Ontario

Ontario Geological Survey
Open File Report 5985

Special Project: Timmins Ore Deposit Descriptions

1999

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ONTARIO GEOLOGICAL SURVEY

Open File Report 5985

Special Project: Timmins Ore Deposit Descriptions

Edited by

R. Pressacco

1999

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Foreword

The Archean aged gold deposits of the Abitibi subprovince comprise one of the largest concentrations of gold on Earth. These deposits have been continuously mined at Timmins, Ontario for the past 90 years. Gold production of +60 million ounces has been mined from over 60 operations at Timmins and this represents about 45% of all gold mined in Ontario.

Consequently, the geology of the area has been well studied and a wealth of information is available for many of the individual deposits. As well, several studies have provided a geological overview of many of the salient features of the mines. In particular, reports relevant to the Timmins area include *Structural Geology of Canadian Ore Deposits* by the Canadian Institute of Mining and Metallurgy (1948, 1957, 1967), geological overviews by the Ontario Department of Mines and the Abitibi chapter of *Geology of Ontario* by the Ontario Geological Survey. Excellent descriptions for many of the producing and past producing mines are available in these and other sources, and are referenced within the body of this report.

The aim of *Special Project: Timmins Ore Deposit Descriptions* is to provide a geological description for those currently producing and past producing gold mines that are active in the Timmins area at the end of the 20th Century. In sum, the work documents eight deposits (Figure I), several of which have not previously been described in the published literature. The regional and property scale geological settings of each of the eight deposits are briefly described, but the descriptive emphasis is on the detail of individual deposits. Discussions on the origin of the deposits are intentionally omitted. With a focus on the descriptive, this report will serve as a valuable reference tool in the quest for similar deposits long after the present mines are depleted and the geological concepts regarding the deposit origins themselves have evolved.

Brian Atkinson
Regional Resident Geologist
Timmins District

Acknowledgements

This project could not have proceeded without the consent and co-operation of the various corporations and individuals present at the mines. Special thanks are extended to Kinross Gold Corporation (Randy Roussain, Keith Green, Henry Hutteri, Wally Smith, Chris Parolin, Sandra Young, Bill McRae, and David Rhys), Pentland Firth Ventures Limited (Gord Yule, Ken Tylee, and Albert Rentelis), Placer Dome North America Limited (Roger Hill, Mark Croteau, Mort Shannon, Stephen Price, Ralph Koch, and Dave Gliddon), and Royal Oak Mines Inc. (Peter Harvey, Brian O'Connor, Brian Kilbride, Paul Coad, Kim Tyler, Mike Simunovic, Stan Wilson, Dave Penna, and Deb Girth), and to Dr. Dan Brisbin for his contributions, insights and discussions.

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District Geologist
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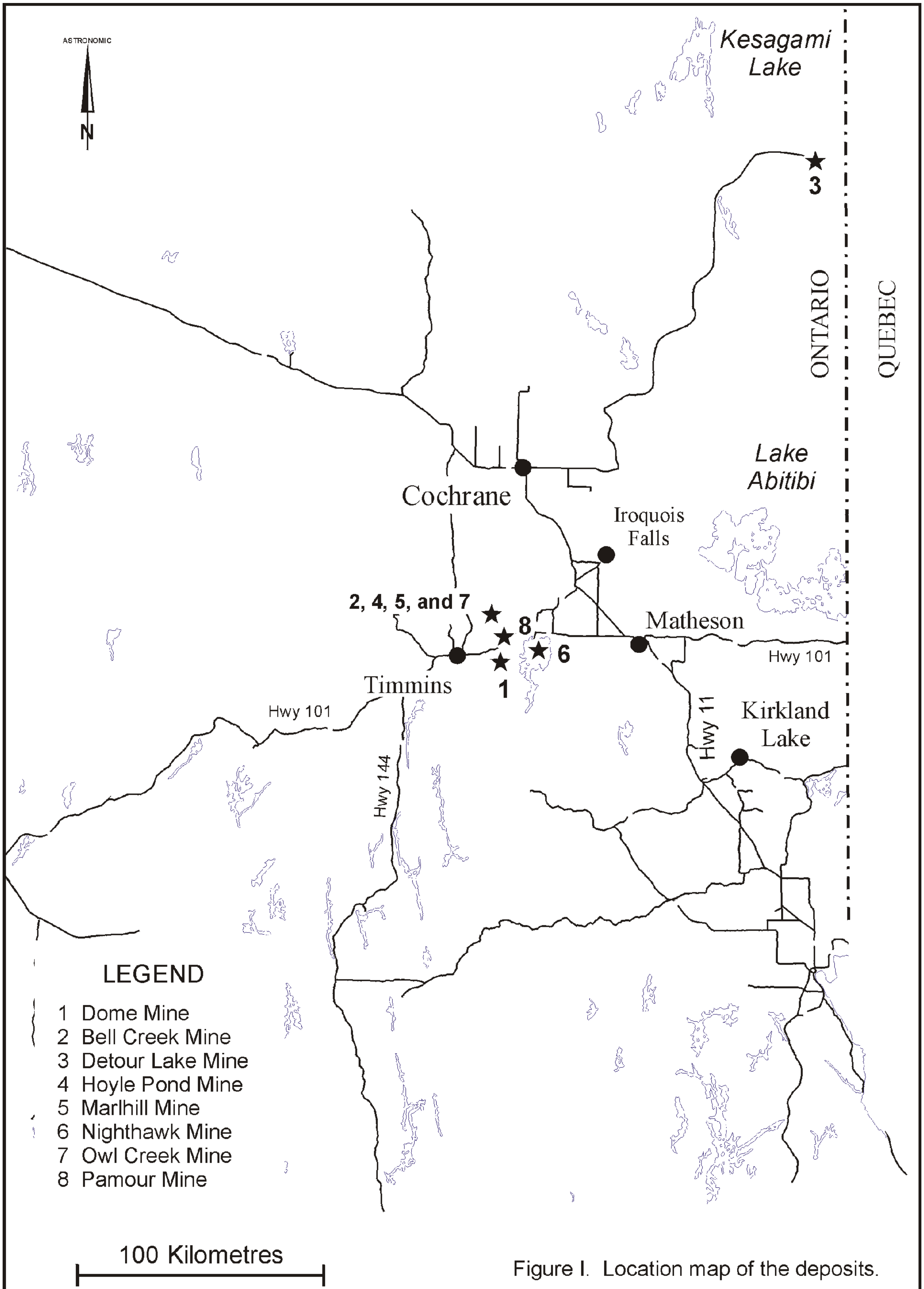

Figure I. Location map of the deposits.

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R.K. Tyler, M. Simunovic, S. Wilson, D. Penna, D. Gerth, B. Kilbride, P. Coad and P. Harvey
Royal Oak Mines Inc.

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Economic Geology and Mineralization of the Dome Mine

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INTRODUCTION

The Timmins area is one of the world's largest producers of gold, having produced more than 60 800 000 ounces of gold to-date. The Dome Mine is the second largest gold producer of the Timmins camp, having produced a total of 13 592 747 ounces of gold up to December 31, 1998. Much of this gold was produced from quartz veins hosted either in mafic metavolcanic rocks, sedimentary rocks, or porphyritic intrusive rocks. The first discovery of gold on the mine property was in the summer of 1909 when two large quartz veins were discovered. The mine has been in continuous production since a small amount of gold was produced in 1910. An excellent account of the history of the Dome Mine is given in Girdwood, et. al. (1983).

LOCATION, OWNERSHIP, AND CLAIMS

The Dome Mine is located in southeastern Tisdale Township, approximately 6 kilometers southeast of Timmins, Ontario (Figure 1). The mine consists of both an underground and open pit mine located in the north half of Lot 4, Concession I, Tisdale Township. The mine property forms part of Placer Dome North America Limited's large land holdings in the area that include the mine property itself as well as the neighboring Preston and Paymaster mine properties.

REGIONAL GEOLOGICAL SETTING

The Dome mine is hosted within a mixed assemblage of mafic and ultramafic volcanic rocks containing interbedded clastic and graphitic sediments that have had a complex folding and intrusive history (Figure 2). The rock units located on the mine property form part of the type stratigraphy of the Timmins camp and include members of the Tisdale, Krist, Porcupine, and Three Nation Assemblages as defined in Jackson and Fyon (1991). Additional descriptions of these rock units have been provided by such other authors as Ferguson, et. al. (1968), Pyke (1982), Brisbin (1998), and the references contained therein. Although a detailed division of the stratigraphic units of this area was done at the assemblage level by Jackson and Fyon (1991), many workers in the Timmins camp utilize the broader nomenclature (eg. Tisdale and Deloro Groups) as defined by Dunbar (1948) and modified by Pyke (1982) This broader usage is essentially identical to that of Jackson and Fyon, except for the inclusion of the Krist Assemblage in the Tisdale Group. These regional units are briefly summarized below:

The Tisdale Group consists of: i) a lower portion consisting of mixed ultramafic and Mg-tholeiite mafic metavolcanic rocks that have returned an age date of 2707 Ma, ii) a middle sequence dominated by Fe-tholeiitic basalts capped by two distinctive variolitic units, and iii) an upper sequence consisting dominantly of calc-alkaline felsic pyroclastic rocks (Krist Assemblage, 2698 Ma) with minor amounts of carbonaceous argillite. The Tisdale Group is in fault contact in southern Tisdale Township with the older Deloro Group (2727 Ma) located to the south across the Destor-Porcupine fault zone. The rock types in the Deloro Group are dominantly calc-alkaline basalts, andesites, rhyolitic and dacitic tuffs, chemical sediments (Eldorado Assemblage), and lapilli tuffs. A sequence of clastic sediments (Porcupine Assemblage) conformably overlie the Tisdale Group units, and are in turn unconformably overlain by younger clastic sediments of the Timiskaming Assemblage that are at least 2679 Ma in age. A schematic illustration of the stratigraphy and age dates for the Timmins Camp is given in Figure 3.

All of these units have been affected by at least two periods of folding which have resulted in the formation of basinal structures such as the Porcupine Syncline and minor folds such as the South Tisdale

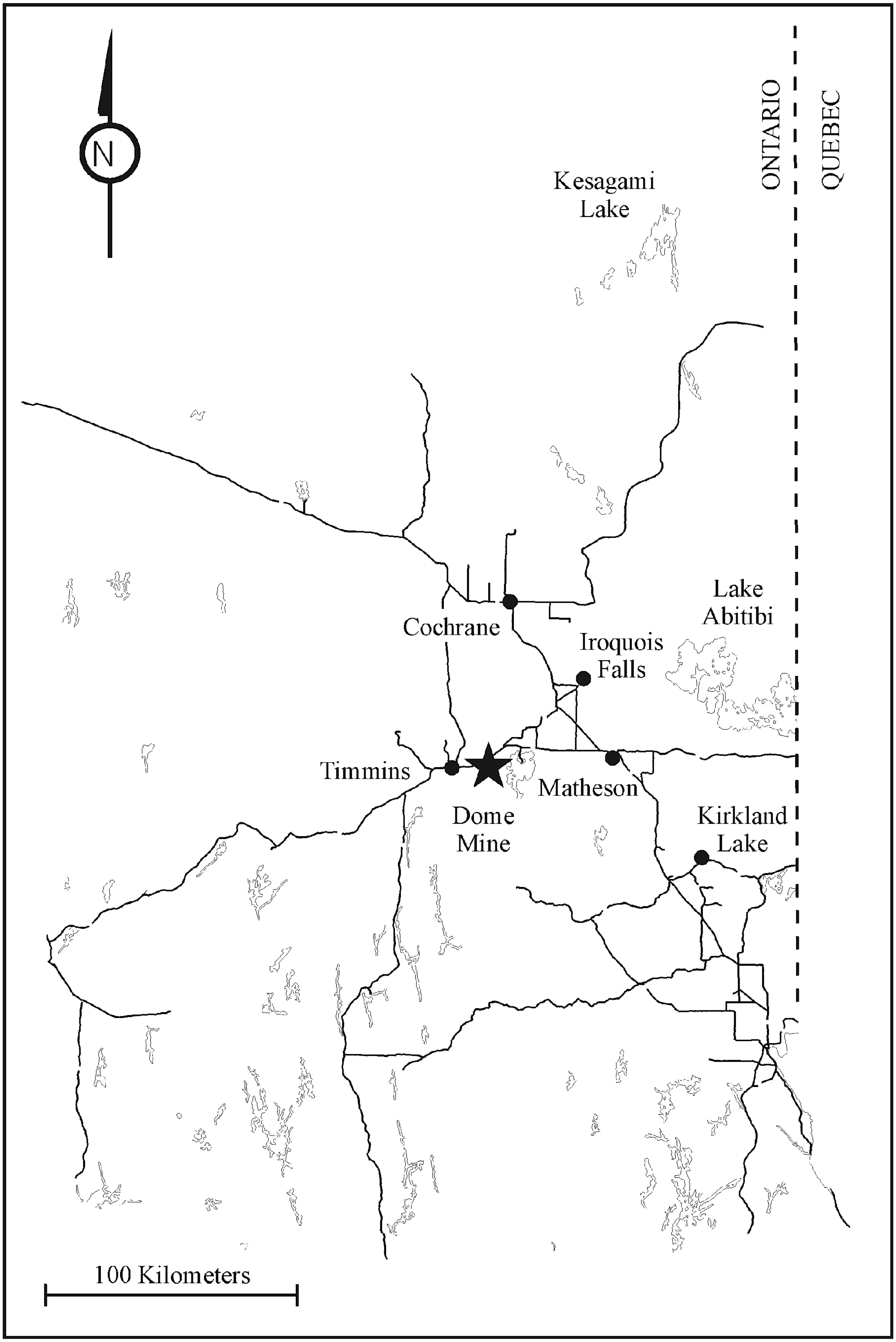


Figure 1. Location Map of the Dome Mine.

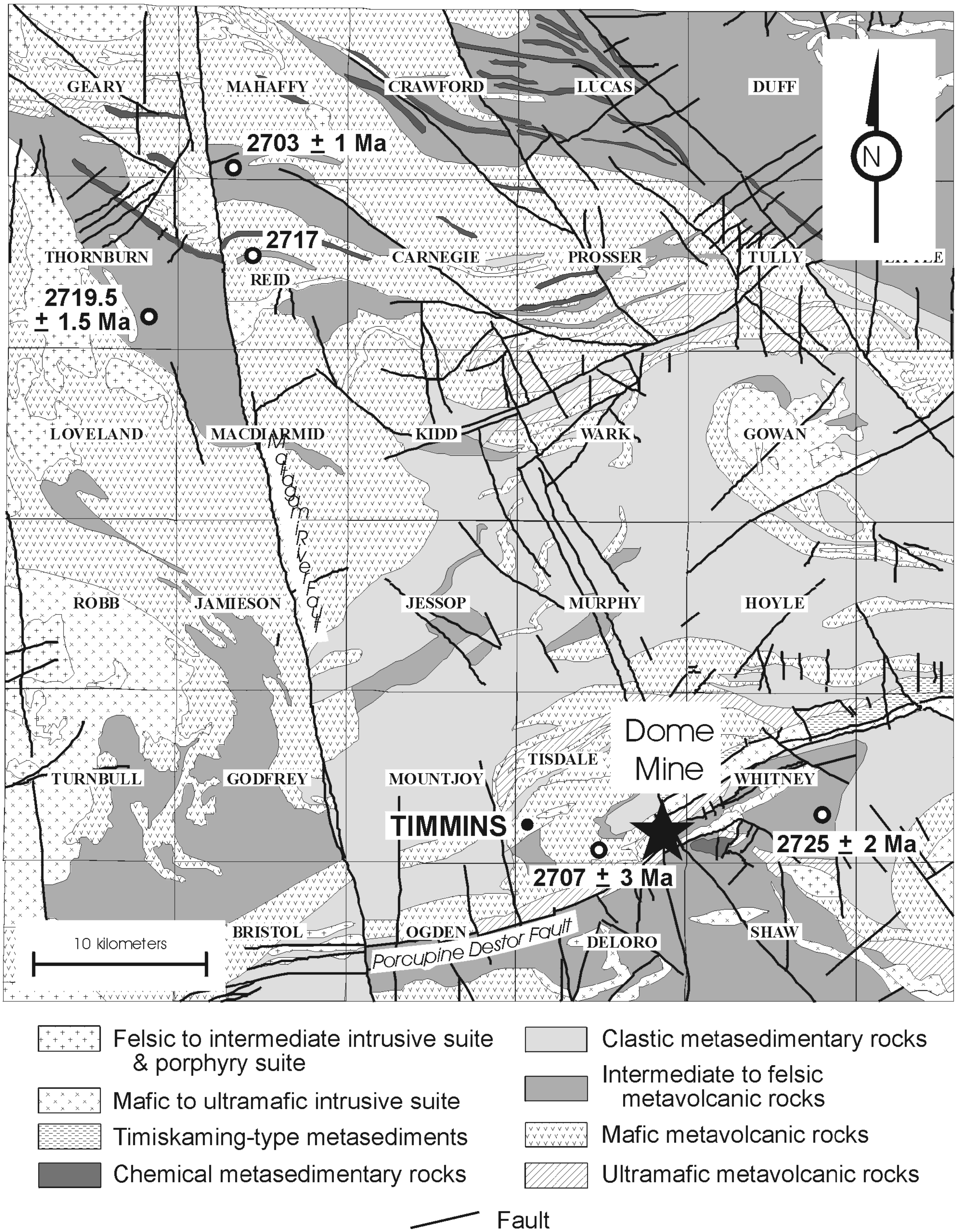


Figure 2. Regional Geological Setting of the Timmins Area (modified from Ayer and Trowell 1998).

