopyrite are generally well formed with numerous branches (Fig. 7-2B). Ramdohr (1969) considers such star-shaped sphalerite in chalcopyrite to have formed by exsolution and to be restricted to high-temperature deposits. Chalcopyrite blebs in sphalerite are also produced by exsolution from sphalerite and is further evidence of a high temperature of

formation (Edwards, 1954; Ramdohr, 1969).

Electron microprobe analyses of sphalerite from the East Mine (Table 7-2) showed that there is no significant difference in iron content between the sphalerite blebs and sphalerite stars. It is reasonable to assume that both the sphalerite stars and blebs have formed by exsolution from their host minerals.

Pyrrhotite, $Fe_{1-x}S$:

Pyrrhotite, a common constituent of the East Mine sulfide deposit, is found in the majority of the sections studied. The mineral is usually associated with chalcopyrite and is rarely found in sections that do not contain chalcopyrite.

Pyrrhotite is associated with chalcopyrite in sulfide blebs in the disseminated ore, in the sulfide veins and in some small inclusions in pyrite. In addition pyrrhotite fills fractures in and replaces pyrite porphyroblasts in chalcopyrite-pyrrhotite veins (Figs. 7-6, 7-7).

In a number of chalcopyrite-pyrrhotite veins the pyrrhotite occurs as narrow lenses which appear to vein the chalcopyrite (Fig. 7-2D). Pyrrhotite stringers rimming chalcopyrite grains appear to have formed by exsolution from the chalcopyrite.

Although individual blebs of pyrrhotite in chalcopyrite-pyrrhotite may consist of a single pyrrhotite crystal, the blebs and stringers of pyrrhotite are generally polycrystalline. A number of the chalcopyrite-pyrrhotite blebs in the disseminated ore often contain unicrystalline blebs of pyrrhotite up to 1 mm in length.

Deformation lamellae were found in several specimens (Fig. 7-3A), however, the pyrrhotite seldom shows any evidence of deformation. Very narrow polysynthetic twinning was observed in

Table 7-2. ELECTRON MICROPROBE ANALYSES OF SPHALERITE,
            EXSOLVED FROM CHALCOPYRITE, EAST MINE.

            Each analysis is the mean of at least 3
            points on each specimen.

No.	wt. % S	wt. % Fe	wt. % Zn	Total
1	33.23	12.22	ND*	-
2	33.49	12.28	ND*	-
3	33.11	11.73	ND*	-
4	33.73	12.69	ND*	-
5	33.02	12.07	ND*	-
6	33.28	12.35	ND*	-
7	33.45	11.52	ND*	-
8	33.24	11.40	ND*	-
9	32.76	11.71	ND*	-
10	31.74	10.12	58.77	100.63
11	31.69	10.03	57.41	99.12
12	32.53	11.03	57.80	101.36
13	32.00	11.67	55.23	98.90
14	31.80	10.79	55.44	98.03

* For purposes of correcting the raw probe data the
  weight percent zinc was taken as:
  wt. % Zn = 100 - (wt. % S + wt. % Fe).

Table 7-3. ANALYSES OF PYRRHOTITE BY X-RAY DIFFRACTION[3].

East Mine

No.	Type[1].	d-space	At % Fe[2]
1	M	2.0663	47.35
2	M	2.0671	47.41
3	M	2.0641	47.15
4	M	2.0637	47.11
5	M ≫ H	2.0663	47.35
6	M ≫ H	2.0644	47.18
7	M	2.0656	47.28
8	H ± M	2.0686	47.55
9	M ≫ H	2.0663	47.35
10	H ≃ M	2.0678	47.48
11	M ≫ H	2.0686	47.55
12	M	2.0652	47.25
13	M	2.0663	47.35
14	H ± M	2.0697	47.65
15	M ± H	2.0659	47.31
16	M	2.0637	47.11
17	M ± H	2.0663	47.35
18	M ± H	2.0671	47.41
19	M	2.0656	47.28
20	M	2.0659	47.31
21	M	2.0641	47.15
22	M	2.0652	47.25
23	M	2.0652	47.25
24	M	2.0652	47.25
25	M	2.0667	47.38

Rambler Mine

No.	Type	d-space	At % Fe
1	M	2.0648	47.21
2	H ≫ M	2.0690	47.58
3	M ≻ H	2.0671	47.41
4	M	2.0659	47.31

1. M = monoclinic phase only detected; M≫H = monoclinic phase greatly exceeding hexagonal phase; M±H = hexagonal phase barely detectable; H≃M = hexagonal and monoclinic phases present in approximately equal proportions; H = hexagonal phase only present

2. Calculation based on the expression of Yund and Hall(1969):
$\%fe = 45.212 + 72.86 (d_{102}-2.0400) + 311.5(d_{102}-2.0400)^2$

3. Lithium fluoride used as an internal standard.

only one specimen.

Structural etching of pyrrhotite with chromic acid revealed the presence of two phases of pyrrhotite in all of the specimens etched. In several cases, such as in Figure 7-2D, structural etching revealed that the pyrrhotite lamellae were oriented perpendicular to the boundaries of the pyrrhotite lense.

X-ray diffraction studies of 25 pyrrhotites from the East Mine showed that both monoclinic and hexagonal pyrrhotites constitute the major phase. The total metal contents of the analysed pyrrhotites are presented in Table 7-3. Pyrrhotites veining and replacing pyrite porphyroblasts were determined by etching to consist mainly of the monoclinic phase. The hexagonal phase was only found as a replacement of pyrite in porphyroblasts that had been almost completely replaced by pyrrhotite

Chalcopyrite, $CuFeS_2$:

Chalcopyrite occurs in association with pyrrhotite as blebs in the disseminated ore, in sulfide veins, as pressure fringes around pyrite porphyroblasts, as inclusions in pyrite and rarely as exsolutions in sphalerite blebs in pyrrhotite.

On the basis of a comparison of sulfide-host rock relationships it would appear that there are at least two generations of chalco-pyrite (and pyrrhotite), namely: (1) in the disseminated chalcopyrite -pyrrhotite blebs and the chalcopyrite intergrown with pyrite in the upper pyrite-rich parts of the mine; and (2) chalcopyrite occurring in sulfide veins. The descriptions of chalcopyrite given below apply to all chalcopyrite in the East Mine unless otherwise stated.

Chalcopyrite is invariably associated with pyrrhotite and

although occasional sections do not contain both phases it is quite possible that the absent phase would be present if the section could be viewed in three dimensions.

The chalcopyrite grain size generally ranges from 0.1 to 0.5 mm, however, grains up to 0.5 x 1.0 mm were noted in a number of sections.

Chalcopyrite exhibits mutual boundary textures with pyrrhotite and although it sometimes appears to be 'veining' pyrrhotite, the reverse relationship is also true. Chalcopyrite seldom shows lineated grain outlines except in the disseminated ore where the grains commonly extend completely across the chalcopyrite-pyrrhotite blebs and the grain shape is bounded by the surrounding silicate (Figs. 7-4C, 7-4D).

Chalcopyrite generally exhibits twinning in unetched specimens under crossed polars and this twinning is accentuated by etching. Lanceolate and 'oleander leaf' inversion twin lamellae are the most common types of twinning observed (7-3C). Narrow to broad straight edged twin lamellae, probably deformation twin lamellae, are present in a number of sections. A poly-synthetic twinning was noted in several sections after etching (Fig. 7-3B). Inversion twin lamellae are transected by deform-ation twin lamellae when both occur in the same section.

Exsolutions from chalcopyrite are quite common and although they are not found in all chalcopyrite grains they are present in nearly every polished section studied. The exsolved minerals are cubanite, sphalerite, mackinawite, and pyrrhotite.

Several small bodies of sphalerite in pyrrhotite from the sulfide veins were observed to contain exsolved chalcopyrite

particles less than 5 microns in diameter.

Chalcopyrite grains occasionally have stringers of sphalerite and pyrrhotite at the grain boundaries which probably formed by unmixing from the chalcopyrite with subsequent migration to the grain boundaries.

The presence of inversion twin lamellae and stars of sphalerite in chalcopyrite are indicative of a high-temperature origin (Ramdohr, 1969). Exsolution lamellae of cubanite and of exsolved mackinawite also suggest that the chalcopyrite originally crystallized as a non stoichiometric'high-temperature chalcopyrite'.

Pyrite, FeS_2:

Pyrite occurs in nearly all of the sections studied. Pyrite grains have anhedral to euhedral forms. Pyrite porphyroblasts commonly have euhedral forms. The size of pyrite grains varies from less than 0.1 to 5 mm. Disseminated porphyroblastic pyrites commonly attain diameters of 5 mm whereas the grains in nearly massive pyrite specimens are generally less than 1 mm in diameter and have an average diameter of about 0.5 mm.

Porphyroblastic pyrite commonly encloses tiny grains of silicate and other sulfides such as chalcopyrite, pyrrhotite and sphalerite. In addition, porphyroblastic pyrite commonly encloses anhedral grains of an earlier harder pyrite. Prolonged etching with chromic acid (for approximately 1 hour) reveals that many of the pyrites are polycrystalline aggregates of earlier pyrite rimmed by a later growth of pyrite. In addition, some of the porphyroblasts consist of a central zoned pyrite crystal surrounded by an unzoned pyrite rim (Fig. 7-6A).

Lineated pyrite grains were found in only one specimen which

contained more than 99 percent pyrite. The pyrite grains seldom

exhibit polygonal grain boundaries with triple point junctions.

Pyrite grains in specimens consisting almost entirely of pyrite

are generally anhedral whereas disseminated pyrites have a

subhedral to euhedral form which probably represents a greater

freedom of crystallization in the gangue-rich specimens.

In a number of specimens evidence can be found for both pre-,

syn, and post-deformational crystallization of disseminated pyrites.

Pyrite crystals with lineated chlorite crystals bending around

them are interpreted as having crystallized before or during the

main deformation. Pyrite crystals with pressure fringes of

chlorite are interpreted as having formed during the deformation.

In a number of polished thin sections pyrite porphyroblasts

interrupt and grow across the lineated silicate minerals and are

therefore considered to have crystallized after the main deform-

ation had ceased.

Pyrite grains in sulfide veins seldom contain inclusions of

silicate minerals but minute inclusions of chalcopyrite and

pyrrhotite are common. Pyrite grains in chalcopyrite-pyrrhotite

veins occur as small rounded grains less than 0.2 mm in diameter

and as euhedral pyrite porphyroblasts 0.5 - 3 mm in diameter.

In addition some sections contain irregularly shaped pyrites full

of inclusions which appear to have been partly replaced by

chalcopyrite (Fig. 7-4B). A similar pyrite is present as tiny

inclusions in some pyrite porphyroblasts (Fig. 7-6C). The rounded

pyrite grains are generally free of inclusions and are found in

both chalcopyrite and pyrrhotite whereas the pyrite porphyroblasts

are restricted to a chalcopyrite matrix. Furthermore, only the porphyroblastic pyrite has been replaced by pyrrhotite.

The pyrite porphyroblasts exhibit unusual textures in that the majority of them have undergone some deformation and alteration. Although fracturing is present in a number of the porphyroblasts (Figs. 7-6B, 7-6C), they are commonly replaced by pyrrhotite along the fractures. The replacement appears to proceed mainly along fractures in the pyrite and develops fastest in the cores of the porphyroblasts (Figs. 7-6D, 7-7B). In several specimens replacement has completely destroyed the core of the pyrite crystal with the original euhedral outline of the crystal still discernible in the unreplaced rim (Fig. 7-7A). Although the pyrite porphyroblasts are found only in a chalcopyrite matrix, they are replaced only by pyrrhotite. Although several attempts were made to etch the pyrite porphyroblasts, no structural features were observed. The reason for this unusual texture is not known.

Cubanite, $CuFeS_2$:

Laths of cubanite were observed in a number of polished sections from the sulfide veins but were rarely observed in chalcopyrite-pyrrhotite blebs of the disseminated ore. Although there is only one set of lamellae present in most sections, a few sections contain two intersecting sets of lamellae (Fig.7-5A). The cubanite lamellae are generally less than 20 microns wide and less than 0.5 mm in length. However, in one section a lamella only 10 microns in width has a length of 1 mm.

The cubanite is distinctly bireflecting in air with creamy grey and very pale brown colours and it has a moderate anisotropy

under crossed polars. The mineral occasionally exhibits

twinning with twin lamellae both parallel and oblique to the

length of the cubanite laths. The cubanite probably has tetra-

gonal symmetry since the laths exhibit identical colours under

crossed polars in the 45 degrees position either side of the

extinction position.

The cubanite laths cut across inversion twin lamellae but

are themselves interrupted by deformation lamellae in the

chalcopyrite host. Mackinawite threads often parallel the

cubanite laths and in one specimen a mackinawite thread was

observed to penetrate a cubanite lath. for approximately 5 microns.

The relative ages of the sphalerite stars and the cubanite laths

is unknown since the two were not observed in contact with each

other.

The cubanite laths must have exsolved later than the

inversion twin lamellae which they cut and prior to the devel-

opment of the transformation twins which deform them. The

cubanite laths must also have exsolved before the development

of the mackinawite threads which intrude them.

Yund and Kullerud (1966) recognized that 'cubic cubanite'

was stained by an etch solution of ammonium dichromate in

hydrochloric acid. Although a number of sections were etched

with this solution, no 'cubic cubanite' was identified.

Mackinawite, FeS:

Exsolution threads, platelets and blebs of mackinawite

in chalcopyrite have been identified in a majority of the

polished sections containing chalcopyrite. The mineral is

bireflecting from pinkish grey to grey in air and has a very

strong anisotropy under crossed polars. Since various authors

state that the mineral may be mistaken for valleriite

(Uytenbogaardt and Burke, 1971; Ramdohr, 1969; Evans et al.,
1964) a number of mackinawite blebs were analysed for copper by
electron microprobe but no copper was detected.

The mineral occurs mainly as platelets and threads 5-20
microns wide by 50-100 microns in length and as tiny blebs,
5-10 microns in diameter, which probably represent end sections
of thread shaped bodies. En echelon patterns are common and
individual chalcopyrite grains commonly contain either threads
or blebs of mackinawite. Although many of the platelets are
straight, a number make an angle of approximately 120 degrees
which suggests a crystallographically controlled exsolution
(Fig. 7-5B). Platelets of mackinawite are interrupted by
deformation twin lamellae in chalcopyrite but they appear to
have formed later than the development of the inversion twin
lamellae in the chalcopyrite since they continue uninterrupted
across the inversion twins.

Other opaque minerals:

Poikiloblastic ilmenite and euhedral magnetite have been
identified in the silicate matrix of a number of sections.
These minerals probably formed during the second metamorphic
event affecting the Rambler area since the ilmenite is
unoriented and poikilitically encloses lineated quartz and
chlorite.

Gangue minerals:

The main gangue mineral in the sulfide veins is quartz.
Chlorite, biotite and carbonate are present but rarely
constitute more than 1 percent of the total minerals in the

veins.

The gangue minerals in the disseminated ores are the normal constituents of quartz-chlorite and quartz-sericite schists - quartz, chlorite, actinolite, biotite and traces of carbonate.

C. Big Rambler Pond Deposit

Ten polished sections were studied from this deposit. The main sulfide minerals in the Big Rambler Pond deposit are, in decreasing order of abundance, chalcopyrite, pyrrhotite, pyrite, sphalerite, mackinawite and cubanite. Cubanite, mackinawite and sphalerite are present as exsolutions from chalcopyrite. The textures of the sulfide minerals are similar to those found in the chalcopyrite-pyrrhotite veins of the East Mine. Several of the sections contained approximately 5 percent magnetite which is partly replaced by pyrite.

D. The New Prospect

In each of the 5 polished sections studied from this deposit pyrite is the main sulfide mineral. Chalcopyrite, pyrrhotite and sphalerite are present in pressure fringes to porphyroblastic pyrites and also as inclusions in the pyrite. The pyrite from this deposit has a well developed lineation which is parallel to the lineations in the silicate host rock.

E. Geothermometry

Sulfide phase relationships

Since the pyrrhotite and sphalerite geothermometers have been shown to be dependent largely upon the activity of sulfur (Arnold, 1969; Yund and Hall, 1969; Scot and Barnes, 1971) there are very few geothermometers that can be applied to the Rambler area sulfides.

The presence of inversion twin lamellae in chalcopyrite suggests that the chalcopyrite crystallized or recrystallized as cubic chalcopyrite which inverted to tetragonal chalcopyrite with decreasing temperature. Yund and Kullerud (1966) have recorded this inversion as taking place at 547 ± 5°C.

Since the cubanite laths are not now cubic but probably tetragonal, then they either exsolved from the tetragonal, inverted chalcopyrite below the inversion temperature of cubic-tetragonal cubanite at 252 ± 3°C (Yund and Kullerud, 1966) or the cubanite inverted to the tetragonal (?) form after initial exsolution as cubic cubanite from cubic chalcopyrite above 547 ± 5°C.

The temperature of exsolution of mackinawite from chalcopyrite is not accurately known. Ramdohr (1969) suggests a temperature of formation of roughly 200-250°C.

Investigation of fluid inclusions

Two-phase fluid inclusions were observed in the quartz gangue of sulfide ore samples during routine observation of polished thin sections. In view of the recent serious questioning of the applicability of the pyrrhotite and sphalerite geothermometers (Arnold, 1969; Barton and Toulmin,

1966; Yund and Hall, 1969; Scott and Barnes, 1971; and others)
and the possibility of using fluid inclusion studies to elucidate
the geothermometry and/or the mode of emplacement of the gangue
and sulfide mineralization (Roedder, 1960, 1967; Ermakov, 1965)
a brief study was made of some of the material available. The
following section is based on a preliminary study of the quartz
gangue in chalcopyrite-pyrrhotite veins and selected quartz
veins.

a. Material studied:

At the time of sampling the ore zone and the surrounding
country rocks, the writer was not aware of the existence of
fluid inclusions in the gangue minerals. Consequently, only a
small number of specimens were collected from the gangue-rich
sulfide veins and quartz veins noted in the course of geological
mapping and core logging.

Fifteen sphalerite specimens were selected from the Main
Mine samples, and 25 gangue-bearing sulfide specimens and 5
samples of milky-white quartz veins were selected from samples
collected from the hanging wall and ore zone of the East Mine.
One or more double-side polished thin slices were prepared from
each specimen and all were examined for contained fluid
inclusions.

Liquid-gas, liquid-gas-solid, and liquid phase inclusions
were found in two sphalerite specimens from the Main Mine. The
extremely dark colour of the sphalerites necessitated the pre-
paration of very thin slices, often less than 0.2 mm, which may
be partly responsible for the low incidence of observation of
fluid inclusions in this material, since some of the inclusions

may have leaked during preparation of the sections. In general, the sphalerites contained only scattered fluid inclusions which were secondary in origin. Filling-temperature measurements were not performed on sphalerites from the Rambler Mine.

Samples examined from the East Mine were taken mainly from chalcopyrite-pyrrhotite veins from the 750 and 1000 levels. Fluid inclusions were found in the quartz gangue and in one specimen several inclusions were found in carbonate crystals.

The gangue quartz consists of two varieties: (1) fine grained, less than 0.1 mm, milky-white quartz, and (2) clear, glassy quartz grains, 0.5 to 1 mm in diameter. Fluid inclusions suitable for filling-temperature measurements were found in the clear, glassy quartz of approximately half the specimens examined. A large proportion of the glassy quartz is completely free of fluid inclusions and many of the grains with inclusions contain single planes of pseudosecondary or secondary inclusions.

Two of the 5 samples of quartz veins came from the ore zone. The remainder were obtained from quartz veins in the hanging wall. Inclusions suitable for filling-temperature measurements were found in 4 of these samples. Fluid inclusions were present in the other sample but were too small to be satisfactorily resolved with the equipment used. The two samples taken from the ore zones contained angular blocks of wall rock and patches of sulfide mineralization.

b. Method of Study:

Specimens were initially studied with a petrographic micro-scope. After identification of the types of inclusions present and the initial selection of suitable material, the filling-temp-eratures of liquid-gas inclusions were determined using the

equipment and procedure described in Appendix B.

c. Types of Inclusions:

The correct distinction of the type of fluid inclusion present is necessary before any fluid inclusion geothermometry can be undertaken. Roedder (1967) considers the origin of inclusions and discusses the processes which can lead to changes after their initial entrapment, such as necking down and leakage.

An attempt was made to classify inclusions into those of primary, pseudosecondary and secondary origin. In most cases only a few could be classified with any certainty and in cases of doubtful origin, where evidence of secondary origin was definitely lacking, the inclusions were classified as pseudo-secondary. The criteria used by Roedder (1967) and Kelly and Turneaure (1970) for distinguishing inclusions of primary origin, i.e. using only the relationships of inclusions to features of known primary origin, could not be applied in the present study due to the lack of such criteria as primary colour zones and growth twins. In this study, an inclusion was considered to be of primary origin if it was (a) separated from other inclusions by several inclusion diameters, (b) not related to any obvious planar or linear structures, and (c) not evidently necked down or leaked (Fig. 7-8).

Inclusions of a planar or linear nature, occurring along fractures, are either secondary or pseudosecondary in origin. The distinction between pseudosecondary and secondary inclusions is difficult and undisputed examples of pseudosecondary inclusions with definite restriction of the healed fracture to the inner core of the quartz grain are absent from the material studied because

of the lack of zoning in the quartz grains. Most of the pseudo-secondary inclusions were identified on the basis of healed fractures or linear structures which do not continue to the limits of the grain boundary.

Secondary inclusions are those inclusions occurring along healed fractures that completely cut across the quartz grain and reach the grain boundary or transect several grains.

The most abundant inclusions present are of secondary origin. In several cases they are the only type of inclusion recognizable and the large number of planes of secondary inclusions present give the otherwise clear quartz a dark, cloudy appearance. The majority of the secondary inclusions are too small for determination of their filling-temperatures. A small number of measurements were made on secondary inclusions in order to determine their range of filling-temperatures.

When pseudosecondary inclusions occurring within a single plane of inclusions gave a range of filling-temperatures of more than $25°C$, the data were discarded.

d. Interpretation of the filling-temperature data

The data obtained for fluid inclusions in the quartz gangue of sulfide veins are plotted separately from that obtained for quartz veins (Fig. 7-9). The filling-temperatures for individual specimens are presented in Table 7-4.

Primary and pseudosecondary inclusions have filling-temperatures in the range 145 to $330°C$ in the quartz gangue and 130 to $290°C$ in the vein quartz.

Secondary inclusions homogenized over a temperature range of 95 to $125°C$.

Table 7-4. FILLING TEMPERATURE OF FLUID INCLUSIONS IN
GANGUE QUARTZ AND VEIN QUARTZ

Specimen	Type of Inclusion	Number Tested	Filling Temperature
625-40-88	S	3	97-117
	PS	3	172-199
	PS	3	215-230
	PS	1	≳240
	PS or S(?)	1	134
	PS	6	177-200
7-F-1	PS or S(?)	10	171-189
	PS	8	200-216
	PS(?)	9	290-368
	P(?) or PS	2	290
	P(?) or PS	6	260-283
	S	1	98
750-22	P	1	198
	P or PS(?)	5	220-226
	PS	7	240-250
	P	2	286
	P	2	330-348
	P(?) or PS	6	307-330
68-28-9	PS	3	174-194
	P	2	≳255
7-1W	PS	4	170-191
	PS	1	217
	PS	7	236-251
	PS	2	≳260
8-1-6	PS	2	271
63-581	S	4	123-125
	PS(?) or S	25	184-198
	PS	8	210-217
	PS	20	192-196
	PS	2	202-205
61-278	PS	25	230-255
	P(?) or PS	4	273-290
	PS	6	313-323
	PS	7	191-203
	PS	16	234-256
	PS(?)	1	271
10L	P(?) or PS	20	215-250
	P	6	227-236
7-IN	P	7	212-276
	PS	15	147-176

P=Primary, PS=Pseudosecondary, S=Secondary.
≳ greater than or equal to:temperature given is a
minimum.

Interpretations based only on filling-temperature data are fraught with difficulties and pitfalls. Some of the difficulties are: (1) the filling temperatures of the inclusions are minima requiring positive pressure corrections if the inclusions resulted from the cooling of supercritical fluids of varied density; (2) filling temperatures will be true depositional temperatures if the inclusions trapped only one of a heterogeneous system of immiscible ore fluids; (3) the filling temperatures will be maxima if the inclusion trapped a mixture of a heterogeneous system of immiscible fluids; (4) filling temperatures of inclusions trapped at the boiling temperature are true temperatures of trapping, whereas inclusions trapped above the boiling temperature of the inclusion will indicate only a minimum temperature of trapping. These problems are discussed in some detail by Roedder (1967), Kennedy (1950) and Kelly and Turneaure (1970).

Since pressure and salinity data have not been determined for the inclusions studied, it is not possible to make pressure corrections for the temperatures obtained and therefore the temperatures given in Table 7-4 must be treated as minimum temperatures.

A further factor which will affect the fluid-inclusion filling temperatures is deformation of the host quartz, which can cause complete or partial leakage from the inclusion. In the present study, inclusions of a primary or pseudosecondary nature were found only in quartz which did not exhibit undulatory extinction or polygonal grain boundaries.

The fluid-inclusion filling temperatures do not prove or disprove crystallization of the quartz gangue and the vein quartz

under biotite grade, greenschist metamorphism. Although the maximum filling temperatures of 330°C are within the range 250-450°C given by Turner (1968) for greenschist metamorphism, they are well below the range 400-550°C given by Winkler (1967) for the greenschist facies.

The fluid inclusion studies indicate that the quartz gangue of the sulfide veins probably crystallized at temperatures in the range of 150 to 330°C and a similar temperature of crystallization or recrystallization can also be ascribed to the sulfides associated with the gangue quartz.

Although the presence of fluid inclusions may be considered to be evidence for 'hydrothermal activity' being involved in the formation of the sulfide veins, it must be borne in mind that the mode of transport and methods of mobilization of sulfide and silicate minerals during metamorphism are little known and little investigated processes even though they are established concepts in the geological literature.

