PRECIOUS METAL MINERALIZATION RELATED TO THE FALCON LAKE INTRUSIVE COMPLEX, SOUTHEASTERN MANITOBA

by

JANICE LYNN FINGLER

Department of Geological Sciences

University of Manitoba

Winnipeg, Manitoba

Canada

A Thesis

Submitted to the

University of Manitoba

In partial fulfillment of the requirement

for the degree of

MASTER OF SCIENCE

October 1991

ISBN 0-315-76814-2

PRECIOUS METAL MINERALIZATION RELATED TO THE FALCON LAKE INTRUSIVE COMPLEX, SOUTHEASTERN MANITOBA

BY

JANICE LYNN FINGLER

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

I hereby declare that I am the sole author of this thesis.

I authorize the University of Manitoba to lend this thesis to other institutions or individuals for the purpose of scholarly research. I further authorize the University of Manitoba to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

Janice Lynn Fingler

ABSTRACT

The Falcon Lake Intrusive Complex (FLIC) is a composite pluton located in the Lake of the Woods greenstone belt of the Western Wabigoon Subprovince. Gold occurrences in the area are concentrated within the complex, itself, and in the country rock bordering the pluton to the north.

Relationships between host rocks, structure, alteration, and mineralization suggest that the occurrences in the study area were formed during at least two mineralizing events. An early, pre-FLIC event localized low grade gold in zones of deformation in the country rocks. The intrusion of a diorite phase of the complex served to generate new structures, and remobilize and concentrate the gold precipitated during the early event. A later mineralization event giving rise to the interior occurrences is related to the final consolidation of quartz monzonite. Late stage magmatism coincident with tectonism produced structural traps such as breccia pipes, and may have been the source for the gold bearing fluids.

FLIC had multiple roles in the development of the occurrences in the study area: as a host, the generation of structures during emplacement and consolidation, the initiation of orthomagmatic and convective hydrothermal systems, and as a source of mineralization.

The interior occurrences can be considered as porphyry deposits in most aspects, except size. These occurrences may represent a small scale, gold dominated analogue of plutonic-type porphyry deposits.

ACKNOWLEDGEMENTS

This thesis was supported by a contract on the federal side of the Canada-Manitoba Mineral Development Agreement (1984). The author wishes to thank advisors R.F.J. Scoates and W.C. Brisbin for their guidance and patience in the completion of this study. Field assistance was provided by R. Wright and C. Duncan. The liberty of discussion and information from H. Currie and A. Mickelson greatly aided the project. Thanks are also in order to W. Rocky Thompson for numerous enlightening and entertaining discussions.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

This thesis reports the results of a study of mineralization related to the Falcon Lake Intrusive Complex (FLIC). Syn- to late tectonic plutons display a common spatial relationship with gold mineralization, and tend to occur more frequently in deformation zones. The emplacement and consolidation of zoned plutons such as FLIC may play a role in localizing mineralization both within and surrounding the pluton. Structures favourable for mineralizing fluids may develop during consolidation and the mineralizing fluids, themselves, may have been derived from late stage magmatic fluids.

This study reviews relationships such as the source of magma, mechanisms controlling its emplacement and consolidation, the source of gold, controls on its deposition, and the temporal relationships between these events. Through this process, a model useful for the evaluation of the potential of FLIC to contain economic concentrations of gold is developed.

1.1 LOCATION AND ACCESS

The study area is located within the Whiteshell Provincial Park of southeastern Manitoba, and is four kilometres west of the Manitoba-Ontario boundary (Figure 1). The area is easily accessed by Highway #1, Provincial Highways 44 and 301, and several roads within the park.

The topography of this area is typical of the Canadian Shield, with relatively low relief expressed as ridges separated by low lying muskeg. Previous exploration and logging operations have left excellent outcrop exposures both within the complex and the country rocks to the north. The access and excellent exposure have greatly facilitated recent work in the area.

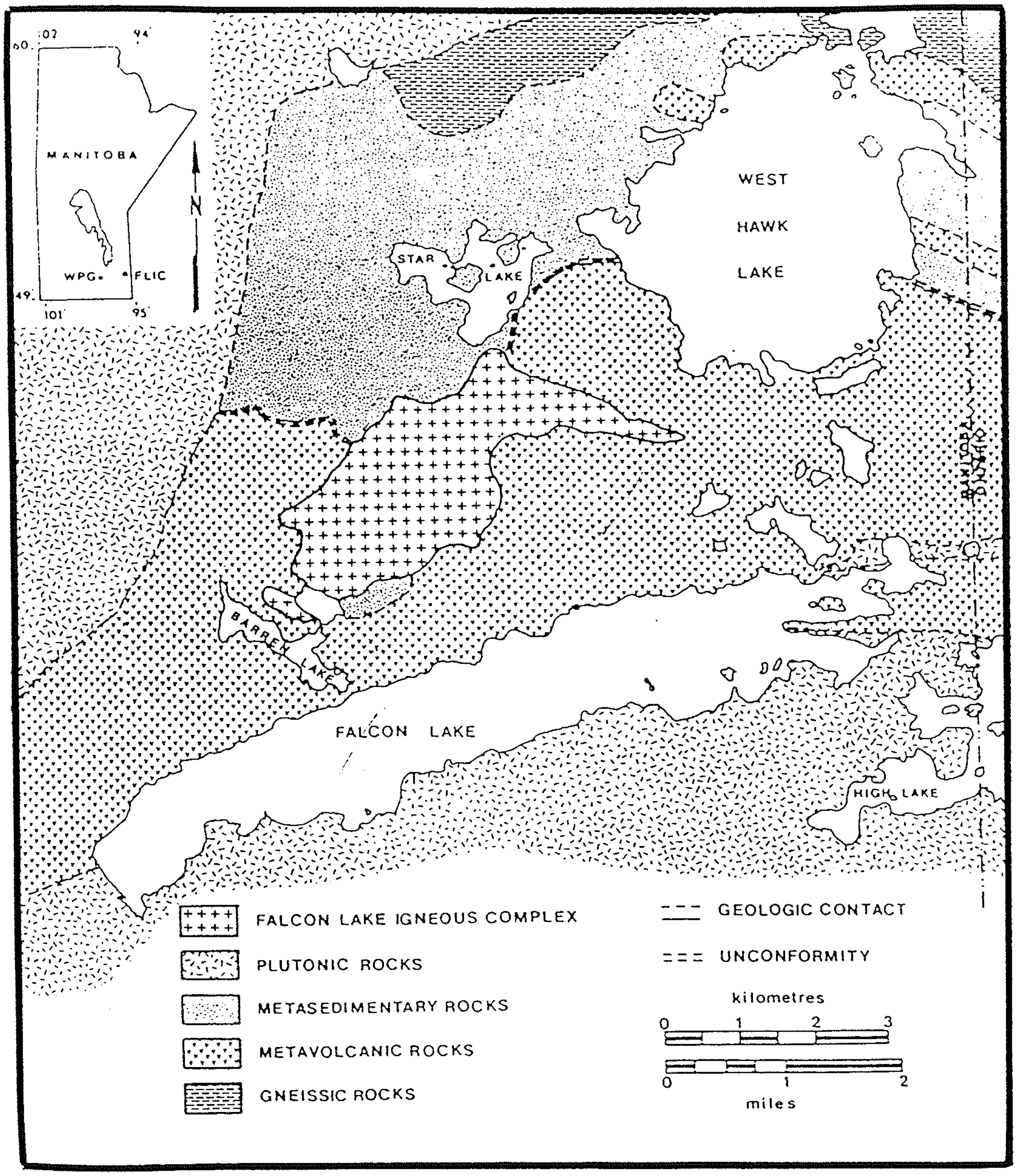


Figure 1: Location of the Falcon Lake Complex (from Mandziuk,1988)

1.2 PREVIOUS WORK

The West Hawk-Falcon Lake district has been the subject of studies in regional geology and mineralization since the early 1880's. Government and university research, combined with results from periodic exploration activity, provide abundant information pertaining to precious metal mineralization related to the FLIC.

Regional Studies

The earliest investigation of the area was completed by Lawson in 1886, and was the first reference to volcanic rocks as the Keewatin series. Wallace (1917) included the Falcon Lake area in his broad reconnaissance survey of the area to the east of the Red River. Marshall published a regional Geological Survey of Canada report of the Star Lake area in 1918. There were no further investigations until exploration inspired Brownell's (1941) study of the Falcon Lake Stock, which noted the zoned nature of the body and proposed mechanisms of emplacement. Following this investigation, Delury (1942) mapped the West Hawk-Falcon Lake area. Springer (1952) and Davies (1954) conducted regional mapping for the Department of Mines and Natural Resources, Manitoba. Both investigations noted the stratigraphy of the supracrustal sequence, and the variability of rock types comprising FLIC. Research during the years following was focussed on FLIC and possible emplacement mechanisms in studies by House (1955), Haugh (1962), and Gibbins (1967, 1971).

In 1974 and 1975, Lamb mapped much of the park area, inclusive of the West Hawk-Falcon Lakes region, in a summer program with the Manitoba Mineral Resources Division.

More recent work conducted in and around the study area includes a number of undergraduate and graduate studies by:

Chayter (1985) - a geochemical study of part of the Falcon Lake Intrusive Complex.

Johanasson (1985) - a limited gravity survey over the complex.

Quinn (1985) and Beaubien (1988) - petrographic studies of the metamorphic aureole surrounding the complex.

Mandziuk (1988) - a study of the primary structures of the complex.

Tirschmann (in progress) - a geochemical study of the different phases of the complex.

Mineralization Studies

Investigations of mineralization in the West Hawk-Falcon Lake area were first initiated in the early 1990's. The results of this work, combined with that of exploration companies (subsurface work and grade evaluation), provide valuable information concerning the nature of occurrences in the area.

The earliest studies of mineralization were conducted by Bruce (1918, 1919) and Delury (1917) who reported occurrences of gold, molybdenite and scheelite. From 1925 to 1945, several investigations were concurrent with intense exploration activity. J. F. Wright, as a consulting geologist, authored several corporate reports of activities conducted in this study area. The reports included descriptions, and grade and tonnage estimates for occurrences within the complex. Under the supervision of Wright, Harrison (1938) completed a report of the paragenesis of ore minerals associated with the Sunbeam-Kirkland mine.

The first review of occurrences in the area of the complex was done by Brownell (1941), who considered the economic potential of four characteristic mineralized zones: (a) inner contact (b) outer contact (c) pipe and (d) late fractures. Springer (1952) and Davies (1954) both reported on the economic geology of the West Hawk - Falcon Lakes area. Davies included a collective description of several occurrences. Since 1954, periodic exploration activity has been conducted, and has resulted in revised grade and tonnage estimates.

More recent studies of mineralization of selected localities include:
Halwas (1984) - a study of the features associated with the Sunbeam breccia pipe.
Barc (1985) - a study of mineralization associated with the Moonbeam occurrence.

1.3 STATEMENT OF PROBLEM AND METHODS

Since 1880, FLIC and its environs have been the focus of regional exploration for precious metal mineralization (gold and platinum group elements). Precious metal occurrences have been reported in regional studies, and also investigated independently, as in the case of the Sunbeam breccia pipe. Despite the extensive work completed to date, there lacks a collective study of the occurrences considering the relationship between crystallization processes in FLIC, and mineralization. The objective of this study are to determine:

(1) the number of mineralizing events

(2) the timing of mineralizing events

(3) the relationship between the mineralizing events and the magmatic history of FLIC

These objectives were achieved in a two phase program. Phase 1 involved reconnaissance mapping and sampling of trenches within FLIC, and its surrounding country rocks (within three hundred metres of the intrusive contact). Samples were analyzed for gold, platinum, and palladium as listed in Appendix 1.

From these results, 11 localities were selected as being representative of various types of precious metal mineralization in the study area. For each of these localities, detailed geological maps were prepared and samples were collected for geochemical analysis and thin sections (Phase 2). Historical results from sampling of the occurrences are reported in imperial units (ounces per ton, feet); results obtained during this study are reported in metric units (ppb, grams per tonne, meters). Appendix 2 lists relevant conversion factors factors from imperial units to metric units.

From this database, similarities and differences between occurrences were identified, to determine the number and timing of mineralizing events, and the role of crystallization processes and late stage magmatic fluids.

CHAPTER 2: GENERAL GEOLOGY

2.1 REGIONAL GEOLOGY

The study area is located in the Lake of the Woods greenstone belt, in the westernmost extension of the Archean Wabigoon Subprovince. The supracrustal sequence in this area consists of basal thoeliitic flows with an overlying package of sedimentary rocks, and minor proportions of intercalated pyroclastic rocks (Figure 1). The regional unconformity separating the volcanic and sedimentary sequences can be traced by a narrow horizon of underlying chert-magnetite iron formation. The entire sequence has been metamorphosed to upper greenschist facies, except in the area of post tectonic intrusions, where the metamorphic grade has been elevated to lower amphibolite facies (Gibbins, 1971, Beaubien, 1985). The prefix "meta" has been omitted from supracrustal rocks described herein.

The entire succession has been deformed into a series of closely spaced synclinal-anticlinal folds. The axial surfaces of the folds consistently strike to the northeast (Davies, 1954). Brittle shear zones cut the supracrustal sequence in northwesterly and northeasterly directions, and are commonly axial planar to the regional folds.

In the Lake of the Woods belt, the supracrustal sequence has been disrupted by several post-tectonic felsic to mafic intrusions; notably the Rennie Lake batholith to the north, and pink porphyritic granites to the west and south. The intrusion of these plutons caused local attenuation of preexisting fold axes and deflection of regional foliation to conform with the intrusive contacts.

Much of the significant gold mineralization of the western Wabigoon Subprovince is associated with felsic intrusions and regional structures (Poulsen, 1984). In the Lake of the Woods area, gold occurrences are clustered in three areas: High Lake, Shoal Lake, and northeastern Lake of the Woods, in close proximity to the post tectonic High Lake stock, the Canoe Lake stock, and the Dryberry batholith, respectively.

Gold occurrences in the High Lake stock are adjacent to, or occur within the youngest of two intrusive phases (Davies, 1965). Native gold, chalcopyrite, and molybdenite occur in quartz veins and silicified shear zones.

The Shoal Lake area hosts four past producing mines: Cornucopia, Mikado, Olympic, and Duport. Gold occurrences are concentrated around the southwest end of the Canoe Lake stock, in quartz and quartz-carbonate veins in fractures. The few showings in the stock are characterized by molybdenite, chalcopyrite, and low tenor gold.

In northeastern Lake of the Woods, the showings are clustered in close proximity to the contact between the metavolcanics and the Dryberry batholith. Four past producing deposits are hosted by fracture systems in volcanic rocks; the Wendigo mine (67,000 ounces of gold) was the largest producer. The Champion mine is the only deposit hosted by the batholith, itself.

In the Falcon Lake area, gold mineralization is sporadically distributed within the complex and in supracrustal rocks adjacent to the contact. A broad metal zonation surrrounds the complex, with predominantly gold occurrences proximal to FLIC, and tungsten (scheelite) and molybdenum (molybdenite) occurrences in distal areas.

2.2 STUDY AREA GEOLOGY

The study area comprises a folded succession of older volcanic rocks which are unconformably overlain by younger sedimentary rocks. Both sequences are folded and have been intruded by FLIC across the unconformity (Figure 2).

Supracrustal Sequence

Much of the original stratigraphy of the supracrustal sequence is preserved to the north of the complex, along the unconformable contact between the older volcanic sequence and the overlying sedimentary sequence. The supracrustal sequence is laterally continuous to the east, and top indicators are reported to indicate that the sedimentary package consistently overlies the volcanic succession (Davies, 1954). The entire sequence has been folded into a series of anticlinal and synclinal structures.

The volcanic succession is exposed to the northwest of FLIC, and consists of a series of pillowed and massive mafic to intermediate volcanic flows, which are commonly epidotized. Narrow (<5 metres) intervals of intermediate tuff occur throughout the succession and are interbedded with chert-rich horizons in the uppermost stratigraphic levels of the sequence.

The volcanic succession is separated from the overlying clastic sedimentary succession by a 0.5 to 1.0 metre wide unit of magnetite iron formation, which is exposed along a strike length of 1 kilometre. The iron formation represents either the uppermost unit of the volcanic sequence, or the basal unit of the sedimentary sequence. Both the iron formation and the matrix of the overlying conglomerates are highly gossanous.

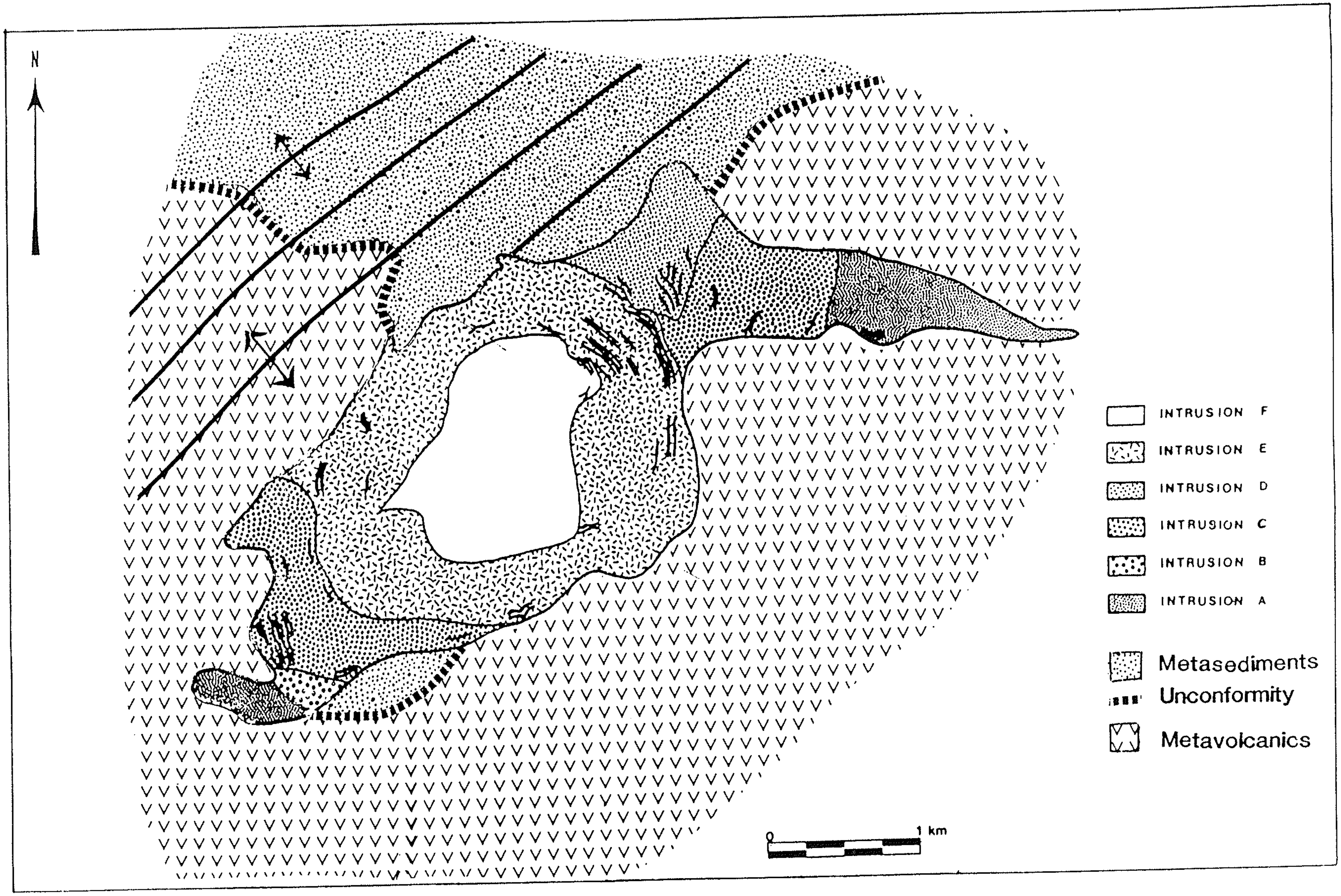


Figure 2: Study area geology (adapted from Mandziuk,1988)

The clastic sedimentary sequence consists primarily of conglomerates with interbeds of conglomeratic arkose and arkose. The exposed widths of these units ranges from 2 - 25 metres, and they pinch and swell laterally. The conglomerates are polymictic and paraconglomeratic, and contain varying proportions of clasts. The mafic volcanic clasts range from 1 - 10 centimetres in size. The matrix component is predominantly quartz, feldspar, and mafic minerals, in variable abundances. The conglomerate matrix is locally arenaceous.

Within the map area, graded cycles in the sedimentary succession are documented by upward increasing proportions of matrix to clasts and decreasing clast size. The sedimentary sequence has several cycles of upward grading, as shown by increasing matrix abundances and decreasing clast sizes. Internal fluctuations from normal to reverse grading within the conglomerates are indicative of an intermittent process.

The association of poorly sorted conglomerates with rounded clast component is indicative of an active environment of deposition, possibly similar to those which form submarine fan or slump deposits. The sedimentary processes postdated active volcanism, and therefore, the contact between the volcanic sequence and the overlying sedimentary sequence represents a regional unconformity.

Falcon Lake Intrusive Complex

FLIC is a composite intrusive body with an area of approximately 10 square kilometres. The core of the complex is elliptical in form and surrounding intrusions form tapering extensions to the southwest and northeast. Large dykes cutting the country rocks have been observed along the northern contact of FLIC.

In his study of the primary structures, Mandziuk (1988) has identified six individual intrusions that constitute FLIC (Figure 2). The four outermost intrusions (A,B,C,D) are all coarse grained gabbros and pyroxenites with cumulate textures. Towards the interior of the body, there is an annular ring intrusion (E) ranging from diorite to granodiorite in composition. The innermost intrusion (F) is composed of quartz monzonite. Intrusions (E) and (F) both display porphyritic textures. The compositional trend, from gabbro in the outer intrusions to a core of quartz monzonite, suggests a common magma source, possibly from a differentiating magma chamber at depth. The textural variation indicates that the intrusions were crystal-liquid mixtures during emplacement and remained as such throughout much of their cooling histories.

The form and arrangement of primary structures such as mineral orientation, layering, discordant intrusive structures, erosional structures, xenoliths and cognate inclusions, and breccia pipes, all serve to indicate the nature of emplacement mechanisms and later magmatic processes. The variety of orientation of mineral lineations and planar laminations throughout the intrusions resulted from fluctuating flow conditions during much of the magmatic history of the complex. Modal and grain size layering are found in straight, planar, or wavy forms. Scours and trough-banding features, and the truncation of layering to form angular unconformities are common erosional products. Such fabric elements might be generated under fluctuating flow conditions, and crystal-liquid segregation and accretion to sidewalls. Intrusive dykes are distributed throughout FLIC, and their age relationships show that successive intrusions cooled sufficiently to support brittle behaviour. Breccia pipes near the core of the complex are believed to be related to a late volatile-rich hydrothermal event during the final consolidation of intrusion (F).

Mandziuk (1988) has made the following interpretations concerning the emplacement and consolidation history of the complex:

(1) Crystallization has occurred in several stages, both before and after emplacement.

(2) Magmatic flow was the major process both during emplacement and consolidation.

(3) The individual intrusions had complex and dynamic emplacement and consolidation histories.

(4) The relationship between the six component intrusions indicate a sequential emplacement history.

2.3 GEOCHRONOLOGY

Although the ages of supracrustal rocks in the studyt area remain undetermined, the result of a regional study of ages for the western Wabigoon Subprovince by Blackburn et al. (1985) suggests that most of the volcanic rocks devoloped between 2700 and 2800 Ma. Folding and tilting of the supracrustal rocks was followed by emplacement of plutons. In the western Wabigoon greenstone terranes, the post tectonic intrusions have an estimated age range of 2695 to 2710 Ma, and are the youngest rock type to host gold mineralization.

A precise crystallization age for the component intrusions of the FLIC has not yet been determined. A recalculation of a K-Ar (biotite age for the quartz monzonite gives a minimum age of 2246 +/- 70 Ma (Halden et al.,1990). Two samples of galena in quartz monzonite from the Sunbeam mine, yielded Pb-Pb ages of 2685 and 2678, +/-6 Ma (R.I. Thorpe, pers. comm.). A similar post tectonic intrusion, the Rennie Lake batholith, yielded a minimum whole rock Rb/Sr age of 2300 Ma.

CHAPTER 3: DISTRIBUTION AND EXPLORATION HISTORY OF OCCURRENCES

In the study area, reported occurrences of precious metal mineralization are located within the boundaries of nine mineral leases and two mining claims (Figure 3). Exploration has been conducted in the area since the claims were first surveyed around the turn of the century. Since that time, several of the claims have become mineral leases; some have been renamed. The occurrences are referred to by former claim names under which much of the exploration work was completed. The study references and present names are:

Study Reference	Present Status
Sunbeam	Lease
Moonbeam	Lease
Waverley	Lease
Sundog	Lease
Gold Coin	Lease
Denmark	W6389
Moore	Lease
Narwark	Lease[Naswaak]
Sheba	W4809[Sun]
Gem	Lease
Rad	W50346[Pen]

The assay results of sampling of trenches and pits on these claims are listed in Appendix 1. Significant gold values were associated with samples from localities

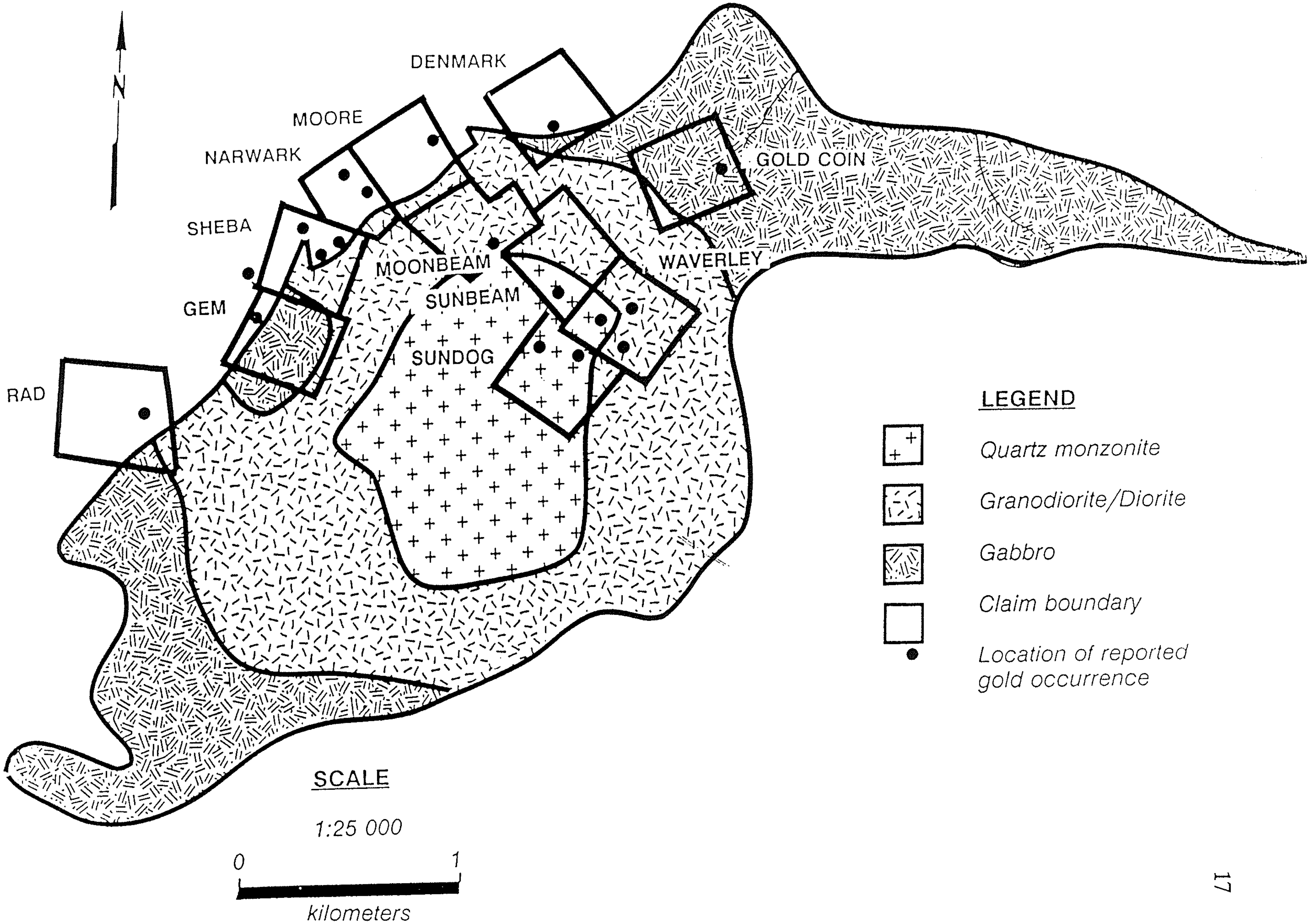


Figure 3: Distribution of gold occurrences on claims in the study area

on the Sunbeam, Moonbeam, Waverley, Sundog, Moore, and Rad claims. Previously reported values for platinum group elements could not be substantiated.

The occurrences have a distribution which is either centered within the complex (interior occurrences), or in country rocks to the northwest of the intrusive contact (exterior occurrences). The interior occurrences are hosted by various component intrusions of FLIC, and confined to brittle or brittle-ductile structures. The exterior occurrences are hosted by a variety of lithologies and structures.

3.1 INTERIOR OCCURRENCES

Distribution

The documented gold occurrences within FLIC are located in all phases of the complex, but are concentrated near the northeastern intrusive contact between granodiorite and quartz monzonite (Figure 3). An exception is the Gold Coin showing, which is hosted by gabbro.

Exploration History

Occurrences within the complex are situated on the Sunbeam, Moonbeam, Waverley, Sundog, and Gold Coin claims, which were first staked during the years 1912-1913. Samples taken at this time reported gold values at these localities, and platinum group element values on the Waverley and Gold Coin claims, as well.

The Sunbeam group of contiguous claims were restaked, reassigned to various holders, until 1928, when all were assigned to Fred Kennedy. From this time, continuing in the 1930's, there was extensive exploration activity. The focus of the efforts was on the Sunbeam claim, were a shaft was sunk on the breccia pipe. In 1936, the option for the Sunbeam group was sold to Sunbeam-Kirkland Gold Mines

Limited, who developed the three levels of drifting on the pipe. Early reserve estimates by Wright(1943) indicated 110,000 tons at 0.256 opt gold.

In 1941, mineral leases with 21 year terms were issued for all claims held as the Sunbeam group. During 1941-1943, the property was assigned to Goldbeam Mines Limited and extensive drilling led to the sinking of an exploration shaft (Waverley shaft) on the Letain structures.

Since this time, the Sunbeam group of claims have been optioned to several different holders. Most recent work on the property was reevaluation of the old workings, and drilling, conducted from 1985-1987.

3.2 EXTERIOR OCCURRENCES

Distribution

The reported gold occurrences concentrated in the country rocks surrounding FLIC are all within 300 metres of the northern intrusive contact (Figure 3). The country rocks along this contact consist of a sequence of mafic to intermediate volcanic flows which are separated from overlying units of arkose and conglomerate, by a narrow iron formation. The occurrences in this area are hosted by a variety of lithologies and structures.

Exploration History

Interest in the area north of FLIC commenced during the years 1890-1910. The majority of stripping and trenching in the area was also completed during this time. By 1910, Penniac Reef Gold Mines Limited developed an 85 foot open shaft on the Moore showing. Bulk sampling was completed, and reported both gold and platinum values. During the 1930's, diamond drilling was concentrated on the

Moore and Rad claims. Little work is recorded beyond this time, and the claims have been optioned and reassigned to several holders.