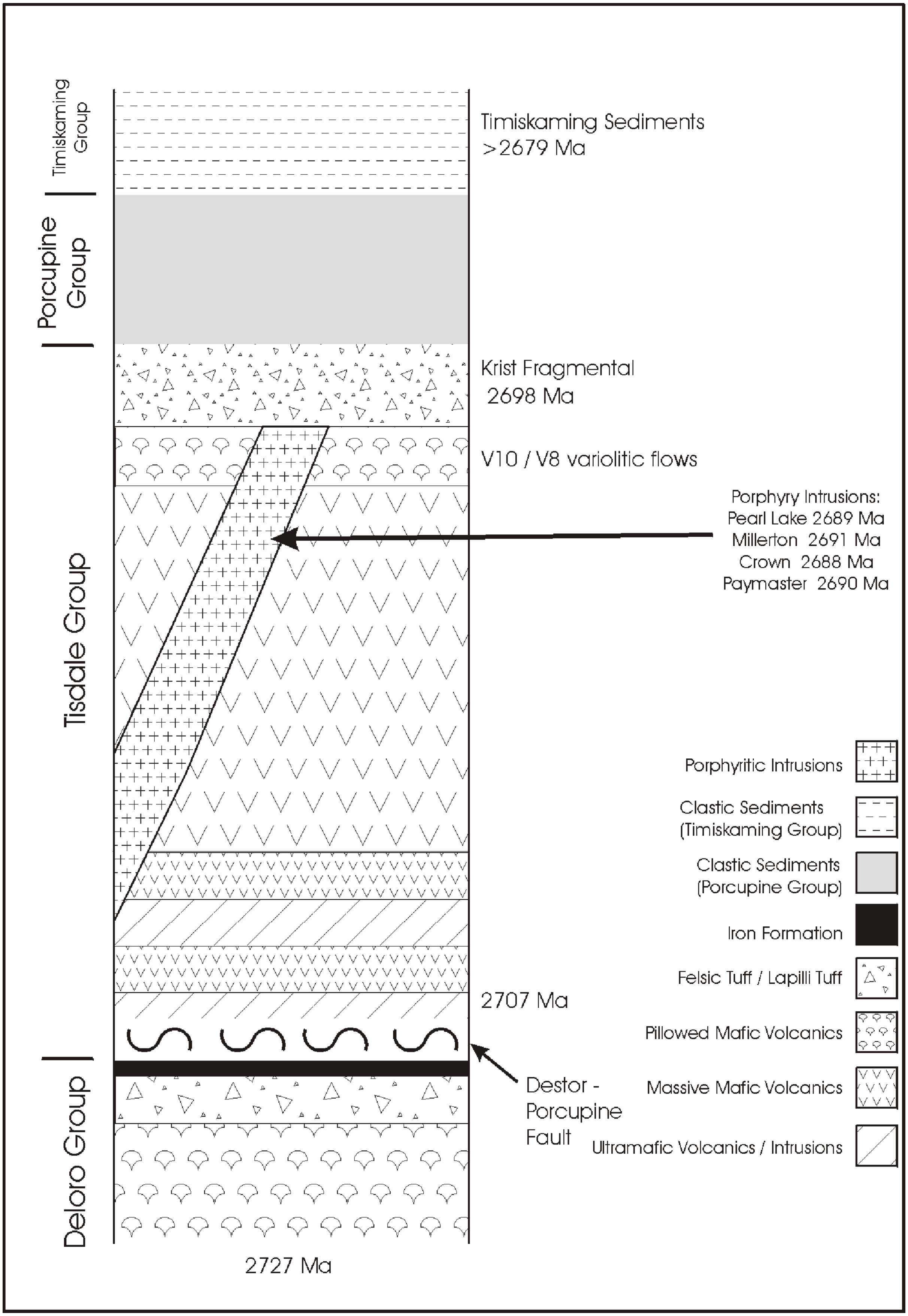


Figure 3. Generalized Stratigraphic Column of the Timmins Camp.

Anticline (Figure 4). These two periods of folding are evident by examination of regional-scale map patterns, and observation of two distinct cleavages in such locations as the Marlhill Mine Project (Barclay 1994). The regional scale fold patterns have been disrupted by a number of fault structures such as the Destor-Porcupine Fault, the Dome Fault, and the Burrows-Benedict Fault.

The Destor-Porcupine Fault is the most significant structure in the area and it consists of a number of zones of shearing and ductile deformation focussed mainly within ultramafic flows and intrusions. The fault is either vertical, or dips steeply to the north, has been traced continuously eastwards to the Duparquet, Quebec area where it splits into the east-trending Manneville Tectonic Zone and the southeast-trending Parforu Lake Fault (Couture 1991). The Destor-Porcupine Fault has an apparent sinistral sense of movement in the Timmins area. A set of brittle faults oriented in a general northwesterly direction is present throughout the region. An example of these brittle faults is the north trending Burrows-Benedict fault which passes through the eastern portions of the mine property. These brittle faults are the youngest structural features in the area and offset all stratigraphic units and older structures. The Dome Mine is located in the hangingwall to the Destor Porcupine Fault, and is in very close proximity (+\- 2 kilometers) to its' surface trace.

PROPERTY SCALE GEOLOGICAL SETTING

Macroscopic Description of Rock Types

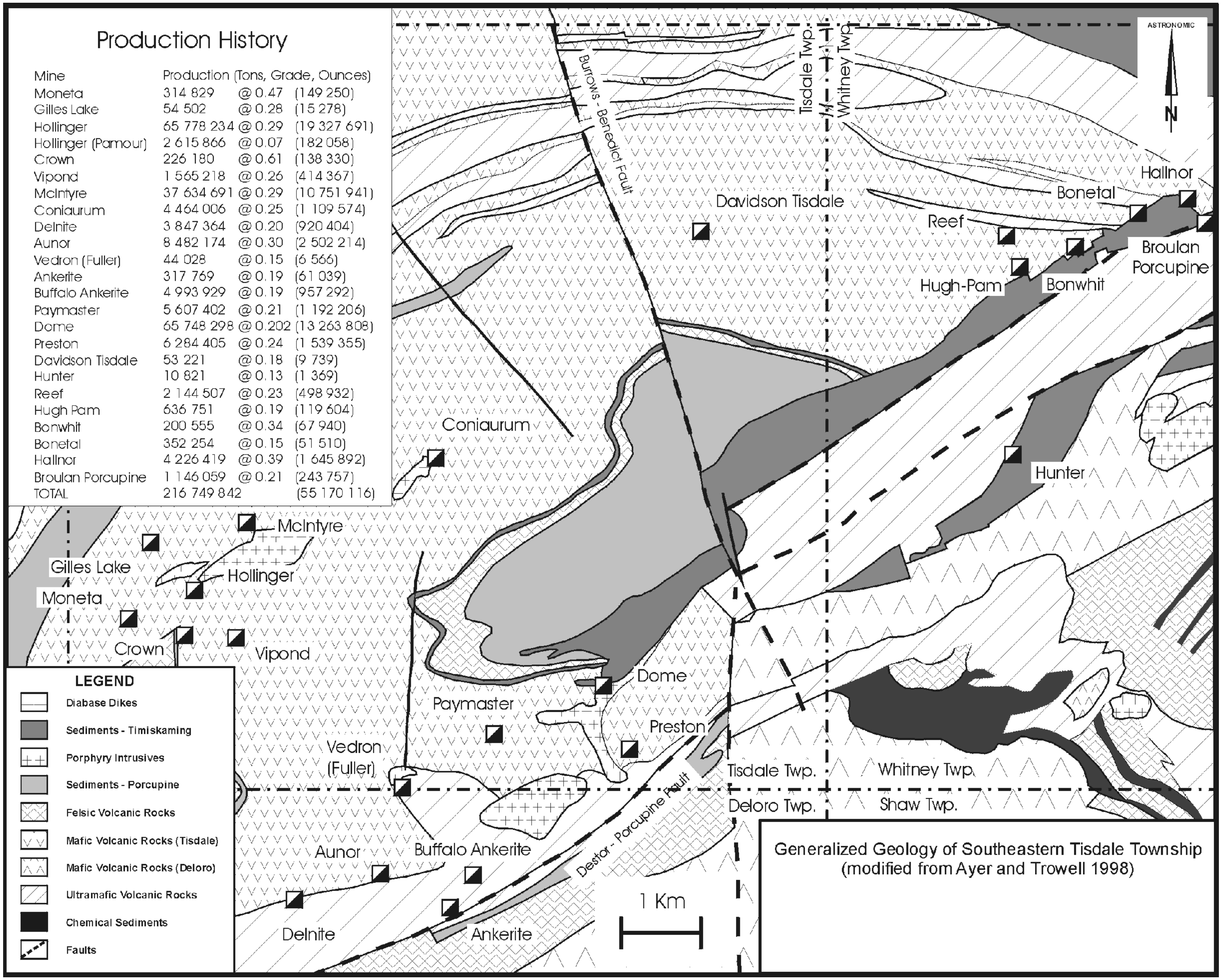
The property scale geologic setting of the Dome Mine property consists predominantly of two structural blocks that are separated by the Dome Fault into a southeastern and northwestern block (Figures 5, 6, and 7). The southeastern structural block has long been recognized as a separate structural member and has been termed the "South Greenstones" by Holmes (1968). This block is separated from units of the Deloro Group to the south and southeast by the Destor-Porcupine Fault. The western and northwestern structural block has not been assigned a distinct name, however the area is known as the "Greenstone Block" on the Dome Mine property. The "South Greenstone" block contains units belonging to the Hershey Lake and Central Formation as described by Brisbin (1998). The term "Greenstone Nose" is used at the mine to describe the contact between the mafic volcanic stratigraphy with the Timiskaming-aged sediments. The "Greenstone Block" contains a more complete stratigraphic section that includes units belonging to the Hershey Lake, Central, Vipond, Gold Center, Krist, Beatty, and Three Nations Formations as subdivided in Brisbin (1998) along with the Paymaster and Preston Porphyries. A comparative tabulation of the mine terminology and the more regional, township scale terminology is given in Table 1. A brief description of the distinguishing characteristics of these regional scale units as described in Brisbin (1998) follows:

Table 1. Comparison between Geological Terms Used at the Dome Mine and the remainder of Tisdale Township.

Mine Terminology	Description	Regional Unit
Greenstone Block - Dacite Flow - Andesite Flow	Massive, pillowed, or variolitic Fe-tholeiites Massive, hyaloclastic mafic flow Massive mafic flow	Central and Vipond Fms, Tisdale Assemblage V10 (c, d) Members, Vipond Fm, Tisdale Assemblage V10 (a , b) Members, Vipond Fm, Tisdale Assemblage
Southern Greenstone	Massive and pillowed Mg-tholeiites	Central Formation, Tisdale Assemblage
Felsic Pyroclastic (Krist Fragmental, Gold Centre Porphyry)	Felsic, calc-alkaline coarse pyroclastic breccia	Krist Assemblage
Conglomerate	Clast-supported polymictic conglomerate	Three Nations Assemblage
Slate / Greywacke	Turbiditic, fine grained argillaceous rocks & greywacke	Three Nations Assemblage
Porphyry	Quartz-porphyritic intrusive rocks	Felsic Porphyritic intrusions
"Carb Rock"	Intensely carbonatized mafic & ultramafic volcanic rocks	No regional correlative unit
"Highly Altered Rock"	Fuchsite-dominated alteration	No regional correlative unit
Matachewan Diabase	Quartz diabase dikes	Matachewan Diabase Dikes

HERSEY LAKE FORMATION

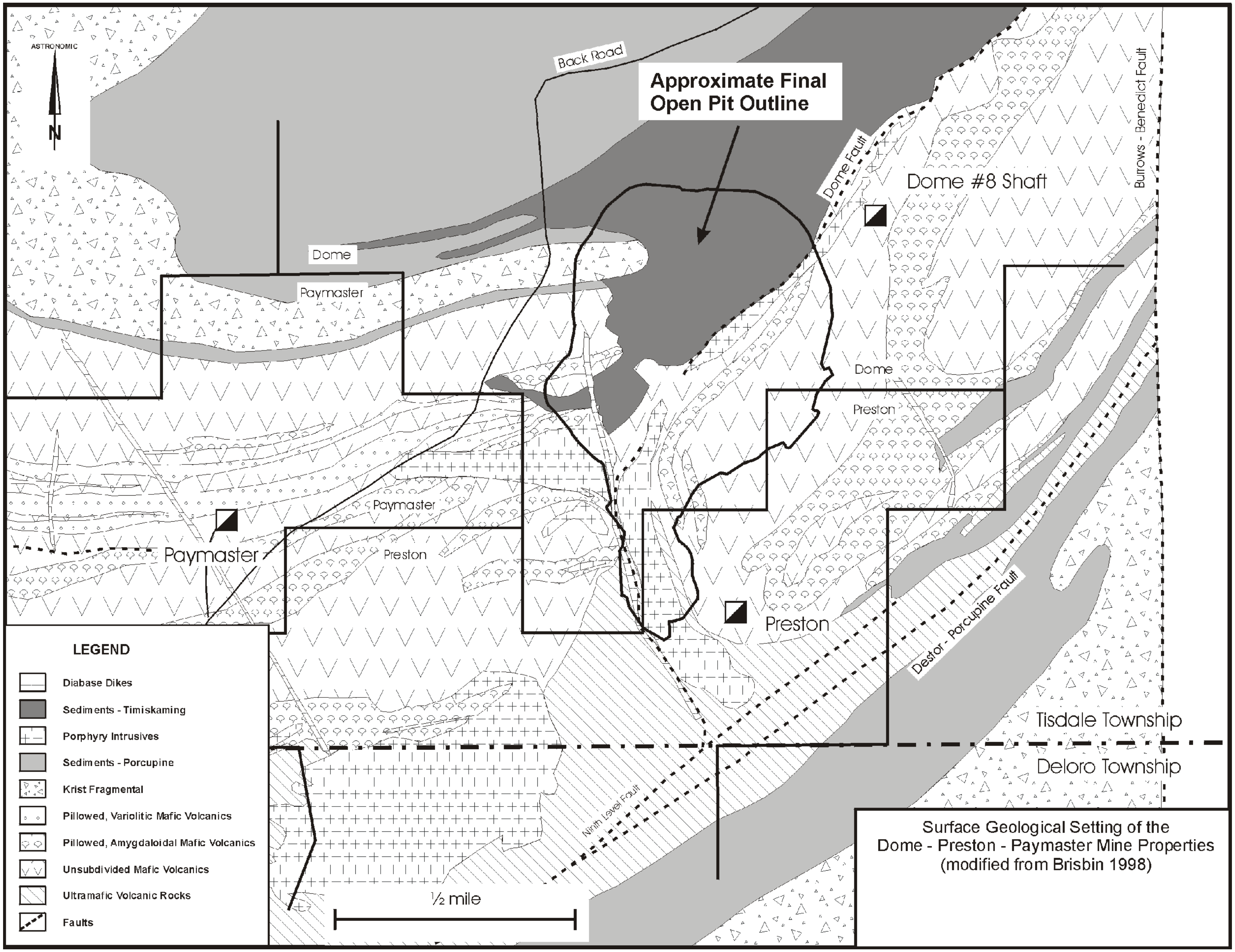
This unit is characterized by the presence of interbedded mafic and ultramafic volcanic flows, and can be traced continuously from the Dome Mine area southwestwards into central Ogden Township, a distance of



Production History

Mine	Production (Tons,	Grade,	Ounces)
Moneta	314 829	@ 0.47	(149 250)
Gilles Lake	54 502	@ 0.28	(15 278)
Hollinger	65 778 234	@ 0.29	(19 327 691)
Hollinger (Pamour)	2 615 866	@ 0.07	(182 058)
Crown	226 180	@ 0.61	(138 330)
Vipond	1 565 218	@ 0.26	(414 367)
McIntyre	37 634 691	@ 0.29	(10 751 941)
Coniaurum	4 464 006	@ 0.25	(1 109 574)
Delnite	3 847 364	@ 0.20	(920 404)
Aunor	8 482 174	@ 0.30	(2 502 214)
Vedron (Fuller)	44 028	@ 0.15	(6 566)
Ankerite	317 769	@ 0.19	(61 039)
Buffalo Ankerite	4 993 929	@ 0.19	(957 292)
Paymaster	5 607 402	@ 0.21	(1 192 206)
Dome	65 748 298	@ 0.202	(13 263 808)
Preston	6 284 405	@ 0.24	(1 539 355)
Davidson Tisdale	53 221	@ 0.18	(9 739)
Hunter	10 821	@ 0.13	(1 369)
Reef	2 144 507	@ 0.23	(498 932)
Hugh Pam	636 751	@ 0.19	(119 604)
Bonwhit	200 555	@ 0.34	(67 940)
Bonetal	352 254	@ 0.15	(51 510)
Hallnor	4 226 419	@ 0.39	(1 645 892)
Broulan Porcupine	1 146 059	@ 0.21	(243 757)
TOTAL	216 749 842		(55 170 116)

Figure 4.



ASTRONOMIC
N
Back Road
Approximate Final
Open Pit Outline
Dome Fault
Dome #8 Shaft
Burrows - Benedict Fault
Dome
Paymaster
Dome
Preston
Paymaster
Paymaster
Preston
Preston
Destor - Porcupine Fault
Ninth Level Fault
Tisdale Township
Deloro Township
½ mile
LEGEND
Diabase Dikes
Sediments - Timiskaming
Porphyry Intrusives
Sediments - Porcupine
Krist Fragmental
Pillowed, Variolitic Mafic Volcanics
Pillowed, Amygdaloidal Mafic Volcanics
Unsubdivided Mafic Volcanics
Ultramafic Volcanic Rocks
Faults
Surface Geological Setting of the
Dome - Preston - Paymaster Mine Properties
(modified from Brisbin 1998)

Figure 5.

