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STRATIGRAPHY, STRUCTURE
AND GOLD MINERALIZATION OF
THE NO.5 VEIN / IRON FORMATION ZONE,
PICKLE CROW GOLD MINES,
PICKLE LAKE, ONTARIO

by

JOHN KENNETH MacQUEEN, B.Sc.

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of

Master of Science

Department of Geology

Carleton University

Ottawa, Ontario

May, 1987

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THE NO.5 VEIN / IRON FORMATION ZONE,
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submitted by John Kenneth MacQueen, B.Sc.
in partial fulfilment of the requirements for
the degree of Master of Science

Thesis Co-Supervisor

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ABSTRACT

The No.5 Vein-/ Iron Formation(B.I.F.)-hosted gold deposit of the Pickle Crow Gold Mines, Pickle Lake, Ontario, is situated within the Uchi subprovince of the Superior Structural Province of northwestern Ontario. Proven reserves are over 2.5 million tons of ore grading .25 ozAu/ton or 10 g^m Au/ tonne and probable reserves in the Pickle Crow property are over 6 million tons at the same grade. The No.5 Vein / I.F. Zone is a structurally controlled epigenetic gold deposit hosted within multiply deformed oxide and sulphide facies Algoma-type banded iron formations (B.I.F.) and high iron to magnesium tholeiitic basalts. The ore deposits, which occur in the north limb of the steeply plunging Pickle Crow Anticline, are controlled by D₂ structures, and are spatially associated to the No.5 shear zone and the Pickle Crow Fault.

Gold mineralization occurs in two styles: 1) gold hosted within the No.5 shear zone as the auriferous No.5 Vein, a high-grade(>30 g^m Au/tonne) quartz-tourmaline-scheelite vein; and 2) gold in stratabound sulphides contained in oxide and sulphide facies B.I.F. as pyrite, pyrrhotite, chalcopyrite and arsenopyrite.

The basalts in the No.5 Vein / I.F. Zone area have been subdivided into two stratigraphic units: 1) Lower pillowed and massive basaltic flows of inferred deep-water origin, and 2) Upper pillowed and massive basaltic flows of inferred shallow-water origin. The Lower and Upper basalts are interbedded with sulphide facies (chert-pyrite) B.I.F. and oxide facies (chert-magnetite) B.I.F., respectively. Compositionally graded bedding within chert-magnetite and chert-sulphide layers provide reliable younging directions. Hydrothermal alteration of basalts by fluids ascending along the No.5 shear zone occurred in two distinct zones: 1) a broad zone enveloping the No.5 Vein/I.F. Zone that has a mineral assemblage consisting of quartz-albite-chlorite-calcite-actinolite-epidote, and a narrow 10m zone on either side of the No.5 shear zone that has a mineral assemblage consisting of quartz-albite-sericite-chlorite-ankerite-pyrite. The transition from the former mineral assemblage to the latter is chemically expressed by a relative increase in Fe₂O₃ (Total), K₂O, CaO, CO₂, S and Au and a relative decrease in SiO₂, MgO and Na₂O.

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This study would not have been possible without the kind co-operation of Mr. D.G. Innes, Vice President of Exploration and Chief Geologist of Highland Crow Resources, who encouraged me to undertake this study and who provided financial support for both field work and chemical analyses, unrestricted access to company data, and permitted maps and other information to be incorporated in this thesis on the Pickle Crow Property. Dr. J.A. Donaldson initially drew my attention to this interesting project, provided financial support at Carleton University through NSERC operating Grant A5536, and was an excellent source of advice during a visit to the Pickle Crow property and during numerous rounds of manuscript revision and editing. Dr. K.H. Poulsen of the Geological Survey of Canada provided invaluable guidance in the field during his visit to the Pickle Crow property, and also during supervision and final editing of the thesis. Their joint supervision is greatly appreciated. I also thank my colleagues of Highland Crow Resources with whom I worked from June to December, 1986: Dave Silverside, Dr. Peter Mills, Ed Sawitzky, Ron Fenlon, Ron Hill, Todd Kampman, Dave Mimeault, Joe Clarke, Terry Johnson, Susan Butorac, Angela Gaspareto and Jeff Pearce. Their co-operation, advice and assistance is deeply appreciated. Drafting was done by Al Wells of Highland Crow Resources. Carl Boyd assisted in the application of various CAD and graphical computer programs in this thesis. The Longyear diamond drilling crew made logging in the winter an enjoyable experience. Thanks also to Dr. D.C. Harris of the Geological Survey of Canada for providing polished sections of the vein material, and for advice on problems of ore mineralogy. Special thanks go out to the the Faculty and Staff as well as my fellow graduate students of the Ottawa Carleton Geoscience Centre.

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BACK POCKET

MAP 1- Geology of the No.5 and No.1 Vein/I.F. Zone Areas
at a scale of 1 inch to 100 feet.

MAP 2- Geology of the No.5 Vein/I.F. Zone area at a scale
of 1 inch to 20 feet.

1.0 INTRODUCTION

Early Precambrian banded iron formations (B.I.F.) and their associated facies are known to commonly host concentrations of gold well above normal background. The gold has attained viable economic concentrations in iron formations at many places, e.g., Beardmore-Geralton, Ont. (Macdonald, 1984 ; Anglin and Franklin, 1985); Central Patricia Gold Mines, Ont (Barrett, 1948 and Pye, 1956); Homestake Gold Mine, Montana (Noble, 1950); Lupin Mine, N.W.T. (Kerswill, 1985); Water Tank Hill & Nevoria Gold Mines, Australia (Phillips et al, 1984); Kolar, India (Siddaiah & Rajamani, 1984; Hamilton and Hodgson, 1986) and Vubachickwe Gold Mine, Zimbabwe (Phillips et al, 1984; Fripp, 1976). The two principal explanations for the presence of gold in B.I.F.'s are:

- 1) Gold is indigenous to the B.I.F., having accumulated as a result of sedimentary processes, to be remobilized later during tectonic deformation, and concentrated in favourable structural and geochemical sites (Ridler, 1970 and Hallager, 1984).
- 2) Gold is epigenetic with respect to the B.I.F., having been introduced into the system from an external source along shear zones or wallrock contacts. The auriferous fluids react with the B.I.F by oxidation and sulphidation of the magnetite, and by the formation of quartz veins (Phillips and Groves, 1984 and Phillips et al, 1984).

The present study evaluates these concepts of gold mineralization with respect to the No. 5 Vein / Iron Formation Zone, Pickle Crow Gold Mines, Pickle Lake, Ontario (Figure 1).

In the past, the Pickle Lake Greenstone Belt in the Uchi Subprovince of the Superior Structural Province in the Canadian Shield

was an active gold mining area, with production coming from gold-rich quartz veins in the Pickle Crow Gold Mine and from B.I.F. in the Central Patricia Gold Mine. In recent years, the possibility of additional gold in economic quantities remaining in the widespread B.I.F. units of the belt has resulted in renewed interest in the area, particularly in the former producing sites.

Re-evaluation of the Pickle Crow property by Highland Crow Resources was initiated on previously discovered but unmined gold zones in B.I.F. adjacent to gold-bearing quartz veins already mined for their gold. Preliminary field work by the author suggested that the auriferous B.I.F. containing magnetite is localized by the extensive shears which also contain gold-bearing quartz veins beyond the confines of the iron formation. If more detailed work lends confirmation to this observation, then additional economic gold deposits may exist in the area where auriferous quartz-bearing shear zones intersect B.I.F.

Accordingly, the author under the auspices of Highland Crow Resources conducted detailed field studies in several selected locations to ascertain if the gold-bearing quartz veins were formed during shearing processes, and to determine whether the transected B.I.F. was enriched in gold derived from the shear zones, or whether the gold within the shear zones was derived from the iron formation.

1.1 LOCATION

The Pickle Crow Gold Camp is approximately 10 km from the town of Pickle Lake in northwestern Ontario (Figure 1). Access to the Pickle Lake area is by Highway 599, approximately 300 km north of Ignace. There is no bus service to Pickle Lake, but daily air flights to Pickle Lake are provided by Austin Airways and by Norontair Air Service. For access to areas surrounding Pickle Lake, float planes or helicopters can be chartered from several companies in the area. Approximately 300 residents in the Pickle Lake and Central Patricia townships are served by two Hudson Bay stores, Precambrian Wholesale, three hotels, three charter aircraft companies, a Ministry of Natural Resources (M.N.R.) fire control centre, one health clinic, one post office and one hardware store; Koval Brothers provide construction and trucking transportation services to the area. The township of Pickle Crow is abandoned.

1.2 GENERAL GEOLOGY

1.2.1 SUPERIOR PROVINCE IN NORTHWESTERN ONTARIO

The Superior Province of northwestern Ontario consists of seven major easterly trending subprovinces (Figure 2). From south to north these are the Wawa, Quetico, Wabigoon, English River, Uchi, Berens River and God's Lake (Sachigo) Subprovinces. These subprovinces range in widths from 40 to 290 kilometres, and each contains many greenstone belts. The many small but numerous greenstone belts in northwestern Ontario appear to be isolated remnants of metavolcanic-metasedimentary sequences. (Condie, 1981; Wilson, 1971; Ojakangas, 1985; Wilson and Morrice, 1977 and Ayres et al, 1985) that once covered most of the greenstone-granodiorite subprovinces. Each

FIGURE 1 - LOCATION MAP OF STUDY AREA

belt has characteristic lithologies, structure, and metamorphic features; lithological boundaries between subprovinces are generally sharp, and usually at fault contacts (Ayres et al, 1985 and Condie, 1981).

Wawa, Wabigoon, Uchi, and God's Lake Subprovinces comprise isoclinally folded metavolcanic-metasedimentary sequences (ie. Greenstone Belts) intruded by large composite granitic batholiths (Blackburn et al, 1985; Ayres and Thurston, 1985 and Thurston et al, 1985). The grade of metamorphism is generally lowest (greenschist) in the central portions of the belts and increases toward granitic contacts.

In the Quetico and English River Subprovinces, the metamorphic grade ranges from amphibolite to granulite facies (Pirie and Mackasey, 1978, Ermanovics and Froese, 1978 and Ayres, 1978). Both subprovinces appear to be underlain mainly by metasedimentary gneiss derived from turbidites and contain numerous small granitic plutons (Percival and Card, 1985).

The Berens River Subprovince (or Berens Batholith Belt) is composed mainly of granitic plutons with less than 10% recognizable greenstone belt remnants at mid to upper amphibolite facies grade metamorphism (Pirie and Mackasey, 1978). This subprovince is interpreted by Sage and Brëaks (1982) to represent: (1) a granodiorite Subprovince and/or (2) a zone of deeper and more intense plutonic activity than either of the adjacent greenstone-granodiorite subprovinces.

**FIGURE 2: Sketch map of the Superior Province showing the various subprovince boundaries.
(after Ayres and Thurston, 1985)**

1.22 UCHI SUBPROVINCE

The study area lies within the Uchi Lake Subprovince, Western Superior Structural Province of the Canadian Shield (Figures 2 and 3).

The Uchi Lake Subprovince consists of a series of bifurcating and anastomosing metavolcanic-metasedimentary belts that have been complexly folded (most folds are isoclinal), refolded and intruded by composite granitic stocks and batholiths. Rocks within the subprovince are predominantly mafic to intermediate metavolcanics, typically pillowed (Sage and Breaks, 1982). Felsic to intermediate metavolcanic rocks composed mainly of pyroclastic and/or massive flows are a minor component of the belt, but are important in that they mark the cessation of major mafic volcanism. According to Sage and Breaks (1982), the complete volcanic cycle as described by Wilson (1971) is present in a number of areas within the Uchi Subprovince; however, multicycle volcanism has not yet been recognized in the Pickle Lake area. Metasedimentary rocks are common throughout the Uchi Lake Subprovince; wackes predominate but arenites as well as argillaceous and conglomeratic units also are present (Sage and Breaks, 1982). Algoman type banded iron formations (B.I.F.) including oxide, sulphide and silicate facies are widespread throughout all areas; as a result of their high magnetic and strong conductive properties they are easily detected by aeromagnetic surveys (ODM-GSC, 1960; OGS 1986). These geophysical properties enable exploration geologists to recognize patterns of folding and refolding as well as important structural breaks in the patterns. The degree of metamorphism in the Uchi Subprovince is variable from greenschist facies to amphibolite facies (Ayres, 1978). Generally, areas in the central portions of Uchi greenstone belts that are

REGIONAL GEOLOGY

- Granitic rocks ☐
 Sedimentary rocks ☒
 Volcanic rocks ☐

FIGURE 3- Regional Geology of the Uchi Subprovince, showing the major mineralized areas.

not affected by intrusive granitic stocks are in the greenschist facies, and areas near the edges of the belt and/or near intrusive granitic stocks attain amphibolite facies grade.

1.23 PICKLE LAKE GREENSTONE BELT

The Pickle Lake Greenstone Belt of the Uchi subprovince (Figures 4 and 5) consists of a 10- to 12-km wide belt of metavolcanic and intercalated metasedimentary strata that strike generally northeast to east and locally southeast (Pye, 1956; Sage and Breaks, 1982 and Stott, 1986). The Pickle Lake Belt is dominated by mafic to intermediate metavolcanic rocks (predominantly massive and pillowed flows) ranging from greenschist to upper amphibolite facies in metamorphic grade (Pye, 1956 and Stott, 1986). Widely intercalated with the mafic volcanic successions are banded iron formation units of oxide, sulphide and silicate facies that in places are locally interbedded with wackes and other clastic metasedimentary rocks (Pye, 1956; Ferguson, 1966 and Stott, 1986). A thick assemblage of felsic to intermediate metavolcanic rocks (predominantly pyroclastic flows of dacitic composition) are located in the south central portion of the belt (Pye, 1956). Underlying much of the area are ultramafic-mafic intrusive rocks north of the Pickle Lake Stock, near the Thierry Cu-Ni Mine, approximately 10 km northwest of the Pickle Crow and Central Patricia properties. Several quartz feldspar porphyry intrusions in the Pickle Crow and Central Patricia properties occur as lenticular bodies that are conformable to the enclosing strata.

The Pickle Lake Greenstone Belt is bordered to the north by the Cat

FIGURE 4- Regional Geology of the Pickle Lake Greenstone Belt (after Stott, 1986).

Lake - Williams Lake Batholithic Complex and to the south by the English River Subprovince (Sage and Breaks, 1982). Stott (1986) has re-examined the Seach-Achapi Lakes granitoid complex, south of the Pickle Lake Greenstone Belt, and has further subdivided it (Figure 4) into three separate granitic intrusions: the oldest metamorphosed, Quarrier Lake tonalite-gneissic terrane; younger slightly metamorphosed, Croshaw Lake Pluton (quartz-phyric tonalite) and the youngest unmetamorphosed Kagami Pluton (quartz-phyric tonalite). Northwest of the Pickle Lake Belt is an extensive granitoid terrane, referred to by Stott (1986) as the Bow Lake Batholith, a single-phase intrusion composed of medium- to coarse-grained megacrystic monzogranite to granodiorite. North and adjacent to the Pickle Lake Belt is the unmetamorphosed late- to post-tectonic Tarp Lake Pluton (Stott, 1986). Intruded into the Tarp Lake Pluton is the circular Kibler Lake Stock, a multiphase layered intrusion, locally composed of magnetite-rich melanocratic diorite.

The Pickle Lake Greenstone Belt contains three late- to post-tectonic felsic diapiric stocks: the Hooker-Burkoski Stock, Pickle Lake Stock and Ochig Lake Pluton (Pye, 1956 and Stott, 1986). According to Stott (1986), the Ochig Lake Pluton, Hooker-Burkoski Stock and Pickle Lake Stock are quartz-phyric trondhjemite intrusions that have warped and displaced the surrounding strata; these intrusions may be domical exposures of a common granitoid mass.

A late geological feature of the map area is the Pickle Crow Diabase Dyke which extends northwest to North Caribou Lake and southeast to Lake Nipigon. Pye (1956) considered this dyke to be of Late Precambrian age on the basis of his field work on the Central Patricia

Gold Mine property. This diabase dyke, like the iron formation, has a prominent aeromagnetic expression (O.G.S. Maps No.80631 to 80632, 1986 and ODM-GSC 1960). The area has undergone extensive glaciation; all sections are extensively covered by glacial drift. These deposits are important in the area as a source of sand and gravel, used extensively for road construction. Almost all roads in the area follow eskers and/or recessional moraines.

STRUCTURAL GEOLOGY OF THE PICKLE LAKE GREENSTONE BELT

Dominating the Pickle Lake Belt is a schistosity which lies parallel or at a small angle to the strike of the strata (Stott, 1986). Development of the schistosity is variable in the belt, with a weak flattening fabric typical of the northwesternmost part of the belt, and moderate deformation typical of other parts of the belt (Stott, 1986). Exceptions to the above include (after Stott, 1986):

- (1) Discrete deformation zones of strong to intense schistosity in the Pickle Crow area.
- (2) An almost purely lineated zone south of the Ochig Lake Pluton, between several late plutons.
- (3) Strong flattening fabrics imposed on strata within contact strain aureoles developed by late to post tectonic plutons.

Stratigraphic younging in the Pickle Lake Belt, from reliable top indicators, is toward the southeast; locally this southeastern younging direction has been reversed by isoclinal folding, such that the younging direction is toward the north.

Stott (1986) has recognized regional patterns of total strain, which allow for subdivision of the belt into three structural domains (Figure 5). Domain 1, containing the oldest observed strain elements in the belt,

is defined by easterly to north-northeasterly-plunging stretching lineations, which are characteristic of the Pickle Crow and Central Patricia properties. Domain 2, is characterized by westerly-plunging lineations which are parallel to lineations in the adjacent quartz-phyrlic Croshaw Lake Pluton. Domain 3, is spatially restricted to contact strain aureoles surrounding, or adjacent to, late felsic plutons such as the Hooker-Burkoski Stock, Ochig Lake Pluton and Pickle Lake Stock. Stott (pers. comm. 1986) suggests that Domain 1 possibly may be related to emplacement of the Quarrier Lake Tonalite Terrane; and Domain 1 may have covered a much larger area prior to evolution of Domain 2 and the emplacement of the Croshaw Lake Pluton (Stott, 1986).

ECONOMIC GEOLOGY OF THE PICKLE LAKE GREENSTONE BELT

Since the early 1920's, the Pickle Lake Greenstone Belt has undergone extensive exploration and mining. Activity in the area over the years has included the development of two gold mines that were shut down in 1965 [(Pickle Crow Gold Mines (Thomson 1939; Corking, 1948) and the Central Patricia Gold Mine (Barrett and Johnston, 1948)], the development of a low-grade copper-nickel deposit at the Thierry Mine (also closed: Patterson, 1980), and recent discovery of the Dona Lake gold deposit (Cohoon, 1986). The Pickle Crow Gold Mines property is now being re-examined by Highland Crow Resources. From 1986 up to the time of writing (February, 1987), Highland Crow Resources had conducted an extensive surface trenching and diamond drilling program that had outlined sufficient ore for an open pit in the No. 1 I.F. Zone (400,000 tons grading 15 gm Au/tonne; D.G. Innes, pers. comm. 1986). The No. 5 I.F. Zone situated 650 metres southwest of the No. 1 I.F. Zone, was defined consistently from 1500 to 3800 feet by Pickle Crow Gold

FIGURE 5- Structural Domains in the Pickle Lake Greenstone Belt

(after Stott, 1986)

Mines Ltd. just before closure in 1966. In addition, the present program has defined this zone from surface to 700 m, with probable reserves between surface and 3800 feet of 2.5 million tons grading .25 oz Au/ton or 10 gm Au/tonne. The Dona Lake gold deposit (Cohoon, 1986), located 20 km southwest of Pickle Lake, is operated by Dome Mines; reserves as of writing are 1.18 million tonnes grading 7.5 gm/tonne gold or 0.219 oz Au/ton, and this property is now being further evaluated. Gold at the Dona Lake Deposit is confined to pyrrhotite in oxide facies banded iron formation, with only minor associated quartz veining (Cohoon, 1986). The bands of oxide facies iron formation observed at Dona Lake are similar to the iron formation in the Pickle Crow and Central Patricia properties, except that instead of being at greenschist facies metamorphism, they are at amphibolite facies. The only base metal mine developed in the area was the Union Miniere Exploration's (U.M.E.X.) Thierry Cu-Ni Mine 20 km north of Pickle Lake. This deposit is associated with ultramafic intrusive rocks, with the ore consisting of chalcopyrite, pyrite, pyrrhotite, pentlandite and platinum group metals (Patterson, 1980). The mine opened in the mid 1970's and was closed a few years later due to a fall in world Cu-Ni prices. Sage and Breaks (1982) mentioned in their report that some iron formation units in the region offer a future potential as a source of iron. In the 70's this might have been true, but in the 80's and onward the iron formation more likely will be examined as a potential host for gold mineralization.