CHAPTER 4: GEOLOGY OF INTERIOR OCCURRENCES

The interior occurrences are hosted by various component intrusions of FLIC, but are concentrated near the contact between granodiorite and quartz monzonite (Figure 4). The occurrences are all localized within structures such as breccia pipes, shear zones and faults. Two exploration shafts located in the area investigated the Sunbeam breccia pipe and fault, and the Letain and Sundog shear zones.

Each occurrence within the complex demonstrates structural control as either breccia pipes or shear zones. The development of most of these structures and associated mineralization postdated the emplacement of all intrusive phases. However, there remains some question concerning the nature of the Gold Coin occurrence. Shear zones consistently trend northeasterly, and have variable dips to the southeast. Breccia pipes on the Sunbeam and Moonbeam claims are reported to plunge to the northwest. The Sunbeam fault is exposed on the 300 level of the mine; the surface expression may be the fault reported on the Sundog claim.

4.1 SUNBEAM CLAIM

Sunbeam Breccia Pipe

The Sunbeam property hosts the gold-bearing Sunbeam-Kirkland breccia pipe, located in the northeastern corner of the quartz monzonite core of the complex. The pipe has an elliptical outline on surface, and has a surface area of approximately 1500 square meters. The orebody contained within the pipe plunges 60 degrees at N30W.

Between the years 1938-1945, the structure was explored downdip with an inclined shaft to the 425 foot level (Figure 5). Approximately 900 feet of drifting

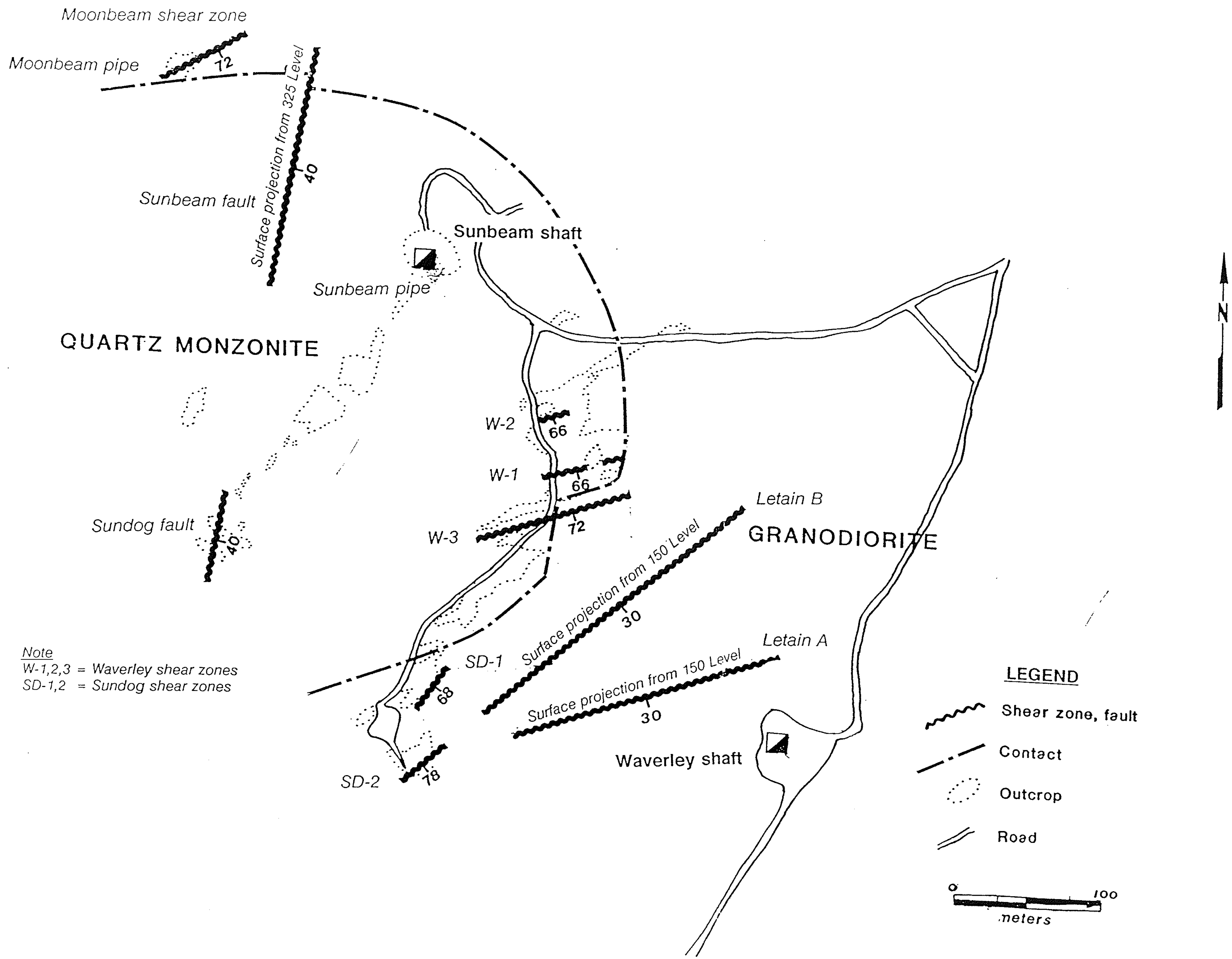


Figure 4: Distribution of interior occurrences

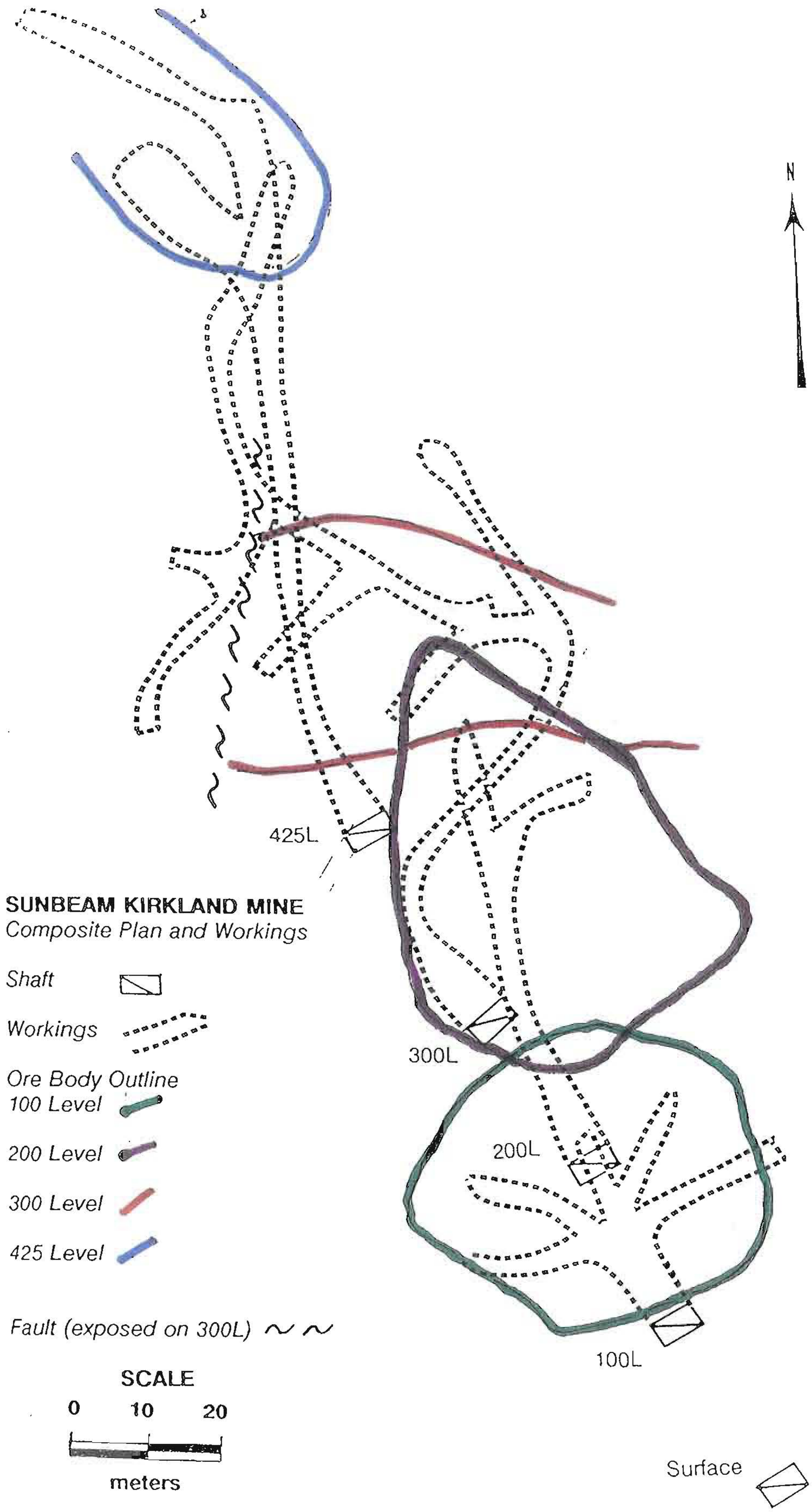


Figure 5: Composite plan of the Sunbeam-Kirkland Mine workings (adapted from Portigal, 1938)

was completed on the 100, 200, 300, and 425 foot levels. This development work confirmed both the plunge of the pipe, and its consistency in form, to the 425 level. A fault identified on the third level has displaced the pipe 35 meters to the northeast. Drilling shows that the pipe continues below the fault and remains open at depth.

Halwas (1984) examined the surface exposure of the Sunbeam breccia pipe, and identified four zones, on the basis of lithologic and structural components (Figure 6). Zone 1 (outermost) consists of quartz monzonite with widely spaced fractures. This zone is gradational towards the core, into Zone 2 which is composed of closely spaced "sheeted" fractures that are concentric around Zones 3 and 4. Zone 3 is confined to the west and northwestern portions of the inner core. It is characterized by brecciated and altered quartz monzonite which is locally mineralized. Zone 4, which is an area of brecciated, more intensely altered quartz monzonite hosting the bulk of the mineralization, defines a high grade core.

Zone 1

Zone 1, the outermost zone of the pipe, consists of an array of widely spaced fractures parallelling the concentric alignment of oligoclase and microcline crystals that are interpreted to owe their alignment to magmatic convection (Haugh, 1962). The fracture spacing decreases from 5 meters to 1.5 meters towards the core of the pipe. The fractures have been dilated to widths of 0.5-1 mm and filled with coarse grained quartz and biotite-pyrite clusters.

The host quartz monzonite is relatively fresh, as noted by the preserved coarse grained crystalline phenocrysts of microcline and overgrowths of microcline

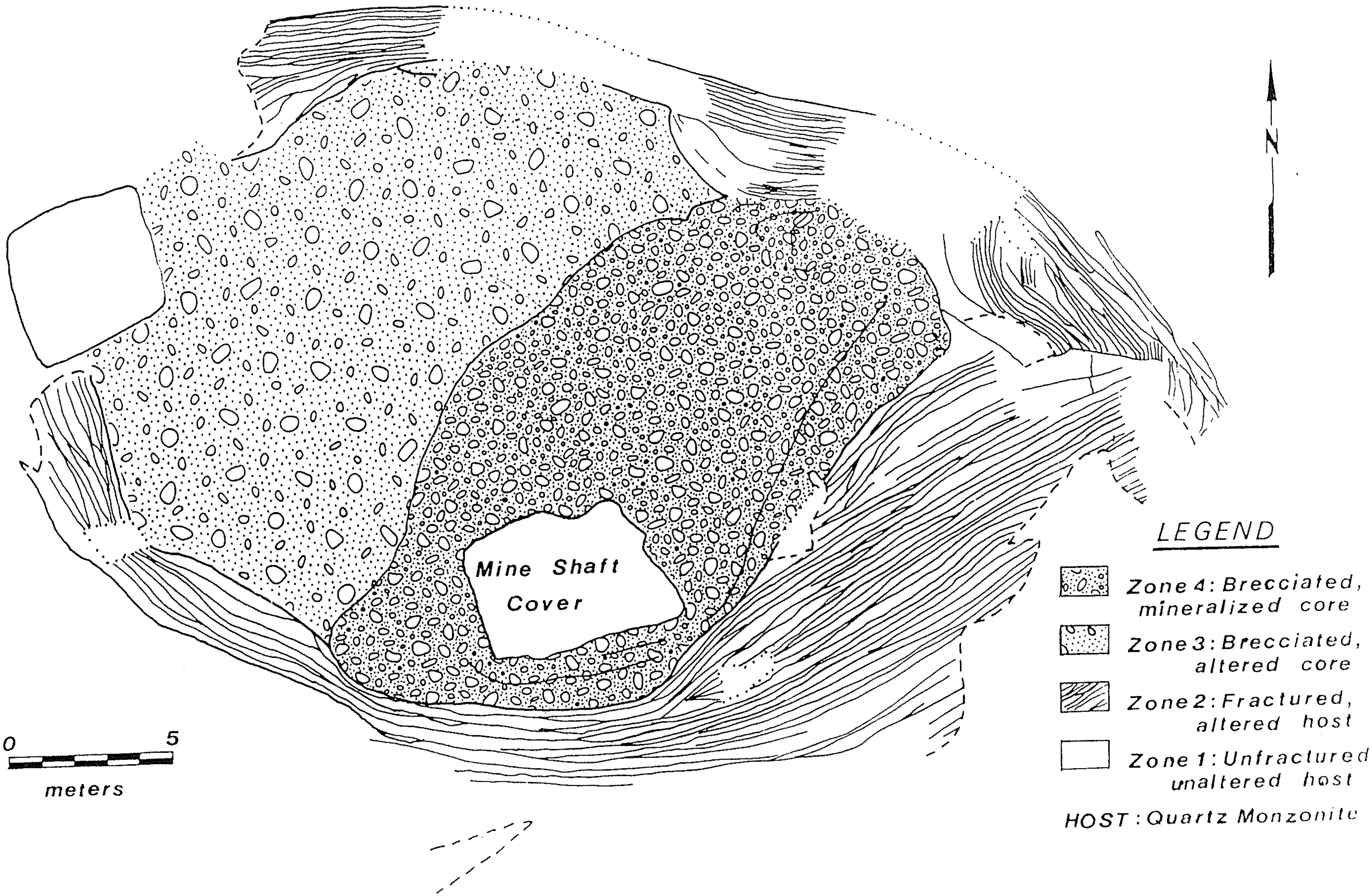


Figure 6: Geology of the Sunbeam breccia pipe (from Halwas, 1984)

on oligoclase. The medium grained groundmass is composed of microcline, oligoclase, and hornblende replaced by fine chlorite, biotite, and epidote. The degree of alteration observed is slight, and is most prominent adjacent to fractures. Alteration consists of weak sericitic and carbonate replacement of oligoclase and microcline.

Zone 2

Zone 2 is defined by closely spaced parallel fractures which are concentric around the core of the pipe. The outer contact between Zones 1 and 2 is defined by a 2 centimeter thick quartz-filled fracture and an abrupt increase in fracture density. The steeply dipping fractures are 1-5 cm apart, separated by unrotated blocks of quartz monzonite. The contact between Zone 2 and Zone 3 is gradational over 1 meter, where concentric fractures are replaced by blocky fractures, brecciation, and intense alteration.

The fractures are 0.8-2.2mm bands of medium grained quartz and biotite-pyrite, with minor amounts of sericite and fine grained quartz concentrated along the borders. Sericite and quartz are interpreted as representing the products of alteration of cataclastic material which was generated by small displacements along the fractures. The blocks of quartz monzonite between fractures are variably altered, and alteration is more pronounced towards the core of the pipe. Locally, alteration of quartz monzonite is more intense immediately adjacent to fractures. The fractures were thus preferred loci for the migration of hydrothermal fluids.

Zone 3

Zone 3 occupies the west and northwestern portion of the inner core of the pipe (Figure 6). The zone is characterized by a clast supported monolithic breccia of relict quartz monzonite fragments and a comminuted matrix. The fragment population is dominated by angular to subangular blocks of quartz monzonite with subordinate amounts of rectangular tablets of similar composition, and traces of medium grained quartz with associated hydrothermal biotite-pyrite clusters. The angular blocks are distributed evenly throughout the zone; however, the breccia itself is poorly sorted in terms of fragment size. The fragments typically show moderate sericitic, carbonate and potassic alteration which is concentrated along clast rims. In outcrop, the alteration bleaches fragment edges (Figure 7). The rectangular tablets range from 5-15cm x 1-3cm in size, and are concentrated in the area adjacent to Zone 2. Rare clasts of medium grained quartz (1-10mm x 1-3mm in size) are observed in thin section; however, the distribution remains undetermined.

Alteration of the matrix component, derived from milled, altered quartz monzonite, produced a fine grained rock flour composed of quartz, sericite, carbonate and biotite-pyrite. Sericite veinlets anastomose around breccia fragments.

Zone 4

Zone 4 occupies the eastern area of the inner core and is in contact with Zones 2 and 3. This zone is brecciated throughout; however, clast:matrix relationships have been obscured by intense alteration and a well developed gossan. The fragment varieties and distribution are similar to Zone 3. However, in the area

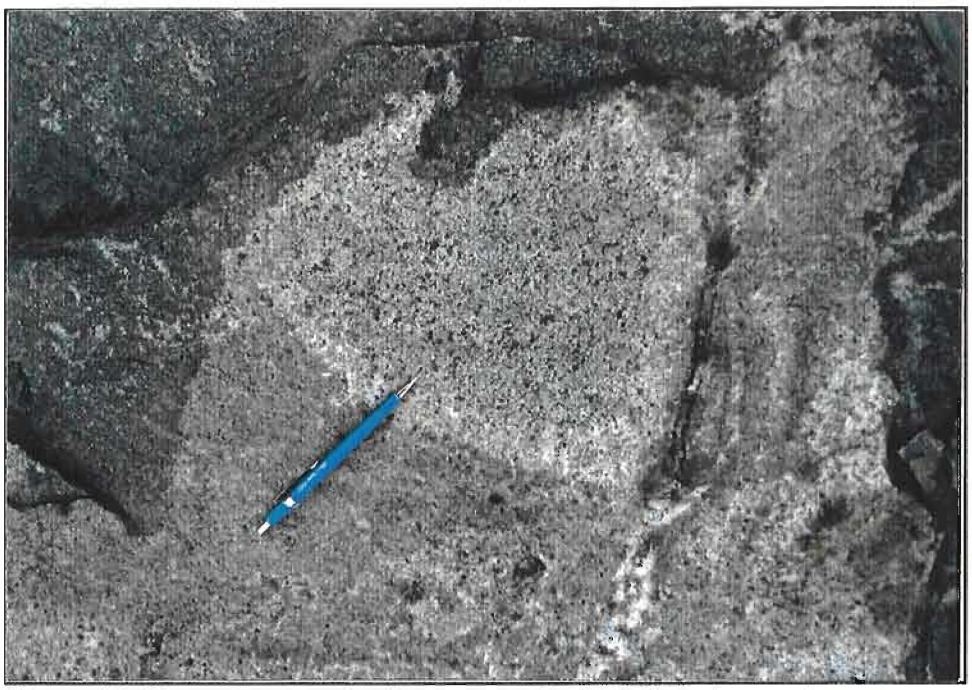


Figure 7: Quartz monzonite fragment with bleached, intensely sericitized rim, Zone 3, Sunbeam occurrence.

adjacent to Zone 2, there is an abrupt increase in the abundance of rectangular tablets. Alteration is also similar to Zone 2 and original crystals of microcline and oligoclase may be completely obliterated by sericite, carbonate and silicic alteration.

Late fractures and narrow shear zones of irregular orientation are concentrated in Zone 4, and also cut boundaries with other zones. The shear zones form anastomosing networks (1-5 cm wide) continuous over 1-5 metres. Coarse grained quartz and sulphides were introduced along many of these late structures.

Alteration

Propylitic, biotitic, sericitic, carbonate and fine grained and coarse grained silicic alteration are recognized at the Sunbeam occurrence. The distribution of these alteration types define a discrete halo centered around Zone 4 (Figure 8).

Propylitic alteration of hornblende to biotite, chlorite and epidote is common to all zones and extends beyond the breccia pipe into unfractured quartz monzonite. Propylitic alteration is overprinted by a halo of sericite, carbonate, and silicic alteration which is confined to the fractured and brecciated areas of the pipe. The volume of sericite in a zone appears to be porportional to the number of alteration (+/- deformation) events which affected the area.

Sericite commonly occurs as flakes and fine grained aggregates with minor carbonate in quartz monzonite blocks of Zones 1, 2, and clasts and matrix of Zones 3, 4. In Zones 1 and 2, sericitization increases towards each fracture and bleaches the quartz monzonite blocks. Within Zones 3 and 4, sericitic alteration has affected the comminuted matrix component, and flakes of sericite are aligned parallel to cataclastic textures of the matrix, or in intensely milled, unoriented sections of matrix, form mats of flakes commonly oriented at right angles to each other

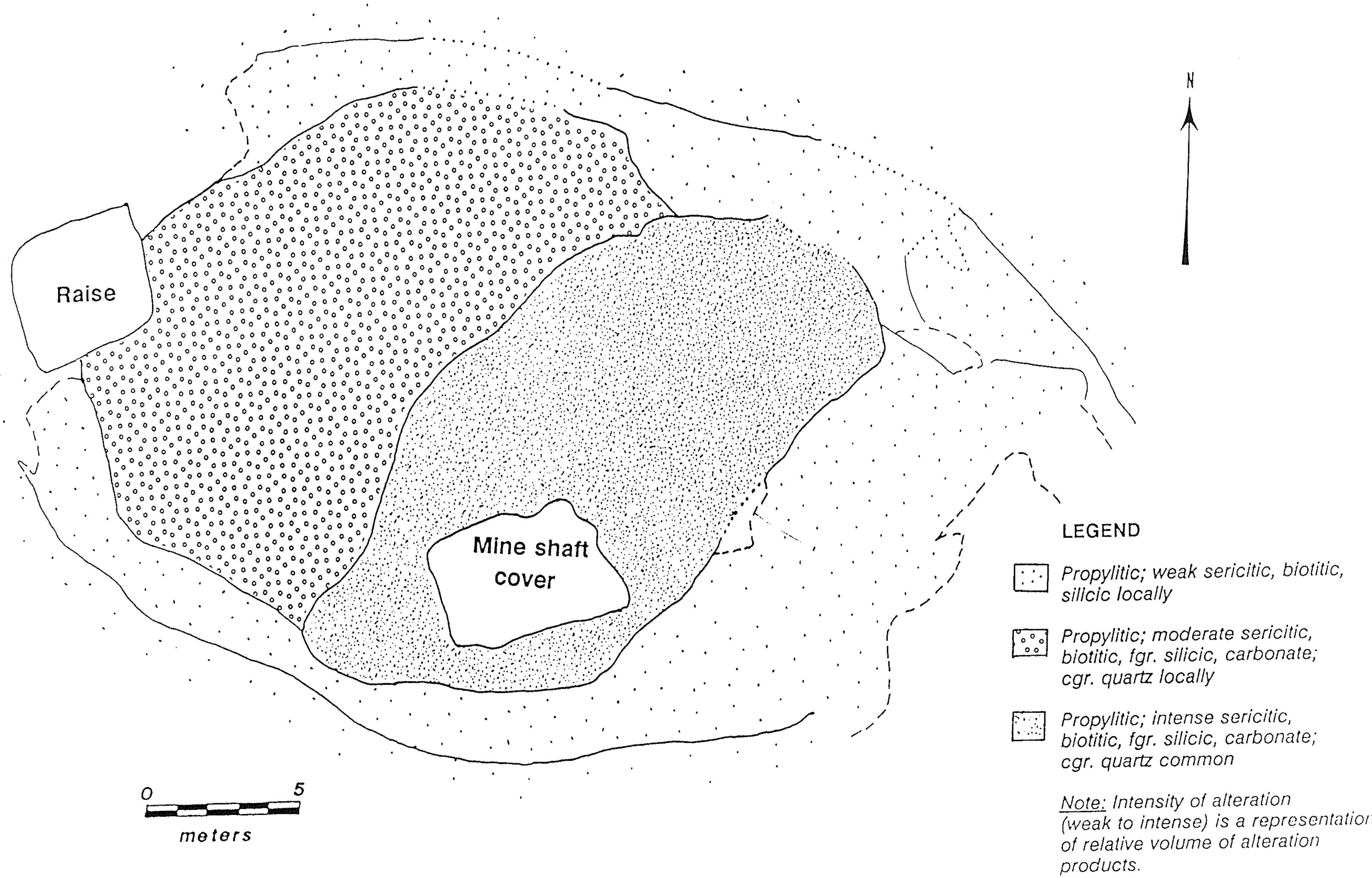


Figure 8: Distribution of alteration within the Sunbeam breccia pipe

(Figure 9). On the weathered surface, this altered matrix appears as areas of grey-green material between fragments (Figure 10). Some of the larger fragments have bleached, sericitized rims, presumably as a result of hydrothermal fluid migration restricted to matrix areas. There is an abrupt increase in sericitic alteration in Zone 4 and feldspars have been completely obliterated.

Clusters of pale brown hydrothermal biotite ranging in size from 0.5 to 10mm, averaging 2mm, are indicative of potassic alteration (Figure 11). Sulphides such as pyrite may be associated with these clusters. This alteration occurs throughout the breccia pipe, most commonly in sericitized, silicified zones, or as fracture fillings. Biotite in fractures produces a dark outline on the weathered surface. Clusters of biotite are common to both fragments and matrix of the breccia, and increased abundances correspond with abundances of other types of alteration.

Fine grained silicification has a similar distribution as sericitization. The silica front occurs as 0.1mm granular mosaic quartz aggregates. In the fracture zone, quartz monzonite blocks separated by fractures show weak silicification. Fragments in breccia zones are moderately silicified, and the matrix has been extensively silicified (up to 50-60% quartz).

Coarse grained silicification is localized in dilational fractures of Zones 1 and 2, or patches and veins within the late fractures and shear zones which transect Zones 3 and 4 (Figure 12). Coarse grained quartz is also concentrated in matrix areas of the breccia zones. This variety of introduced quartz crosscuts all other alteration species in all areas. Coarse grained biotite-pyrite clusters commonly accompany the coarse grained quartz (Figure 13).

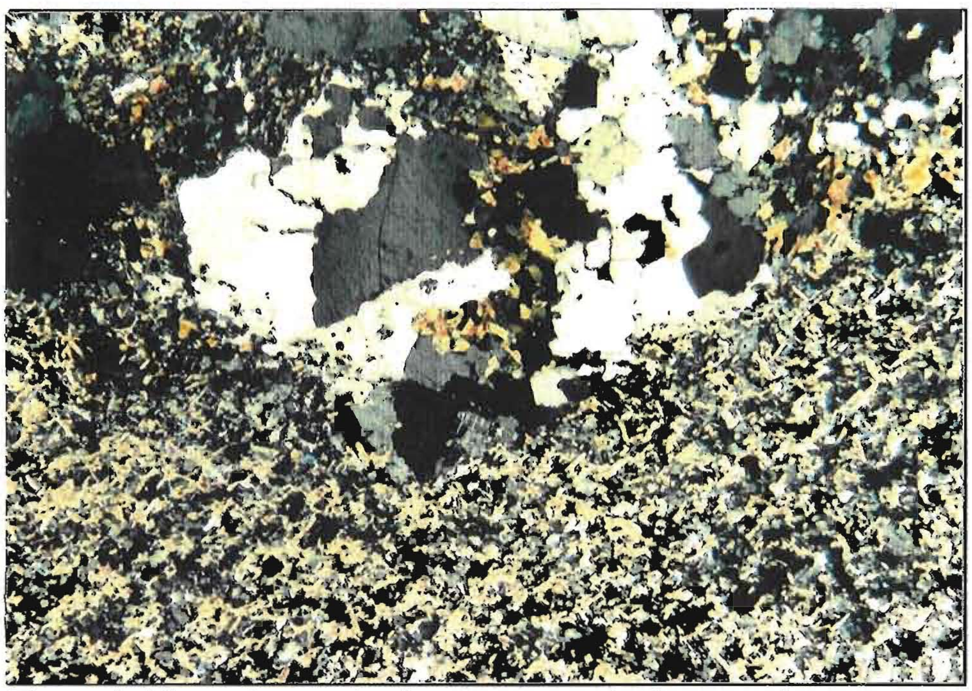


Figure 9: Photomicrograph of quartz monzonite fragment (upper, coarse grained) in a fine grained highly sericitized matrix (lower), Zone 3, Sunbeam occurrence. Field of view = 6.5 mm, cross polarized light.

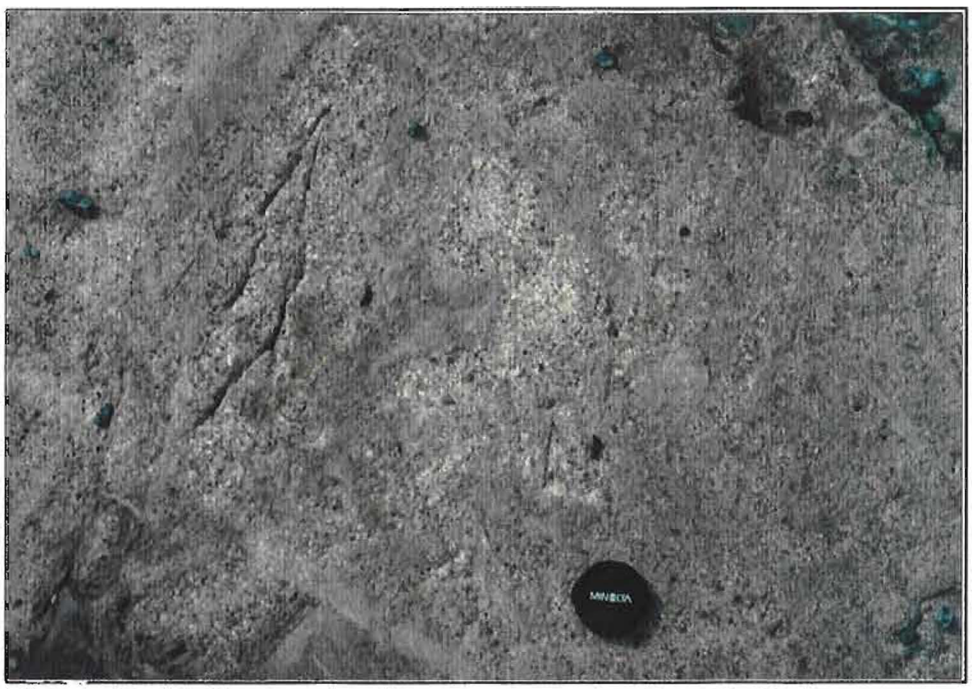


Figure 10: Highly brecciated quartz monzonite, Zone 3, Sunbeam occurrence. Highly altered matrix (sericite, carbonate, fine grained quartz, biotite) appears as fine grained, pale grey masses separating fragments.