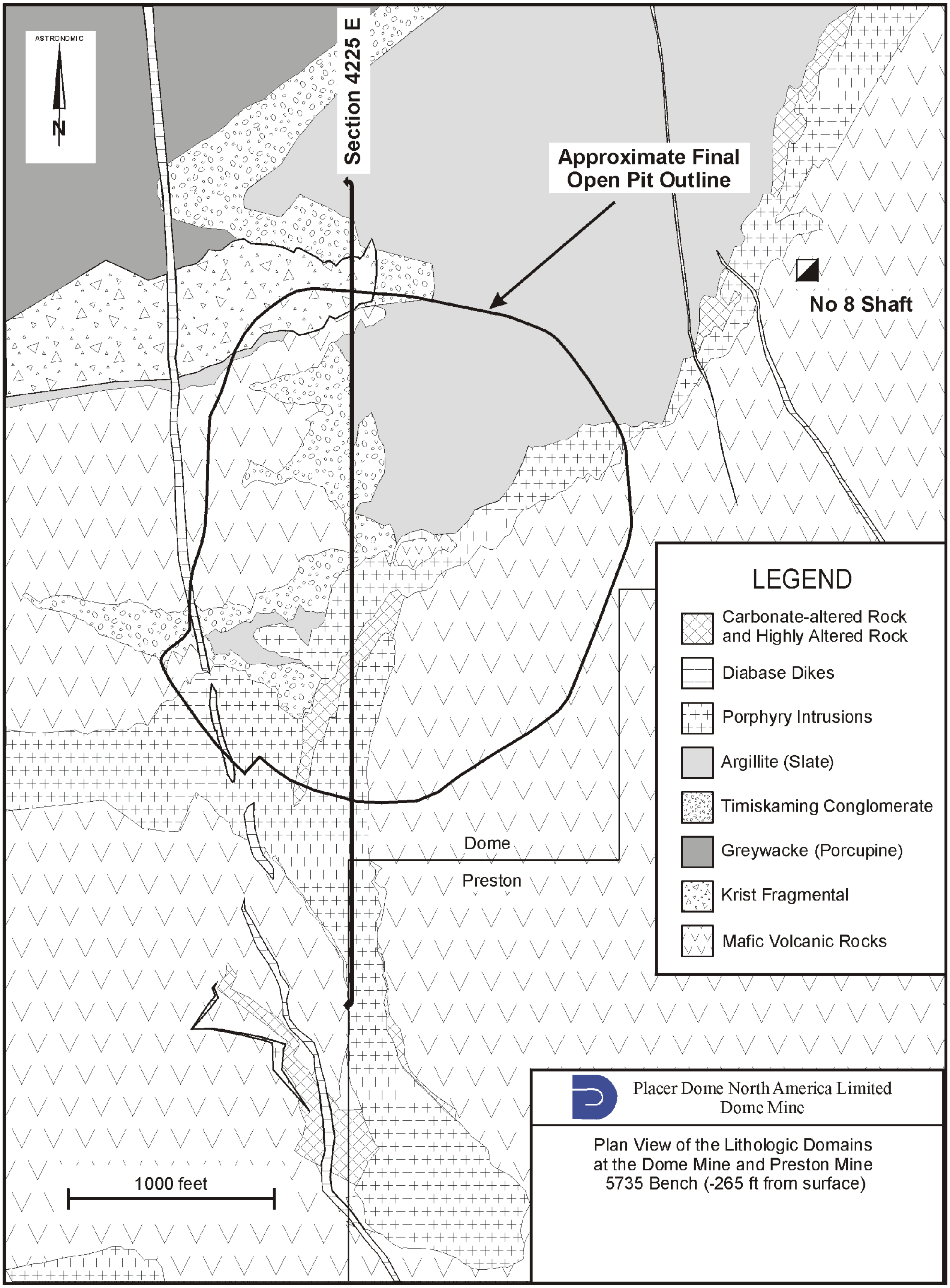
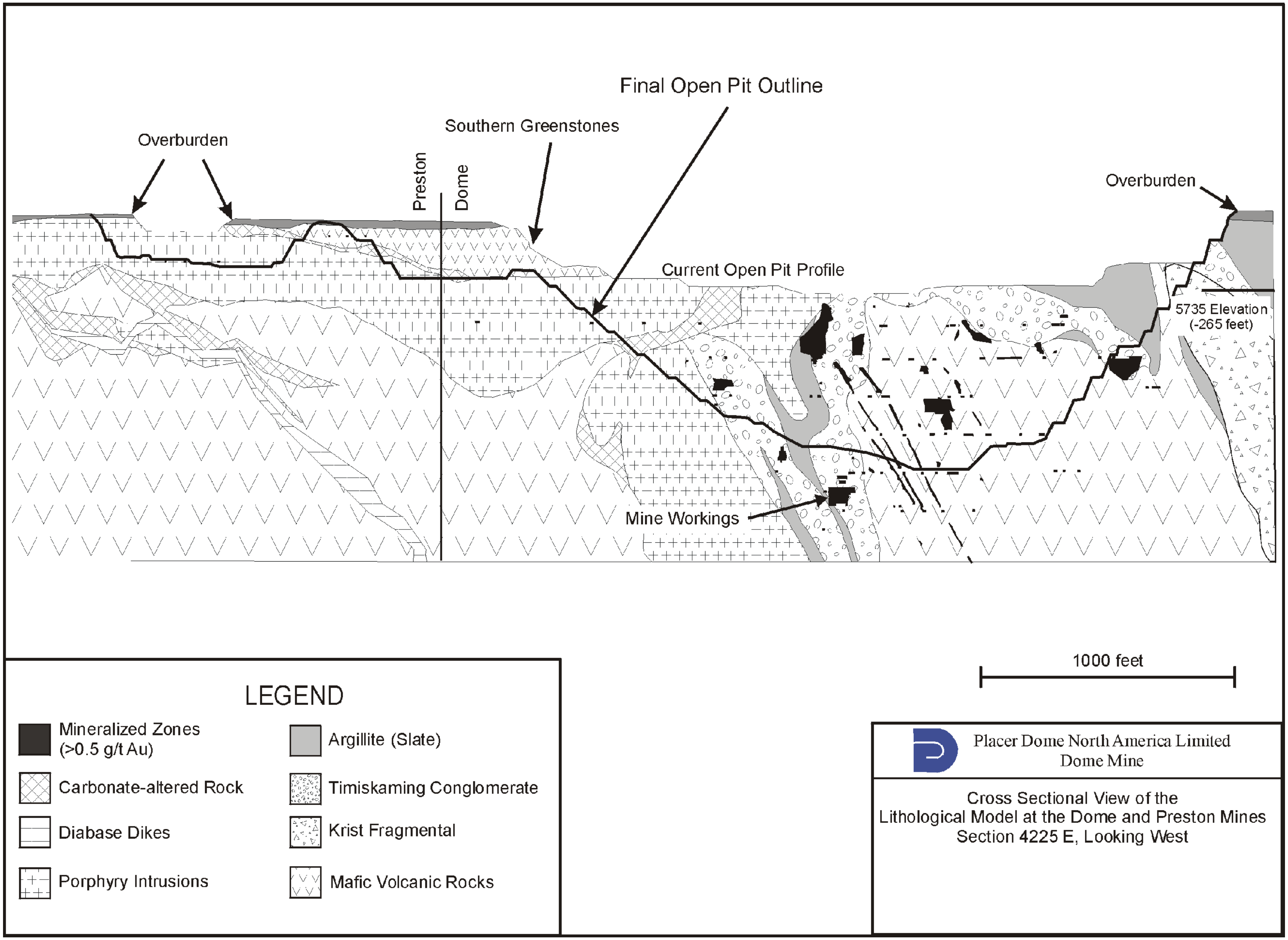

ASTRONOMIC
N
Section 4225 E
Approximate Final
Open Pit Outline
No 8 Shaft
LEGEND
Carbonate-altered Rock and Highly Altered Rock
Diabase Dikes
Porphyry Intrusions
Argillite (Slate)
Timiskaming Conglomerate
Greywacke (Porcupine)
Krist Fragmental
Mafic Volcanic Rocks
Dome
Preston
1000 feet
Placer Dome North America Limited
Dome Mine
Plan View of the Lithologic Domains
at the Dome Mine and Preston Mine
5735 Bench (-265 ft from surface)

Figure 6



Final Open Pit Outline
Southern Greenstones
Overburden
Preston
Dome
Overburden
Current Open Pit Profile
5735 Elevation
(-265 feet)
Mine Workings
1000 feet
LEGEND
Mineralized Zones
(>0.5 g/t Au)
Argillite (Slate)
Carbonate-altered Rock
Timiskaming Conglomerate
Diabase Dikes
Krist Fragmental
Porphyry Intrusions
Mafic Volcanic Rocks
Placer Dome North America Limited
Dome Mine
Cross Sectional View of the
Lithological Model at the Dome and Preston Mines
Section 4225 E, Looking West

Figure 7.

over 10 kilometers. Regional mapping by Pyke (1982) determined that the mafic flows were of tholeiitic composition and that their interbedded association with the ultramafic flows suggested that they were more specifically Mg-tholeiites. Pyke (1982) also recognized two sub groups of ultramafic flows and discriminated them into peridotitic komatiites and basaltic komatiites on the basis of their major element chemistries. The peridotitic komatiites typically weather to a dark grey to orange colour and are either black to very dark green on the fresh surface. While (olivine) spinifex textures are observed only locally, these units more commonly contain polysutured textures. Brisbin (1998) determined that individual peridotitic komatiite flows are very thin, often being only 1-4 meters in thickness. The basaltic komatiite flows contain massive to pillowed textures in addition to weakly developed (pyroxene) spinifex and polysutured textures.

CENTRAL FORMATION

This unit is characterized by interbedded mafic flows that are either massive, pillowed, or pillow breccia textured, and can also be traced continuously from the Dome Mine area southwestwards into central Ogden Township. Folded equivalents of these units can be traced from the Hollinger Mine area northeastwards into northwestern Whitney Township (Brisbin 1998). Both Fe-tholeiitic and Mg-tholeiitic compositions dominate this unit, and the characteristic volcanic features include the presence of pillowed, amygdaloidal flows. The pillows are typically quite small in size with dimensions of 100 cm x 50 cm in plan view and containing pillow selvages on the order of 1-5 cm in thickness. The cores of the pillows typically contain 1 mm sized amygdules that are filled either with calcite, chlorite, or quartz. Pillow breccia fragments can be present either in the interpillow area, or can be so abundant as to be the dominant feature of the flow. Individual pillow breccia fragments are usually irregular in shape and are typically 1-10 cm in size when viewed in plan view. The massive textured flows are generally fine grained and contain tan coloured, subhedral grains of leucoxene.

VIPOND FORMATION

This unit is characterized by mafic volcanic flows that contain distinctive textures dominated by the presence of varioles, and it can be traced continuously from the Dome Mine area around the western nose of the Porcupine Syncline, into northwestern Whitney Township. The unit consists of a number of variably textured individual mafic flows and interflow sedimentary rocks. The two most distinctive sub-units are the V8 and the V10 members that serve as stratigraphic marker horizons in the area. The V8 member consists largely of pillowed, variolitic mafic flows, with individual pillows ranging from 0.5 to >3 meters in length and from 0.25 to 1 meters in width. The pillow selvages are generally 2-10 cm in thickness. The V10 member is itself subdivided into individual units, of which the V10b and V10d units contain abundant varioles. In describing the form and distribution of the varioles, Brisbin (1998) writes:

> "…The V8, and the overlying V10b and V10d, are characterized by the conspicuous presence of white varioles up to 5 centimetres but generally less than 1 centimetre in diameter which stand out against the dark green chlorite and actinolite-rich groundmass of the pillow. The largest varioles tend to occur in the thickest flows (Crick, 1985). Varioles occur both in pillow interiors and in selvages. Those in selvages are generally less than 1 millimetre in diameter. Distribution of varioles within pillow interiors is variable, and pillows exhibiting rim type, central type, and random type distributions occur together on a single outcrop. Masses several centimetres to tens of centimtres across composed of coalesced varioles are often present. Pillow cores are locally composed entirely of coalesced varioles, and concentric bands of coalesced varioles up to 5 centimetres thick are also present. Crick (1985) describes four morphologies of varioles present in Vipond Formation flows exposed in the Dome Mine, which he terms chickenfeed, birdseye, eye-type, and flower-type".

GOLD CENTER FORMATION

This unit forms the uppermost unit of the Tisdale Assemblage, and consists of massive, hyaloclastic, and orbicular textured mafic volcanic flows that are best developed in the area of the Coniaurum Mine. This unit is largely absent on the Dome Mine property.

KRIST ASSEMBLAGE

This unit consists of a basal sedimentary unit composed of carbonaceous argillite and an overlying unit composed of felsic volcaniclastic rocks of calc-alkaline composition. A second bed of carbonaceous argillite is present within the Krist formation, marking a hiatus period in volcanism and indicating that the volcaniclastic rocks were emplaced in two eruptive periods. At the Dome Mine, Krist formation volcaniclastic rocks are capped by a carbonaceous argillite (Roberts 1980, 1981). The felsic volcaniclastic units are dominated by a poorly sorted heterolithic tuff breccia, lapilli tuff, and lapillistone which contain a variety of fragment compositions that are dominated by feldspar-porphyritic tuffs and felsic flows.

The intercalation of the argillites and volcaniclastic units argues strongly for a subaqueous environment of deposition for the volcaniclastic deposits, as does the presence of pillowed mafic flows underlying the Krist formation and turbidities overlying it.

PORCUPINE ASSEMBLAGE

This unit consists entirely of fine clastic sedimentary rocks, and is largely restricted to the central portions of the Porcupine Syncline. The sediments consist of rhythmically interbedded wackes and argillites that are characteristic of turbiditic deposits formed in a lower mid-fan to outer fan depositional environment (Brisbin 1998).

THREE NATIONS ASSEMBLAGE

This unit is composed entirely of clastic sedimentary rocks and is the youngest stratigraphic unit in the Timmins area. The unit typically grades from a polymicitic conglomerate in the basal portions through massive and cross-bedded sandstones to argillites in the upper portions of the sequence. Clast compositions of the conglomerates are highly variable, containing fragments of mafic and ultramafic volcanic rocks, porphyry intrusions, felsic volcanic rocks, and graphitic sediments. Of particular note is the presence of pebbles of smoky to white coloured quartz veins, and the most distinctive feature is the presence of clasts of massive pyrite. The absence of clasts of granitic composition is noteworthy and is one of the features used in discriminating these units from Huronian aged sediments. Other distinctive features of these units are the quartz-rich nature of the sediments, and the common presence of clasts of jasper iron formation. Brisbin (1998) concluded that these sediments were deposited in a deltaic, intertidal environment.

FELSIC PORPHYRITIC INTRUSIONS

Several porphyritic intrusive bodies of calc-alkaline composition are present on the mine property (eg. the Paymaster, Preston, and Dome porphyries), of which the Paymaster and Preston porphyries are the two largest. A number of smaller porphyry bodies are also present on the adjoining Preston Mine property such as the West Porphyry, the Center Porphyry, and the Lower West Porphyry as described in Ferguson et. al. (1968). All of these porphyries are similar in composition and typically contain quartz and plagioclase phenocrysts set in a very fine grained groundmass of intergrown quartz and plagioclase crystals. The plagioclase phenocrysts are typically subhedral to euhedral and range in size from 0.5-2 mm. The quartz phenocrysts are anhedral, are 0.3-3mm in size, and may constitute up to 20% of the rock mass. The character of the Paymaster and Preston porphyries differs in the presence of inclusions of country rock and the amount and nature of pyrite. The Paymaster porphyry is characterized by the inclusion of 1-3% small (1-10mm) clasts of the country rock, typically of ultramafic composition. No country rock clasts were observed in the Preston porphyry by Brisbin (1998). The Paymaster porphyry was observed by Brisbin (1998) to contain <1% pyrite that occurred as fine grained disseminations and fracture controlled veinlets. The pyrite content of the Preston porphyry was observed to range from trace amounts in the southern end up to 2% fracture controlled pyrite in the northern end. No economic concentrations of gold have been located in the Paymaster porphyry to-date. The Preston porphyry however has been a major host to the historic gold production from the Preston Mine, and its' northern portion is currently being mined by open pit and underground mining methods and was the source of approximately 25% of the underground production in 1998. Both the Paymaster and Preston porphyries have been affected by development of a penetrative fabric termed a quartz-sericite schist (QSS) texture by Brisbin (1998). This fabric is developed as a complete alteration of the original mineral composition to an assemblage of carbonate and sericite. The sericite is typically fracture-controlled, with the fractures defining a moderate to strong, spaced, anastomosing cleavage.

"CARB ROCK" AND "HIGHLY ALTERED ROCK"

These two units were first described by Holmes (1968) and remain in general usage at the Dome Mine with some slight updates. The term "Carb Rock" is used to describe intensely carbonatized material occurring mostly within the Dome Fault on the Dome Mine property, and as envelopes surrounding the Preston Porphyry on the Preston Mine property. The primary mineralogy of this "Carb Rock" has been determined to be magnesite, with lesser amounts of ankerite, which alters the mafic and ultramafic volcanic protoliths to a light brown-grey to buff colour. Locally developed schistose textures with chloritic slips may be present, and pyrite commonly occurs near the contacts of the alteration envelope.

The term "Highly Altered Rock" was originally used to describe any other severely altered rock types other than the "Carb Rock". The definition has since been slightly modified in 1997 to describe fuchsitic-altered rocks which occur along and within the Dome Fault. These fuchsitic-altered rocks can occur along the contacts of the "Carb Rock", the porphyry intrusions or within the greenstones of the Dome Fault. Occurrences of "Highly Altered Rock" are also present on the Preston Mine property, occurring in two flexures on the hangingwall of the Preston Porphyry.

MATACHEWAN DIABASE DIKES

Diabase dikes of the Matachewan swarm are present on the Dome Mine property. A single 30 foot wide dike is present along the western wall of the open pit mine, and several smaller, narrow dikes that cross cut the Dome Fault are also present in the Blueberry Hill area, northeast of the Number 8 Shaft. All dikes trend in a north-northwesterly orientation.