1.3 EXPLORATION AND MINING HISTORY

Prospectors hired by the Northern Aerial Minerals Exploration Ltd. (N.A.M.E.) carried out the first mineral exploration in the Pickle Lake region in 1926. N.A.M.E. supported 100 prospectors with ten airplanes,

ten pilots, ten pilot mechanics and ten experienced bush engineers. Many showings were investigated and dropped due to poor assay results; the Howell Vein or No. 1 Vein (named by Pickle Crow Gold Mines) discovered in 1928 by N.A.M.E. prospectors H.H. Howell and J. Mcfarlane was the first significant find at that time (Hammel, 1949). Exploration capital was raised and follow-up trenching and diamond drilling was started in 1929. Near surface EX-core diamond drilling indicated a small orebody in the vein, but the property remained dormant for over three years while capital was raised for mining. J.E. Hammel (1938 and 1949) was the principal promoter of the discovery and advised three groups consisting of a South African gold mining company and two American mining companies. Substantial money was raised by overselling the stock, so that by 1933 a steam-powered mining plant was installed and shaft sinking started on the No.1 Vein. Following this mining development, Pickle Crow Gold Mines Ltd. was incorporated in 1934. That same year a 125 ton / day mill was installed on the site of the No.1 Vein. Early in 1935, amalgamation and cyanidation of the ore commenced. Other gold-producing veins discovered in the same area included the Springer Vein to the southwest and the Albany River claims to the northeast (Figure 6). World War II halted many operations on the property, but after the war, interest in the area increased again and mining was revived on the No. 1 Vein operation. By 1947, the No. 5 Vein was found underground by drifting southwest of the No. 1 Vein through the B.I.F. on the 1350 foot level. At about the same time the No. 2 Vein was also intersected by drifting eastward off the No. 1 Vein on the 750 foot level. This vein later became the richest vein mined on the property.

Depleting ore grade in these auriferous veins encouraged geologists to look elsewhere for gold; a major investigation into possible B.I.F. hosted gold zones was conducted off the stoped workings of the No. 1 and No. 5 Veins between the 1500 and 3800 foot levels. However, due to rising costs and a steady gold price of \$32.00 / oz., all mining ceased in 1965 after 1,446,214 ounces of gold and 168,757 ounces of silver had been produced with a 98% recovery grade of 0.452 oz. gold / ton and 0.05 oz. silver / ton. In all, fourteen veins were developed, of which eight were prolific producers.

1.4 PRESENT WORK

Field and other techniques used in this study during the work period from June to December, 1986 included:

- 1) Mapping of rock outcrops and surface trenches in detail (see below for scales used in mapping). All mapping was performed in imperial measurement (i.e., feet and inches) because the results of all previous surface mapping, underground mining and property surveys are in these units. Scales used by the author are listed below:

A) Detailed Mapping 1"= 5'
 1"= 20'
 1"= 40'

B) Compilation of Detailed Mapping
 1"= 100'
 1"= 400'
 1"= 2000'

- 2) Trenching and stripping was done by using a D-8 Caterpillar bulldozer, Long Hoe and WAJAX water pumps.
- 3) A magnetometer and V.L.F. survey was conducted by the author over the No. 5 Vein / B.I.F. zone at 25' intervals.
- 4) Diamond drill hole logging by the author of some 30 drill holes: approximately 25,000 feet of core. Also included was the relogging of some 10,000 feet of previously logged holes. Compilation of individual mine level geology allowed construction of a multi-scale three dimensional mine model.
- 5) Figure 6 was modified after: Pickle Crow Mine Geologists, Pye (1956) and Ferguson (1966). New diamond drilling and a recent aeromagnetic map of the Pickle Crow and Central Patricia properties.
- 6) Map 1, at a scale 1: 1800, was constructed from 100,000 feet of past and present drill hole logs, mine level geology and geophysical data. This map does not represent the real surface geology, but instead is a projection of lithological contacts to surface.
- 7) Map 2, at a scale 1: 360, was constructed from geology and structural measurements taken on surface exposures, 50,000 feet of drill hole logs and geophysical data.
- 8) Structural measurements with a compass in areas of magnetite oxide facies B.I.F. had to be checked and corrected and in some cases taken with a solar compass.

- 9) Petrographic examination of 15 polished thin sections, 6 polished sections and 15 regular thin sections.
- 10) Samples collected for whole rock geochemistry were analyzed by Bondar and Clegg Laboratories of Ottawa.

2.0 GEOLOGY OF THE PICKLE CROW PROPERTY

The geology of the Pickle Crow and Central Patricia properties has been mapped by other workers at various times, with much of the information summarized by Pye (1956) and Ferguson (1966). The geology of the Pickle Crow property and to a lesser extent the Central Patricia property was examined by the author during field studies in 1986 (Figure 6). Previous mapping was comprehensive in its time, but new structural data have been acquired by the author. In addition, intermediate to felsic volcanic rocks had been incorrectly mapped (Ferguson, 1966) within a large area north and east of the Pickle Crow No.1 Vein mine workings. These are now recognized as basaltic volcanic rocks. Figure 6 illustrates the revised geology and structure of the Pickle Crow and Central Patricia properties; the inferred geological history for the area is summarized in Table 1.

BASALTIC VOLCANIC ROCKS

The most voluminous rock type exposed at the Pickle Crow and Central Patricia properties is of basaltic composition (Figure 8). The basalts are generally fine grained and weather pale grey. Massive flows (1a) are medium grained and commonly contain albite variolites up to 3 mm. Pye (1956, p.19) described the massive flows from thin section as "consisting essentially of fibrous amphibole (35 - 60 %), chlorite, highly altered plagioclase with small amounts of carbonate (siderite and ankerite), epidote, sericite and quartz, and subordinate leucoxene,

TABLE 1- INFERRED TEMPORAL RELATIONSHIP OF
MAJOR ROCK UNITS IN THE PICKLE CROW
AND CENTRAL PATRICIA PROPERTIES

PROTEROZOIC ?

DIABASE

-----Intrusive Contact-----

GRANITE

(Hooker-Burkoski Stock)

-----Intrusive Contact-----

ARCHEAN ?

PORPHYRY

(Quartz-albite porphyry)

(Albite porphyry)

-----Intrusive Contact-----

FELSIC VOLCANIC ROCKS

(Predominantly Dacite)

BANDED IRON-FORMATION

(Oxide, Silicate and Sulphide Facies)

GABBRO

-----Intrusive Contact-----

MAFIC VOLCANIC ROCKS

(Predominantly Basalts)

apatite, sphene and pyrrhotite". During the present study the fibrous amphibole was identified as actinolite. In a few areas within the property, extensive massive flows have been interpreted by Pickle Crow Mine geologists as sill-like diorites conformable to the enclosing rocks. Most pillows in the pillowed flows range in size from 0.2- to 1.5-metres in diameter. Two environments of pillow formation are inferred (this study, see Ch.3): pillows in flows of presumed deep-water origin are generally > 0.8 m in diameter and lack both vesicles and drainage cavities; pillows of presumed shallow-water origin are < 0.8 m in diameter and contain vesicles and drainage cavities. Pillow breccias (1c), which are common components of the vesicular basalts, contain pillow fragments up to 30 cm long. Thin, well-bedded units of banded iron formation are intercalated with the pillow breccia.

BANDED IRON FORMATION

Intercalated with the basalts are banded iron formation (B.I.F.) units of oxide, sulphide and silicate facies. The B.I.F. units are primarily of the oxide facies on both properties and are very distinctive in that they are well-layered with alternate layers of chert and magnetite ranging in thickness from 0.5- to 10-cm. The individual chert and magnetite layers are finely laminated on a mm-scale. The iron formation units range up to 80 m thick (with an average thickness of 10 metres); greatest thickness corresponds to fold hinges. The chert layers generally are light grey to white in drill core, but rarely appear dark grey to black; red jasper bands were not observed on surface or drill core. The magnetite layers are typically black, but on weathered surfaces are yellow-orange. Compositional grading from chert-rich to magnetite-rich laminae accompanied by thinning of laminae is locally

apparent in oxide facies and chert-sulphides in sulphide facies (Figure 9 and Plates 1h, 5g, 9g,h and 10 a,b). Such top determinations were particularly helpful for the definition of folds in the B.I.F. (see Ch.4;Figure 15). Also associated with the magnetite in the B.I.F. are minor quantities of sulphide minerals (mainly pyrite and pyrrhotite) and siderite, ankerite and chlorite (Plates 10 a to h). The sulphides occur as patches of grains that have replaced the magnetite, or as veinlets that cross-cut the layers (Plates 10 a to h). Commonly associated with the oxide facies B.I.F. throughout the area are continuous and discontinuous units of sulphide facies B.I.F., 1.5- to 35-m thick. Also associated with the B.I.F. units are zones of intraformational breccia and minor interbeds of argillite and graphitic argillite (Plates 2 g, 6 f).

FELSIC VOLCANIC ROCKS

Overlying the basalts and iron formation to the southeast of the Pickle Crow property is a thick succession of intermediate to felsic metavolcanic rocks (Figure 6), consisting of pyroclastic ash flows of dacitic composition (Pye, 1956 and Ferguson, 1966). The dacites contain both feldspar, quartz and sericite and minor amounts of chlorite, epidote and leucoxene (Pye, 1956; Ferguson, 1966). Also widespread throughout the area are dacite breccias consisting of scattered light-coloured angular felsic fragments with individual fragments < 5 cm in diameter (Ferguson, 1966). Some of these rocks were mapped as conglomerates by Pickle Crow Gold Mine geologists in their No. 2 Vein operation, from the 750 to 2900 foot levels. Examination of specimens obtained from the mine and from surface led Donaldson and Jackson (1965) to support a pyroclastic origin, but for specimens from the 2900

foot level they supported a conglomerate designation (Ferguson, 1966).

QUARTZ FELDSPAR PORPHYRIES

Intruding the basalts and iron formation, and possibly coeval with the dacites, are at least four major quartz-feldspar porphyries (QFP's): the formally named Pickle Crow Porphyry (PCP) and Albany Porphyry (AP); and the informally named Springer Porphyries (SP) and Central Patricia Porphyries (CPP) (Figure 6). Associated with the QFP's are 0.5- to 2-m QFP dykes and sills that emanate from the ends of each porphyry. All of the porphyries have similar mineralogy and textures in hand, specimen; they also, have similar chemistry (see Appendix 2, Table 1b).

The Pickle Crow Porphyry (PCP) is 2000 m long by 150 m wide, and is conformable in strike and dip with the enclosing rocks. The Pickle Crow Porphyry is distinctive in containing large quartz phenocrysts ranging in size from 2- to 10-mm (most are rounded to oval in cross section and a few are rectangular with rounded corners). Fractured crystals of albite ranging in size up to 5 mm are abundant, and the schistose groundmass is composed of small aggregate grains of quartz and altered plagioclase with accessory amounts of magnetite-ilmenite, leucoxene, clinozoisite, apatite, sphene, rutile, sericite and chlorite (Plate 9e).

The dimensions of the Albany Porphyry (AP) are 700 m by 120 m; it is positioned 150 to 250 m away from the PCP. The AP consists of abundant albite, scattered quartz phenocrysts and a few biotite phenocrysts all of which are up to 5 mm in diameter. The albite is altered to sericite. The AP is similar to the PCP in chemical composition (see Appendix 2, Table 1b), but the geometry of the (AP) is much more

irregular at each end, with numerous small QFP dykes and sills.

The Springer Porphyries (SP) are similar in composition to the PCP and AP (Appendix 2); the Central Patricia Porphyries (CPP) occur as several small to large sills.

The quartz-albite porphyries have all been sheared to widely varying degrees, with the more massive varieties being the most favourable for gold mineralization. The intrusive nature of these bodies is indicated by chilled margins along contacts with the enclosing wall rocks, by cross-cutting relations, and by irregular xenolithic inclusions of metavolcanic rocks.

LATE TO POST TECTONIC DYKES

Small felsic and lamprophyre dykes were mapped by Pickle Crow Mine geologists and Pye (1956); both types of dykes are observed to crosscut the basalts and iron formation (Figure 7 ; Map 1). In the No. 1 Vein area, a 2 m-wide biotite lamprophyre dyke cuts both the iron formation and the No. 1 Vein. Pye (1956) reported that small biotite lamprophyre dykes are numerous. These dykes are massive, dark-grey to black, medium- to coarse-grained and porphyritic with biotite phenocrysts exceeding 1 cm in diameter.

HOOKE-BURKOSKI STOCK

The Hooker-Burkoski Stock (described in Ch.1.23) is located southwest of the Pickle Crow property (Figure 6). This quartz phyrlic trondhjemitic stock is undeformed and intrudes all strata.

DIABASE DYKES

Small to large diabase dykes cross-cut all other rock types exposed on the property. These dykes are fine-grained, dark-grey, massive, and composed of a matted aggregate of chlorite, sericite, carbonate,

magnetite, secondary quartz, and biotite (Pye, 1956). A large composite 90 m wide diabase dyke (the Pickle Crow Diabase Dyke) cuts across all rocks in the Central Patricia area, including the Hooker-Burkoski Stock, and also the granitic terrane to the southeast as far as Lake Nipigon, and as far northwest as North Caribou Lake (Pye, 1956; Sage and Breaks, 1982)(Figure 6). The aeromagnetic maps covering its southeastward extension (ODM-GSC, 1960), suggests that the dyke consists of a series of en-echelon segments.

2.1 STRUCTURAL GEOLOGY OF THE PICKLE CROW PROPERTY

Four distinct, superimposed styles of deformation are recognized in the rocks of the Pickle Crow Property.

The earliest generation of structures, referred to as D_1 , is observed as rare 1- to 3-m isoclinal fold closures (F_1) within B.I.F. units, preserved within large (> 90 m) D_2 fold hinge zones (Plate 4e). S_1 axial planar foliation is locally moderate to well developed in the F_1 fold closures. Due to refolding, F_1 folds have axial planes with a mean strike direction between ENE to E and a steep dip to the north with hinge lines (L_1) plunging steeply (60° to 70°) to the NE. Pye (1956), Corking (1948) and Ferguson (1966) also observed many of these folds.

The second generation, D_2 , is represented by a penetrative axial planar flattening schistosity (S_2), parallel or at a small angle to S_0 , striking NE and dipping 75° to 87° to the NW throughout the Pickle Crow property (Figure 6). Stretching lineations (L_2) in the S_2 plane, defined by chert and magnetite in B.I.F., quartz phenocrysts in QFP and

varioles in basalts, are steeply plunging (70° to 85°) to the NE. D_2 fold closures (F_2) have axial surfaces that strike NE and dip steeply (75° to 85°) to the northwest, and hinge lines (L_2) that plunge 60° to 80° to the NE. D_2 fold closures are characterized by 1- to 200-m wide tight isoclinal similar folds, (best developed in B.I.F.) with thickened hinge zones, attenuated limbs and wavelengths of 300 m (Figure 6). The large D_2 folds outlined by the B.I.F. in Figure 6 include: the Pickle Crow Anticline, Pickle Crow Syncline, Sawmill Anticline and Powder House Anticline (Ferguson 1966; Figure 6). Reliable younging directions obtained from pillows, compositional grading in B.I.F. and volcanic flow bases are: tops to the south, on the south limbs of anticlines and north limbs of synclines, and tops to the north, on the north limbs of anticlines and on the south limbs of synclines (Figure 6). Common on the limbs of these large F_2 folds are large (up to 60 m) asymmetric folds that are consistent with folding.

The superposition of the D_2 isoclinal to tight folds (F_2) upon the D_1 isoclinal folds (F_1) has produced on a minor scale, Type 3 fold interference patterns (cf. Ramsay, 1967); F_1 and F_2 fold axial surfaces are at moderate angles (20° to 50°) to each other, and their hinge lines are coaxial.

D_2 shear zones occur throughout the Pickle Crow property as: shear zones parallel to S_2 surfaces (Type 1) and as discrete shear zones (S_2') that splay off the Type 1 shear zones in a direction ENE, connecting

Type 1 shear zones. Type 1 shear zones are strongly foliated zones greater than 30 m wide which dip steeply (75° to 85°) to the NW and include: the Pickle Crow Fault, Highland Crow Shear Zone, Pumphouse shear zone and Powderhouse shear zone (Figure 6). Locally, discrete shear dislocations occur along the S_2 axial surfaces of minor (1- to 3-m) F_2 folds (Plate 3d). Slickenside-stepped surfaces in Type 1 shear zones indicate steep (75° to 85°) oblique normal shearing with south side up.

Shear fractures in outcrop surfaces (Stott, 1986) trend ENE at low to moderate angles (20° to 40°) to S_2 (Figure 6). These ENE-striking sets of shear fractures have in some instances developed into discrete 2- to 5-m wide Type 2 shear zones that are strongly foliated (S_2' : see Ch.4). Geophysical data from (VLF) methods confirm that Type 2 shear zones splay off and connect Type 1 shear zones. Type 2 shear zones crosscut S_0 in the B.I.F. and form intersection lineations (L_2') that plunge 55° to 70° to the NE. S_2' and S_2 crosscut one another in Type 2 shear zones (Figure 14), indicating that S_2' was formed during the same NW-directed shortening that formed D_2 . Type 2 shear zones and the gold-bearing quartz veins they contain commonly are folded into Z-shapes. Stott and Brown (1986) also have observed these two types of D_2 shear zones within the region and have interpreted them to represent one member of a conjugate set of shear fractures. Also associated with Type 2 shear zones are rare variably oriented (average are NW-striking) fractures along D_2 folded lithological contacts.

The D_3 generation of structures on the Pickle Crow property

consists of NW- and N-striking conjugate faults, steeply dipping to the NE, and crosscutting and displacing earlier structural fabrics (Figure 6). Late undeformed veins, felsic dykes and lamprophyre dykes have been emplaced along fractures parallel to NW- and N-striking conjugate sets of fractures which crosscut D_2 fabrics. The Hooker-Burkoski Stock body is bounded on both sides by these faults, and this suggests that the stock emplacement may have been controlled by these fractures. Elsewhere, Stott and Brown (1986) have recognized a third type of shear zone related to D_3 which consists of a single shear zone at the outboard margin of a broad contact strain aureole produced by batholiths or stocks similar to the Hooker-Burkoski Stock. This third type of shear zone has not been observed nor geophysically detected by magnetics, VLF and IP methods, near the eastern and northern borders of the Hooker-Burkoski stock. This type of shear zone may be restricted to the margins of larger plutons such as the Ochig Lake and Pickle Lake plutons (Stott, 1986).

The final (D_4) generation is represented by the development of late continuous NW-striking en-echelon extensional fractures that crosscut earlier fabrics (Sage and Breaks, 1982). These fractures are up to 20 m wide and have considerable strike lengths up to 100's of metres. The Pickle Crow diabase dyke and other diabase dykes (Figure 6) crosscut all strata, including the Hooker-Burkoski Stock and the granitic terrane to the north and south of the Pickle Lake Greenstone Belt. The Pickle Crow diabase dyke has been displaced sinistrally along a NE-trending fault, the only record of post- D_4 deformation within the Pickle Crow area (Figure 6).

2.2 METAMORPHISM

Basaltic rocks in the Pickle Crow area have been metamorphosed to greenschist facies. Mineral assemblages were determined petrographically to be:

- (1) chlorite+actinolite+epidote+quartz+albite
- (2) chlorite+sericite+quartz+albite

The chlorite and actinolite are aligned due to growth parallel to S_2 and locally to S_2' foliations, suggesting that peak metamorphism accompanied D_2 deformation.

The principal minerals in the Pickle Crow quartz-albite porphyries include: quartz, albite, sericite, biotite and minor pyrite/pyrrhotite, chlorite, clinozoisite and apatite. The above mineral assemblage is representative of greenschist facies, compatible with the basalts.

2.3 ECONOMIC GEOLOGY OF THE PICKLE CROW PROPERTY

Gold mineralization at Pickle Crow Gold Mines occurs in five (5) different styles:

- (1) High-grade gold-bearing quartz veins that occupy the ENE-striking Type 2 shear zones which crosscut strata at low to moderate angles (e.g., No.5, 1 and 2 Veins).
- (2) Low-grade gold-bearing quartz veins that occupy Type 1 shear zones (e.g., Albany Shaft shear veins).
- (3) Stockwork auriferous quartz veins in the porphyries and gabbros, which are contained in or are spatially associated with Type 2 shear zones (e.g., ABC Zone).
- (4) High-grade auriferous veins in NW-trending fractures of short strike length that commonly splay off Type 2 shear zones (e.g., No.9).

Vein).

- (5) Auriferous sulphide zones which are stratabound and are contained within iron formation. These I.F. Zones occur adjacent to Type 2 shear zones (e.g., No.5 and 1 I.F. Zones, Central Patricia Gold Mine).

The subsequent chapter will examine in detail the stratigraphy and structure of the No. 5 Vein / Iron formation Zone which typifies the most significant style of mineralization in the Pickle Crow and Central Patricia properties.

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This thesis contains coloured
photographs & explanatory tables
which when microfilmed lose their
significance. The hardcopy of the
thesis is available upon request
from Carleton University Library.

FIGURE 6- Geology of the Pickle Crow and Central Patricia Properties.

3.0 GEOLOGY OF THE NO.5 VEIN / I.F. ZONE

Stratigraphic relationships in the vicinity of the No.5 Vein / I.F. Zone are shown in Figures 7 and 12 and are illustrated in Maps 1 and 2. Map 1 (prepared by the author) is a compilation of all previous and present work performed in the area at a scale of 1: 1800 in an area approximately 3000' by 3000' ; Map 2 is a detailed map of the No.5 Vein / I.F. Zone at a scale of 1: 360 in an area 1500' by 1000'. A cross-section of the No.5 Vein/I.F. Zone area is shown in Figure 12.