F. Interpretation of textures observed in the sulfide deposits.

Although reference is made only to the Rambler and East Mine sulfide deposits, the textural relationships described and the conclusions drawn can also be applied to the Big Rambler Pond and the New Prospect deposits.

It has been noted in the description of the sulfide mineralization that a number of features of the textural relationships of the sulfides are similar to those ascribed by various authors (cited in Ramdohr, 1969) to 'high-temperature' sulfide deposits. These textures are: (1) mackinawite exsolution from chalcopyrite;

(2) cubanite and pyrrhotite exsolution from chalcopyrite;

(3) stars and blebs of sphalerite exsolved from chalcopyrite;

(4) chalcopyrite exsolution from sphalerite which may in turn have exsolved from pyrrhotite; and (5) the presence of inversion twin lamellae in chalcopyrite.

In addition to the 'high-temperature' textures, the sulfide ores exhibit a number of textures that are best interpreted as formed by deformation and metamorphism, namely: (1) pretectonic or syntectonic crystallization of pyrite and sphalerite with L-tectonite fabrics; pretectonic crystallization of pyrite around which are wrapped silicate mineral lineations; (3) formation of lineated sulfide blebs with their long axes parallel to the long axes of mineral and particle lineations formed during the first deformation; syntectonic and/or posttectonic crystallization of poikiloblastic pyrite grains; (5) syntectonic growth of pyrite porphyroblasts with pressure fringes of chlorite, quartz and other sulfides; and (6) development of biotite grains poikiloblastically enclosing grains of sulfide in mineralized rocks.

In addition to the textural relationships mentioned above, any interpretation of the history of these deposits must take into consideration the formation of the sulfide veins, which are mineralogically and texturally similar to the disseminated ore in the East Mine.

It was noted earlier, in Chapter IV, that a second metamorphic event affecting the Rambler area resulted in the development of unoriented, porphyroblastic biotite in both the country rocks and the ore zones. The development of biotite indicates that this second metamorphic event attained at least biotite grade, upper greenschist metamorphic conditions (Winkler, 1967; Turner, 1968).

Since sulfide minerals are generally more chemically reactive and respond more readily to deformation than silicate minerals, they are more susceptible to metamorphic events, which tend to mask the original textures and contribute largely to the controversy over the origin of many conformable sulfide deposits in metamorphic terrains.

Review articles by Vokes (1969) and McDonald (1967) consider the effects of metamorphism on sulfide mineral assemblages. Some of the changes which may take place during metamorphism are: (1) changes in original textures; (2) changes in original mineralogy; (3) differential mobilization of constituents; (4) reaction of sulfides and sulfur with non-sulfide minerals; and (5) the generation of accumulations of sulfides.

Buerger (1928) showed that not only could textural changes be brought about in sulfide minerals by metamorphism, but also that some sulfur minerals were more susceptible to metamorphism than silicates. Ramdohr (1950), Vokes (1963) and Stanton (1960, 1964) showed that the textures developed in some ore deposits in metamorphic terrains could be the end product of a metamorphic event producing recrystallization and growth. Solomon (1965) found a decreasing order of deformation for sulfides to be galena-pyrrhotite-sphalerite-pyrite. A similar order of deformation is reflected in the textures of the Rambler ores where the less easily deformed pyrite and sphalerite retain their first deformation, lineated shapes and are veined by the more easily mobilized pyrrhotite and chalcopyrite. According to McDonald (1967), a feature of sulfide deposits considered to have been metamorphosed is a lack of undoubted replacement textures. The only textures in the Rambler sulfide deposits which can be interpreted as a

replacement feature is the replacement of pyrite porphyroblasts by pyrrhotite and the replacement of magnetite by pyrite.

That mineralogical changes can take place during metamorphism and deformation has been demonstrated by Gammon (1966) who found that pyrite was transformed into pyrrhotite during prograde metamorphism. Richards (1966) found that sphalerite, pyrrhotite and valleriite (which is probably misidentified mackinawite) exsolved from chalcopyrite during deformation.

Differential mobilization of sulfides relative to each other and the enclosing wallrocks has been proposed by several authors. Stanton (1960) considered that banding in metamorphosed sulfide deposits could have originated by metamorphic differentiation. Vokes (1963) considered chalcopyrite-pyrrhotite schists to have formed by metamorphic concentrations.

An observation by McDonald (1967, p.212), which is relevant to the interpretation of the Rambler sulfide deposits, is that "Chalcopyrite is commonly found as small, blind veinlets in metamorphosed volcanic rocks or is preferentially enriched in small scale fractures in wall rocks associated with ore deposits in which it is present in minor amounts". George (1969a) has described pyrite and pyrrhotite veinlets in the metamorphosed Nairne pyrite deposits of Australia. The presence of the sulfide veins in the Rambler deposits is attributed to a similar process of remobilization in response to metamorphism.

The 'high-temperature' textures observed in the sulfide minerals can be explained as having been formed by biotite grade greenschist metamorphism in the temperature range of 400-550°C (Winkler, 1967).

With the exception of the trace amounts of zinc, three of

the sulfide deposits approximate to the Cu-Fe-S system while

the Rambler Mine deposit approximates to the system Zn-Fe-Cu-S.

Only the Cu-Fe-S system is considered in the following discussion.

At the temperatures of the biotite grade metamorphism of

$400-550^{\circ}C$, the most common mineral assemblage in the sulfide

deposits (chalcopyrite + pyrrhotite) is not a stable assemblage

in the Cu-Fe-S system (Yund and Kullerud, 1966). The stable

mineral assemblage for the composition chalcopyrite + pyrrhotite

above $334^{\circ}C$ is cubanite + pyrite. This does not, however, indicate

that the Rambler sulfide deposits have not attained a temperature

of more than $334^{\circ}C$, since a characteristic feature of the sulfide

minerals is their tendency toward rapid reactions in the solid

state and metamorphic 'cooling' can persist over considerable

periods of time. At elevated temperatures, the Cu-Fe-S system is

capable of extensive solid solution involving chalcopyrite and

cubanite (Yund and Kullerud, 1966). Slow cooling of a sulfide

deposit under decreasing metamorphic conditions will enable these

solid solutions to re-equilibriate by exsolution and reaction,

thereby giving rise to stable 'low-temperature' mineral assemblages,

i.e. chalcopyrite + pyrrhotite.

Ramdohr (1969) notes that 'cubic high-temperature chalcopyrite',

the cubic cubanite of Yund and Kullerud (1966), breaks down upon

cooling to chalcopyrite + cubanite, chalcopyrite + pyrrhotite, or

chalcopyrite + mackinawite assemblages which are quite common in

the Rambler sulfide deposits. According to Ramdohr (1969) the

breakup of cubanite can be complete in that it can disappear without

any relict structure or trace of its previous existence.

If the writer's interpretation of the lanceolate twin lamellae

in chalcopyrite as inversion twin lamellae is correct, then the temperature of the sulfide deposits must have been close to the upper limits of the greenschist facies since the temperature of inversion from cubic chalcopyrite to tetragonal chalcopyrite is given as $547 \pm 5°C$ (Yund and Kullerud, 1966). In the presence of cubanite, the inversion temperature is lowered to $480°C$ (Barton and Skinner, 1967). The effect of impurities such as ZnS on the inversion temperature is unknown. However, if impurities tend to lower the inversion temperature then the Rambler area chalcopyrites could easily have undergone inversion well within the temperatures of greenschist metamorphism.

The sequence of events deduced from the study of textures and minerals in the sulfide deposits is: (1) sulfides were introduced into the rocks prior to, or during the first deformational event and were deformed along with their host rocks with the production of mineral lineations and the segregation of some of the sulfides into essentially monomineralic bands, as well as the development of syntectonic textures such as pressure fringes; (2) metamorphism under biotite grade greenschist conditions resulted in heating of the sulfide deposits and the mobilization of some of the sulfides into fractures; (3) slow cooling of the sulfides during the end stages of the metamorphism resulted in the inversion of chalco- pyrite from a high-temperature form to a low-temperature form, exsolution of pyrrhotite from chalcopyrite, exsolution of cubanite from chalcopyrite, exsolution of sphalerite from chalcopyrite, and the exsolution of mackinawite from chalcopyrite; (4) later tectonic movements produced deformation twinning in the chalcopyrite.

Figure 7-1 A. Pyrite with triple point junctions.

Interstices between the pyrite grains are filled

with chalcopyrite (medium grey) and silicate

(black). Rambler Mine. (X 20)

B. Subhedral pyrite in massive pyrite-

sphalerite ore, Rambler Mine. Light grey mineral

adjacent to pyrite in the upper right hand corner

is galena. (X 20)

C. Lineated pyrite in massive pyrite ore,

Rambler Mine. Medium grey mineral is sphalerite.

(X 20)

D. Chalcopyrite and sphalerite, Rambler

Mine. (X 50)

Figure 7-2 A. Sphalerite stars in chalcopyrite. The

black mineral is quartz. East Mine. (X 200)

B. Sphalerite star in chalcopyrite. East

Mine. (X 500)

C. Sphalerite exsolved from pyrrhotite. The

light grey mineral is chalcopyrite. East Mine.

(X 50)

D. Pyrrhotite vein in chalcopyrite. The

pyrrhotite has been etched with chromic acid and

shows both hexagonal (high reflecting) and mono-

clinic phases (same specimen as that shown in

Figure 6-6 C). East Mine. (X 10)
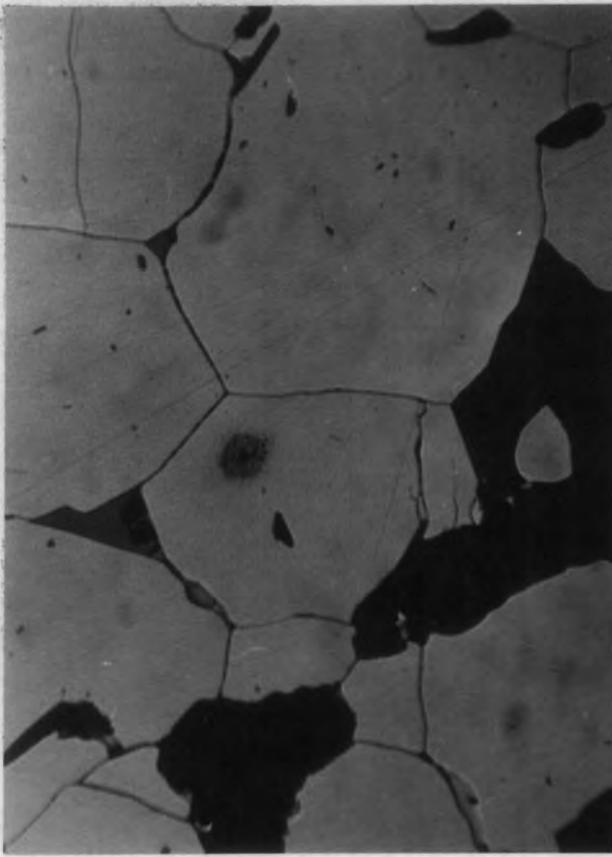
A
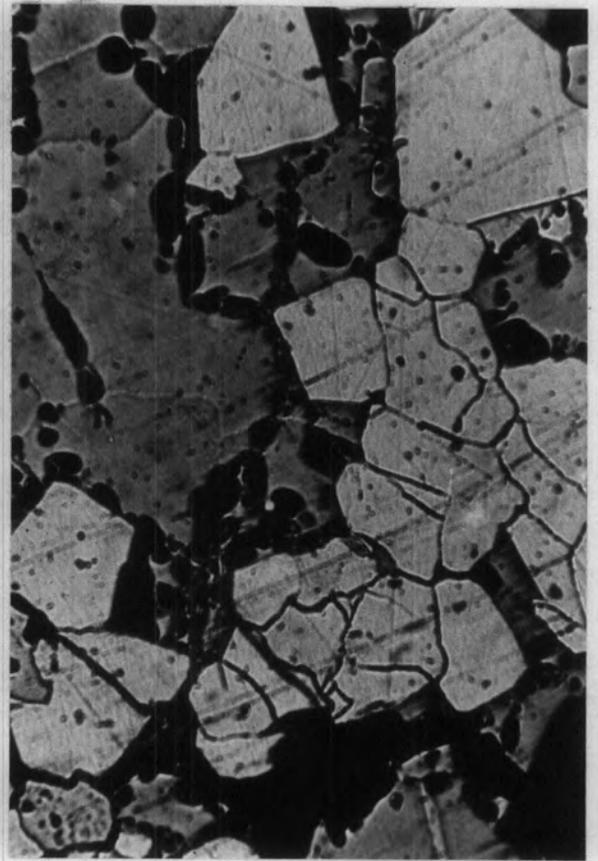
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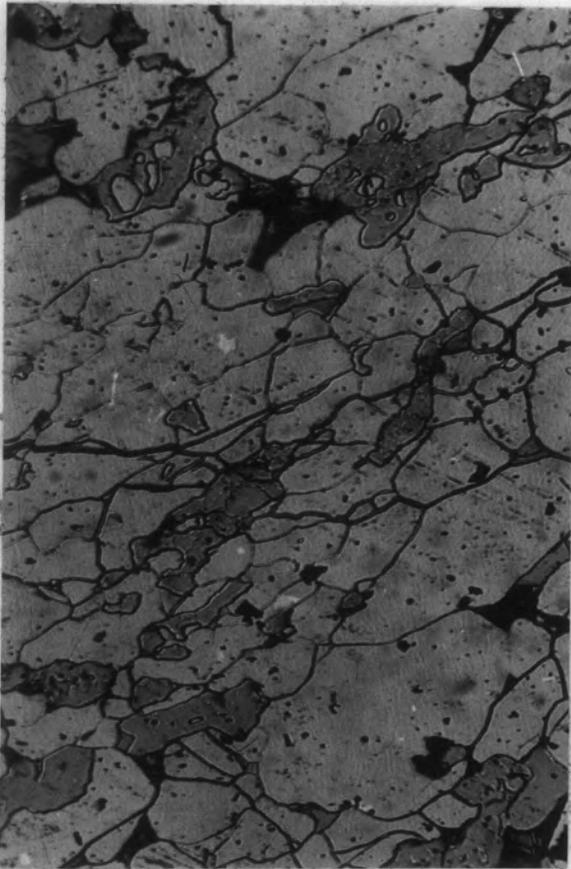
C
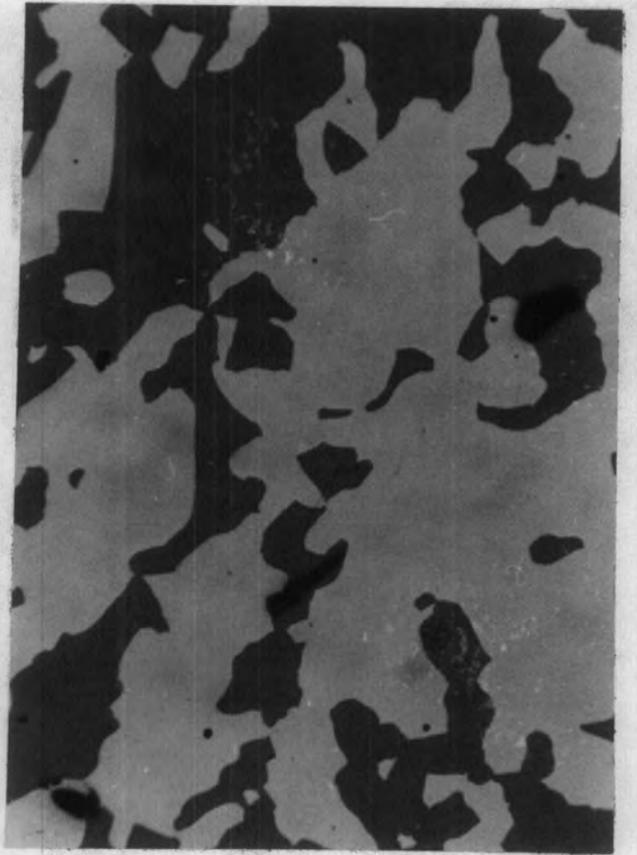
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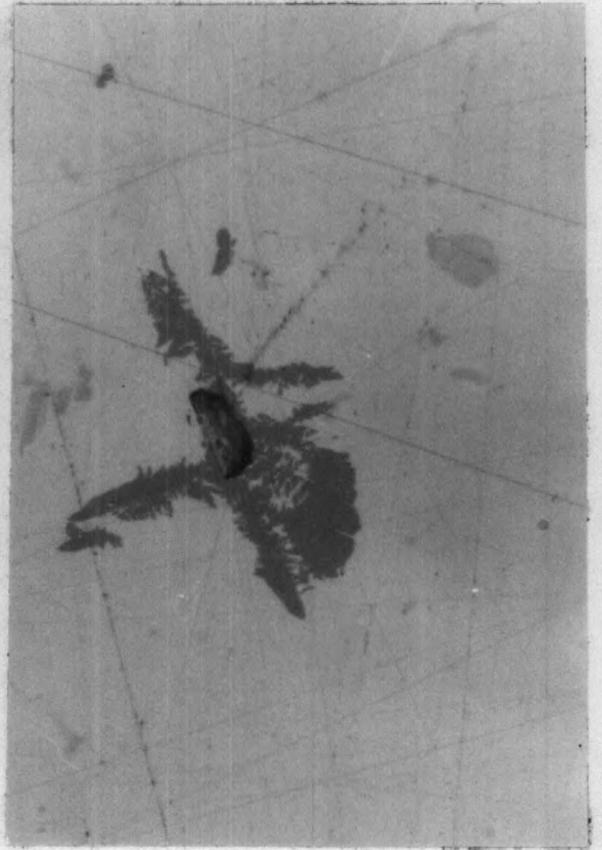
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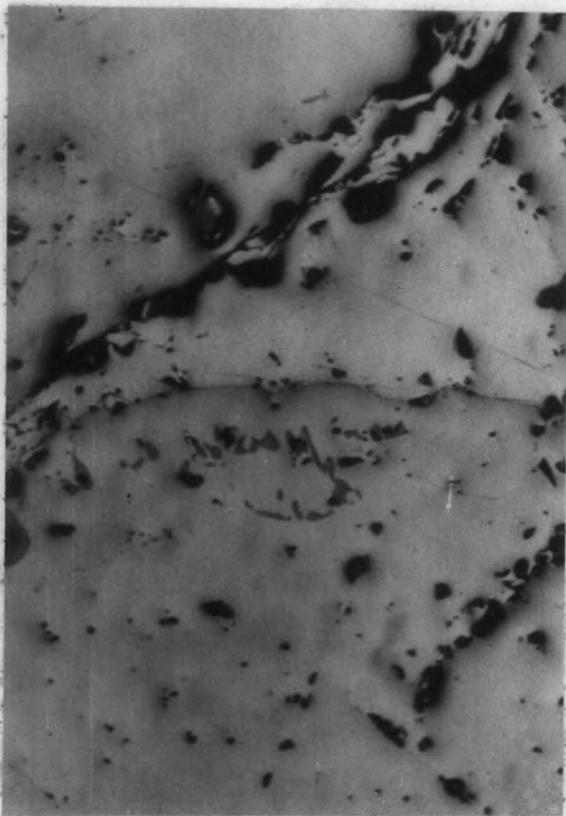
C

D

Figure 7-3 A. Pyrrhotite deformation lamellae. Partly
crossed polars. East Mine. (X 200)

B. Deformation twin lamellae in chalcopyrite.
Specimen etched with chromic acid. Partly crossed
polars. East Mine. (X 200)

C. Inversion twin lamellae in chalcopyrite.
The light grey mineral is pyrite. Chalcopyrite
etched with chromic acid. Uncrossed polars. East
Mine. (X 170)

D. Chalcopyrite pressures fringes around
pyrite. East Mine. (X 200)

Figure 7-4 A. Granular chalcopyrite and pyrite.
Specimen etched for a short time in chromic acid.
Note twinned chalcopyrite near top of photograph.
East Mine. (X 20)

B. Chalcopyrite with two generations of
pyrite. Note corroded appearance of earlier (?)
pyrite. East Mine. (X 20)

C and D. Lineated chalcopyrite. Normal (C)
and parallel (D) to the lineation. East Mine.
(C - X 50, D - X 20)

A
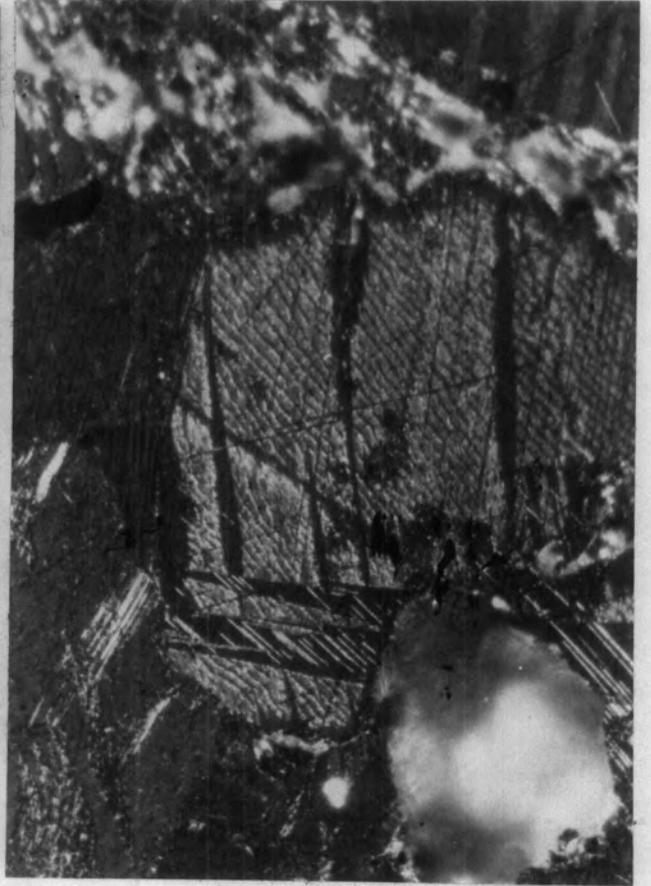
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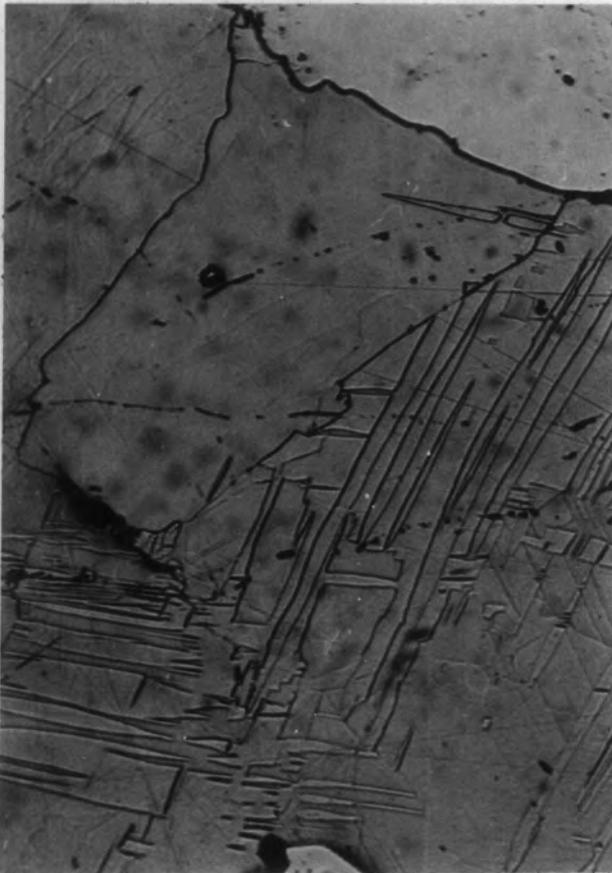
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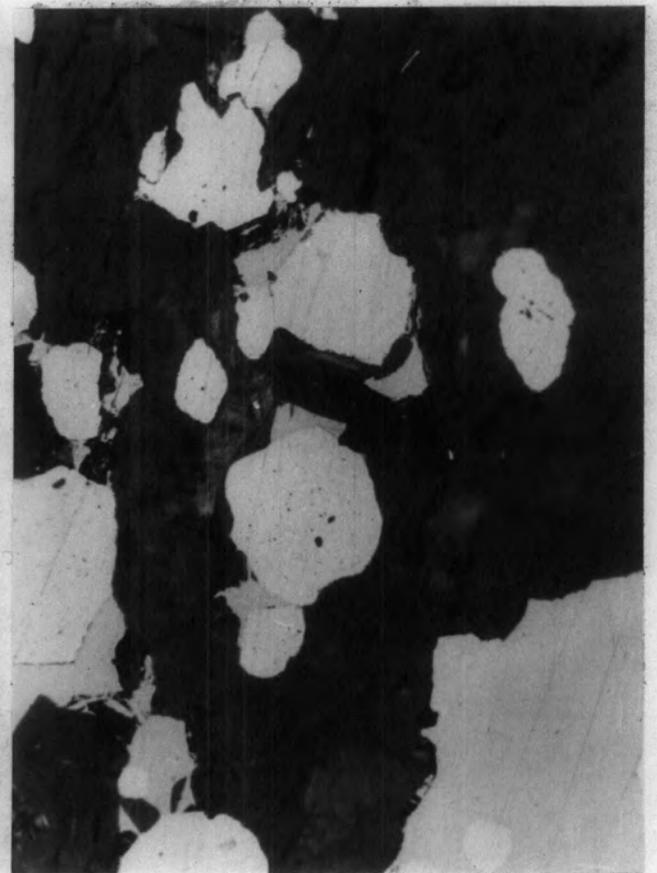
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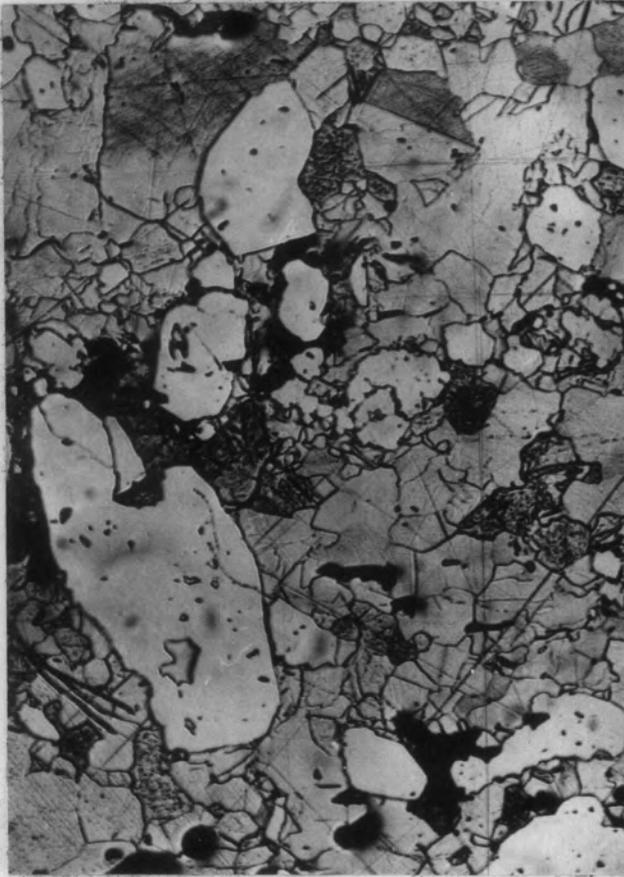
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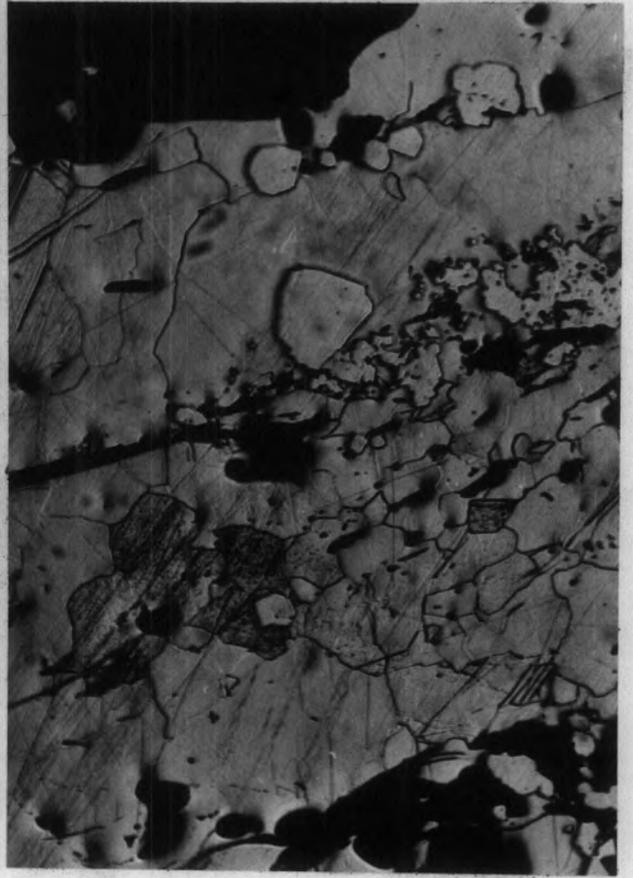
B

C

D

Figure 7-5 A. Cubanite laths in chalcopyrite. East

Mine. (X 50)

B. Cubanite laths, sphalerite star and

mackinawite exsolved from chalcopyrite. Mackina-

wite (white), sphalerite (dark grey) and cubanite

(medium grey). East Mine. (X 50)

C. Mackinawite exsolutions in chalcopyrite.

Mackinawite laths are disrupted by deformation

twinning (barely discernable) in the chalcopyrite.