Macroscopic Description of Alteration Types and Assemblages

All rock types at the mine have some degree of alteration developed, with four principal types of alteration being recognized. Carbonatization and sericitization are the two dominant alteration types, with silicification and chloritization being developed to a lesser degree. The alteration is most strongly developed in the Preston Porphyry where it occurs as strongly developed "apple green" sericitization immediately adjacent to gold-bearing veins, and as an alteration halo around groups of veins. This alteration is essentially barren of gold mineralization. Minimal alteration is associated with gold mineralization away from the Preston Porphyry, as individual quartz veins are typically lacking of visible alteration halos. However some of the closely spaced quartz veins in the "Dacite Flow" contain alteration halos that are locally described as "bleaching" and which may penetrate up to 2 to 3 feet into the vein walls. This alteration is also barren of gold mineralization. A similar "bleaching" style of alteration is observed in association with the Ankerite Veins. Only the higher grade veins contain this alteration selvage which contains fine grained euhedral pyrite and minor amounts of chalcopyrite. Significant gold values are present when these sulphides occur in the alteration halos. These four alteration types have been described by Placer Dome Exploration (1997) as follows:

> "Intense carbonatization, in the form of ankerite, is associated with all of the mineralization at Dome Mine. Magnesite predominates within the Dome Fault and the associated mineralization is generally weak. Away from the Main Pit and Blueberry Hill areas, the carbonate grades from ankerite to ferroan dolomite, and then to calcite, which eventually disappears completely. Carbonatization generally occurs as halos of intense alteration adjacent to quartz and ankerite veins, where it extends up to a few feet into the wall rock. Alteration halos around quartz veins are wider, whereas those around ankerite veins tend to be narrower, extending only a few feet into the wall rock. The halos have a bleached appearance, are pale green to grey, and are composed mostly of ankerite and sericite with lesser quartz and accessory minerals.
>
> Sericitization occurs in porphyry and accompanies ankerite in carbonatized greenstone. Sericitization is strongest in sheared porphyry where it forms large zones that commonly contain quartz veins. Sericitized porphyry has a shiny-waxy appearance and is composed of sericite with lesser carbonate, quartz and chlorite, and accessory minerals.

Silicification occurs primarily as quartz veins, which are discussed in the section on mineralization. Pervasive silicification is difficult to identify and may be more widespread than recognized. An isolated lens of silicified greenstone occurs within the Dome Fault between the Main Pit area and the Blueberry Hill area. It is characterized by extensive bleaching, lack of quartz veining, and a pyrite-gold association. Its alteration and mineralization styles are different from those in the Main Pit area.

Chloritization is common in basalt. It is especially intense along and adjacent to zones of intense carbonatization, where the chlorite is accompanied by calcite."

Lithogeochemical Data

A search of available literature has discovered only limited lithogeochemical data that describes the major- and trace-element abundances of the rock types found on the Dome Mine property. A study of the alteration patterns and metal distribution at the Dome Mine was conducted by Fryar et. al., (1979) and their results are summarized in Tables 2a and 2b below. Additional lithogeochemical data is presented in Roberts and Reading (1981).

Table 2a. Major element abundances of selected samples from the Dome Mine property (modified from Fryar, et. al., 1979).

Sample ID	Rock Type	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	MgO (%)	CaO (%)	K2O (%)	Na2O (%)	P2O5 (%)	LOI (%)
1A	Metabasic Schist	53.26	- -	11.80	12.69	- -	4.69	4.51	1.35	0.20	0.05	9.45
1H	Metabasic Schist	62.42	1.12	9.39	11.56	0.19	4.04	5.73	1.76	0.08	0.09	3.59
2H	Metabasic Schist	41.66	1.58	18.39	8.15	0.15	6.07	2.49	2.61	0.21	0.11	7.62
5H	Metabasic Schist	51.78	1.55	14.62	14.97	0.27	4.49	2.15	2.30	0.18	0.05	7.01
7H	Metabasic Schist	70.69	0.89	15.33	11.48	- -	0.78	0.92	0.77	0.18	- -	0.20
10H	Metabasic Schist	31.08	2.34	27.39	18.50	0.18	9.29	0.32	3.65	0.28	0.52	7.50
D3	Wk. Min. Andesite	52.53	1.47	12.10	14.53	0.21	2.45	5.40	0.73	- -	0.41	8.01
D4	Wk. Min. Andesite	49.78	1.27	9.22	12.74	0.33	3.24	8.63	2.21	- -	0.52	13.45
D11	Wk. Min. Andesite	54.61	1.40	12.62	15.00	0.21	2.14	5.46	0.70	2.10	0.42	8.44
D12	Wk. Min. Andesite	52.69	1.32	10.00	14.40	0.29	2.73	5.63	1.54	- -	0.51	9.28
D2	Min Andesite	37.59	1.51	11.34	27.05	0.43	4.92	7.16	1.16	- -	0.56	7.72
D7	Min Andesite	54.23	1.57	12.03	13.73	0.17	2.72	3.85	2.14	- -	0.62	7.31
D8	Min. Andesite	40.31	1.20	8.97	22.27	0.54	5.43	9.38	0.59	- -	0.48	10.39
D5	Unmin. Dacite	66.19	0.53	8.42	9.87	0.20	1.31	3.53	1.40	- -	0.08	7.28
14H	Timiskaming Slates	53.93	0.99	20.59	6.96	0.08	3.07	2.01	4.02	2.18	0.19	5.47
15H	Timiskaming Slates	52.04	0.93	20.81	7.27	0.09	3.45	2.70	3.53	2.93	0.18	7.03
B15	Timiskaming Slates	58.80	0.95	19.27	7.13	- -	2.91	0.49	2.87	- -	0.16	6.49
B6	Timiskaming Slates	50.82	0.52	9.43	12.08	0.47	3.82	7.38	1.24	0.44	0.09	12.86
21H	Preston Porphyry	61.53	0.34	16.10	3.30	0.05	1.85	3.64	1.31	6.74	0.08	6.26
35LH	Preston Porphyry	70.18	0.24	15.14	1.94	0.03	0.84	1.76	1.34	6.90	0.50	2.73

Table 2b. Trace element abundances of selected samples from the Dome Mine property (modified from Fryar, et. al., 1979).

Sample ID	Rock Type	Au (ppm)	Cr (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Ba (ppm)
1A	Metabasic Schist	1.10									
1H	Metabasic Schist		23	14	14	326	29	48		86	86
2H	Metabasic Schist	0.26	88	63	200	280	56	46		143	161
5H	Metabasic Schist	6.4	80	47	167	153	52	50		126	184
7H	Metabasic Schist	5.0					43	54		74	81
10H	Metabasic Schist	2.4	133	37	65	264	85	34	56	190	320
D3	Wk. Min. Andesite	0.030	68	- -	11	40	16	58	62	162	105
D4	Wk. Min. Andesite	0.030	28	- -	- -		43	191	0.6	128	407
D11	Wk. Min. Andesite	0.010	19	- -	- -	262	16	23	10	78	1
D12	Wk. Min. Andesite	0.042	37	- -	- -	53	17	58	62	157	93
D2	Min. Andesite	1.20	- -	- -	- -	137	7	87	12	22	15
D7	Min. Andesite	2.10	17	- -	10	316	31	34	50	110	122
D8	Min. Andesite	2.90	13	- -	- -	75	36	35	91	264	69
D5	Unmin. Dacite	0.003	16	- -	53	88	20	43	40	90	106
14H	Timiskaming Slates	1.6	168	108	87	67	112	215	13.5	161	731
15H	Timiskaming Slates	7.3	168	97	75	86	80	146	13.2	138	651
B15	Timiskaming Slates	7.4	193	115	49	108	96	253	10.7	142	650
B6	Timiskaming Slates	18.4	101	160	184	332	28	151	19.6	82	183
21H	Preston Porphyry	0.12	23	18	8	39	34	461		96	333
35LH	Preston Porphyry	0.22	24	67	10 918	87	13	5.1	6.5	25	- -

STRUCTURAL GEOLOGY

Stratigraphy

As mentioned above, the distribution of the geologic units in and about the immediate vicinity of the mine property are defined by two structural blocks. The units in the “Greenstone Nose” block (eg the Hersey Lake, Central, and Vipond Formations, and the Krist and Porcupine Assemblages) face north on the Dome Mine property, generally dip steeply north at 65-80°, and are folded about the Porcupine Syncline. Brisbin (1998) determined stratigraphic younging directions by the use of such features as the transition of flow top breccia into interflow sediments or the chilled base of the succeeding flow, shapes of pillow tails in outcrops of low strain, spinifex textures in ultramafic flows, and graded bedding, and channel scours. However he states that:

> “Comparison of a succession of flows and/or strata being mapped against established sections was a major aid in making stratigraphic correlations and younging determinations. The laterally persistent, texturally distinct V10b and 95c hyaloclastitic flow top breccias proved to be invaluable, not only as structural markers, but also as indicators of stratigraphic position… .”

On the basis of these criteria, Brisbin (1998) has interpreted that an essentially complete stratigraphic succession is present along the southern limb of the Porcupine Syncline in the “Greenstone Nose” block, from the basal Hersey Lake Formation ultramafic volcanic rocks through to the Porcupine Assemblage sedimentary rocks. The Porcupine Syncline is a basinal fold feature resulting from a Type I interference pattern, and is broken into a western and eastern block by the Burrows-Bennedict Fault. The F1 axial plane of the syncline within the western block is interpreted to trend in a northeasterly direction. The orientation of the F1 fold axis was determined to plunge to the northeast by Piroshco and Kettles (1991).

The distribution of the stratigraphic units of the “South Greenstone” suggest that these units form a tightly folded succession that strikes in a northeasterly direction, and dips steeply to the southeast. Limited facing determinations and fold axes observed by Brisbin (1998) supports the interpretation that the units are folded into an F1 synclinal fold that is plunging to the northeast at 38-46°. The geologic units that dominate this area are ultramafic volcanic rocks that are correlateable to the Hersey Lake Formation, and massive and pillowed mafic volcanic rocks that are correlateable to the Central Formation.

Stratigraphically overlaying the units of the “Greenstone Nose” block are sedimentary rocks of the Three Nations Assemblage. These units strike in a general northeasterly direction and have been observed by Brisbin (1998) to face south, and dip steeply to the south at 60-80°. This reversal of younging and dip directions from the units of the "Greenstone Nose" suggests that these sediments are in an unconformable relationship with the underlying strata. The unconformable relationship between units of the PorcupineAssemblage and the Three Nations Assemblage is exposed in east-central Tisdale Township where an angular unconformity clearly demonstrates that a major structural reorientation took place following deposition of the Porcupine Assemblage units. No such dramatic unconformity is observed on the Dome Mine property, however the presence of tightly folded Porcupine Assemblage sedimetary rocks exposed in the open pit mine supports this concept (Photo 1).

The felsic porphyritic intrusions on the mine property such as the Paymaster and Preston Porphyries have been emplaced such that they cross-cut and intrude the units of the Hershey Lake and Central Formations. Both of these bodies plunge to the east-northeast at 50-60°, and remain in close spatial proximety to each other but separated by the Dome Fault and Carb Rock down to at least the 30 level (Approximately 4200 feet below the shaft collar, Ralph Koch, personal communication).

Limited geochronological data has been obtained from the stratigraphic units of the area. A sample taken from a dunite intrusive into the upper Deloro Formation in Shaw Township by Corfu et. al. (1989) returned an age date of 2707 +/- 2 Ma which Pyke (1982) interpreted to be the intrusive equivalent to the Hershey Lake Formation. This interpretation is in close agreement with the age date by Ayer, et. al. (1997) of 2707 +/- 3 Ma from the 99 Flow, a unit that is present in the central portions of the Vipond Formation. Corfu et. al. (1989) also determined the Krist Assemblage to have an age date of 2698 +/- 4 Ma, and that both the Paymaster and Preston Porphyries had an age of 2690 +/- 2 Ma. Corfu et. al. (1991) found that detrital zircons recovered from the Three Nations Assemblage had age dates of 2679 +/- 4 Ma.

Faults and Shears

Three main faults are present in the vicinity of the mine property (the Destor-Porcupine, Dome, and Burrows-Benedict Fault), and they control the distribution of the geologic units in this area. The Destor-Porcupine Fault is the most extensive feature in the area and consists of a regional scale fault zone

Photo 1. Faulted, and tightly folded sediments of the Porcupine Assemblage, 5735 Bench, Dome open pit, looking east.

that can be continuously traced from the Timmins area eastwards to the Duparquet area of Quebec, a distance of some 150 kilometers. The fault has been described by Pyke (1982) as a shear zone which is at least 150 meters in width, and which is intimately associated with ultramafic volcanic rocks. In the area of the Dome Mine, the Destor Porcupine Fault has a general northeast strike, and dips steeply to the north.

The Dome Fault is an enigmatic but important structural feature on the mine property and has been described by Brisbin (1998) as:

> "A northeast striking fault with an arcuate subvertical dip (steep south near surface, steep north at depth) inferred to form the southern boundary of Timiskaming sedimentary rocks present on the Dome Mine property was referred to as the Dome fault by Davies (1977). The actual fault surface cannot be identified in underground exposures at the Dome Mine where it is thought to have been obscured by subsequent porphyry intrusion and alteration …
>
> The main evidence for the existence of the fault, as first noted by Holmes (1968), is that Timiskaming sedimentary rocks north of the fault face south toward older Tisdale Group mafic volcanic rocks on the south side of the fault. The fault zone is now occupied by a melange of porphyries, carbonatised serpentinites, talc-chlorite schists, and Timiskaming sedimentary rocks. Along this zone regional 110° cleavage azimuths have been transposed parallel to the inferred fault. The Quartz-Fuchsite vein and Quartz-Tourmaline vein at the Dome Mine occur within a strongly carbonatised and sericitized section of this melange referred to as the "Highly Altered Zone" (Holmes, 1968)…
>
> Timiskaming strata are truncated by the Dome Fault, thus indicating that movement on the fault in part post-dates Timiskaming sedimentation. The timing of movement along the fault relative to intrusion of the porphyry dyke that roughly follows its trace in uncertain…
>
> West of the "Highly Altered Zone", the inferred trace of the Dome fault is defined by a talc-chlorite schist interval that separates the Preston and Paymaster porphyries (Holmes, 1968). To the south, a 90 metre wide zone of intense schistosity, known as the Footwall fault, is present along the west side of the Preston porphyry (Butterfield, 1941; Hawley and Hart, 1948)"

The Burrows-Benedict Fault trends in a northerly direction in the area of the mine property and displaces the Destor-Porcupine and Dome faults by approximately 1.5 kilometers in a left-lateral sense of movement (Pyke 1982). This fault intersected in diamond drill core on Pentland Firth Ventures Limited south-central Murphy Township property where it consisted of a broad zone of clay-filled fault gouge and very blocky ground at least 100 meters in width (Ken Tylee, pers. com). This fault forms part of a broader system of northerly trending faults belonging to the Ottawa-Bonnechere Fault System.

ECONOMIC GEOLOGY

Production History

Gold was produced from the Dome Mine in 1910 and 1911 in small quantities until the mine entered into full production in 1912 and produced 35 515 ounces of gold that year. Except for an interruption due to World War I, the mine has been in continuous production and has produced a total of 13 263 808 ounces of gold and 2 351 665 ounces of silver as at December 31, 1997 (M. Shannon, Placer Dome North America Limited, written communication, 1998). A detailed summation of the annual production history of the mine for the 1910 – 1981 period is provided in Girdwood, et. al. (1983). A detailed summation of the annual production for the 1982 – 1997 period is given in Table 3, and a summary of the mineral inventory is given in Tables 4 and 5.

Table 3. Summary of Gold and Silver Production from the Dome mill. Note that the 1998 production includes some ore from the Preston property. Data for the 1982 – 1998 period provided courtesy of M. Shannon, Chief Geologist, Placer Dome North America Limited.

Year	Tons Milled	Mill Head Grade - Au (Oz / ton)	Recovered Grade - Au (Oz / ton)	Recovered Ounces Au	Recovered Ounces Ag
1910-1981	39 355 914		0.270	10 625 382	1 889 467
1982	707 600		0.120	85 201	14 501
1983	762 400		0.132	138 006	19 286
1984	860 000		0.138	118 476	18 791
1985	1 028 100		0.122	125 797	19 329
1986	1 060 100	0.134	0.129	137 023	19 659
1987	1 087 100	0.126	0.121	132 017	23 951
1988	1 131 800	0.101	0.097	109 890	17 578
1989	1 315 500	0.114	0.110	144 135	24 319
1990	861 800	0.098	0.093	79 987	13 374
1991	1 267 200	0.119	0.114	144 681	25 370
1992	1 507 800	0.121	0.115	172 997	32 962
1993	1 616 400	0.119	0.115	185 082	36 295
1994	1 691 400	0.108	0.103	175 017	33 041
1995	3 041 286	0.089	0.084	256 204	47 421
1996	4 224 629	0.077	0.072	305 183	57 859
1997	4 229 269	0.084	0.078	328 729	58 462
1998	4 591 426	0.077	0.072	328 939	59 591
TOTAL	**70 339 724**		**0.193**	**13 592 747**	**2 411 256**

Table 4. Summary of Reserves and Resources at the Dome Mine as at Dec. 31, 1998. Note that the Ore Reserve category includes material on a fully diluted basis, and that the total mineral inventory includes gold mineralization located on the adjoining Paymaster and Preston Mine properties. Both Ore Reserves and Mineralization are estimated on the basis of a gold price of $US 350 / oz. Data modified from information provided on the Placer Dome North America Limited web site (http://www.placerdome.com) as of November, 1998 and from data provided courtesy of Mort Shannon, Chief Geologist, Placer Dome North America Limited.