The lowermost unit in the No.5 Vein / I.F. Zone area consists of Lower Basaltic Flows, comprising pillowed flows and massive flows intercalated with minor discontinuous units of pillow breccia and sulphide-facies B.I.F. Overlying this unit is a variable 5- to 80- m-thick unit of B.I.F, consisting of a 1- to 30-m-thick basal sulphide-facies B.I.F, succeeded by a 5- to 80-m -thick oxide-facies B.I.F. Overlying the B.I.F. are the Upper Basaltic Flows, consisting of vesicular pillowed flows, massive flows, pillow breccia and minor intercalated oxide-facies B.I.F. Basaltic, lamprophyric and felsic dykes cut the strata in the No.5 Vein/ I.F. Zone. The chemical compositions of the above rock units are listed in Appendix 2, Tables 1a, b, c. Chemically the Lower and Upper Basaltic Flows both plot as high-iron and high-magnesium tholeiitic basalts, according to the Jensen (1976) cation plot (Figure 8); this has been interpreted by Thurston (1986) to represent cyclicity within the mafic units. According to Thurston (1986), within basaltic sequences, iron enrichment cycles progressing from iron-poor units at the base to iron-rich at the top are common. The basalts may also have been altered by 1) hydrothermal activity associated with the No.5 Vein/I.F. Zone, or by 2) seafloor alteration; either process could mobilize

FIGURE 7-IDEALIZED STRATIGRAPHIC SECTION IN THE NO.5 VEIN / IRON-FORMATION ZONE(SURFACE).

magnesium to various degrees from the basalts, and would lead to inaccurate classification in the Jensen Cation Plot. Nevertheless, the presence of pillowed flows is indicative of basaltic composition.

3.1 LOWER BASALTIC FLOWS (1a,1b,1c and 2b)

The Lower Basaltic Flows consist mainly of pillowed flows(1b), massive flows(1a) and minor pillow breccia(1c) (Maps '1 and 2).

Lower Pillowed Flows (1b):

The pillows range from 15- to 100-cm in diameter, with an average diameter of approximately 70 cm. They weather light to dark grey and are green in drill core due to abundant chlorite and minor amounts of actinolite (Plates 7a,e). The pillows also contain highly altered microcrystalline albite, calcite, sericite, epidote and pyrite/pyrrhotite. The pillows have a selvage thickness of .5-to1-cm consisting of essentially chlorite. The pillows are inferred to be of deep-water origin (Figure 10, Plate 1a) based on the absence of vesicles (Wells et al ,1979; Dimroth et al, 1978; Higgins, 1971; MacDonald,1967). Also associated with the pillows are pale brecciated and deformed quartz veins and quartz infills between the pillows (Plate 2b). The pillows are deformed to varying degrees throughout the map area, with the most pervasive deformation associated with the No.5 and Riopelle shear zones and the No.11 splay shear (Figures17 and 18; Plate 1c). Even within these deformed zones, some pillows show only minor deformation (Plate 1a). The younging direction from the undeformed pillows is consistently to the north (Maps 1 and 2 and Plate1a) in the No.5 I.F. Zone (compatible with other areas on the Pickle Crow Anticline); however, southeast of the No.5 I.F. Zone the pillow younging direction shifts from north to the southeast (Map1). This younging

reversal is consistent with the position of the Pickle Crow Anticline (Map 1). Several individual pillowed flows have been identified on the basis of surface and drill-core mapping (Maps 1 and 2); they typically grade along strike into smaller massive flows, pillow breccia zones and less than 30 cm thick sulphide-facies B.I.F. units. One distinct pillowed flow in the No.5 area (that hosts most of the No.5 Vein), approximately 30 m thick, contains abundant 2- to 5-mm euhedral magnetite crystals (Plate 7e). This flow has been mapped from drill core to a depth of at least 800 m, and is easily detected on surface by magnetic geophysical methods; thus, it is an important stratigraphic marker. In polished section the euhedral magnetite phenocrysts have no ilmenite lamellae present, suggesting that the magnetite may have formed in an oxidizing environment distal from the hydrothermal alteration associated with the No.5 Vein/I.F. Zone.

Lower Massive Flows (1a):

Massive flows in the Lower Basaltic Flows (Map 2) are generally fine- to medium-grained and weather light to dark grey. In unweathered drill core this rock is light to dark green. On the basis of thin section examination and mineral identification by X.R.D., the massive flows consist of 1- to 3-mm grains of albite and actinolite, microcrystalline chlorite and 1- to 3-mm grains of calcite and/or ankerite, and trace amounts of pyrite / pyrrhotite. The massive flows are generally thin (3- to 30-m thick) and grade into pillowed flows. The massive flows are typically less foliated than the pillowed flows.

Lower Pillow Breccia (1c):

Pillow Breccia units (Map 2) are intercalated within pillowed flows as 2- to 4-m thick discontinuous units, and consist of 1- to 50-cm pillow

fragments within a fine-grained matrix of similar material (Plates 1g and 9a). The pillow breccias are composed of large 1- to 5-cm pillow fragments that are fine-grained with an altered rim, within a microcrystalline matrix of chlorite and calcite, (Plate 9a). In surface exposures the pillow breccias are differentially weathered, with the pillow fragments being more resistant than the matrix. The pillow breccias within flow tops or flow bottoms locally show well-developed normal grading (especially in drill core), defined by lower coarse-grained (> 5 cm) pillow fragments overlain by fine-grained (< 5 cm) pillow fragments; this suggests a younging direction toward the north, compatible with pillow tops. Pillow breccias occur at the top or bottom of pillowed flows, but only rarely are they hosted within the pillow flows. The pillow breccias possess a much stronger foliation than the pillowed and massive flows.

Sulphide Facies B.I.F.(2b), associated with the Lower Basalts:

Interbedded within the Lower Basaltic massive, pillowed, and pillow breccia flows are .1- to 12-m thick discontinuous units of sulphide-facies B.I.F. (Plates 4g,6c,8e) to h ; Maps 1 and 2). The sulphide-facies B.I.F. consists of 90 % massive sulphides and 10 % chert-sulphide layers that are themselves finely laminated on a mm scale. The massive sulphide layers are 1 cm to 1 m thick, consist of marcasite and pyrite, show textures indicative of the replacement of pyrrhotite (Plate 8e) and are interbedded with finely layered chert-sulphide units. The massive pyrite-marcasite is typically yellow in drill core, and weathers yellow-orange. Marcasite and pyrite occur as 0.5- to 2-cm ellipsoidal concretions; also common are small 1- to 2-cm vugs lined with 1- to 3-mm euhedral pyrite. The chert-sulphide layers,

which range from .2 mm to 5 cm, have an average thickness of 1 cm, are finely laminated with alternating 1mm laminations of chert and sulphides. The chert and sulphide layers commonly are compositionally graded (Figure 9) with a younging direction toward the north in the No.5 I.F. Zone area. The abundance of these sulphide-facies B.I.F. units increases toward the top of the Lower Basaltic flows or main B.I.F. contact, suggesting that B.I.F. precipitation increased as basaltic volcanism diminished.

3.2 MAIN BANDED IRON-FORMATION (2a,b)

Overlying the Lower Basaltic Flows is the main B.I.F., which hosts the No.5 I.F. Zone (Maps 1 and 2). Ranging in thickness from 2- to 80-m, this large B.I.F. assemblage marks the cessation of the Lower Basaltic Flows. The B.I.F. consists of a distinctive 1- to 30-m basal sulphide-facies B.I.F. (2b) and an overlying 5- to 80-m oxide-facies B.I.F. (2a). Field trenches to the west of the map area are the only surface exposures of the unaltered B.I.F.; however, unaltered B.I.F. was encountered during diamond drilling.

Basal Sulphide Facies B.I.F. (2b):

The base of the main B.I.F. is marked by a distinctive well-layered sulphide-facies B.I.F. that has a variable thickness from 1.5- to 30-m. The sulphide facies B.I.F. consists of layers of massive marcasite and pyrite (80-90%) interbedded with layers of chert (10-20% : Plate 4g); textures in the pyrite are indicative of the replacement of pyrrhotite (Plate 8e). The sulphide-facies B.I.F. is much the same as the sulphide-facies B.I.F. units intercalated with the Lower Basaltic Flows, except that chert-sulphide layers are more abundant. The chert bands consist of .2- to .5-mm recrystallized grains of quartz (Plate 10b). This

basal sulphide-facies B.I.F. unit persists to a depth of at least 600 m from surface. Compositional grading of the laminae from chert-rich to sulphide-rich, accompanied by a progressive thinning of the laminae, suggests a younging direction toward the north (Figure 9). Intraformational breccias occur as discontinuous units within the B.I.F. and persist to a depth of at least 230 m (Plate 6f). The massive sulphide-facies B.I.F. grades stratigraphically upwards into oxide-facies B.I.F. (Map 2).

Oxide Facies B.I.F. (2a):

The oxide facies B.I.F., which dominates the entire B.I.F. assemblage (Maps 1 and 2), consists of layers of chert and magnetite with rare chlorite and carbonate bands (Plate, 1h).

The chert layers comprise 40- to 60-% of the main B.I.F., are white to grey on weathered surfaces and white to pale grey in drill core (Plate 5g). The chert layers are generally between 1- to 5-cm in thickness and are themselves internally finely laminated on a mm scale (Figure 9 and Plates 9gh, 10abc). They are composed of a mosaic of recrystallized polygonal quartz grains with a maximum grain size of 0.5 mm. Some subhedral magnetite crystals are also present, but usually quartz is the only constituent of these layers (Plate 10 abc).

Magnetite layers appear black to rusty orange-yellow on weathered surfaces and black in unweathered drill core (Plate 5g). The magnetite-rich layers range from 0.05 mm to 5 cm in thickness and constitute 30- to 50-% of the B.I.F. (Plates 9gh & 10 abc). Commonly, interlocking grains up to .05 mm constitute the fine micro-bands in the B.I.F. Fine .2- to .5-mm laminations of chert and magnetite are interbedded within the cm-scale layers in which magnetite and chert

FIGURE 8- Classification Of No.5 Area Volcanic Rocks According To The Jensen Cation Plot.

alternately predominate (Plates 1b and 5g).

Rare chlorite-rich layers are interbedded with chert and magnetite layers. These layers are associated with thin conformable quartz veins that form selvages adjacent to the veins (Plate 9f), and in other areas are distinct layers not associated with veining. The chlorite-rich layers range in thickness from tenths of a mm to several cm. They are composed predominantly of microcrystalline chlorite, with minor amounts of chert. Rare carbonate layers consist of ankerite crystals that are associated with chert layers, and range up to 1 cm in thickness. Common within the B.I.F. are intraformational breccia units < 20 cm that consist of angular fragments of both chert and magnetite (Plates 2g,6g).

3.21 GRADING IN THE OXIDE AND SULPHIDE FACIES B.I.F. AND DEPOSITIONAL ENVIRONMENT.

Compositional grading in chert-magnetite B.I.F. (2a) and chert-sulphide B.I.F. (2b) layers is accompanied by a progressive thinning of laminations within the layers (Figure 9 and Plate 10 abc). This feature proved to be very helpful during diamond drilling, in recognizing reversals in the younging direction due to isoclinal folding (Figure 14). The bands are uniform in grain size and therefore are not graded by differences in grain size. Barrett and Fralick (1985) have interpreted chert-magnetite grading within the Beardmore-Geralton area as uniform magnetite bands interbedded with siltstone/sandstone units (not chert beds). They did not report the additional thinning-upward grading within the chert-magnetite layers as described here.

Grading of layers possibly occurred due to an increase, followed by a gradual decrease, in the chemical-rainout (precipitation) of silica and

iron (oxide facies) or silica and sulphides (sulphide facies). The chlorite layers in the oxide facies B.I.F. could possibly be related to hydrothermal activity in the No.5 I.F. area, or perhaps may be derived from volcanic ash. Close association of the chloritic layers with the magnetite layers supports a volcanic origin, whereby both constituents were simultaneously deposited. The author favours the volcanogenic models of Gross (1965) and Goodwin (1973), rather than "the upwelled deep ocean water models" of Holland (1973) and Drever (1974), which apply to Superior-type I.F. deposition. Recent studies on the hydrothermal metalliferous deposits on the seafloor, suggest that hydrothermal fluids emanating from the seafloor rise as buoyant plumes (McConachy 1987), entraining ambient bottom sea water on the way up, until they reach density equilibrium and spread laterally in a direction that is controlled by near-bottom currents. Pulsing plumes may therefore control the chemical-rainout of silica and iron. Alternating deposition of chert and iron oxide layers in vent-proximal regions reflects processes now operating at 21° N (R.I.S.E. Project Group, 1980) and 11° N (Mc Conachy et al, 1986) on the East Pacific Rise, and at 86°W on the Galapagos Rift (Ballard et al, 1982). The evolutionary development of a smoker field (R.I.S.E. Project Group, 1980) from black to white smokers will produce a layering of the chemical sediment with the thickest layers proximal to the field and finer layers distal to the field. Rona (1984), in examining the episodic nature of the mid-Atlantic Ocean Ridge magmatic events and related hydrothermal activity noted that cycles range from 10^{-1} to 10^4 years. Similarly, Archean B.I.F.'s could have formed as a result of cyclic heat flow during repeated injections of magma. The thickness of the layers may reflect proximity

FIGURE 9- Compositional Grading within the Chert and Magnetite Bands of Oxide Facies B.I.F.

LEGEND

- - Chert
- - Magnetite

to the vent source, amount of dissolved material vented and current direction and both strength and stability of the plume. Distal from the volcanically active areas, chemical sedimentation would proceed more slowly, forming thinner layers.

3.3 UPPER BASALTIC FLOWS (1a,1b,1c):

Overlying the main B.I.F. are the Upper Basaltic Flows, dominated by pillows (1b) of presumed shallow-water origin, and massive flows (1a) intercalated with pillow breccia (1c) and oxide-facies B.I.F. (2a : Plates 1beg, 2d, 4a, 7abcd fgh, 9a).

Upper Pillowed Flows (1b):

The Upper pillowed basaltic flows (Plate 1b) are fine grained, weather light grey, and appear green-grey in drill core. The pillows range from 15- to 60-cm in diameter with an average diameter of 30 cm. They generally are smaller in size than in the Lower Basaltic Flows. The selvages are 1- to 2-cm thick (approximately 50% thicker than in the Lower Basaltic pillows). The Upper pillowed flows are inferred to be of shallow-water origin on the basis of the presence of 1- to 5-mm vesicles that are commonly concentrated in the upper parts of the pillows. Other features observed in the Upper pillows include: rare radial fractures, drainage cavities (3- to 5-cm long and 1- to 2-cm wide), abundant 1- to 3-mm albite variolites, rare concentric 4- to 8-cm cooling cracks and hyaloclastites (Figure 10). The Upper pillowed flows also locally exhibit pillow budding (Figure 11) that suggests a flow direction toward the northeast (J.A. Donaldson, pers. comm, 1986). The pillows contain 1- to 3-mm plagioclase (albite) phenocrysts and actinolite set in a fine- to medium-grained groundmass of carbonate,

chlorite, sericite and minor pyrite and pyrrhotite (Plates 7abcd fgh, 9a). In drill core, selvage thickness and the presence of vesicles and variolites are the best indicators of the Upper pillow flows. Pillow younging directions from pillow shapes (Plate 1b; Map 2) indicate tops to the north-northeast, compatible to the younging direction determined for the Lower Basaltic pillowed flows and the main B.I.F. Also associated with the pillows are small (< 10 cm) pale greyish brecciated and fractured interpillow quartz pods that are unmineralized and have a well-developed foliation, which are similar to masses of quartz observed in the Lower Basaltic pillowed flows (Plates 2d, 7d). These quartz pods may have formed in part by deuteritic fluids in the basaltic magma or may have been formed during seafloor hydrothermal activity.

Upper Massive Flows (1a):

Massive flows within the Upper Basaltic unit are widespread throughout the map area (Plate 1e). They weather dark grey and are dark green in drill core. The massive flows are fine - to medium-grained and contain abundant 2- to 4-mm variolites of albite in a microcrystalline groundmass of chlorite. The massive flows are small conformable tabular bodies that are intercalated with the pillowed flows and breccia. One large massive flow extends from the Riopelle Vein / shear zone area to the No.1 Vein area (refer to Map 1) and is conformable to strata.

Upper Pillow Breccia (1c):

Commonly associated with the pillowed flows are units of pillow breccia that are most abundant in the Upper Basaltic Flows, especially northwest of the No.5 I.F Zone (Maps 1 and 2; Plate 1g). They are similar

Figure 10- Morphological Differences Between Lower and Upper Pillowed Basaltic Flows.

A) UPPER BASALTIC FLOWS (Shallow-Water Pillows)

B) LOWER BASALTIC FLOWS (Deep-Water Pillows)

to the pillow breccias in the Lower Basaltic Flows, but are much more abundant. The pillow breccia fragments range from 0.5 cm to 1.5 m, and consist of pillow fragments within a fine-grained chloritic matrix (Plate 9a). The Upper pillow breccias are differentially weathered, consisting of resistant angular pillow fragments within a less resistant fine-grained matrix. The matrix contains abundant chlorite, calcite and 0.25- to 3-mm grains of albite, set in an identical fine-grained groundmass (Plate 9a). Commonly associated with the breccia zones are debris flows, containing 20- to 120-cm blocky fragments (> 50%) of pillow breccia and oxide-facies B.I.F. within a fine-grained matrix of chlorite, carbonate, albite and pyrite. The thick assemblage of pillow breccias northwest of the No.5 I.F. Zone (Maps 1 and 2) grades into pillowed and massive flows in less than 100 m. The zone possibly was controlled by a slope or paleotopography developed on the Lower Basaltic flows.

Banded Iron Formation (Oxide-facies.2a) within the Upper Basaltic Flows

Oxide facies B.I.F. units (2a) are commonly intercalated within the Upper Basaltic flows (Map 2). They generally are less than 1 m thick (some are only a few centimetres thick) and consist of mm- to cm-scale layers of chert and magnetite (Plate 1h). The complex geology north of the No.5 Vein/I.F. Zone (Map 2) shows these long narrow B.I.F. units interbedded within the Upper Basaltic Flows; this may represent earlier F_1 folds and a way to prove this is to examine the compositional graded bedding (wasn't examined during logging) in the B.I.F. for reversals in the younging direction which would indicate isoclinal folds.

3.4 MAFIC DYKES (1d)

Only one mafic dyke (1d) is exposed at surface. This dyke strikes NNE and dips 75° to the NW, cutting the B.I.F. in the No.5 I.F. Zone (Plate 2e); it is 60- to 90-cm wide and is dark grey, with a fine-grained chilled margin (Plate 2e; Figure 23). X.R.D. analysis of a sample from this dyke shows it to consist almost entirely of chlorite with minor amounts of albite and pyrite (Plate 9b). The chemical composition of the mafic dyke plots as a high-Fe tholeiitic basalt (Figure 8). This dyke is located within the No.5 I.F. Zone and has been less altered than the B.I.F.; the dyke has a lower CaO and a higher Fe_2O_3 (Total Fe) values in comparison to the Upper and Lower basaltic pillowed and massive flows. This mafic dyke has been deformed by shearing parallel to the regional schistosity. Several additional mafic dykes were encountered during diamond drilling and all of them have a fine-grained chilled margin and a medium-grained central zone, weather dark grey brown, and appear dark grey in drill core. In drill core these mafic dykes are easily recognized by their coarser grain size with a strong regional schistosity.

3.5 LAMPROPHYRE DYKES (6):

Dykes that contain abundant large ($>1\text{cm}$) biotite phenocrysts are here tentatively identified as lamprophyre. Observed in drill core near the No.5 I.F. Zone, these dykes strike NW and dip steeply to the NE (Figure 23); they are 0.5- to 1.5-m wide, dark grey to black, display fine-grained chilled margins and have medium- to coarse-grained central zones that exhibit porphyritic texture due to large (up to 3 cm) biotite phenocrysts. These dykes appear to have a relatively short strike length (approximately 20- to 30-m), as deduced from diamond

drilling. One large coarse-grained lamprophyre dyke, exposed in the No.1 Vein area (2 m-wide by 80 m-long : Map 1), clearly cuts the B.I.F. strata along a NNW trend (Plate 3e). This dyke is composed of 0.5- to 3-cm biotite phenocrysts, 0.5- to 5 -mm hornblende, orthoclase, quartz, chlorite and albite grains, abundant 0.5 cm ankerite grains and rare clinopyroxene (Plate 9d).

3.6 FELSIC DYKES (5):

A 1.5 m-wide felsic dyke is exposed in outcrop 100 m west of the No.5 I.F. Zone; it strikes N and dips 80° to the ENE (Map 2; Figure 23). This dyke weathers white to grey and is medium-grained, with a fine-grained chilled margin. The dyke consists of 1- to 3-mm quartz and plagioclase phenocrysts within a fine-grained groundmass of sericite, ankerite, kaolinite (from XRD) and pyrite/pyrrhotite (Plate 9c). The dyke contains (Appendix 2, Table 1c) approximately 20 wt.% SiO_2 less than the quartz-albite porphyries and the Hooker-Burkoski Stock (quartz-phyric trondjemite) (Appendix 2, Table 1a); also, the dyke shows slightly higher Fe_2O_3 and MgO values. Additional felsic dykes with similar features and orientation, were encountered during diamond drilling.