(X 50)

Figure 7-6 A. Zoned pyrite porphyroblasts. Etched

with chromic acid. East Mine. (X 20)

B. Fractured pyrite porphyroblast. East

Mine. (X 16)

C. Fractured pyrite prophyroblast enclosing

grains of an earlier pyrite. The two light grey

inclusions are pyrrhotite. East Mine. (X 20)

D. Euhedral pyrite in chalcopyrite partly

replaced by pyrrhotite. East Mine. (X 20)
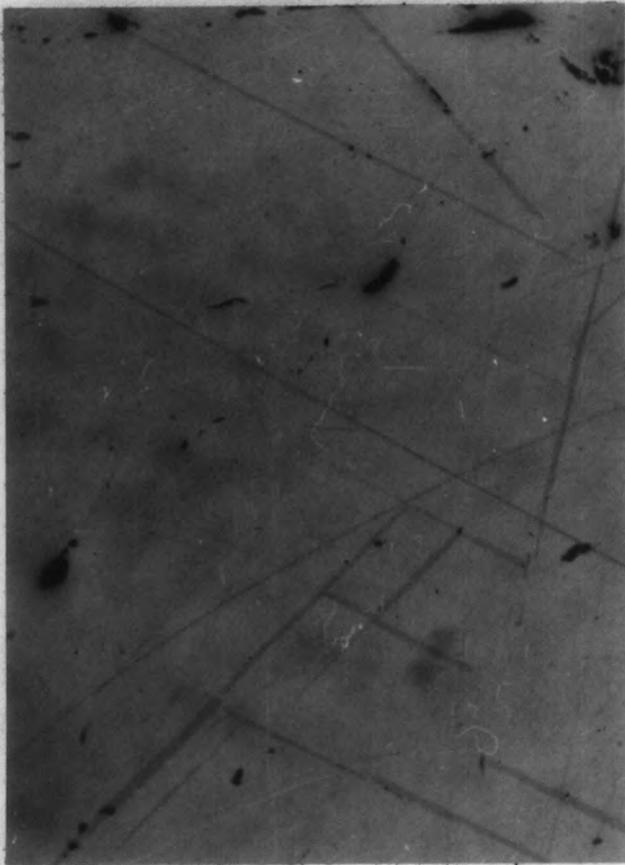
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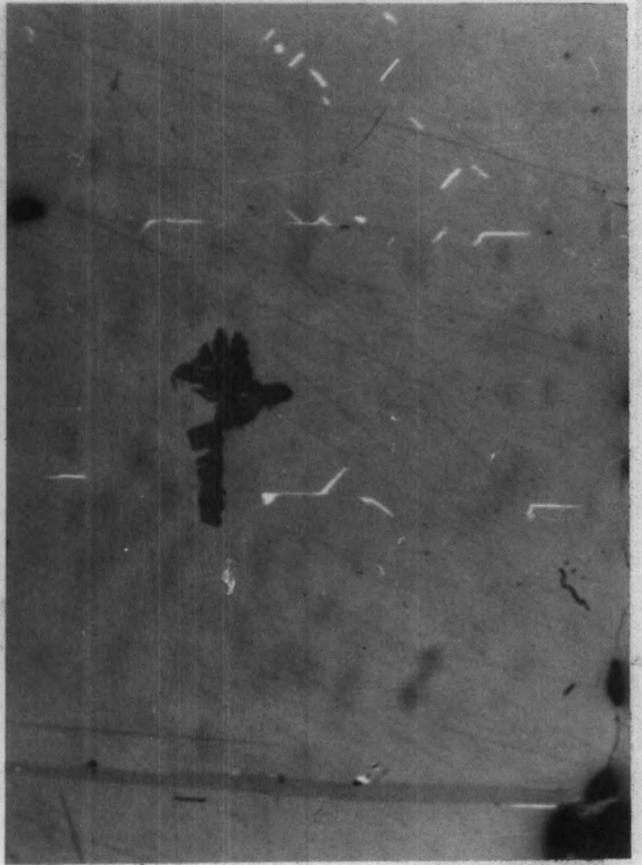
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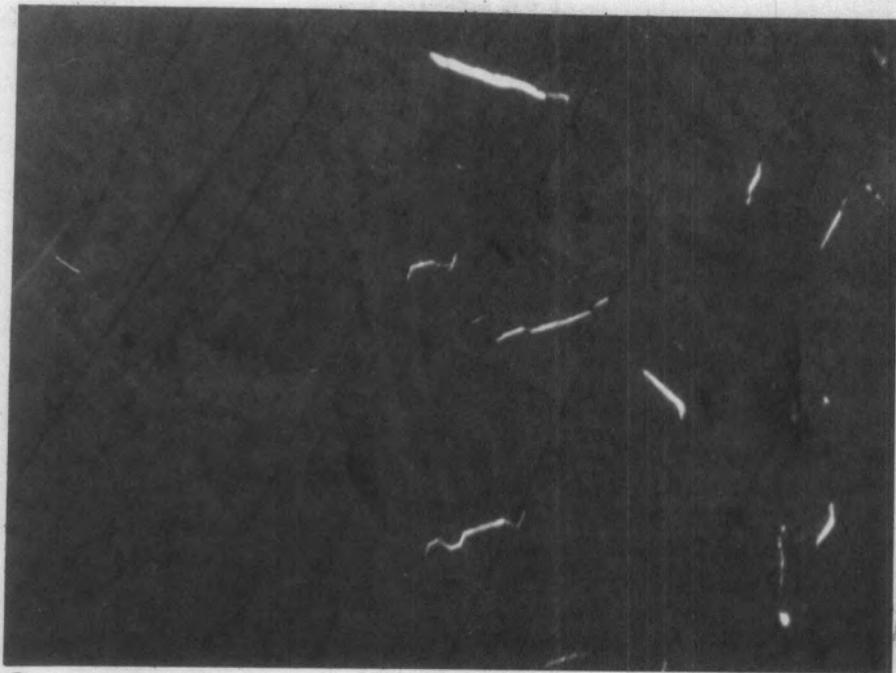
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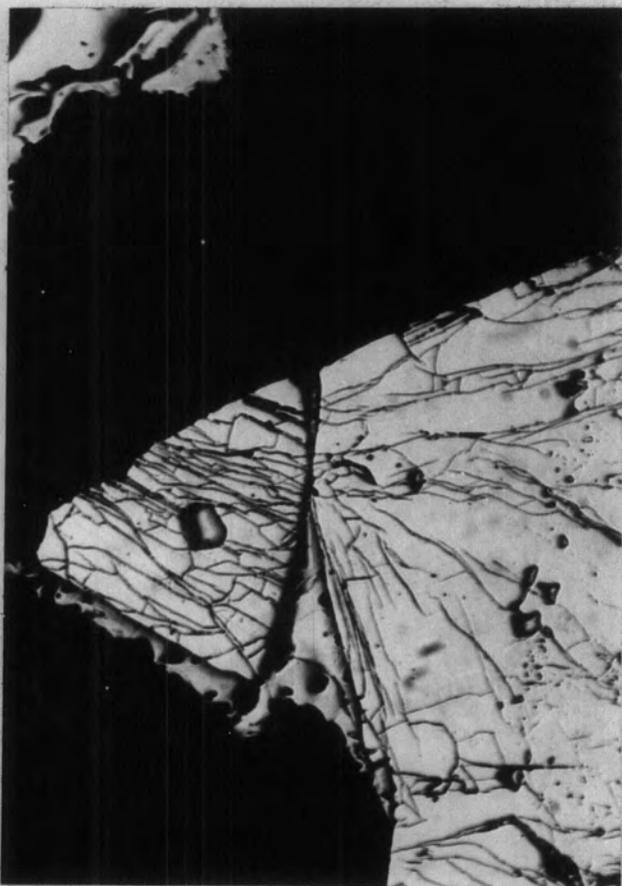
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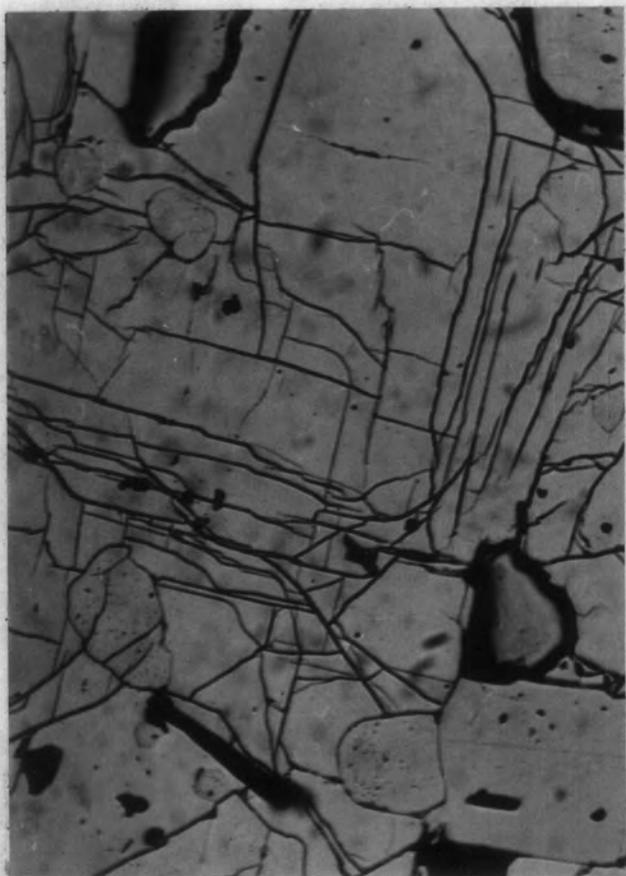
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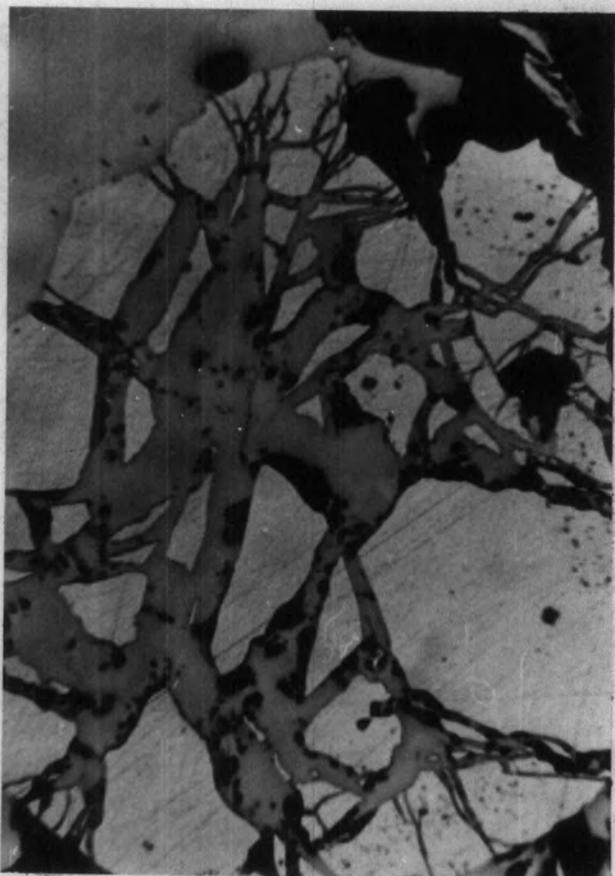
D

Figure 7-7 A.   Skeletal pyrite surrounded by chal-

copyrite and almost completely replaced by

pyrrhotite. East Mine. (X 80)

B.   Euhedral pyrite in chalcopyrite

replaced by pyrrhotite. East Mine. (X 80)

C.   Pyrite enclosing or being replaced by

pyrrhotite. East Mine. (X 80)

D.   Pyrite porphyroblast enclosing or

being replaced by chalcopyrite. Etched with

chromic acid. Note poikiloblastically enclosed

silicate (black). East Mine. (X 50)

Figure 7-8 A.   Quartz gangue in a sulfide vein.

Black mineral is sulfide. Crossed polars.

(X 50)

B, D and E. Primary fluid inclusions in

quartz. East Mine. (B - X 200, D - X 500,

E - X 300)

C and F. Pseudosecondary and secondary

inclusions in quartz. Note apparent necking-

down of the two largest inclusions in the center

of C. East Mine. (C - X 300, F - X 200)
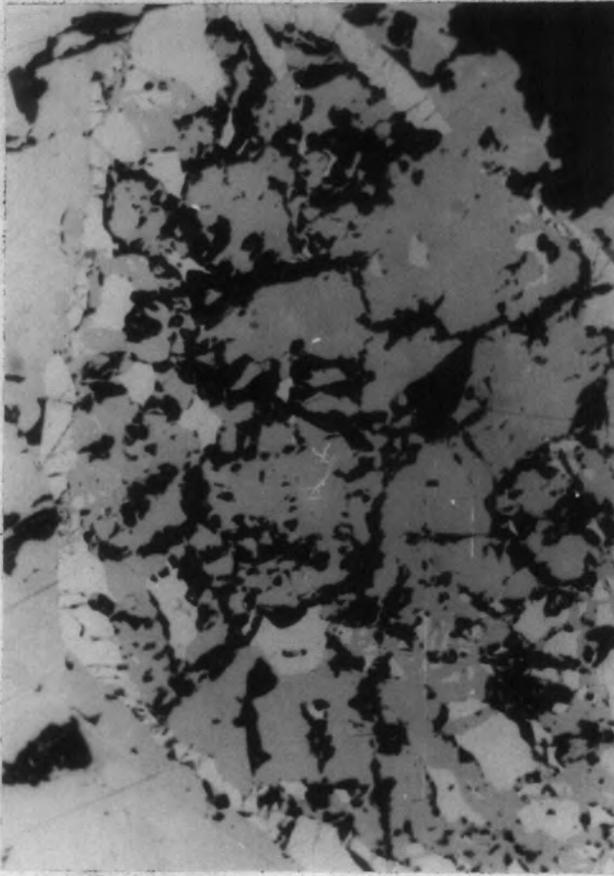
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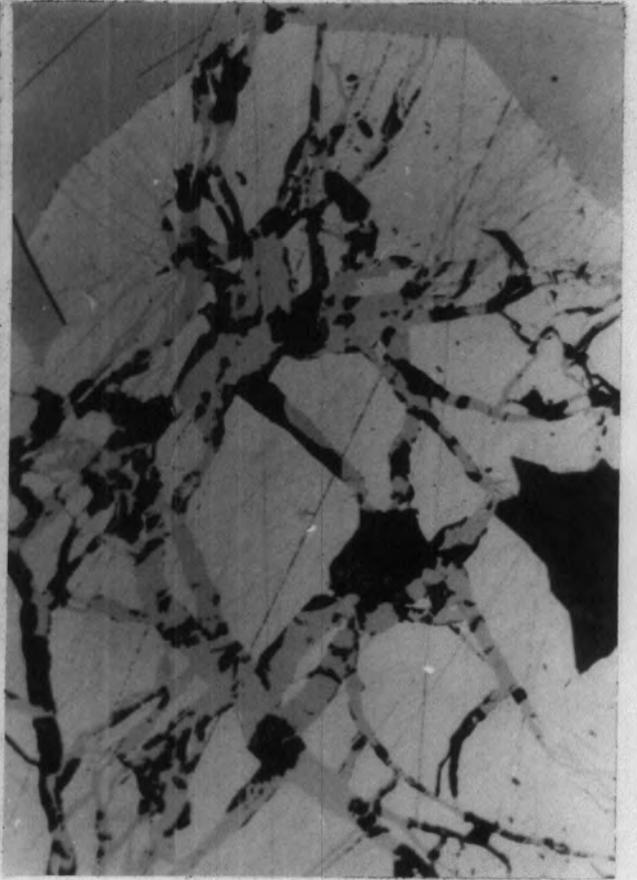
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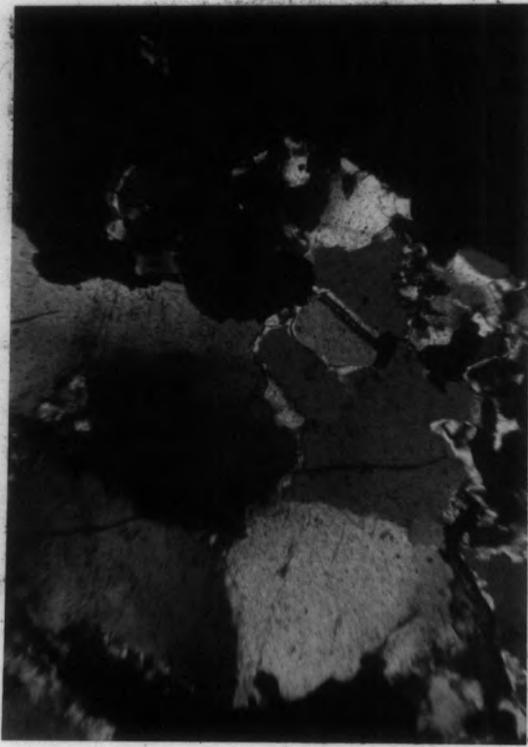
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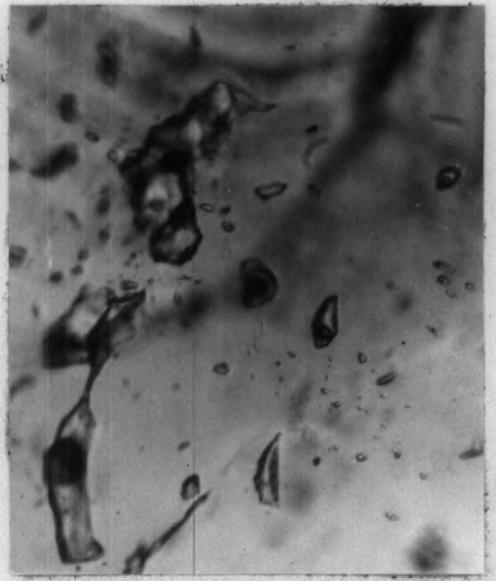
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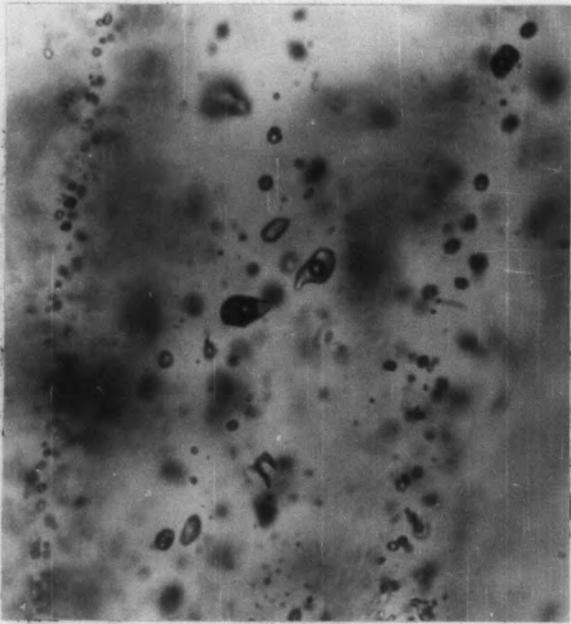
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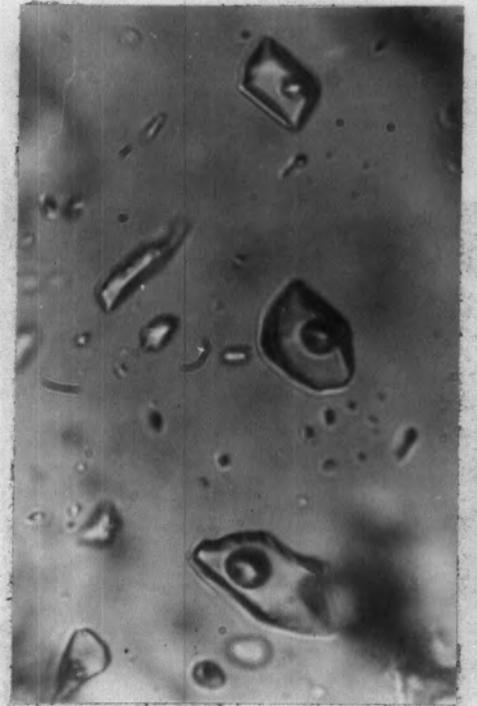
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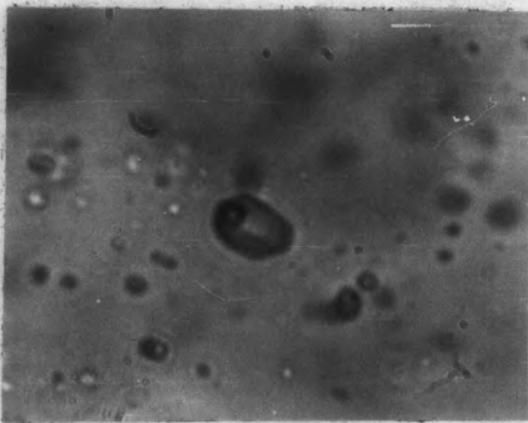
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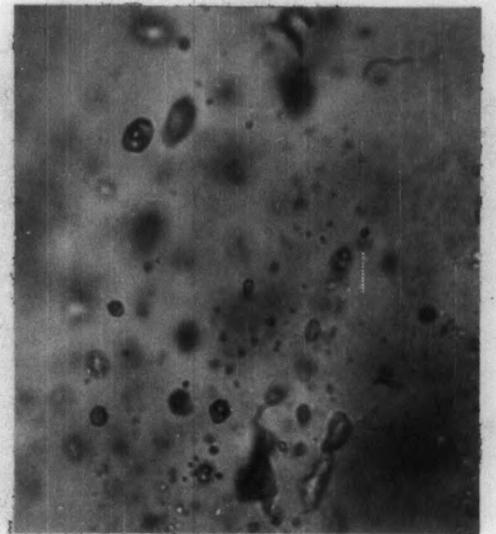
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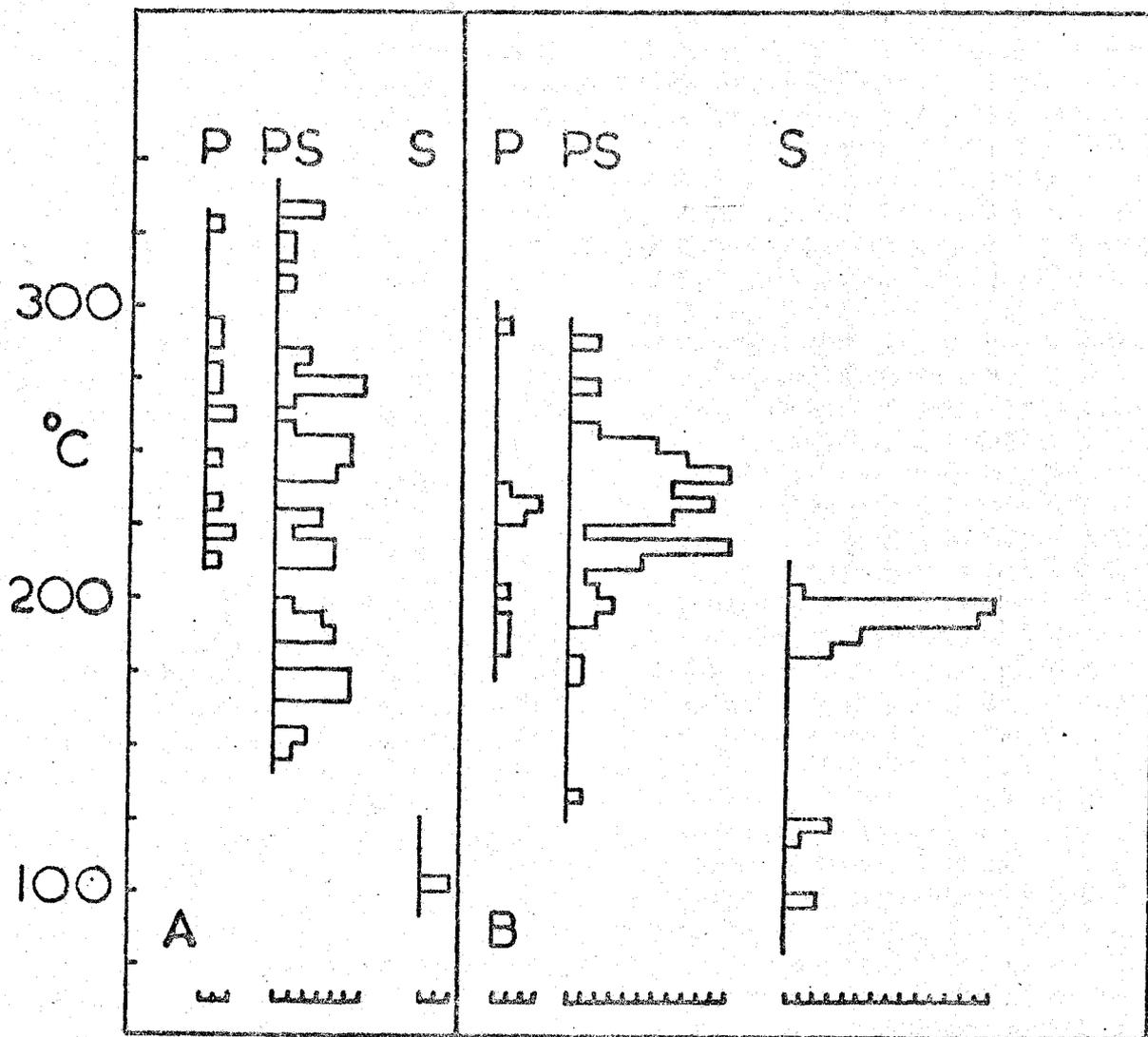
Figure 7-9. Histogram of fluid inclusions filling-temperatures.
One scale unit represents one determination. P-primary, PS-
pseudosecondary, and S-secondary. A. Filling-temperatures of
liquid-gas inclusions in quartz gangue of sulfide veins.
B. Filling-temperatures of liquid-gas inclusions in quartz
veins.