Category	Tons	Grade (Oz / ton Au)	Contained Ounces Au
Ore Reserves	36 989 000	0.055	2 029 000
Mineral Resources			
- Measured and Indicated	34 913 941	0.073	2 523 000
- Inferred	4 895 837	0.081	395 000

Table 5. Split of Reserves Between Open Pit and Underground Mines at the Dome Mine as at Dec. 31, 1998. Data provided courtesy of Mort Shannon, Chief Geologist, Placer Dome North America Limited

Source	Tons	Grade (Oz / ton Au)	Contained Ounces Au
Underground	4 486 000	0.113	505 000
Open Pit	32 503 000	0.047	1 524 000
TOTAL	**36 989 000**	**0.055**	**2 029 000**

Mining Methods

Both open pit and underground mining methods are utilized at the Dome Mine. Mining of the open pit began in 1988, and was significantly increased in 1994 with implementation of the open pit expansion. Open pit mining operations began on the Dome Mine property in 1988 and was centered about the Sedimentary Trough. The open pit has since been expanded southwards in 1998 such that in now includes a portion of the Preston Porphyry on the Preston Mine property. The Open Pit mine produced ore at the rate of 8 000 tonnes per day (8 900 tons per day) at an overall strip ratio of 7:1 and a breakeven cut-off grade of 0.5 g/t gold (0.015 oz/ton gold) in 1997. The open pit was designed with the inter-bench slope angles averaging 52°, the grades of the haulage ramps to be 10%, and the bench heights to be 9.2 metres (30 feet). The underground mine is accessed via the No. 8 Shaft which extends to a depth of –1650 metres (-5413 feet). A number of underground mining methods have been employed over the mine’s long life, but only longhole (open stoping) and cut-and-fill methods are currently in use. The underground mine contributed an average of 2 600 tonnes of ore per day to the mill (2 900 tons per day) in 1997.

The mill was upgraded and expanded in 1995, and processed an average of 10 600 tonnes per day (11 800 tons per day) to produce 328 729 ounces of gold in 1997. The mill flowsheet is quite straightforward and consists of primary crushing, two stage secondary crushing, rod/ball mill grinding, gravity concentration, cyanide leaching, CIP gold recovery, stripping, electrowinning, and refining. The average gold recovery was 93.5% for 1998.

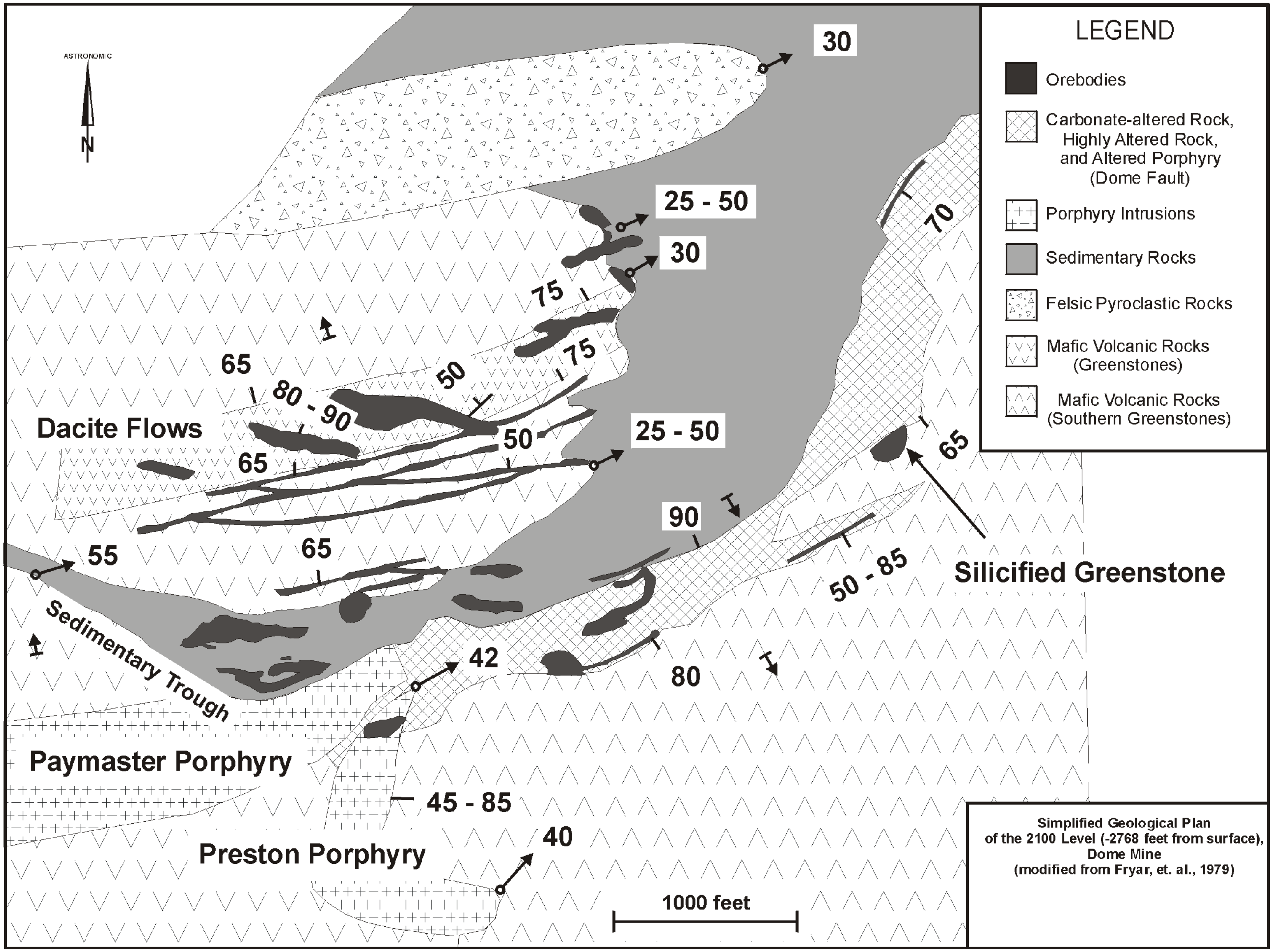
Description of Orebodies

Gold at the Dome Mine occurs mainly as free gold associated with either ankerite- or quartz-rich veins, however some gold is associated with sulphide minerals present either within the veins themselves, or in the enveloping alteration halo. In general terms, many ankerite-rich veins contain gold values, however not all quartz veins are auriferous. Indeed the "Carb Rock" often contains extensive vein sets devoid of gold values (R. Koch, Placer Dome North America Limited, written communication). Sulphide minerals are commonly associated with all ore types, typically occurring in two to three percent abundance. The dominant sulphide minerals consist of pyrite and pyrrhotite, however chalcopyrite, sphalerite, and galena are found locally and are often good indicators of elevated gold content. Aresenopyrite is present in rare amounts throughout the mine, and minor amounts of telluride minerals such as altaite, petzite and tellurobismuthite have been recognized.

A number of styles of mineralization are present on the mine property (Figure 8), and have been described in Holmes (1968). These descriptions were reviewed and slightly modified for clarity by Placer Dome staff in 1997 to facilitate their use as guides to construction of geological and mineralization models (Table 6).

Table 6. Summary of the characteristics of the styles of mineralization found on the Dome Mine property (modified from data provided by Mort Shannon, Placer Dome North America Limited, written communication).

Type and Description	Sub-Types
I) Long, narrow veins in schist, parallel to the trend of the mafic flows	A) Ankerite Veins (largely contained in "Greenstone Nose). B) Quartz-Tourmaline Veins (largely contained in "Highly Altered" unit) C) Quartz-Fuchsite Vein (hosted in "Carb Rock" unit – Dome Fault)
II) Lenticular ore irregular "tension" veins in massive and schistose rocks that cut Type I veins	A) Dacite-type – en echelon quartz veins in massive flows in the "Greenstone Nose" B) Sedimentary Trough – "stockwork" of quartz veins in conglomerate C) Porphyry Veins – "stockworks" of quartz veins in porphyry intrusions and "highly altered" rock of the Dome Fault D) Greenstone Nose – similar to Type IIb mineralization, but containing more abundant and coarser grained sulphide minerals.
III) Sulphide-rich rock. Gold is associated with pyrite and/or pyrrhotite with minor or no quartz veining	
IV) Silicified Greenstone. Occurs only within a xenolith of mafic volcanic rocks in the Dome Fault	
V) Narrow quartz vein systems hosted by slate/greywacke	



ASTRONOMIC
N
LEGEND
Orebodies
Carbonate-altered Rock, Highly Altered Rock, and Altered Porphyry (Dome Fault)
Porphyry Intrusions
Sedimentary Rocks
Felsic Pyroclastic Rocks
Mafic Volcanic Rocks (Greenstones)
Mafic Volcanic Rocks (Southern Greenstones)
Dacite Flows
Sedimentary Trough
Paymaster Porphyry
Preston Porphyry
Silicified Greenstone
30
25 - 50
30
75
75
50
50
65
80 - 90
65
25 - 50
55
65
90
70
65
50 - 85
42
80
45 - 85
40
1000 feet
Simplified Geological Plan of the 2100 Level (-2768 feet from surface), Dome Mine (modified from Fryar, et. al., 1979)

Figure 8.

The distribution of the gold-bearing zones which are amenable to mining by open pit methods is shown in plan view in Figures 9 and 10. Cross-sectional views of the mineralization are presented in Figures 11, 12, and 13. The detailed descriptions of the different styles of mineralization below have been excerpted from Placer Dome Exploration (1997) and R. Koch (Placer Dome North America Limited, written communication):

TYPE 1 (a) – ANKERITE VEINS

Ankerite Veins are hosted by the basalt flows of the “greenstone block”. They occur mostly in the part of the “greenstone block” immediately north of the “sedimentary trough”. They also are present on the south side of the “sedimentary trough” further to the west, where there has been little underground development.

Ankerite veins are the most consistent veins in the mine with some extending for more than 1 500 ft along strike and 3 000 ft vertically. They are less than 6 feet in width, are commonly boudinaged, and do occur in sets of two or more parallel veins (Photo 2). They trend approximately parallel to the flows (N70-80°E / 65°N), occur at or near flow contacts, or trend at shallow angles across the flows.

Internal “crack-seal” structures are common in ankerite veins and are commonly accompanied by quartz veining. This gives the veins a ribboned or banded appearance, which some workers have used to support the hypothesis that the veins have a sedimentary origin. It is more likely that the veins formed during successive movements along the host shear. Each movement probably allowed the addition of more mineralized fluids and/or caused the remobilization of existing minerals.

Ankerite veins tend to pinch out when they cross the contact from basalt into conglomerate. There may also be a transition from ankerite into quartz veins. A similar transition can be seen in places within the basalt where the amount of quartz locally increases to the point where it becomes the dominant mineral. Tourmaline may accompany the quartz. Quartz also occurs as irregular stringer veins and masses within the ankerite veins. It is most common as cross-cutting tension-gash veins, which extend from one side of the ankerite vein to the other, but not into the wall rock (Photo 3).

Ankerite veins are composed of fine to coarse-grained, dark grey to black, massive ankerite with minor quartz, pyrite, and less commonly pyrrhotite. Minor amounts of hydromuscovite are also observed on occasion. The sulphides occur in the veins and adjacent wall rock in amounts of 2 to 3%, which can locally be up to 10% (Photo 4). Pyrite is generally fine-grained and occurs as massive patches and fine-grained bands, whereas pyrrhotite occurs as large masses and stringer veins. Gold is fine-grained and is associated with the sulphides. Coarse gold, although locally spectacular, is not common.

TYPE I (b) – QUARTZ-TOURMALINE VEINS

Two types of quartz-tourmaline veins occur at Dome Mine. The first type is characterized by iron-rich tourmaline (schorl) that occurs as black ribbons and needles. They are hosted by the mafic flows of the “greenstone block” and may be laterally continuous with the ankerite veins. These veins are laterally extensive and are 4 to 6 inches wide, are pyrite-bearing and may contain significant gold values.

The second type of quartz-tourmaline veins occur at or near the contact between porphyry and “carb rock” along the Dome Fault. They consist of very fine-grained quartz and brown tourmaline, and commonly appear banded. This variety, known as dravite, is magnesium-rich, which probably reflects the predominance of magnesite in “carb rock”. Sulphides are rare, and gold ocurs as very fine free grains. The grade of these quartz-tourmaline veins is higher if hosted by the porphyry than by the “carb rock”. Tension-gash quartz veins commonly cross-cut this type of quartz-tourmaline vein, and extend into the wall rock on either side. These tension-gash quartz veins are not mineralized.

TYPE I (c) – QUARTZ-FUCHSITE VEIN

The quartz-fuchsite vein is hosted by “carb rock” within the Dome Fault. The vein occurs close to the contact of porphyry and “carb rock” adjacent to the contact with slate, between the No. 6 and No. 18

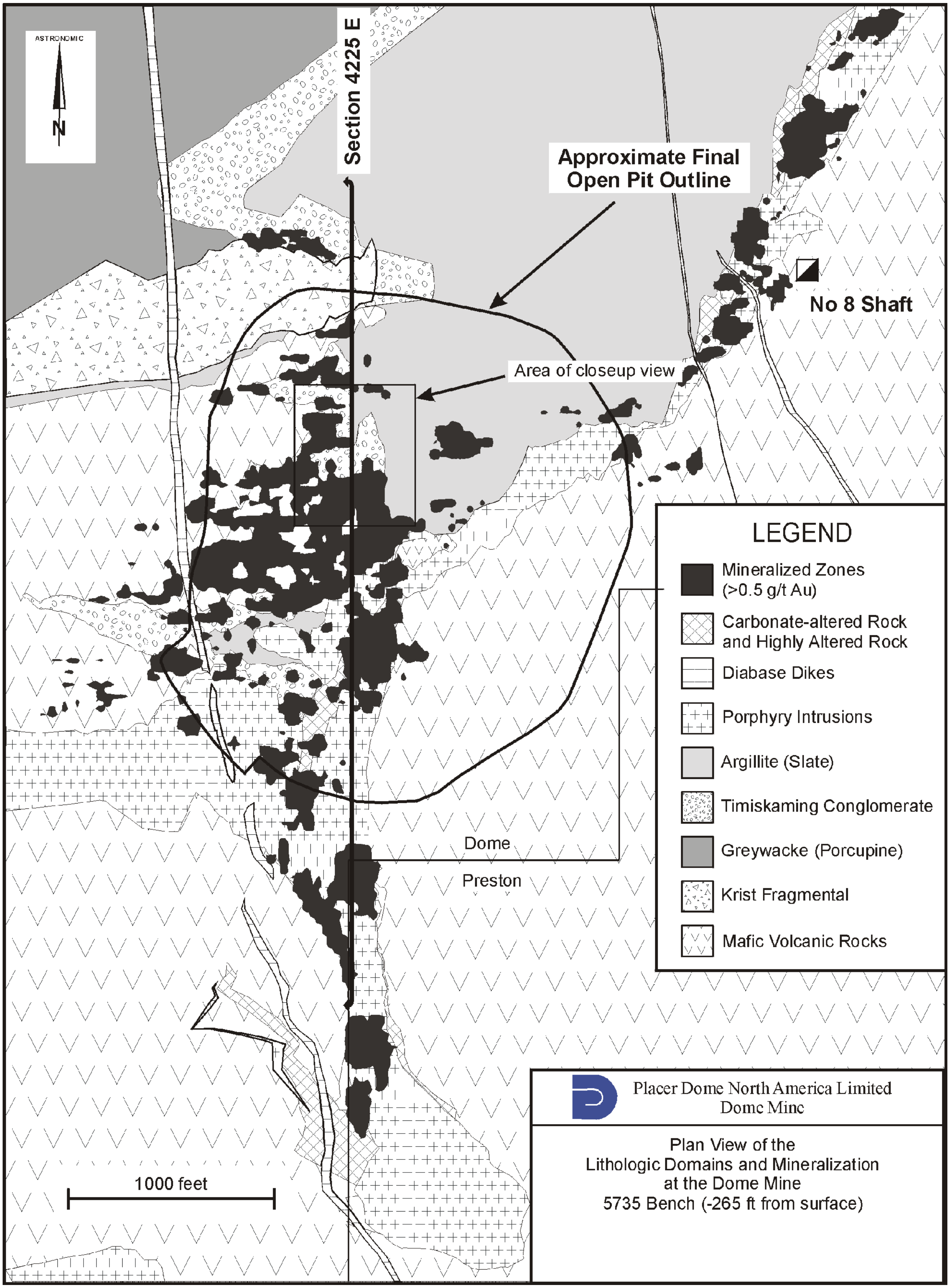

ASTRONOMIC
N
Section 4225 E
Approximate Final
Open Pit Outline
No 8 Shaft
Area of closeup view
LEGEND
Mineralized Zones
(>0.5 g/t Au)
Carbonate-altered Rock
and Highly Altered Rock
Diabase Dikes
Porphyry Intrusions
Argillite (Slate)
Timiskaming Conglomerate
Greywacke (Porcupine)
Krist Fragmental
Mafic Volcanic Rocks
Dome
Preston
1000 feet
Placer Dome North America Limited
Dome Mine
Plan View of the
Lithologic Domains and Mineralization
at the Dome Mine
5735 Bench (-265 ft from surface)

Figure 9.