FIGURE 12- Cross Section of the No.5 / I.F. Zone
Between 26S and 32S on Line 55 W

LEGEND

Oxide Facies B.I.F.

Sulphide Facies B.I.F.

Massive Flows

Pillowed Basalts

Mafic Dyke

Diamond Drill Hole

Shear Zone

Scale

100 0 100 200

(Feet)

4.0 STRUCTURAL GEOLOGY OF THE NO. 5 VEIN / I.F. AREA

The scarcity of outcrop in the No.5 I.F. Zone area, prior to extensive stripping by Highland Crow Resources, hindered development of a satisfactory stratigraphic-structural framework. However, recent surface exposures created during the course of this study by bulldozer, backhoe and hydraulic stripping, in addition to some 40,000 feet of diamond drilling, have allowed the collection of numerous new structural measurements (Maps 1 and 2). Because structural measurements obtained by Brunton compass near magnetite-bearing oxide-facies B.I.F. generally are inaccurate, measurements in the vicinity of B.I.F. have been made by means of a solar compass that is accurate to about 3° . Most measurements were located on a grid established by both solar compass and Brunton compass. Geophysical techniques also were most helpful in detecting and mapping some structures beneath the glacial overburden.

The strata (S_0) in the No.5 Vein / I.F. Zone area (Figure 6 and 21 a; Maps 1 & 2) strike northeast and dip steeply (75° to 87°) to the northwest. They form the north and south limbs of the Pickle Crow Anticline (Pye, 1956 and Corking, 1948), a large D_2 fold (F_2) overturned to the southeast (Map 1). Reliable younging directions from pillows and compositional grading in the B.I.F. are: tops to the north in the north limb; tops to the south in the south limb (Figure 6; Map 1). Three deformation periods of the four outlined in Section 2.1 have been recognized in the No.5 Vein / I.F. Zone area.

The earliest generation (D_1) is recognized as rare 0.2- to 3-m

isoclinal fold closures (F_1) preserved in D_2 fold closures within oxide facies B.I.F. units (Map 2; Plates 2a, 4ef). Due to refolding, F_1 folds have axial surfaces with a mean strike direction between ENE to E, dip 80° to the north and have hinge lines (L_1) that plunge 60° to 75° to the NE (Figure 21 b). Axial planar penetrative foliation (S_1) is weak to moderately developed.

A second generation, D_2 , is indicated by a dominant penetrative axial planar flattening schistosity (S_2), which is parallel or at a small angle to S_0 , striking NE and dipping 75° to 87° to the north (Figure 21d; Maps 1 and 2). S_2 is best developed in the basalts as a planar alignment of actinolite and chlorite and is less developed in massive flows and B.I.F. Stretching lineations (L_2 : Figure 21d) in the S_2 plane (defined from stretched chert and magnetite in the B.I.F. and stretched clusters of pyrite grains and varioles in the basalts) are steeply plunging to the NE at 65° to 85° .

D_2 fold closures (F_2) are isoclinal to tight similar folds, both in basalts and in B.I.F. units. F_2 folds have axial surfaces that strike NE, dip 80° to 85° to the NW and hinge lines (L_2) that plunge 65° to 80° to the NE (Figure 21c; Map 2; Plates 2b, 3abcd, 5c). F_2 minor folds have wavelengths of 0.3- to 1-m and amplitudes of 0.5- to 3-m. A large F_2 fold not exposed on surface occurs 100 m northeast of the No.5 Vein / I.F. Zone (Maps 1 and 2) in B.I.F.; it is 75 m wide by 30 m long and plunges 70° to 80° to the northeast. The configuration of the fold was

determined by detailed examination of drill core which revealed a younging direction reversal on the basis of compositional graded bedding in the B.I.F., accompanied by successive changes in bedding attitude from 85° to 70° to 20° to 5° to 80° relative to the long core axis (L.C.A) (Figure 13). F_2 hinge zones in B.I.F. show considerable brittle fracture cleavage (Plate 3d); less fracture cleavage is developed in the basalts (Plate 2b). Superposition of D_2 isoclinal to tight folds (F_2) upon the D_1 isoclinal folds (F_1) has resulted in an outcrop pattern of Type 3 fold interference pattern (Ramsay, 1967; Plates 2a, 4e); F_1 and F_2 axial surfaces are at a moderate angle (20° to 60°) to each other; hinge lines are coaxial (Figure 21 bc).

D_2 -Type 1 shear zones (as described in Ch. 2.1) are not exposed in the No.5 Vein / I.F. Zone area, but they are recognized in drill core (variable core recovery due to shearing and alteration) as a wide zone (50- to 100-m) of strongly foliated rocks. Type 1 shear zones are parallel to S_2 and occur as wide (> 30 m) strongly foliated zones and locally as smaller (< 1 m) discrete shear zones associated with minor F_2 folds (Plate 3d). Type 2 shear zones exposed at surface strike ENE, dip 65° to the north and comprise narrow (< 5 m) strongly foliated (S_2') splay shears that emanate outward from, and connect, Type 1 shear zones (Figure 22 a).

Type 1 shear zones in the No.5 Vein / I.F. Zone include (Map 1): the Pickle Crow Fault to the north, and the Highland Crow Shear Zone to the south. The Pickle Crow Fault, exposed at the east end of the Pickle Crow

FIGURE 13- Idealized cross-sectional diagram showing how a large fold was determined from bedding attitudes in drill core;(b) Outlined fold from (a).

B) (Looking West) HC-92

property, is an intensely foliated and altered zone at least ~~100 m~~ wide (Plate 6g). These shear zones were detected as a low frequency (VLF) conductor with low- to medium-resistivity, high-chargeability and a low-total magnetic field. Minor Type 1 shear dislocations occur as discrete zones parallel to S_2 in and near minor F_2 fold closures (Plate 3d); in some instances they are parallel to S_0 (Plate 2e). Slickenside-stepped surfaces record the final brittle movements in the Pickle Crow Fault, and indicate a steep oblique normal slip movement with south side up.

Type 2 shear zones exposed in the No.5 Vein / I.F. Zone include parts of the No.5 and Riopelle shear zones and the No.11 splay shear (Maps 1 and 2; Figures 17 and 18; Plates 1 cd, 2h and 3f). They consist of strongly foliated (S_2') rocks in zones 2- to 5-m wide that strike ENE and dip 60° to 70° to the N. Type 2 shear zones have strike lengths up to 500 m connecting Type 1 shear zones, and extend to a depth of at least 1500 m (Figure 20). Most of these Type 2 shear zones are crosscut by S_2 (Figure 14), and are folded into Z-shaped asymmetric folds. These shear zones intersect the B.I.F. in a line which plunges 55° to 70° to the NE (Figure 22 b) and rake (pitch) at an average angle of 65° in a direction of N 20° E to N 30° E. Adjacent to Type 2 shear zones, ENE-striking shear fractures increase in abundance, and shear dislocations become considerably stronger (Plate 2f; Figures 17 and 18). Horizontal and vertical displacement of rock units has occurred due to the high oblique normal shearing of the No.5 shear zone. Type 2 shear zones and related splay shears contain gold-bearing quartz-tourmaline-scheelite veins, including the No.5, Riopelle and

**Figure 14- S₂ and S₂' within the NO.5 SHEAR ZONE.
(Looking Southwest)**

No.11 Veins. Each Type 2 shear zone will be discussed separately below.

D_3 structures are recorded by NW to NNE striking conjugate faults that offset and displace earlier D_2 fabrics, consistent with a NW-directed shortening. Undeformed conjugate quartz veins less than 10 cm wide which crosscut S_0 , S_2 and S_2' fabrics, strike NNE and NW, and dip steeply to the NE (Figure 23). Lamprophyre and felsic dykes in the No.5 Vein / I.F. area are parallel to the strike of these conjugate fractures, and thus, the emplacement of these dykes may have been controlled by these conjugate fractures (Figure 23).

4.1 No. 5 Shear Zone:

The No. 5 shear zone (Maps 1 and 2; Figures 15 and 22 a; Plate 2h) is a strongly foliated (S_2') zone up to 3 m wide, striking east-northeast, dipping 60° to 70° to the N. The No.5 shear zone is discordant to both strata (S_0) and flattening schistosity (S_2) (Figures 17 and 18); the No.5 shear zone intersects the B.I.F. in a line (L_2') that plunges 55° to 70° to the NE and rake at an average of angle of 65° in a direction of N 20° E to N 30° E (Figure 22 a,b). Surface exposures near the No.5 shear zone shows strong sets of ENE-striking shear fractures parallel to S_2' (Plates 1e,2f,4b). The No.5 Vein, a gold-bearing quartz-tourmaline-scheelite vein up to 1m wide, is contained within the No.5 shear zone with a strike length of 100 m, and has significant concentrations of gold. (> 30 gm Au/ tonne). The No.5 Vein occurs within part of the No.5 shear zone as an infilling of quartz-tourmaline-scheelite and gold in a multistage brittle dilational fracture that extends for a strike length of 100 m along the south contact of the main B.I.F., through the magnetite-bearing

Lower Pillowed Basaltic Flow (Map 2). The No.5 Vein (Figure, 22c; Plate 2h) is spatially associated to the main B.I.F. and Lower Basalt contact area in the No.5 shear zone (Map 2). The No.5 shear zone has offset the main B.I.F. unit dextrally by 15 m in the horizontal and 40 m in the vertical with a net slip of 45 m (Figure 15; Map 2). This offset is consistent with oblique normal shearing with south side up and is compatible to stepped-slickenside surfaces in the No.5 shear zone. Locally the No.5 Vein and shear zone are folded into Z-shaped, asymmetric folds and boudinaged; the No.5 Vein boudins are .5- to 1-m long, and hinge lines of folded quartz veins plunge 60° to 70° to the NE, comparable to the host rocks outside of the zone. Surface exposures near the No.5 shear zone were mapped at a scale of 1 inch to 5 feet, in order to record the deformation of the individual pillows (Figures 17 and 18). The No. 5 shear zone crosscuts all strata in the area (Maps 1 and 2); at the B.I.F. contact, several minor 0.3- to 1-m wide splay shears penetrate the B.I.F. along an E-trend and contain auriferous quartz veins (No.11 Vein) which are similar to the No. 5 Vein (Figure 18, Plate 3fh). Within the No.5 shear zone, parallel (mm scale) foliated bands are spaced 5- to 10-mm, similar to those shown in Plate 5e; in places S_2' is crosscut by S_2 as illustrated in Figure 14. The No.5 shear zone is expressed geophysically as a magnetic low within a linear magnetic high (Figure 16) and as a strong VLF conductor. This magnetic signature is also detected near the Riopelle shear zone, the No. 1 I.F. Zone, the ABC Zone, Lakeshore Vein (Plate 4c), Sawmill Vein and the Pumphouse Creek Zone (Figure 6).

Figure 15- Block diagram showing the strike-slip, dip-slip and net-slip associated with the No.5 shear zone and the main B.I.F.

Legend

2a
2b

Oxide facies B.I.F.

Sulphide facies B.I.F.

Scale

(Metres)

FIGURE 17- Detailed Map of the Lower Basaltic Pillowed Flow- B.I.F. Contact, the No.5 Shear Zone and the No.5 Vein/I.F. Zone. Traced from Photographs taken on a detailed grid.

FIGURE 18- Detailed Map of a Lower Basaltic Pillowed Flow Showing the Effects N
of the No.11 Splay Shear and the No.5 Shear Zone on the Shape of the
Individual Pillow. Traced from Photographs taken on a detailed grid.

NO.5 SHEAR ZONE

SCALE

5 0 5 10 (Feet)

1.5 0 1.5 3.0 (Metres)

4.2 Riopelle Shear Zone

The strongly foliated Riopelle shear zone (Figure 22 a) (S_2'), which contains the auriferous Riopelle Vein (Plates 1f,5e; Figure 22 c; Maps 1 and 2), strikes ENE, is up to 5 m wide and has been outlined by diamond drilling for at least 300 m of horizontal distance to a depth of 150 m; the Riopelle Vein (Figure 22 c) has only been outlined for a horizontal distance of 180 m to a depth of 100 m. Due to a lack of surface exposure and the absence of a B.I.F. marker horizon in the Riopelle shear zone, estimation of horizontal and vertical displacement is impossible, and therefore it is assumed that movement is similar to the No.5 shear zone (Figure 15). The Riopelle shear zone is similar to the No. 5 shear zone, in that it is an intensely foliated (S_2' : Plate 1f) zone which crosscuts strata (S_0) with several minor splay shears. The Riopelle shear zone has been folded into Z-shaped asymmetric folds and boudinaged (Map 1; Plate 5 de), having hinge lines which plunge 60° to 65° to the NE. The thickest part of the Riopelle Vein occurs in the N- to NNE-striking fracture developed along a folded contact between a pillowed and massive flow (Map 1; Plate 5d).

4.3 Splay shears and fractures related to the No.5 and Riopelle shear zones:

Both the No. 5 and the Riopelle shear zones have several splay shears 0.6- to 3-m wide, that are strongly foliated (S_2') and strike E-ENE as much as 60 m in horizontal distance. Almost all splay shears contain quartz veins, 1- to 10-cm wide and 20- to 100-m in strike length; most yield concentrations of gold well above background. The No.11 splay shear, off the No. 5 shear zone, contains the past-producing

No. 11 Vein (Figures 18 and 25; Plate 3f). Also associated with the No. 5 and Riopelle shears are NW- to N-striking fractures that contain auriferous quartz-tourmaline veins. These fractures may represent extensional fractures consistent with a NW-directed shortening; this is the case for part of the Riopelle vein and the past-producing No. 9 Vein (Figures 24, 25, 26 and 27).

4.4 QUARTZ VEINS IN THE NO. 5 AREA

The major gold-bearing quartz veins in the No. 5 I.F. Zone map area are the previously mined No. 5, 11 and 9 veins and the unmined Riopelle Vein (Figures 24, 25, 26 and 27). Many smaller quartz veins that occur throughout the No. 5 map area belong to generations that either pre-date (Early veins) or post-date (Late veins) these major auriferous veins (Figure 19).

4.41 Early Veins:

Early quartz veins are recognized in outcrop and drill core as pale veins that are strongly foliated and contain minor amounts of pyrite/pyrrhotite and calcite (Figure 19). These early veins generally strike NE and dip 70° to 85° to the north (Figure 22d); parallel to the strike of strata. These early quartz veins are barren of gold mineralization and have been crosscut and displaced by quartz veins related to the No. 5 shear zone. These early quartz veins are almost entirely restricted to the basaltic flows, and have not been recognized in B.I.F. Early formed quartz pods (Plate 2d) also occur in the Upper Basaltic Flows, occupying both pillow drainage cavities and interspaces between individual pillows. These quartz pods may represent silica-rich deuteric fluids or possibly seafloor hydrothermal alteration.

Figure 19-Idealized Diagram Illustrating mineralization in the No.5 Vein (plan view).

4.42 Gold-Bearing Quartz-Tourmaline-Scheelite Veins:

No. 5 Vein

The No. 5 Vein (Plate 2h), contained in the No. 5 shear zone, strikes east-northeast and dips 60° to 70° to the N (Figure 22 c), crosscutting the Lower and Upper Basaltic Flows and the B.I.F; however, the No. 5 Vein occupies only a small strike length (100 m) of the No.5 shear zone. The No.5 Vein is hosted in part by the Lower magnetite-bearing pillowed flow, and to a lesser extent by the main B.I.F (Map 2). The No. 5 Vein at surface has an average width of 0.6 m and a horizontal length of 100 m (Map 2). It has been mined to the 3800 foot level (1150 m) and explored to 4300 feet (1300m). On the 2900 foot level, the No. 5 Vein penetrates through B.I.F. into the Upper Basaltic Flows (Figure 27). The quartz in the No. 5 Vein is white to dark grey away from the main B.I.F. contact, but close to the B.I.F. the quartz becomes bluish, which may possibly be due to an iron impurity within the quartz. The No.5 Vein contains 1- to 5-mm wide stringers and layers of tourmaline, sericite, scheelite and gold that parallel the strike of the vein. These stringers and layers exhibit well-developed slickensides that indicate a steep oblique normal slip with south side up. The No. 5 vein has been asymmetrically folded with a Z-shaped asymmetry; fold hinge lines plunge 65° to the NE. Within the No.5 Vein are folded crosscutting quartz veins that lie at about 40° to the No.5 shear zone and strike ESE.

4.43 No. 11 Vein:

The No. 11 vein, a past-producing auriferous quartz-tourmaline-scheelite vein, mined from the 750 to 1350 foot levels (Figure 25), is not exposed on surface, but the shear zone splay in which the vein occurs is exposed (Plate 3f; Figure 18; Maps 1 and 2). The No. 11 Vein,

discovered near surface during diamond drilling, is 2- to 10-cm wide and strikes east over a horizontal distance of 60 m (Maps 1 and 2). The No. 11 vein is similar to the No. 5 Vein, because it contains stringers and layers of tourmaline, sericite, scheelite and free gold, but it is much thinner and has a more limited horizontal extent.

4.44 Riopelle Vein:

The gold-bearing Riopelle Vein strikes ENE, and dips 65° to 75° within the Riopelle shear zone (Plates 1f, 5e, 6d; Figure 22 c). The Riopelle Vein is hosted primarily within the Upper Basaltic Flows near the contact of a large massive flow unit (Plates 1e, 5d) and a pillowed flow unit (Plate 5c; Map 1). The contact of the pillowed flows and the massive flows is folded (F_2), and in this area, a N-NNE-striking fracture has developed off the main Riopelle shear zone, with this fracture hosting the thickest part of the vein (Plate 5d, Map 1). The Riopelle Vein ranges from 2 cm to 1 m wide in the fracture off the shear zone. The quartz in the Riopelle Vein is white and coarse-grained (>5 mm : Plate 6d). The Riopelle Vein is different from the No. 5 Vein in that there are only minor .2- to .5-cm stringers and layers of tourmaline and sericite parallel to the strike of the vein (Plate 6d); however, it contains .5- to 1-cm layers of scheelite adjacent to the footwall and hangingwall. Visible gold occurs throughout the strike length of the vein. The Riopelle Vein has only been outlined for 180 m of horizontal distance to a depth of 100 m. Previous exploration on the Riopelle Vein was concentrated on the vein within the N-striking fracture off the ENE-striking Riopelle shear zone, but concentration on the main shear zone probably would have been more rewarding.

4.45 No. 9 Vein:

The No. 9 Vein was mined from the 1700 to the 3200 foot mine level (Figures 24, 25, 26 and 27), and is not exposed on surface nor was it encountered in shallow diamond drilling. The No. 9 Vein is a 30 m long north-striking vein within a fracture off the No. 5 shear zone (Figure 27), similar to the part of the Riopelle Vein (Map 1). This No.9 Vein may possibly be within a tensional fracture developed during the D_2 deformation. The No. 9 Vein is smaller in strike length than the No. 5 Vein and it was also richer in gold.

4.46 Other Gold-Bearing Quartz Veins within the Pickle Crow Property

A comparison of the orientations of other auriferous quartz veins from other areas in the Pickle Crow property was made to investigate possible similarities with the No.5, 11 and Riopelle Veins (Figure 22c; Maps 1 and 2). An equal-area plot showing orientations of other gold-bearing veins (Figure 24) clearly shows that most of them strike E to ENE and dip 60° to 70° to the north; similar to the No.5, 11 and Riopelle Veins. This suggests that auriferous quartz veins on the Pickle Crow property are possibly controlled by similar ENE-striking Type 2, shear zones, similar to the No.5 Vein/shear zone. A few gold-bearing quartz veins that strike N to NNE and dip 60° to 75° to the NE, may possibly be similar to part of the Riopelle Vein and the No.9 Vein.

4.47 Late Veins:

Late quartz veins (Figure 19), are recognized in outcrop as small white veins, less than 15 cm thick, that strike N to NW, dip 60° to 70° to the NE (Figure 22d) and crosscut the strongly foliated No. 5 shear zone (Plate 3g). These quartz veins are barren, although some contain

89

minor amounts of calcite. These veins have not been deformed, and therefore, must post-date the No. 5 Vein/shear zone.

4.5 Relationship of Folds and Shear Zones to the No.5 Vein/I.F. Zone:

The generations of structures recognized in the No.5 Vein/I.F. Zone area (D_1 , D_2 and D_3) are all consistent with a progressive northwest directed shortening. An attempt is made here to place the various structural elements into their temporal relationships.

The first formed structures are rare D_1 isoclinal folds in B.I.F. with axial planes parallel to S_1 foliation. They are distinguished from D_2 tight folds by an S_2 axial planar foliation which transects the axial planes of the D_1 folds; they are commonly refolded by D_2 . There is no shearing parallel to S_1 nor is there fracture cleavage developed in the chert-magnetite layers of D_1 fold closures.