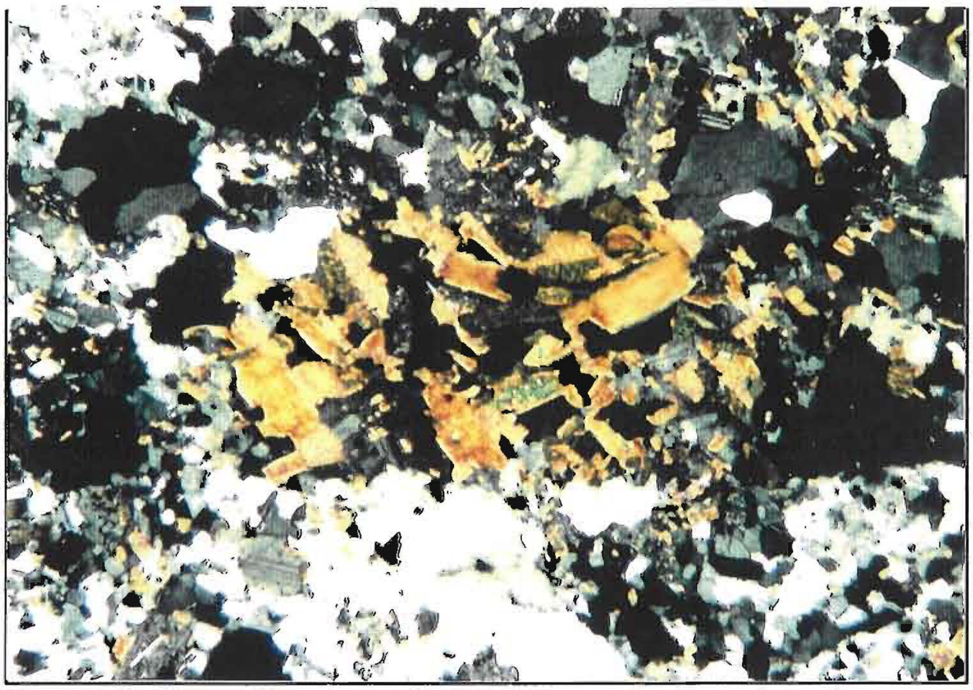


Figure 11: Photomicrograph of quartz monzonite, Zone 2, Sunbeam occurrence. Hydrothermal biotite-pyrite cluster (centre) with biotite (yellow) and pyrite (black). Field of view = 6.5 mm, cross polarized light.

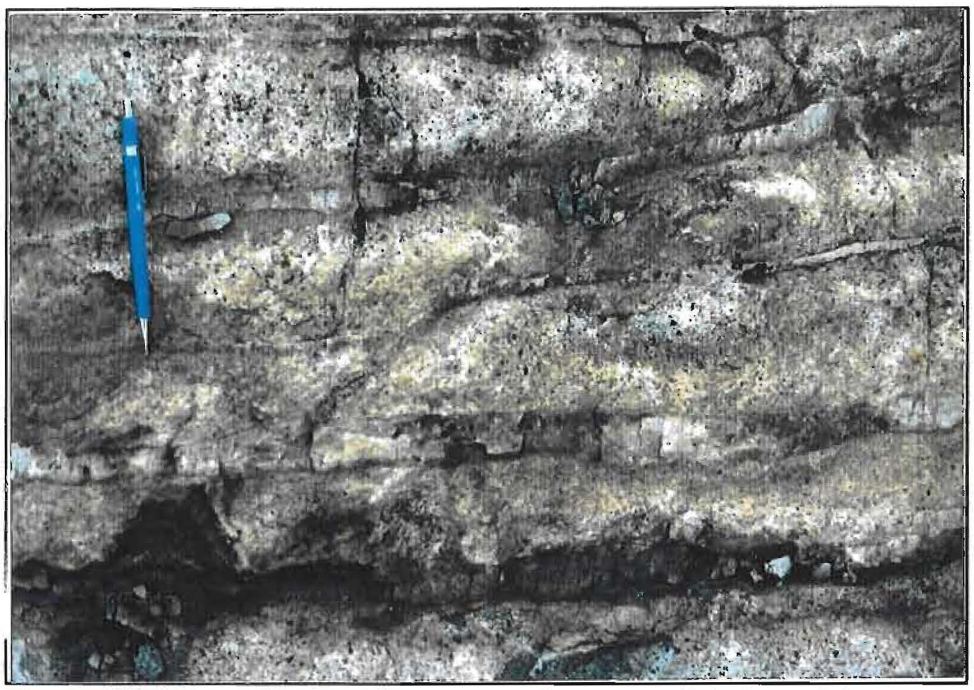


Figure 12: Rusty coarse grained quartz filling parallel sheeted fractures, forming veins, Zone 2, Sunbeam occurrence.

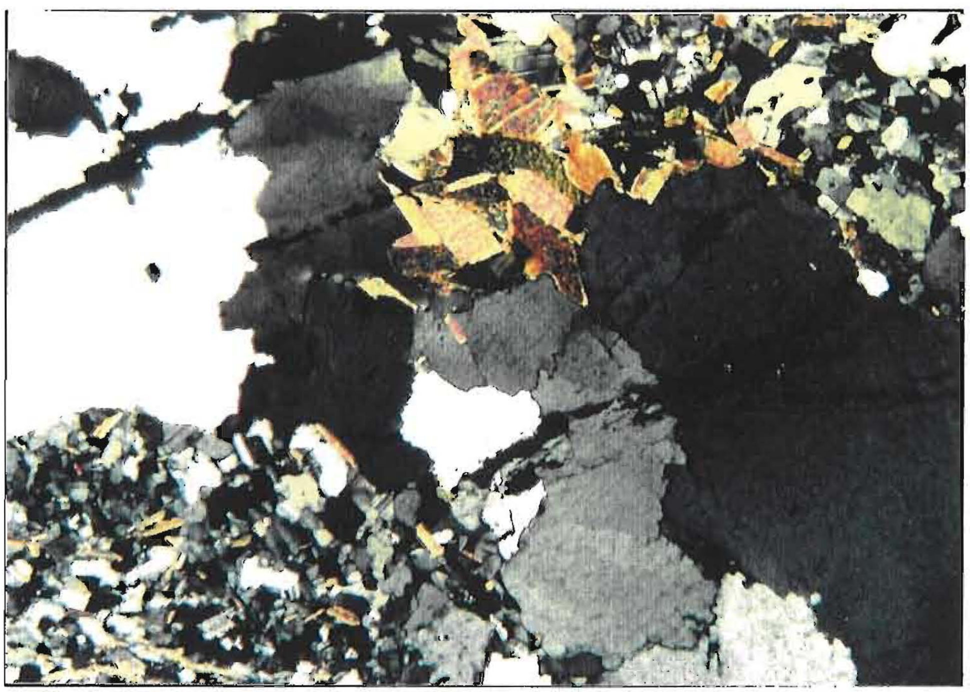


Figure 13: Photomicrograph of coarse grained quartz vein with hydrothermal biotite cutting quartz monzonite of Zone 3, Sunbeam occurrence. Quartz vein crosses photo diagonally from upper left to lower right. Field of view - 6.5 mm, cross polarized light.

Mineralization

Type and Form

Mineralization associated with the Sunbeam breccia pipe consists of an assemblage of sulphides that predominantly occur with coarse grained quartz. The sulphide assemblage consists of pyrite, sphalerite, galena, arsenopyrite, chalcopyrite, tennantite and pyrrhotite (in decreasing order of abundance). Sulphides are also disseminated or occur as clusters and stringers (Figures 14,15). Pyrite and sphalerite commonly occur as veinlets up to 5mm wide, continuous over 0.5-8 metres. Such veinlets appear to crosscut all structural features and alteration patterns.

Sulphides are in abundances exceeding 5% of the rock, where they are hosted by silicified areas or pods (5cm-1m) of quartz. Quartz stringers and veinlets following fractures and narrow shear zones range from barren up to semi massive sulphide.

In this study, free gold was observed in two samples, occurring as 0.5 - 2mm grains at quartz grain boundaries of coarse grained quartz, and also at a fragment-matrix interface.

Distribution

As shown in Figure 14, mineralization is distributed in various forms throughout the breccia pipe. In the surface exposure, sulphides appear to be concentrated around the shaft area of Zone 4 and along structures radiating out from this locus, into other zones. Mineralization is concentrated in areas of silicification.

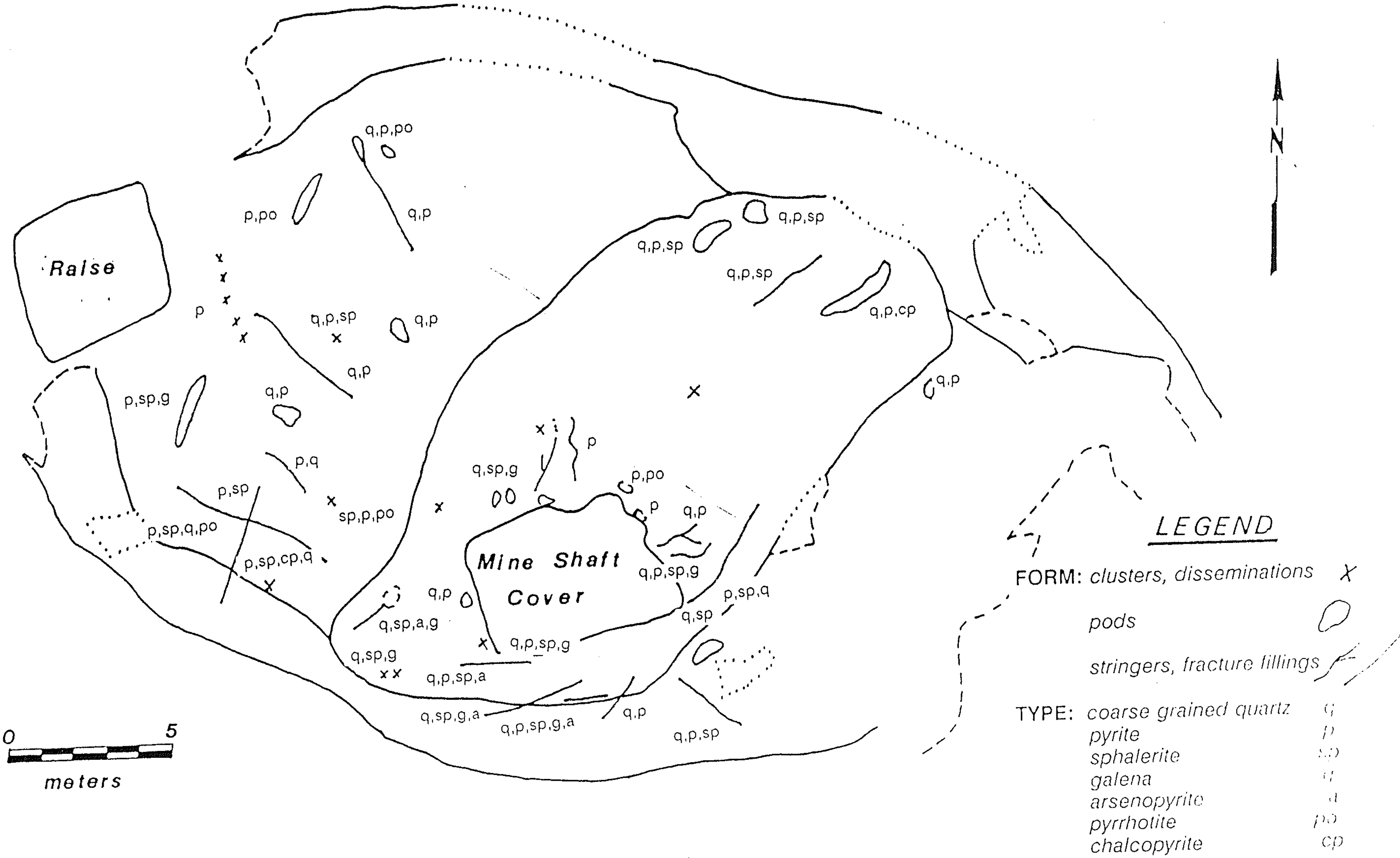


Figure 14: Distribution of mineralization within the Sunbeam breccia pipe

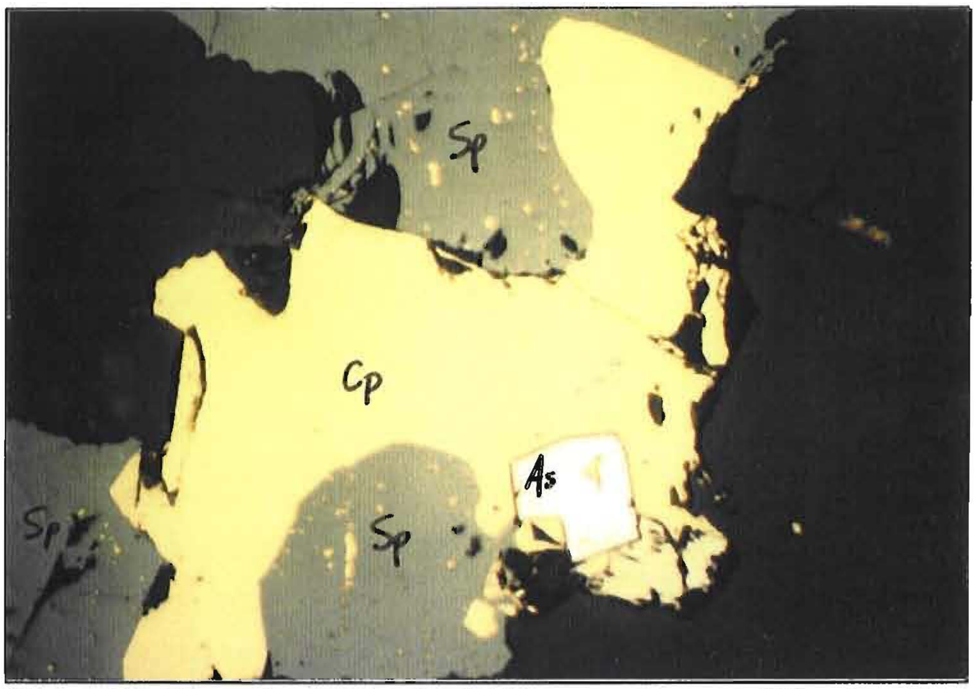


Figure 15: Photomicrograph of sulphides as open space filling in quartz, Zone 4, Sunbeam occurrence. As (arsenopyrite), Cp (chalcopyrite), Sp (sphalerite). Field of View = 11.3 mm, plane polarized light.

Gold is distributed erratically throughout the pipe, according to assay results (Appendix 1). Samples taken in Zone 4 were well silicified and mineralized, yet returned values ranging from 26-166 ppb gold (Figure 16). Sample SB1 returned a value of only 37 ppb; whereas the remaining slab contained several grains of visible gold. Higher gold values in Zones 2 and 3, however, are associated with coarse grained quartz and sulphides. Similarly, exploration sampling programs by Goldbeam Resources (Wright 1946) produced results with high grade values consistently separated by much lower grade values, within a defined "high grade" zone. Portigal (1936) first defined a high grade and peripheral low grade zone, corresponding with the structural Zones 4 and 3, respectively. A comparison of grade estimates for outcrop samples taken by Wright (1938) and Goldfrey (1983) also show erratic gold distribution (Appendix 3).

Interpretation

The persistence to depth of the concentric fractures enclosing a brecciated zone defines the host structure for the Sunbeam occurrence as a breccia pipe. The disposition of structures, alteration and mineralization associated with the Sunbeam breccia pipe implies several stages of evolution. Zone 4 within the pipe appears to be an intensely milled and rebrecciated portion of an originally broader Zone 3. The intense alteration and strong mineralization confined to Zone 4 suggests multiple events may have produced the observed features of the pipe.

A proposed mechanism for pipe formation must account for breccia development and therefore be capable of generating a void. Five major hypotheses have been proposed for the production of space in breccias (Sillitoe, 1985):

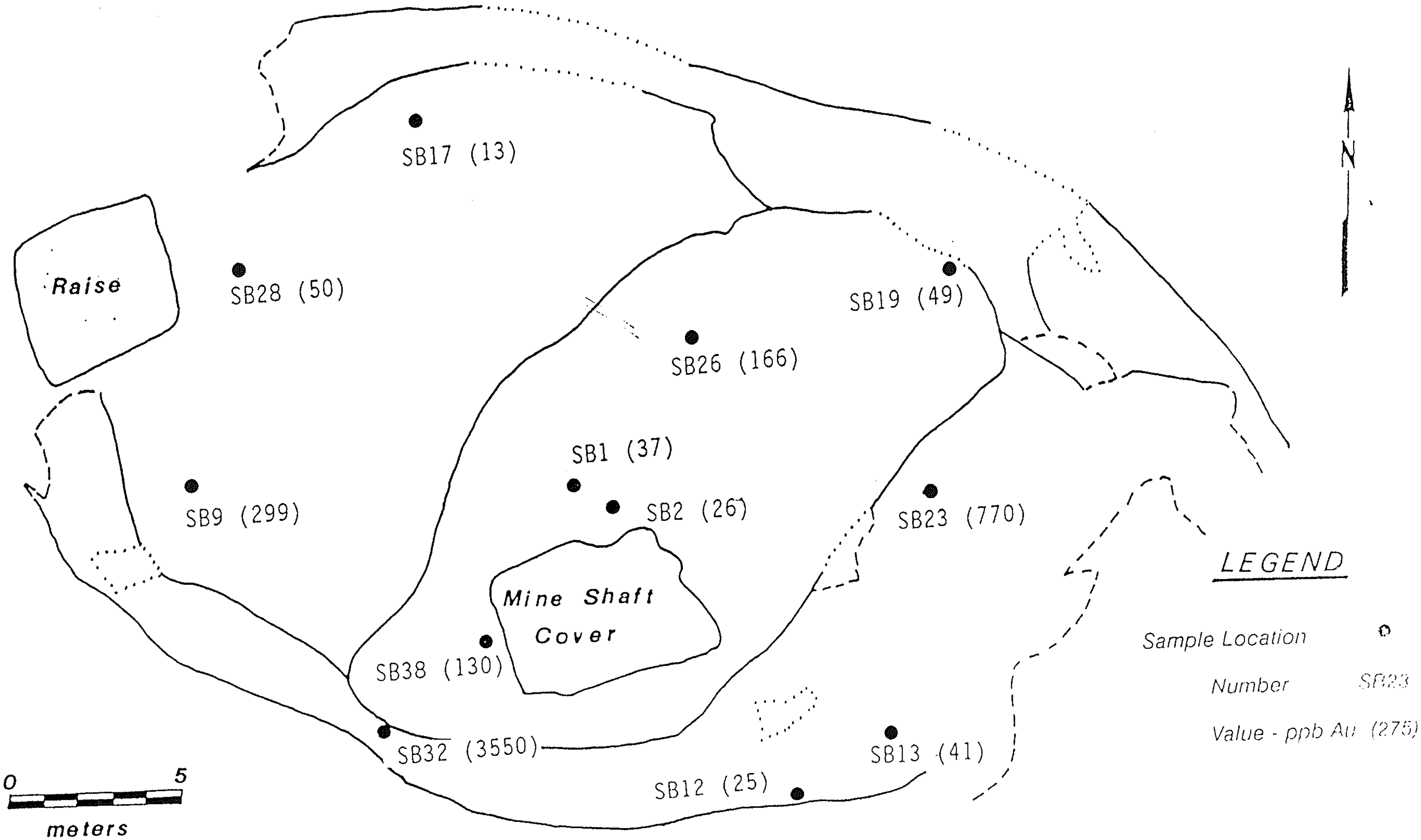


Figure 16: Distribution of grade within the Sunbeam breccia pipe

(1) Localized dissolution and removal or alteration of rock by fluids released from a cooling magma (Locke, 1926, Sillitoe and Sawkins, 1971)

(2) Violent release of volatiles from a magma, with materials carried physically upward (Walker, 1928, Emmons, 1938)

(3) Downward movement of magma by either shrinkage or withdrawal (Hulin, 1948, Perry, 1961)

(4) Development of a bubble on the roof of a stock by accumulation of exsolved fluids (Norton and Cathles, 1973)

(5) Production of dilatent zones on major faults during displacement (Mitcham, 1974)

These mechanisms may all contribute to the formation of a breccia pipe, according to Burham's (1979, 1985) model involving two stages of energy release (decompression) related to magma emplacement and crystallization processes. The model requires that the inner portions of the pluton remained a hydrous, partial melt while progressive crystallization was in progress. During solidification, the mechanical energy release required for brecciation can be initiated from the process of resurgent boiling and subsequent decompression. The resurgent boiling process is a natural consequence of crystallization of a water saturated melt. Progressive crystallization leads to hypersolidus saturation of the melt, and exsolution of an aqueous fluid from the melt. The presence of this fluid considerably increases the volume of the magma body, and the resulting increased pressure may be released by either brittle failure of confining rocks, or migration of the aqueous fluid to an area of weakness. This decompression of the residual water-saturated melt and the aqueous fluid is rapid, and results in further exsolution of fluid and expansion of the previously exsolved fluid. The resulting increase in fluid pressure is relieved by brittle failure of confining rocks, causing an energy release. The energy released during this process would be greater than that due to the resurgent boiling reaction and would therefore be the more likely of the two events to cause brecciation and milling of the host rocks.

The decrease in fluid pressure during the resurgent boiling reaction requires that the fluid encountered an area of weakness such as the surface, a preexisting structure, or fabric anisotropies developed in the crystallizing melt. In his study of internal features of FLIC, Mandziuk (1988) interpreted late stage magmatic flow conditions and crystallization processes operable in the vicinity of the granodiorite-quartz monzonite contact, which may have produced a conduit. Mandziuk (1988) has suggested that magma in FLIC consolidated in solidification fronts grading from outer static zones where crystallization was occurring, to inner zones of flowing magma. The inner zone is characterized by laminar and locally turbulent flow conditions. In the granodiorite-quartz monzonite contact zone hosting occurrences, observed modal layering and erosional features such as troughs and scours suggest there were initial high flow rates with periodic turbulence in the magma (eg. see Hupper and Sparks, 1985). The velocity and direction of flow would be affected by irregularities along conduit walls (such as the large scale scour into the granodiorite) or the presence of inclusions to result in flow deflection, eddying, and/or further turbulent conditions (eg. see Shaw, 1965, Kille et al., 1986). The increased rates of flow in the area of the quartz monzonite could result in late crystallization and constriction to develop a conduit(s). Such a conduit may have been the site of hydrothermal fluid migration and decompression to generate the Sunbeam breccia pipe. Alternatively, concentric structures could result from fluid migration into sites of crystal alignment development during consolidation of eddies. Halwas (1984) has suggested that the earliest stage of pipe development occurred during late crystallization of the crystal-laden quartz monzonite melt, forming a conduit with a reported concentric alignment of oligoclase and microcline crystals.

During solidification, the resurgent boiling reaction of a hydrous, high level magma could have resulted in exsolution of an aqueous fluid phase (eg. see Burnham, 1979, 1985). The high pressure fluid phase may have migrated upwards in a conduit, altering the host quartz monzonite. Sericitization of feldspars could generate the required void space equivalent to 15-20% of the feldspar volume (eg. see Burnham, 1985), and further weaken the conduit.

If such a fluid migrated to the area of crystal alignment, fluid pressures would have decreased, causing decompression. Decompression of the exsolved fluid would release a large amount of energy which could have generated concentric dilational fractures (eg. see Allman-Ward et al. 1982). The development of fractures would have caused continued decompression, exsolution of fluid, and energy release resulting in brecciation of the core of the pipe. The local distribution of rectangular tablets in Zone 3 may be the result of spalling of fractured blocks from Zone 2, as fluid pressures decreased.

The presence of unbent, unbroken sericite flakes is common to the matrix of Zone 3 breccia and several fragments have bleached, sericitized rims. Increased sericitic, biotitic and fine grained silicic alteration is characteristic of matrix areas, fragment edges, and blocks bordering dilational fractures. These features represent the result of fluid-rock interaction and strongly suggest that the fractures and matrix of the breccia represent the former pathways for hydrothermal fluid migration.

The more restricted breccia Zone 4, with its truncation of parallel fractures and increased abundances of rectangular tablets, may represent the products of a second decompression event. This event may have resulted when a late exsolved fluid phase migrated up a conduit to the preexisting breccia zone (Halwas, 1984). Upon contact with the breccia, decompression may have occurred, and the energy released could have developed a more restricted brecciated Zone 4 within the original boundaries of Zone 3. Extensive sericitic, biotitic and silicic alteration of both matrix and clasts are characteristic of Zone 4, and are interpreted to be related to this hydrothermal event.

An array of discontinuous fractures and shear zones is concentrated within Zone 4, but also radiate out into Zones 3 and 4. These features are considered to be late adjustments of the pipe, and to have developed after decompression. Coarse grained quartz and sulphides are consistently associated with the structures, but are not mutually exclusive to them. Quartz veins fill dilational fractures, and also occur as discrete mineralized pods in the brecciated areas.

The distribution of gold into low and high grade areas corresponds to variations in structural host, alteration intensity, and volume of coarse grained quartz. The high grade area shows a spatial correlation with the intensely altered breccia of Zone 4, which is interpreted to have been produced during a second decompression event. This area is characterized by an abundance of the introduced quartz and sulphides, and high grade gold values associated with the mineralized areas. The concentration of intense alteration and mineralization in Zone 4 suggests the following mechanisms for gold introduction are possible:

1. Low grade gold may have been introduced during the first decompression event and subsequently concentrated by hydrothermal fluids which introduced coarse grained quartz.
2. Gold may have been introduced in the second decompression event and may have been subsequently concentrated by remobilization by hydrothermal fluids which introduced coarse grained quartz.
3. Gold may have been introduced with coarse grained quartz, by late stage hydrothermal fluids during an event which may have postdated both decompression events.

Mineralization within the pipe is known to be concentrated in areas of higher permeability (Zone 4 breccia, late shear zones in Zones 3,4) which would have been preferred pathways for hydrothermal fluids. The association of mineralization with late shear zones suggests that the third mechanism appears most appropriate, of migration of mineralizing fluids after formation of the Sunbeam pipe.

The erratic distribution of gold values in Zone 3 and concentration of of high grade values in Zone 4 (this study) have also been reported by extensive sampling programs conducted during exploration. Wright (1938) and Godfrey (1983) reported that gold is related to the distribution of coarse grained quartz. In his 1938 study of the paragenesis of the ore minerals associated with the Sunbeam breccia pipe, Harrison concluded that gold was introduced during the last magmatic event.

Sunbeam Fault

The Sunbeam fault was not investigated during this study; the only reported exposure of the fault is on the 300 level of the Sunbeam-Kirkland workings (Figure 4) (Wright, 1943; Rodgers, 1940; Godfrey, 1983; Chastko, 1986). The fault has been described as a linear, multi-shear zone trending N10°E, dipping 35 to 40° to the southeast. The fault extends over 130 feet of drift, and drilling has intersected the structure over a minimum strike length of 700 feet, and with an average width of 30 feet. The discontinuity of the Sunbeam pipe between the 300 and 425 levels indicates a 60 foot displacement of the lower fault block, towards the northeast (Portigal, 1938).

The fault zone is extensively silicified, sheared quartz monzonite. Minor carbonate and potassium feldspar are alteration products associated with silicification. Fine to medium grained pyrite with subordinate galena and sphalerite are disseminated within both the altered fault zone and the footwall quartz monzonite.

Sampling programs have shown that both high and low grade gold values occur along the fault. On the 300 level, where the fault intersects the breccia pipe, Wright (1943) reported values of 0.25 ounces per ton (opt) over 100 feet. Chastko (1986) documented similar high grade values of 0.254 opt Au in a sample taken from the fault zone, adjacent to the pipe. Low grade gold values were obtained from core samples of the fault zone and the footwall from drill holes which have investigated extensions of the fault, away from the pipe. The observed variation in grade distribution may represent remobilization of high grade mineralization from the breccia pipe.

4.2 MOONBEAM CLAIM

The Moonbeam occurrence is located at the granodiorite-quartz monzonite intrusive contact approximately 200 metres northwest of the Sunbeam breccia pipe (Figure 4).

A 600 square metre exposure has been divided into three zones, based on their characteristic structural elements (Figure 17):

Zone 1: unfractured granodiorite

Zone 2: fractured, altered granodiorite

Zone 3: brecciated, altered granodiorite

Other important features include shearing imposed on these zones, and several undeformed, unaltered mafic dykes. As shown in Figure 17, the disposition of these features is complex, and combined with poor exposure, precludes a complete interpretation.

Surface drilling investigations have outlined a mineralized, linear structure with an average grade of 0.22 opt Au, to a depth of 200 feet (Appendix 3).

Zone 1

Zone 1 defines a broad peripheral zone of unfractured granodiorite. In this area, the host granodiorite is relatively undeformed and unaltered, except in areas to the north, which have been subjected to shearing. Propylitic alteration products are ubiquitous, as are biotite-pyrite clusters.

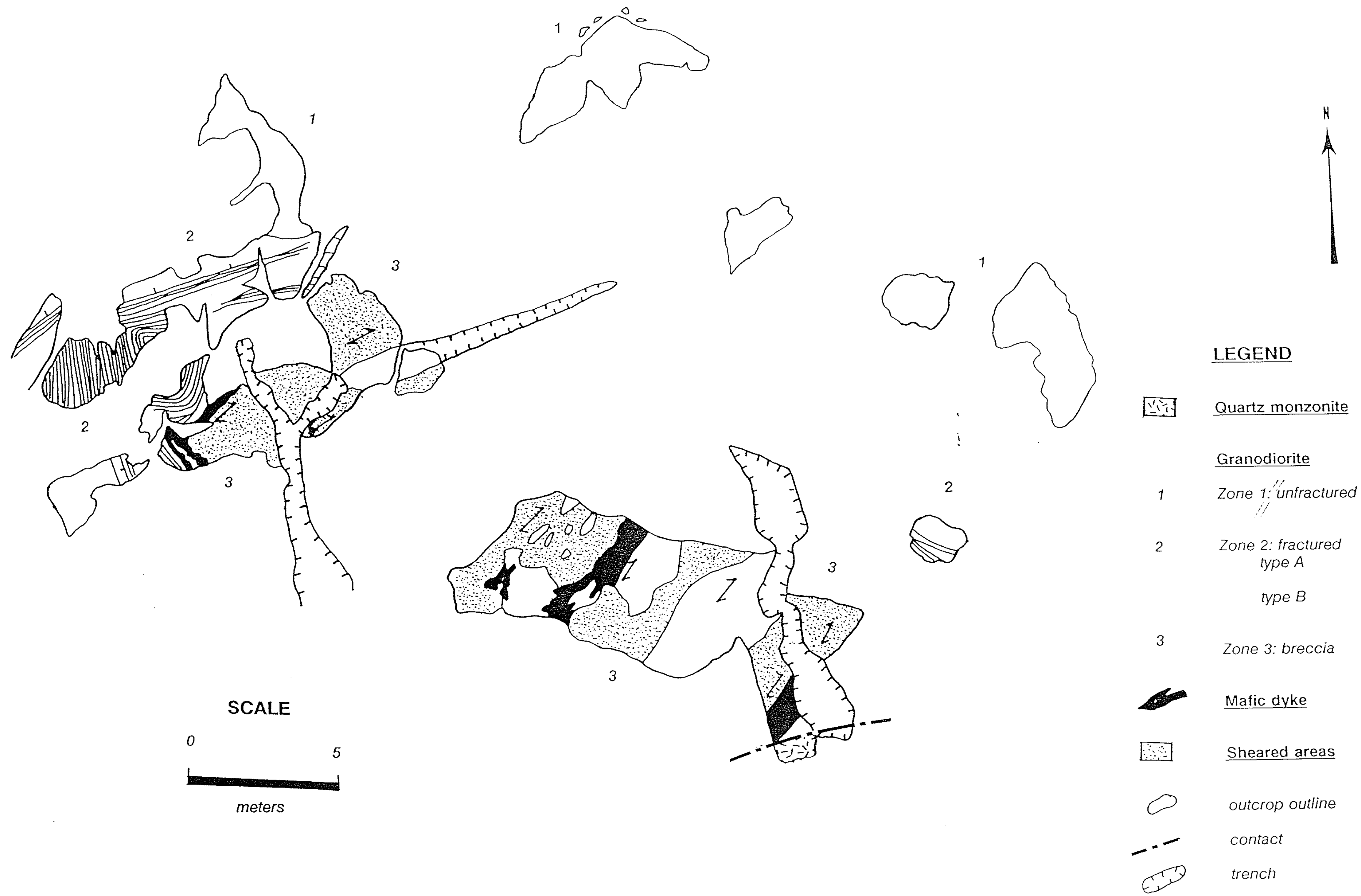


Figure 17: Geology of the Moonbeam occurrence

Zone 2

Zone 2, located in the extreme western and eastern portions of the study area, is a locus of fractures. One set of fractures, type "A", are northeasterly and northwesterly trending, and are continuous in length up to 5 metres (Figure 18). The fractures are straight, parallel, and regularly spaced 7-10 centimetres apart. The fractures have been dilated 1-2 cm and filled with coarse grained mosaic quartz with biotite-pyrite clusters. Blocks of granodiorite separating the fractures show extensive sericite alteration and fine grained silicification, which increases in intensity with proximity to the fractures. Altered rocks are bleached.