CHAPTER ·VIII

GEOCHEMISTRY OF THE EAST MINE ORE ZONE

Four diamond drill holes were sampled in order to provide
three representative profiles through the East Mine ore body.
Major and trace element analyses were performed on a total of
120 samples. The results of these analyses are presented as
Appendix D.

Diamond drill hole (DDH) 500-23, drilled on the 500 Level
of the mine, provides a profile through the pyritic upper part
of the ore body.

Diamond drill holes 750-21 and 750-22 provide a continuous
profile through the central part of the ore body.

Diamond drill hole 61, which intersected the ore body at
approximately the 1000 Level, was sampled continuously only where
it contained visible chalcopyrite mineralization and thus the
samples analysed do not provide a continuous profile through the
ore body.

The main aims of analysing samples from the ore zone were to
determine whether major or trace element halos existed around the
mineralized zone and to determine if it were possible to deduce
whether the deposits had been formed by the addition of material
to the original host rock or whether the deposit had formed by
the selective replacement of constituents in the host rock by the
method outlined by Croxford (1965) and Stanton (1966).

A. Halos

No trace element or major element halo was found with the
exception of the Cu and S, surrounding the mineralized zones or
the ore body itself.

Although no Ca halo could be established, it is noted that
the CaO content of the ore zone samples is much lower than the
CaO content of basic lavas and pyroclastic rocks of the Rambler
area. It is not possible to determine at this time whether the
low CaO values (see Tables 8-1, 8-2 and 8-3) are due to original
conditions of deposition or whether they are due to alteration -
leaching of the original sediment by the mineralizing fluids.

The absence of trace element halos around the mineralization
could be due to either the destruction or the obliteration of
any existing halos by metamorphism and deformation or it could be
a reflection of the mineralizing process, i.e. the ore did not
form by a replacement process.

B. Geochemistry of the ore zone

According to the arguments of Croxford (1965) and Stanton
(1966) it is theoretically possible to distinguish between sulfide
deposits formed by replacement of the host rock and those formed
by addition of sulfides to the host rock.

In brief, the theoretical basis of the method is: (1) "If
a given stratiform ore were deposited by the replacement of
sedimentary or metasedimentary materials the process involved
was one of substitution" (Stanton, 1966, p.B75). This process
is generally considered to be selective in that one or more
minerals in the rock are preferentially replaced and increases
in the sulfide content of the rock should reflect a corresponding
decrease in the constituents being replaced; and (2) if the
sulfides were added to the rocks at the time of deposition then
the increase in the sulfide content should not be accompanied by
a corresponding decrease in the proportion of the other rock
constituents (Stanton, 1966).

If the ores were formed by a replacement process then

ORE = SEDIMENT (variable) + SULFIDE (variable)

on the other hand if the ore were formed by addition of sulfide

to sediments during deposition of the sediments then the system

can be considered to be one of

ORE = SEDIMENT (constant) + SULFIDE (variable)

George (1969b) in applying the technique to the study of

the Nairne pyrite deposits in Australia was able to show that

the geochemical data favoured a sedimentary rather than a re-

placement origin for the deposit.

The procedure outlined by Stanton (1966) was followed and

the analyses were divided into units on the basis of their sulfur

and chalcopyrite contents.

After omission of the analyses of dike rocks the mean

chemical analyses of each unit are plotted in Figure 8-1 in

terms of the coordinates SiO_2 - (Al_2O_3 + S + Cpy) - (MgO + CaO +

Na_2O + K_2O). With decreasing S+Cpy the analyses from drill holes

750-21, 750-22 and 61 trace out a path ending in the most sulfide

deficient samples. When the analyses are recalculated on a

sulfide-free basis and plotted as SiO_2 - Al_2O_3 - (MgO + CaO +

Na_2O + K_2O) the mean analyses plot in a very restricted field.

The samples from drill hole 500-23 do not show a similar

path with decreasing S+Cpy and there is a wide scatter of points

in both the sulfide-bearing and the sulfide-free plots.

According to Croxford (1965) and Stanton (1966) the analyses

from drill holes 750-21, 750-22 and 61 favour a sedimentary rather

than a selective replacement hypothesis for the formation of the

sulfide deposit. On the other hand the wide scattering of the

analyses from drill hole 500-23 could be interpreted as favouring

formation by selective replacement, however, it should be noted that

the number of analyses from drill hole 500-23 is much smaller than

from the other three drill holes.

Although the recalculated sulfide free analyses for drill

hole 500-23 can be interpreted as evidence of selective re-

placement it should be noted that the ratio of Al_2O_3 to SiO_2

is the same for all four of the mean analyses. This could

reflect merely a change in the original composition of the host

rock rather than selective replacement of an originally

homogenous host rock.

Table 8-1 Mean ore analyses used in constructing Figure 8-1A.

Diamond drill holes 750-21 and 750-22

	1	2	3	4	5
SiO_2	60.88	58.92	58.10	52.43	43.45
Al_2O_3	13.13	11.99	10.67	9.50	8.37
Fe_2O_3	15.88	15.78	14.88	15.57	21.22
MgO	6.18	5.55	4.28	3.74	3.03
CaO	1.23	1.21	0.47	1.00	0.72
Na_2O	0.62	0.64	0.63	1.35	1.26
K_2O	0.15	0.25	0.61	0.44	0.43
TiO_2	0.21	0.28	0.18	0.22	0.15
MnO	0.16	0.12	0.08	0.07	0.07
S	1.50	3.19	5.23	6.66	12.28
P_2O_5	0.00	0.00	0.00	0.00	0.00
Cpy	0.71	3.53	7.36	12.33	15.16
O=S	0.71	1.51	2.54	3.33	6.17
Ba	30	38	11	19	33
Nb	2	4	1	4	3
Zr	35	39	20	34	19
Y	5	4	2	4	2
Sr	23	12	1	14	20
Rb	2	4	1	5	7
Zn	97	265	907	715	480
Ni	107	103	64	56	48
No. of analyses	16	16 ·	4	2	2
Range of S+Cpy	0-5%	5-10%	10-15%	15-20%	20-30%

Table 8-2 Mean ore analyses used in constructing Figure 8-1B.

Diamond drill hole 61

	1	2	3	4
SiO_2	60.93	61.60	60.89	57.54
Al_2O_3	13.93	12.34	11.34	11.03
Fe_2O_3	11.1	16.76	17.04	17.01
MgO	7.32	5.35	6.05	6.06
CaO	4.06	1.75	1.36	1.89
Na_2O	1.92	0.90	0.14	0.18
K_2O	0.19	0.08	0.19	0.17
TiO_2	0.14	0.20	0.23	0.22
MnO	0.16	0.16	0.14	0.13
S	0.15	1.00	1.89	2.51
P_2O_5	0.01	0.00	0.00	0.00
Cpy	0.03	0.28	1.47	4.39
O=S	0.07	0.48	0.89	1.18
Ba	16	9	28	24
Nb	4	3	3	3
Zr	37	34	31	27
Y	5	4	3	4
Sr	64	22	15	11
Rb	3	2	4	3
Zn	--	95	123	100
Ni	--	124	159	170
No. of analyses	6	27	11	5
Range of S+Cpy	**	0-2.5%	2.5-5%	5-10%

** Samples collected outside the mineralized zone in the
   hanging wall of the East Mine.

- not determined.

Table 8-3 Mean ore analyses used in constructing Figure 8-1C.

Diamond drill hole 500-23

	1	2	3	4
SiO_2	54.88	55.65	59.49	49.56
Al_2O_3	14.62	13.47	11.43	10.70
Fe_2O_3	11.72	12.56	12.98	17.98
MgO	12.52	9.24	3.51	6.25
CaO	2.13	1.26	2.28	0.41
Na_2O	0.13	0.57	0.25	0.24
K_2O	1.29	1.35	2.56	1.22
TiO_2	0.19	0.28	0.14	0.14
MnO	0.10	0.06	0.04	0.05
S	2.83	5.37	9.73	13.01
P_2O_5	0.02	0.04	0.09	0.01
Cpy	0.88	2.73	2.15	6.76
O=S	1.36	2.61	4.68	6.36
Ba	85	145	248	133
Nb	3	3	3	3
Zr	40	32	17	18
Y	6	5	3	4
Sr	29	33	11	16
Rb	9	13	21	10
Zn	386	125	113	114
Ni	35	42	18	24
No. of analyses	5	4	2	2
Range of S+Cpy	0-5%	5-10%	10-15%	15-20%
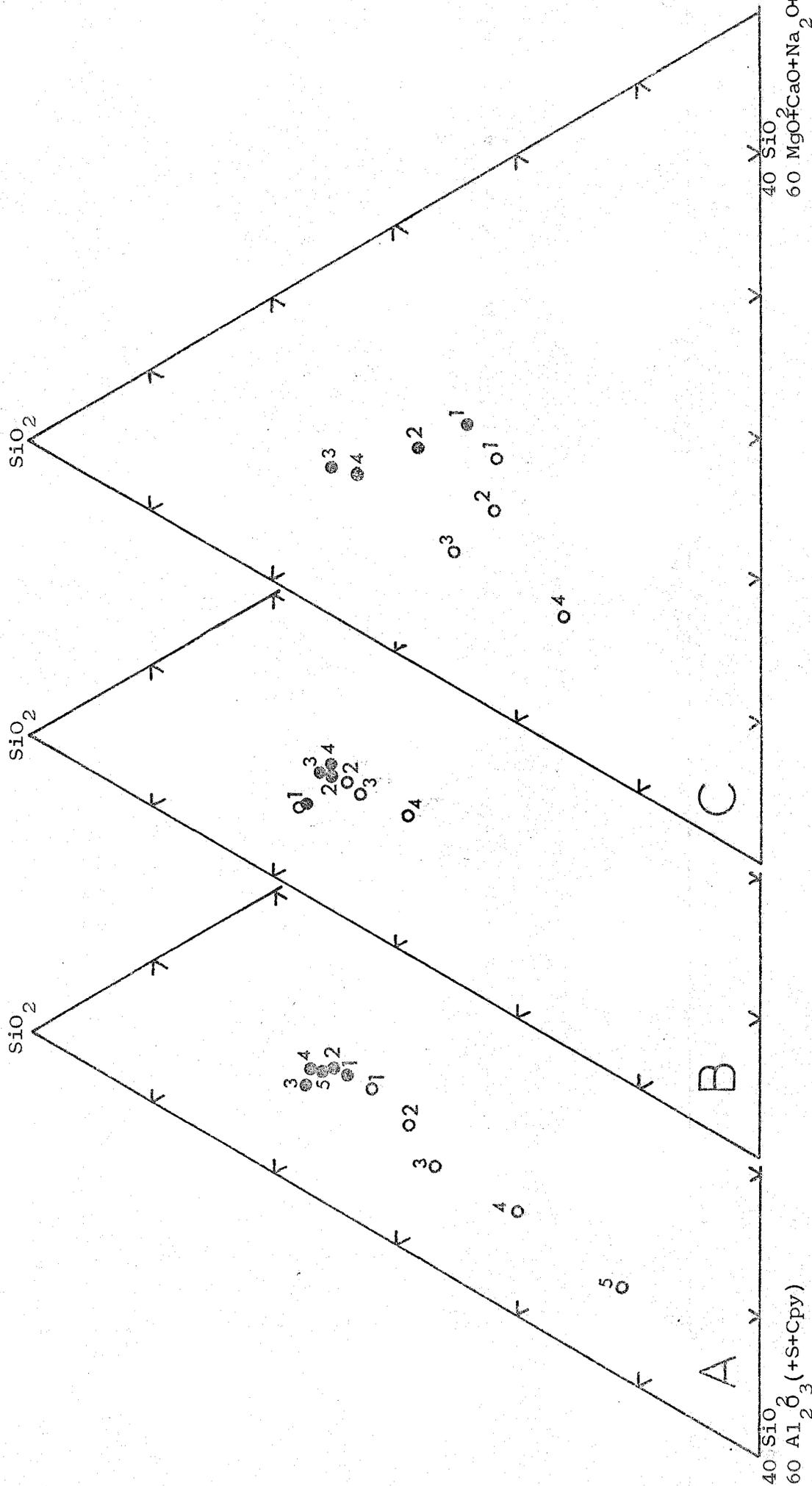
Figure 8-1   Ternary diagram comparing chemical composition of ore zone samples on a sulfide bearing and a sulfide free basis. A. Drill holes 750-21 and 750-22. B. Drill hole 61. C. Drill hole 500-23.   Solid symbols are sulfide free compositions. Numbers refer to Tables 8-1, 8-2 and 8-3.

CHAPTER IX

GENESIS OF THE ORE DEPOSITS

General features of the country rocks and sulfide deposits of the Rambler area noted during the present investigation which are considered to be pertinent to a discussion of the origin of the mineralization are:

(1) The mineral deposits are found in stratiform volcanic sediments associated with submarine volcanism.

(2) The ore deposits were deformed along with the host rocks during the first deformational event recorded in the Rambler area.

(3) Metamorphic events affecting the Rambler area have also affected the sulfide deposits and have resulted in mobilization of some of the sulfides.

(4) There is no evidence of a chemical or mineralogical alteration envelope around the sulfide deposits.

(5) The sulfide deposits of the East Mine may have formed by addition of sulfides to the host rocks rather than by selective replacement of the host rocks.

All of the presently known sulfide deposits in the Rambler area occur in stratiform volcanic sediments which consist of clastic sedimentary and tuffaceous rocks. The volcanic sediments are associated with pillow lavas and agglomeratic rocks

The association of ultramafic pillow lavas (komatiites), ocean floor tholeiitic basalts, quartz-albite porphyritic lavas and chert-like sedimentary units plus the presence of low

potassium doleritic dikes intruding the above mentioned rocks

indicates a geological environment similar to that of the

Troodos ophiolite complex of Cyprus, which has been described

as a remnant oceanic floor (Gass, 1968); Moores and Vine (1971).

Thus it can be determined that the Rambler area sulfide

deposits have either deposited in volcanic sediments on the

floor of the ocean or else they have been emplaced into ocean

floor volcanic sediments prior to or after consolidation.

The best known sulfide deposits of the Rambler area, the

Rambler Mine and the East Mine deposits, appear to have

hanging walls which are stratigraphic units. The hanging wall

of the Rambler Mine is a quartzitic unit which grades into a

'magnetite-tuff' horizon. The East Mine hanging wall is a

tuffaceous acidic horizon.

The presence of elongated sulfide minerals and elongated

sulfide blebs with their long axes parallel to the long axes

of the mineral and particle lineations in the host rocks

indicates that the ore bodies were deformed along with the

country rocks during the first deformational event which pro-

duced the lineations.

It could be argued that the lineated sulfides owe their

linear structure to the post-deformation replacement of

lineated silicates. A replacement origin for these sulfides

is not consistent with the absence of replacement textures in

both the silicates and the sulfides. Furthermore, the lineated

sulfide blebs in the East Mine ore zone are not interconnected

and show no evidence of 'channelways' linking individual sulfide

blebs which should be present if the sulfide blebs formed by

a replacement process.

The presence of lineated silicate minerals, namely chlorite and sericite, wrapped around disseminated pyrite grains indicate that some of the sulfides were present in the rock prior to the development of lineated silicates. Pressure fringes of silicate and sulfides around pyrite grains indicate formation during deformation in which case the mineral constituents must have been introduced into the rock prior to or at the onset of the deformation. The presence of pyrite grains growing across silicate grains is compatible with a pre-deformation origin for the sulfides since some of the pyrites are porphyroblastic and have recrystallized during a metamorphic event which post dates the first deformation.

The absence of an alteration halo around the sulfide deposits is incompatible with a post deformation replacement origin. Furthermore the gangue minerals of the sulfide deposits are normal constituents of the host rocks.

Further evidence to support a pre deformation origin for the sulfide deposits is the presence in the massive sulfide ore of the Rambler Mine of blocks of the host rock with mineral lineations oriented parallel to mineral lineations in country rock. If the block had been enclosed in the sulfides after development of the mineral lineations it would be reasonable to expect some randomly oriented blocks.

Triple point grain junctions and porphyroblastic pyrite crystals are indicative of growth and recrystallization of pyrite in response to a metamorphic event. The exsolution of other mineral species from chalcopyrite is evidence to support

a slow cooling history which is compatible with regional
metamorphism. In addition relatively coarse grained sulfides
are more characteristic of strongly metamorphosed sulfide
deposits than weakly metamorphosed deposits (for examples see
Vokes, 1968).

Recognition of the presence of the sulfides in their host
rocks prior to the first deformation necessitates the recognit-
ion that the sulfides were metamorphosed during the upper
greenschist metamorphism (quartz-albite-epidote-almandine sub-
facies) which accompanied that deformational event and also
during subsequent metamorphic events.

The second metamorphic event recognized in the Rambler area
certainly post dates the mineralization since biotites
poikiloblastically enclosing pyrite are found in the ore zone
of the East Mine.

One of the features of the Rambler area mineralization which
could favour a post first deformation mineralization is the
presence of undeformed sulfide veins cutting across the sulfide
deposits. Although pyrite veins are present in the sulfide
deposits the majority of the veins consist mainly of chalco-
pyrite and pyrrhotite. Sphalerite veins are unknown however
their presence cannot be ruled out due to the lack of detailed
information on the Rambler Mine.

Chalcopyrite and pyrrhotite are very mobile sulfides and
their presence as veins cutting across sulfide deposits and
as remobilized masses adjacent to metamorphosed sulfide
deposits has been well documented (McDonald, 1967; George, 1969a;
Waltham, 1968a; and others).

Although the fractures which the sulfides fill could not be related to any definite structural event in the Rambler area their contained minerals are the main constituents of the sulfide deposits.

Although the geochemical evidence is not conclusive it does appear to substantiate the hypothesis that the East Mine ore body formed by additive rather than replacement processes. The geochemical data does show the absence of a geochemical alteration envelope around the East Mine ore body which further substantiates the petrographic observations.

Since it has been established that the ore deposits were formed before the main deformational and metamorphic events affecting the Rambler area, and it is nearly impossible to determine the pre metamorphic history of this type of mineral deposit, the question of genesis has been limited to a consideration of whether the ore deposits were formed by an 'epigenetic' process involving addition to an already consolidated rock or by a 'syngenetic' process involving formation at the same time as the host rocks.

Factors favouring an 'epigenetic' process are:

(1) the presence of undeformed sulfide veins post dating the formation of the main silicate rock fabric;

(2) the elongated pipe-like shape of the ore bodies which parallel the long axis of the first deformation ellipsoid and could conceivably represent emplacement of the sulfides along a linear structure, such as a fold crest.

The first of these factors has already been discounted as evidence of introduced mineralization since the veins could

have formed by selective mobilization of constituents of the

ore zones in response to metamorphism and (?) deformation.

The second factor is difficult to evaluate due to the scarcity

of data on the lateral extension of the ore bearing horizons.

Factors which can be interpreted as favouring a 'syngenetic'

mode of deposition are:

(1) the ore deposits are stratigraphically conformable to

their enclosing host rocks;

(2) the absence of an envelope of alteration surrounding

the ore zones;

(3) the possible formation of the ore deposits by

addition of sulfides to the stratiform volcanic sediments;

(4) all of the presently known sulfide deposits are

located within stratiform volcanic sediments - although it

cannot yet be conclusively shown that these belong to one

stratigraphic horizon.

(5) the disseminated chalcopyrite-pyrrhotite ore of the

East Mine appears to be located in several traceable strati-

graphic units.

Since the bulk of the evidence gathered in this investi-

gation appears to favour a 'syngenetic' origin for the

sulfide deposits it is possible to speculate briefly on the

mode of deposition.

It is possible that the Rambler deposits formed by

exhalation of metal carrying brines into unconsolidated

sediments on the ocean floor by a process analogous to the

present day formation of the Red Sea sulfide deposits by pre-

cipitation from geothermal brines (Bischoff, 1969). The

average metal assays of 29 percent Fe, 3.4 percent Zn, 1.3

percent Cu, 0.1 percent Pb and 54 ppm Ag (Bischoff and Manheim,

1969) are sufficient to produce an economically viable metal

deposit even without further concentration by diagenetic and

metamorphic processes.

In view of the similarity of the geological environments

of the Rambler area and Cyprus it is tempting to suggest that

the Rambler deposits have,like the Cyprus deposits, formed on

the ocean floor or in unconsolidated sediments on the ocean

floor by volcanic exhalations (Kinkel, 1966).

One of the interesting features of the Cyprus deposits is

the occurrence of a number of ore deposits, both massive and

disseminated sulfide deposits, near the upper parts of the

pillow lava sequence. An examination of the geological map

(Plate I) of the Rambler area reveals that the main known

sulfide deposits (the Rambler Mine, the East Mine, the Big

Rambler Pond deposit and the new prospect) are all found in

stratiform volcanic sediments around the edges of the main mass

of ultramafic pillow lavas. Although the present knowledge of

the geology of the area does not warrant the assignment of the

stratiform volcanic sediments in which the sulfide deposits are

found to one stratigraphic unit, it is possible that such a

relationship does exist and may possibly become apparent as a

result of future geological mapping and research in the area. The

definite recognition of the restriction of sulfide deposits to

particular stratigraphic unit(s) will greatly facilitate the

search for hidden deposits.

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APPENDIX   A

Analytical Methods

Preparation and analysis of rocks and ores.

Hand specimens of rock samples selected for analysis were cleaned of all foreign material including weathered surfaces prior to crushing to less than one-half inch sized pieces in a jaw crusher. The crushed sample was quartered and approximately 100 grams of the crushed sample were placed in a swing mill for 3 to 5 minutes until the resultant powder began to adhere to the walls of the mill.

Ore samples were selected from split diamond drill cores and where possible from powders remaining from the mine assay samples. Samples usually consist of continuous 5 foot sections of the split core. The drill cores were crushed and ground in the same manner as the rock samples. The mine assay samples were all reground in the swing mill to ensure a constant powder size for all samples.

Neat briquettes were prepared from the rock and ore powder by mixing the powder with 4 drops of 2 percent solution of Mowioil and compressing under a pressure of 6 tons for 5 minutes (Holland and Brindle, 1966). The briquettes were allowed to dry for several days prior to analysing by an automatic Phillips 1212 X-ray fluorescence spectrophotometer (XRF).

Instrumental drift was corrected by means of a control standard (monitor) and a fixed number of counts.

Errors arising from absorption-enhancement effects were corrected by means of a mass absorption correction program (see Reeves, 1971).