The next structures to develop are the D_2 generation of structures which include tight isoclinal D_2 folds, S_2 axial planar foliation and Type 1 and 2 shear zones (Figures 15 and 20). D_2 tight isoclinal folds are developed in part before shearing, because they are displaced by D_2 shear dislocations. D_2 folds, unlike D_1 folds possess fracture cleavage; thus, these folds were formed in a more brittle regime relative to D_1 folds. Type 1 and 2 shear zones and S_2 foliation developed simultaneously during the late stages of D_2 folding because: 1) S_2

foliation is an axial planar foliation to the D_2 folds; 2) Type 1 shear zones are parallel to S_2 and they offset minor D_2 folds and 3) Type 2 shear zones crosscut strata and D_2 fold closures in bedded units, yet they are weakly folded themselves. Type 1 and Type 2 shear zones have a major component of dip-slip and a small component of right handed strike slip such that they are oblique normal shear zones with south side up (Figures 15 and 20). Type 2 shear zones have been folded into Z-shaped asymmetric folds that have hinge lines that plunge steeply (shallower than D_2 fold axes in bedded units) to the NE. Stretching lineations in S_2 and Type 1 shear zones and slickensides in Type 2 shear zones also plunge steeply to the NE. This extension parallel to fold axes is still an unexplained feature here, and in many other areas (Hobbs, Means and Williams, 1976). The reasons why Type 1 shear zones develop where they are is uncertain, but Type 2 shear zones favour areas near D_2 fold closures (No.1 shear zone) or near folds on the limbs of these folds (No.5 shear zone). Thus, pre-existing structures have some control on these Type 2 shear zones.

D_3 generation of structures are recognized as NNE and NW striking conjugate faults and fractures that have displaced strata and D_2 structures consistent with conjugate fracturing and a NNW directed shortening (Figure 6). They are readily distinguished from D_2 fractures on the basis of: 1) their crosscutting relationship to the strongly foliated Type 2 shear zones (No.5 and Riopelle shear zones, and 2) they commonly contain quartz-carbonate veins that are undeformed.

**Figure 20- Block diagram showing the various D2 structures
between the No.5 and 1 Vein/I.F. Zones.
and the main B.I.F.**

Legend

2a

Oxide facies B.I.F.

Scale

0 100 200

 (Metres)

FIGURE 21. Equal-area plots showing orientations of (a) S_0 , (b) F_1 hinge lines and axial traces, (c) F_2 hinge lines and axial traces, and (d) S_2 Foliations and stretching lineations, in the No.5 I.F. Area. Contours are in intervals of 20 measured points.

FIGURE 22. Equal-area plots showing orientations of
A) shear zones, B) intersection lineation
and rake direction of No. 5 Vein, C) No. 5,
11 and Riopelle Veins, and D) early and
late veins.

Pole to Surface Trace
of Mafic Dyke
in the NO.5 Vein/I.F. Zone

Pole to the Surface Trace
of Felsic Dyke
near the No.5 Vein/I.F. Zone

Pole to the Surface Trace
of Lamprophyre Dyke
at the No.1 I.F. Zone.

FIGURE 23. Equal-area plots showing the orientations of the various dykes in the No.5 Vein/I.F. Zone Area.

FIGURE 24. Equal area plot showing orientations of major gold-bearing quartz-tourmaline-scheelite veins in the Pickle Crow property including:

A= No.5, ABCD Zones, Sawmill, Cohen-MacArthur and Lakeshore Veins

B= No.1, 6 and E Zone Veins

C= No.2 Vein, No.9 South Vein

D= Riopelle and No.13 Veins

E= Sigmoid

F= No.12 Vein

G= Riopelle and No.9 Veins

H= Hook, Springer, Riopelle, Strickland Veins, No.9 North Vein

I= L40 W Veins, Albany shear veins, Porphyry contact veins

**FIGURE 25- Composite Plan
of the No.5, 1, 11, 9N and 9S
Auriferous Veins.**

**FIGURE 26- DIAGRAM OF MAJOR GOLD-BEARING VEINS SHOWING
PLAN VIEWS OF THEIR VEIN TRACES, FROM SURFACE
AND UNDERGROUND MAPPING, PLOTTED THROUGH A
SINGLE POINT TO EMPHASIZE THEIR TRENDS.**

FIGURE 27- Location of the No.5 and No.1 Vein/ I.F. Zones on the 2900' Level, relative to the Main B.I.F. and the Pickle Crow Fault (Shear Zone).

4.6 ALTERATION OF BASALTS BY THE NO.5 SHEAR ZONE IN THE VICINITY OF THE NO.5 I.F. ZONE:

Altered parts of the Upper and Lower basalts within and spatially associated to the No.5 shear zone were examined in drill core from three unweathered drill holes (DDH HC-58, HC-87 and HC-89; Figures 28, 29 and 30) that provide complete cross-sections of the deposit, in order to seek mineralogic and geochemical criteria that might aid in finding other gold-related Type 2 shear zones. All drill holes intersected the No.5 Vein. Core samples were taken at 20 foot intervals in DDH HC-58 (Figure 28) and at 100 foot intervals in DDH HC-89 (Figure 30); a few additional samples were taken from DDH HC-87 (Figure 29). The drill core samples were examined during logging of the drill core, in thin section, and by both whole rock geochemistry (Appendix 2, Table 1abc) and X-ray diffraction (X.R.D.) methods. The exact proportions of the mineral constituents (Tables 2 and 3) present in samples were difficult to determine even by X.R.D. (G. Chao, pers.comm. 1987) due to the rocks being so fine grained; however, the relative proportions of each mineral from XRD and thin section is used in this study. The relative proportions of iron and magnesium in the ankerite is unknown and therefore distinguishing ankerite from ferrous dolomite cannot be made; however, ankerite will be used here to represent both mineral species. During logging of the drill core, a zone 10 m on either side of the No.5 shear zone in both Upper and Lower Basaltic Flows, had a noticeable colour change from green outside the zone to pale grey in the zone (Plate 6b); drill core samples from each drill hole were taken from each of these zones.

4.61 Alteration Mineralogy:

Ten basalt samples spaced approximately 20 feet apart, in drill hole DDH HC-58 (Figure 28; Map 2), were examined in thin section and by X-ray diffraction to determine the minerals present (Table 2). This drill hole, collared in the least altered Upper Basalts, cuts through the No.5 shear zone, the main B.I.F. and the Lower Basalts, providing an excellent cross-section of the No.5 I.F. Zone (Figure 28). The most obvious form of alteration in surface exposures is a pervasive carbonatization that gives the basalts a pale bleached appearance.

The least-altered basalts in drill hole HC-58 (Assemblage 1; Table 2 ; Figure 28) consist of major amounts of quartz, albite, chlorite and calcite, and trace amounts of pyrite, pyrrhotite, epidote and actinolite. This assemblage occurs from 10- to at least 30-m to the north of the No.5 shear zone in the Upper Basalts; and 10- to at least 60 m to the south of the No.5 shear zone at the B.I.F. contact (Figure 28). Chlorite probably formed during D₂ regional metamorphism and is a common mineral in Assemblage 1, occurring within a microcrystalline groundmass. Calcite occurs within a microcrystalline groundmass and as porphyroblasts in Assemblage 1 (Plate 7a). X-ray diffraction studies indicate that the dominant phase is calcite. Assemblage 1 also could be a reflection of seafloor hydrothermal alteration.

Pervasively altered (Assemblage 2; Figure 28) basalts in drill hole HC-58 consist of quartz, albite, sericite, ankerite, pyrite with minor amounts of chlorite and calcite (Table 2). Assemblage 2 occurs within 10 m on either side of the No.5 shear zone and the gold-bearing No.5 quartz-tourmaline-scheelite Vein, in both the Upper and Lower Basalts respectively (Figure 28). Surface exposures of this Assemblage 2 zone

show intense alteration consisting of ankerite, sericite and pyrite. The pyrite occurs as 1- to 3 -mm euhedral grains. The presence of abundant sericite in the basalts within a discrete narrow zone suggests that fluids relatively enriched in potassium (K_2O) passed through these rocks and formed sericite. Ankerite is more dominant than calcite in Assemblage 2 and this suggests that hydrothermal fluid relatively enriched in iron reacted with calcite to form ankerite. Gold assays in the Assemblage 2 zones were significant (2- to 5 gm Au/ tonne), with the highest gold assays coming from areas with significant pyrite concentrations (2- to 5 volume%).

Minerals present in drill hole HC-89 (Figure 30; Table 3; Maps 1 and 2) were examined because it is located approximately 200 m farther north and 100 m to the east of drill hole HC-58 (Figure 28); it also intersects the Riopelle shear zone 100 m to the north. This hole shows a quartz, albite, chlorite, calcite and actinolite assemblage from 10 - to 300 m to the north in the Upper Basalts and 10- to 30-m in the Lower Basalts away from the No.5 Shear Zone/Vein/I.F. Zone and from 5- to 30 m north of the Riopelle shear zone (Figure 30). This assemblage of minerals is similar to what was determined in drill hole HC-58; therefore, this comparable zone will also be denoted Assemblage 1. Minerals similar to the Assemblage 2 minerals in HC-58 also occur in HC-89, consisting of quartz, albite, sericite chlorite, ankerite and pyrite with minor amounts of siderite. This mineral assemblage occurs within 10 m on both side of the the No.5 shear zone /Vein and 2 m on both side of the Riopelle shear zone (Figure 30;Table 3).

Three samples from the No.5 shear zone in drill hole HC-87 (Figure 29) were examined because of significant assays obtained from this

area; these samples complement the results obtained from drill holes HC-58 and 89 (Table 2). All three samples consist of quartz, albite, sericite, ankerite and pyrite and have minor amounts of chlorite and calcite; this assemblage of minerals are consistent with Assemblage 2 from drill holes HC-58 and 89.

4.62 Alteration Geochemistry:

Whole rock analyses of least altered (Assemblage 1) and more intensely altered (Assemblage 2) basalts were determined by Bondar and Clegg Laboratories in Ottawa for the drill core samples to investigate major element variations which accompany the hydrothermal alteration. The major elements include: SiO_2 , Al_2O_3 , total Fe as Fe_2O_3 , FeO , MgO , CaO , Na_2O , K_2O , TiO_2 , P_2O_5 , MnO , CO_2 , and S, and loss on ignition (LOI) (Appendix 2, Table 1a, b, c). H_2O^+ and H_2O^- were not analyzed for, but instead an estimated H_2O total value was calculated by subtracting ($\text{CO}_2 + \text{S}$) values from LOI values.

The transition from Assemblage 1 to Assemblage 2 is marked by a relative decrease of SiO_2 , TiO_2 , Al_2O_3 , MgO and Na_2O , and an increase in Fe_2O_3 , MnO , CaO , P_2O_5 , CO_2 , FeO , S, K_2O and H_2O (total) in going from Assemblage 1 to Assemblage 2 zones (Figures 28, 29, 30, 31 and 32; Tables 2 and 3; Appendix 2, Table 1 abc, samples 86149, 86150 and 86151 in DDH HC-58; 86182, 86183 and 86187 in DDH HC-89; 86191, 86192 and 86193 in DDH HC-87). The decrease in MgO is complemented by a decrease in the chlorite content in Assemblage 2 relative to Assemblage 1. The decrease in Na_2O content is possibly attributed to

the breakdown of albite in the Assemblage 2 zone. The increase in K_2O content is complemented by an increase in the amount of sericite within the Assemblage 2 zone. Increase in the Fe_2O_3 (total) content may reflect the pyrite formed in Assemblage 2; the S content also increases with the amount of pyrite (except in HC-58). Highest gold assays correlate strongly with pyrite content; hence, S content should also correlate strongly. In HC-58 the S content did not complement an observed increase in the pyrite content, but in HC-89, the S content correlates strongly with an observed increase in pyrite content. Increases in CO_2 and CaO reflect the increased content of ankerite in the Assemblage 2 zone. A small decrease in the SiO_2 content may be due to the liberation of Si outward from the No.5 shear zone (cf. Grunsky, 1986). Geochemical alteration patterns of SiO_2 , Fe_2O_3 (Total), Na_2O , CaO, K_2O , MgO, CO_2 , LOI and Au were plotted for diamond drill holes HC-58 and HC-89 in Figures 31 and 32 to illustrate this chemical change due to the alteration: both outline Assemblage 1 and the No.5 shear zone (Assemblage 2); HC-89 also outlines the Riopelle shear zone (Assemblage 2). Chemical changes toward these shear zones are marked by a decrease in SiO_2 , MgO and Na_2O and an increase in Fe_2O_3 , K_2O , CaO, CO_2 , LOI and Au.

4.63 Alteration and Gold Deposition

The two alteration assemblages (1 and 2) associated with the No.5 Vein/shear zone/I.F. Zone are similar to those recognized in other Archean gold deposits (Melling, 1986; Colvine et al, 1984; Phillips, 1985).

2

In the No.5 Vein/shear zone/ I.F. Zone area, Assemblages 1 and 2 are very distinctive from each other; Assemblage 1 is a broad zone of mainly chlorite and calcite, and Assemblage 2 is a narrow 10 m zone on either side of the No.5 shear zone. According to Phillips (1985) this outer zone or Assemblage 1, represents the break down of amphibole by carbonation, represented in the following reaction (after Phillips, 1985):

Further carbonation yields a zone of ankerite closer to the No.5 Vein (Assemblage 2):

Development of the No.5 shear zone (Type 2 shear zone) during the latter stages of D₂ and peak greenschist metamorphism, introduced hydrothermal fluids into the shear zone, ascending due to thermal and fluid pressure gradients. Fluids relatively enriched in CO₂, CaO, K₂O, B, W, Cu, As, Fe, S, H₂O and Au gained access to the No.5 shear zone and these fluids subsequently contributed to the formation of the No.5 Vein. Shear fractures in the No.5 Vein/I.F. Zone area increase toward the No.5 shear zone, and this would create the permeability necessary for fluids to migrate outward from the No.5 shear zone into the basalts. The 10 m wide Assemblage 2 zone on either side of the No.5 shear zone, relative to the broad Assemblage 1 zone, experienced the greatest temperature, pressure and fluid to rock ratio, and added CO₂, CaO, K₂O, S and Au to the zone, as well as forming Assemblage 2 alteration

is a larger target for geophysical surveys. This has been applied to other areas on the Pickle Crow property and has been most successful in locating and tracing out other gold-associated Type 2 shear zones under snow and overburden.

FIGURE 28- Cross Section of the No.5 / I.F. Zone
32S showing location of drill hole HC-58 and alteration
assemblage zones. Looking West. 24S

Surface Datum HC-58 (-65)

LEGEND

Oxide Facies B.I.F.

Pillowed Basalts

Diamond Drill Hole
with sample locations

Shear Zone

Scale

(Feet)

FIGURE 29- Cross Section of the No.5 / I.F. Zone
 showing location of drill hole HC-87 and alteration
 assemblage zones. Looking West.

LEGEND

Oxide Facies B.I.F.

Pillowed Basalts

Diamond Drill Hole
with sample location

Shear Zone

Scale

100 0 100 200

(Feet)

FIGURE 30- Cross Section of the No.5 I.F. Zone
showing location of drill hole HC-89 and alteration
assemblage zones. Looking West.

HC-89 (-70)

Surface Datum (Line 55W)

LEGEND

Oxide Facies B.I.F.

Pillowed Basalts

Diamond Drill Hole with sample locations

Shear Zone

Scale

100 0 100 200

(Feet)

Table 2- List of Alteration minerals in samples by XRD in. DDH HC-58 and HC-87. S > 20% , W < 20% and Tr < 5%.					
DDH HC-58					
Samples	Chlorite	Sericite	Ankerite	Calcite	Py+Po
86145 (20')	S	Tr	-	S	Tr
86146 (40')	S	-	-	S	Tr
86147 (60')	S	Tr	-	S	-
86148 (80')	S	Tr	W	W	Tr
86149 (100')	Tr	S	S	Tr	W
86150 (120')	W	S	S	-	W
86151 (135')	W	S	S	-	W
86152 (240')	S	-	-	-	Tr
86153 (260')	S	W	Tr	W	Tr
86154 (300')	S	W	W	S	Tr
DDH HC-87					
86190 (315')	S	W	Tr	S	Tr
86191 (520')	W	S	S	W	W
86192 (550')	Tr	S	S	Tr	W
86193 (590')	W	S	S	W	W

Table 3- List of Alteration mineral in samples from DDH HC-89. S > 20% , W < 20% and Tr < 5%; Act= Actinolite

Samples	Chlorite	Sericite	Ankerite	Calcite	Py+Po
86179 (20')	S (Act)	-	-	S	-
86180 (100')	S (Act)	-	Tr	S	Tr
86181 (200')	S	Tr	W	S	Tr
86182 (300')	W	S	S	Tr	W
86183 (325')	Tr	S	S	Tr	W
86184 (400')	S	-	Tr	S	-
86185 (500')	S	Tr	-	S	Tr
86186 (600')	S	Tr	W	W	Tr
86187 (700')	Tr	S	S	S	W
86188 (800')	S	W	W	S	-
86189 (1000')	S	-	-	S	-

Riopelle
Shear
Zone

No.5
Shear
Zone

FIGURE 31- Lithogeochemical profiles for samples taken from DDH HC-58.

FIGURE 32- Lithogeochemical profiles for samples taken from DDH HC-89.

5.0 ECONOMIC GEOLOGY

5.1 OCCURRENCE OF GOLD IN THE NO.5 VEIN/ I.F. ZONE

Economic gold mineralization in the No. 5 Vein / I.F. Zone occurs as two distinct types:

- 1) Gold in auriferous quartz-tourmaline-scheelite veins (No. 5, 11 and Riopelle veins), contained within discordant Type 2 shear zones (No.5 and Riopelle shear zones) and associated minor splay shears (No. 11 splay shear).
- 2) Auriferous sulphide zones which are stratabound and contained within oxide and sulphide facies B.I.F., in part associated with small crosscutting quartz veins.

5.11 Gold-Bearing Quartz Veins in Discordant Shear Zones

Mineralization within the No. 5, 11 and Riopelle quartz-tourmaline-scheelite veins occur centrally within strongly foliated Type 2 shear zones (No.5 and Riopelle shear zones). The gold-bearing veins consist of major amounts of quartz, ankerite and calcite and minor amounts of sericite, chlorite, tourmaline, scheelite, siderite, pyrite, pyrrhotite, arsenopyrite, chalcopyrite and free gold. The paragenetic sequence of mineralization based on field and petrographic observations is shown in Table 4 .

Quartz is the most abundant mineral in the gold-bearing veins (> 95%); several generations of quartz are restricted to the veins and do not extend outward into the wallrock. Microscopic examination of quartz from the No. 5 and Riopelle veins shows coarse (5mm to 1cm) angular grains surrounded by fine-grained (< 2mm) anhedral quartz grains.

Carbonates are the next most abundant minerals in the veins, with major amounts of ankerite and minor amounts of calcite. Ankerite occurs as less than 5 mm grains between coarse 5 mm to 1 cm quartz grains. Chlorite and sericite occur as ≤ 1 mm grains in larger 2- to 5-mm wide stringers and layers in the No. 5 and 11 veins, but are only a minor component in the Riopelle vein. These minerals commonly occur within 2- to 5-mm wide stringers and layers of tourmaline that are parallel to the strike of the veins (Figure 19). Tourmaline is present within the No. 5 (Plate 8acd), No.11 and Riopelle veins as 2- to 5-mm wide stringers and layers that are parallel to the strike of the veins (No. 5 and No.11 Veins), or have no preferred direction (Riopelle Vein : Plate 6d). Tourmaline also occurs as 2 mm- to 1-cm black and brown crystals within the wallrock adjacent to the veins. The tourmaline layers are commonly associated with sericite and chlorite (Figure 19). The tourmaline layers in the No.5 Vein commonly have surfaces with stepped-slickensides that plunge 65° to 75° to the NE, and indicate south side up movement in the No. 5 shear zone. Scheelite is a minor constituent of the gold-bearing veins, occurring as 5mm to 1cm layers parallel to the strike of the vein and adjacent to the walls of the veins (Figure 19). The scheelite is light tan to brown, making it difficult to distinguish from quartz; however, shining an ultraviolet light on the veins at night easily identifies the scheelite by its bright fluorescent blue colour. Pyrite and pyrrhotite are the most abundant sulphides in the No.5, No.11 and Riopelle Veins. Pyrite, the most abundant sulphide, occurs in 5 mm to 1 cm wide veinlets in the veins, and as 2- to 5-mm

ehedral grains within the wallrock (Plate 8c). Pyrrhotite commonly occurs as .5-to 1-mm anhedral grains associated with the pyrite veinlets. In the No.5 Vein, the pyrite content increases toward the main B.I.F. contact. Arsenopyrite occurs in minor amounts within the No.5 and Riopelle Veins as small 2-to 5-mm euhedral crystals, replacing pyrite grains; arsenopyrite never occurs without pyrite. Gold commonly occurs within fractures in the quartz veins closely associated with arsenopyrite as 10- to 30-micron size grains. Chalcopyrite, a rare sulphide within the veins, occurs as small blebs (< 1 mm) associated with arsenopyrite that have replaced pyrite and pyrrhotite grains. Galena was not observed in the No.5 Vein, but was reported by the Pickle Crow mine geologists to have been a minor constituent in the No.5 Vein. Magnetite occurs within the No.5 Vein as rare isolated 2- to 5-mm euhedral crystals that contain no exsolution lamellae of ilmenite.