The second set of fractures are referred to as the "B" type (Figure 19). This set occurs in the same vicinity as "A" type fractures. "B" fractures form a polygonal pattern in plan view, similar to upper levels of pipe structures. The fracture array appears to dip inwards towards the core and the entire pipe-like form plunges to the west. The fractures are subparallel within the polygonal pattern, spaced 1-3 cm apart, and filled with biotite. Locally the fractures intersect foliated to sheared granodiorite.

Zone 3

Zone 3 is an area of brecciated granodiorite in the central part of the map area (Figure 17). The breccia is poorly defined, due to alteration and superimposed effects of shearing. A notable feature is the size range of clasts, from large blocks (5m) to angular fragments (5cm) (Figure 20). Clast-matrix relationships are obscured by pervasive silicification, sericitization, carbonatization and biotite-pyrite clusters. The degree of communition, of the breccia matrix, therefore, remains unknown.

Figure 18: Straight, parallel type A fractures in granodiorite, Zone 2, Moonbeam occurrence.

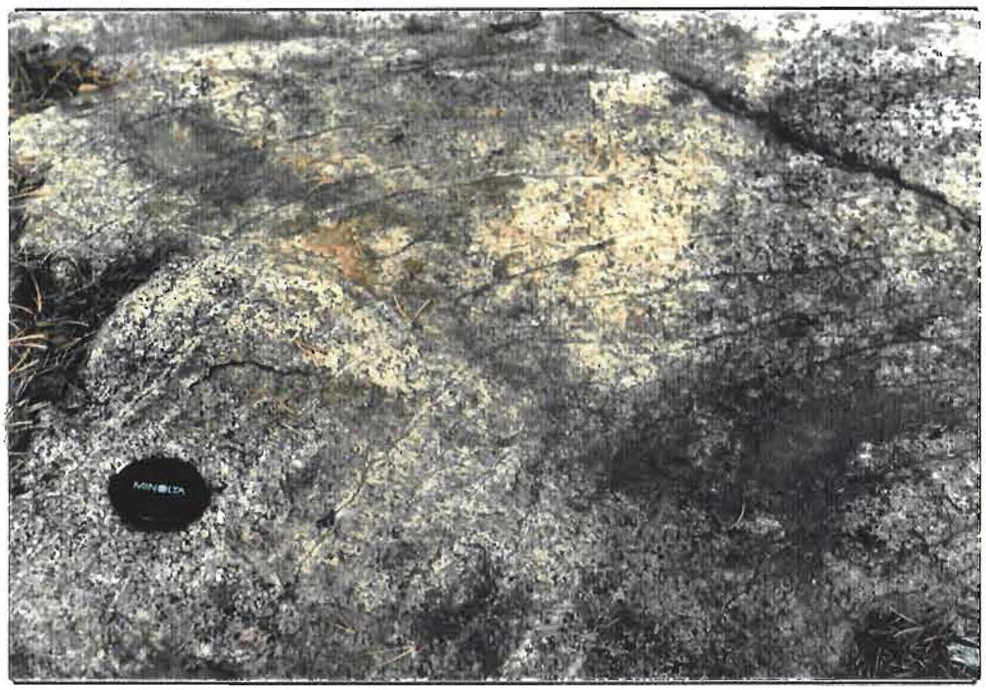


Figure 19: Polygonal type B fractures in granodiorite, Zone 2, Moonbeam occurrence.

Figure 20: Brecciated granodiorite, Zone 3, Moonbeam occurrence. Fragments (mottled white-orange-brown) are variable in size and have poorly defined matrix interface.

Northeast-trending foliations imposed on type "A" fractures, both clasts and matrix of the breccia, and unfractured granodiorite is evidence of late shearing. The poor exposure of the area precludes an estimate of the strike extent of the shear zone. On a microscopic scale, shearing has caused bent and strained K feldspar crystals, and an alignment of phyllosilicate alteration products to form schlieren elongate to the northeast.

Late mafic dykes intruded Zones 2 and 3, and have intruded parallel to the northeast shearing trend in breccia Zone 3. On a local scale, the dykes anastomose around fragments (Figure 21). Mafic phenocrysts within the dykes are aligned parallel to the northeast trend, and discordant to contacts, reflecting a close temporal relationship to the shearing event.

Alteration

Propylitic, sericitic and carbonate, fine grained silicic, biotitic alteration and introduced coarse grained quartz are recognized at the Moonbeam occurrence. The patterns and extent of these alteration types are shown is Figure 22.

Propylitic alteration (hornblende to biotite, chlorite and epidote) has been found in quartz monzonite and granodiorite. Towards the central breccia zone, propylitic alteration has been overprinted by sericitization, of varying intensity. In the area of dilational fractures, sericite and carbonate cause saussauritization of feldspars in the granodiorite blocks, which results in the complete obliteration of feldspars adjacent to the fractures. In the breccia zone, sericitization is more intense and flakes of sericite are in breccia fragments and matrix. In the matrix, the mats of sericite anastomose around the fragments.

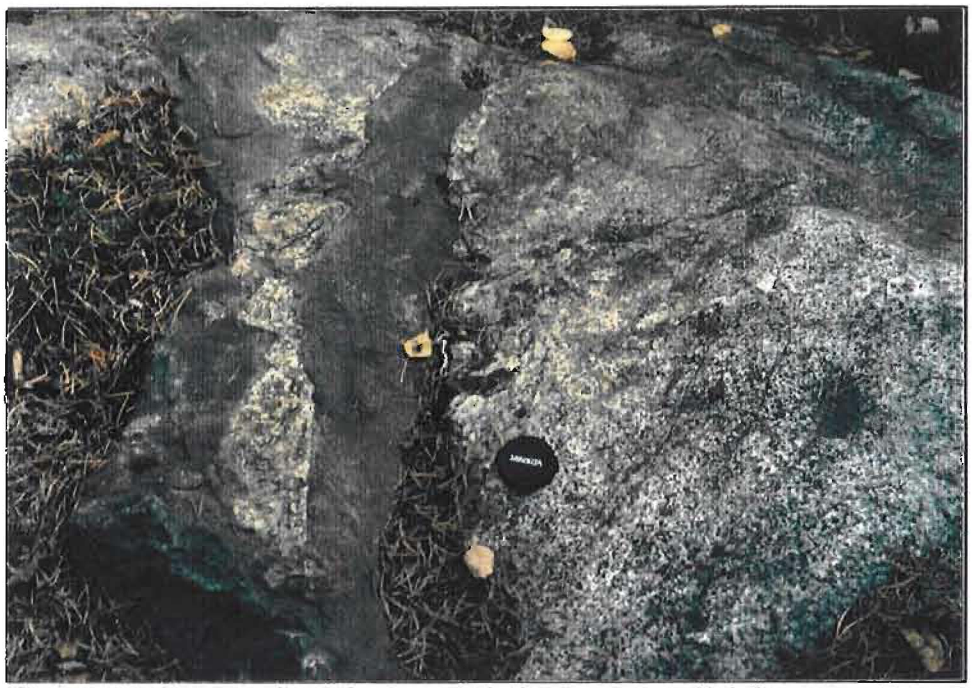


Figure 21: Late mafic dyke intruded along two parallel fractures, Zone 2, Moonbeam occurrence. Dark grey-green dyke appears to have absorbed the granodiorite block which originally separated the fractures.

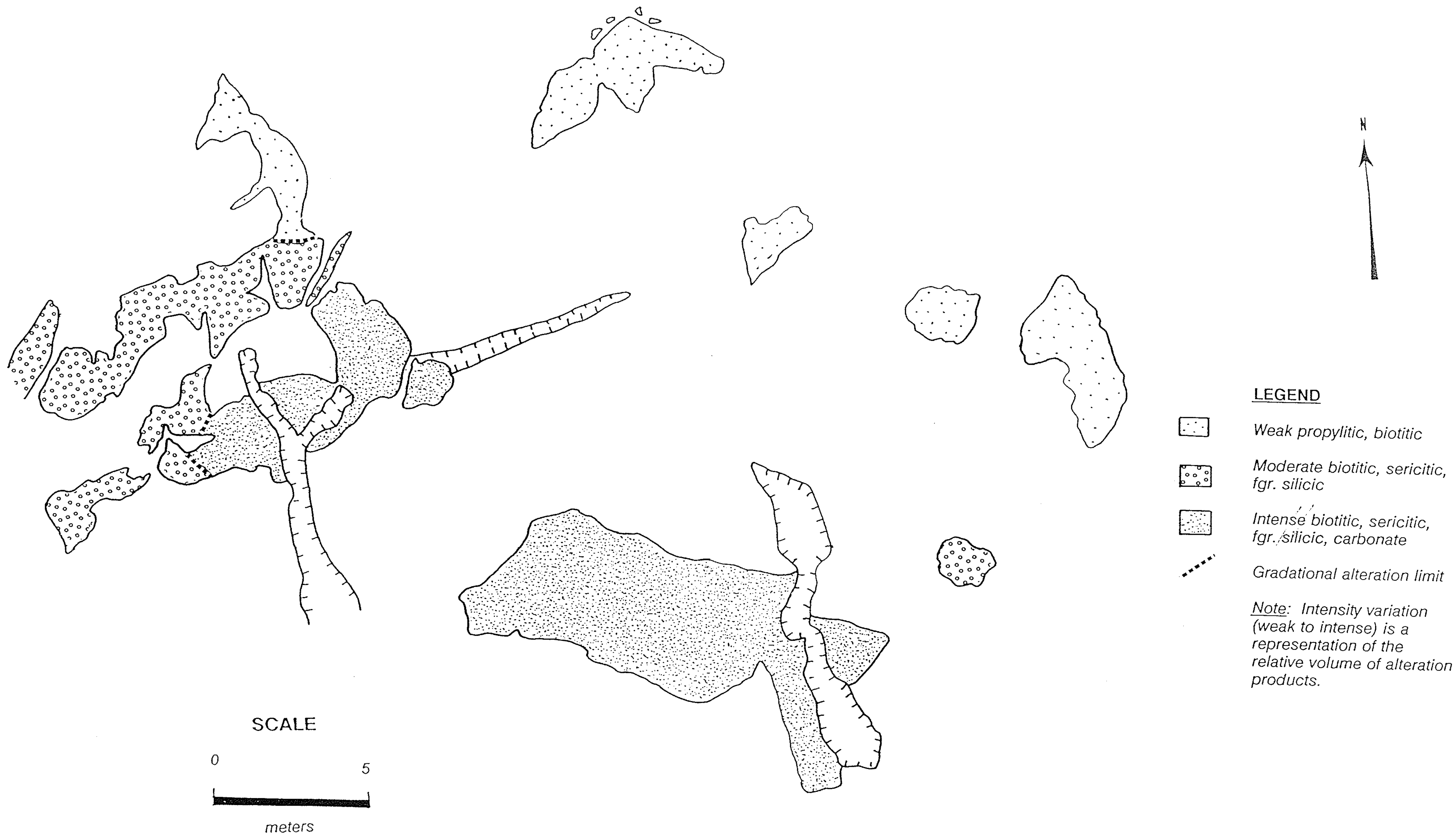


Figure 22: Distribution of alteration at the Moonbeam occurrence

Fine grained silicification has a distribution similar to sericitization, and is concentrated in the brecciated zone. The quartz is subangular and aggregates of quartz produce a mosaic texture. Complete silicification obliterates original textures.

Biotitization, another widespread and variable alteration type which affects all zones of the Moonbeam map area, is composed of clusters of biotite around cores of euhedral pyrite. These aggregates, which are variable in size and shape, increase in abundance towards the core. Biotitization is associated with both fine grained and coarse grained silicification, and clusters of biotite-pyrite are concentrated along the margins of Zone 2 dilational fractures.

Introduced coarse grained quartz is more restricted than fine grained silicification, and is concentrated filling dilational fractures, and the areas near the intrusive contact. Quartz grains are typically 1-5mm in size and subangular to angular, and form aggregates, producing a mosaic texture. Coarse grained biotite-pyrite clusters and sulphides commonly occur with the coarse grained quartz. Coarse grained quartz crosscuts earlier fine grained quartz and sericite, and is was clearly introduced later than these products.

Mineralization

Sulphide and associated gold mineralization is spatially related to coarse grained silicification. Pyrite, chalcopyrite, galena, sphalerite and arsenopyrite typically occur as veinlets and disseminations within the quartz (Figures 23,24). Galena commonly replaces pyrite in biotite-pyrite aggregates. The sulphide grains are up to 3mm in size.

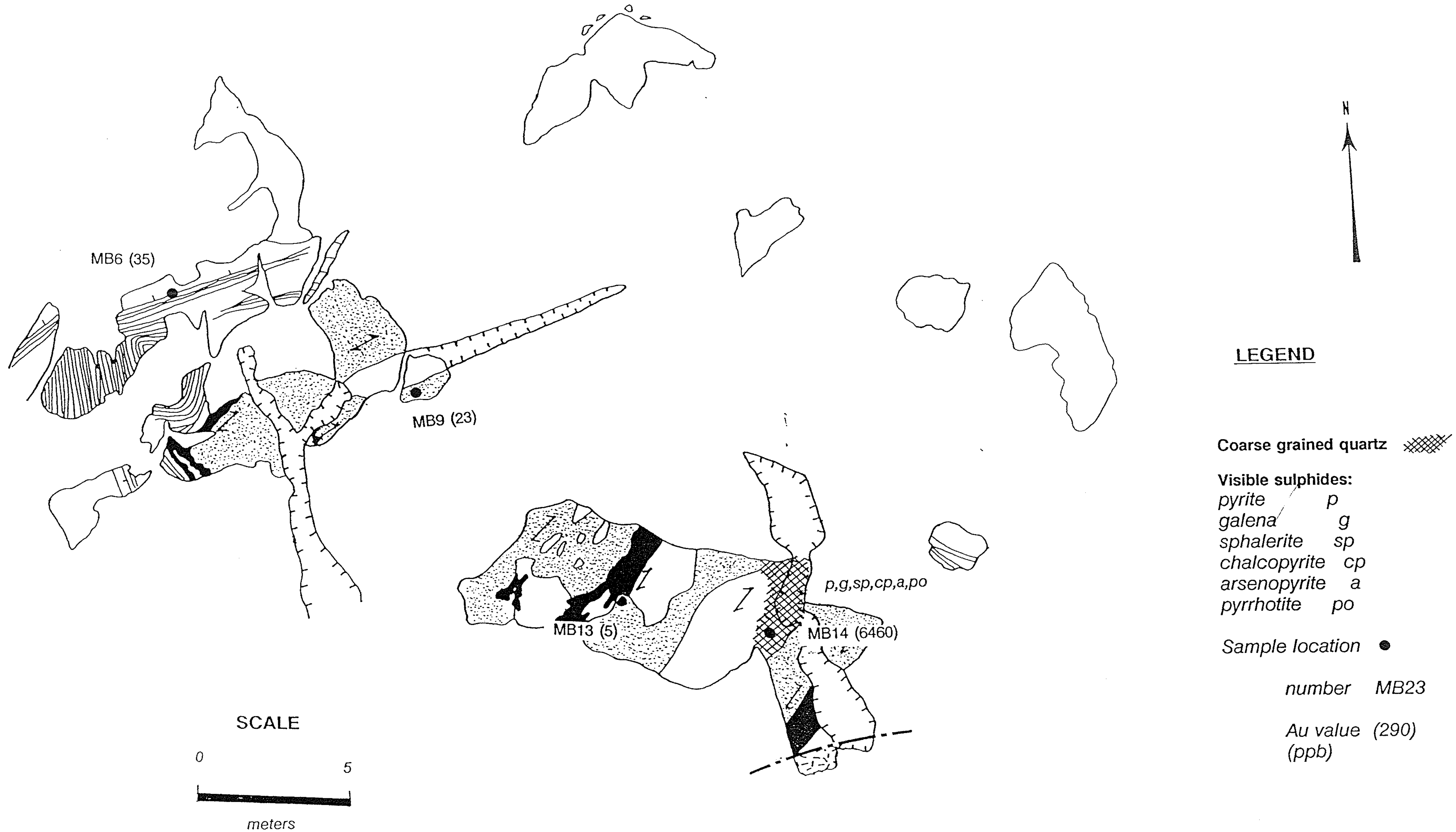


Figure 23: Distribution of mineralization and grade at the Moonbeam occurrence

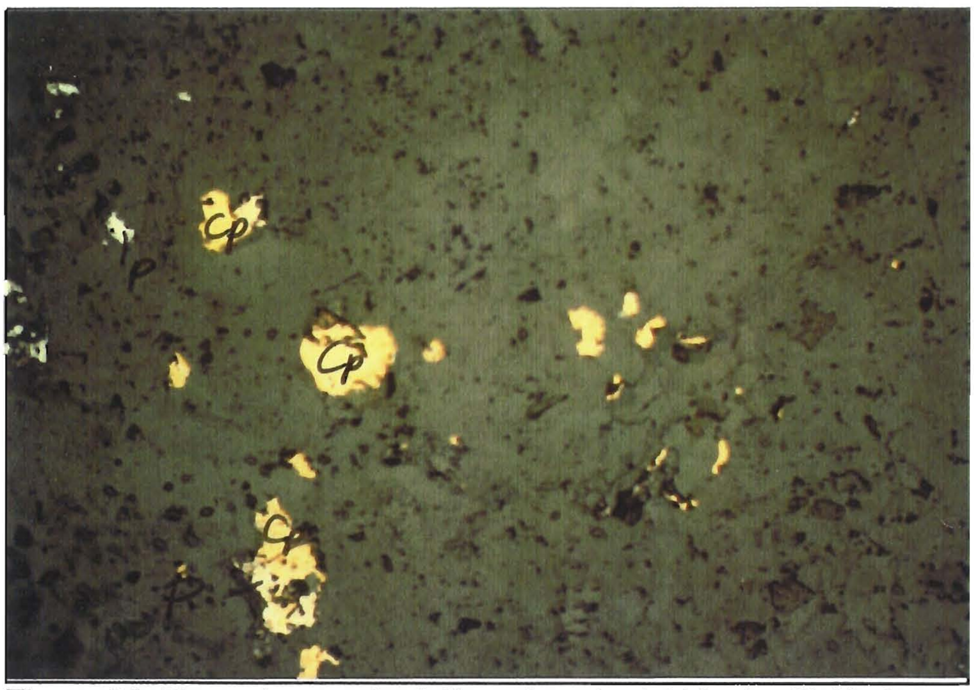


Figure 24: Photomicrograph of disseminated sulphides in silicified matrix of brecciated granodiorite, Zone 3, Moonbeam occurrence. Cp (chalcopyrite), P(pyrite). Field of view = 11.3 mm, plane polarized light.

Although gold was not observed, sample MB14 of silicified granodiorite with abundant sulphides returned geochemical gold values of 6460 ppb. Other well silicified samples returned low gold values. The extent of this gold-bearing zone appears limited on surface; however, Wright (1946) reported that a northeast trending linear structure with a width of 15-25 feet had been found in drill holes. This shear zone has a reported probable reserve of 20,000 tons at 0.22 opt gold (Appendix 3).

Interpretation

The Moonbeam occurrence has previously been reported as a breccia pipe; however, this study has interpreted two superimposed breccia pipes and a shear zone. As well, exploration drilling outlined a mineralized linear structure at depth. These features occur in granodiorite, at its contact with quartz monzonite core of FLIC. The breccia zone contains hosts large fragments of granodiorite. Given the limited exposure of quartz monzonite, it is possible that similar sized fragments of quartz monzonite are part of this zone. Apophyses of quartz monzonite have not been observed in the breccia zone. Based on these observations, it is interpreted that the features associated with the Moonbeam occurrence likely developed after the consolidation of quartz monzonite. The presence of large, angular fragments implies that the breccia fragments underwent minimal transport.

The localization of the breccia pipes and shear zones at the granodiorite-quartz monzonite contact suggests the contact, itself, may have provided a migration route for hydrothermal fluids exsolved from a crystallizing melt at depth. A fluid may have first ascended along the contact, causing sericitic and biotitic alteration of both granodiorite and quartz monzonite in the area. A-type dilation fractures may have originated through processes similar to those that gave rise to the Sunbeam pipe fracture system. The limited extent of the fractures and the large fragment size of the associated breccia suggests that some of the energy producing these features may have been dissipated along the quartz monzonite-granodiorite contact. Moderate sericitic, carbonate, biotitic and silicic alteration accompanying this event would have affected both the breccia and the blocks between fractures.

Late northeasterly-directed shearing was imposed on the pipe and granodiorite to the north, producing a strong foliation. On a microscopic scale, sericite alteration is recognized as flakes of sericite in the matrix which show a northeasterly trend, except in areas bordering fragments. In these areas, masses of sericite appear to anastomose around the fragments. An increase in abundance of biotite-pyrite clusters and coarse grained quartz is also common in the sheared areas.

Northeasterly-trending, late mafic dykes conform to breccia fragment margins and also follow along fractures of varying orientations. Phenocrysts within the dykes consistent show a northeasterly alignment, suggesting that late magmatism related to the dykes was synchronous with shear zone development.

A polygonal fracture set (type B) in the southwest corner of the area appears overlap sheared areas. The development of this feature may be related to a late decompression event which postdated both shearing and dyke emplacement.

The poor exposure and complex disposition of the features observed at the Moonbeam occurrence leaves much speculation regarding the evolution of the structures. The interpretation presented assumes that the development of all structures, alteration, and mineralization post dated consolidation of quartz monzonite. The successive development of pipe features and a shear zone suggests that a close temporal relationship existed between late magmatic processes and brittle fracturing.

The introduction of sulphides and gold, with or without coarse grained quartz, was a late event. Coarse grained quartz is erratically distributed throughout the breccia zone but is concentrated in the vicinity of the easternmost trench. The greatest abundances of sulphides correspond with gold values of up to 6500 ppb obtained from samples taken in this area. Drilling conducted during exploration programs delineated a linear northeast trending structure with similar moderately high gold values. The gold mineralization thus appears to be related to coarse grained silicification and the late shearing event.

4.3 WAVERLEY CLAIM

Two groups of occurrences are located on the Waverley claim: the Letain A and B shear zones, and the Waverley shear zones (Figure 4). The Letain shear zones are not exposed, but were investigated by underground development and drilling. In 1985, the workings were dewatered and further drilling was completed by Whiteshell Ventures Limited. During this time, the zones were briefly observed and sampled for this study.

The Waverley shear zones which cut quartz monzonite are exposed in outcrop to the west of the Letain workings. These structures were discovered during the 1985 stripping program, and have not been assessed previously.

Letain Shear Zones

Past exploration work has reported the Letain structures as six, or three, or two major shear zones with numerous zones between them. Wright (1946) identified A, B and C zones, whereas Chastko (1986) identified A and B zones. The latter structures were observed when the workings were dewatered in 1985. The A and B structures each represent a network of parallel to subparallel shear zones up to 1.5 metres wide. The orientation and continuity of the A and B structures are:

A. N77E/30SE - strike length of 500 feet [Open]

B. N55E/30SE - strike length of 250 feet [Open]

As shown in Figure 4, the Letain shear zones appear to converge in an area southwest of the shaft.

The structures are typically strongly sheared and have been subjected to pervasive silicification and carbonatization. Narrow (1-2cm) veins of light to medium grey quartz are common in the silicified areas. Linear zones of chlorite schist irregularly distributed through the workings have been interpreted as mafic dykes. However, outcrop exposures to the west show numerous mafic xenoliths hosted by granodiorite, which are also potential protoliths for the chlorite schists.

Mineralization

Type and Form

Mineralization consists of pyrite, arsenopyrite, with minor amounts of pyrrhotite, sphalerite and galena associated with silicified shear zones. Pyrite and arsenopyrite commonly comprise 70-80% of the assemblage, as fine grained disseminations and fine stringers of pyrite, and fine to medium grained disseminations of arsenopyrite (Figure 25). In areas where arsenopyrite is in greater

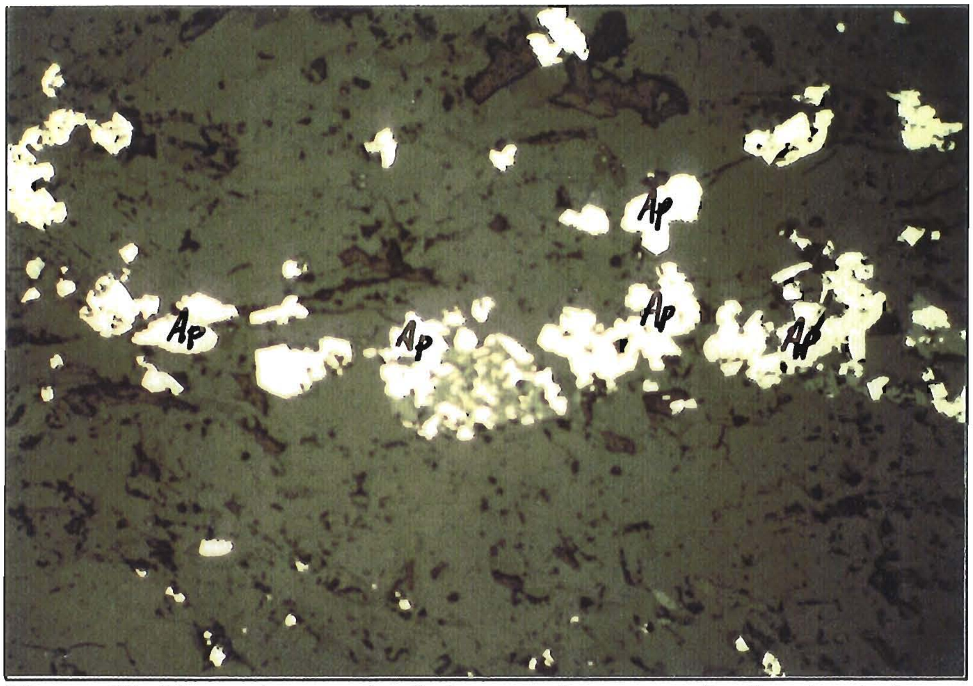


Figure 25: Photomicrograph of clusters of arsenopyrite forming trains within silicified, sheared granodiorite, Letain A occurrence, 150 level. Ap (arsenopyrite). Field of view = 11.3 mm, plane polarized light.

abundances than pyrite, arsenopyrite occurs as fine grained stringers concordant with late foliations developed within the shear zones. Pyrrhotite, sphalerite and galena in minor abundances have been reported in drill core (Wright, 1938; Chastko,1986), however, they were not observed in this study. Visible gold, which was also commonly reported, was also not observed.

Distribution

As discussed above, mineralization is concentrated in silicified areas associated with shear zones. Previous exploration work has reported erratic gold distribution with visible gold occurring with or independent of sulphides. An affinity of gold with a particular sulphide phase has not been established. A silicified sample (W-1) with up to 10% arsenopyrite lacking visible gold, assayed 18 grams gold per tonne (Appendix 1). Similar high grade values were reported by Wright (1938) in three (A, B, C) shear zones:

A. 78,000 tons at 0.447 opt gold

B. 110,000 tons at 0.303 opt gold

C. 106,000 tons at 0.277 opt gold

<u>Waverley Shear Zones</u>

The Waverley shear zones W-1, W-2 and W-3 occur in quartz monzonite, near the contact with granodiorite (Figure 4). W-1 and W-2 have similar orientations of N50E/66SE and N55E/62SE, respectively. W-3 (N45W) is exposed in a water-filled trench which crosses the intrusive contact. As characteristics of these three shear zones are similar, a detailed examination was focussed on W-1 as being representative.

W-1, which cuts quartz monzonite in an area of abundant exotic xenoliths and cognate inclusions, is exposed over a length of 35 meters, and is 8 meters wide (Figure 26). Across the width, there is a network of widely spaced, anastomosing fractures. The density of fractures increases towards the northern boundary, where there is a 0.5 to 1 metre wide zone of intensely sheared, altered quartz monzonite. Here, the quartz monzonite has been brecciated and milled and the resulting fragments have been rotated (Figure 27).

Alteration is concentrated in the intensely sheared area, and appears to be synchronous with the deformation. The milled matrix has been altered to sericite, quartz, minor carbonate and biotite-pyrite clusters. Fragments within the shear zone range from unaltered to moderately altered.

Mineralization

Type and Form

In the Waverley shear zones, mineralization is associated with coarse grained quartz, in 1-2 cm wide shears, which occur in the central portion of the main shears (Figure 28). Biotite-pyrite clusters are common in the veins. Fine grained disseminated pyrite is irregularly distributed throughout the altered and milled quartz monzonite, and the quartz veins.

Distribution

The distribution of gold in these shear zones was not tested during this study, and visible gold was not observed.