The international rock standards W-1, GSP-1, T-1, BR,
AGU-1, BCR-1 and G-1 were used to establish calibration curves
for the elements Si, Al, Fe, Mg, Ca, Na, K, Ti, Mn and P.
Standards for sulfur and copper analyses were prepared by
mixing various proportions of the international rock standards
with chalcopyrite and pyrite which had been analysed for
sulfur by wet chemical methods and for copper by an atomic
absorption spectrophotometer.

Trace element analyses were performed on the same neat
briquettes used for the major element determinations.

Calibration curves for trace element analyses were
established using a series of standard powders spiked with the
trace elements Cr, Ni, Cu, Zn, Rb, Sr, Y, Zr, Nb and Ba. The
matrix material had a composition close to that of the average
lunar basalt (Brown et al, 1970).

The mean neutron activation analyses for the U.S.G.S.
international standards were used to determine a calibration
curve for Lanthanum.

The background scatter was used as a variable internal
standard (Andermann and Kemp, 1958) and the concentration of
the elements were determined by referring the peak to back-
ground ratios of the unknowns to the calibration curves.

The detection limits of the trace elements are:-

Element	ppm	Element	ppm
Ba	9	Rb	3
Nb	2	Zn	1
Zr	3	Cu	2
Y	3	Ni	1
Sr	3	La	2

For Cu as a major element the detection limit was 50 ppm.

Electron Microprobe analysis.

The Cambridge Instruments Co., Geoscan Mark 2 probe was operated at 12 Kv when analysing Na and K, the other elements were analysed at 15 Kv with the exception of Ca in feldspar which was analysed at 12 Kv. Polished thin sections and polished sections were carbon coated at the same time as the pure element, oxide and sulfide standards. The computerized correction procedures of Rucklidge and Gasparrini (1969) and Boyd et al (1969) were used.

Recalculation of Amphibole analyses.

A computer program written by R. Phillips (Department of Geology, Durham University) was used to recalculate the electron microprobe analyses into the standard unit formulae of Phillips and Layton (1964). Since H_2O was not determined a value of 2.00 percent H_2O was assumed for purposes of the recalculation on the basis of 24 Oxygen atoms.

APPENDIX B

Preparation and analysis of specimens for
fluid inclusion geothermometry

Specimens of quartz-bearing sulfide veins and vein quartz were prepared for fluid inclusion studies by preparing several doubly polished wafers of rock, 0.1 to 0.5 mm in thickness, from each specimen. These were initially examined by means of an ordinary petrographic microscope in order to identify suitable inclusions for study on the heating stage.

A homemade heating stage mounted on a Leitz heating stage microscope fitted with UM 20/0.33 and H 32/0.60 objectives and a 10X ocular was used to determine the filling temperatures of liquid-gas inclusions. Temperatures were measured with a cromel-alumel thermocouple which was connected via a melting ice cold junction to a Phillips chart recorder. The specimen being studied was placed so that it touched the thermocouple while the inclusions under observation were approximately 2 mm away from the thermocouple itself.

The thermocouple was calibrated by observing organic compounds of known melting points which had been sealed into short pieces of capillary tubing. The tube being heated was placed in approximately the same position as inclusions under investigation so as to obtain as near identical conditions as possible. Frequent checks against the melting point of Analar p-nitro analine (M.P. $147.5^{o}C$) showed that the accuracy of measurement ($\overset{+}{-}$ $2^{o}C$) was comparable to that obtained by Sawkins (1966) on the same equipment.

The liquid-gas inclusions being investigated were observed with the microscope as the temperature was increased at a rate of $10-15^{o}C$ per minute. When the inclusions showed signs of approaching homogenization the heating rate was reduced to

minimise thermal gradients within the specimen chamber of the

heating stage. The temperature at which the inclusion was

completely homogenized was recorded. If the end point of

homogenization was in doubt, due to movement of the gas

phase into a part of the inclusion with high internal

reflection, the temperature at which the bubble was last

discernible was recorded as a minimum temperature provided

the inclusion appeared to be very close to homogenization.

After homogenization all inclusions were examined upon cooling

for evidence of leakage. Duplicate runs were made on many

of the inclusions and the filling temperatures obtained were

discarded if they could not be duplicated to within $\pm$ 10°C.

APPENDIX   C

Chemical Analyses of Country Rocks

Detection limits of trace elements

Element	ppm	Element	ppm
Ba	9	Rb	3
Nb	2	Zn	1
Zr	3	Cu	2
Y	3	Ni	1
Sr	3	La	2

SI = Solidification Index

= $MgO \times 100/Fe_2O_3$ (total Fe) + MgO + Na_2O + K_2O

Rock Type refers to Plate I

- Not determined

	1	2	3	4	5	6	7	8	9	10
	'9796'	'97171B'	'97283'	'97316'	'97319'	'9812'	'9864'	'9983'	'99185'	'99182'
PERCENT										
SIO2	49.20	48.91	50.81	48.25	50.44	49.25	48.81	51.03	49.19	48.11
AL2O3	14.38	13.22	12.36	13.70	13.22	16.34	13.53	12.49	19.83	13.32
FE2O3	10.74	12.98	13.79	11.15	12.44	9.33	13.41	12.18	7.07	12.70
MGO	10.98	9.17	6.88	15.74	10.75	9.54	8.45	11.73	8.69	6.84
CAO	10.55	10.89	9.88	7.81	8.02	11.58	10.06	7.21	10.75	14.68
NA2O	2.42	2.58	3.42	2.27	3.34	1.89	2.92	3.30	2.64	2.01
K2O	0.20	0.19	0.14	0.01	0.01	0.59	0.49	0.01	0.78	0.25
TIO2	1.18	1.49	2.20	0.80	1.35	1.03	1.87	1.62	0.78	1.65
MNO	0.16	0.19	0.21	0.17	0.17	0.15	0.18	0.15	0.16	0.18
S	0.01	0.13	0.04	0.01	0.09	0.14	0.03	0.01	0.05	0.04
P2O5	0.19	0.23	0.26	0.10	0.17	0.06	0.25	0.27	0.08	0.21
PPM										
BA	46	30	32	24	8	78	71	12	68	62
NB	5	6	7	2	7	11	3	1	3	2
ZR	100	152	180	60	115	113	142	120	71	125
Y	18	27	38	13	26	17	31	16	11	28
SR	364	315	192	195	218	319	206	157	427	629
RB	8	7	4	1	1	12	9	1	40	9
ZN	77	92	128	98	104	91	88	94	45	58
CU	28	76	23	33	69	78	45	46	37	101
NI	111	78	33	233	80	130	58	107	114	98
LA	1	5	4	2	3	4	3	14	5	5
SI	45.12	36.80	28.39	53.96	40.50	44.68	33.43	43.10	45.31	31.37
Rock Type	8a	8a	8a	8a	8a	8a	8a	8a	6	7

	11	12	13	14	15	16	17	18	19	20
	'99181'	'10L-19'	'9723'	'9726'	'97102'	'9717'	'971810'	'97225'	'97312'	'9863'
PERCENT										
SIO2	50.84	47.49	49.70	50.13	49.57	48.63	49.28	50.63	51.57	50.63
AL2O3	17.41	14.43	13.71	12.28	12.68	14.76	13.41	12.72	12.44	12.10
FE2O3	6.91	13.03	12.66	12.18	12.65	12.71	12.79	13.01	13.47	13.45
MGO	10.21	11.55	7.32	9.87	5.60	7.20	10.26	7.58	7.42	8.40
CAO	10.00	8.57	12.60	10.00	10.80	10.48	9.46	10.50	9.14	9.90
NA2O	3.19	2.84	2.45	2.59	2.42	3.27	2.46	3.13	3.57	3.21
K2O	1.05	0.01	0.02	0.44	0.01	0.55	0.66	0.30	0.09	0.11
TIO2	0.69	1.56	1.35	1.95	1.71	1.78	1.23	1.53	1.73	1.78
MNO	—	0.17	0.00	0.19	0.20	0.19	0.18	0.20	0.20	0.19
S	0.02	0.14	0.02	0.06	0.01	0.19	0.06	0.19	0.06	0.04
P2O5	0.18	0.23	0.16	0.30	0.34	0.24	0.21	0.20	0.29	0.19
PPM										
BA	—	6	23	98	17	76	86	56	46	35
NB	—	6	4	14	14	6	3	6	5	9
ZR	—	148	99	160	171	175	131	110	146	105
Y	—	23	23	21	19	29	25	27	33	25
SR	—	331	397	232	234	256	329	262	216	214
RB	—	5	3	10	1	12	17	7	2	2
ZN	—	85	69	97	115	89	88	98	125	48
CU	—	86	14	54	1	108	57	84	42	21
NI	—	103	50	118	146	30	97	41	39	46
LA	—	0	4	15	15	7	0	6	10	6
SI	47.79	42.11	32.61	39.36	38.90	30.34	39.22	31.56	30.22	33.39
Rock Type	7	8b	8b	8	8	8	8	8	8	8

	21	22	23	24	25	26	27	28	29	30
	'9866'	'98211'	'982213'	'9944'	'9985'	'10L-2'	'10L-32'	'10L-36'	'R2-33'	'10L-18'
PERCENT										
SIO2	53.02	51.75	50.76	52.71	52.35	46.91	48.14	46.80	46.43	49.87
AL2O3	12.29	13.72	15.58	12.33	13.84	12.47	13.33	11.24	11.56	11.04
FE2O3	12.60	13.12	9.30	12.05	11.09	11.79	12.72	14.26	14.51	15.67
MGO	6.47	7.24	9.40	6.61	8.08	11.62	10.85	8.25	8.16	6.35
CAO	8.71	9.02	10.48	10.11	8.46	10.60	10.99	13.99	14.13	8.06
NA2O	4.32	3.10	3.11	3.91	3.98	2.29	1.62	2.78	2.36	2.10
K2O	0.04	0.09	0.01	0.01	0.01	0.30	0.41	0.22	0.28	3.39
TIO2	2.16	1.57	1.08	1.87	1.82	2.30	1.32	1.85	1.94	2.72
MNO	0.18	0.18	0.14	0.19	0.15	0.24	0.19	0.27	0.22	0.19
S	0.01	0.02	0.01	0.01	0.02	1.28	0.16	0.08	0.15	0.16
P2O5	0.20	0.18	0.12	0.20	0.21	0.22	0.25	0.25	0.25	0.45
PPM										
BA	9	15	29	11	15	49	13	6	–	–
NB	6	4	2	7	7	15	11	9	–	–
ZR	153	129	83	153	166	156	168	115	–	–
Y	36	28	19	33	31	20	26	14	–	–
SR	118	280	260	285	261	134	122	94	–	–
RB	1	3	1	1	1	5	1	1	–	–
ZN	108	85	66	126	79	110	73	72	–	–
CU	1	70	3	1	19	118	10	12	–	–
NI	25	36	87	21	27	40	271	402	–	–
LA	12	8	2	6	6	–	–	–	–	–
SI	27.61	30.74	43.09	29.27	34.89	44.71	42.39	32.32	32.23	23.09
Rock Type	8	8	8b	8	8	8	8b	8	8	–

	31	32	33	34	35	36	37	38	39	40
	'96203'	'96203A'	'96206'	'96232'	'96272'	'972410'	'972411'	'97284'	'97285'	'9988A'
PERCENT										
SIO2	53.13	54.09	50.63	51.15	51.41	55.50	52.42	54.42	53.12	48.59
AL2O3	8.32	11.11	9.86	10.36	9.03	9.11	10.34	9.59	7.84	15.02
FE2O3	11.55	10.28	12.86	11.66	11.24	9.76	9.62	9.16	10.43	11.35
MGO	14.52	12.29	13.31	16.40	15.75	13.87	13.40	13.76	14.25	7.02
CAO	9.78	8.95	10.71	8.82	10.51	9.64	11.64	10.08	12.02	11.80
NA2O	2.21	2.70	1.97	1.79	1.60	1.58	1.97	2.57	1.70	3.95
K2O	0.03	0.17	0.34	0.06	0.04	0.04	0.14	0.04	0.19	0.03
TIO2	0.20	0.18	0.15	0.16	0.14	0.13	0.20	0.15	0.16	1.77
MNO	0.18	0.17	–	–	0.22	0.17	0.19	0.16	0.15	0.19
S	0.01	0.00	0.05	0.00	0.00	0.02	0.00	0.00	0.05	0.04
P2O5	0.06	0.06	0.11	0.10	0.05	0.08	0.08	0.07	0.08	0.24
PPM										
BA	25	65	–	–	26	20	46	15	34	14
NB	1	3	–	–	2	1	3	1	4	3
ZR	11	19	–	–	12	10	17	15	13	166
Y	2	3	–	–	5	4	4	2	3	31
SR	98	129	–	–	95	142	216	155	119	227
RB	3	2	–	–	2	1	4	1	5	1
ZN	73	61	–	–	91	74	65	53	75	90
CU	1	1	–	–	1	97	1	1	1	84
NI	253	150	–	–	257	518	347	302	484	21
LA	0	0	–	–	0	0	0	0	3	6
S.I	51.28	48.31	47.64	54.83	55.01	54.93	53.32	53.90	53.63	31.40
Rock Type	1a	1a	1a	1a	1a	1a	1a	1a	1a	1a

	41	42	43	44	45	46	47	48	49	50
	'5123'	'991816'	'97232'	'97234'	'97249'	'9841'	'98134'	'9841'	'9943'	'96124'
PERCENT										
SIO2	49.23	49.41	50.37	52.14	56.83	57.88	57.44	58.76	58.46	61.70
AL2O3	16.95	14.20	15.23	12.25	11.54	12.76	14.49	15.46	13.18	7.97
FE2O3	11.98	13.23	10.21	9.40	9.34	7.88	8.96	9.46	10.15	8.32
MGO	7.59	8.92	9.35	15.34	10.84	8.17	8.01	4.23	11.83	12.44
CAO	7.71	9.60	9.94	8.41	8.20	7.32	5.35	6.00	3.75	6.54
NA2O	4.01	2.88	2.70	2.29	2.72	4.99	5.29	4.49	2.21	2.65
K2O	0.15	0.09	0.07	0.32	0.14	0.07	0.04	0.97	0.00	0.01
TIO2	1.80	1.49	1.25	0.18	0.20	0.21	0.19	0.30	0.22	0.17
MNO	0.16	0.00	0.16	—	0.12	0.13	0.13	0.12	0.13	0.13
S	0.18	0.04	0.04	0.06	0.00	0.02	0.04	0.15	0.00	0.00
P2O5	0.23	0.14	0.15	0.10	0.07	0.07	0.06	0.06	0.07	0.07
PPM										
BA	11	13	38	—	32	27	9	189	8	9
NB	5	6	5	—	3	7	3	3	3	4
ZR	178	103	115	—	19	33	20	35	37	32
Y	32	25	22	—	3	4	6	8	4	2
SR	242	250	270	—	255	122	75	209	63	101
RB	2	3	4	—	5	1	1	25	1	1
ZN	114	96	73	—	73	60	66	43	111	73
CU	102	10	27	—	91	7	167	65	1	1
NI	45	65	129	—	126	121	56	10	156	116
LA	8	5	5	—	1	0	0	4	5	1
SI	31.98	35.51	43.16	56.07	47.05	38.70	35.92	22.12	48.90	53.09
Rock Type	1a	1a	1b	1b	1b	1	1	1	1	2a

	51	52	53	54	55	56	57	58	59	60
	'96233'	'96252'	'97911'	'97108'	'96258'	'951710'	'97107A'	'99184'	'97175'	'98215'
PERCENT										
SIO_2	53.02	51.13	52.17	50.12	57.41	57.52	54.29	50.38	60.63	46.86
AL_2O_3	8.24	12.49	7.36	7.10	12.29	9.77	13.48	11.58	11.65	16.44
FE_2O_3	10.24	10.84	12.53	8.16	8.63	9.79	10.08	11.62	7.70	11.97
MGO	14.42	16.67	13.13	10.33	8.52	13.89	11.20	13.83	11.73	8.91
CAO	11.39	6.57	12.56	10.67	8.54	5.95	6.97	11.04	5.67	9.86
NA_2O	2.27	1.85	1.58	2.58	3.68	1.68	3.55	1.57	2.03	3.94
K_2O	0.01	0.00	0.04	0.09	0.12	0.00	0.02	0.10	0.10	0.18
TIO_2	0.17	0.19	0.34	0.17	0.18	0.13	0.19	0.18	0.22	1.46
MNO	0.18	0.19	0.21	0.17	0.17	0.17	0.14	-	0.13	0.15
S	0.03	0.00	0.00	0.03	0.39	0.03	0.01	0.00	0.00	0.06
P_2O_5	0.06	0.07	0.03	0.09	0.07	0.07	0.07	0.10	0.08	0.17
PPM										
BA	10	10	5	34	26	1	14	-	25	32
NB	1	2	2	1	1	2	4	-	5	3
ZR	17	12	29	9	17	26	29	-	56	113
Y	6	6	6	2	4	4	4	-	5	22
SR	91	85	114	122	75	75	130	-	167	298
RB	1	1	1	3	2	1	1	-	3	1
ZN	75	114	94	58	106	96	102	-	65	95
CU	1	32	1	247	152	1	7	-	1	57
NI	397	384	120	499	90	216	168	-	204	104
LA	0	0	0	1	0	3	0	-	4	3
SI	53.53	56.78	48.13	50.00	40.67	54.77	45.07	50.98	54.29	35.54
Rock Type	2a	2a	2a	2a	2	2	2	2a	2	1

	61	62	63	64	65	66	67	68	69	70
	'98221'	'98223'	'98212'	'6862'	'9729'	'97233'	'96113'	'971711'	'971710'	'97165'
PERCENT										
SIO2	53.35	54.66	47.13	52.73	47.25	58.99	67.33	64.09	68.92	67.87
AL2O3	14.70	16.26	17.66	15.93	20.50	12.93	13.77	11.43	14.66	15.22
FE2O3	11.91	12.03	13.23	11.39	8.17	9.67	4.99	8.02	5.50	5.37
MGO	5.37	5.93	10.30	10.54	9.63	7.61	1.51	7.25	3.70	3.82
CAO	6.99	4.18	6.03	4.33	9.10	5.25	5.07	6.42	1.93	2.78
NA2O	4.59	5.33	3.67	3.24	3.30	4.56	6.75	1.73	4.64	2.72
K2O	0.31	0.11	0.10	0.12	0.70	0.58	0.17	0.66	0.12	1.80
TIO2	1.23	1.10	1.49	1.59	0.98	0.22	0.26	0.22	0.28	0.29
MNO	0.16	0.16	0.18	0.16	0.12	0.12	0.06	0.10	0.06	0.06
S	0.05	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01
P2O5	0.23	0.24	0.18	0.16	0.15	0.07	0.08	0.08	0.08	0.07
PPM										
BA	68	8	20	52	231	62	26	74	14	648
NB	5	9	2	3	7	2	1	1	5	6
ZR	106	108	115	152	93	29	53	45	118	75
Y	25	28	32	32	19	7	4	7	8	5
SR	160	126	198	266	379	84	117	170	219	178
RB	1	1	3	5	15	11	6	24	5	27
ZN	99	127	118	99	50	75	39	65	59	-
CU	100	43	25	2	1	112	50	30	3	-
NI	14	16	89	82	97	85	13	90	9	-
LA	6	5	1	7	7	1	6	4	9	6
SI	25.88	25.34	37.73	41.69	44.17	33.94	11.25	41.05	25.32	27.86
Rock Type	2d	2d	2d	2b	2b	2d	4a	4	4a	4a

	71	72	73	74	75	76	77	78	79	80
	'91810'	'97188'	'97187'	'9942'	'97182'	'97177'	'971611'	'9989'	'9736'	'96256'
PERCENT										
SIO2	74.43	72.94	75.02	78.17	79.40	80.76	72.87	72.86	80.89	84.96
AL2O3	12.67	13.47	11.97	9.59	10.08	9.54	13.65	10.72	10.25	7.37
FE2O3	3.39	3.78	3.50	3.38	2.56	2.00	3.48	4.39	2.55	2.54
MGO	1.49	2.05	1.82	0.59	0.99	1.03	1.97	2.18	0.80	0.79
CAO	0.60	1.74	1.33	2.52	1.07	0.96	1.46	4.61	0.27	1.17
NA2O	5.99	5.20	5.10	4.85	5.27	5.09	5.77	4.48	1.45	0.00
K2O	1.03	0.45	0.50	0.33	0.25	0.26	0.41	0.31	2.41	1.85
TIO2	0.29	0.25	0.25	0.28	0.24	0.25	0.28	0.25	0.14	0.07
MNO	0.03	0.04	0.04	0.05	0.02	0.02	0.03	0.06	–	–
S	0.01	0.01	0.33	0.01	0.01	0.02	0.01	0.05	1.59	1.71
P2O5	0.07	0.07	0.07	0.13	0.11	0.07	0.07	0.09	0.04	0.03
PPM										
BA	192	43	49	55	18	25	51	27	–	–
NB	7	8	8	1	4	5	6	2	–	–
ZR	80	99	33	38	85	75	106	37	–	–
Y	6	11	7	10	8	8	11	3	–	–
SR	141	141	104	151	121	116	124	216	–	–
RB	22	14	12	6	7	5	9	7	–	–
ZN	22	43	45	19	34	9	31	35	–	–
CU	58	113	6	1	1	25	4	173	–	–
NI	1	1	1	28	17	5	1	26	–	–
LA	9	8	9	4	5	8	12	4	–	–
SI	12.52	17.86	16.67	-6.45	10.92	12.29	16.94	19.19	11.14	15.28
Rock Type	4a	4b	4b	4b	4b	4b	4b	2c	3	3

	81	82
	'981441'	'982311'
PERCENT		
SIO2	83.63	55.68
AL2O3	8.11	17.33
FE2O3	2.08	10.17
MGO	1.57	5.20
CAO	0.59	5.05
NA2O	1.99	5.12
K2O	1.27	0.24
TIO2	0.17	0.53
MNO	-	0.55
S	1.07	0.00
P2O5	0.03	0.13
PPM		
BA	-	40
NB	-	1
ZR	-	57
Y	-	15
SR	-	426
RB	-	7
ZN	-	111
CU	-	56
NI	-	46
LA	-	9
SI	22.71	25.08
Rock Type	3	5

APPENDIX   D

Chemical Analyses of Ores from the East Mine

	1 'E7401'	2 'E7402'	3 'E7403'	4 'E7404'	5 'E7405'	6 'E7406'	7 'E7407'	8 'E7408'	9 'E7409'	10 'E7410'
PERCENT										
SIO2	61.35	59.86	54.21	56.34	57.12	41.97	57.16	57.64	57.15	55.56
AL2O3	11.83	14.39	13.37	13.69	12.74	13.03	8.37	11.04	14.73	15.43
FE2O3	11.31	10.93	13.17	12.98	12.99	16.06	19.90	14.65	12.62	9.94
MGO	5.82	5.80	12.85	13.15	11.04	10.65	1.86	1.20	5.36	14.84
CAO	0.00	0.00	0.00	0.00	0.00	0.71	0.11	4.57	0.88	1.40
NA2O	0.39	0.32	0.26	0.18	0.26	0.49	0.00	0.11	0.00	0.09
K2O	1.96	1.57	0.45	0.28	0.63	0.31	2.14	3.16	3.47	1.18
TIO2	0.12	0.17	0.16	0.17	0.16	0.18	0.11	0.16	0.33	0.24
MNO	0.04	0.06	0.07	0.08	0.08	0.08	0.02	0.04	0.04	0.15
S	5.98	1.47	4.13	2.66	3.71	7.33	18.70	13.48	8.72	2.00
P2O5	0.01	0.02	0.02	0.02	0.02	0.03	0.00	0.18	0.05	0.04
CPY	4.07	2.11	3.29	1.72	3.03	12.70	0.82	0.24	0.96	0.09
O=S	2.89	0.69	1.97	1.27	1.79	3.53	9.19	6.47	4.31	0.96
PPM										
BA	243	194	78	47	89	43	224	253	230	80
NB	4	1	2	1	5	5	1	1	2	5
ZR	21	25	23	29	28	24	12	13	32	40
Y	2	4	3	3	3	7	1	4	4	6
SR	3	5	4	4	5	26	7	20	21	15
RB	17	14	3	3	7	1	19	26	33	12
ZN	217	201	147	116	100	213	15	9	48	413
NI	14	31	69	54	39	22	26	22	7	41

	11 'E7417'	12 'E7418'	13 'E7413'	14 'E7414'	15 'E7415'	16 'E7416'	17 'R1024'	18 'R1023'	19 'R1022'	20 'R1021'
PERCENT										
SIO2	60.66	42.01	54.12	43.36	47.79	43.61	47.06	52.04	54.12	59.39
AL2O3	13.45	16.15	13.04	16.45	16.17	15.01	16.53	9.65	6.32	12.63
FE2O3	11.00	13.77	11.48	13.16	11.39	12.75	13.66	14.53	14.79	16.95
MGO	9.54	15.30	7.73	11.67	10.21	10.51	4.12	8.52	10.86	5.93
CAO	0.80	8.48	4.16	9.32	8.44	12.58	11.85	12.44	12.82	0.49
NA2O	0.04	0.04	1.78	3.09	3.30	2.22	4.36	1.55	0.13	0.64
K2O	1.97	1.46	0.85	0.00	0.16	0.24	0.70	0.19	0.01	0.08
TIO2	0.17	0.22	0.49	1.26	1.05	1.48	1.30	0.83	0.70	0.15
MNO	0.08	0.17	0.08	0.15	0.16	0.19	0.19	0.22	0.23	0.12
S	3.83	4.22	4.92	1.44	0.66	0.36	0.36	-	0.00	2.63
P2O5	0.03	0.01	0.08	0.15	0.13	0.19	0.01	0.01	0.01	0.00
CPY	0.30	0.21	3.67	0.62	0.84	1.02	0.03	0.02	0.01	2.20
O=S	1.87	2.03	2.39	0.67	0.30	0.16	0.18	0.00	0.00	1.21
PPM										
BA	13	93	184	-	37	54	98	14	1	11
NB	7	1	5	-	9	11	2	4	3	8
ZR	75	31	45	-	66	89	117	66	40	28
Y	15	4	11	-	13	17	24	10	5	4
SR	95	25	102	-	101	210	206	58	2	2
RB	1	17	3	-	1	3	13	4	1	1
ZN	647	557	206	116	139	148	62	69	69	43
NI	24	25	56	259	32	73	72	889	1230	149