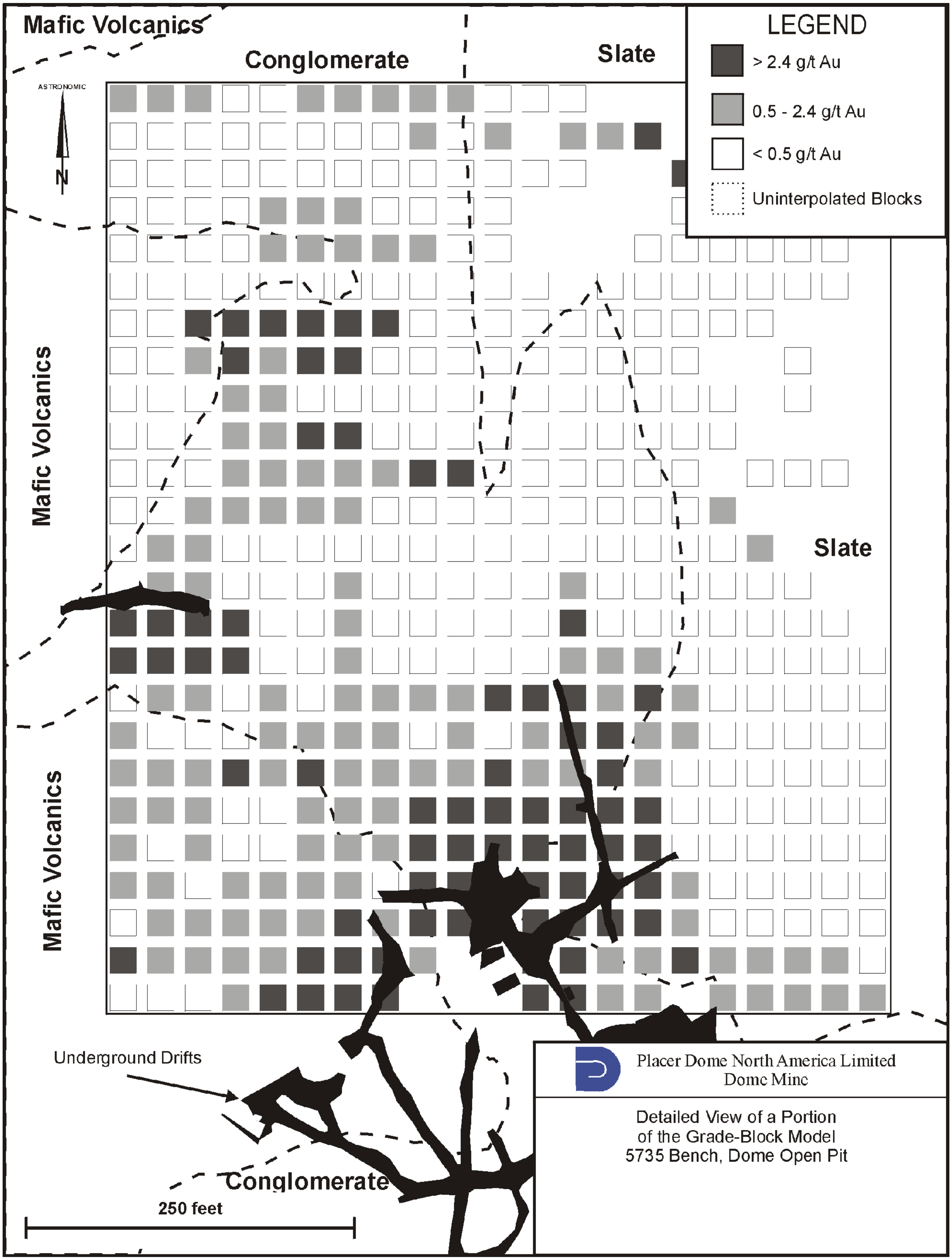

Mafic Volcanics
Conglomerate
Slate
LEGEND
> 2.4 g/t Au
0.5 - 2.4 g/t Au
< 0.5 g/t Au
Uninterpolated Blocks
ASTRONOMIC
N
Mafic Volcanics
Slate
Mafic Volcanics
Underground Drifts
Conglomerate
250 feet
Placer Dome North America Limited
Dome Mine
Detailed View of a Portion
of the Grade-Block Model
5735 Bench, Dome Open Pit

Figure 10.

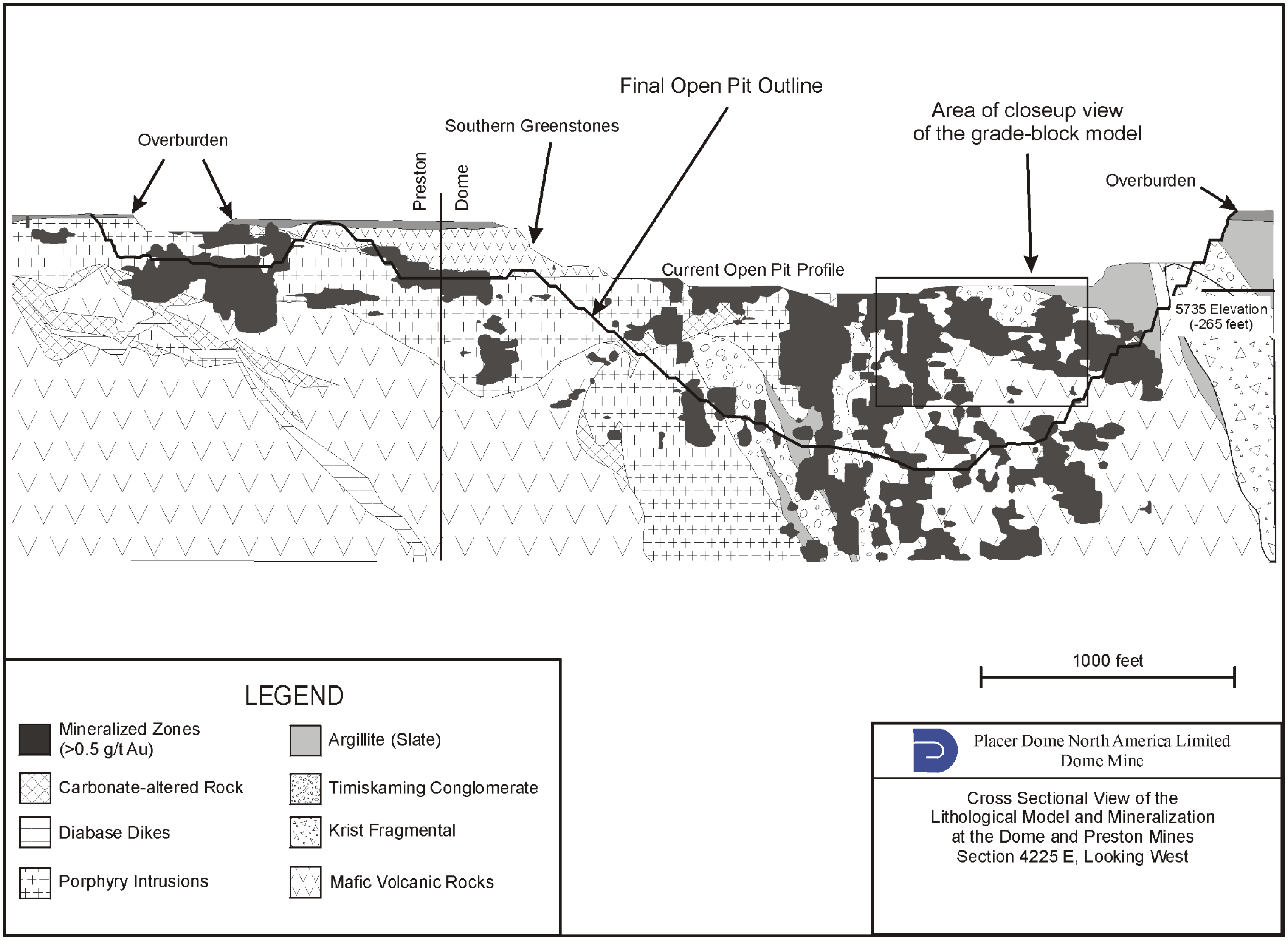

Final Open Pit Outline
Southern Greenstones
Overburden
Preston
Dome
Area of closeup view
of the grade-block model
Overburden
Current Open Pit Profile
5735 Elevation
(-265 feet)
1000 feet
LEGEND
Mineralized Zones
(>0.5 g/t Au)
Carbonate-altered Rock
Diabase Dikes
Porphyry Intrusions
Argillite (Slate)
Timiskaming Conglomerate
Krist Fragmental
Mafic Volcanic Rocks
Placer Dome North America Limited
Dome Mine
Cross Sectional View of the
Lithological Model and Mineralization
at the Dome and Preston Mines
Section 4225 E, Looking West

Figure 11.

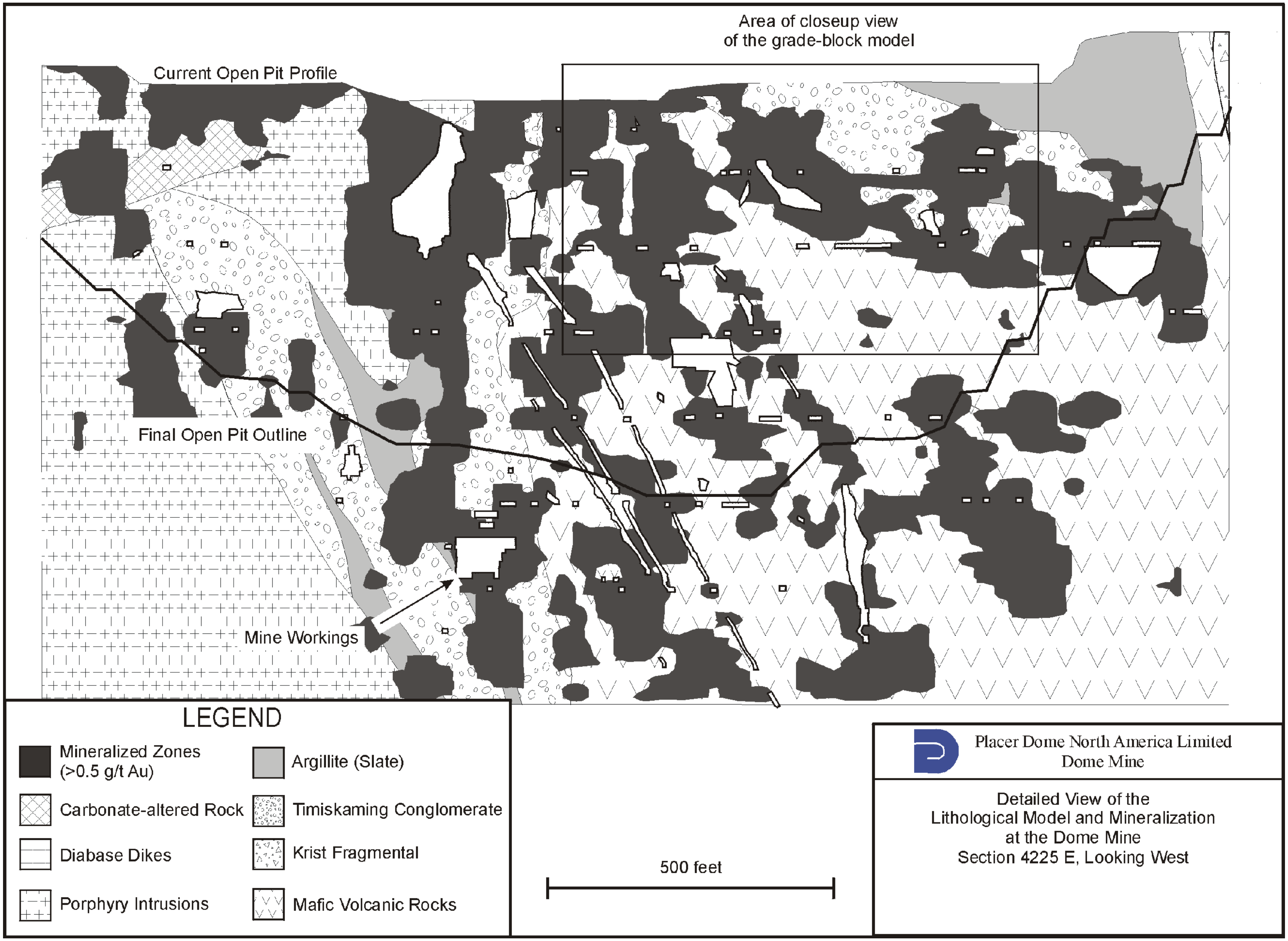
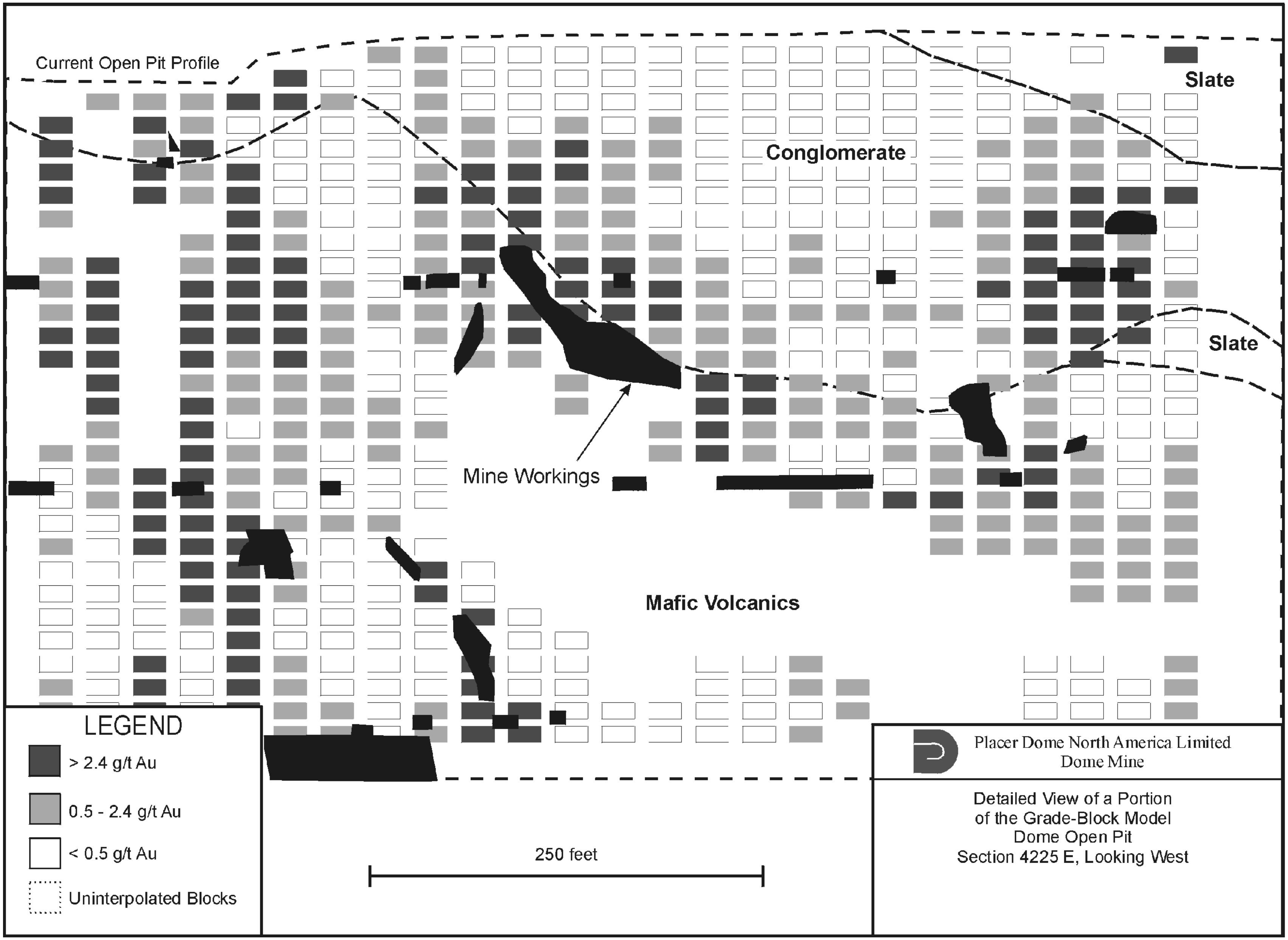

Area of closeup view
of the grade-block model
Current Open Pit Profile
Final Open Pit Outline
Mine Workings
LEGEND
Mineralized Zones
(>0.5 g/t Au)
Argillite (Slate)
Carbonate-altered Rock
Timiskaming Conglomerate
Diabase Dikes
Krist Fragmental
Porphyry Intrusions
Mafic Volcanic Rocks
500 feet
Placer Dome North America Limited
Dome Mine
Detailed View of the
Lithological Model and Mineralization
at the Dome Mine
Section 4225 E, Looking West

Figure 12.



Current Open Pit Profile
Slate
Conglomerate
Slate
Mine Workings
Mafic Volcanics
LEGEND
> 2.4 g/t Au
0.5 - 2.4 g/t Au
< 0.5 g/t Au
Uninterpolated Blocks
250 feet
Placer Dome North America Limited
Dome Mine
Detailed View of a Portion
of the Grade-Block Model
Dome Open Pit
Section 4225 E, Looking West

Figure 13.

Photo 2. Example of ankerite veins hosted in strongly carbonatized mafic volcanic rocks, 5735 Bench, Dome open pit, looking west.

Levels. It is continuous for about 1 500 ft in horizontal and vertical extent, and varies in width from a few inches to 15 ft.

The quartz-fuchsite vein comprises white massive quartz with narrow bands, ribbons, and patches of fuchsite, dravite, and chlorite. Gold is intimately associated with the fuchsite and frequently occurs as coarse grains, yielding some of the highest grade ore in the mine. Minor tellurides and galena are locally present whereas iron sulphides are uncommon.

TYPE II (a) – DACITE-TYPE

Initially, this type of mineralization was interpreted to be hosted by mafic flows in which the intense carbonate alteration resulted in the flow being mis-identified as dacitic in composition. Subsequent geological mapping has determined that this type of mineralization actually occurs as an altered and quartz veined horizon that is approximately 300 feet thick, 1200 feet in strike length, and extends 2500 feet in depth from near surface. This horizon dips to the northwest at approximately 70°, such that it gradually crosses individual flow contacts with increasing depth. Quartz veins which occur in this altered horizon can also be observed to cross flow contacts in plan view.

The “dacite-type” mineralization consists of quartz veins that occur as sets of en echelon, sigmoidal veins, which individually strike northeasterly and dip moderately to the northwest (Photo 5). The veins occur within three sets. One of these sets appears to trend approximately east-west and dip 80-90° to the north, the second set occurs in zones which parallel flow contacts, and the third set consists of flat dipping veins (<35°) with variable strikes. In general, lower grade gold values are associated with the flow-parallel vein set.

The quartz veins consist of white, massive quartz with 2 to 3% grey ankerite occurring along the vein margins. Pyrrhotite in association with quartz is a good indicator of higher gold values. Other accessory minerals include pyrite, tourmaline and minor sphalerite and chalcopyrite. Native gold can be coarse with this type of mineralization.