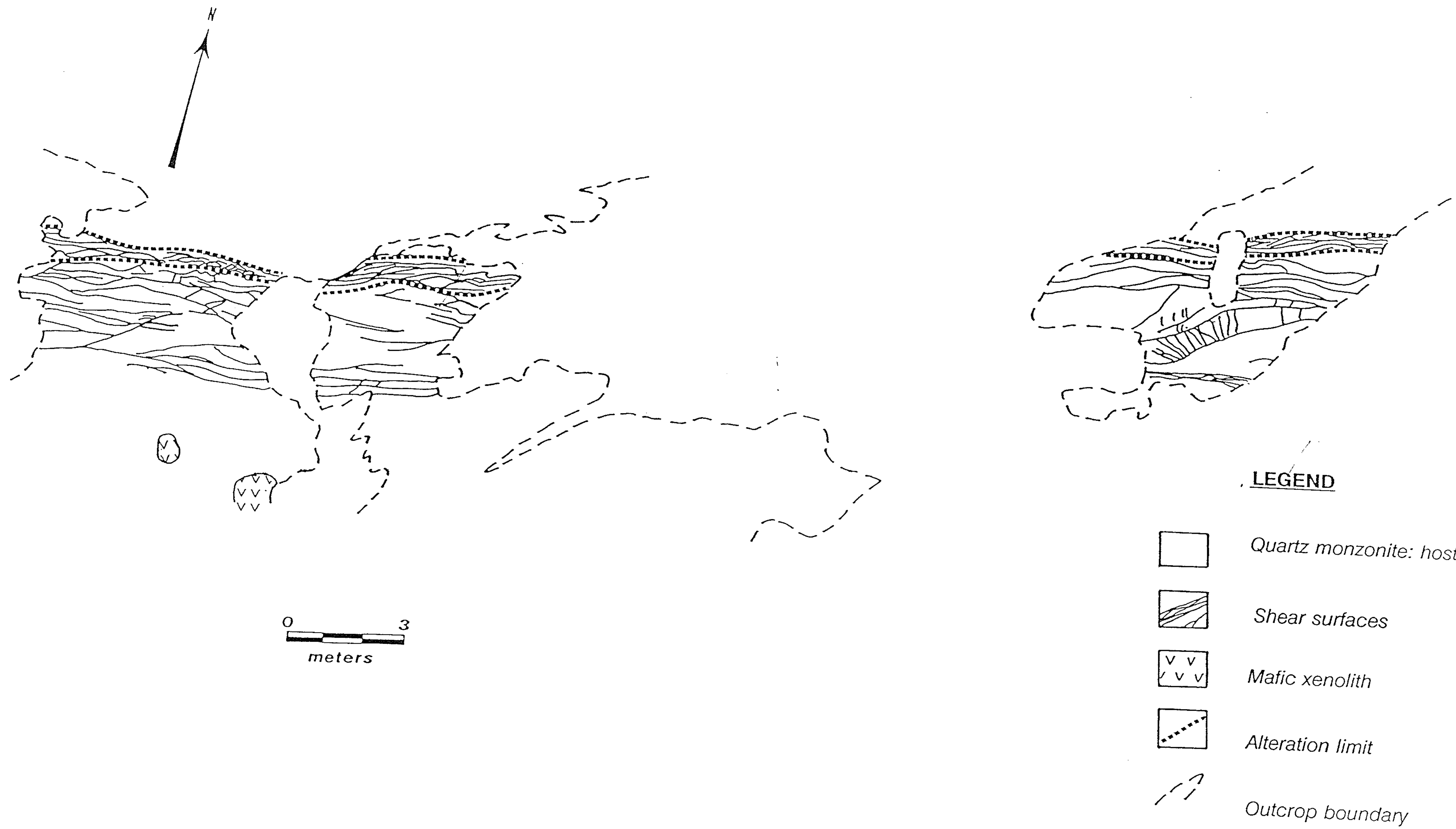


Figure 26: Geology of the W-1 shear zone

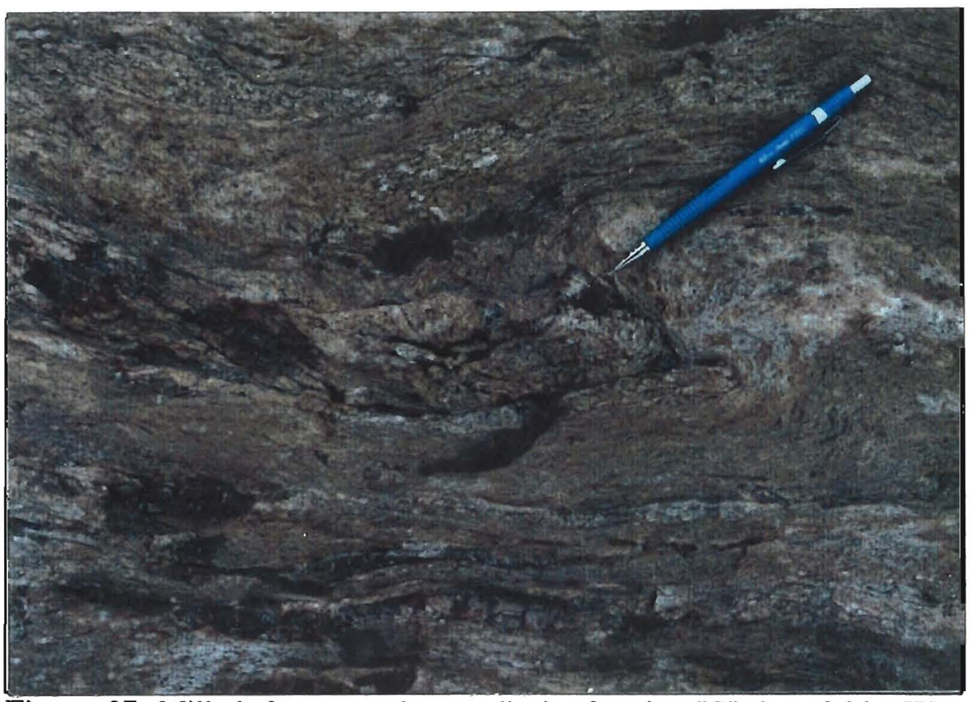


Figure 27: Milled, fragmented granodiorite forming "S" drag folds, W-1 shear zone.

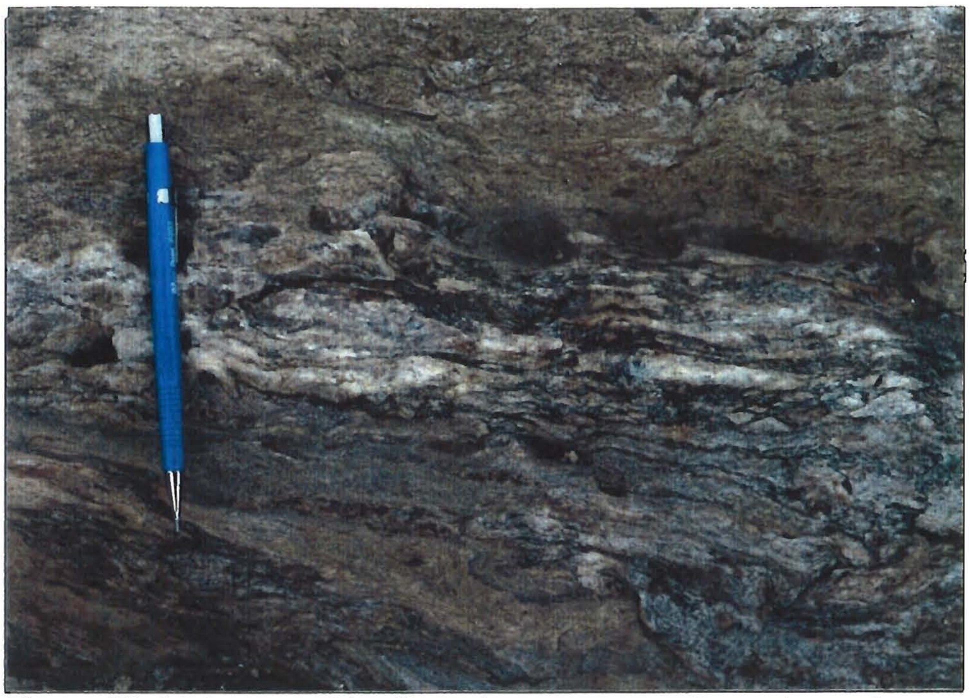


Figure 28: Light grey-white discontinuous quartz veins, stringers in sheared, carbonatized and sericitized quartz monzonite, W-1 shear zone.

4.4 SUNDOG CLAIM

The Sundog claim encompasses the previously reported SD-1 shear zone, and the SD-2 shear zone and Sundog fault, which are newly discovered structures. The SD-1 and SD-2 shear zones are northeast trending, steeply dipping structures that cut granodiorite, within 50 metres of the contact with quartz monzonite (Figure 4). The Sundog fault, which cuts quartz monzonite and is located 150 metres northwest of SD-1 and SD-2, is northerly trending and shallowly dipping.

Sundog Shear Zones

SD-1 and SD-2 trend N20E/68SE and N35E/78SE respectively, over limited strike lengths of 10 to 15 metres and widths of one to two metres. SD-1 was selected for representative study and has also been investigated by surface and subsurface drilling programs.

In the northern part of the exposure, SD-1 is in sharp contact with unaltered granodiorite (Figure 29). The degree of milling and alteration decreases southward, where the shear becomes an array of fractures.

In the intensely sheared southern area, sericitic, weak carbonate, silicic and biotitic alteration has further obliterated the original character of the rock. The combined alteration effects give rise to a gossan imposed on the shear zone (Figure 30). In areas to the north, small gossanous patches reflect concentrations of biotite-pyrite clusters.

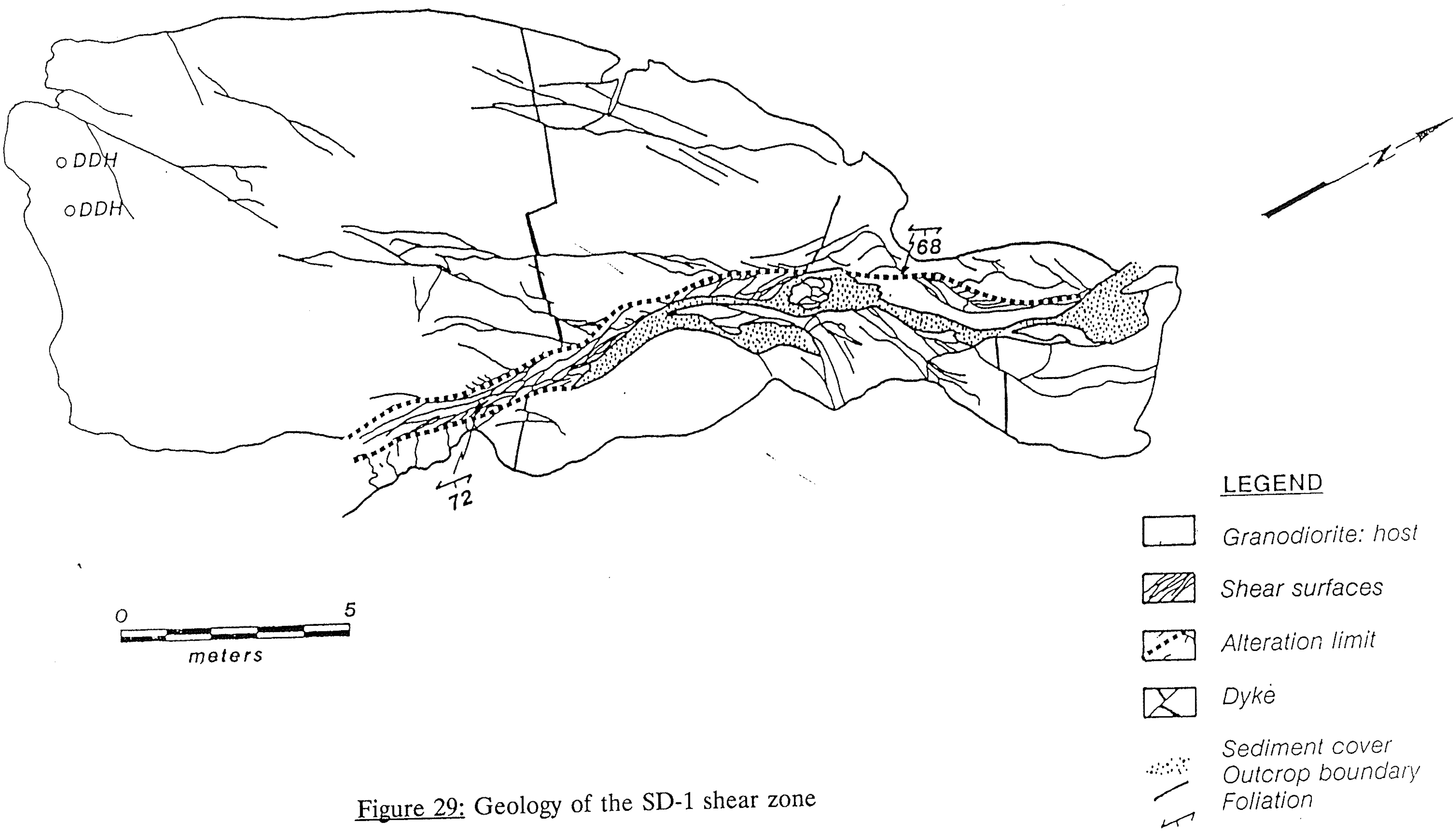


Figure 29: Geology of the SD-1 shear zone

Figure 30: Silicified shear zone in granodiorite, SD-1 shear zone. Photo facing northeast. Patchy gossan indicates concentrations of biotite-pyrite clusters within zone.

Mineralization

Type and Form

The observed mineralization consists of trace to 2% disseminated pyrite and arsenopyrite which are restricted to the highly altered portion of the shear zone. White to light grey coarse grained quartz occurs as pods in the sheared zones, and as fracture filling in the fractures to the north.

Distribution

The distribution of gold within this structure was not investigated during this study. Previous exploration confirmed the strike extent of SD-1 as 625 feet, to a depth of 400 feet. The structure remains open in both directions. In two drill holes which intersected the zone, Wright (1938) reported values of 0.54 opt gold over a width of 1.5 feet and 1.12 opt gold over a width of 3 feet.

Sundog Fault

The Sundog fault cuts quartz monzonite and is approximately 150 metres northwest of SD-1 (Figure 4). The fault is exposed in a trench which follows its strike extent over 7 metres. The fault is a sheared, strongly silicified zone trending N10E/40SE. Pyrite occurs as fine grained disseminations throughout the altered zone.

Although the structure is poorly exposed, its alteration and general trend appear to be similar to that of the reported Sunbeam fault. The Sundog shear zone is along strike from the proposed surface projection of the Sunbeam fault. The structure has therefore been named the Sundog fault, considering the possibility that it is related to the system of branching shear zones comprising the Sunbeam fault.

This locality was not tested for gold values; however, if it is part of the Sunbeam fault network, low grade gold may be present.

4.5 GOLD COIN CLAIM

The Gold Coin occurrence is exposed in a 1 x 1 metre trench within one of the earlier emplaced gabbroic intrusions of the complex (Figure 4). In the walls of the trench, a 30 centimetre wide shear zone trends to the northeast, dipping 80 degrees to the east.

The gabbro of the sheared area has been weakly chloritized and silicified, and contains 40-50% white to light grey quartz veins 1-5 centimetres wide, which are foliation parallel. Subhedral, medium grained arsenopyrite (up to 2-3%) is disseminated in the quartz veins and in silicified wallrock near the contact between the two. Gold and platinum group element values were previously reported for this locality, however, in this study, samples taken from well mineralized areas of the trench did not duplicate the earlier reported results.

CHAPTER 5: COMPARISON OF INTERIOR OCCURRENCES

The similarities and differences between the interior occurrences with respect to distribution, structure, alteration and mineralization, and the observed age relationships ultimately place constraints on the relative timing of mineralizing events. This section compares these features and considers age relationships of the events forming them, and presents a development model for the interior occurrences.

5.1 DISTRIBUTION

The documented gold occurrences within FLIC are found in various phases of the complex, but are most concentrated near the northeastern intrusive contact between granodiorite and quartz monzonite. The area of concentration is an embayment of quartz monzonite into granodiorite. Xenoliths of country rock and cognate inclusions from component intrusions of the complex, are common in the granodiorite and quartz monzonite in this region. The Gold Coin showing, hosted by a peripheral gabbroic intrusion, appears to be anomalous in terms of host rock.

5.2 STRUCTURE

Gold mineralization of the interior occurrences is localized within five types of structures:

Structure	Occurrence
(1) Breccia pipe	Sunbeam, Moonbeam
(2) Shear zones NE-ENE/steep	Waverley, Sundog shear zones
(3) Shear zones NE/shallow	Letain A, B
(4) Late shears in breccia	Sunbeam, Zone 4
(5) Faults	Sunbeam/Sundog fault

Brecciation and milling in the shear zones, and the generation of angular fragments in breccia pipe structures were caused by processes which must have occurred after the host rocks had cooled sufficiently to support brittle deformation. Therefore, minimum ages of structural processes relative to the intrusive events, as designated by letters on Figure 2, are:

	Post intrusion:
Gold Coin	C
Waverley; W-1, 2, 3	E
Letain; A, B	E
Sundog; SD-1, 2	F
Sunbeam pipe	F
Sunbeam/Sundog fault	F
Moonbeam	F

The disposition of brittle features associated with the Sunbeam pipe suggest that the pipe may have formed during a multi-stage decompression event which occurred syn- to post crystallization of the host quartz monzonite (see 4.1). Although the Moonbeam pipe and shear zone are hosted by granodiorite, they are tentatively interpreted as having developed after consolidation of quartz monzonite. This is based on the observation of a lack of late quartz monzonite dykes which would have formed as a result of magma migration to areas of improved permeability, if there was a preexisting, brecciated zone in granodiorite.

The Waverley shear zones have similar orientations, dimensions and brittle features; and may represent products of a single deformational system. In this case, the extension of W-3 across the intrusive contact, into quartz monzonite suggests that deformation forming these structures may have postdated consolidation of quartz monzonite. For the same reason, the Sundog shear zones (SD-1 and SD-2) may be part of a network of brittle-ductile shear zones which also developed after consolidation of quartz monzonite.

The Letain A and B structures also trend northeasterly but are unique in having shallow dips to the south. No further inferences can be made regarding the development of these features.

The late, narrow shear zones confined to the Sunbeam pipe, form a crude array concentrated in Zone 4, extending out into other shear zones. These features have been interpreted to be the result of settling after fluid withdrawal, and are therefore not considered to be related to the shearing in the area (see 4.1).

The Sunbeam fault displaces the lower portion of the Sunbeam pipe and therefore developed after the formation of the pipe.

5.3 ALTERATION

The variety of alteration products associated with the interior occurrences (Table 1) define six dominant alteration types: propylitic, sericitic, carbonate, biotitic, silicic, and feldspathic.

Propylitic alteration of hornblende to epidote, chlorite, and carbonate has been noted at the Sunbeam and Moonbeam occurrences, where it has the greatest extent of all alteration types.

Sericitic alteration is pervasive in the occurrences hosted by granodiorite and quartz monzonite intrusions of FLIC. Sericite ranges from fine grained flakes to medium grained laths, associated with biotite-pyrite clusters and fine grained, mosaic quartz. Together, these products have replaced the milled host rock of shear zones

	Sunbeam pipe	shear zone	Moonbeam pipe	shear zone	Sunbeam fault	Sundog fault	SD-1 shear zone	W-1 shear zone	Letain zone A	Letain zone B	Gold Coin
ALTERATION/GANGUE MINERALS											
Rutile	+	+	+	+	+	+					
Fluorite	+	+	+	+	+	+					
Apatite	+	+	+	+	+	+					
Tourmaline	+	+	+	+							
K feldspar				+	+	+			+	+	
Albite	+	+									
Carbonate	+	+	+	+	+	+	+	+	+	+	+
Saussurite	+	+	+	+							
Pyrite	+	+	+	+	+	+	+	+	+	+	+
Biotite	+	+	+	+	+	+	+	+	+	+	+
Muscovite	+	+					+	+			
Chlorite	+	+	+	+	+	+				+	+
Epidote	+	+	+	+							
Sericite	+	+	+	+	+	+	+	+	+	+	+
Quartz-fgr	+	+	+	+	+	+	+	+	+	+	+
Quartz-cgr	+	+	+	+	+	+	+	+	+	+	+
ORE MINERALS											
Gold	+	+	+	+	+	+	+	+	+	+	+
Tennantite	+	+									
Galena	o	o		+	+	+			+		
Sphalerite	o	o		+	o	o	+	+	+		
Chalcopyrite	+	+	+	+							
Pyrrhotite	+	+	+	+					+		
Arsenopyrite	+	+		+	o	o	o	+	o	o	o
Pyrite	*	*	*	*	*	*	*	*	*	*	*

Relative abundances of ore minerals

* >50%
o >20%
+ <20%

Table 1: Relative amount of ore minerals, gangue and alteration minerals for the interior occurrences

and breccia pipes. Several generations of sericite are common. The intensity of sericitic alteration, as defined by the volume of sericite, appears directly proportional to the intensity of shearing and brecciation.

Carbonate, as fine grains with sericite, replacing feldspars, and associated with biotite-pyrite clusters is common. The intensity of carbonate alteration is low, except within the Letain shear zones, where increased carbonate alteration has resulted in chlorite-carbonate schists. The development of chlorite is unique to the Letain and Gold Coin localities, and is related to the mafic character of the protolith.

Biotite surrounding cores of euhedral pyrite is an alteration species common to all occurrences, but displays greatest abundances in the Sunbeam and Moonbeam breccia pipes. Biotite-pyrite clusters (of variable size and abundance) are found with sericite, carbonate, fine grained and coarse grained quartz. The clusters are disseminated throughout the altered host rock and mineralized areas. The presence of biotite along fracture surfaces in the pipe structures has caused a distinct blackening of the fractures.

Fine grained silicification, which is characteristic of all the interior occurrences, accompanies and/or postdates sericite alteration. Silicification is pervasive in areas of comminution, such as the matrix of the breccias, and milled areas of shear zones. The Letain A and B shear zones are examples of highly silicified, mineralized structures.

The concentration of discrete grains of potassium feldspar is unique to the Sunbeam fault where feldspars are reportedly distributed within the silicified fault zone.

The common alteration types yielding sericite, biotite, and fine grained quartz indicate that volatile-rich hydrothermal fluids were active in the interior of the complex. Carbonate, sericite, and silicic alteration of similar intensity is predominant within the Zone 4 breccia of the Sunbeam occurrence and shear zones of the Moonbeam, Waverley, and Sundog occurrences. This spatial relationship suggests that the introduction and migration of hydrothermal fluids causing the intense alteration may have been coeval with the deformation event(s) which produced these structures.

5.4 MINERALIZATION

The gold occurrences found within FLIC are all associated with a coarse grained variety of quartz, and sulphides (Table 1). Sulphide minerals observed (all occurrences) include pyrite, arsenopyrite, sphalerite, galena, pyrrhotite, chalcopyrite, and rare tennantite. Pyrite and arsenopyrite typically exceed 50% of the sulphide component at each locality. At the Moonbeam, Letain, and Gold Coin shear zones, the abundance of arsenopyrite exceeds that of pyrite. Sphalerite and galena are also common, although in lesser amounts, and there are subordinate amounts of pyrrhotite, chalcopyrite, and rare tennantite.

The sulphides have three general modes of occurrence:

(1) disseminated throughout variably altered host rocks

(2) disseminated in coarse grained quartz veins and pods

(3) blebs and stringers of sulphides along fractures, or within shear zones

The Sunbeam and Moonbeam occurrences host the most diverse sulphide assemblages (pyrite, arsenopyrite, pyrrhotite, chalcopyrite, sphalerite, and galena).

Rare tennantite was also reported (Harrison, 1935). An assemblage of pyrite, arsenopyrite, sphalerite and galena, with pyrrhotite is associated with the Waverley and Sundog shear zones near the granodiorite-quartz monzonite contact. Arsenopyrite is the only sulphide present at the Gold Coin showing.

Free gold has been reported for all occurrences in the interior of the complex, with the exception of the Waverley shear zones. The similarities between these structures and the gold-bearing SD-1 shear zone, identify the Waverley shear zones as potential occurrences of free gold.

In this study, free gold was only observed at the Sunbeam breccia pipe, within coarse grained quartz, or along its grain boundaries. The gold particles are irregular to subrounded and range from 0.01 - 1.0 mm in size. In his study of the paragenesis of the ore minerals of the Sunbeam pipe, Harrison (1935) interpreted the gold as the latest mineral to be introduced. The suggested gold-sphalerite affinity (Chastko, 1985) is not apparent in polished section.

Sampling from this program and from exploration activities has shown consistently erratic gold values within each of the occurrences (Appendix 3). Low grade values are confined to the host rocks; however, small pockets of high grade values have a sporadic distribution. This has made the estimate of grade and tonnage difficult.

The consistent affiliation of increased sulphide abundance and gold values with intensely altered structures, suggests that mineralization may have been synchronous with late alteration and deformation forming Zone 4 of the Sunbeam pipe, and the Moonbeam, Waverley, and Sundog shear zones. The close temporal relationship between shearing, alteration, and mineralization of the shear zones, combined with the similarity of late stage alteration and mineralization assemblages, suggests that a single stage of gold introduction was common to the Sunbeam, Moonbeam, Sundog, and Waverley occurrences.

The Sunbeam/Sundog fault is a north trending network of shear zones which offset the Sunbeam pipe on the 325 level of the workings. The distribution of low grade gold values along the fault and elevated values adjacent to the pipe may be indicative of remobilization of gold introduced during mineralization of the Sunbeam pipe. The abundant potassium feldspar distributed throughout the altered shear zones is not found is the Sunbeam pipe, and suggests that the remobilization may have involved percolation of an hydrothermal fluid unrelated to other mineralizing events.

5.5 DEVELOPMENT MODEL

The relative timing of development of structures, alteration, and mineralization associated with the interior occurrences is summarized in Figure 31. Other occurrences are compared with the Sunbeam breccia pipe, because of its excellent exposure. The sequential development of features observed in the pipe places constraints on the nature of mineralization of the interior occurrences. From this, a dynamic development model can be proposed for the interior occurrences of FLIC, although the relationship of the Letain and Gold Coin occurrences remains problematic. The Sunbeam, Moonbeam, Waverley and Sundog occurrences have all been interpreted unequivocally as developing after consolidation of the granodiorite phase of FLIC.

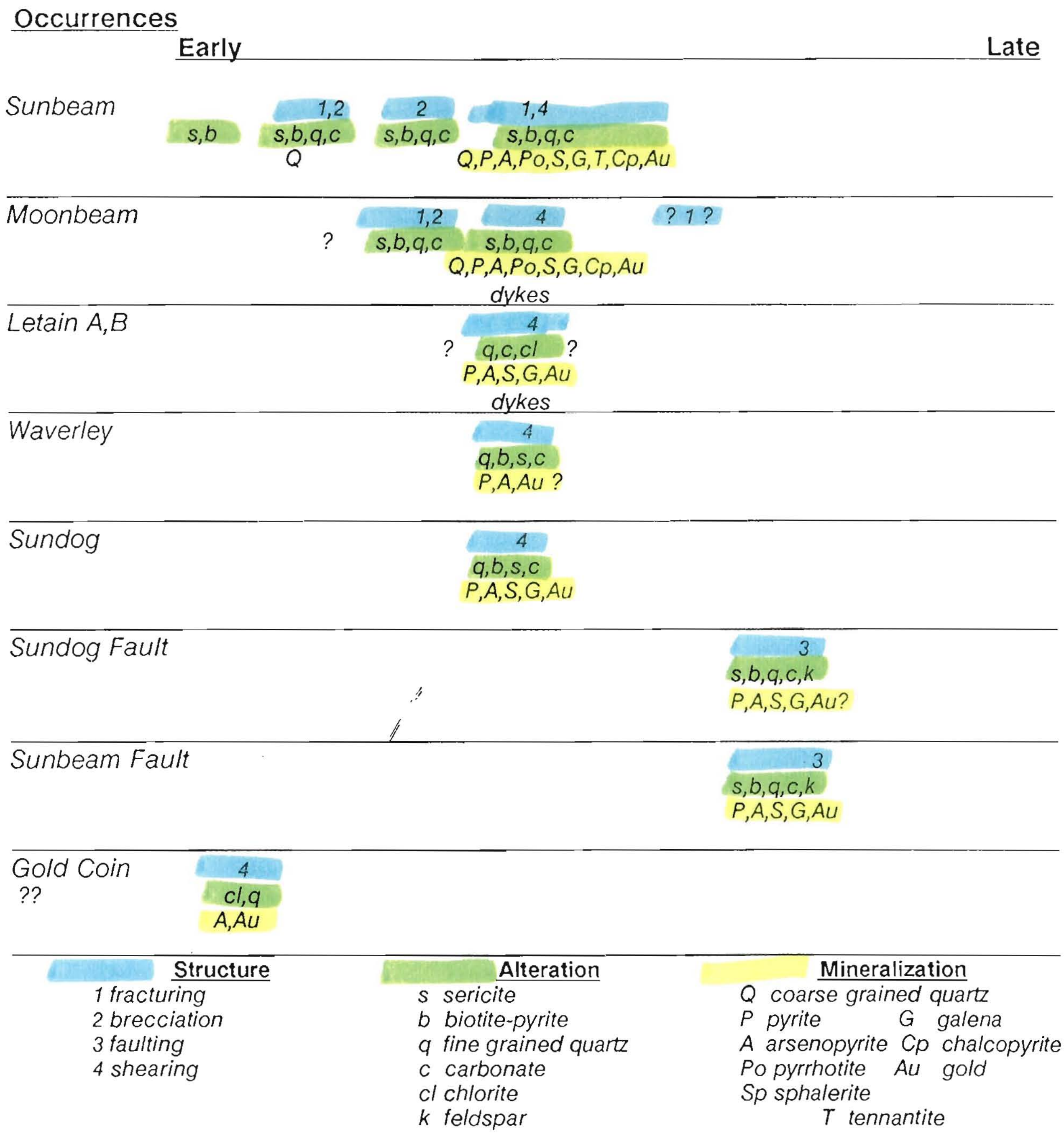


Figure 31: Relative timing of events generating the interior occurrences

Late stages of crystallization of quartz monzonite may have produced restricted, conduit-like structures (see 4.1, 4.2) in the vicinity of the quartz monzonite-granodiorite contact. Volatile-rich fluids migrating up such a conduit could produce sericitization and carbonatization of quartz monzonite, in the area adjacent to the conduit. The Sunbeam breccia pipe may have originated as such a conduit. Depressurization of the fluid would result in an energy release, and could have produced the observed concentric fractures and breccia of Zone 3. Alteration was synchronous with the brecciation. A minor amount of coarse grained quartz was also introduced as veins filling dilational fractures.

A similar depressurization event likely followed, but was restricted to the area of Zone 4 of the Sunbeam pipe. Further brecciation and intense alteration of a portion of the breccia zone resulted. This more restricted event may also have developed the breccia pipe of the Moonbeam occurrence. The large fragment size and discontinuous fracture pattern at the Moonbeam locality may suggest less energy dissipation in their development. If the Sunbeam and Moonbeam pipes were part of the same system, the Moonbeam may represent an area which is more distal from the source of hydrothermal fluids. Energy could also have been dissipated along the intrusive contact at the Moonbeam occurrence.

Withdrawal of the hydrothermal fluid related to the second decompression event generated an irregular network of discontinuous fractures and shear zones concentrated within, but not restricted to the rebrecciated zone of the Sunbeam pipe.

Shearing was imposed on the Moonbeam breccia, and areas of the granodiorite-quartz monzonite contact zone (Waverley, Sundog shear zones).

Deformation and alteration appear to have been synchronous, and accompanied by the introduction of gangue, sulphides and gold. The similarity of the alteration and ore assemblages suggests that the same or similar mineralizing hydrothermal fluids migrated through the Waverley, Sundog, and Sunbeam pipe. Therefore, a single episode(s) of shearing, alteration, and gold introduction likely postdated formation of the Sunbeam breccia pipe.

At the Moonbeam occurrence, late mafic dykes were introduced and crystallized during the shearing event. A subsequent decompression event may have caused brittle deformation, superimposing a concentric fracture pattern on the sheared granodiorite. These observations suggest that late stage magmatism associated with the complex remained active before, during, and after gold introduction.

The mineralized Sunbeam pipe was faulted and rotated, and later hydrothermal fluids unrelated to the original gold introduction may have remobilized gold from the pipe to the fault.

CHAPTER 6: GEOLOGY OF EXTERIOR OCCURRENCES

The exterior occurrences are hosted by the supracrustal sequence to the north of FLIC. In this area, the volcano-sedimentary sequence has been folded, and subsequently unconformably intruded by FLIC. Gold occurrences are distributed around the complex and are hosted by a variety of rock types (Figure 32).

The unconformable contact between the older volcanic sequence and the overlying younger sediments is well exposed and its morphology defines a series of fold limbs and noses. The unconformity and an iron formation representing the top of the volcanic sequence are useful markers from which relative stratigraphic positions can be determined. In the study area, intrusion of the complex has resulted in attentuation of the stratigraphic sequence; however, a portion of the stratigraphic section can confidently be reconstructed for areas in the vicinity of the unconformity.

Figure 33 is a stratigraphic reconstruction of detailed study areas to the north of FLIC, uncomplicated by deformation. The stratigraphy is presented in an overturned mode, for easier comparison to the regional geology. The level of intrusion of the diorite gives an indication of the portion of stratigraphy which was lost by intrusion of the complex.

A broad silicified gossan defining a deformation zone is exposed from the Moore to Sheba claims. This zone cuts the stratigraphy at a low angle and has a reported strike extent of 2 kilometres.