Gold occurs as two types within the No.5, 11 and Riopelle Veins: 1) coarse (>10 microns) free gold hosted in the quartz (Plate 8abc) and 2) more abundant free gold (> 10 microns) associated with the chlorite, sericite and tourmaline stringers and layers (Plate 8d). Gold samples from the No.5 Vein were analyzed using the Carleton University Geology Department's Cambridge electron microprobe operated at a 20 Kv acc. potential and a specimen current of 40 nanoamperes. The gold grains were quantitatively analyzed using a synthetic gold-silver alloy standard of composition (Au-.83, Ag-.17) or (Au-89.7 wt.%, Ag-10.3 wt.%). X-ray data were corrected by a modified version of Rucklidge's EMPADR program. Six gold grains were analyzed, and the average result

for each grain are:

(1) n=4, Au-94.7 wt.% (2)n=4, Au-95.3 wt.% (3)n=3, Au-95.89 wt.%

Ag-5.21 " " Ag-5.31 " " Ag-5.39 " "

Total 99.91 100.61 101.28 —

(4)n=4, Au-95.73wt.% (5)n=2, Au-94.48wt.% (6)n=3, Au-95.65wt.%

Ag-4.80 " " Ag-5.05 " " Ag-5.03 " "

Total 100.53 99.53 100.68

Thus, the gold generally contains between 94.5 to 96 wt.% Au and 4.75 to 5.5 wt.% Ag. The grains analyzed are shown in Plates 8abcd.

Minor amounts of gold are hosted within the strongly foliated pillowed basaltic footwall and hangingwall adjacent to the No.5 Vein for up to 10 m within the the No.5 shear zone (see Ch. 4.43, Figure 31 and 32). The Lower pillowed flows on surface form the hangingwall and footwall adjacent to the No.5 Vein, and they have been altered to ankerite (see Alteration Ch. 4.4) and contain abundant 2- to 5-mm euhedral pyrite grains that are associated with gold. Petrographic work on these altered zones failed to reveal any gold grains; however, the best assays (up to 0.2 oz/ton or 5 gm/tonne) were obtained from areas of abundant euhedral pyrite. Small cm-scale quartz veinlets are also associated with the footwall and hangingwall (Plate 3h), and significant assays were also obtained from these areas.

Gold grade in the No.5 Vein is greatest in areas where the vein is thickest, and in areas of abundant sericite-tourmaline stringers and layers. The mining grade at depth generally decreases, due to the size of

the vein decreasing in thickness and in horizontal extent. This suggests that the No.5 shear zone was less dilational in the lower levels. This decreasing grade was similar for the No.1 and No.2 Veins.

5.12 GOLD MINERALIZATION IN THE NO.5 I.F. ZONE:

Gold mineralization in the No.5 I.F. Zone is hosted primarily within sulphide zones which are stratabound and contained within oxide-facies B.I.F., and to a lesser extent by a smaller basal unit of sulphide facies B.I.F (Map 2). The No.5 I.F. Zone is spatially associated to the No.5 shear zone, which sheared the B.I.F and carried hydrothermal fluids relatively enriched in CO_2 , Ca, B, Cu, As and Au. Gold assay data were compared to mesoscopic features from trench samples and drill core to seek criteria that could provide a guide for prospecting. Gold was not observed in polished sections made from high-grade samples, and this can be attributed to the low probability of finding an isolated grain due to the nugget effect; however, gold grains were observed during core logging. The paragenetic sequence of mineralization at the No.5 Vein/I.F. Zone is shown in Table 4.

Gold in Oxide Facies B.I.F:

Primary unaltered magnetite-bearing oxide-facies B.I.F. was sheared by the No.5 shear zone (Map 2: Figure 33) which passed hydrothermal fluids along brittle fractures within the deformed zone associated with the No.5 shear zone. The hydrothermal fluid sulphidized the magnetite forming pyrite and minor amounts of pyrrhotite, arsenopyrite, and chalcopyrite (Plates 5fg, 6a, 9f, 10 abcdefh) that contain gold or are closely associated with the gold mineralization. Small

quartz-tourmaline veinlets crosscut the B.I.F. striking N and ENE in the No.5 I.F. Zone, and commonly contain visible gold; they have selvages of pyrite when they crosscut magnetite layers. Also associated with the No.5 I.F. Zone is an intense carbonate halo of ankerite in the B.I.F. and in the basalts (refer to Section 4.4). According to Phillips (1985), ankerite forms as a result of carbonation with magnetite and calcite (reaction 1, below). The alteration and replacement of the oxide-facies B.I.F. is particularly evident in surface exposures and in drill core near the No.5 I.F. Zone (Plate 4 abf and 5 ae). The gold is directly associated with pyrite and pyrrhotite and minor amounts of quartz-tourmaline veining in the B.I.F. zone (Plates 9f, 10 fgh). The quartz-tourmaline veins in the altered B.I.F. are < 3 cm wide, and are grey to bluish, probably due to the introduction of iron from the B.I.F. Most of the quartz veins in surface exposures are discordant to the bedding, infilling ENE-striking shear fractures (Plate 2c) or en-echelon step fractures (Plate 3h). Southwest and northeast of the structurally controlled No.5 I.F. Zone, unaltered oxide facies B.I.F. lacks anomalous amounts of gold. This gold relationship with sulphides is compatible with the model of Phillips and Groves (1984); the generalized reactions for replacement of magnetite are ((after Phillips and Groves (1984))):

The above reactions are confined to magnetite, pyrite and ankerite

only, leaving out other minerals formed in the No.5 I.F. Zone. The combination of reactions 1 and 2 with the other minerals, trace elements and veining is shown below in an idealized system.

$\text{Fe}_3\text{O}_4 + \text{Hydrothermal Fluids}(\text{SiO}_2 + \text{CaCO}_3 + \text{CO}_2 + \text{Cu} + \text{B} + \text{As} + \text{S} + \text{Au}) \rightarrow \text{FeS}_2 + \text{FeS} + \text{FeAsS} + \text{Au}$
 + Quartz +/- Tourmaline veining + Carbonate Alteration (Ankerite- $\text{CaFe}(\text{CO}_3)_2$,
 Siderite FeCO_3)

Chalcopyrite patches and euhedral arsenopyrite grains commonly occur with pyrite or pyrrhotite (Plate 10 efg), and they probably formed by pyrite or pyrrhotite reacting with fluids relatively enriched in copper (Cu) and arsenic (As) respectively. Siderite probably formed in areas that lacked calcium (Ca), which could be due to the generation of ankerite consuming all the calcium (Ca). Small (< 3 cm) quartz-tourmaline veins and veinlets similar to the No.5 Vein contain free gold, but on a much smaller scale. During drilling, zones that contained pyrite and minor quartz veins gave the highest assays (13 to 16 gm Au/tonne and higher)

The B.I.F. southwest and northeast of the No.5 I.F. Zone (up to 60 m laterally) contain crosscutting quartz veins. Magnetite layers that make up the oxide facies B.I.F. show progressive alteration toward the No.5 I.F. Zone; minor amounts of ankerite and pyrite replace the magnetite layers (Plate 10 a to h). Progressive replacement of individual magnetite layers by pyrite on a mesoscopic scale can be traced out on outcrop surfaces; this change from magnetite to pyrite is sharp (Figure 33; Plate 5 ab). The cherty layers are composed of 100% SiO_2 (Plate 9gh, 10ab) and they did not react with the invading hydrothermal fluid.

Gold in Sulphide-Facies B.I.F.:

The unaltered primary sulphide-facies B.I.F. is 0.5- to 30-m thick and contains massive well-bedded sulphides that compose > 90% of the rock, consisting of marcasite and pyrite (Plate 8 efgh). Interbedded with the massive sulphides are light to dark grey 0.5- to 5-cm chert beds which are graded and constitute 10 % of the rock (Plate 6c). This sulphide facies unit was also sheared and crosscut by the No.5 shear zone and No.5 Vein. Sulphide-gold-bearing fluids ascending in the No.5 shear zone reacted with the magnetite in oxide facies B.I.F. and formed pyrite; however, the same fluids did not react as much with this basal sulphide facies B.I.F. unit, due to it already containing sulphur-bearing pyrite and marcasite. The fluid was relatively enriched in arsenic and copper that would react with pyrite and marcasite grains (< 1 mm) and form chalcopyrite and arsenopyrite (Plates 8 fgh; 10g) that contain, or are associated with, gold mineralization. Quartz-tourmaline veinlets less than 3 cm crosscut the sulphide facies B.I.F. and commonly contain visible gold. Ankerite occurs throughout the sulphide facies B.I.F. in the No.5 I.F. Zone. Near-surface samples have been oxidized, and goethite commonly has replaced the pyrite (Plate 8 efgh). Gold within the sulphide facies B.I.F. is spatially associated to the No.5 shear zone and 100 m laterally away from the zone, lacks anomalous amounts of gold. This suggests that the gold is stratabound (not stratiform) within the sulphide facies B.I.F.

In unweathered drill core, small quartz veins and veinlets which are discordant to the B.I.F. commonly have a selvage of light-coloured

pyrite (Plate 4g;) containing gold; this clearly shows the spatial relationship. The gold occurs within the sulphide-facies B.I.F., associated with the chalcopyrite, arsenopyrite and pyrite, and in small discordant quartz veins and veinlets. To attain economic ore grade of greater than .15 oz Au/ ton or 5 gm Au/ tonne, both the gold-bearing sulphides in oxide and sulphide facies B.I.F. along with the gold-bearing quartz veins and veinlets are necessary; without one or the other, the grade would not be sufficient to justify designation as an economic ore zone.

The No.5 I.F Zone is detected as a magnetic low flanking a strong magnetic high (Figure 16). The field trenches west of the No.5 area have exposed unaltered oxide facies B.I.F. that coincides with a strong magnetic high. The No.5 shear zone is also a strong conductor both by V.L.F. and I.P. methods.

The above descriptions for the No.5 Vein/I.F. Zone favour an epigenetic replacement model for ore genesis. The many arguments supporting this are:

- 1) The No.5 I.F. Zone is structurally controlled by the No.5 shear zone.
- 2) Gold occurs stratabound within the oxide and sulphide facies B.I.F.
- 3) Gold in the B.I.F. is spatially associated to: a) the high grade quartz-tourmaline-scheelite No.5 Vein contained in the No.5 shear zone and basalts, and b) minor crosscutting auriferous veins in B.I.F.
- 4) Mineral textures show magnetite in oxide facies B.I.F. is replaced by pyrite, pyrrhotite, chalcopyrite and arsenopyrite.

TABLE 4- The Paragenetic Sequence of Mineralization in the No.5 Vein T.F. Zone.

<u>MINERALS</u>	D2-DEFORMATION		
	Pre	Syn	Post
<u>Quartz</u>			
<u>Galcite</u>			
<u>Ankerite</u>			
<u>Chlorite</u>			
<u>Scheelite</u>			
<u>Tourmaline</u>			
<u>Gold</u>			
<u>Pyrite</u>			
<u>Chalcopyrite</u>			
<u>Arsenopyrite</u>			
<u>Magnetite</u>			
<u>Pyrrhotite</u>			
<u>Sericite</u>			
<u>Siderite</u>			

FIGURE 33- Perspective View of the Intersection between the No.5 shear zone and the Main B.I.F.

LEGEND

Oxide Facies B.I.F.

Sulphide Facies B.I.F.

Lower Pillowed Basalts

Pervasively Altered Basalts

Quartz-Tourmaline Veins

Sulphidated B.I.F. + Quartz Veins

Scale

6.0 SUMMARY AND DISCUSSION

The list below summarizes the principal observations and conclusions presented in this thesis, on the stratigraphy, structure, alteration and gold mineralization associated with the No.5 Vein / I.F. Zone:

SUMMARY

1) The basalts consist of two different morphological and environmental types:

(a) The Lower Basaltic Flows are non-vesicular pillowed flows, massive flows and minor to rare intercalated pillow breccia which are inferred to be of deep-water origin relative to the Upper Basaltic Flows.

(b) The Upper Basaltic Flows are vesicular pillowed flows, massive flows and intercalated pillow breccia which are inferred to be of shallow-water origin relative to the Lower Basaltic Flows.

2) The Lower and Upper basalts plot as high-iron and high-magnesium tholeiitic basalts on the Jensen Cation Plot.

3) The banded iron-formation (B.I.F.) consists of two distinct facies types: oxide and sulphide facies.

(a) Oxide facies B.I.F. is the predominant facies type, forming the main B.I.F. unit that hosts most of the No.5 I.F. Zone, and it consists of finely layered chert (60%) and magnetite (40%). The oxide facies units are interbedded only within the Upper Basalts.

(b) Sulphide facies B.I.F. consists of massive marcasite and pyrite interbedded with finely layered chert. A distinctive basal sulphide facies B.I.F. unit overlies the Lower pillowed basalts and in part hosts

the No.5 I.F. Zone and part of the No.5 Vein. This facies is interbedded only within the Lower Basaltic Flows.

4) Reliable younging directions provided by compositionally graded chert-magnetite (oxide facies B.I.F.) and chert-sulphide (sulphide facies B.I.F.) layers and pillow shapes are consistently to the north in the No.5 Vein / I.F. Zone, and define the north limb of the Pickle Crow Anticline; to the south of the map area, pillow tops are toward the southeast, consistent with the Pickle Crow Anticline.

5) Dykes in the No.5 I.F. Zone area comprise three types:

(a) mafic dykes that crosscut all strata, but which are concentrated within the basalts. These dykes generally are narrow (< 2 m) and have been deformed by the D_2 regional deformation.

(b) lamprophyre dykes crosscut all strata, are generally narrow (< 2 m), coarse-grained and are weakly deformed. One biotite lamprophyre dyke cuts the No.1 Vein, suggesting post-gold emplacement.

(c) felsic dykes are generally narrow (< 2 m) and crosscut all strata.

6) The strata (S_0) in the No.5 I.F. Zone strike northeast and dip steeply to the northwest, straddling the north and south limbs of the Pickle Crow Anticline. Reliable younging directions from pillow shapes and compositional grading in the B.I.F. are: tops to the north, in the north limb and tops to the south in the south limb.

7) Four distinct episodes of deformation have been recognized in the Pickle Crow area, but evidence of only the first three is apparent in the No.5 Vein / I.F. Zone.

D_1 - produced rare small isoclinal folds (F_1), having a mean axial surface strike of east to east-northeast, preserved within larger D_2 fold closures. The D_1 fold hinge lines (L_1) plunge steeply to the northeast. S_1 axial planar foliation is weak to moderately developed.

D_2 - produced the dominant penetrative axial planar flattening schistosity (S_2), striking northeast and dipping 75° to 85° to the NW. D_2 tight to isoclinal F_2 folds (1- to 75-m) strike NE and dip steeply to the NW with hingelines (L_2) plunging steeply to the NE. Two types of D_2 shear zones are recognized: S_2 parallel shear zones (Type 1) which are wide (> 50 m) and narrow (< 0.5 m) shear zones; and S_2' parallel shear zones (Type 2) which are narrow (< 5 m) discrete shear zones that splay off and connect large S_2 parallel (Type 1) shear zones. S_2' parallel shear zones commonly are asymmetrically folded into Z-shapes, consistent with folding and shearing during a NW-directed shortening that produced S_2 and stretching lineations L_2 . Stepped-slickensides in both Type 1 and 2 shear zones consistently indicate steep oblique normal slip, with the south side up. Type 2 shear zones intersect the B&F. in a line with a rake at an average angle of 65° in a direction N 20° E to N 30° E.

D_3 - produced undeformed conjugate sets of fractures which crosscut S_0 , S_2 , and S_2' fabrics, that in places have been infilled by quartz veins which strike N and NW respectively. Late lamprophyre and felsic dykes are oriented parallel to the strike of these conjugate sets of fractures.

D_4 - produced NW-striking fractures which have been intruded by diabase dykes that crosscut all earlier fabrics and lithologies. This deformation is not recognized in the No.5 Vein / I.F. Zone area.

8) Three deformations recognized (D_1 , D_2 and D_3) are all consistent with a NW-directed shortening.

9) Hydrothermal alteration of basalts by hydrothermal fluids carried along by the No.5 shear zone occurs in two distinct zones: (1) a large envelope of alteration, consisting of an assemblage of quartz-albite-chlorite-calcite- actinolite-epidote (Assemblage 1) and (2) a distinctive 10 m alteration zone on either side of the No.5 Vein in the No.5 shear zone, consisting of quartz-albite-sericite-chlorite-ankerite and pyrite (Assemblage 2). The chemical transition from Assemblage 1 to Assemblage 2 is expressed by a relative increase in Fe_2O_3 (total), CaO, CO_2 , K_2O , S and Au, and a decrease in SiO_2 , MgO, and Na_2O , relative to Assemblage 1.

10) Gold in the No.5 I.F. Zone is epigenetic and is structurally controlled by D_2 structures; it is spatially associated to the No.5 shear zone which contains the No.5 gold-bearing quartz-tourmaline-scheelite vein.

11) The gold-bearing quartz veins within Type 2 shear zones (No.5,11

and Riopelle Veins) contain major amounts of quartz, carbonate (calcite, ankerite and siderite), chlorite and sericite and minor to trace amounts of pyrite, pyrrhotite, arsenopyrite, chalcopyrite, galena, magnetite, tourmaline, scheelite and gold. They are commonly folded into Z-shaped asymmetric folds and boudinaged consistent with shearing.

12) The composition of the gold consistently analyzed as 95 wt.% Au and 5 wt.% Ag.

13) The No.5 I.F. Zone consists mainly of pyrite, pyrrhotite, chalcopyrite, arsenopyrite, chert, ankerite and quartz-tourmaline veinlets that contain, or are associated with, gold.

14) Most of the large past-producing auriferous quartz-tourmaline-scheelite veins (Nos.1, 5, 2 and ABC veins) are hosted within the ENE-trending Type 2 shear zones.

15) Most of the major gold zones on the property are spatially related to the Pickle Crow Fault, a wide Type 1 shear zone.

16) Previously mined ore zones in the Pickle Crow property are tabular bodies that plunge steeply to the NE to at least 1500 m.

17) Unaltered oxide facies B.I.F. is outlined by magnetometer surveys as a magnetic high, and the altered No.5 I.F. Zone can be detected as a magnetic low off a linear magnetic high. Type 1 and 2 shear zones are detected by VLF and I.P. surveys.

DISCUSSION

The No.5 Vein / I.F. Zone has provided an excellent opportunity to study the combination of gold hosted by gold-bearing quartz veins (vein-hosted) within shear zones (No.5 and Riopelle Veins), and gold in a stratabound sulphide deposit (No.5 I.F. Zone) that consists of both oxide and sulphide facies B.I.F (B.I.F.-hosted).

Gold was mined, beginning in the early 1930's and continuing to 1965, primarily from high-grade gold-bearing quartz veins. The Howell Vein or No.1 Vein represents the only prolific vein to be found by surface exploration (prospecting). The other prolific veins mined in the property included the No.5, No.2 and Albany Shaft Veins, all of which were discovered by drifting off the No.1 stoped workings. The Pickle Crow Mine geologists used this hit and miss approach to find the veins, and as a result they did not establish a model to explain how and why the veins occur where they do. By 1960, their luck ran out using this random approach of underground exploration, because they failed to discover any additional high-grade gold-bearing veins. This study represents the first attempt to relate the veins to the overall geology and structural history of the Pickle Crow property, leading to a general model that provides a guide for exploration.

The No.5 Vein/I.F. Zone was exposed for the first time during the field work of 1986, and represents the first stratabound sulphide-gold zone to be exposed since discovery of the No.1 Vein by H. Howell in 1929. For the first time one could examine on surface: 1) the No.5 Vein, 2) the footwall and hangingwall on either side of the No.5 Vein, 3) the

No.5 I.F. Zone (stratabound sulphide zone), 4) the geology and structural geology of the rocks that host the deposit, and 5) the geometry of the ore zones in relation to the enclosing basalts and B.I.F. and structures. The results have enabled the author to formulate a model that can be applied to other areas within the Pickle Crow property, and probably to other areas.

This study represents the first attempt to define the stratigraphic relationships in the Pickle Crow property, with emphasis on the volcanic units and banded iron formations as exposed in a small area (No.5 Vein/I.F. Zone). The basaltic flows in the No.5 Vein/I.F. zone have been subdivided into the Lower and Upper Basaltic Flows, based on the presence/absence of vesicles in the pillowed flows; the Lower Basaltic Flows are non-vesicular and are inferred to be of deep-water origin; the Upper Basaltic Flows are vesicular and are inferred to be of shallow-water origin. This subdivision enabled the author to distinguish basaltic flows in other areas on the property (Lakeshore Vein area and Albany Shaft area). Additional features that were used to distinguish the pillowed flows include; the presence of variolites, pillow generation by budding and pillow drainage cavities. This distinction between flows appears to be valid throughout most of the property, suggesting that a re-examination of the basalts in other areas is warranted.

The main banded iron formation in the No.5 Vein/I.F. Zone consists of two types of facies: 1) oxide facies B.I.F. (chert and magnetite) and 2) sulphide facies B.I.F. (chert and pyrite). These two facies together associated with an I.F. stratabound gold zone; similar relationships have

led workers in other B.I.F. deposits to consider the sulphides to be the epigenetic products of fluid-wallrock interactions that took place during deformation of the B.I.F. In the No.5 I.F. Zone, the sulphide facies B.I.F. forms a basal stratiform unit that was deposited on top of the Lower Basaltic Flows, consistent for over 330 m of strike length and to a depth of at least 700 m. The B.I.F. provided an important tool for mapping the No.5 I.F. Zone area, because compositional graded bedding (chert-rich to magnetite-rich layers in oxide facies B.I.F.; chert-rich to pyrite-rich layers in sulphide facies B.I.F.), accompanied by a progressive, upward thinning of laminae within the graded layers, provided reliable younging directions. This study is the first to recognize this chemical grading in the B.I.F. in the Pickle Crow area, and possibly the first to apply it to diamond drilling (Figure 13). The significance of this is that D_2 fold closures commonly associated with Type 2 shear zones can be outlined using this method.