“Dacite-type” mineralization is also present in mafic volcanic rocks elsewhere in the mine, but to a lesser degree. These occurrences are always located near the Greenstone / Sediment contact, usually where

Photo 3. Close up view of an ankerite vein hosted by strongly carbonatized mafic volcanic rock showing development of quartz-rich ladder-type veins, 5735 Bench, Dome open pit, looking west.

a conglomerate-filled embayment is present in the contact. These occurrences become less well developed with increasing distance from the Dome Fault.

Roberts (1990) concluded that the geometry of the veins is consistent with the pattern expected from a dexteral shear zone resulting from rotational shear strain. The dextral shearing is part of a conjugate set which includes sinistral shears that host the ankerite veins.

TYPE II (b) – SEDIMENTARY TROUGH

The gold mineralization contained in this type of mineralization is associated with swarms of randomly oriented quartz veins that often bear little spatial relationship to the overall attitude of the gold-bearing zone. Flat lying quartz veins which dip 35° to 50° to the northeast are commonly developed in these zones, but they are more irregular in shape and less continuous that the flat dipping quartz veins of the "Dacite-type". These vein sets may assume vertical dips locally.

The quartz veins are hosted primarily by conglomerate, and individual veins may contain up to several percent sulphide minerals. Pyrrhotite and pyrite are the dominant sulphide minerals in these veins,

Photo 4. Example of a mafic volcanic – hosted quartz-rich vein containing abundant pyrite and minor ankerite, 5735 Bench, Dome open pit, looking west.

however chalcopyrite, sphalerite, and galena may also be present. The wall rocks of the veins often contain smaller quartz veinlets and disseminated sulphide minerals, and are typically gold-bearing in these instances. Where these vein sets cross into either a porphyry or greenstone host rock, they continue to be gold-bearing, but when they cross into a slate host rock they typically loose their sulphide content and gold values.

Many of the larger orebodies have been observed to occur where there is a change in the thickness of the conglomerate host rock or where there are embayments in the mafic-sediment contact. Some gold-bearing vein sets are known to exist in slate host rocks, and these occurrences are typically related to flexures in the trace of the Dome Fault. In many cases, these occurrences are located vertically below the flexures in the Dome Fault.

TYPE II (c) – PORPHYRY VEINS

This style of mineralization is restricted by definition to those quartz veins hosted by the Preston Porphyry and immediately adjacent Carb Rock. The veins occur as randomly oriented stockworks, of which quartz-tourmaline veins are the most economically significant. These veins occur along the contact between the Preston Porphyry and Carb rock envelope, within the northern limb of the Preston Porphyry, and as discrete, vertically dipping veins that are oriented along an easterly trend which separates the Preston Porphyry into the northern and southern limbs.

Quartz veins within porphyry generally have a northeasterly strike with shallow dips. The veins contain 2 to 3% ankerite along their margins and as patches within the veins. Pyrite is the most common sulphide with minor chalcopyrite also present. The sulphides generally comprise less than 1% of the veins such that many of the veins have a milky, "barren" appearance. However, throughout the mineralized zones, the wall rock can contain up to 10% pyrite as disseminated cubes and fine-grained stringer veins.

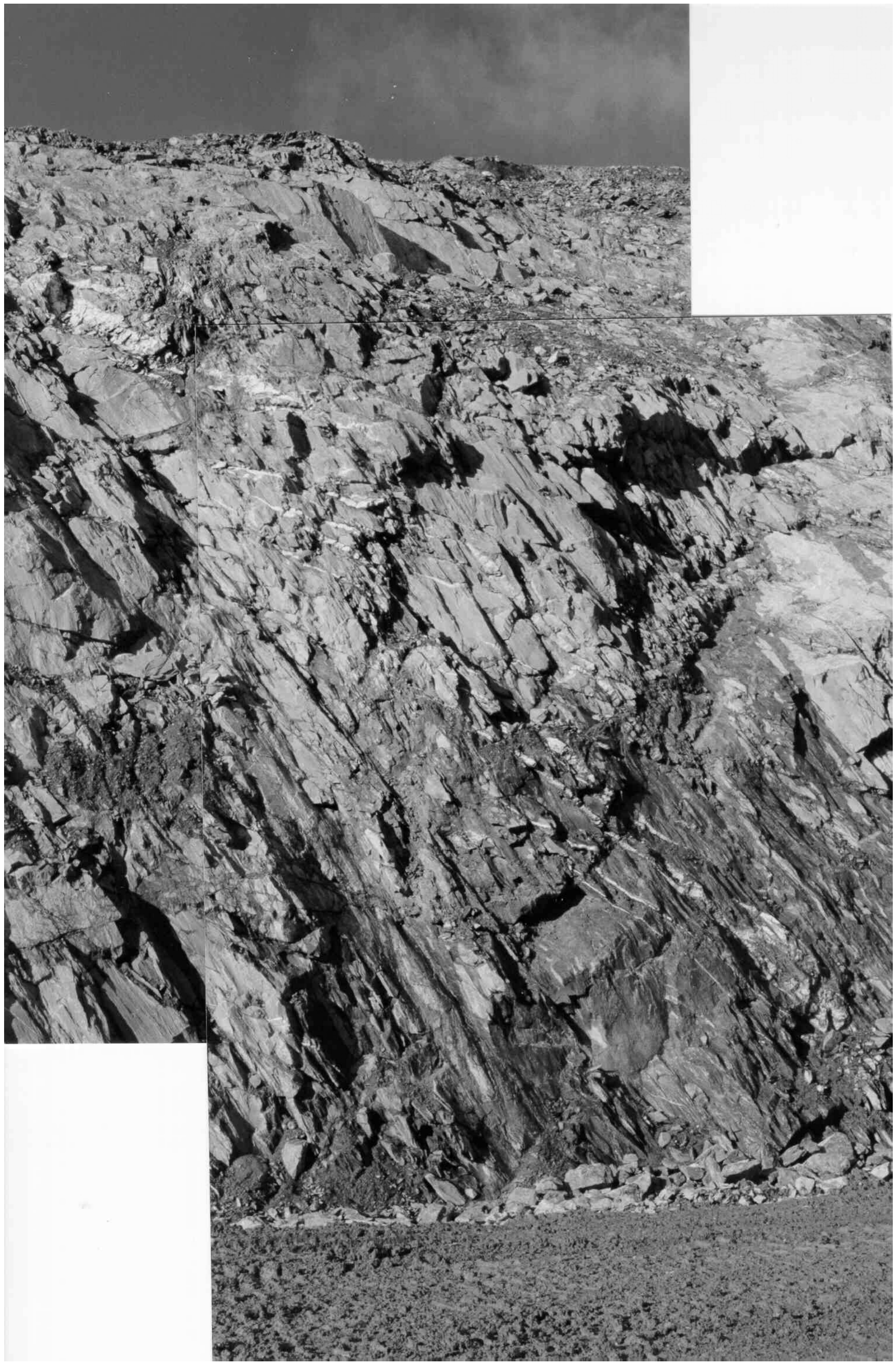


Photo 5. Example of en echelon quartz veins hosted by mafic volcanic rocks, Dome open pit, looking west. Height of pit wall is approximately 265 feet.

The quartz veins within porphyry also form localized large quartz breccia zones. Within these zones, the fragments of porphyry caught up in the quartz are well-mineralized.

Where mineralized porphyry is in contact with “carb rock”, the quartz veins commonly extend into the “carb rock” with little change in their character. There is however, a marked decrease in the pyrite and gold content of the veins within the “carb rock”. Because of this, the mineralized “carb rock” rarely constitutes ore.

Of particular note is that while most of the historical and current gold production has been hosted in the northern limb of the Preston Porphyry, the southern limb is generally devoid of economic gold values. While quartz veining is present in this southern limb, the veins typically lack development of the tourmaline bands.

TYPE II (d) – GREENSTONE NOSE

This style of mineralization is similar to Type II(b) mineralization (Sedimentary Trough), but differs in that the gold mineralization occurs in association with coarse grained pyrite and calcite with little to no pyrrhotite. Sulphide contents in individual veins may attain 20%, and sulphide-rich, pyrite-bearing wall rock is typically auriferous.

TYPE III – SULPHIDE-RICH ROCK

Sulphide-rich rock is gold-bearing, highly-altered and contains pyrite +/- pyrrhotite +/- sphalerite, with little to no quartz veining. Although it is classified as a separate type of mineralization, it occurs either as envelopes or extensions of gold-bearing quartz veins. Most sulphide-rich rock occurs within conglomerate located along the Greenstone Nose, and consists primarily of coarse, anhedral pyrite with lesser amounts of fine grained pyrite and pyrrhotite. Those occurrences of sulphide-rich rock located completely within the greenstones or the conglomerate generally lack development of coarse grained pyrite.

TYPE IV – SILICIFIED GREENSTONE

Only one area of silicified greenstone is documented at Dome Mine. A block of basalt, thought to be the “southern greenstone”, occurs within the Dome Fault. The rock is medium grey to buff with increasing intensity of alteration and is mineralized with fine-grained pyrite, pyrrhotite, arsenopyrite and gold. Only a few small quartz veins, 2 to 12 in. wide, are present.

TYPE V – NARROW QUARTZ VEIN ZONES

Narrow, lenticular to tabular zones of quartz mineralization within the slates extend at approximately 070° away from the “greenstone nose”. They have vertical to step northerly dips and may extend to a considerable depth. The orientation of the quartz veins within these zones is not known, although they do not appear to parallel the zone. Bedding in the slates can be highly disrupted within the zones of narrow quartz veins.

The slates have been intensely carbonatized with sericitized borders and holes commonly developed around the quartz veins. Tourmaline,pyrite, pyrrhotite, sphalerite, galena and chalcopyrite are common accessory minerals, comprising up to 5% of the veins. Native gold is locally common and can be coarse-grained.

ACKNOWLEDGEMENTS

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Economic Geology and Mineralization of the Bell Creek Mine

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INTRODUCTION

The gold mineralization at Kinross Gold Corporation's Bell Creek Mine occurs in a number of settings, however the economic mineralization is associated with a single, continuous quartz vein hosted within mafic volcanic rocks. This mineralization is located at western limit of the currently recognized productive stratigraphy of the area which includes such mines as the Hoyle Pond Mine, the Owl Creek Mine, and the Marlhill Mine, all of which have produced a total of 1 374 700 ounces of gold to-date (Atkinson, et. al. 1998).

The first recorded exploration activity in the area was by Hollinger Consolidated Gold Mines Ltd. who conducted a stripping and sampling program on the Johnston Option in the north half of Lots 9 and 10, Concession II, Hoyle Twp. There they discovered several narrow quartz veins in surface outcrop with the best sample returning a value of $11.80 / ton (0.337 oz / ton Au @ $35 Au) in 1936 (Jones 1936). Other work in the area conducted by Broulan Reef Mines Limited in 1957 discovered additional quartz veins and stringers on what is now Pentland Firth Ventures's Marlhill Mine property, and the best assay was 0.37 oz / ton Au / 24.5 feet strike length from Trench N (Backman 1958). Exploration activity through a joint venture between Rosario Resources Ltd. and Dupont of Canada Exploration resulted in the discovery of the Bell Creek Zones in 1980 and the North Zones in 1981. The Bell West Zone was discovered in 1989. Several changes of property ownership took place, culminating with the purchase of Falconbridge Gold Corporation by Kinross Gold Corporation in 1994.

The mine commenced commercial production in 1986 with an on-site mill constructed in 1987. Mining operations at Bell Creek ceased in late 1991 with operations at the mill continuing by milling of ore from the nearby Hoyle Pond Mine. The mine workings are currently on a care-and-maintenace basis.

LOCATION, ACCESS, AND CLAIMS

The Bell Creek Mine is located in southwestern Hoyle Township, approximately 16 kms northeast of Timmins, Ontario (Figure 1), and the shaft is located in the north half of Lot 10 Concession II. The mine property forms part of Kinross Gold Corporation's extensive land holdings in the area that consists of three properties (Hoyle Pond, Owl Creek, and Bell Creek Mines). In total, these three properties comprise 889 Ha of patented claims, 453 Ha of leased claims, 32 Ha as unpatented mining claims, and 64.6 Ha which are under a private lease agreement. All lands are currently registered to Kinross Gold Corporation.

REGIONAL GEOLOGICAL SETTING

The mine is hosted within a mixed assemblage of mafic and ultramafic volcanic rocks containing interbedded clastic and graphitic sediments that strike in an easterly direction and dip steeply south (Figure 2). These rock units are located to the immediate north of the traditional Timmins camp stratigraphy which has been described in detail by Ferguson, et. al. (1968), Pyke (1982), Jackson and Fyon (1991), and Brisbin (1998).

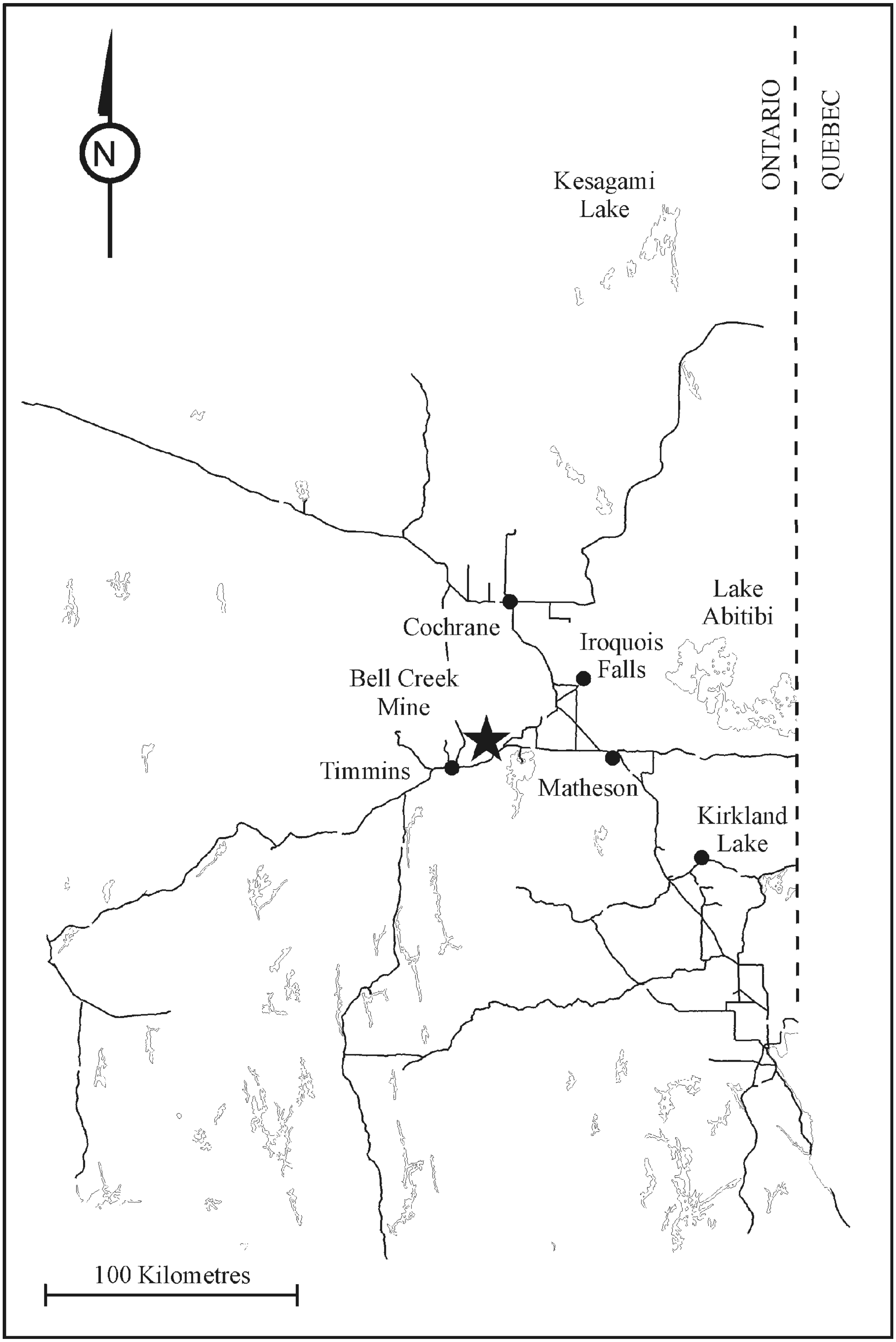


Figure 1. Location map of the Bell Creek Mine.