	21 'R1020'	22 'R1019'	23 'R1018'	24 'R1017'	25 'R1016'	26 'R1015'	27 'R1014'	28 'R1013'	29 'R1012'	30 'R1011'
PERCENT										
SIO2	68.70	58.32	57.02	61.45	50.95	59.65	57.99	47.36	58.95	62.00
AL2O3	13.25	14.07	12.23	11.77	13.23	12.70	13.01	13.81	13.01	13.83
FE2O3	10.10	17.54	15.78	16.30	18.24	16.43	18.29	13.83	18.14	15.47
MGO	2.97	7.41	6.66	7.12	7.52	8.39	7.91	3.97	7.19	7.40
CAO	0.24	0.75	4.03	2.32	4.58	1.53	1.69	15.04	1.49	0.23
NA2O	4.07	0.00	0.00	0.16	0.70	0.00	0.14	2.71	0.05	0.08
K2O	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00
TIO2	0.13	0.15	0.20	0.08	0.64	0.16	0.09	1.85	0.10	0.12
MNO	0.08	0.17	0.21	0.21	0.23	0.20	0.21	0.27	0.23	0.22
S	0.71	0.98	1.07	0.59	2.93	0.67	0.93	0.09	1.54	1.16
P2O5	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.03	0.01	0.01
CPY	0.07	1.04	3.29	0.28	2.33	0.56	0.19	0.01	0.05	0.05
O=S	0.35	0.43	0.49	0.29	1.36	0.29	0.46	0.04	0.76	0.57
PPM										
BA	10	1	2	1	1	1	1	144	1	1
NB	3	1	1	3	7	1	2	15	1	1
ZR	45	31	27	29	55	27	27	147	27	32
Y	6	4	3	2	6	2	3	20	3	2
SR	45	1	11	1	27	1	1	297	1	1
RB	1	1	1	1	1	1	1	17	1	2
ZN	18	51	76	91	111	91	90	71	97	89
NI	19	121	168	184	191	164	169	12	173	136

	31 'R1010'	32 'R1009'	33 'R1007'	34 'R1006'	35 'R1005'	36 'E2568F'	37 'E2567F'	38 'E2566F'	39 'E2565'	40 'E2564F'
PERCENT										
SIO2	61.69	48.62	44.46	45.03	48.17	60.67	61.58	59.66	66.39	62.62
AL2O3	13.26	14.73	17.77	18.83	16.75	12.38	12.42	11.70	10.46	11.07
FE2O3	16.30	16.61	14.68	14.15	14.27	16.94	16.84	16.27	15.70	15.75
MGO	7.05	4.82	5.79	5.52	4.94	6.23	5.60	6.51	5.41	5.90
CAO	0.58	7.78	13.03	11.61	10.82	0.76	0.03	0.63	0.16	0.39
NA2O	0.20	1.91	2.41	3.17	2.53	0.00	0.00	0.00	0.01	0.00
K2O	0.00	2.97	0.06	0.13	0.51	0.17	0.07	0.00	0.08	0.00
TIO2	0.12	2.28	1.33	1.32	1.70	0.23	0.15	0.14	0.11	0.14
MNO	0.23	0.20	0.22	0.19	0.19	0.16	0.15	0.15	0.14	0.12
S	1.22	0.08	-	0.03	0.12	2.28	3.18	2.60	2.00	3.28
P2O5	0.01	0.03	0.01	0.01	0.02	0.00	0.00	0.00	0.01	0.00
CPY	0.03	0.00	0.27	0.01	0.03	1.22	1.46	3.55	0.51	2.27
O=S	0.60	0.04	-	0.01	0.06	1.05	1.48	1.20	0.99	1.52
PPM										
BA	1	379	1	18	52	4	8	5	1	1
NB	1	18	1	2	5	1	2	15	1	4
ZR	27	183	120	125	151	35	29	26	29	32
Y	5	24	21	20	25	7	3	4	1	5
SR	1	223	319	317	294	1	1	1	1	1
RB	1	52	1	1	10	2	1	1	1	1
ZN	102	85	80	77	79	532	188	151	0	140
NI	165	75	184	156	92	138	109	135	0	104

PERCENT	41 'E2563F'	42 'R1004'	43 'E2506F'	44 'R1003'	45 'R1002'	46 'R1001'	47 'E2581F'	48 'E2582F'	49 'E2583F'	50 'E2584F'
SIO_2	59.26	57.69	58.47	60.94	59.29	60.14	57.03	61.58	55.36	60.92
AL_2O_3	10.75	13.44	13.74	15.49	15.94	13.85	11.58	11.67	12.80	11.52
FE_2O_3	15.51	16.52	17.16	15.26	13.89	14.18	18.36	15.98	17.21	13.92
MGO	6.37	7.08	5.60	5.21	4.52	4.02	6.34	5.60	5.27	4.31
CAO	2.24	0.60	0.16	0.15	1.67	3.64	1.18	0.03	0.83	0.29
NA_2O	0.00	0.09	0.32	0.34	2.82	1.47	0.00	0.00	0.83	1.27
K_2O	0.00	0.28	0.30	1.05	0.25	0.73	0.00	0.07	0.55	0.35
TIO_2	0.45	0.17	0.17	0.16	0.70	0.83	0.14	0.15	0.33	0.16
MNO	0.11	0.13	0.12	0.12	0.12	0.11	0.12	0.15	0.12	0.10
S	2.74	2.29	3.10	1.90	1.27	1.97	4.79	2.52	4.05	3.45
P_2O_5	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
CPY	3.87	2.75	2.32	0.30	0.14	0.03	2.71	3.41	4.57	5.28
O=S	1.29	1.03	1.45	0.94	0.63	0.97	2.24	1.18	1.94	1.68
PPM										
BA	1	30	99	292	70	85	15	2	51	78
NB	7	1	4	2	2	6	1	1	1	1
ZR	45	30	37	44	64	67	20	26	51	34
Y	7	3	4	5	15	16	3	2	5	3
SR	1	1	10	17	95	201	1	7	34	10
RB	1	2	2	9	2	15	1	1	11	2
ZN	302	168	203	87	0	0	109	265	113	457
NI	161	85	64	29	0	0	193	156	50	36

PERCENT										
SIO2	62.98	62.37	59.46	59.69	61.54	51.59	58.85	58.05	53.27	56.13
AL2O3	11.46	11.89	12.24	11.64	10.89	10.20	10.39	10.99	8.81	10.99
FE2O3	12.77	13.89	15.02	14.79	14.09	16.20	15.55	12.73	14.94	16.36
MGO	3.37	4.69	4.45	4.78	4.25	4.92	3.77	3.21	2.56	5.15
CAO	0.28	0.27	0.83	0.43	1.97	1.78	0.19	0.96	0.22	0.40
NA2O	1.36	1.07	1.72	1.19	1.82	0.42	0.42	1.39	2.29	0.54
K2O	0.48	0.32	0.22	0.62	0.61	0.44	1.03	1.08	0.44	0.26
TIO2	0.16	0.16	0.25	0.33	0.45	0.29	0.17	0.27	0.15	0.15
MNO	0.10	0.11	0.10	0.10	0.10	0.09	0.08	0.08	0.06	0.09
S	2.54	2.61	4.51	3.73	3.53	5.69	6.70	4.11	7.63	5.05
P2D5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CPY	5.21	3.86	3.40	4.51	2.45	11.13	6.10	9.20	13.53	6.78
O=S	1.22	1.25	2.20	2.81	1.70	2.75	3.26	2.06	3.90	2.90

PPM										
BA	77	54	38	52	67	19	–	–	–	–
NB	6	1	3	1	3	4	–	–	–	–
ZR	37	38	39	41	53	34	–	–	–	–
Y	3	2	4	5	6	4	–	–	–	–
SR	11	8	21	10	26	4	–	–	–	–
RB	7	4	3	11	10	5	–	–	–	–
ZN	316	346	547	387	427	204	814	1677	1227	627
NI	35	68	43	60	102	49	78	61	63	58

	61 'E2642F'	62 'E2643F'	63 'E2644F'	64 'E2645F'	65 '61793'	66 '61752'	67 '61781'	68 '61852'	69 '61898'	70 '61924'
PERCENT										
SIO2	53.20	46.27	59.39	40.63	47.21	47.31	47.36	58.66	49.67	69.86
AL2O3	12.13	7.07	10.33	9.68	15.15	14.20	14.14	16.11	18.35	14.26
FE2O3	17.09	20.90	14.89	21.55	17.27	13.92	13.89	10.10	13.60	6.07
MGO	6.26	2.87	5.02	3.20	3.96	5.84	4.71	4.74	8.29	4.94
CAO	4.80	0.54	0.33	0.91	10.38	13.23	13.95	4.41	7.01	0.37
NA2O	0.00	0.55	0.20	1.97	3.68	1.66	2.93	4.79	2.23	4.21
K2O	0.29	0.27	0.10	0.60	0.30	1.44	0.01	0.60	0.50	0.02
TIO2	0.77	0.12	0.16	0.18	1.78	2.08	2.31	0.19	0.24	0.15
MNO	0.14	0.07	0.10	0.08	0.21	0.09	0.17	0.05	0.06	0.10
S	2.43	12.29	4.06	12.27	0.07	0.32	0.68	0.62	0.06	0.01
P2O5	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.01	0.01	0.01
CPY	4.04	15.24	7.38	15.09	0.00	0.04	0.17	0.04	0.00	0.00
O=S	1.14	6.18	1.95	6.17	0.03	0.16	0.34	0.31	0.03	0.00
PPM										
BA	39	32	11	35	28	66	1	55	34	1
NB	5	3	1	3	7	15	8	4	5	4
ZR	66	13	20	26	165	148	181	47	45	53
Y	9	1	2	2	37	18	39	7	7	6
SR	38	21	1	20	263	209	176	153	122	61
RB	6	4	1	9	3	24	1	7	7	1
ZN	201	433	511	528	115	97	71	0	0	0
NI	166	53	61	42	67	110	43	0	0	0

	71 '61926'	72 '61928'	73 '61934'	74 'E4545'	75 'E4546F'	76 'E4547'	77 'E4548F'	78 'E4549'	79 'E4550'	80 'E4551'
PERCENT										
SIO2	63.10	59.00	65.31	61.06	63.01	61.82	60.01	62.75	61.28	61.40
AL2O3	12.11	11.77	11.01	10.97	10.48	10.53	12.02	11.10	11.74	11.21
FE2O3	11.94	13.54	11.85	15.48	15.52	17.58	16.37	17.61	17.40	16.30
MGO	9.12	8.55	8.31	8.28	6.94	6.47	7.23	6.14	5.82	6.13
CAU	3.04	6.58	2.96	2.89	1.37	1.72	1.73	0.70	1.51	0.31
NA2O	0.11	0.11	0.12	0.00	0.13	0.18	0.00	0.09	0.24	0.02
K2O	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.14	0.64	0.36
TIO2	0.11	0.11	0.09	0.14	0.15	0.09	0.14	0.11	0.33	0.16
MNO	0.23	0.30	0.27	0.30	0.21	0.22	0.18	0.20	0.19	0.14
S	0.11	0.01	0.12	0.88	2.51	2.29	1.45	1.18	0.67	1.34
P2O5	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00
CPY	0.15	0.02	0.00	0.39	0.82	0.21	1.52	0.55	0.50	3.25
O=S	0.05	0.00	0.06	0.39	1.15	1.13	0.67	0.58	0.33	0.62
PPM										
BA	2	1	1	1	10	1	2	11	66	38
NB	5	1	5	3	5	1	1	3	3	3
ZR	27	28	22	25	24	23	21	34	45	29
Y	2	5	2	5	3	3	2	5	7	3
SR	3	44	3	6	7	4	2	19	15	3
RB	1	1	1	1	1	1	1	2	10	1
ZN	0	0	0	389	200	300	115	104	99	94
NI	0	0	0	255	188	198	197	134	147	119

| | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
	'61976'	'E4553'	'E4554'	'E455'	'E4556'	'611005'	'E4557F'	'E4558'	'611034'	'E4559'
PERCENT										
SIO2	48.38	62.47	60.70	62.06	60.77	47.24	59.12	59.36	58.69	60.40
AL2O3	10.85	10.80	11.27	12.20	11.46	14.40	12.04	11.72	15.01	11.14
FE2O3	18.36	16.58	16.79	16.02	16.70	16.49	17.43	16.21	19.24	17.73
MGO	11.21	6.07	5.59	5.89	6.45	6.08	6.94	5.04	6.13	6.78
CAO	9.59	0.30	0.17	0.97	3.08	11.27	1.38	2.93	0.28	1.93
NA2O	0.41	0.00	0.12	0.75	0.00	2.58	0.00	1.24	0.04	0.00
K2O	0.01	0.34	0.30	0.01	0.00	0.05	0.01	0.68	0.11	0.01
TIO2	0.93	0.17	0.15	0.32	0.14	1.53	0.23	0.94	0.15	0.13
MNO	0.24	0.11	0.11	0.12	0.13	0.21	0.13	0.12	0.12	0.13
S	0.04	1.25	1.75	0.80	1.13	0.20	2.04	2.46	0.44	1.19
P2O5	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.00
CPY	0.00	2.49	3.86	1.22	0.64	0.03	1.63	0.45	0.00	1.11
O=S	0.02	0.58	0.81	0.37	0.51	0.10	0.95	1.17	0.22	0.54
PPM										
BA	1	40	38	1	1	5	12	106	16	1
NB	8	2	1	4	2	13	2	8	2	3
ZR	78	26	17	42	21	114	24	79	29	15
Y	11	2	3	3	1	23	4	7	1	1
SR	13	5	1	9	16	144	8	97	7	1
RB	1	7	4	1	1	1	1	12	3	1
ZN	80	66	72	86	82	81	105	81	32	133
NI	1208	200	159	195	235	345	259	147	78	323

	91	92	93	94	95	96	97	98	99	100
PERCENT	'E4560'	'E4561'	'E41071'	'E4562'	'E4563'	'E4564'	'E4565'	'E4566'	'E4567F'	'E4568'
SIO2	60.90	60.59	45.40	68.71	67.22	69.93	66.54	63.01	52.28	50.34
AL2O3	8.70	10.73	15.19	11.73	12.03	11.82	9.73	11.76	14.39	12.38
FE2O3	15.33	15.85	16.07	10.77	14.15	11.88	14.22	17.08	19.46	17.90
MGO	5.25	6.24	5.14	2.81	3.99	3.67	4.93	6.04	6.49	3.34
CAO	1.31	1.39	13.18	0.42	0.18	0.18	1.44	0.31	1.32	9.81
NA2O	0.05	0.41	2.48	3.87	1.66	2.14	0.01	0.00	0.16	2.41
K2O	0.00	0.00	0.02	0.08	0.01	0.02	0.00	0.00	0.56	0.71
TIO2	0.10	0.18	2.19	0.21	0.11	0.11	0.13	0.16	0.59	2.00
MNO	0.10	0.12	0.20	0.73	0.09	0.08	0.12	0.13	0.15	0.26
S	3.27	1.85	0.18	0.45	0.68	0.16	0.73	2.08	2.71	1.54
P2O5	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.00	0.00	0.02
CPY	6.04	3.50	0.01	0.45	0.21	0.07	2.49	0.38	3.16	0.07
O=S	1.56	0.87	0.09	0.21	0.34	0.08	0.34	0.95	1.27	0.76
PPM										
BA	3	11	4	6	4	2	1	1	63	73
NB	1	2	17	3	2	4	1	3	4	7
ZR	14	25	188	46	39	43	19	28	64	180
Y	1	2	18	5	2	3	2	2	11	36
SR	1	6	162	37	38	43	8	3	35	136
RB	1	1	1	1	1	1	1	1	8	12
ZN	95	80	52	74	66	45	124	105	141	135
NI	195	184	128	91	50	21	179	115	112	36

	101	102	103	104	105	106	107	108	109	110
	'E4569'	'E4570'	'E4571'	'E4572'	'E4573'	'E4574'	'E4575F'	'F'611222'	'E4580'	'E4581'
PERCENT										
SIO2	61.75	65.20	62.69	57.72	59.55	59.89	59.10	60.94	55.80	53.25
AL2O3	11.81	12.40	12.90	13.38	12.97	12.07	13.68	12.04	11.55	10.10
FE2O3	19.07	15.24	16.64	15.94	18.43	20.08	18.73	14.99	18.17	17.16
MGO	4.99	3.94	4.46	4.33	4.93	5.38	5.41	6.66	6.87	6.74
CAO	0.72	0.17	1.76	5.10	1.64	0.49	1.02	4.41	6.63	5.27
NA2O	0.24	2.30	1.60	2.30	1.10	0.48	0.53	0.00	0.05	0.19
K2O	0.03	0.01	0.13	0.05	0.08	0.02	0.10	0.00	0.01	0.00
TIO2	0.17	0.19	0.28	0.72	0.35	0.12	0.15	0.11	0.08	0.12
MNO	0.11	0.13	0.14	0.16	0.14	0.14	0.14	0.15	0.22	0.17
S	2.06	0.69	0.72	0.50	1.51	2.22	1.69	0.35	0.87	3.00
P2O5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00
CPY	0.05	0.06	0.03	0.04	0.03	0.20	0.26	0.51	0.17	5.42
O=S	1.02	0.34	0.36	0.25	0.75	1.10	0.84	0.15	0.43	1.41
PPM										
BA	2	1	12	1	6	1	25	6	1	4
NB	3	4	2	7	5	1	2	2	1	5
ZR	30	41	45	75	44	26	27	17	16	13
Y	6	6	6	10	4	2	5	3	1	1
SR	10	19	36	96	24	6	11	18	17	14
RB	1	1	3	1	1	1	1	1	1	1
ZN	89	104	80	76	69	74	69	72	81	112
NI	100	87	66	85	105	110	104	195	225	200

	111 'E4582'	112 'E4583'	113 'E4584'	114 'E4585'	115 '611269'	116 '611277'	117 'E4586'	118 'E4587'	119 'E4588'	120 'E4590'
PERCENT										
SIO_2	61.57	63.52	56.35	63.26	59.52	54.95	56.21	60.43	63.87	62.36
AL_2O_3	12.49	12.93	12.90	11.77	13.05	15.13	12.38	11.84	11.64	12.80
FE_2O_3	15.13	14.09	19.47	14.19	17.35	21.95	22.86	17.08	18.24	18.21
MGO	5.30	4.01	5.66	3.97	5.96	6.34	5.12	5.76	5.08	5.25
CAO	3.36	2.28	3.50	2.92	0.63	0.55	0.57	2.65	0.11	0.22
NA_2O	1.61	2.41	0.63	2.23	0.00	0.02	0.02	0.00	0.05	0.18
K_2O	0.02	0.06	0.01	0.04	0.47	0.36	0.23	0.00	0.01	0.33
TIO_2	0.12	0.21	0.41	0.15	0.21	0.16	0.15	0.16	0.14	0.16
MNO	0.13	0.12	0.15	0.12	0.11	0.13	0.12	0.12	0.11	0.10
S	0.37	0.64	1.48	1.79	1.06	0.68	4.02	1.74	1.22	0.62
P_2O_5	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01
CPY	0.07	0.03	0.16	0.40	2.12	0.05	0.28	1.00	0.12	0.06
U=S	0.18	0.32	0.73	0.84	0.48	0.34	1.97	0.80	0.60	0.31
PPM										
BA	1	5	15	2	39	32	–	–	–	–
NB	4	2	3	4	5	1	–	–	–	–
ZR	26	40	43	36	32	27	–	–	–	–
Y	4	5	6	11	3	4	–	–	–	–
SR	20	27	21	42	2	2	–	–	–	–
RB	1	1	1	1	5	7	–	–	–	–
ZN	69	83	146	245	83	0	144	51	61	34
NI	191	124	111	47	78	0	80	107	93	84

	121 'IOL-26'	122 'IOL-34'
PERCENT		
SIO2	51.50	46.38
AL2O3	14.76	4.53
FE2O3	12.85	10.02
MGO	17.91	26.64
CAO	0.00	11.68
NA2O	0.00	0.00
K2O	0.00	0.00
TIO2	0.16	0.41
MNO	0.16	0.20
S	0.83	0.16
P2O5	0.09	0.06
CPY	2.13	0.00
O=S	0.39	0.08
PPM		
BA	7	1
NB	2	6
ZR	26	30
Y	2	3
SR	6	40
RB	1	1
ZN	170	77
NI	135	1284

APPENDIX   E

C.I.P.W. Norms for Country Rocks

RAMBLER AREA

SUMMARY NORM TABLE

	1	2	3	4	5	6	7	8	10	9	11	12
	9796	97171B	97283	97316	97319	9812	9864	9983	99182	99185	99181	10L-19
QUARTZ	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.0
ORTHOCLASE	1.2	1.2	0.9	0.1	0.1	3.5	2.9	0.1	1.5	4.5	5.2	0.1
ALBITE	20.7	22.1	29.3	19.4	28.6	16.2	25.1	28.2	17.1	20.8	27.0	24.4
ANORTHITE	28.1	24.2	18.2	27.5	21.3	34.7	22.5	19.5	26.8	40.5	30.1	27.0
NEPHELINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
DIOPSIDE	18.9	23.5	24.2	8.8	14.3	18.7	21.3	12.0	35.1	10.7	14.5	11.8
HYPERSTHENE	16.2	14.9	15.9	19.4	20.4	17.2	11.3	27.8	0.9	0.0	2.2	13.0
OLIVINE	8.6	6.3	0.0	19.8	8.2	3.9	7.8	4.4	0.0	24.7	15.1	16.0
MAGNETITE	3.6	4.0	5.2	3.2	3.8	3.4	4.6	4.3	9.5	-4.1	3.1	3.9
HEMATITE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0
ILMENITE	2.3	2.9	4.2	1.5	2.6	2.0	3.6	3.1	3.1	1.5	1.3	3.0
APATITE	0.4	0.5	0.6	0.2	0.4	0.1	0.6	0.6	0.5	0.2	0.4	0.5
PYRITE	0.0	0.3	0.1	0.0	0.2	0.3	0.1	0.0	0.1	0.1	0.0	0.3
DIFF. INDEX	21.8	23.3	31.5	19.5	28.7	19.7	28.0	28.3	22.7	0.0	33.2	24.4
NA/(NA+K)	0.95	0.95	0.97	1.00	1.00	0.83	0.90	1.00	0.92	0.00	0.82	1.00
(NA+K)/AL	0.29	0.34	0.47	0.27	0.42	0.23	0.39	0.44	0.27	0.26	0.37	0.32
F3/(F2+F3)	0.24	0.22	0.26	0.20	0.22	0.25	0.24	0.25	0.62	-0.42	0.32	0.21

RAMBLER AREA

NORMAL .. R.C.O.GILL

SUMMARY NORM TABLE

	13	14	15	16	17	18	19	20	21	22	23	24
	9723	9726	97102	97171	971810	97225	97312	9863	9866	98211	982213	9944
QUARTZ	0.3	0.0	0.2	0.0	0.0	0.0	0.9	0.0	2.2	2.8	0.0	2.1
ORTHOCLASE	0.1	2.6	0.1	3.3	3.9	1.8	0.5	0.7	0.2	0.5	0.1	0.1
ALBITE	21.0	22.2	20.7	28.0	21.1	26.8	30.6	27.5	37.0	25.5	25.5	33.4
ANORTHITE	25.6	20.8	24.0	24.2	23.9	20.0	17.9	18.5	14.2	23.6	28.3	15.2
DIOPSIDE	28.9	21.9	22.6	21.7	18.1	25.6	21.3	24.3	22.8	16.8	18.3	26.9
HYPERSTHENE	15.8	23.0	23.8	3.6	17.0	16.5	20.1	19.3	13.7	22.0	15.2	12.4
OLIVINE	0.0	0.0	0.0	10.1	9.4	1.3	0.0	1.2	0.0	0.0	5.2	0.0
MAGNETITE	4.2	4.9	4.5	4.8	3.6	4.2	4.5	4.6	5.2	4.2	3.5	4.8
ILMENITE	2.6	3.7	3.3	3.4	2.4	2.9	3.3	3.4	4.1	3.0	2.1	3.6
APATITE	0.4	0.7	0.8	0.6	0.5	0.5	0.7	0.5	0.5	0.4	0.3	0.5
PYRITE	0.0	0.1	0.0	0.4	0.1	0.4	0.1	0.1	0.0	0.0	0.0	0.0
DIFF. INDEX	21.4	24.8	21.0	31.2	25.1	28.6	32.1	28.2	39.4	30.0	25.5	35.6
NA/(NA+K)	0.99	0.90	1.00	0.90	0.85	0.94	0.98	0.98	0.99	0.98	1.00	1.00
(NA+K)/AL	0.30	0.39	0.31	0.40	0.36	0.43	0.48	0.45	0.58	0.38	0.33	0.52
F3/(F2+F3)	0.23	0.28	0.25	0.26	0.20	0.23	0.23	0.24	0.29	0.22	0.27	0.28