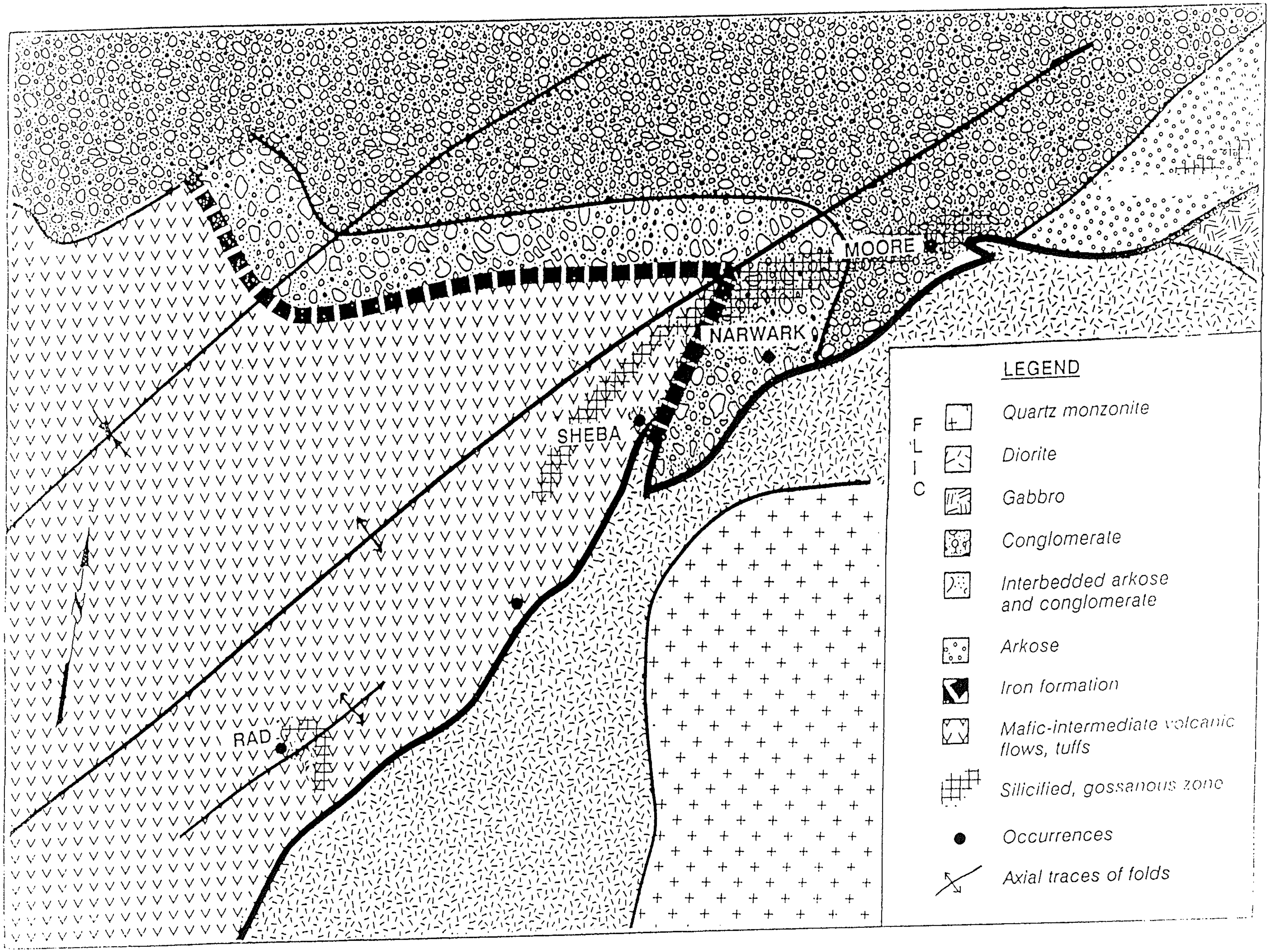


Figure 32: Distribution of exterior occurrences

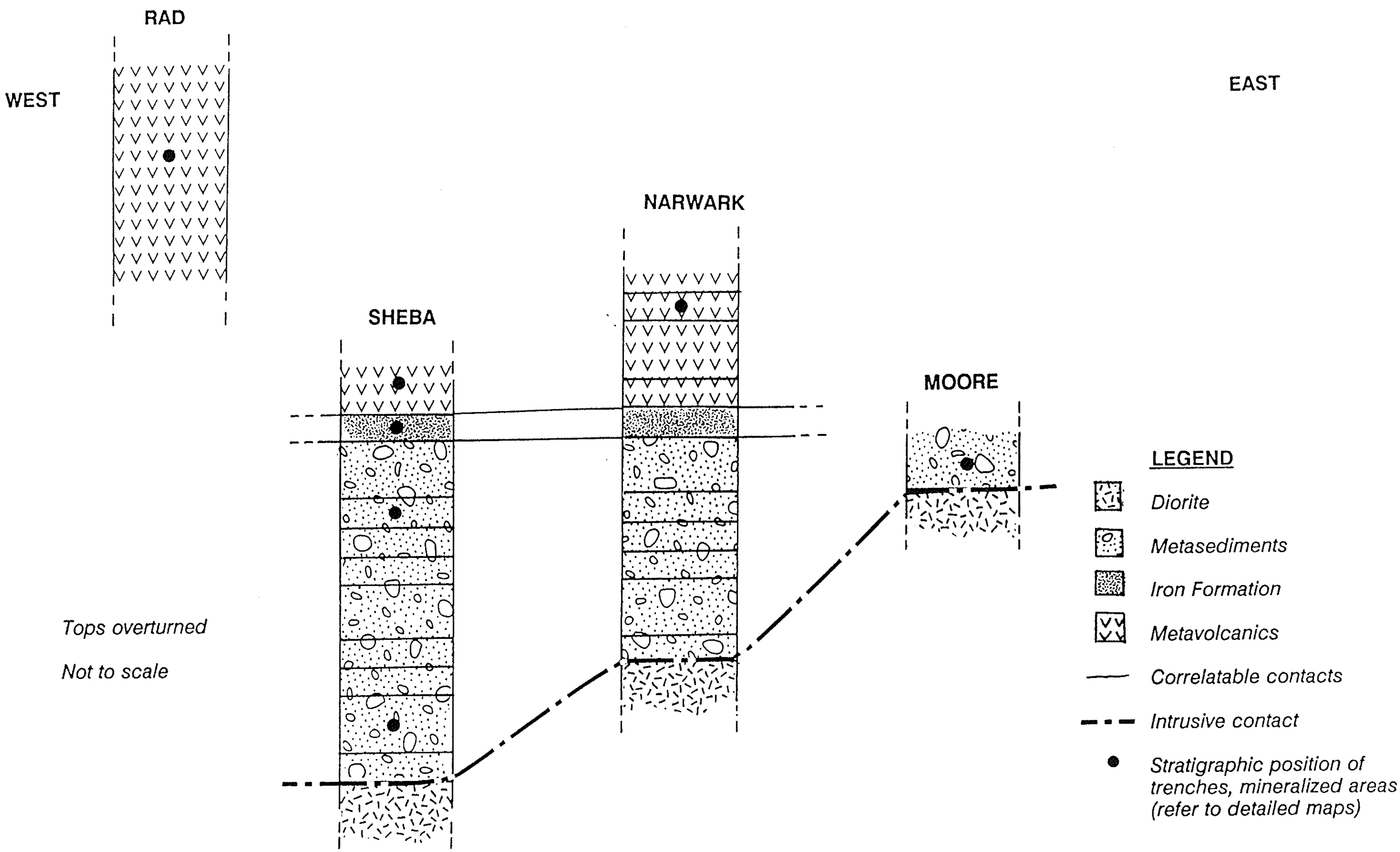


Figure 33: Stratigraphic setting of detailed study areas on the Moore, Narwark, Sheba, and Rad claims

6.1 MOORE CLAIM

The Moore occurrence is located in the supracrustal package to the north of FLIC, in the vicinity of a regional anticlinal axis (Figure 32). The basal paraconglomerate, which overlies the unconformity marking the beginning of the sedimentary sequence, hosts several narrow (0.5-1.0 m) discontinuous shear zones (Figure 34). The shear zones consistently trend northeasterly and dip 50 to 72 degrees to the northwest.

The structures on the Moore claim have been investigated by sampling and trenching as far back as 1917. A lobe of diorite is exposed on a small outcrop to the south of the largest trench. The large proportion of diorite in the waste dump surrounding the trench is indicative of a greater subsurface extent for the diorite than is exposed.

The network of shear zones are contained within the regional gossanous zone, which is laterally continuous to the southwest and northeast. Silicification and sulphides are restricted to the narrow shear zones within the limits of the gossan. The sulphides include fine grained disseminated pyrite, pyrrhotite, and arsenopyrite. A sample of silicified conglomerate taken from the dump assayed 818 ppb gold (Appendix 1). Previous sampling programs reported values of up to 0.24 opt gold (Marshall, 1917). Previously reported values of platinum group elements were not substantiated.

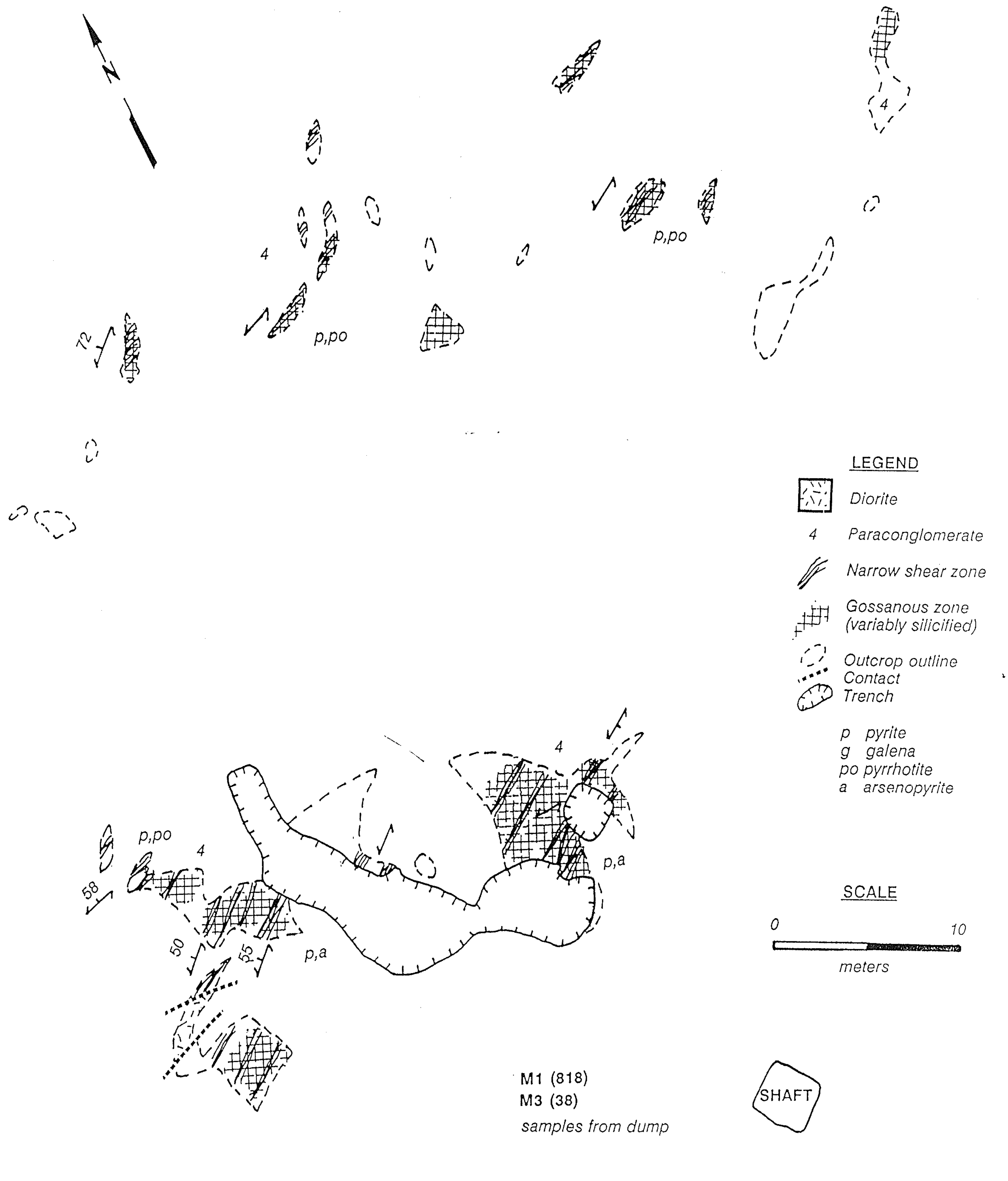


Figure 34: Geology of the Moore occurrence

6.2 NARWARK CLAIM

The supracrustal sequence at the Narwark claim has been folded into an anticline, and the volcanic-sedimentary contact traces a fold nose in this area (Figure 35). The volcanic rocks consist of massive mafic volcanic flows with interlayered narrow horizons of mafic tuff and iron formation. The uppermost part of the sequence is marked by a magnetite +/- chert iron formation, which is laterally continuous to the southwest. The continuity of this unit to the northeast is speculative, due to limited exposure. The overlying sedimentary sequence consists of a conformable package of conglomerate, conglomeratic arkose and arkose representing an active depositional environment. In the Narwark area, the stratigraphically highest portion of the section has been attenuated by the intrusion of diorite of FLIC.

The broad gossanous area observed on the Moore claim is a deformation zone which can be traced along a northeasterly trending arc to the Narwark area, where it crosscuts conglomerates, volcanic flows, and a unit of quartz banding. The latter unit is 0.5-2 metres wide, and is characterized by recrystallized quartz bands 0.5-2 centimetres wide which are separated by mafic volcanic septa. The siliceous bands are fractured, ptygmatically folded and dismembered (Figure 36). The bands may have been either an exhalative chert horizon, or a network of ribbon type veins.

Mineralization is associated with the banded quartz unit, as very fine grained pyrite and pyrrhotite disseminated in the mafic septa, and along fractures crossing quartz bands. Trace disseminated pyrite is pervasive throughout the entire gossan zone.

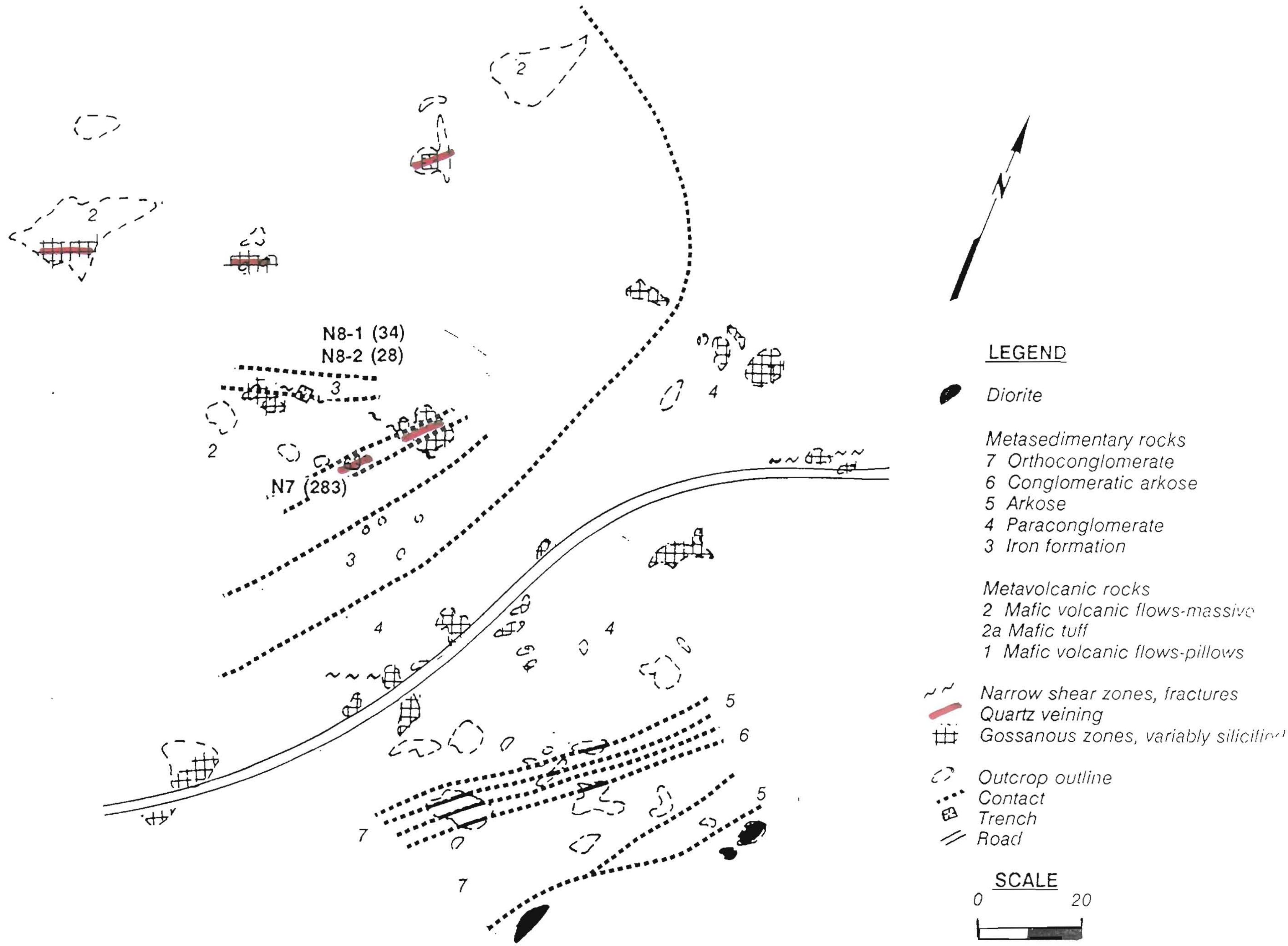


Figure 35: Geology of an area on the Narwark claim

Figure 36: Intensely folded, dismembered quartz bands with mafic volcanic flows, Narwark claim.

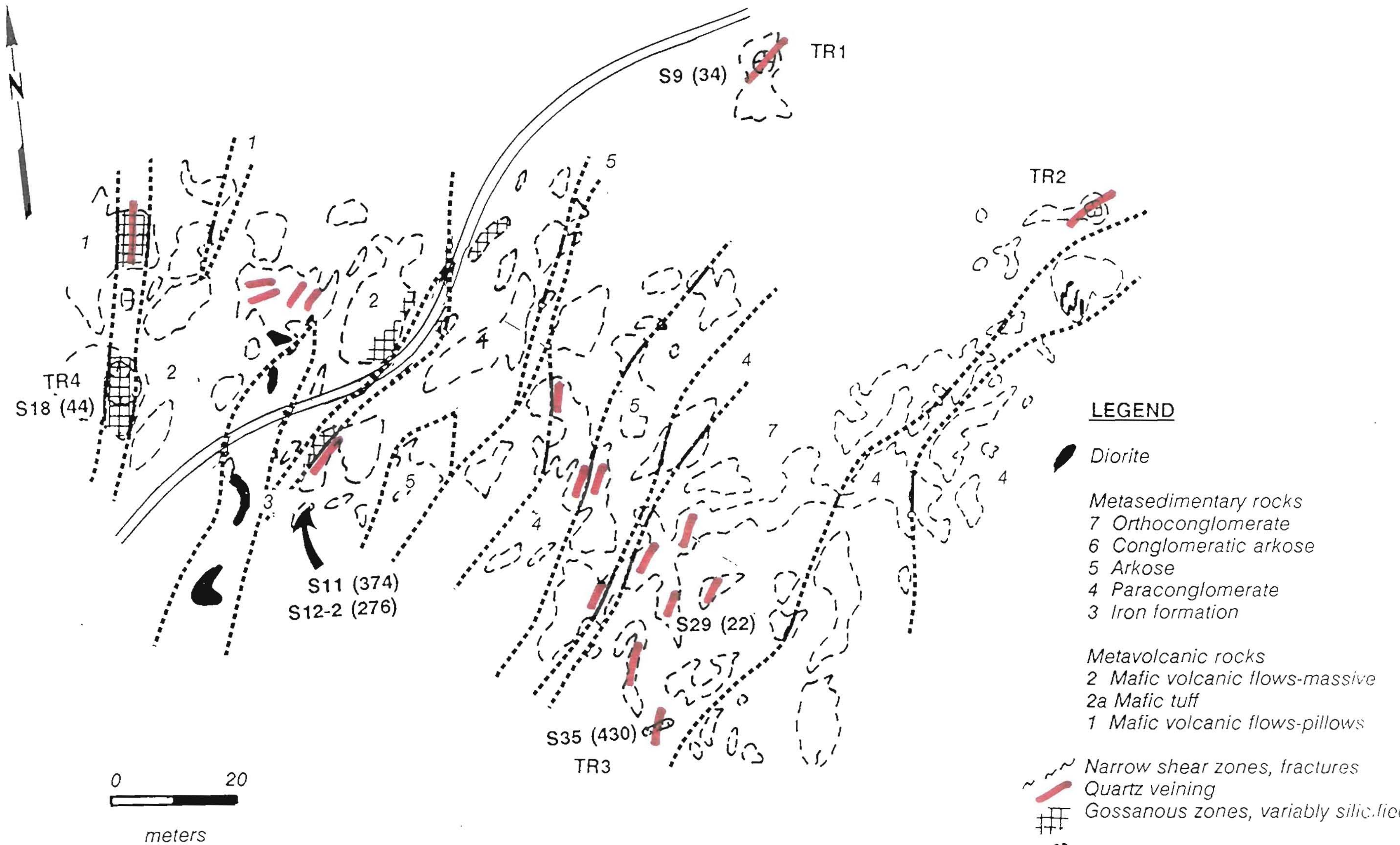
A similar horizon of siliceous bands is located to the south of the deformation zone. In this area, the unit appears concordant with stratigraphy. The quartz bands have been folded and fractured where intersected by a later E-W trending shear zone. Pyrite and pyrrhotite are localized along fractures of the deformed the quartz bands. Geochemical analysis of the mineralized area returned an anomalous gold value of 283 ppb.

Chert +/- magnetite horizons form a unit of iron formation at the top of the volcanic sequence. This unit and the overlying conglomerate of the sedimentary sequence are highly gossanous. Geochemical analysis of samples of the iron formation returned only background gold levels of 34 and 28 ppb.

Quartz veins are not common to the Narwark area. However, a single trench north of the deformation zone exposes a 60 centimeter wide, white, subtransluscent quartz vein with up to 10% of angular volcanic wallrock fragments. The vein contains no visible mineralization.

6.3 SHEBA CLAIM

The general stratigraphy on the Narwark claim is laterally continuous to the west, and is observed on the Sheba claim. On this claim, FLIC has intruded a stratigraphically higher position of the supracrustal sequence on the north limb of the syncline, leaving a larger section of the sequence preserved than on the Narwark claim (Figure 32). Massive and pillowed mafic flows which comprise the volcanic component of the section are overlain by a 0.5 metre wide magnetite iron formation followed by a package of interbedded conglomerate, conglomeratic arkose, and arkose (Figure 37). The section here faces southeast. A lobe of diorite intrudes the



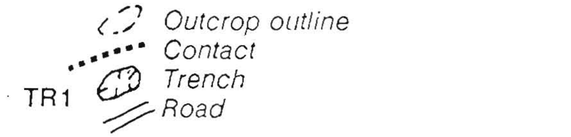


Figure 37: Geology of an area on the Sheba claim

section along the unconformity and the volcanic flows. Progressively more silica rich veins extend from the tip of the diorite lobe, and produce an array of sinuous quartz veins.

The gossanous deformation zone on the Narwark claim is continuous towards the Sheba area, where it narrows to less than 3 metres wide. The zone consists of sheared mafic flows to chlorite-carbonate schists, with discontinuous quartz bands. These bands are 1-2 centimetres wide, recrystallized, and separated by septa of mafic flows. Folding and fracturing has locally dismembered the quartz bands.

A second diffuse gossan occurs in the conglomerate bordering the unconformity.

Quartz veins filling tension fractures are localized in two areas: (1) within the mafic flows near the apex of the diorite lobe, and (2) a northeast-trending, discontinuous network extending through the sedimentary sequence. The irregular quartz-filled fractures and the progressively more silica-rich stockwork extending out from the lobe indicate that the intrusion of the diorite may have produced the structures, and may have been the source of the hydrothermal fluid which migrated through them (Figure 38). The veins appear void of sulphides. The extension veins within the sedimentary sequence are generally narrow (1-10 cm), discontinuous, and lacking visible sulphides and broad alteration halos. Three trenches are centered on veins of this variety, and gold values have been reported previously. Samples of veins taken during this study yielded erratic results, from 22 ppb to 430 ppb from Trench 3. A third variety of quartz veins is adjacent to the iron formation. The light to medium grey quartz veins with trace to 1% pyrite returned geochemically

Figure 38: Discordant quartz veins (white) extending out from narrow concordant diorite dyke, into mafic volcanic flows, Sheba claim.

anomalous values of 374 and 276 ppb gold.

The reported and documented gold occurrences on an area of the Sheba claim are quartz veins filling tension fractures, the majority of which are hosted by sedimentary units. The intrusion of FLIC diorite may have produced the fractures, in a manner similar to veins clustered around the dioritic lobe. The erratic distribution of gold and apparent lack of pervasive alteration associated with the veins, suggests that the gold may have been remobilized from another source by a late stage hydrothermal fluid. The anomalous character of the veins adjacent to the iron formation, and the elevated gold values may be a have been derived from metals scavenged from the iron formation. The poor exposure of the unconformity area limited further assessment of this possibility.

6.4 RAD CLAIM

The Rad occurrence has been investigated with a series of 15 trenches exposing a mineralized zone within mafic volcanic flows (Figure 39). The precise stratigraphic position of the mineralized zone is unknown; the marker unconformity has been attenuated by intrusion of FLIC (Figure 33). The FLIC intrusive contact is estimated to be 150-200 metres south of the showing. The host volcanic sequence is a monotonous series of massive mafic to intermediate flows. Local folding of these units is observed in late quartz veins, and in the volcanic flows exposed in Trench 4 (Figure 40). The axis of the fold trends easterly and plunges 60 degrees to the east.

The mineralized zone, herein referred to as the Rad unit, is 3-5 metres wide, highly gossanous and variably silicified. The extensive trenching of this horizon has

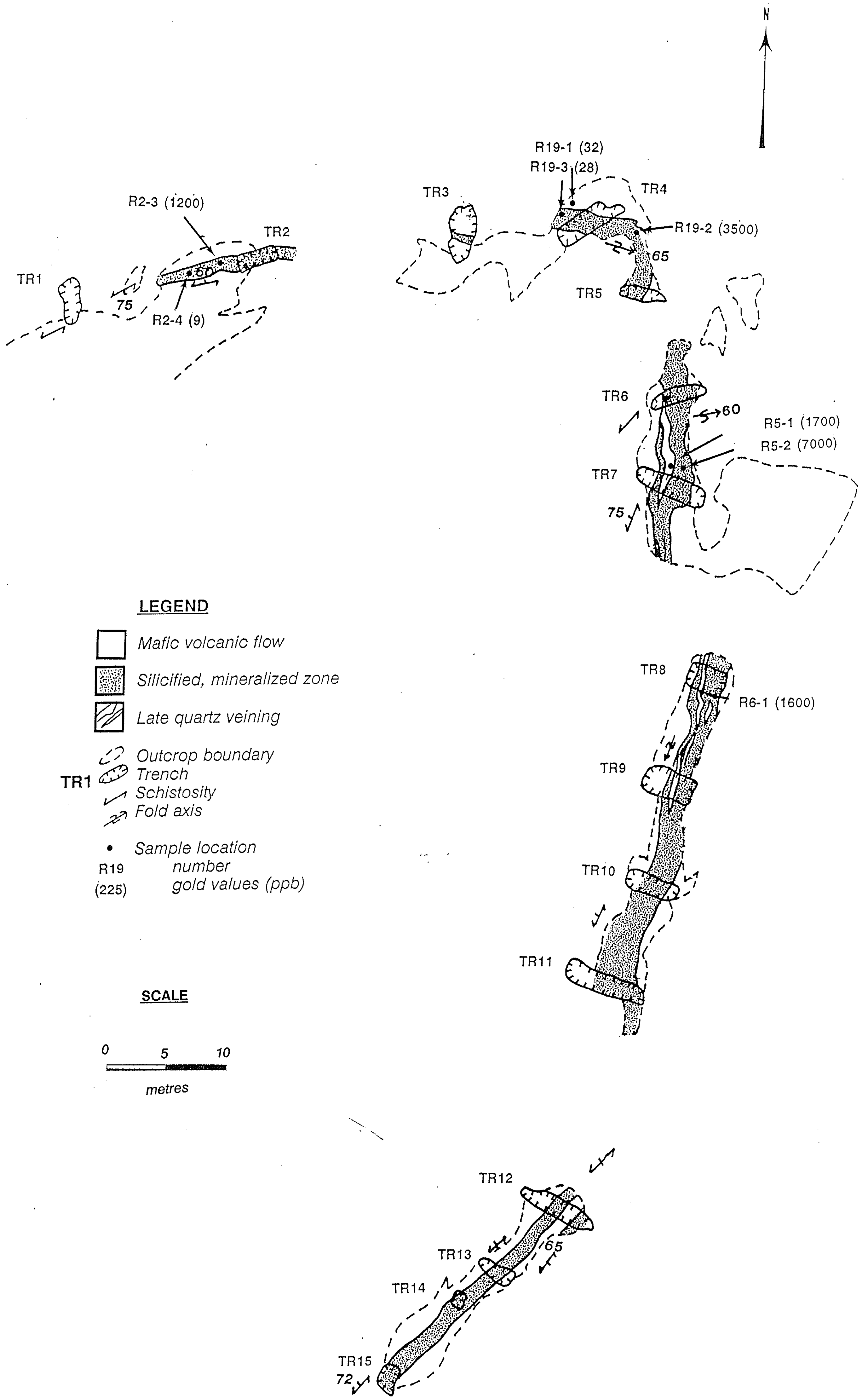


Figure 39: Geology of the Rad occurrence

Figure 40: Northeast plunging drag folds in altered mafic volcanic flows, Trench 4, Rad occurrence. Photo facing northeast.

exposed a continuous mineralized zone, which forms a broad open fold concordant with those observed in the volcanic flows. The zone is intensely sheared and altered. Deformation and alteration of the volcanic host has produced a variably silicified chlorite-carbonate schist characteristic of the Rad unit. Boundaries between the Rad unit and the volcanic flows range from sharp to diffuse.

The area between Trenches 5 and 8 has been subjected to more intense deformation and alteration, forming a silicified, carbonatized, and chloritized area (referred to as the Rad unit) lacking any relict features of the protolith. The alteration results in a distinct bleaching of the Rad unit. The pervasive fine grained silicification front changes laterally within the Rad unit, into a series of parallel 0.5-3 centimetre wide, white to light grey quartz veins, with septa of the mafic volcanic host. In Trench 8, these veins are parallel, steeply dipping, and have been deformed into a series of crenulations (Figures 41,42). The ribboned appearance of these veins is characteristic of formation by a crack-seal mechanism (Hodgson, 1985). Microfolding of these veins is also observed in the Trench 4 area (Figure 43). The alteration of the wallrock follows a similar trend as the quartz vein.

A variety of later quartz veining has been observed in the area from Trenches 1 to 9. The veins are light to dark grey, mottled, and occur as either anastomosing networks of veins 0.6-1.0 metre wide, or single 30 centimetre wide veins (Figure 44). In the silicified area, late quartz veins have caused brecciation and incorporation of the altered wallrock (Figure 45). Brittle emplacement features are also observed in the Trench 2 area, where angular protrusions of sheared, altered host occur in the quartz vein (Figure 46). The drag folded ribbon veins are truncated by the later quartz veins (Figure 42).

Figure 41: Parallel, steeply dipping ribbon veins in Rad unit, Trench 8, Rad occurrence. Photo facing southwest. Rad unit recognized by orange-brown gossan.

Figure 42: Crenulated ribbon veins in Rad unit, truncated by later emplaced quartz veins. Between Trenches 8 and 9, Rad occurrence. Photo facing southeast.