This study represents the first time that distinctive generations of structures were distinguished in the Pickle Lake property. In prospecting for gold deposits in the Pickle Lake greenstone belt, the recognition of D_2 structures is important, because all gold zones on the Pickle Crow property appear to be associated with D_2 structures. The D_2 structures most important to gold mineralization are the D_2 fold closures in B.I.F. closely associated with Type 1 and 2 shear zones (Figures 20 and 34). The term shear zone was not applied before this study to the strongly foliated zones that contain the No.5 Vein. No.11

Vein and Riopelle Vein. Of particular importance are the Type 2 shear zones (similar to the No.5 and No.1 shear zones) that both crosscut strata and connect Type 1 shear zones. A conceptual model showing the relationship between these structures and the B.I.F. units is illustrated in Figure 34. In comparison to major gold camps in other greenstone belts, the Pickle Crow Fault appears to be analogous in style (but not in magnitude) to other major breaks such as the Cadillac-Malartic Break in the Abitibi Subprovince. The recognition of these Type 2 shear zones is vital in the search for gold in the Pickle Crow property. The exact location of where Type 2 shear zones will form appears to be in or near D_2 fold closures (Figure 6) or smaller asymmetric D_2 folds on the limbs of the larger D_2 fold closures.

The other important structures that the author wants to emphasize are NW and NNE striking conjugate faults. These D_3 conjugate faults have crosscut and displaced both the earlier strata and the D_2 fabrics which are associated with the gold mineralization. This study is the first to recognize these faults as post-dating the earlier D_2 structures. The significance of this is that these conjugate faults have offset and displaced the Pickle Crow Fault over its strike length, most notably where it is crossfolded around the Hooker-Burkoski Stock. Workers in the past have assumed a southwest continuation of the Pickle Crow Fault, but instead they should have concentrated on the displaced terrane to the north of the stock. The significance of these later D_3

structures to an exploration geologist is that the displacement of B.I.F. may show up locally as a magnetic low or as a displaced magnetic high. This magnetic displacement to some exploration geologists might be interpreted as an altered zone associated with a stratabound sulphidized zone, where in fact it is not. A quick way to distinguish whether it is due to a D_2 -Type 2 shear zone (ore zone) or to a D_3 conjugate fault (no ore zone) is to use geophysical methods such as V.L.F. and I.P. which should detect and be able to follow out of the Type 2 shear zone: D_3 conjugate faults should have no response from these geophysical methods.

The authors conceptual model of the deformation and intrusions related to the evolution of the Pickle Lake Greenstone Belt is shown in Figure 35 abcd.

Another important feature that the author wants to emphasize is the hydrothermal alteration associated with fluids that ascended along Type 2 shear zones as in the case of the No.5 shear zone (see Ch. 4.4). The alteration zone associated with the No. 5 shear zone is visually detected in unweathered drill core as green basaltic rock outside of the zone grading into a pale grey zone up to 10 m on either side of the No.5 shear zone, consisting of sericite, chlorite, quartz, albite, pyrite, and ankerite (Assemblage 2). The No.5 Vein is only contained in a short strike length of the No.5 shear zone; thus, the recognition of these shear zones using their altered zone represents a much larger continuous target. Drill core from these shear zones where quartz veins are absent

could easily be overlooked and therefore not sampled.

The surface exposures of both the No.5 Vein and the I.F. Zone were important, because, for the first time one could examine the ore zones on surface rather than in drill core. Examination of the No.5 Vein over its strike length shows it to pinch and swell and be folded, such that, the vein may be 10 cm wide at any one point or be up to 1.5 m wide. This is significant because in drilling of the No.5 Vein or intersection of a similar vein in another area, one would expect to find variable vein thickness or perhaps no vein at all. This emphasizes the need for recognizing the Assemblage 2 alteration zone associated to these Type 2 shear zones. Examination of the No.5 I.F. Zone clearly shows that the stratabound sulphide zone consists of a pervasively sulphidized central zone with crosscutting quartz veins that have a sharp cut-off, and an outer fish spine arrangement away from this central zone. The No.5 shear zone and the main B.I.F. intersects in a line that with a rake at an average angle of 65° in a direction of $N 20^{\circ}E$ to $N 30^{\circ}E$. The No.5 Vein/I.F. Zone follows this direction to a depth of at least 1500 m. Recognition of this direction was very useful in determining where to drill the zone at depth. In the past, workers have used the plunge and direction of plunge rather than the rake and direction of rake, and as a result the zones would be missed. Therefore, the ore zones and the related structures represent a complex three-dimensional problem, as in Figures 15 and 20. The conceptual model shown in Figure 34 has been applied to other areas on the property to discover new zones.

Further research on the area and on the deposit should involve:

- 1) More stratigraphic-structural mapping in the region to refine the stratigraphy, and to outline additional D_2 shear zones and fold closures in the B.I.F.
- 2) Underground mapping of the No.5 shear zone and other zones, superimposing the geological and structural data from the various levels.
- 3) Geochronological studies are needed to 1) assess the stratigraphic relationship in the Pickle Lake Greenstone Belt to other greenstone belts, and 2) pinpoint the timing of mineralization.
- 4) Isotope studies on the No.5 Vein and sulphides in the No.5 I.F. Zone.
- 5) Fluid inclusion studies all the auriferous veins in the Pickle Crow property.
- 6) Mapping of the felsic volcanic rocks southeast of the Pickle Crow property, to investigate possible Casa-Berardi type gold deposits.

FIGURE 35 a,b,c&d- Idealized Evolution of the Pickle Lake Belt.

Figure 35- (cont'd)

C)

D)

7.0 CONCLUSIONS

The No.5 Vein/I.F. Zone is a structurally controlled epigenetic gold deposit hosted within multiply deformed oxide and sulphide facies B.I.F. and tholeiitic basalts, with proven reserves of over 2.5 million tons of ore grading .25 oz/ ton or 10 gm/ tonne. The No.5 Vein / I.F. Zone occurs in the north limb of the steeply plunging Pickle Crow Anticline, controlled by D₂ structures and spatially associated to the Pickle Crow Fault and the No.5 shear zone. Gold mineralization occurs in two styles: 1) gold hosted within the No.5 shear zone as the auriferous No.5 Vein, a high grade (> 30 gm Au/tonne) quartz-tourmaline-scheelite vein; and 2) stratabound gold mineralization associated with the oxidation and sulphidation of magnetite in oxide facies B.I.F. (forming pyrite, pyrrhotite, chalcopyrite and arsenopyrite) and the replacement of marcasite and pyrite in sulphide facies B.I.F.

The basalts in the No.5 Vein / I.F. Zone area have been subdivided into two stratigraphic units: the Lower Basaltic Flows with non-vesicular pillowed flows of presumed deep-water origin and the Upper Basaltic Flows with vesicular pillowed flows of presumed shallow-water origin. The Lower and Upper basalts are interbedded with sulphide facies (chert-pyrite) B.I.F. and oxide facies (chert-magnetite) B.I.F., respectively. Compositional graded bedding within chert-magnetite and chert-sulphide laminae provides reliable younging directions. Hydrothermal alteration of basalts in the No.5 shear zone by ascending fluids occurred in two distinct zones: 1) a broad zone that envelopes the

deposit consisting of quartz-albite-chlorite-calcite-actinolite-epidote (Assemblage 1) and 2) a distinct 10 m zone on either side of the No.5 shear zone and vein, consisting of quartz-albite-sericite-chlorite-ankerite and pyrite (Assemblage 2). The transition from Assemblage 1 to Assemblage 2 zones involves a relative increase in Fe_2O_3 , CaO , CO_2 , K_2O , S and Au and a relative decrease in SiO_2 , MgO , and Na_2O .

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APPENDIX 1**(Photographic) Plates**

PLATE 1

Plate 1

Note: The black cap on the 15 cm marking pen points north unless otherwise stated.

A) Lower Basaltic Pillowed Flow near No.5 Vein / I.F. Zone. Pillows are undeformed and show a reliable younging direction to the north.

B) Upper Basaltic Pillowed Flow near No.5 Vein / I.F. Zone showing altered rims (light grey).

C) Lower Basaltic Pillowed Flow progressively sheared (from right to left of photo) toward the No.5 shear zone (far left of photo). A detailed sketch of this surface exposure is shown in Figure 17.

The less altered pillows in (A) are ten metres to the east.

D) Close-up view of a sheared pillow, shown above the marking pen in (C). Note slight Z-asymmetry of sheared pillow.

E) Upper Massive Flow near N-trending part of the Riopelle Vein. Four fracture sets occur throughout the outcrop, with the dominant fracture direction being ENE-trending, and minor directions N-, NE- and NW-trending. View looking south.

F) Riopelle shear zone and the auriferous Riopelle Vein (white). Shear Zone is marked by the S_2' foliation.

G) Pillow Breccia (Upper Flows) near No.5 Vein / I.F. Zone.

H) Relatively unaltered oxide facies B.I.F. showing fine layers of chert and magnetite that are compositionally graded (iron-poor to iron-rich) accompanied by a thinning upwards of layers. Tops to left.

PLATE 2

PLATE 2

Note: Black cap on the 15 cm marking pen points north unless otherwise stated.

A) An isoclinal F_1 fold in oxide facies B.I.F. is refolded by an F_2 fold, near the No.5 I.F. Zone.

B) Small-scale Z-shaped F_2 fold at contact between Upper pillow flow (right) and pillow breccia (left).

C) Sigmoidal en-echelon right-stepping fractures striking north in oxide facies B.I.F. infilled with quartz. Width of field of view is 1.0 m.

D) Barren and foliated quartz pods that occur along same Upper pillow-pillow breccia contact as in (B).

E) Mafic dyke crosscutting B.I.F. in the No.5 Vein / I.F. Zone has been sheared parallel to S_2 (white bar) in B.I.F. and offset right-handed. See Plate 9b for description of mineralogy. Width of field of view in foreground is 2.0 m.

F) Well-developed ENE-trending shear fractures (white bars normal to marking pen) in B.I.F. that increase in abundance toward the No.5 Vein / I.F. Zone (toward top of photo). Conjugate shear direction is to the N.

G) Intraformational breccia within oxide facies B.I.F. near the No.5 Vein / I.F. Zone. Note angularity of grey chert fragments.

H) The No.5 Vein (white) within the No.5 shear zone (only footwall exposed). Fire hose is 5 cm in diameter. Looking east.

PLATE 3

PLATE 3

A) Isoclinal F_2 fold near No.1 Vein / I.F. Zone. . Black cap on marker points NE.

B) Isoclinal F_2 fold, near No.1 Vein / I.F. Zone. Black cap on marker points NE.

C) Tight F_2 fold in the B.I.F. near No.5 Vein / I.F. Zone. Black cap on marker points N. White bar is parallel to axial surface of F_2 fold.

D) A small discrete Type 1 shear zone that contains an auriferous quartz vein (white; right hand side of photo) is parallel to the axial surface of a minor isoclinal F_2 fold in the No.1 I.F. Zone.

E) Lamprophyre dyke (black) that strikes NNW (toward bottom left corner of photo). Host rock is B.I.F. and dyke is 2 m wide.

F) The No.11 splay shear which hosts the No.11 Vein. Refer to Figure 17 in text for a detailed sketch of the surface exposure. View looking north.

G) A Late Vein that crosscuts the No.5 shear zone. A detailed sketch of the this photo is shown in Figure 18.

H) A small auriferous quartz-tourmaline veinlet that crosscuts the B.I.F. at the No.5 I.F. Zone. The vein is folded with axial surfaces parallel to S_2 . The white lines above vein are painted on the outcrop.

PLATE 4

PLATE 4

A) Upper pillowed flow showing altered rims around pillows within dark selvages. Field of view is 1.5 m wide.

B) Conjugate set of fractures that crosscut laminated tuff surface S_0 (wrinkled layers left to right) near Lakeshore Vein. The two dominant fracture trends are ENE-trending (upper left to bottom right of photo) and NW-trending (bottom to top of photo).

C) Lakeshore Vein showing early quartz-ankerite vein (dark grey) crosscut by small dilational quartz veins (white) that in turn have been cut by small tourmaline (filled) fractures (light grey; parallel to pen). Pen tip points East.

D) NQ-size (5 cm diameter) drill core showing crosscutting quartz-tourmaline veins that have altered the chert-magnetite layers in the No.5 Vein/I.F. Zone.

E) Isoclinal F_1 fold in oxide facies B.I.F. that is refolded by an F_2 fold. Pen points NE, parallel to axial surface of F_2 fold. Pumphouse trench area.

F) Close up of (E) showing minor F_1 fold patterns within hinge area of the superimposed folds. Field of view is 10 cm wide.

G) NQ-size drill core showing primary sulphide facies B.I.F. The vug in the central part of the core is infilled with quartz and enveloped by a selvage of pyrite and chalcopyrite that contains gold. Cherty layers are the dark grey areas. Near No.5 Vein/I.F. Zone.

H) Gold-bearing quartz vein (light grey) that infills dilational fracture in Pickle Crow Quartz Albite Porphyry. Vein is 10 cm wide.

PLATE 5

PLATE 5

A) Sharp contact between pervasively sulphidized (left of centre) and slightly sulphidized B.I.F. (right of centre) in the No.5 I.F. Zone. Field of view is 5 cm wide.

B.) Close up of (A) showing preferential sulphidation of the magnetite beds(below marker) and only minor alteration of the chert layers. Marker points north.

C) F₂ fold hinge area in Upper Basaltic pillowed flow near Riopelle Vein area. S₀ surface arcs across outcrop; a strong NE-trending S₂ foliation is nearly normal to the marker. Marker points NW.

D) Part of the N-trending Riopelle Vein following folded contact between a massive and pillowed flow, Vein is 5 cm wide; North is to the right of the photo.

E) Riopelle Vein in the Riopelle shear zone showing boudinage structure. Field of view is 3 cm wide.

F) NQ-size drill core from No.5 I.F. Zone, showing sulphidation by pyrite of magnetite in oxide facies B.I.F. Sulphidation is associated with a small crosscutting pyrite vein normal to the chert-magnetite layers.

G) NQ-size drill core from the No.5 I.F. Zone showing fine layers of chert and magnetite. Compositional grading from chert-rich to magnetite-rich layers is accompanied by a progressive thinning of laminations within the layers(central part of photo). Tops is to left.

H) Garnets formed in the B.I.F.-Upper Basaltic Flow contact area. Garnets are up to 5 mm in diameter. Field of view is 15 cm.

PLATE 6

PLATE 6

A) NQ-size drill core from No.5 I.F. Zone showing quartz veins in B.I.F. with associated selvages of pyrite. Note, high gold assays from this core.

B) NQ-size drill core in their core boxes (1.5m wide) from No.5 Vein/I.F. Zone, showing progressive alteration of Lower Basaltic Pillowed Flows (from dark grey (chlorite-rich) at bottom (Assemblage 1) to light grey (sericite-rich) at top (Assemblage 2) of Lower Basaltic Pillowed Flows.

C) NQ-size drill core in their core boxes showing a 30 m thickness of primary sulphide facies B.I.F., consisting of massive pyrite and marcasite interbedded with chert. From drill hole HC-75, 150 m west of the No.5 I.F. Zone.

D) Close up of the Rièpelle Vein showing tourmaline within fractures. Field of view is 3 cm wide.

E) NQ-size drill core from the No.5 I.F. Zone showing crosscutting quartz veins (white) in B.I.F.(light grey) and associated pyrite (medium grey).

F) NQ-size drill core from the No.5 I.F. Zone showing intraformational breccia within oxide facies B.I.F. Note angular chert fragments.

G) Type 1 shear zone near L40 area (east part of property) showing a strongly foliated zone containing a rare large quartz vein (light grey) up to 1.5 m wide.

H) Stockwork quartz veins within gabbro in the ABC Zone. Veins follow conjugate sets of fractures. View looking south; lens cap for scale.

5

PLATE 7

PLATE 7

A) Photomicrograph of least altered basalt showing large twinned calcite crystals(Ca), epidote(Ep) and fine-grained matrix of albite, actinolite and microcrystalline chlorite. From DDH HC-58. Field of view is 3 mm wide. (Assemblage 1).

B) Photomicrograph of less altered massive basalt showing edge of calcite vein (white) with a selvage of chlorite (light grey) and fine-grained pyrite (black dots). From DDH HC-58. Field of view is 3mm wide. (Assemblage 1).

C) Photomicrograph of Upper basalt near the No.5 shear zone showing quartz-carbonate vein (white, upper left of photo) with a selvage of chlorite (light & dark grey). From DDH HC-58. Field of view is 3 mm wide. (Assemblage 1).

D) Photomicrograph of Upper pillow flow showing a brecciated barren quartz pod (white) with a chlorite (dark grey layer) selvage. From DDH HC-58. Field of view is 3 mm wide. (Assemblage 1).

E) Photomicrograph of slightly altered Lower pillowed flow. Magnetite occurs locally as euhedral crystals (black). Field of view is 3 mm wide. (Assemblage 1).

F, G & H) Photomicrographs of magnetite-bearing Lower Basaltic pillowed flow in (E), showing progressive deformation and alteration of the magnetite grains (black) in the No.5 shear zone. Note that alteration of the basalts also changes, with the addition of quartz, ankerite (white), microcrystalline sericite and a decrease in chlorite (grey). Field of view in all is 5 mm wide.(Assemblage 2).

PLATE 8

PLATE 8

A) Photomicrograph of the No.5 Vein showing a tourmaline layer (light grey) with associated coarse free gold (white). Field of view is 3 mm wide.

B) Photomicrograph of the No.5 Vein showing coarse free gold (white) not associated with a tourmaline layer. Field of view is 3 mm wide.

C) Photomicrograph of the No.5 Vein showing coarse free gold (white) associated with a tourmaline layer (light grey) and a small pyrite (Py) grain. Field of view is 3 mm wide.

D) Photomicrograph of the No.5 Vein showing coarse free gold (white) associated with a tourmaline layer (light grey) that contains fine-grained gold. Field of view is 3 mm wide.

E) Photomicrograph of primary sulphide facies B.I.F. near the No.5 I.F. Zone showing pyrrhotite (Po) replaced by pyrite and marcasite (light grey). Field of view is 3 mm wide.

F) Photomicrograph of pyrite (white) replacement in primary sulphide facies B.I.F. with goethite (dark grey). Field of view is 3 mm wide.

G) Photomicrograph of pyrite (Py) and goethite (Go) (similar to f) in sulphide facies B.I.F. Field of view is 1 mm wide.

H) Photomicrograph of primary sulphide facies B.I.F. showing euhedral pyrite (white) and associated goethite (dark grey). Field of view is 3 mm wide.

PLATE 9

PLATE 9

A) Photomicrograph of the Upper pillow breccia showing pillow fragments (dark grey) in a matrix of small pyrite grains (black) and microcrystalline chlorite. Note the crosscutting quartz vein (white) in upper left of photo. Field of view is 5 mm wide.

B) Photomicrograph of the mafic dyke in the No.5 I.F. Zone showing abundant pyrite grains within a matrix of microcrystalline chlorite. Field of view 3 mm wide.

C) Photomicrograph of the felsic dyke near the No.5 Vein / I.F. Zone showing a large polygonized quartz grain within a fine-grained groundmass of quartz, albite, ankerite, sericite and kaolinite. Field of view is 5 mm wide.

D) Photomicrograph of the lamprophyre dyke in the No.1 I.F. Zone showing a large biotite phenocryst (upper right corner of photo) within a finer grained matrix of quartz, albite, ankerite and pyrite. Field of view is 5 mm wide.

E) Photomicrograph of the Pickle Crow Quartz Albite Porphyry near a Type 2 shear zone showing 2 large quartz grains (one has undulose extinction and the other has been polygonized) within a fine grained matrix of quartz, albite, sericite and ankerite. Field of view is 5 mm wide.

F) Photomicrograph of sulphidized B.I.F. in the No.5 I.F. Zone showing chert/magnetite layers (right side of photo; white to light grey layers), with magnetite layers replaced by chlorite (light grey) and pyrite (black). Field of view is 3 mm wide.

G & H) Photomicrographs of unaltered oxide facies B.I.F. showing compositional grading from chert-rich to magnetite-rich layers accompanied by a thinning of layers. The younging direction is toward the right side of each photo. Field of view is 3 mm wide.

PLATE 10

PLATE 10

A) Photomicrograph of unaltered oxide facies B.I.F. showing recrystallized chert layers (white) interbedded with magnetite layers (dark grey). Compositional grading from chert-rich to magnetite-rich layers accompanied by thinning of layers is shown from bottom to top of photo(to north). Photo taken with both plane polarized and reflected light. Field of view is 3 mm wide.

B) Photomicrograph of less altered oxide facies B.I.F. showing compositional graded chert (white) and magnetite (dark grey) layers. Younging direction is from bottom to top of photo. Photos taken with both plane polarized and reflected light. Field of view is 5 mm wide.