RAMBLER AREA

SUMMARY NORM TABLE

NORMCAL .. R.C.O.GILL

	25	26	27	28	29	30	31	32	33	34	35	36
	9985	10L-2	10L-32	10L-36	R2-33	10L-18	96203	96203A	95205	95232	95272	972410
QUARTZ	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	6.1
ORTHOCLASE	0.1	1.8	2.5	1.3	1.7	20.3	0.2	1.0	2.0	0.4	0.2	0.2
ALBITE	34.0	19.6	13.9	17.1	16.7	18.0	18.9	23.1	15.8	15.3	13.7	13.5
ANORTHITE	20.1	23.1	28.3	17.8	20.4	10.9	12.8	17.9	17.2	20.2	17.5	17.8
NEPHELINE	0.0	0.0	0.0	3.6	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIOPSIDE	16.8	22.6	20.5	41.4	39.9	21.8	28.8	21.4	28.8	18.6	27.9	24.0
HYPERSTHENE	19.7	12.9	22.6	0.0	0.0	16.4	32.7	33.4	18.0	31.5	29.9	35.5
OLIVINE	0.0	7.4	5.1	9.7	9.9	0.0	3.4	0.0	14.1	11.2	7.9	0.0
MAGNETITE	4.6	5.3	3.8	4.7	4.8	6.1	2.5	2.5	2.3	2.3	2.4	2.4
ILMENITE	3.5	4.4	2.5	3.6	3.7	5.2	0.4	0.3	0.3	0.3	0.3	0.2
APATITE	0.5	0.5	0.5	0.6	0.6	1.1	0.1	0.1	0.3	0.2	0.1	0.2
PYRITE	0.0	2.4	0.3	0.2	0.3	0.3	0.0	0.0	0.1	0.0	0.0	0.0
DIFF. INDEX	34.8	21.3	15.4	22.1	20.3	38.3	19.1	24.4	18.9	15.6	13.9	19.9
NA/(NA+K)	1.00	0.92	0.86	0.95	0.93	0.48	0.99	0.96	0.90	0.98	0.98	0.98
(NA+K)/AL	0.47	0.33	0.23	0.43	0.36	0.64	0.44	0.42	0.37	0.29	0.30	0.29
F3/(F2+F3)	0.29	0.31	0.21	0.23	0.23	0.27	0.15	0.16	0.12	0.14	0.15	0.17

NORMCAL .. R.C.O.GILL

SUMMARY NORM TABLE

	37	38	39	40	41	42	43	44	45	46	47	48
	972411	97284	97285	9988A	5123	991816	97232	97234	97249	9841	98134	98141
QUARTZ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	1.5	0.3	7.4
ORTHOCLASE	0.8	0.2	1.1	0.2	0.9	0.5	0.4	1.9	0.8	0.4	0.2	5.9
ALBITE	16.8	21.9	14.5	28.2	34.3	24.6	23.1	19.5	23.2	42.5	45.1	38.3
ANORTHITE	19.1	14.6	13.3	23.3	28.1	25.8	29.5	22.2	19.0	12.3	15.8	19.4
NEPHELINE	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIOPSIDE	31.0	28.3	37.2	27.6	7.3	17.4	15.4	15.2	17.3	21.2	8.6	8.5
HYPERSTHENE	25.9	32.0	30.2	0.0	10.3	18.8	22.9	28.1	30.0	18.9	26.4	17.1
OLIVINE	3.3	0.1	0.6	8.9	10.0	5.2	2.1	10.0	0.0	0.0	0.0	0.0
MAGNETITE	2.5	2.4	2.4	4.8	4.8	4.4	3.7	2.4	2.5	2.5	2.5	2.5
ILMENITE	0.4	0.3	0.3	3.4	3.5	2.9	2.4	0.3	0.4	0.4	0.4	0.6
APATITE	0.2	0.2	0.2	0.6	0.5	0.3	0.4	0.2	0.2	0.2	0.1	0.1
PYRITE	0.0	0.0	0.1	0.1	0.3	0.1	0.1	0.1	0.0	0.0	0.1	0.3
DIFF. INDEX	17.6	22.2	15.7	31.4	35.1	25.2	23.5	21.4	30.6	44.5	46.2	51.5
NA/(NA+K)	0.96	0.99	0.93	1.00	0.98	0.98	0.98	0.92	0.97	0.99	1.00	0.88
(NA+K)/AL	0.33	0.45	0.33	0.44	0.40	0.34	0.30	0.34	0.40	0.65	0.60	0.54
F3/(F2+F3)	0.18	0.18	0.16	0.29	0.28	0.23	0.26	0.18	0.18	0.22	0.19	0.19

RAMBLER AREA

SUMMARY NORM TABLE

	49	50	51	52	53	54	55	56	57	58	59	60
	9943	96124	96233	96252	97911	97108	96258	961710	97107A	99184	97175	98215
QUARTZ	14.7	14.4	0.0	0.0	0.0	11.5	6.0	10.2	0.0	0.0	16.2	0.0
CORUNDUM	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ORTHOCLASE	0.0	0.1	0.1	0.0	0.2	0.5	0.7	0.0	0.1	0.5	0.5	1.1
ALBITE	18.9	22.7	19.4	15.8	13.5	22.0	31.4	14.3	30.3	13.4	17.7	24.3
ANORTHITE	18.3	9.8	12.4	26.0	13.0	7.6	16.8	19.3	21.0	24.7	22.3	26.9
NEPHELINE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8
DIOPSIDE	0.0	17.9	35.5	5.1	40.0	36.2	20.5	12.1	10.9	24.0	4.4	17.3
HYPERSTHENE	42.1	32.2	23.3	41.8	29.5	19.1	20.9	41.3	33.2	25.5	35.6	0.0
OLIVINE	0.0	0.0	5.9	8.2	0.2	0.0	0.0	0.0	1.5	8.9	0.0	17.5
MAGNETITE	2.5	2.4	2.4	2.5	2.7	2.4	2.5	2.4	2.5	2.4	2.5	4.3
ILMENITE	0.4	0.3	0.3	0.4	0.7	0.3	0.3	0.2	0.4	0.3	0.4	2.8
APATITE	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4
PYRITE	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.1	0.0	0.0	0.0	0.1
DIFF. INDEX	33.6	37.1	19.4	15.8	13.8	34.1	38.0	24.5	30.4	14.0	34.6	30.7
NA/(NA+K)	1.00	1.00	1.00	1.00	0.98	0.98	0.98	1.00	1.00	0.96	0.97	0.97
(NA+K)/AL	0.28	0.55	0.45	0.24	0.36	0.61	0.50	0.28	0.43	0.23	0.30	0.41
F3/(F2+F3)	0.17	0.20	0.15	0.16	0.15	0.21	0.20	0.17	0.17	0.14	0.23	0.25

RAMBLER AREA

SUMMARY NORM TABLE

	61	62	63	64	65	66	67	68	69	70	71	72
	98221	98223	98212	6852	9729	97233	96113	971711	971710	97165	91810	97188
QUARTZ	1.2	0.8	0.0	5.7	0.0	5.4	16.8	25.5	30.1	32.0	32.1	33.8
CORUNDUM	0.0	0.4	1.3	3.6	0.0	0.0	0.0	0.0	3.6	3.9	0.8	1.4
ORTHOCLASE	1.9	0.7	0.6	0.7	4.2	3.5	1.0	3.9	0.7	10.7	6.1	2.7
ALBITE	39.2	45.6	31.4	27.7	24.4	38.9	57.3	14.7	39.4	23.1	50.3	44.1
ANORTHITE	18.8	19.4	29.1	19.2	39.6	13.2	6.8	21.6	9.1	13.4	2.5	3.2
NEPHELINE	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIOPSIDE	12.1	0.0	0.0	0.0	3.9	10.3	14.8	8.0	0.0	0.0	0.0	0.0
WOLLASTONITE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYPERSTHENE	19.9	26.8	9.4	35.2	20.2	25.7	0.0	23.1	13.7	13.6	4.4	6.6
OLIVINE	0.0	0.0	20.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAGNETITE	4.0	3.8	4.4	4.2	3.6	2.5	2.6	2.5	2.5	2.5	2.5	2.5
ILMENITE	2.4	2.1	2.9	3.3	1.9	0.4	0.5	0.4	0.5	0.6	0.6	0.5
APATITE	0.6	0.6	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
PYRITE	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIFF. INDEX	42.2	47.0	32.0	34.2	30.5	47.8	75.2	44.1	70.3	65.8	88.9	80.5
NA/(NA+K)	0.96	0.99	0.98	0.98	0.88	0.92	0.98	0.80	0.98	0.70	0.90	0.95
(NA+K)/AL	0.54	0.55	0.35	0.34	0.30	0.63	0.82	0.31	0.53	0.42	0.87	0.57
F3/(F2+F3)	0.23	0.22	0.23	0.26	0.30	0.18	0.35	0.21	0.32	0.33	0.53	0.47

RAMBLER AREA

SUMMARY NORM TABLE

	73	74	75	76	77	78	79	80	81	82
	97187	9942	971182	97177	971611	9989	9736	96256	98144	98231
QUARTZ	37.8	44.2	44.7	47.2	31.5	35.8	61.3	73.9	63.4	1.5
CORUNDUM	0.7	0.0	0.0	0.0	1.2	0.0	4.8	3.3	2.4	0.0
ORTHOCLASE	3.0	2.0	1.5	1.5	2.4	1.8	14.2	10.9	7.5	1.4
ALBITE	43.2	41.1	44.6	43.1	48.9	37.9	12.2	0.0	15.8	43.7
ANORTHITE	6.4	3.7	3.1	2.4	6.8	8.2	1.1	5.6	2.7	23.8
DIOPSIDE	0.0	4.7	1.2	1.5	0.0	11.0	0.0	0.0	0.0	0.5
WOLLASTONITE	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYPERSTHENE	5.1	0.0	1.9	1.9	5.8	0.4	2.0	2.0	3.9	24.7
MAGNETITE	2.6	2.6	1.7	-0.0	2.6	1.8	-2.5	-2.2	-2.2	3.0
HEMATITE	0.0	0.0	0.6	1.8	0.0	2.3	3.4	3.1	3.1	0.0
ILMENITE	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.1	0.3	1.0
APATITE	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.3
PYRITE	0.6	0.0	0.0	0.0	0.0	0.1	3.1	3.2	2.0	0.0
DIFF. INDEX	84.0	87.3	90.3	91.8	82.8	75.6	0.0	0.0	0.0	46.7
NA/(NA+K)	0.94	0.96	0.97	0.97	0.96	0.96	0.03	0.00	0.00	0.97
(NA+K)/AL	0.75	0.86	0.89	0.91	0.73	0.72	0.49	0.27	0.57	0.50
F3/(F2+F3)	0.51	0.53	0.68	0.88	0.51	0.81	0.65	0.62	0.79	0.20

APPENDIX   F

Location of Samples

Location of analysed rock samples. Coordinates refer to Plate I.
All samples are listed in the same order as in Appendix C.

Sample			Sample		
9796	6100N/	5980E	991816[4]		
97171B	9870	/10680	97232	1480N/	10780E
97283	4370	/11820	97234	2360	/10800
97316	9870	/16660	97249	2430	/11360
97319	10550	/16780	9841	5630	/13200
9812	3820	/13800	98134	6870	/11790
9864	10690	/15700	98141	2730	/ 8800
9983	13790	/14730	9943	7890	/19200
99185	9940	/ 1830	96124	7870	/16820
99182	11130	/ 1190	96233	7160	/14680
99181	11040	/ 750	96252	6660	/ 9430
10L-19[1]			97911	6660	/ 5820
9723	9380	/14360	97108	5620	/ 7920
9726	9310	/14850	96258	5950	/ 9420
97102	6480	/ 7990	961710	7540	/15930
97171	9880	/10660	97107A	5020	/ 7820
971810	9090	/ 6150	99184	9840	/ 730
97225	2150	/ 9530	97175	9280	/10730
97312	9940	/17040	98215	13680	/14020
9863	10790	/15120	98221	13740	/14440
9866	10480	/16000	98223	13740	/14560
98211	13440	/12670	98212	13550	/13420
982213	14040	/16060	6862	8930	/13580
9944	10250	/18030	9729	9020	/13380
9985	9460	/13080	97233	2260	/10790
10L-2[1]			96113	9130	/17660
10L-32[1]			971711	10740	/ 8960
10L-36[1]			971710	10660	/ 9440
R2-33[2]			97165	8940	/10080
10L-18[1]			91810	11500	/ 3850
96203	5540	/16060	97188	10240	/ 7240
96203A	5540	/16000	97187	10320	/ 6160
96206	7850	/14640	9942	7530	/19360
96232	6620	/13020	97182	9480	/10720
96272	5150	/15700	97177	9370	/10690
972410	2250	/11300	971611	10650	/ 9160
972411	1670	/11300	9989	8420	/12250
97284	2200	/11740	9736	5620	/ 9400
97285	2600	/12360	96256	5740	/ 9550
9988A	8910	/13250	98144	4220	/ 9500
5123	8900	/13200[3]	98231	14270	/18270

1 Samples collected from 1000 Level East Mine.
2 Sample taken from Rambler Mine collection, Rambler Mine.
3 Road side exposure approximately one-quarter mile east
    of Sacrey's Mill.
4 Sample collected 121-123 feet from the collar of diamond
    drill hole 353-5, Rambler Mine.

Location of analysed ore samples from the East Mine.

Diamond drill hole 500-23. (Horizontal hole drilled through the ore zone on the 500 level).

Sample	Footage	Sample	Footage
7401	0-5	7409	60-65
7402	5-10	7410	70-75
7403	10-15	7417	80-85
7404	15-20	7418	90-95
7405	20-25	7413	100-105
7406	30-35	7414	110-115
7407	40-45	7415	120-125
7408	50-55	7416	130-135

Diamond drill holes 750-21 and 750-22. Inclined holes drilled from the 750 Level. Location of drill holes shown on Plate VI.

Drill Hole 750-21

Sample	Footage	Sample	Footage
R1024	140-145	R1009	75-76
R1023	135-140	R1007	40-45
R1022	132-135	R1006	35-40
R1021	125-130	R1005	30-35
R1020	121-125	E2568F	67-72
R1019	115-121	E2567F	62-67
R1018	110-115	E2566F	57-62
R1017	105-110	E2565	52-57
R1016	100-105	E2564F	47-52
R1015	95-105	E2563F	25-29
R1014	90-95	R1004	20-25
R1013	88-90	E2506F	15-20
R1012	85-88	R1003	10-15
R1011	80-85	R1002	5-10
R1010	76-80	R1001	0-5

Drill Hole 750-22

Sample	Footage	Sample	Footage
E2581F	128.5-132	E2641F	55-60
E2582F	146-150	E2590F	35-40
E2583F	0-5	E2591F	40-45
E2584F	5-10	E2592F	45-50
E2585F	10-15	E2640F	50-55
E2586F	15-20	E2642F	60-65
E2587F	20-25	E2643F	65-70
E2588F	25-30	E2644F	70-75
E2589F	30-35	E2645F	75-78

Diamond drill hole 61 drilled from the surface. Location
of drill hole shown on Plate V.

Sample	Footage	Sample	Footage
61793	790-793	E4562	1072-1075
61752	750-755	E4563	1075-1080
61781	780-781	E4564	1080-1085
61852	850-852	E4565	1092.5-1095
61898	896-900	E4566	1095-1100
61924	922-924	E4567F	1100-1105
61926	924-926	E4568	1161-1165
61928	926-928	E4569	1165-1170
61934	930-934	E4570	1170-1175
E4545	935-940	E4571	1175-1180
E4546F	940-945	E4572	1180-1185
E4547	945-949.5	E4573	1185-1190
E4548F	949.5-955	E4574	1190-1195
E4549	955-960	E4575F	1195-1200
E4550	960-965	611222	1220-1222
E4551	965-970	E4580	1225-1227
61976	976-978	E4581	1227-1230
E4553	979.5-985	E4582	1230-1235
E4554	985-990	E4583	1235-1240
E4555	990-993	E4584	1240-1245
E4556	993-998	E4585	1245-1250
611005	1003-1005	611269	1268-1270
E4557F	1005-1010	611277	1276-1277
E4558	1010-1014.5	E4586	1277-1281
611034	1032-1036	E4587	1312-1317
E4559	1055.5-1060	E4588	1320-1325
E4560	1060-1065	E4590	1330-1335
E4561	1065-1069.8	10L-26	1000 level Quartz-chlorite schist
611071	1070-1072	10L-34	1000 level Amphibolite

Drill Hole 500-23

Drill Hole 750-21
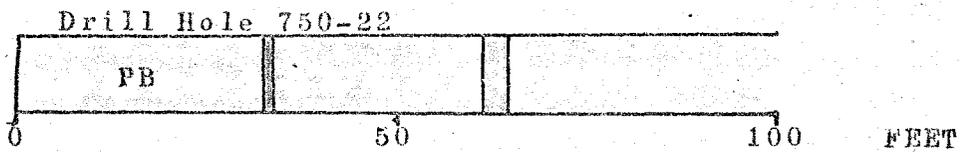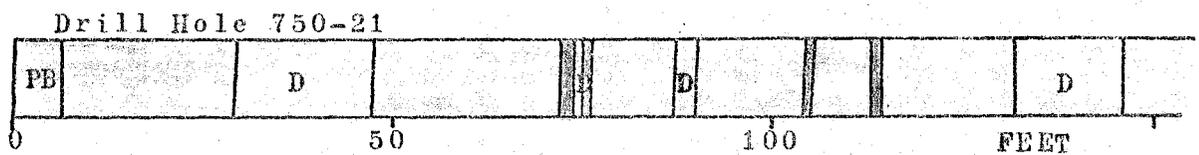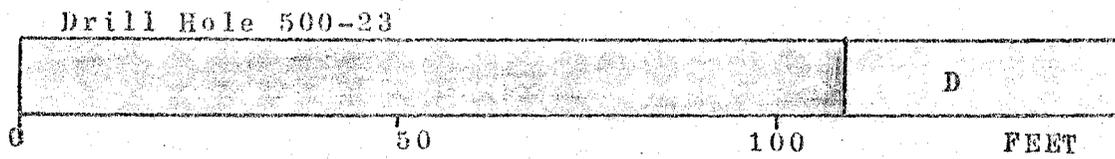
Drill Hole 750-22

Figure 1. Simplified geological log of Drill Holes
500-23, 750-21, 750-22.

      ⊕ Basic dike(D)
      ● Biotitic schist
      ⊕ Quartz-chlorite schist
      ⊕ Quartz-sericite schist
          Clastic Fragments   CF
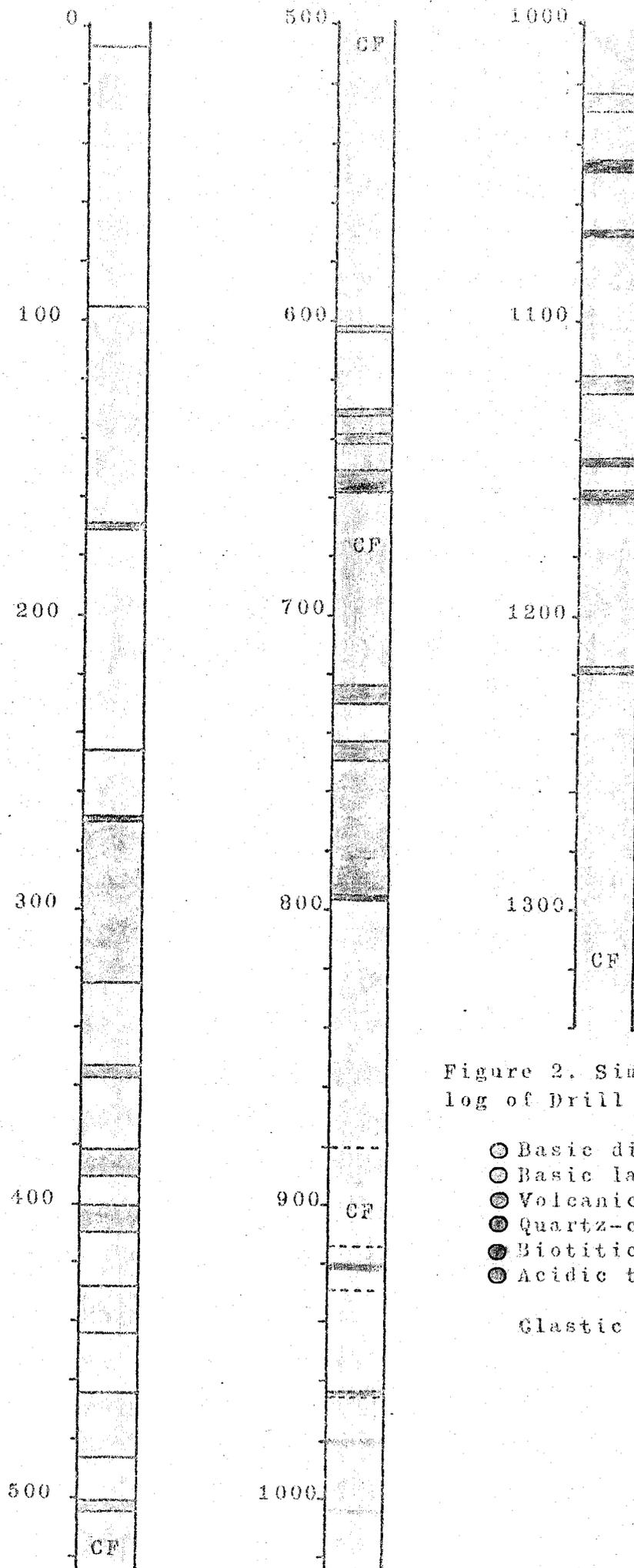   Porphyroblastic Biotite PB

FEET


Figure 2. Simplified geological
log of Drill Hole 61.

○ Basic dike
○ Basic lava
◉ Volcanic sediments
◉ Quartz-chlorite schists
◉ Biotitic schists
◉ Acidic tuffs

Clastic Fragments   CF

Description of samples used in filling-temperature measurements

7F-1-1   Quartz from a 1 cm wide quartz-chalcopyrite vein.
7F-1 drift, 750 level.

7F-1-2   Quartz separate from quartz-chalcopyrite-
pyrrhotite-pyrite veins. 7F-1 drift, 750 level.

7F-1-5   Chalcopyrite-quartz-pyrite vein 2 cm wide. 7F-1
drift, 750 level.

7-1W-3   Chalcopyrite-quartz vein 1 to 2 cm wide. 7-1W
stope muck sample, 750 level.

7-1N-1   Quartz fragments from vein or lense of glassy
quartz containing minor chalcopyrite-pyrrhotite
mineralization. 7-1N stope, 750 level.

8-1-6   Chalcopyrite-quartz vein 0.5 to 1 cm wide. 8-1W
stope, 875 level.

68-28-9   Pyrrhotite-chalcopyrite-quartz vein. 1000 level.

10L   Quartz vein. Milky-white quartz with angular
unoriented blocks of chlorite schist and occasional
pods of remobilized chalcopyrite-pyrrhotite
mineralization. 10-1S drift, 1000 level.

750-22   Chalcopyrite-pyrrhotite-quartz vein. Sulfides
(15-20)   appear to be foliated parallel to schistosity.
15 to 20 foot section of DDH 750-22.

750-22   Chalcopyrite-pyrrhotite-quartz vein 1.5 to 2 cm
(40-45)   wide. 40 to 45 foot section of DDH 750-22.

750-22   Chalcopyrite-quartz vein. 55 to 60 foot section
(55-60)   of DDH 750-22.

61-278   Milky-white quartz vein 10 cm wide cutting basic
volcanic rocks in the hanging wall. 278 foot
section of DDH 61.

63-581   Milky-white quartz vein 25 cm wide cutting basic
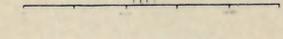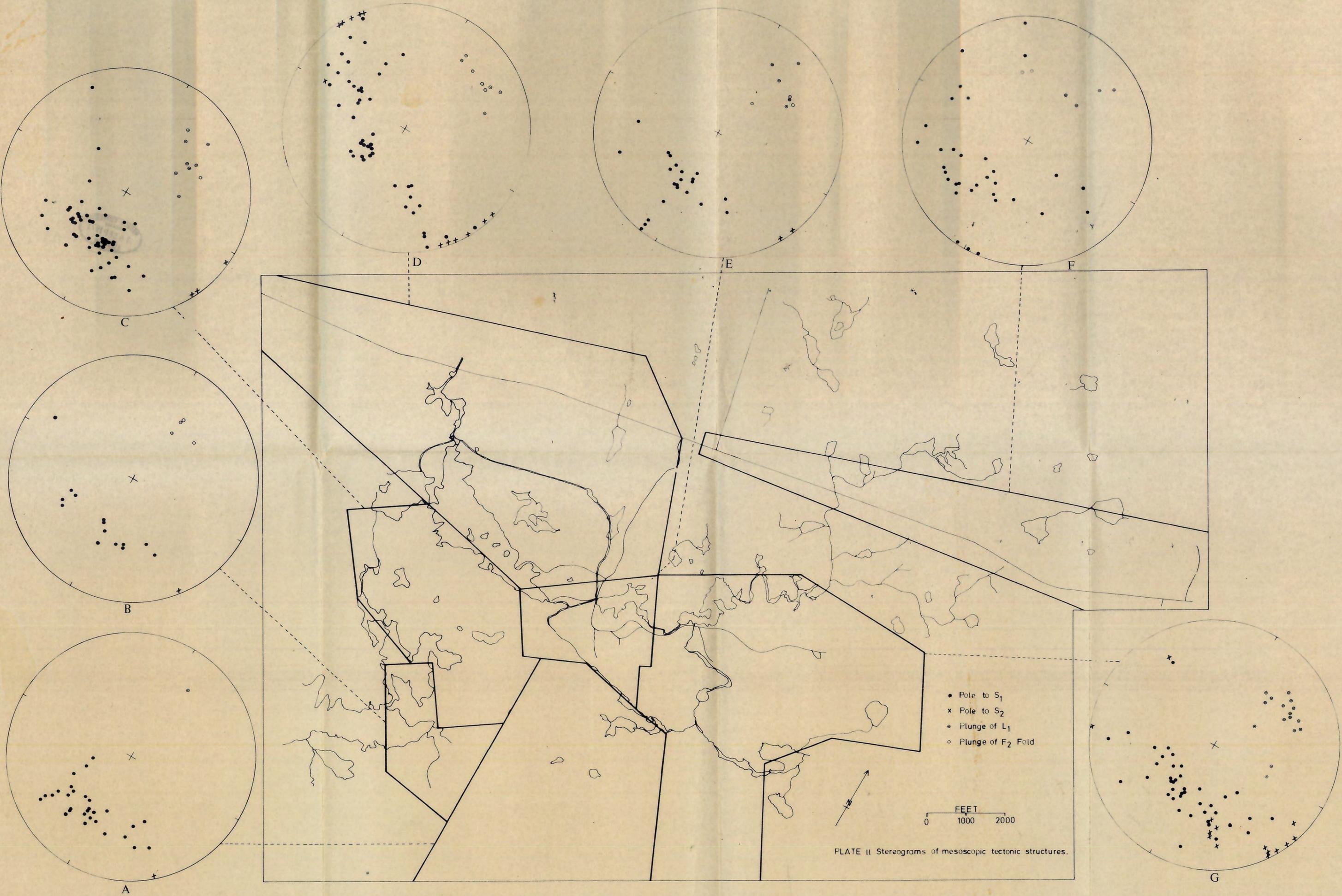volcanic rocks in the hanging wall. 581 foot
section of DDH 63.