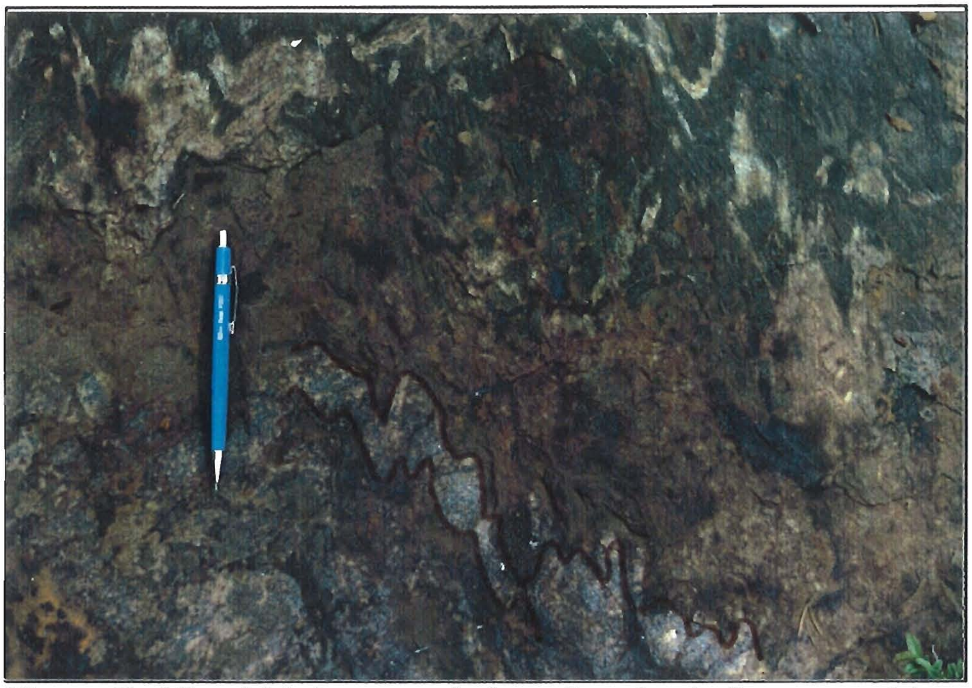


Figure 43: Microfolded quartz vein in mafic volcanic flows comprising Rad unit, Trench 4, Rad occurrence. Photo facing northeast. Dark grey veins are outlined.

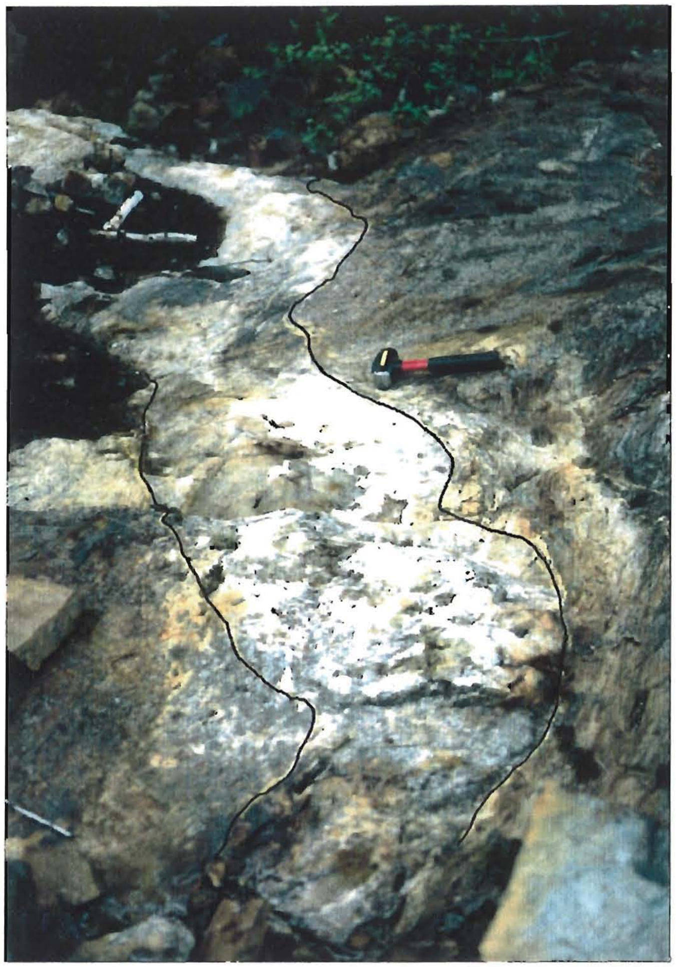


Figure 44: Late, white-light grey quartz vein emplaced into rad unit, area between trenches 6 and 7, rad occurrence. Photo facing east. Quartz vein is outlined.

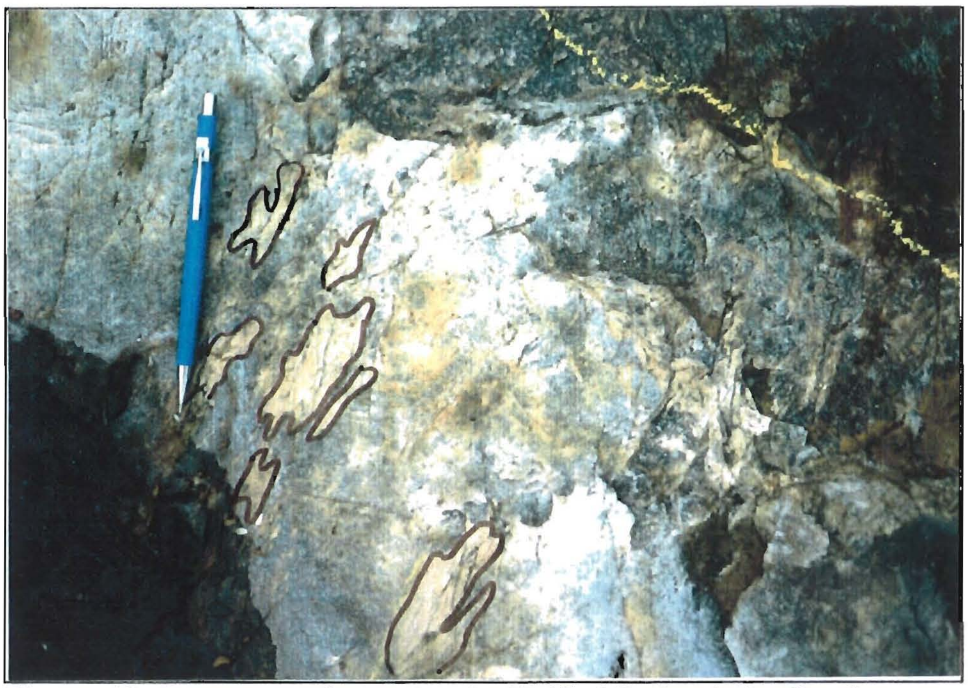


Figure 45: Fragments of crenulated, silicified Rad unit (outlined) suspended in late quartz vein, area between Trenches 6 and 7, Rad occurrence. Photo facing east.

Figure 46: Late quartz vein forcibly injected into Rad unit, forming sharp, subconcordant slivers extending into host, area west of Trench 2, Rad occurrence. Photo facing north. Sharp contact between vein and wallrock is outlined.

Mineralization associated with the Rad unit consists of the two varieties of introduced quartz, and disseminated sulphides: pyrite, pyrrhotite, arsenopyrite, galena, chalcopyrite, and gold. The sulphides are disseminated in the wallrock septa in the ribbon veins, and along fractures extending through the veins. Pyrite, arsenopyrite, galena, and chalcopyrite are also common to the larger, late quartz veins (Figure 47).

Gold is consistently associated with sulphides and silicified host, as indicated by sample assays result ranging from 3500 to 7000 ppb gold (Appendix 1). Late quartz veins in proximity to these areas returned lower values of 1200-1700 ppb gold. The sheared, carbonatized volcanic flows have gold values at or near background levels (32 ppb). The grade distrbution shows a correlation of gold and sulphides in area of quartz veining and silicification.

The observed features of the Rad occurrence indicate that there was early shearing and alteration of the mafic volcanic rocks. The intense silicification and ribbon vein generation accompanied this deformation. Finer banded varieties may represent silicified beds of mafic tuff. The observed change in character from ribbon veins, to an intensely silicified zone appears to be similar to the Hollinger mine, where veins in schist zones developed in bleached, carbonatized mafic flows change along strike into replacement textures (Jones, 1948).

The Rad unit has been folded into an antiform with an E-W trending axis plunging 60 degrees to the east. The schist has been isoclinally folded in the nose area at Trench 4. Intense silicification south of Trench 5 may have been produced during a hydrothermal event synchronous with intense folding. The ribbon veins

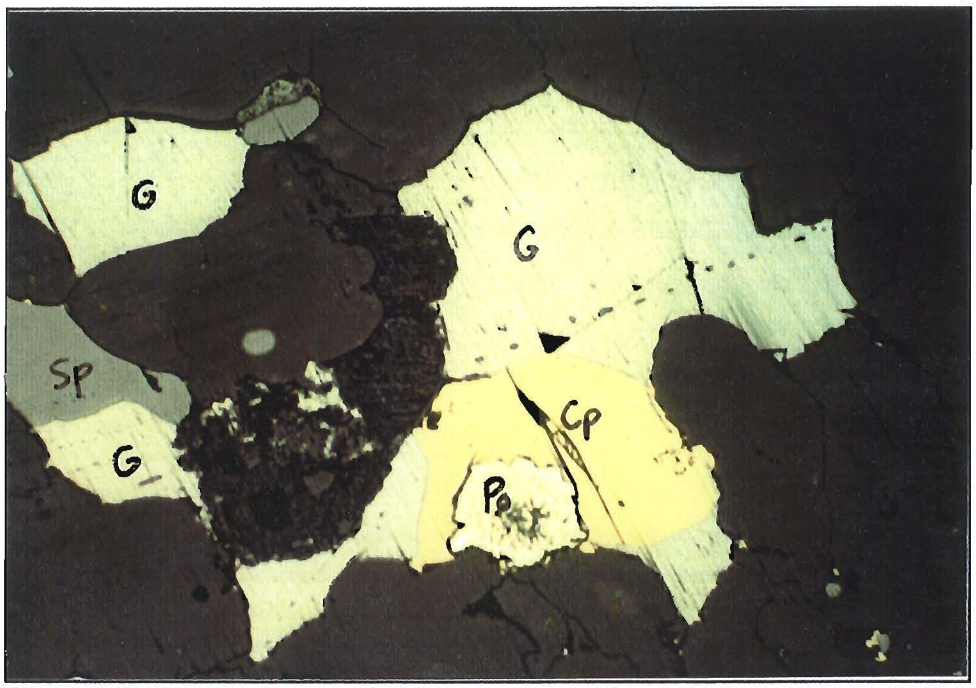


Figure 47: Photomicrograph of coarse grained sulphides as open space filling in late quartz vein, Trench 7, Rad occurrence. Po (pyrrhotite), Cp (chalcopyrite), G (galena), Sp (sphalerite). Field of view - 11.3 mm.

express well developed crenulations on the easternmost limb.

The larger, white to grey quartz veins crosscut earlier developed folds, but are confined to the Rad unit. Where the veins extend through the silicified areas, fragments of the altered wallrock are suspended in the veins. Late fracturing imposed on the ribbon veins may be related to such brittle behavior, as well. The association of sulphides with both the large veins and wallrock septa and fractures of the ribbon veins suggests mineralization is related to the hydrothermal event which generated the late quartz veins. The distribution of gold within these areas is consistent with this conclusion.

CHAPTER 7: COMPARISON OF EXTERIOR OCCURRENCES

The similarities and differences between the exterior occurrences with respect to distribution, structure development, alteration, and mineralization place constraints on the relative timing of these events. This chapter compares these features, considers age relationships forming them, and presents a development model for the exterior occurrences.

7.1 DISTRIBUTION

The exterior occurrences are concentrated in the supracrustal sequence to the north of the intrusive contact. Occurrences may be more uniformly distributed around the complex but are not well exposed to the south of FLIC. The reported gold showings to the north are hosted by both the volcanic and sedimentary rocks of the succession, are locally in close proximity to a phase of FLIC (e.g. Moore occurrence).

7.2 STRUCTURE

The gold occurrences in the country rock surrounding FLIC are all hosted by brittle and brittle-ductile structures of varying ages. On a large scale, mineralization has three major structural associations:

(1) broad deformation zone on the Moore, Narwark, Sheba claims

(2) deformed shear zone on the Rad claim

(3) discontinuous extension fractures

The deformation zone forms a northeast trending arc with variable internal alteration and mineralization. On the Moore claim, the occurrence is hosted by a network of narrow, variably silicified shear zones. Along strike toward the Narwark claim, the zone is more diffuse in character and internal structures are only recognized where the zone cuts horizons of quartz bands. In these areas, the bands have been extensively folded and fractured. Further west, on the Sheba claim, the deformation zone narrows, and is concordant with stratigraphy. Discontinuous areas of quartz banding are straight and undeformed, and may be chert horizons locally present in the sequence. The arcuate form of the deformation and the localized increase in deformation with proximity to the fold nose suggests that the deformation zone may have developed prior to the regional folding event. In its original configuration, the zone may have been subconcordant to concordant with stratigraphy.

Several of the structures hosting the Rad occurrence were produced during the multiple regional deformational events. Early brittle-ductile shearing and quartz veining were followed by regional folding and a second episode of quartz veining. The shear zone is laterally variable from a highly silicified zone, reflecting ductile deformation, to a network of ribbon veins, reflecting more brittle-ductile deformation.. These veins were deformed into crenulations during regional folding during which the entire shear zone was folded into a southwest facing synform. The relict structural anisotropies due to shear folding controlled emplacement of the later quartz veins, which caused local brecciation of wallrock and truncation of microfolds.

Extension fractures filled with quartz veins are widely distributed in the volcanic and sedimentary rocks adjacent to FLIC, but are most concentrated on the Sheba claim. The veins are commonly narrow (2-20cm) and continuous over 0.5-3 metres. The spatial correlation of increased abundance of fractures in country rock proximal to lobes of diorite extending out from the complex suggests that intrusion may have played a role in producing the fractures.

7.3 ALTERATION

Alteration associated with the exterior occurrences is erratic with respect to the products and intensity. The variability of the products is shown in Table 2, which lists alteration products for selected mineralized localities. The variability of intensity appear to be related to structural style. The alteration of wallrock hosting extension veins is not extensive, while the regional deformation zone is highly altered.

The deformation zone is altered to a variably silicified chlorite-carbonate schist and alteration appears to have been synchronous with deformation forming the zone. The size of the alteration zone and its intensity appear to increase with proximity to the fold axis, on the Narwark and Moore claims. It is therefore possible that a hydrothermal event coeval with or later than regional folding produced increased alteration in sites of enhanced permeability, such as fold noses.

On the Rad claim, the arcuate form of the Rad unit and its internal crenulations, suggest that regional folding postdated the intense chlorite-carbonate-quartz alteration charateristic of the unit.

7.4 MINERALIZATION

Mineralization associated with the exterior occurrences consists of (1) sulphide assemblage: pyrite, pyrrhotite, arsenopyrite, with local concentrations of sphalerite, chalcopyrite and galena; (2) gold; and (3) quartz gangue. Most of the occurrences host low tenor gold, with the exception of the Moore and Rad showings.

Relative abundances of ore minerals

* > 50%
\+ < 20%

OCCURRENCES	Pyrite	Arsenopyrite	Pyrrhotite	Chalcopyrite	Sphalerite	Galena	Magnetite	Gold	Quartz-cgr	Quartz-fgr	Chlorite	Biotite	Pyrite	Carbonate	Tourmaline
	ORE MINERALS								**ALTERATION/GANGUE MINERALS**						
Moore	*	+						+	+	+	+			+	
Narwark:															
N-7	*							+						+	
N-8	+						*	+						+	
Sheba:															
S-9	*							+	+		+			+	
S-10	*	+	+					+	+					+	+
S-11	*							+	+		+	+	+	+	+
Rad	*	+	+	+	+	+		+	+	+	+			+	+

<u>Table 2:</u> Relative amount of ore minerals, gangue and alteration minerals for selected exterior occurrences

Anomalous gold values are associated with disseminated pyrite and pyrrhotite which occur in silicified shear zones on the Moore claim (818 ppb gold), and along fractures of deformed quartz bands (283 ppb gold) in the deformation zone crossing the Moore, Narwark, and Sheba claims.

Apparently barren extension veins on the Sheba claim have erratic gold values, ranging from background levels of 22 ppb gold, to anomalous levels of 430 ppb gold. Samples of grey quartz veins with 1% pyrite, bordering the iron formation in this area also returned anomalous gold values (374, 276 ppb). The adjacent, barren iron formation returned only background gold values.

The mineralization associated with the Rad occurrence consists of a diverse sulphide assemblage: pyrite, pyrrhotite, arsenopyrite, chalcopyrite, galena, and sphalerite. The introduction of sulphides and gold was coincident with hydrothermal fluids which produced late quartz veins. Fine to medium grained clusters of sulphides are distributed within these veins, and along fractures of the earlier deformed veins and wallrock. Gold values within the area of late quartz veins are consistently of high grade, typically ranging from 1600 to 7000 ppb gold.

7.5 DEVELOPMENT MODEL

The relative timing of the development of structures, alteration, and mineralization associated with the exterior occurrences is summarized in Figure 48. All events are compared to those affecting the broad deformation zone which is continuous across the Moore, Narwark, and Sheba claims. The supracrustal rocks to the north of the complex have been subjected to several events of deformational events.

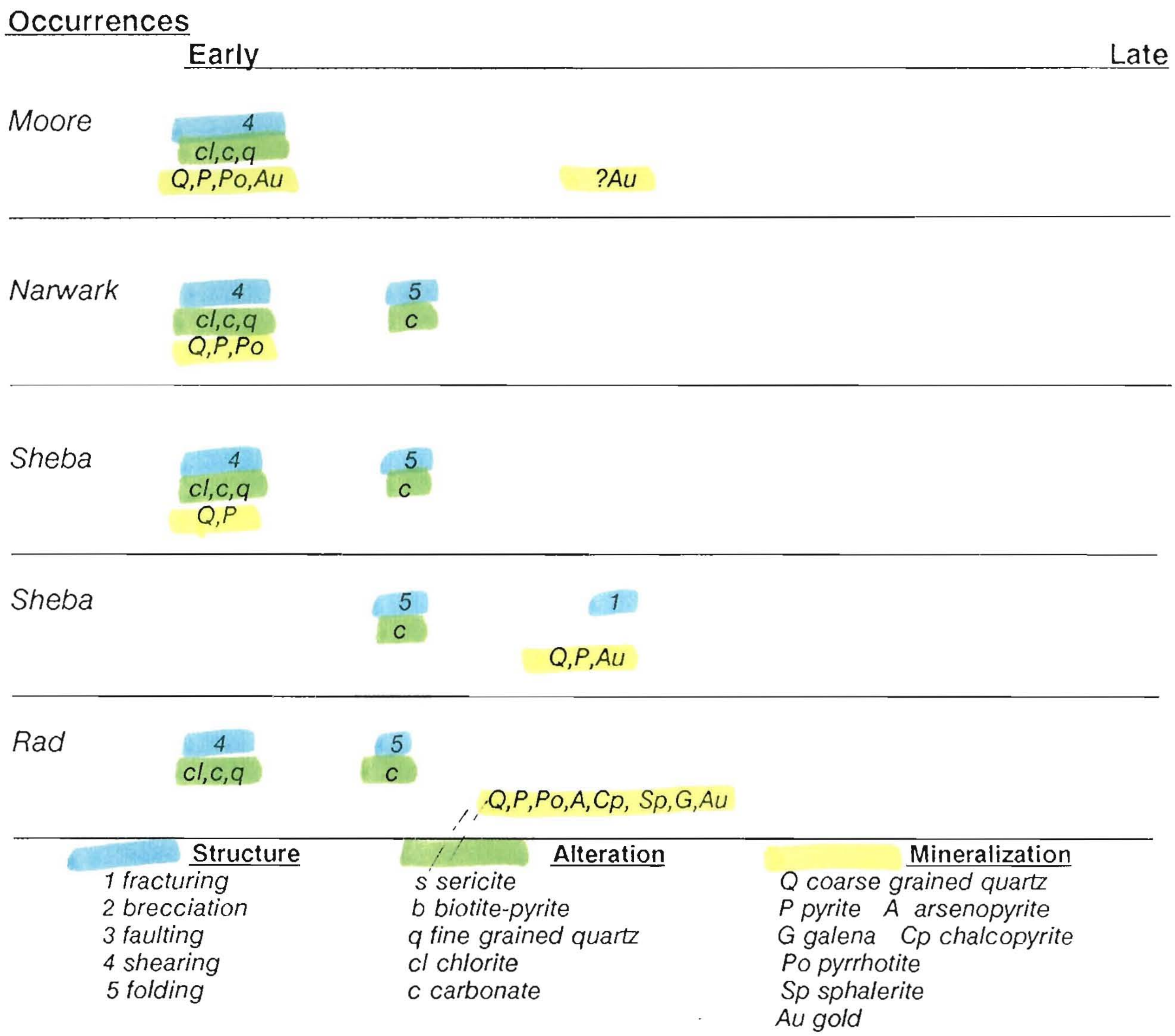


Figure 48: Relative timing of events generation the exterior occurrences

The intrusion of FLIC has caused attentuation of fold axes and stratigraphy along fold limbs, indicating that the emplacement of the peripheral intrusions of FLIC postdated regional deformation. Therefore, all the events (deformation, alteration, and mineralization) and their products which have been affected by regional folding, can be considered to predate FLIC emplacement. Hydrothermal/deformation events forming the Rad unit and the deformation zone thus occurred prior to FLIC emplacement.

The volcanic-sedimentary sequence, in its predeformation configuration, was subjected to shearing and alteration focussed along linear zones which were subconcordant to bedding. The migration of hydrothermal fluids was synchronous with brittle-ductile deformation, and resulted in carbonatization, chloritization, silicification, and the introduction of discontinuous zones of quartz veins to form the deformation zone and the Rad unit. The temporal relationship between the hydrothermal events forming these two features is unknown.

Northeasterly-directed regional deformation resulted in folding of the stratigraphy and pre-existing structures, to produce the arcuate form and internal fold features characteristic of the deformation zone and the Rad unit.

The emplacement of successive intrusions forming the FLIC was centered along a northeast to east trending fold axis. The intrusion locally caused unconformable truncation of portions of the stratigraphy along fold limbs. On the Moore and Sheba claims, lobes of diorite extend into the country rock. The concentration of narrow, discontinuous shear zones at the Moore occurrence and a network of tension fractures at the Sheba occurrences are spatially related to the lobes of diorite in each area. Forceful emplacement of diorite have produced these structures. Volatile-rich fluids exsolved from the dioritic magma may have migrated through the country rock along fractures, producing quartz veins on the Sheba claim.

Alteration and mineralization at the Moore occurrence is concentrated in the narrow shear zones which are at the intersection of the deformation zone and a fold nose. The heat of intrusion of the lobe of diorite may have initiated a convective cell which circulated magmatic or meteoric water. The occurrence of high grade gold values on the Moore occurrence, compared to slightly anomalous values on the Sheba claim, suggests that the dioritic magma forming the lobes, was not the source of mineralization. Rather, late hydrothermal fluids likely migrated through the structural traps at the Moore occurrence, scavenged metals from the deformation zone, and redeposited them as ore minerals in the narrow shear zones forming the Moore occurrence. At the Rad occurrence, later hydrothermal fluids introduced large quartz veins, a diverse sulphide assemblage, and high grade gold. The source of the hydrothermal fluids and mineralization remains uncertain.

The origin of the exterior occurrences remains unclear; the successive deformation events affecting the country rock, and successive intrusions related to FLIC provide several possible hydrothermal associations. However, it is known that the distribution of a majority of the occurrences is controlled by structures which originated before FLIC emplacement. Mineralization may have predated FLIC emplacement, and may have been remobilized by hydrothermal fluids derived from magmatic and/or metamorphic processes related to FLIC. The source of hydrothermal fluids and mineralization for the Rad occurrence remains uncertain.

The Rad occurrence is close to the Rennie Lake batholith and it is possible that its mineralization may be related either this pluton or FLIC.

CHAPTER 8: DISCUSSION AND CONCLUSIONS

8.1 ROLE OF FLIC IN MINERALIZATION

The component intrusions of FLIC have collectively played four major roles in the generation of gold occurrences
in the study area:

(1) Host rock

(2) Generation of structures

(3) Initiation of hydrothermal systems

(4) Source of mineralization

Host

The interior occurrences are all hosted by component intrusions of FLIC. The Gold Coin occurrence is hosted by gabbro; however, the majority of the occurrences are clustered in the center of the complex, where they are hosted by either granodiorite or quartz monzonite.

Generation of structures

Mineralization is consistently associated with brittle and brittle-ductile structures within the intrusions and the country rock of the complex. The breccia pipes and shear zones hosting the interior occurrences indicated that deformation generating these structures must have occurred after the quartz monzonite of this area had solidified and cooled sufficiently to support brittle failure. However, the pipes have been interpreted to have formed in a process related to late stage consolidation of magma at depth. The disposition of structures, alteration, and mineralization of interior breccia pipes and shear zones has been interpreted as being the result of successive decompression events causing brecciation, separated by a shearing event, alteration and mineralization.

The exterior occurrences are concentrated in the country rock surrounding FLIC. Many of the occurrences are controlled by structures which were generated prior to FLIC emplacement. On the Sheba claim, the emplacement of a lobe of diorite may have given rise to a series of extension fractures that host quartz veins.

Initiation of Hydrothermal Systems and Fluid Sources

A hydrothermal system related to intrusions can be defined in a variety of models which represent successive stages in an evolving process. Two end member models define the processes involved as either orthomagmatic or convective (McMillan and Panteleyev,1976), with the fundamental difference between the two models being the source and flow path of the hydrothermal fluids.

In the orthomagmatic model, progressive crystallization of a magma initiates the resurgent boiling reaction, to release an ascending hydrothermal plume which causes alteration and mineralization (see 4.1).

In the convective model, the heat of emplacement of magma initiates thermally driven convection cells. Meteoric water is drawn into these cells and circulates through permeable areas of the country rock and/or pluton. In this manner, convection redistributes fluids for concentration of metals near the intrusion.

The interior occurrences of FLIC have been interpreted as being related to late stage magmatic activity. In this area, a hydrothermal system was therefore initiated according to the orthomagmatic model, and magmatic fluids were likely sources of the mineralization.

Both orthomagmatic and convection hydrothermal systems may have been operative in the formation of the exterior occurrences. On the Moore and Sheba claims, the close spatial relationship between occurrences and diorite of FLIC suggests exsolved magmatic fluids may have deposited ore minerals and gangue. It is also possible that the intrusion of early phases of the complex initiated convective circulation of groundwater which may have scavenged gold and other metals from preexisting occurrences observed on the Moore, Narwark, Sheba, and Rad claims.

8.2 FLIC AS A PORPHYRY STYLE SETTING

8.2.1 Porphyry Deposits

The definition of porphyry deposits and their models have undergone considerable evolution since Parson's 1933 original definition as "large deposits of disseminated copper mineralization which can be mined economically". The development of mass mining techniques first employed at Bingham, Utah, made several large, low grade supergene deposits economic and therefore redefined them as porphyry copper deposits (e.g. Ely, Nevada; Santa Rita, N.M.; El Teniete and Chuquicamata, Chile).

With consideration of only geological features, Lowell and Guilbert (1970) revised the definition of a porphyry deposit as "a copper and/or molybdenum sulphide deposit consisting of disseminated and stockwork veinlet sulphide mineralization emplaced in various host rocks that have been altered by hydrothermal solution, into roughly concentric zonal patterns". The typical zonal alteration and mineralization patterns were defined as those documented for the San Manuel-Kalamazoo deposit; however, departures from these patterns and assemblages are a function of a number of variables (see Guilbert and Lowell, 1974).

Kirkham (1972) provided an alternate definition: " A porphyry deposit is a large, low to medium grade deposit in which the hypogene sulphides are primarily structurally controlled and which is spatially and genetically related to felsic or intermediate, porphyritic intrusions". The size factor is considered most important in separating deposits of this style from widespread copper and molybenum occurrences associated with felsic intrusions. Emphasis is also placed on structural control, to include deposits with regional controlled vein systems (e.g. Butte and Chuquicamata), stockworks, and breccia pipes (e.g. Cananea and Highland Valley). The requirement of structural control also serves to separate porphyry deposits from contact metasomatic (skarn) deposits.

Kirkham's definition is not restrictive as to metal content and is based entiredly on hypogene characteristics. Deposits showing supergene enrichment are considered leached, oxidized, or weathered porphyry deposits.

Characteristics

Within the definitions of Lowell and Guilbert, and Kirkham, the generalized geological characteristics of porphyry deposits are (Mc Millan and Panteleyev, 1976):

(1) spatially and genetically related to an intrusion

(2) intrusions are felsic to intermediate

(3) intrusions are epizonal and commonly porphyritic

(4) multiple intrusions, dyke, swarms, intrusive breccias, breccia pipes, and pebble dykes are common

(5) host for intrusions can be any rock type

(6) intrusions and country rock are intensely fractured

(7) mineralization/alteration is widespread and may exhibit lateral zoning

The typical alteration, mineralization patterns and assemblages for porphyry copper were defined by the San Manuel-Kalamazoo model. The idealized alteration zoning, as developed in the Laramide monzonite porphyry, consists of potassic, phyllic, argillic and propylitic assemblages forming zones which are coaxially arranged outward from a potassic core through phyllic, argillic and propylitic zones. In this model, mineralization zones are conformable to alteration zones, with the ore zone overlapping the potassic and phyllic zones. The sulphide species vary from a core dominated by chalcopyrite-molybdenite-pyrite outwards to galena-sphalerite +/- gold and silver.

The disposition of these features in a porphyry deposit may depart from this model, as affected by exposure, host rock, structural controls, fluid composition, and size of the deposit (Guilbert and Lowell, 1974).

The depth of exposure reflects a zonation based on assemblages stable at the tempertures and pressures of that depth. For example, at the Butte deposit, quartz-sericite-pyrite alteration envelopes in upper levels grade downward into the typical porphyry zonation. The wallrock type also influences the alteration assemblages and the alteration of heterogeneous wallrock will result in poorly defined zonation patterns. In the alteration of mafic volcanic host rocks, alteration of highly reactive mafic minerals could develop a wide propylitic zone (epidote-chlorite-carbonate).

In a high ferro-magnesian host, biotite dominates, instead of sericite, as observed at the El Salvador, Chile and Babine Lake, British Columbia deposits (ibid).

Syn- and post-ore structures can alter the distribution of alteration. If the deformation forming the structures was coeval with alteration and mineralization, the hydrothermal fluids involved would have been focussed along, and possibly confined to the structures. In this case, alteration patterns would overprint each other, and zonation would not be well defined. Post ore structures can alter the configuration of pre-existing alteration and mineralization patterns.

The size of a deposit may also account for the alteration patterns present, and it has been observed that larger occurrences tend to show more regular and well developed zoning of both alteration and mineralization assemblages. The alteration patterns, and intensity of alteration are commonly more erratic for smaller deposits (ibid).

Distribution and Age

Porphyry copper deposits are distributed worldwide, and coincide with island arc or continental margins settings within orogenic belts. The majority of the deposits are Mesozoic and Cenozoic in age, few are Paleozoic. Many Precambrian deposits and occurrences in the Superior Province which are associated with felsic-intermediate plutons have features in common with porphyry deposits; however, few have been defined as being true porphyry style (e.g. Setting Net Lake, Canoe Lake, High Lake, Beidelman Bay, McIntyre Mine, the Tribag breccias, and the Don Rouyn Mine)(Colvine and Sutherland, 1985). The Beidelman Bay, Tribag breccias, and the Don Rouyn Mine are all copper-gold +/- molybdenum occurrences which are dominated by copper. The Canoe Lake, High Lake, and the McIntyre Mine deposits are considered to be gold dominated.