C) Photomicrograph of sulphidized oxide facies B.I.F. in the No.5 I.F. Zone showing recrystallized chert (white) and magnetite(dark grey) layers, with the magnetite layers preferentially sulphidized to pyrite (light grey). Field of view is 3 mm wide.

D) Photomicrograph of sulphidized oxide facies B.I.F. in the No.5 I.F. Zone showing replacement of a magnetite (Mag) layer with pyrite (Py). Recrystallized chert to the right of photo. Field of view is 3 mm wide.

E) Photomicrograph of pervasively sulphidized oxide facies B.I.F. in the No.5 I.F. Zone showing replacement of magnetite layers with chalcopyrite (Cp) and pyrite (Py). Chert layers are dark grey. Reflected light; field of view is 3 mm wide.

F) Photomicrograph of pervasively sulphidized oxide facies B.I.F. in the No.5 I.F. Zone showing pyrrhotite (Po) replaced by arsenopyrite (Asp) that is rimmed with chalcopyrite (Cp). Note disruption of layers by quartz veins (light grey). Field of view is 3 mm wide.

G) Photomicrograph of altered sulphide facies B.I.F. in the No.5 I.F. Zone showing chalcopyrite (Cp) replacing pyrite (Py). Field of view is 3 mm wide.

H) Photomicrograph of pervasively sulphidized oxide facies B.I.F. in the No.5 Vein / I.F.Zone showing euhedral pyrite (Py) grains rimmed with chalcopyrite (Cp). Field of view is 3mm wide.

APPENDIX 2

Table 1a, b, c

List of Chemical Compositions

of

No.5 Area Rock Samples

from Whole Rock Analyses

The samples listed in Tables 1a, b and c were analyzed at Bondar-Clegg Laboratories in Ottawa. The following is a list of methods and techniques used for the various analyses:

<u>Element</u>	<u>Lower Detection Limit</u>	<u>Extraction</u>	<u>Method</u>
SiO ₂	0.01 PCT	Borate Fusion	DC Plasma
TiO ₂	0.01 PCT	Borate Fusion	DC Plasma
Al ₂ O ₃	0.01 PCT	Borate Fusion	DC Plasma
Fe ₂ O ₃	0.01 PCT	Borate Fusion	DC Plasma
MnO	0.01 PCT	Borate Fusion	DC Plasma
MgO	0.01 PCT	Borate Fusion	DC Plasma
CaO	0.01 PCT	Borate Fusion	DC Plasma
Na ₂ O	0.01 PCT	Borate Fusion	DC Plasma
K ₂ O	0.01 PCT	Borate Fusion	DC Plasma
P ₂ O ₅	0.01 PCT	Borate Fusion	DC Plasma
LOI	0.01 PCT	-----	Gravimetric
CO ₂	0.01 PCT	H ₃ PO ₄	Gravimetric
FeO	0.01 PCT	HF/1:1, H ₂ SO ₄ /H ₃ BO ₃	Titrametric
S	0.01 PCT	-----	X-ray Fluorescence
H ₂ O (Total) Estimated- calculated from LOI - (CO ₂ + S)			

<u>Sample Sizes</u>	<u>Size Fractions</u>	<u>Sample Preparations</u>
Drill Core Rock	-200	Crush, Pulverize -200

Key to Tables 1 a. b. c.

<u>Sample No.</u>	<u>Rock Type</u>
86145 to 86151(incl)	Upper Basaltic Flows
86165, 86167 to 86174	
86179 to 86187	
86152 to 86154	Lower Basaltic Flows
86159 to 86164	
86166, 86188,86189,	
86190 to 86193	
86155	Felsic Dyke
86156	Mafic Dyke
86157	No.5 Vein
86158	Riopelle Vein
86122 to 86123	Pickle Crow Porphyry
86124 to 86125	Albany Porphyry
86126 to 86127	Springer Porphyry
86128 to 86129	Hooker-Burkoski Stock
86132	" "
86130 to 86131	Central Patricia Porphyry
86175 to 86178	Iron Formation

Table 1a: List of Chemical Compositions by Whole-Rock Analyses of the
No.5 Vein / I.F. Area Rock Samples

SAMPLE #	SiO2 Wt. %	TiO2 Wt. %	Al2O3 Wt. %	Fe2O3 Wt. %	MnO Wt. %	MgO Wt. %	CaO Wt. %	Na2O Wt. %	K2O Wt. %	P2O5 Wt. %	LOI Wt. %	Total Wt. %	FeO Wt. %	CO2 Wt. %	S Wt. %	H2O Total: Wt. % LOI - (CO2+S)
86145	41.40	0.93	13.20	15.80	0.38	3.79	12.10	0.98	0.37	0.14	11.65	100.74	13.00	9.03	0.19	2.43
86146	49.60	1.18	16.20	6.69	0.18	2.91	10.80	2.19	1.32	0.12	9.35	100.54	5.05	6.86	0.08	2.41
86147	54.80	1.15	15.90	8.10	0.16	3.16	9.65	3.45	0.08	<0.01	1.30	97.75	6.29	4.72	0.10	1.63
86148	51.10	1.09	15.40	5.23	0.11	3.47	9.67	2.40	0.83	0.17	8.25	97.72	4.44	6.70	0.07	1.48
86149	52.80	1.18	15.90	6.02	0.13	2.70	11.50	2.15	0.72	<0.01	8.50	101.60	4.70	3.52	0.08	4.90
86150	44.20	0.82	13.60	11.50	0.15	6.22	8.36	2.45	0.06	0.25	10.15	97.76	9.81	6.82	<0.01	3.32
86151	45.30	0.79	13.10	10.90	0.15	4.38	10.10	1.18	0.68	0.19	12.05	98.82	9.44	8.30	<0.01	3.74
86165	48.10	1.04	16.50	9.98	0.19	3.49	7.61	2.01	0.39	0.24	7.95	97.50	-	-	-	-
86167	46.80	1.20	15.50	12.10	0.19	4.90	6.21	1.25	0.50	0.33	8.25	97.23	-	-	-	-
86168	51.30	1.06	15.80	11.20	0.12	6.25	3.57	2.18	0.30	0.02	5.45	97.25	-	-	-	-
86169	49.80	1.01	17.10	9.48	0.18	5.60	9.87	1.52	0.08	0.22	2.25	97.11	-	-	-	-
86170	48.70	0.62	15.90	10.30	0.19	5.75	7.81	1.74	0.07	0.14	6.10	97.32	-	-	-	-
86171	48.70	0.59	16.00	10.60	0.13	6.52	4.51	1.29	0.93	0.17	8.50	97.94	-	-	-	-
86172	45.30	0.61	15.40	11.40	0.17	8.75	5.67	2.19	0.10	0.17	7.55	97.31	-	-	-	-
86173	47.40	0.57	14.70	10.40	0.15	7.03	6.79	1.44	0.43	0.23	8.90	98.04	-	-	-	-
86174	48.20	0.67	15.50	11.20	0.14	8.25	6.63	1.59	0.05	0.02	4.80	97.05	-	-	-	-
86179	42.70	0.50	10.60	11.20	0.19	8.27	11.40	0.31	0.01	<0.01	13.35	98.53	9.76	9.08	0.03	4.24
86180	46.20	0.59	13.50	11.50	0.15	10.70	7.04	0.99	0.01	0.05	6.60	97.33	9.13	2.26	0.08	4.28
86181	48.40	0.69	14.70	10.90	0.17	9.66	9.45	2.16	0.02	0.11	4.70	100.96	7.16	1.71	0.02	2.97
86182	42.80	0.58	12.20	10.90	0.21	7.95	10.90	1.31	0.02	0.05	12.00	98.92	9.67	8.78	0.02	3.20
86183	39.30	0.42	9.09	13.80	0.43	4.64	16.30	0.26	0.75	<0.01	12.95	97.94	11.28	12.09	0.43	0.43
86184	48.50	1.08	15.10	7.97	0.16	5.59	10.10	2.25	0.02	0.14	6.75	97.66	5.78	3.86	0.04	2.85
86185	49.80	1.14	16.50	9.68	0.15	6.11	8.68	3.08	0.17	0.02	5.20	100.53	6.79	2.56	0.11	2.53
86186	48.50	1.09	16.00	9.55	0.17	7.24	9.56	2.29	0.06	0.07	5.25	99.78	6.84	2.34	<0.01	2.90
86187	41.70	1.33	16.20	11.90	0.40	3.76	12.80	1.22	0.57	0.03	10.70	100.61	10.11	8.64	0.20	1.86
86190	49.00	0.94	13.30	8.56	0.15	4.95	10.70	1.98	<0.01	0.23	10.75	101.47	7.06	8.20	0.04	2.51

Table 1b: List of Chemical Compositions by Whole-Rock Analyses of the
No.5 Vein / I.F. Area Rock Samples

SAMPLE No.	SiO2 Wt. %	TiO2 Wt. %	Al2O3 Wt. %	Fe2O3 Wt. %	MnO Wt. %	MgO Wt. %	CaO Wt. %	Na2O Wt. %	K2O Wt. %	P2O5 Wt. %	LOI Wt. %	Total Wt. %	FeO Wt. %	CO2 Wt. %	S Wt. %	H2O Total: Wt. % LOI - (CO2+S)
86122	71.50	0.15	15.70	2.45	0.05	1.47	1.80	1.95	1.72	<0.01	2.05	98.84	-	-	-	-
86123	71.00	0.15	14.90	1.81	0.03	0.79	1.65	5.40	1.66	<0.01	2.25	99.64	-	-	-	-
86124	63.70	0.38	15.10	4.45	0.09	1.64	4.30	4.55	1.88	0.25	0.95	97.38	-	-	-	-
86125	66.70	0.33	15.10	3.06	0.06	1.12	1.48	4.84	2.31	0.24	2.65	97.89	-	-	-	-
86126	81.20	0.14	13.50	0.63	<0.01	0.11	0.08	0.10	0.63	<0.01	0.90	97.29	-	-	-	-
86127	75.70	0.18	16.80	2.63	0.05	0.41	0.18	0.08	0.40	<0.01	0.80	97.23	-	-	-	-
86128	68.70	0.30	15.70	1.92	0.07	1.30	0.79	5.25	1.78	<0.01	1.50	97.31	-	-	-	-
86129	70.90	0.18	14.40	1.74	0.02	0.60	0.52	6.23	1.50	<0.01	2.45	98.54	-	-	-	-
86130	61.20	0.19	17.20	2.47	0.06	0.91	4.77	2.48	1.39	0.25	6.45	97.37	-	-	-	-
86131	71.90	0.14	14.70	1.66	0.04	0.31	1.05	3.66	1.92	0.08	2.55	98.01	-	-	-	-
86132	69.70	0.23	14.80	1.89	0.03	0.79	2.25	5.06	2.77	<0.01	0.60	98.12	-	-	-	-
86152	38.20	0.72	10.80	11.00	0.21	5.35	15.20	1.35	0.17	0.18	15.60	98.78	9.40	12.67	<0.01	2.92
86153	46.10	0.88	12.70	12.50	0.20	6.31	10.80	1.74	<0.01	0.19	7.70	99.12	7.53	4.93	0.01	2.76
86154	45.60	0.79	13.60	11.40	0.19	3.73	10.60	1.66	0.45	0.12	10.25	98.39	9.61	7.99	<0.01	2.25
86159	50.20	0.93	13.90	11.00	0.16	5.82	9.80	2.94	0.04	0.11	3.25	98.15	-	-	-	-
86160	48.10	1.00	14.90	9.44	0.28	3.95	8.74	2.40	0.57	0.23	8.10	97.71	-	-	-	-
86161	54.00	0.89	16.20	7.24	0.15	4.19	6.97	3.17	0.08	0.14	4.65	97.68	-	-	-	-
86162	54.30	0.91	14.10	8.61	0.22	3.77	6.65	2.11	0.36	0.16	6.50	97.69	-	-	-	-
86163	53.20	0.80	15.30	7.74	0.18	3.31	9.36	2.25	0.05	0.18	5.45	97.82	-	-	-	-
86164	50.70	0.83	16.60	16.30	0.25	4.40	2.96	1.24	0.46	0.14	5.90	99.78	-	-	-	-
86166	50.40	0.94	15.60	13.90	0.25	4.75	4.52	1.53	0.43	0.34	6.80	99.46	-	-	-	-
86188	42.00	0.90	14.40	11.60	0.16	5.52	11.10	2.03	<0.01	0.21	10.85	98.77	10.06	8.42	0.09	2.34
86189	46.87	0.86	15.90	8.45	0.27	4.18	10.50	2.53	0.31	<0.01	8.35	98.22	5.11	6.08	0.08	2.19
86191	41.50	0.88	12.90	11.20	0.16	5.79	10.80	1.51	1.63	0.42	14.90	101.69	9.39	13.48	0.06	1.36
86192	47.00	0.84	12.80	11.70	0.21	3.93	11.30	1.77	0.44	0.16	11.05	101.20	11.47	8.66	0.03	2.36
86193	52.50	0.76	14.00	12.60	0.23	3.29	6.29	2.43	0.24	<0.01	5.90	98.24	10.76	4.20	0.15	1.55

Table 1c: List of Chemical Compositions by Whole-Rock Analyses of the
No.5 Vein / I.F. Area Rock Samples

SAMPLE #	SiO2 Wt. %	TiO2 Wt. %	Al2O3 Wt. %	Fe2O3 Wt. %	MnO Wt. %	MgO Wt. %	CaO Wt. %	Na2O Wt. %	K2O Wt. %	P2O5 Wt. %	LOI Wt. %	Total Wt. %	FeO Wt. %	CO2 Wt. %	S Wt. %
86155	51.80	1.13	13.30	7.42	0.20	3.10	7.90	1.42	2.64	0.06	9.00	97.97	-	-	-
86156	43.40	1.09	18.50	23.90	0.35	3.08	0.27	1.42	1.30	0.13	4.30	97.74	-	-	-
86157	93.70	0.04	2.00	1.20	0.02	0.30	0.27	<0.01	0.15	0.05	0.25	97.98	-	-	-
86158	45.70	0.01	0.40	0.51	0.01	0.11	0.36	0.02	0.02	<0.01	0.40	47.54	-	-	-
86175	63.40	0.05	0.54	25.90	0.61	1.07	0.43	0.05	0.05	0.23	5.15	97.48	-	-	-
86176	62.20	0.05	0.51	22.10	0.85	2.16	1.92	0.06	0.07	0.17	7.40	97.49	-	-	-
86177	60.30	0.01	0.26	29.50	0.55	0.36	0.16	<0.01	<0.01	0.18	7.25	98.57	-	-	-
86178	26.00	0.10	5.76	44.70	0.11	1.45	0.05	0.02	0.53	0.16	19.45	98.33	-	-	-

HC-86 29,27

470

HC-86-24

Pickle, Crow Shear Zone

DOWN
UP

432'

300'

20

720-2

HC 90

MAP 1

RIOPELLE SHEAR ZONE

83 (-60°)

HC-86-84 (-60°)

HC-86-85 (-60°)

70

PICKLE

1b

1b

HC-85-14 (-45°)

2a

2a

er Basaltic Flows

2a

2

2a

2a

2a

HC-86-85 (-60°)

1500 S

PICKLE

CROW

ROAD

DOWN
UP

1a

1b

HC-86-37 (-70°)

HC-86-39 (-90°)

HC-85-6 (-45°)

HC-85-14 (-45°)

2a

2a

2a

2a

2a

2a

2a

2a

1b

2a

LEGEND

MAP 2

INTRUSIVES

- 5 FELSIC DYKE
- 4 LAMPROPHYRE DYKE
- 3 MAFIC DYKE

- 2 IRON FORMATION
- 2a OXIDE FACIES
- 2b SULPHIDE FACIES

- 1 MAFIC VOLCANICS (BASALTS)
- 1a MASSIVE FLOWS
- 1b PILLOWED FLOWS
- 1c PILLOW BRECCIA

----- LITHOLOGICAL CONTACTS

- BEDDING, inclined
- FOLIATION, inclined with stretching lineation
- ~ FOLDS, small scale with asymmetry
- ↑ BEDDING TOPS
- ↑ PILLOW TOPS
- ↑ OVERTURNED ANTICLINE
- ↑ OVERTURNED SYNCLINE
- S_2
- S'_2
- ~ SHEAR ZONE
- L'_2

HC-86-44 (-90°)
 HC-86-42 (-70°)
 HC-85-9 (-45°)

HC-86-30 (-45°)

1b

LEGEND

INTRUSIVES

- 5 Felsic Dyke
- 4 Lamprophyre Dyke
- 3 Mafic Dyke

IRON FORMATION

- 2a Cherty Oxide
- 2b Sulphide Facies

MAFIC VOLCANICS

- 1a Massive Flows
- 1b Pillowed Flows
- 1c Pillow Breccia

- Lithologic contacts
- Foliation strike and dip
- Bedding strike and dip Inclined and vertical
- Foliation with mineral lineation
- Small scale folds
- Bedding
- Pillow Tops

Upper

Quartz vein
in Felsite Dykes

HC-86-75 (-45°)
HC-86-76 (-60°)

HC-86-69
HC-86-70

DOWN
UP

607'

Quartz
Vein

Basaltic Flows

HC-85-14 (-45°)

9 (-45°)
0 (-60°)

HC-86-63 (-45°)
HC-86-64 (-60°)

HC-86-61 (-45°)
HC-86-62 (-60°)

HC-86-59 (-45°)
HC-86-60 (-60°)

HC-86-57 (-45°)
HC-86-58 (-60°)

/N

No.5 SHEAR ZONE

HE

3 → 70 F₂
→ 66 E

305'

365'

597'

70

65

78

70

HC-86-37 (-70°)

HC-86-39 (-90°)

HC-85-6 (-45°)

HC-85-14 (-45°)

HC-86-59 (-45°)
HC-86-60 (-60°)

HC-86-57 (-45°)
HC-86-58 (-60°)

HC-86-55 (-45°)
HC-86-56 (-60°)

HC-86-53 (-45°)
HC-86-54 (-60°)

HC-86-51 (-45°)
HC-86-52 (-60°)

EAR ZONE

Massive Pyrrhotite
and Pyrite

Quartz
vein

HC-86-44 (-90°)
 HC-86-42 (-70°)
 HC-85-9 (-45°)

FOLDS, small scale with asymmetry

BEDDING TOPS

PILLOW TOPS

OVERTURNED ANTICLINE

OVERTURNED SYNCLINE

S₂

S₂'

SHEAR ZONE

L₂'

Upper Mafic Volcanic Seq

HC-86-58 (-60°)

This geological map depicts the Silver Lake area, showing various geological units and structural features. The map includes several labeled units: 1a, 1b, 2a, 2b, and 70F₂. Key structural features include a prominent fault line running diagonally from the bottom left towards the top right, and several other fault segments indicated by dashed lines. Elevation points are marked with numbers and primes, such as 305', 577', 307', 297', 395', 357', 365', 597', 327', and 307'. Specific geological features are labeled, including 'Quartz vein' in two locations and 'F₂' near the center. The map also shows various contour lines and dashed lines representing geological boundaries or structural trends. A scale bar at the bottom right indicates a distance of 85 units. The map is oriented with North at the top.

No.5 I.F. Zone

No.5 Vein

HIGHLAND-CROW RESOURCES LTD.			
PICKLE CROW PROJECT			
*5 VEIN - IRON FORMATION ZONE DIAMOND DRILL PLAN			
1" = 20'	Nov 19/86	J.K.M.	

Geology of th

FIGURE 6
(enlarged)

- 7 Diabase
- 6 Granite
- 5 Porphyry-QFP
- 4 Felsic Volcanic Rocks
- 3 Iron-Formation
- 2 Gabbro
- 1 Mafic Volcanic Rocks

the PICKLE CROW

Shear Zone

Syncline, Anticline
Overturned

S_2

S_2'

Pillow tops

N

Sawm
Vein

PICKLE CROW FAULT

Dome

LE CROW Area

A geological map of the LE CROW Area. The map features a north arrow pointing upwards, labeled 'N'. A prominent feature is the 'Sawmill Vein', shown as a thick, dark, irregular line running diagonally from the lower left towards the upper right. To the right of the Sawmill Vein, there are several other veins and structures, including a 'Dome' at the bottom left, a 'No. 1 Shaft' on the right, and a 'Cohen-MacArthur Veins' area at the top right. The map is marked with various numbers (1, 2, 3, 75, 88) and letters (a, b, c, d) indicating specific locations or features. The overall style is a hand-drawn or simplified geological sketch.

N

Cohen-MacArthur Veins

3

88

75

Sawmill Vein

No. 1 Shaft

Dome

1

2

a

b

c

d

Lakeshore

75

No.1 Shaf

Lake Tahoe

64

S₂'
Pillow tops

Albany Shaft

PCP

AP

ABC Zone

No.3 Shaft

No.2 Vein

Pickle Crow Anticline

No.1 Vein/I.F. Zone

No.5 Vein/I.F. Zone

pelle
ein

Area

- a-Pickle Crow Syncline
- b-Pumphouse Lake Anticline
- c-Sawmill Syncline
- d-Powder House Anticline

LE CROW FAULT

Lakeshore
Vein

Dome
Vein

Hook
Vein

HOOKER
BURKOSKI
STOCK

Vein

Lakeshore Vein

Dome Vein

Hook Vein

Springer Shaft

Springer Vein

Riop Vein

Study Ar

SC

END

2008-88

FIN