GEOLOGY OF THE RAMBLER AREA

PLATE I

Legend:
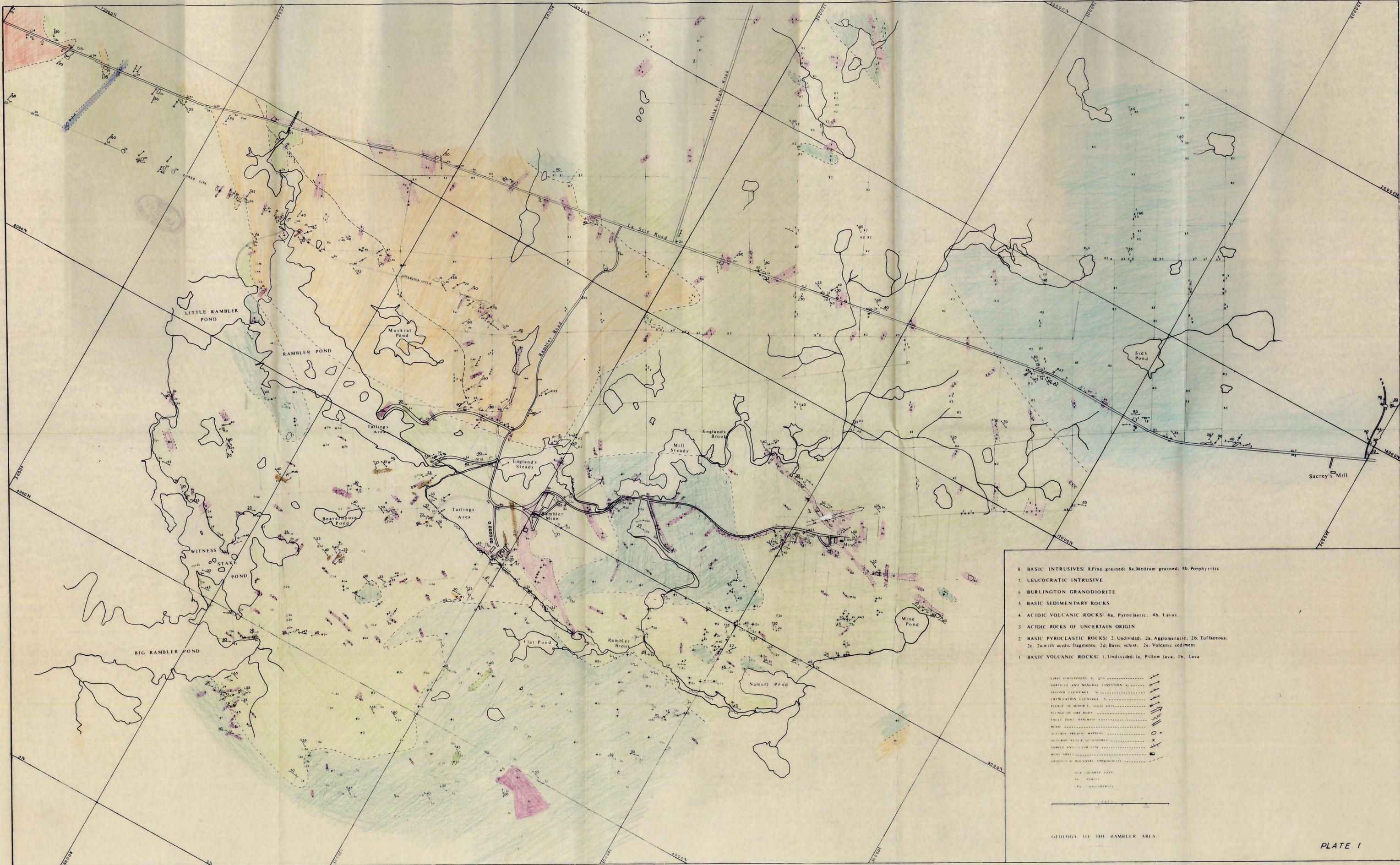
8 BASIC INTRUSIVES: 8.Fine grained; 8a.Medium grained; 8b.Porphyritic

7 LEUCOCRATIC INTRUSIVE

6 BURLINGTON GRANODIORITE

5 BASIC SEDIMENTARY ROCKS

4 ACIDIC VOLCANIC ROCKS: 4a, Pyroclastic; 4b, Lavas

3 ACIDIC ROCKS OF UNCERTAIN ORIGIN

2 BASIC PYROCLASTIC ROCKS: 2, Undivided; 2a, Agglomeratic; 2b, Tuffaceous; 2c, 2a with acidic fragments; 2d, Basic schist; 2e, Volcanic sediment

1 BASIC VOLCANIC ROCKS: 1, Undivided; 1a, Pillow lava, 1b, Lava

Map labels:

LITTLE RAMBLER POND
RAMBLER POND
BIG RAMBLER POND
WITNESS STAKE POND
Beaverhouse Pond
Muskrat Pond
Sid's Pond
Tailings Area
England's Steady
Mill Steady
England's Brook
Rambler Mine
Flat Pond
Rambler Brook
Mine Pond
Namuft Pond
Sacrey's Mill
La Scie Road
Muskrat Brook Road
Rambler Road

PLATE II Stereograms of mesoscopic tectonic structures.

Legend:
- • Pole to S_1
- × Pole to S_2
- ⊙ Plunge of L_1
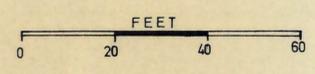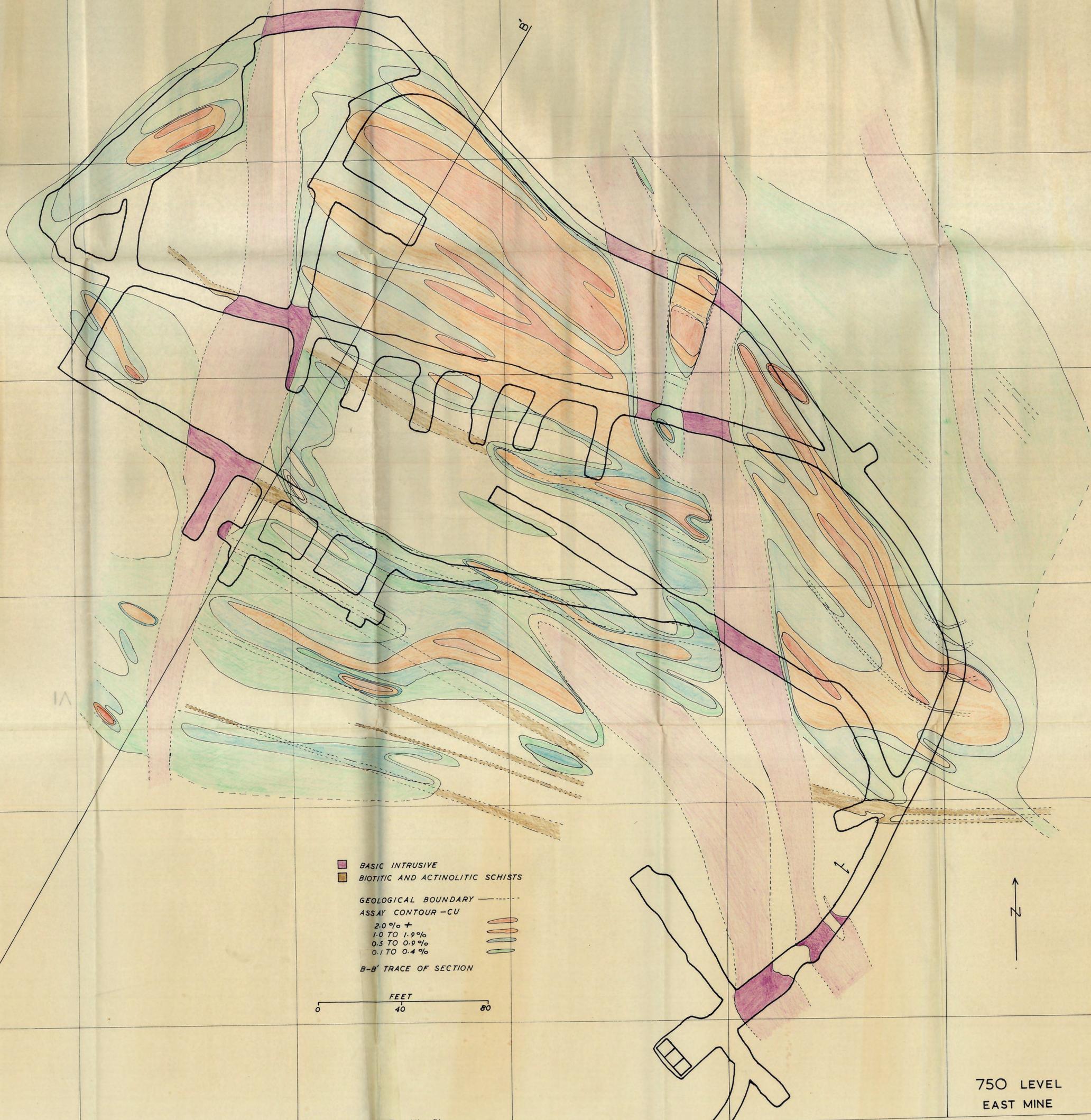- ○ Plunge of F_2 Fold

FEET
0   1000   2000
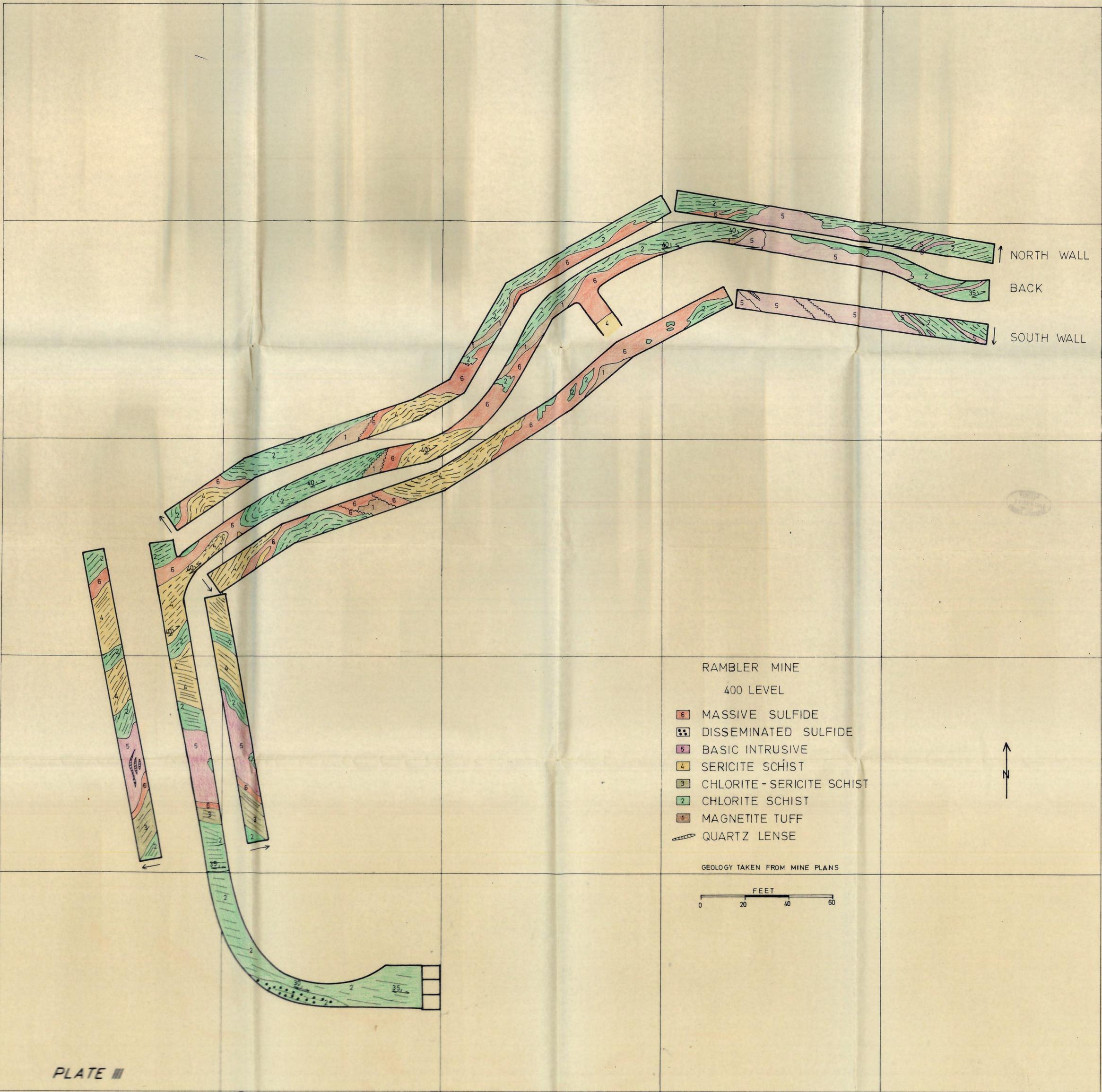
↑ NORTH WALL

BACK

↓ SOUTH WALL

RAMBLER MINE

400 LEVEL

	MASSIVE SULFIDE
	DISSEMINATED SULFIDE
	BASIC INTRUSIVE
	SERICITE SCHIST
	CHLORITE - SERICITE SCHIST
	CHLORITE SCHIST
	MAGNETITE TUFF
	QUARTZ LENSE

GEOLOGY TAKEN FROM MINE PLANS

FEET

0   20   40   60

N

PLATE III

BASIC INTRUSIVE
BIOTITIC AND ACTINOLITIC SCHISTS

GEOLOGICAL BOUNDARY ------
ASSAY CONTOUR —CU

2.0 % +
1.0 TO 1.9 %
0.5 TO 0.9 %
0.1 TO 0.4 %

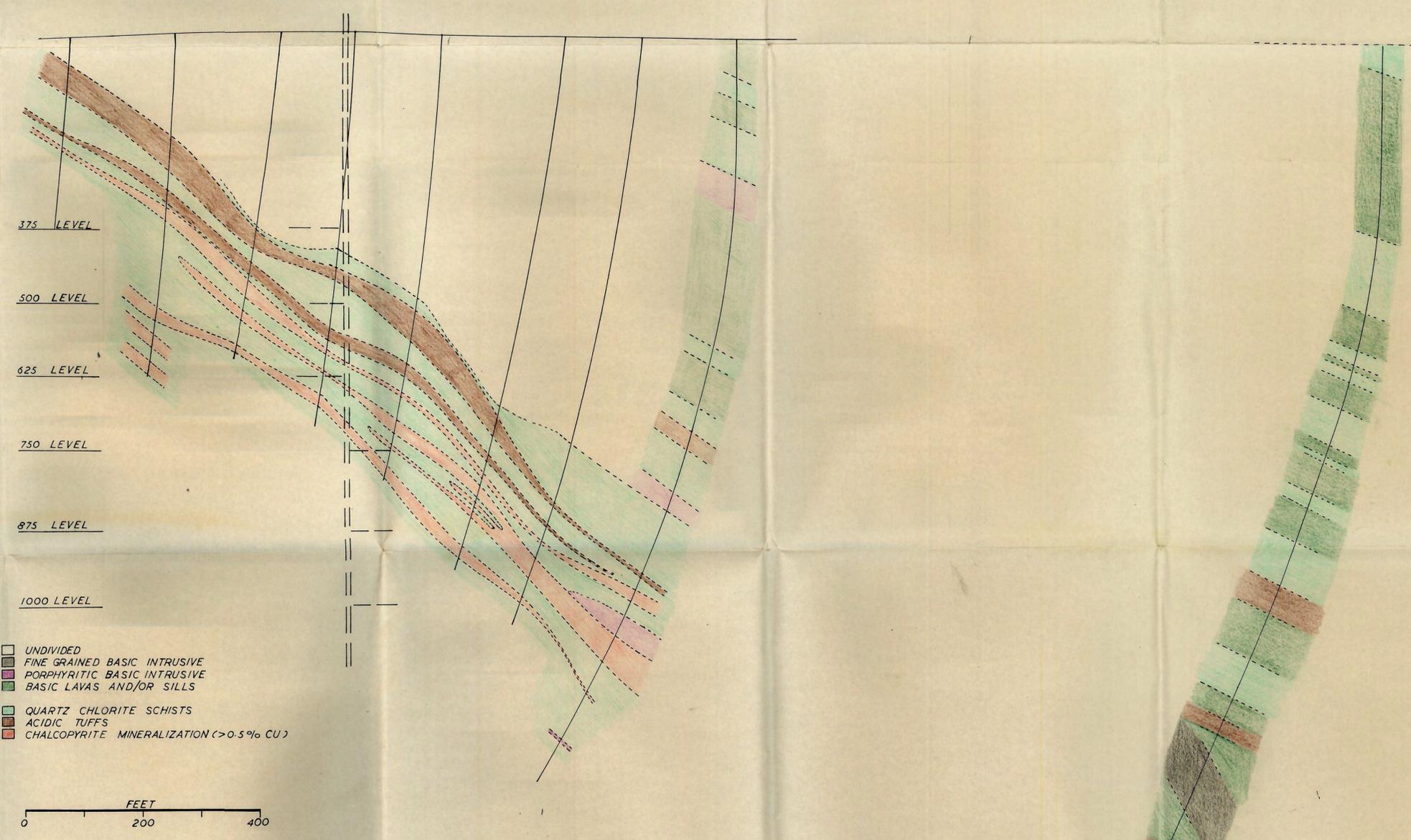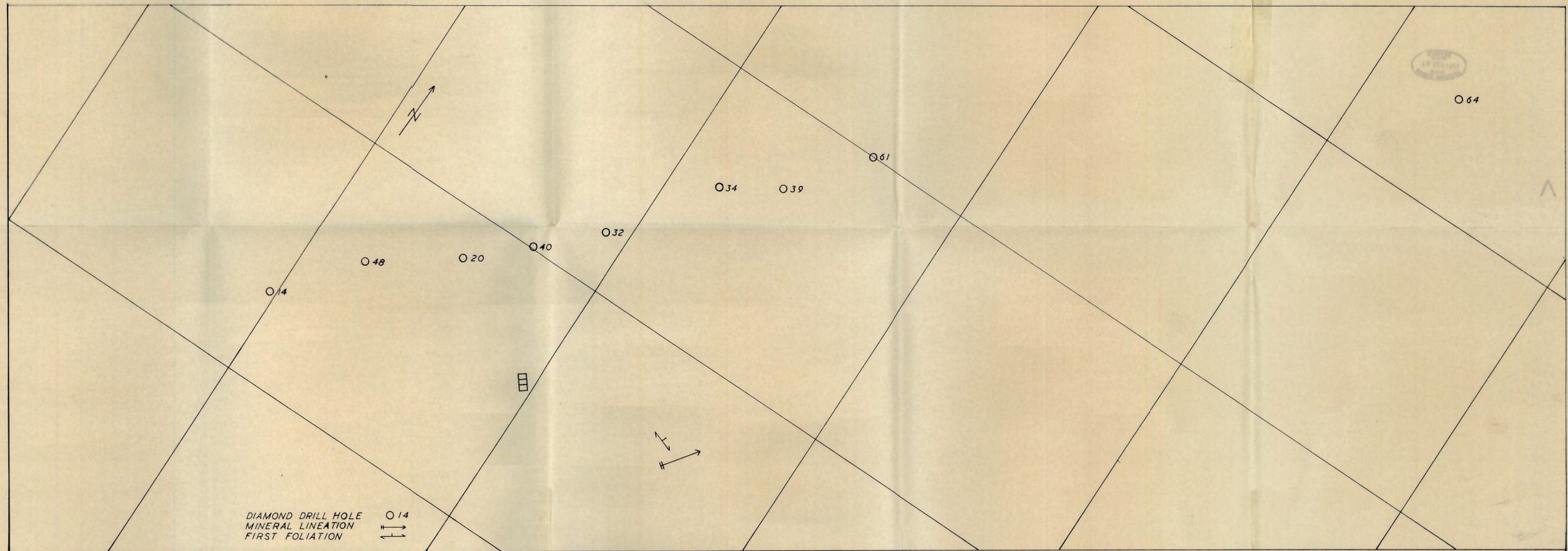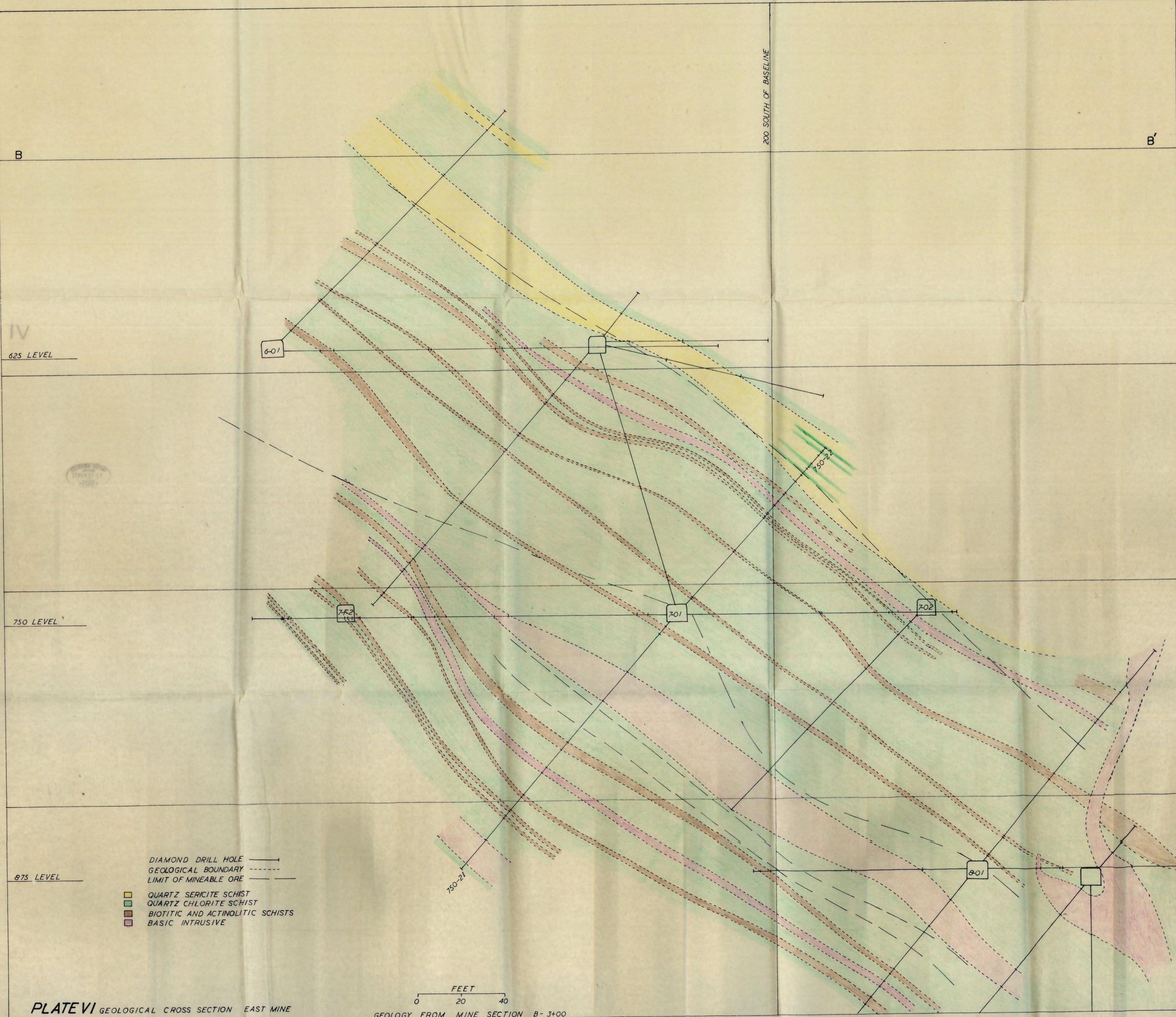B-B' TRACE OF SECTION

FEET
0   40   80
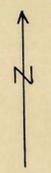
750 LEVEL
EAST MINE

PLATE IV

Data Obtained From East Mine Plans

DIAMOND DRILL HOLE ◯ 14
MINERAL LINEATION
FIRST FOLIATION

375 LEVEL

500 LEVEL

625 LEVEL

750 LEVEL

875 LEVEL

1000 LEVEL

UNDIVIDED
FINE GRAINED BASIC INTRUSIVE
PORPHYRITIC BASIC INTRUSIVE
BASIC LAVAS AND/OR SILLS

QUARTZ CHLORITE SCHISTS
ACIDIC TUFFS
CHALCOPYRITE MINERALIZATION (>0.5% CU)

FEET
0   200   400

PLATE V   GEOLOGICAL CROSS SECTION EAST MINE

B   200 SOUTH OF BASELINE   B'

IV

625 LEVEL

6-01

750-22

750 LEVEL

7-F2   7-01   7-02

875 LEVEL

750-21

8-01

DIAMOND DRILL HOLE
GEOLOGICAL BOUNDARY
LIMIT OF MINEABLE ORE

QUARTZ SERICITE SCHIST
QUARTZ CHLORITE SCHIST
BIOTITIC AND ACTINOLITIC SCHISTS
BASIC INTRUSIVE

FEET
0   20   40

PLATE VI GEOLOGICAL CROSS SECTION EAST MINE

GEOLOGY FROM MINE SECTION B-3+00