The Beidelman Bay, Don Rouyn, and possibly the McIntyre deposits are all associated with small synvolcanic plutons which were emplaced at high levels in the respective volcanic sequences, and therefore may be considered analagous to more recent deposits in island arcs (e.g. Paguna, New Guinea). Porphyry style occurrences such as Canoe Lake, High Lake, and the Tribag breccias are associated with postvolcanic plutons, similar to "typical" style Mesozoic and Cenozoic deposits of the Cordillera.

Classification and Models

McMillan and Panteleyev (1976) have proposed a classification system for porphyry deposits, based on their general setting. Three broad types are defined as plutonic, volcanic and classic; characteristics of each are presented in Table 3. Plutonic type deposits occur in batholiths, with mineralization concentrated in one or more phases of the pluton. Volcanic type deposits occur in the roots of volcanic systems and are considered to be comagmatic. In this setting, the pluton and/or volcanic rocks may be mineralized. Classic type deposits are the "typical" porphyry model of a post-orogenic stock intruding unrelated country rocks. The pluton and/or country rocks may be mineralized.

A variety of models could produce the charcteristic features of porphyry deposits, therefore, the models can be considered as a continuum with two defined end-member models for the hydrothermal regimes involved (McMillan and

	Classic (Stock-related)	Volcanic	Plutonic
Setting	Associated with post-orogenic stocks intruding unrelated host rocks; co-magmatic volcanic piles rarely preserved. Cordilleran deposits are of Late Mesozoic to Tertiary age.	In basic to intermediate volcanic piles intruded by comagmatic calc-alkalic or alkalic (dioritic or shoshonitic suite) plutons; magmatism produces consanguineous and intimately associated intrusive/extrusive assemblages. Cordilleran deposits are of Mesozoic age.	In large calc-alkalic plutons emplaced in or near comagmatic volcanic rocks; plutons typically have mafic borders and are moderately to strongly differentiated. Cordilleran deposits are of Mesozoic age.
Plutons	Multiple phases emplaced as successive, small (0.5 to 2 km^2), cylindrical porphyritic intrusions; numerous pre-, intra-, and post-mineral porphyry dykes emplaced at shallow depth.	Calc-alkalic — very small to small sheets, dykes and plugs (0.2 to 10 km^2), with much textural variety; subvolcanic emplacement. Alkalic — high level sheets, dykes, plugs associated with underlying differentiated mesozonal pluton or small batholith.	Batholithic rocks (>100 km^2) immobilized at relatively deep levels (2 to 4 km). Phaneritic coarse-grained to porphyritic rocks with local swarms of pre- to post-ore porphyritic dykes.
Structural Control of Intrusions	Passive, structure need not be significant; many stocks localized by intersections of regional faults.	Calc-alkalic — emplacement in volcanic vents, fault zones, radial fractures. Alkalic — intrusive centres localized by regional structures. High level intrusive rocks invade volcanic vents and fault zones.	Diapiric emplacement; magmatic pulses and differentiation cause sharp to gradational internal phase boundaries.
Breccias	Abundant and characteristic; post-ore argillic diatremes are common. Other types present include collapse breccias, intrusive breccias, and carapace or stoping breccias. Early breccias can be mineralized.	Calc-alkalic — common and diverse; include primary pyroclastic tephra, alteration pseudo-breccia, vent agglomerate, shatter and igneous breccias. Mineralized breccias are characteristic; some contain magnetite or tourmaline. Alkalic — intrusive and volcanic breccias common and generally mineralized, as in calc-alkalic types.	Common in association with late-stage porphyry dyke swarms. Breccias pre-, intra-, and post-ore, some contain specularite or tourmaline.
Alteration	Potassic, phyllic, and propylitic universally developed as annular shells around intrusions; argillic of varying importance. Early developed biotite (EDB) can be part of an isochemical hornfels and has often been misidentified as part of the potassic zone.	Calc-alkalic — propylitic is widespread; potassic is more restricted but can be intense; alteration centred on zones of high permeability. Similar to classic-type deposits with small core zones of potassic and local phyllic and/or argillic shells. Alkalic — local intense to pneumatolytic potassic alteration; early hydrothermal biotite overprinted by propylitic, then by sodic and/or potassic (albite-K-feldspar) and rarely scapolite alteration.	Phyllic, phyllic-argillic, and propylitic types are best developed; local potassic alteration. Fracture controlled to pervasive, commonly as alteration envelopes on multistage fractures and veins. Centred on orebodies but patterns of zoning complicated by overprinting.
Orebodies	In margins and adjacent to porphyry intrusion(s) as annular ore shells, or as domal cappings; pronounced lateral zoning. Pyrite is found throughout; the weakly mineralized core is surrounded by zones dominated by molybdenite, then chalcopyrite, and, finally, a pyritic halo.	Calc-alkalic — generally Cu-Mo deposits intimately associated with breccias and intensely altered rocks; orebodies lensoid and irregular, with some preferential bedding control. Most ore contains chalcopyrite with rare bornite or molybdenite as 'dry' fracture fillings. Alkalic — generally Cu-Au deposits in intrusive breccia or in highly fractured country rock; some replace porous country rock. Locally magnetite-apatite of magmatic origin present as vein or breccia infillings; zoning is from chalcopyrite ±magnetite and bornite outward to a pyrite halo.	Large and diffuse vein stockworks; some breccia control, some faults mineralized; sulphides relatively sparse. Zoning is evident with iron content increasing outward from bornite to chalcopyrite to pyrite rich zones; Mo distribution is variable. Some deposits have low-grade quartz-rich core zones.

Table 3: Characteristics of three classes of porphyry deposits (from McMillan and Panteleyev, 1976)

Panteleyev, 1976). The end-member orthomagmatic and convective models shown in Figure 49, involve contrasting conditions with magmatic and meteoric fluid sources, respectively.

In the orthomagmatic model, a cooling stock produces a hydrothermal plume, which generates structures and causes alteration. The alteration is dominated by potassic and propylitic varieties, with narrow zones of phyllic zones developed at borders where a minor component of meteoric fluid interacts with magmatic fluids. Pervasive alteration, with mineralization, form concentric zones around the deposit. Ore minerals are derived from the parent magma, and are concentrated in the residual melt.

In the convective model, permeable country rocks are the source of groundwater. The emplacement of the pluton can enhance permeability of the country rock, and initiate convective circulation of the groundwater. In this type of system, alteration consists of phyllic assemblages which surround a potassic core. Metals are scavenged from rocks enclosing the convection cell, and are redeposited as ore minerals.

An orthomagmatic system may evolve into a convective system, but it is also possible for both systems to operate simultaneously. Many porphyry deposits are defined by a model with elements from both end-member models, dependent on the fluid source, and the age and locus of the hydrothermal system.

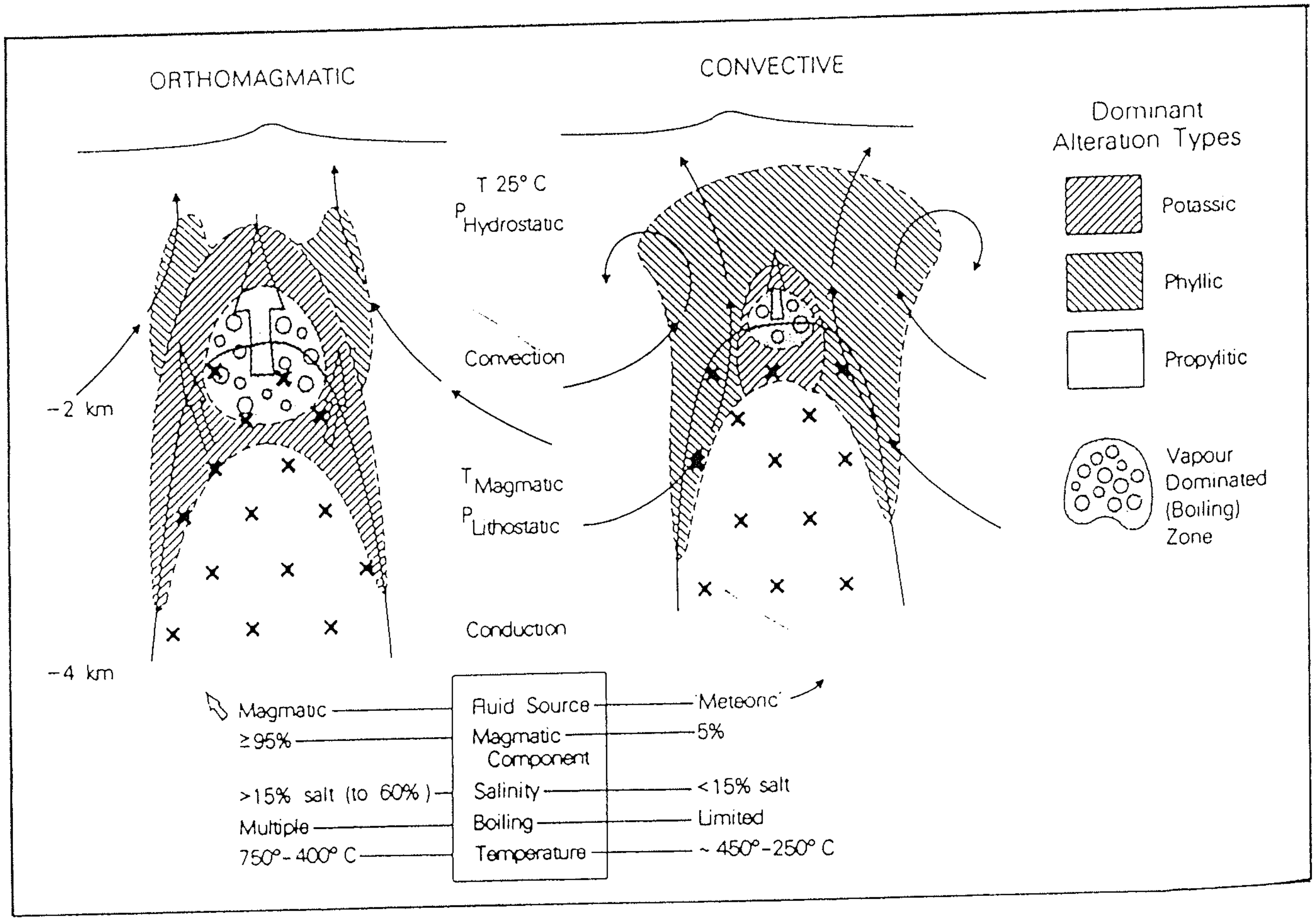


Figure 49: End-member hydrothermal models and generalized alteration patterns for porphyry style deposits (from McMillan and Panteleyev, 1976)

8.2.2 Comparison of FLIC to Porphyry Model

In comparing the mineralization related to FLIC, to the porphyry model, the scale of the comparison must be clarified. Many Precambrian occurrences associated with felsic to intermediate intrusions have been defined as "porphyry" style based on broad scale features, however, more detailed observations commonly indicate that the genetic relationships required in the porphyry model, do not exist.

The acceptance of FLIC as analagous to the porphyry model similarly depends on the scale at which the associated features are considered. The interior and exterior mineralization of FLIC collectively display characteristics similar to, but not definitive of porphyry deposits. The occurrences appear concentrated within the complex and its surrounding hosts, and are commonly gold dominated, although a broad regional halo of copper, molybenum, and tungsten occurrences extends beyond the study area.

The occurrences in this study are hosted by structures, but the deformation events producing the host structures for the interior and exterior occurrences do not appear to be temporally related. The exterior occurrences are spatially related to the peripheral diorite intrusions of FLIC, while the interior occurrences appear both spatially and genetically related to quartz monzonite. Exterior occurrences are typically erratic in gold content, and are confined to small, widely spaced structures. The interior occurrences are high grade with respect to gold content, and are similarly confined to small structures, but are concentrated in a more restricted area than the exterior occurrences. The small extent of FLIC mineralization, and the lack of genetic relationships (exterior occurrences) prevents classification of FLIC as a porphyry deposit, according to Kirkham's definition.

The interior occurrences display several characteristics siimilar to porphyry deposits: a spatial and genetic relationship to a felsic, porpyritic intrusion; breccia pipes; and mineralization/alteration confined to structures. Shear zones are not common to porphyry settings, but in FLIC they are temporally related to late stage magmatism, and the hydrothermal fluids causing alteration and mineralization of these structures are considered to be genetically related to the quartz monzonite phase of FLIC. The Sunbeam and Moonbeam occurrences have concentric alteration zones, from an outer propylitic zone to a core of overlapping phyllic and potassic of varying intensity. The intensity of alteration is proportional to the degree of deformation. The Waverley and Sundog occurrences host phyllic and potassic alteration products, with no apparent zonation. The poorly developed or lack of "typical" zoning patterns may be due to the confinement of the hydrothermal fluids to small, restricted structures (Guilbert and Lowell, 1974).

Mineralization also lacks zonation, and is gold dominated, with respect to grade.

As discussed, the interior occurrences have several features in common with porphyry deposits, and satisfy all aspects of Kirkham's porphyry definition, with the exception of size. The concentration of interior occurrences within an intrusive complex, associated late stage breccias, and structurally controlled alteration and mineralization, are features which are characteristics of plutonic type porhyry deposits. The interior occurrences of FLIC are therefore analagous to the plutonic model presented in Figure 50, on a smaller scale.

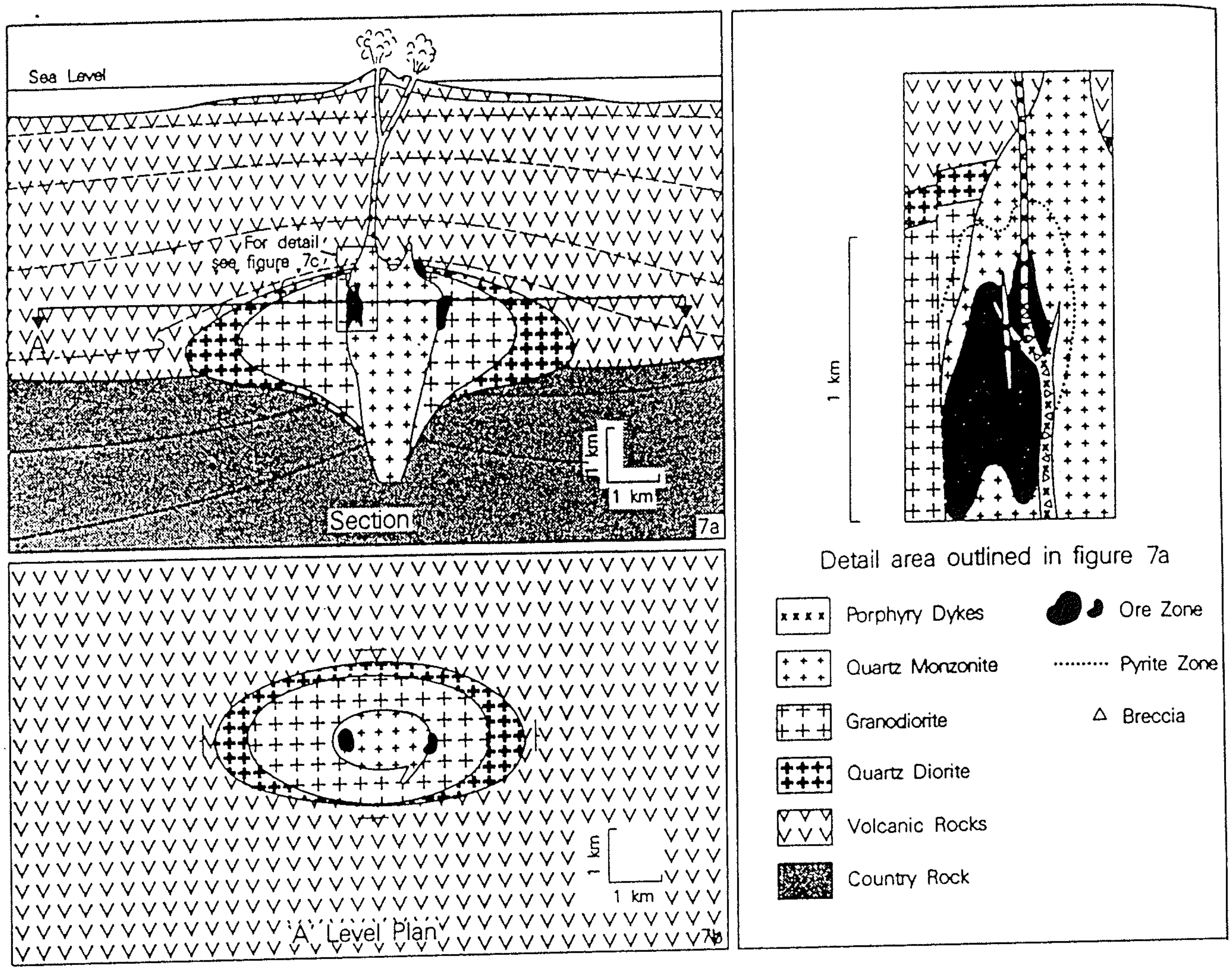


Figure 50: Geologic setting of plutonic-type porphyry deposits (from McMillan and Panteleyev, 1976)

8.3 CONCLUSIONS

The major conclusions drawn from this study are:

1. The distribution of gold occurrences in the study area defines a discrete zone around the complex (exterior), in the country rocks to the north, and a second zone within the complex (interior), concentrated close to the quartz monzonite-granodiorite core.

2. The interior and exterior occurrences are all structurally controlled. The interior occurrences are hosted by shear zones, breccia pipes, late fractures and shear zones, and faults. The exterior occurrences are hosted by a broad deformation zone, a shear zone and local tension fractures. The deformation zone and shear zone have both been subjected to folding.

3. The gold mineralization of the exterior occurrences defines two major styles: (1) a structural association of deformation and mineralization,in the deformation zone and shear zone, and (2) later remobilization of gold by hydrothermal fluids of either a magmatic or metamorphic source. The gold mineralization of the interior occurrences defines two major styles: (1) a structural and closely related magmatic association of deformation and mineralization defining a major event, and (2) later remobilization by hydrothermal fluids.

4. The introduction of gold occurred during at least two events. The exterior occurrences are interpreted as older than those of the interior; mineralization

predated the emplacement of the diorite in the area. The interior occurrences are interpreted as having originated after consolidation of the quartz monzonite, the youngest FLIC intrusion.

5. FLIC has played four major roles in the development of occurrences in the study area: host, generation of structures, initiation of hydrothermal systems, and source of mineralization. For the exterior occurrences, emplacement of early intrusive phases of the complex developed extension fractures in the country rock, and initiated a convective hydrothermal system which scavenged metals from enclosing rocks, for redeposition. For the interior occurrences, FLIC provided a host for structures such as shear zones and breccia pipes. The consolidation of quartz monzonite initiated an orthomagmatic hydrothermal system and produced the breccias at the Sunbeam and Moonbeam occurrences. It has been interpreted that mineralization was derived from the parent magma of quartz monzonite.

6. Collectively, FLIC occurrences do not represent a porphyry system, as defined by Kirkham (1972). The interior occurrences display characteristics similar to porphyry deposits and satisfy all requirements of Kirkham's definition, with the exception of size. If these occurrences are considered porphyry style, they can be classified as a scaled down analogue of the plutonic-type model.

REFERENCES

Allman-Ward, P., Halls, C., Rankin, A., and Bustow, C.W., 1982, An intrusive hydrothermal breccia body at Wheal Remfrey in the western part of the St. Austell granite pluton, Cornwall, England, in Evans, A.M.,ed., Metallization associated with acid magmatism

Ayres, L.D., and Findlay, D.J., 1976, Precambrian porphyry copper and molybdenum deposits in Ontario and Saskatchewan, Report of Activities, Geol. Survey of Canada, Paper 76-1B, p.39-41

Barc, P.S., 1985, Moonbeam claim, S.E. Manitoba; Reconnaissance geology and petrography; unpublished B.Sc. Thesis, Univ. of Manitoba

Blackburn, C.E., Bond, W.D., Breaks, F.W., Davis, D.W., Edwards, G.R., Poulsen, K.H., Trowell, N.F., Wood, J., 1985, Evolution of Archean volcanic-sedimentary sequences of the western Wabigoon Subprovince and its margins: a review; in; Evolution of Archean Supracrustal Sequences, L.D. Ayres, P.C. Thurston, K.D. Card, W. Weber, ed., G.A.C. Spec. Paper 28

Blackburn, C.E. and Janes, D.A., 1983, Gold deposits in Northwestern Ontario, A.C. Colvine, ed., O.G.S. Misc. Pap. 110, 278p.

Brownell, G.M., 1941, Geology of the Falcon Lake stock, southeastern Manitoba; C.I.M.M. Trans., V. 44, p.230-250

Bruce, E.L., 1925, Gold deposits of Kenora and Rainy River Districts, P.1-42 in Annual Report for 1928, ODM, vol. 34. 106p.

Brunham, C.W., 1979, Magmas and hydrothermal fluids, in Barnes, H.L., ed., Geochemistry of hydrothermal ore deposits: New York, Wiley, p.71-136

Burnham, C.W., 1985, Energy release in subvolcanic environments: implications for breccia formation, Econ. Geology, v.80, p.1515-1522

Chastko, L.C., 1986, Summary of 1985-86 exploration and development and a proposal for continued exploration of the Whiteshell mineral claims, Star Lake, Manitoba. Internal report, Whiteshell Ventures Limited.

Chaytor, M., 1985, A report on the geochemistry of the Falcon Lake stock; unpublished B.Sc. thesis, Univ. of Manitoba.

Colvine, A.C. and Sutherland, I.G., 1979, The geology and mineralization of the Pickeral Arm, Canoe Lake, and High Lake bodies, p.233-243 in Summary of Field work 1979, V.G. Milne, ed., O.G.S. Misc. Pap. 90, 245p.

Davies, J.F., 1954, Geology of the West Hawk Lake-Falcon Lake area; Man. Dept. Mines and Nat. Res. Publ. 53-4

Emmons, W.H., 1938, Diatremes and certain ore-bearing pipes, Am. Inst. Mining Metall. Engineers Tech. Publ. 891, p.1-15

Farqharson, R.B., Clark, G.S., 1971, Rb-Sr geochronology of some granitic rocks in southeast Manitoba; in; Geoscience Studies in Manitoba, A.C. Turnock, ed., G.S.C. Spec. Paper 9

Gibbins, W.A. 1967, Geology of the Falcon Lake stock, Manitoba; unpublished M.Sc. thesis, Univ. of Manitoba

Goldie, R., Kolita, B., and Sewal, D., 1979, The Don Rouyn mine: an Archean porphyry coper deposit near Noranda, Quebec, Econ. Geology, v.74, p.1680-1684

Godfrey, J.D., 1983, Geology and mineral occurrences of the Whiteshell mineral claims, Star Lake, Manitoba. Internal report, Goldbeam Mines Limited.

Guilbert, J.M., and Lowell, J.D., 1974, Variations in zoning patterns in porphyry ore deposits, C.I.M. Bulletin, v.67, p.99-109

Halwas, D., 1984, The structure of the Sunbeam-Kirkland breccia pipe, southeastern Manitoba; unpublished B.Sc. thesis, Univ. of Manitoba

Harrison, J.M., 1935, The Sunbeam-Kirkland Gold Mine, Unpublished report, Univ. of Manitoba, Winnipeg, Manitoba

Haugh, I., 1962, A petrographic study of the Falcon Lake stock, southeastern Manitoba, unpublished M.Sc. thesis, Univ. of Manitoba

Hodgson, C.J., 1982, Gold deposits of the Abitibi belt, Ontario, p.192-197 in Summary of Field Work, 1982, OGS Misc. Paper 106, 235p.

House, R.D., 1955, Radioactivity and geology of the Falcon Lake stock, southern Manitoba; unpublished M.Sc. thesis, Northwestern Univ.

Hulin, C.D.,1948, Factors in the localization of mineralized districts, Am. Inst. Mining Metall. Petroleum Engineers Trans., v.178, p.36-52

Huppert, H.E., Sparks, R.S.J., 1985, Cooling and contamination of mafic and ultramafic magmas during ascent through continental crust; Earth and Plan. Sci. Letters, V.74, p.371-386

Johanasson, P.R., 1985, A gravity study of the Falcon Lake Intrusive Complex; unpublished B.Sc. thesis, Univ. of Manitoba

Jones, W.A., 1948, Hollinger mine in Structural geology of Canadian ore deposits, v.1, CIMM p.464-481

Kille, I.C. Thompson, R.N., Morrison, M.A., Thompson, R.F., 1986, Field evidence for turbulence during flow of basaltic magmas through conduits from southwest Mull; Geol. Mag., V.123, p.693-697

Lamb, C.F., 1975, Southeastern Manitoba-preliminary compilation; Man. Min. Res. Div. Prelim. Map 1975 F-8

Lawson, A.C., 1886, Report on the geology of the Lake of the Woods Region, GSC Annual Report, v.1, p.1-151

Locke, A., 1926, The formation of certain ore bodies by mineralization sloping, Econ. Geology, v.21, p.431-453

Lowell, J.D., and Guilbert, J.M., 1970, Lateral and vertical alteration-mineralization zoning in porphyry ore deposits, Econ. Geology, v.65, p.373-408

Mandziuk, W.S., 1988, Primary structures of the Falcon Lake Intrusive Complex, southeastern Manitoba, unpublished M.Sc. Thesis, Univ. of Manitoba, Winnipeg, Manitoba

Marmont, S., 1983, The role of felsic intrusions in gold mineralization, p.38-45 in Geology of Gold in Ontario, A.C. Colvine, ed., OGS Misc. Paper 110, 278p.

Mason, R., and Melnik, N., 1986, The McIntyre-Hollinger investigation, Timmins, Ontario: a gold dominated porphyry copper system, in Current Research, Pt.B., Geol. Survey of Canada Paper 86-1B, p.577-583

McMillan, W.J. and Panteleyev, A., 1976, Ore deposit models I. Porphyry copper deposits, Geoscience Canada, v.7, p.52-63

Mitcham, T.W., 1974, Origin of breccia pipes, Econ. Geol., v.69, p.412-413

Mustard, H., 1986, Geology and genesis of the Kidston gold deposit, Australia, in Proceedings of Gold 86 Symposium, Toronto, 1986, P.404-415

Norton, D.L. and Cathles, L.M., 1973, Breccia pipes: products of exsolved vapor from magmas, Econ. Geol., v.68, p.540-546

Pedora, J.M. 1976, Mineralization of the High Lake pluton and adjacent country rocks, unpublished M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba

Perry. W.J., 1973, Mechanical effects of retrograde boiling and probable importance in the formation of some porphyry ore deposits: Inst. Mining Metallurgy Trans., v.82. sec B

Poulsen, K.H., and Franklin, J.M., 1981, Copper and gold mineralization in an Archean trondjhemitic intrusion, Sturgeon Lake, Ontario, in Current Research, Pt. A, Geol. Survey of Canada, Paper 81-1A, p.9-14

Quinn, W., 1985, A petrographic study of the host rocks along the northwestern contact of the Falcon Lake stock; unpublished B.Sc. thesis, Univ. of Manitoba

Rodgers, C.E., 1940, Report: Sunbeam-Kirkland Mines Ltd., Manitoba

Shaw, H.R., 1965, Comments on viscosity, crystal settling, and convection in granitic magmas; Am. Jour. Sci., V.263, p.120-153

Sillitoe, R.H., and Sawkins, F.J., 1971, Geologic, mineralogic, and fluid inclusion studies relating to the origin of copper bearing tourmaline breccia pipes, Chile, Econ. Geology, v.66, p.1028-1041

Sillitoe, R.H., 1985, Ore related breccias in volcanoplutonic arcs, Econ. Geol, v.48, p.1467-1514.

Springer, G.D., 1952, Geology of the Rennie-West Hawk Lake area, Manitoba; Man. Mines Branch Publ.

Wanless, R.K., Stevens, R.D., Lachance, S.R., Edwards, C.M., 1968, Age determinations and geological studies; K-Ar isotope ages, Rept. 8. Geol. Survey of Canada Pap. 67-2, p.90-91

APPENDIX 1

Geochemical Results

Sample prefixes refer to claim location of sample:

D	Denmark	SB	Sunbeam
M	Moore	MB	Moonbeam
S	Sheba	W	Waverley
N	Narwark	SD	Sundog
R	Rad		

A: Analyses by Bondar-Clegg

Sample Number	Element: Au PPB	Pd PPB	Pt PPB
D-1	34	3	<15
M-1	818	<2	<15
M-3	38	7	<15
MB-14	6460	<2	<15
N-7	283	<2	<15
N-8-1	34	3	<15
N-8-2	28	<2	<15
R-19-1	32	<2	<15
R-19-2	3500	<2	<15
R-19-3	28	<2	<15
S-9	34	<2	<15
S-11	374	<2	<15
S-12-2	276	<2	<15
S-29	22	<2	<15
SB-1	34	<2	<15
Sb-1A	56	<2	<15
SB-9	288	<2	<15
SB-12	25	<2	<15
SB-26	166	<2	<15
SB-32	3550	<2	<15
W-1	365	3	<15
W-2	18000	<2	<15

Sample prefixes refer to claim location of sample:

D -	Denmark	SB -	Sunbeam
M -	Moore	MB -	Moonbeam
S -	Sheba	W -	Waverley
N -	Narwark	SD -	Sundog
R -	Rad		

B: Analyses by Nuclear Activation Services Ltd.

Sample Number	Element: Au PPB	Pd PPB	Pt PPB
SD 2	26	<2	<10
MB 13	41	<2	10
MB 8	37	2	10
MB 15	5	3	10
MB 9	23	3	10
MB 5	35	2	10
SB 33	130	2	10
SB 19	44	3	10
SB 28	50	2	10
SB 27	13	2	10
SB 24	27	<2	<10
SB 23	470	<2	<10
R2-3	1200	3	10
R2-4	9	<2	<10
R5-1	1700	2	<10
R5-2	7000	3	10
R6-1	1600	2	10
D 8	18	<2	<10

APPENDIX 2

Unit Conversions

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	**20.116 8**	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

APPENDIX 3

Summary of Gold Deposits and Exploration Status
Interior Occurrences

DEPOSIT Name	Type	DIMENSIONS and SHAPE	TONNAGE Estimates	GRADE Estimates	EXPLORATION DATA Max. Depth	Methods
SUNBEAM	Pipe in Falcon Lake Stock	Elliptical Pipe 150 X 90 feet	110,000 tons	0.268 oz/t	475 feet (cut grade) 430 feet (vertical)	Inclined shaft 438 feet (inclined)4 levels established. Drifts total 905 feet 92 surface D.D.H. total 10,000 feet Over 2,300 assays
MOONBEAM	Pipe in Falcon Lake Stock	Assumed circular 40 feet diameter	20,00 tons (100 t/vert. ft)	0.22 oz/t (cut grade)	200	Surface D.D.H.
LETAIN A)	Six shear zones en echelon in Falcon Lake Stock	300 X 7.8 ft. wide	78,00 tons	0.447 oz/t (cut grade)	400 feet)	Vertical shaft to 500 feet, 3 levels.
LETAIN B)		250 X 13.0 ft. wide	110,000 tons	0.303 oz/t	400 feet)	91 surface D.D.H. total 27,940 feet
LETAIN C)		350 X 9.2 ft. wide	106,000 tons	0.277 oz/t (cut grade)	400 feet)	Underground D.D.H. total 1,300 feet
SUNDOG	Shear zone in Falcon Lake Stock	625 X 4 ft. wide	80,000 tons	0.91 oz/t (uncut grade)	400 feet	16 surface D.D.H. total over 1,300 feet

* Information based on numerous reports by Dr. J. F. Wright and Manitoba Mines Branch records, covering the period 1937 to 1946.