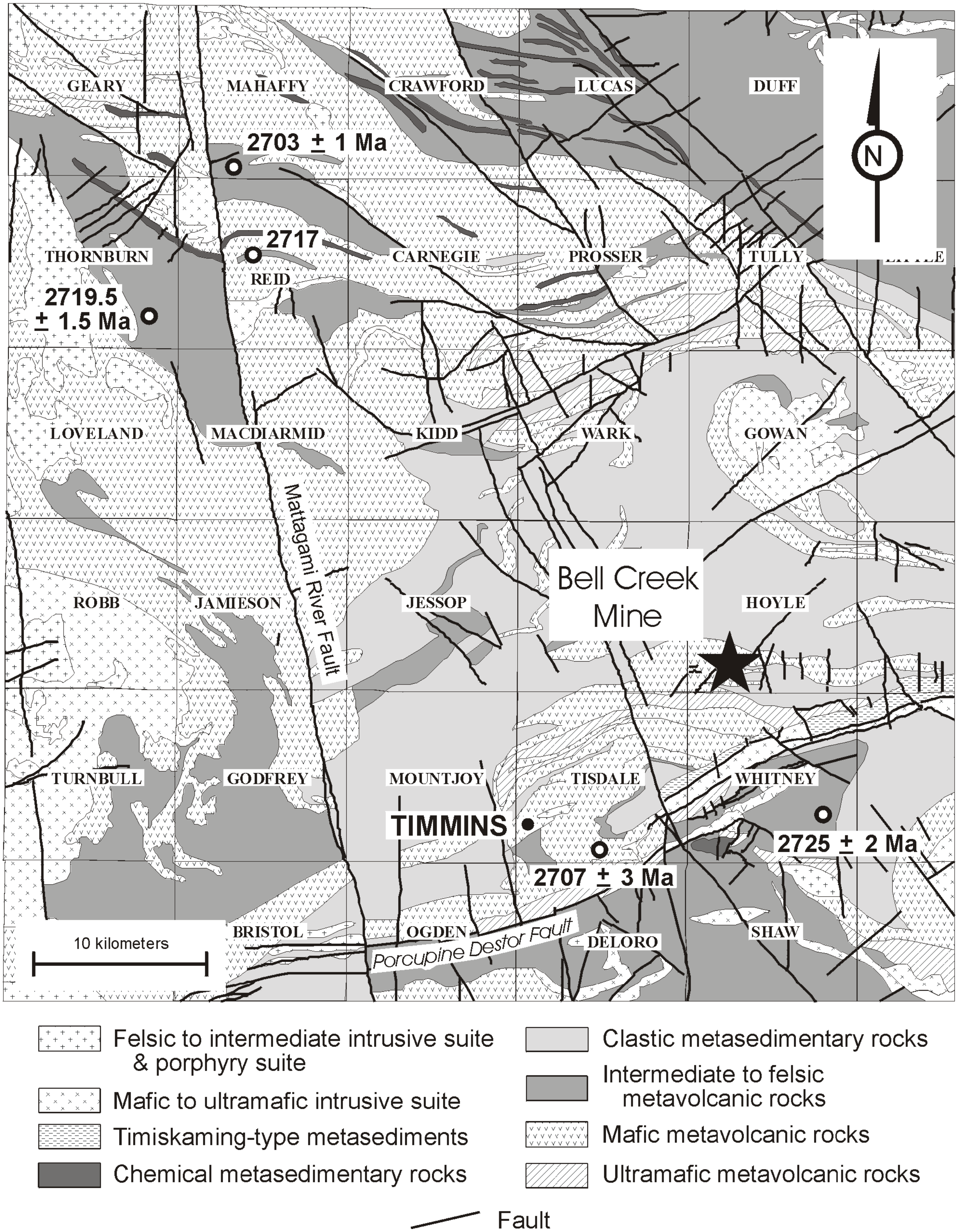


Figure 2. Regional Geological Setting of the Timmins Area (modified from Ayer and Trowell, 1998).

The Tisdale Group consists of: i) a lower portion consisting of mixed ultramafic and Mg-tholeiite mafic metavolcanic rocks that have returned an age date of 2707 Ma, ii) a middle sequence dominated by Fe-tholeiitic basalts capped by two distinctive variolitic units, and iii) an upper consisting dominantly of calc-alkaline felsic pyroclastic rocks (Krist Fragmental, 2698 Ma) with minor amounts of carbonaceous argillite. The Tisdale Group is in fault contact with the older Deloro Group (2727 Ma) to the south across the Destor-Porcupine fault zone. The rock types in the Deloro Group are dominantly calc- alkaline basalts, andesites, rhyolitic and dacitic tuffs, and lapilli tuffs. A sequence of clastic sediments (Porcupine Sediments) conformably overlie the Tisdale Group units, and are in turn overlain by younger clastic sediments of the Timiskaming Group. A schematic illustration of the stratigraphy and age dates for the Timmins Camp is given in Figure 3.

The Destor-Porcupine Fault is the most significant structure in the area and it consists of a number of zones of shearing and ductile deformation focussed mainly within ultramafic flows and intrusions. The fault is either vertical, or dips steeply to the north, has been traced continuously eastwards through to the Duparquet, Quebec area where it splits into the east-trending Maneville Tectonic Zone and the southeast-trending Parforu Lake Fault (Couture 1991). It has an apparent sinistral sense of movement in the Timmins area. A set of brittle faults oriented in a northwesterly direction are present throughout the region. These faults are the youngest structural features in the area and serve to offset all stratigraphic units and older structures. The Bell Creek Mine is located in the hangingwall to the Destor Porcupine Fault, approximately six kilometres north of its' surface trace.

PROPERTY SCALE GEOLOGICAL SETTING

Macroscopic Description of Rock Types

The property scale geology of the Bell Creek Mine area is relatively intricate by comparison with the other mines in the area such as the Hoyle Pond, Owl Creek, and Marlhill mines. Four principal rock types are present, including ultramafic and mafic volcanic rocks, graphitic sediments, and diabase dikes (Figure 4).

The ultramafic volcanic units have been traced by means of outcrop exposure and diamond drilling and are found to extend across the entire length of the property. They occur in an easterly to northeasterly striking band and vary in thickness from 10 metres east of the shaft to 200 metres southwest of the shaft. This unit is well exposed in outcrop to the southwest of the shaft, and Pyke (1982) observed well developed spinifex and polysutured textures in Lots 11 and 12, Concession I of Hoyle Twp. A single sample collected by Berger (1992, 1994) for lithogeochemical analysis of a carbonatized ultramafic rock indicated that this unit is a basaltic komatiite. Mafic volcanic rocks are the most abundant rock type on the property and textures vary from variolitic to pillowed, amygdaloidal to massive. Leucoxene is a common accessory mineral in these mafic volcanic rocks. The mafic rocks occur in a sequence of easterly striking bands north of the shaft and contain a number of interbedded ash and lapilli tuff beds and beds of thin graphitic argillite sediments. A total of six samples were taken by Berger (1992, 1994) of these units for lithogeochemical analysis, three of which plotted as Fe-tholeiites, two plotted as calc-alkaline basalts, and one sample plotted as a tholeiitic andesite.

Sedimentary rocks are relatively minor in abundance on the mine property. The largest occurrence of sediments is known as the Bell Creek Graphite Marker Horizon that consists of a mixture of grey and black coloured greywackes and strongly graphitic argillites. This unit sits in an enigmatic relationship with the other stratigraphic units, being both conformable along its' northern and southern extents and cross-cutting along its' central portions, paralleling Bell Creek.

A single, north-south striking diabase dike is known to occur on the property, and it is likely part of the Matachewan Dike Swarm. These dikes have been correlated with the Hearst Dike Swarm (Osmani 1991) that has been dated at 2454 Ma by Heaman (1988). Their compositions are that of a quartz diabase, however they are often characterized by their porphyritic texture and contain phenocrysts of plagioclase up to 20cm in size.

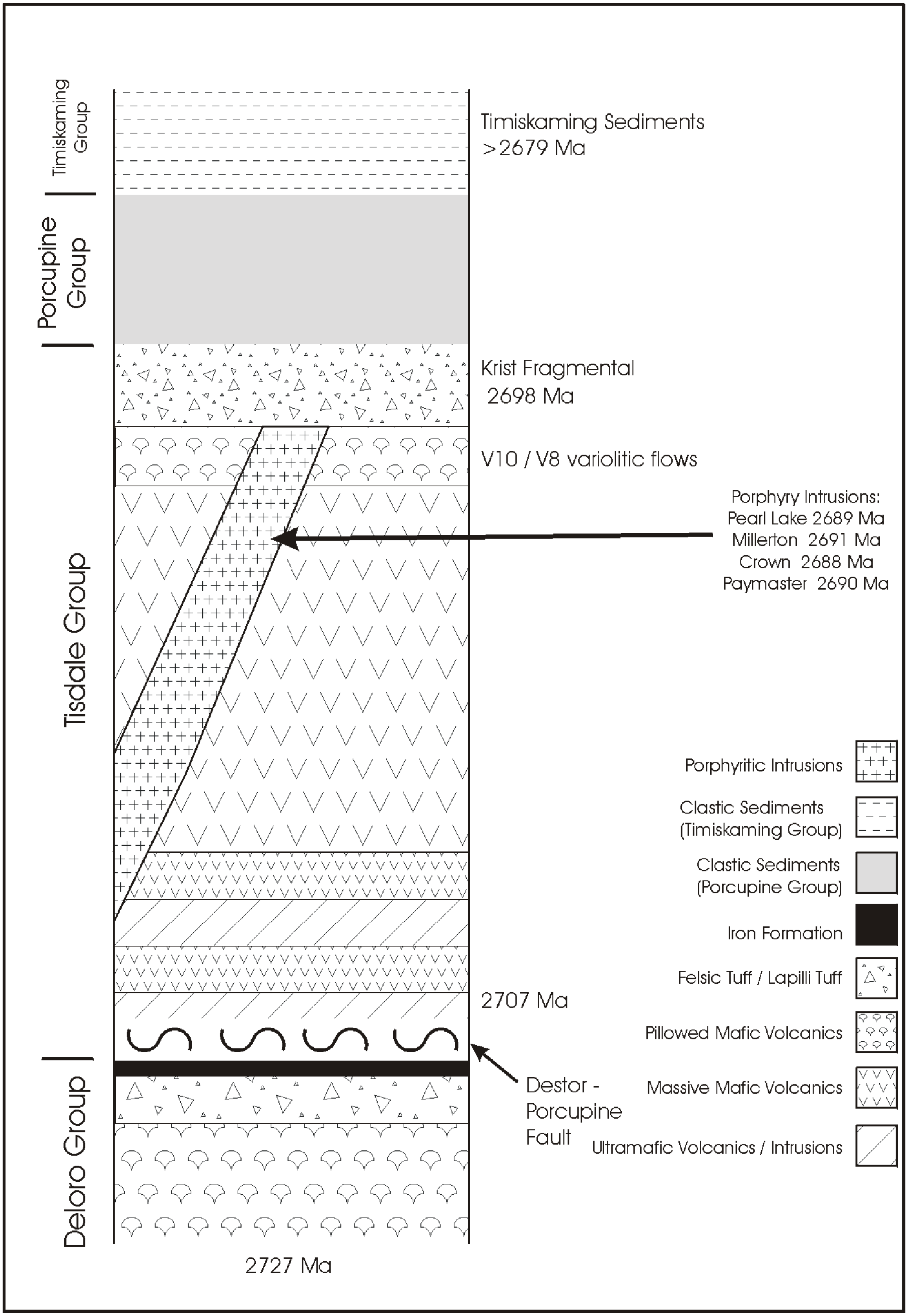


Figure 3. Generalized Stratigraphic Column of the Timmins Camp.

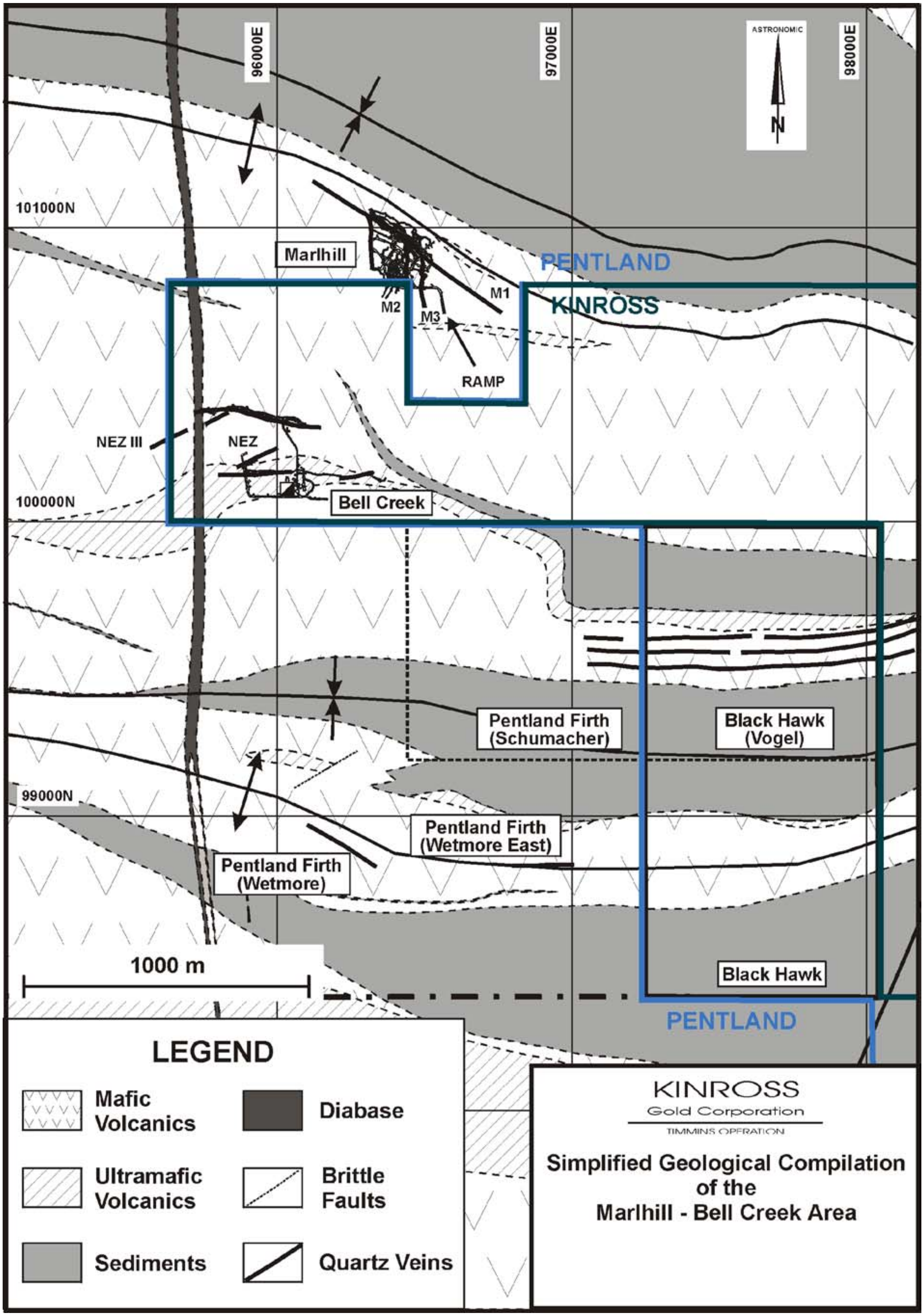

96000E
97000E
98000E
ASTRONOMIC
N
101000N
100000N
99000N
Marlhill
M1
M2
M3
RAMP
PENTLAND
KINROSS
NEZ III
NEZ
Bell Creek
Pentland Firth (Schumacher)
Black Hawk (Vogel)
Pentland Firth (Wetmore East)
Pentland Firth (Wetmore)
Black Hawk
1000 m
PENTLAND
LEGEND
Mafic Volcanics
Diabase
Ultramafic Volcanics
Brittle Faults
Sediments
Quartz Veins
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Geological Compilation of the Marlhill - Bell Creek Area

Figure 4.

Macroscopic Description of Alteration Types and Assemblages

Many zones of alteration are known to exist on the property, most of which contain low grade gold values. The alteration styles and mineral assemblages are discussed.

Lithogeochemical Data

Limited lithogeochemical data is available from the Bell Creek Mine area. Tables 1a and 1b summarize data published by Berger (1994). The reader is referred to that document for individual sample locations.

Table 1a. Major Oxide Geochemistry for Selected Samples from the Bell Creek Mine Property. All samples are of basalts, except for 91-BRB-026 which is of a komatiite (modified from Berger 1994).

Sample ID (91-BRB-)	Mg #	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	P2O5 (%)	CO2 (%)	LOI (%)
001	38.4	56.48	1.37	14.72	11.78	0.23	3.70	9.00	2.48	0.14	0.11	2.03	4.63
002	51.2	53.18	1.08	14.98	12.35	0.19	6.54	8.51	2.78	0.30	0.09	0.37	3.07
026	74.7	43.78	0.61	10.03	14.72	0.23	21.94	8.53	0.02	0.10	0.04	10.3	15.5
029	59.3	57.03	0.88	15.74	7.64	0.20	5.61	10.3	2.43	0.05	0.07	0.95	3.08
034	43.6	53.26	1.35	15.40	13.46	0.21	5.25	8.54	2.26	0.14	0.11	0.14	2.77
038	50.0	51.92	0.92	16.40	12.25	0.20	6.21	9.38	2.55	0.10	0.08	0.05	2.71
059	53.9	54.72	1.23	15.94	10.34	0.21	6.11	7.38	3.72	0.25	0.10	0.55	2.98

Table 1b. Trace Element Geochemistry for Selected Samples from the Bell Creek Mine Property. All samples are of basalts, except for 91-BRB-026 which is of a komatiite (modified from Berger 1994).

Sample ID (91-BRB-)	Cr (ppm)	Ni (ppm)	Co (ppm)	Sc (ppm)	V (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	S (%)	As (ppm)
001	23	77	40	46	363	32	-11	81	0.01	0.00
002	181	144	38	49	311	78	-10	67	0.02	0.00
026	2409	948	96	29	192	87	-12	84	0.23	0.00
029	99	206	66	50	251	142	-10	54	0.13	0.00
034	46	82	35	47	363	123	-10	96	0.02	0.00
038	120	70	42	48	287	113	-10	111	0.43	0.00
059	61	165	38	51	327	121	-10	98	0.01	0.00
Sample ID (91-BRB-)	Au (ppm)	K (ppm)	Rb (ppm)	Ba (ppm)	Sr (ppm)	Li (ppm)	Nb (ppm)	Zr (ppm)	Ti (ppm)	Y (ppm)
001	0.00	1135	6	53	137	17.9	-5.0	97	8201	29
002	0.00	2498	15	119	110	18.7	6.2	86	6472	31
026	0.00	800	-6	18	33	13.3	-6.0	34	3683	12
029	0.00	430	-5	47	120	12.4	-5.2	52	5279	20
034	0.00	1199	6	52	167	23.7	-5.2	93	8103	40
038	0.00	856	4	41	128	15.5	-5.2	66	5502	16
059	0.00	2067	5	218	64	14.5	-5.2	98	7403	28

STRUCTURAL GEOLOGY

Stratigraphy

All rock units on the Bell Creek Mine property generally strike easterly and dip steeply south at 70 – 80°, with two exceptions (Figures 5 and 6). In the first case, the ultramafic unit strikes northeast in the area southwest of the shaft, and its dips correspondingly change to a steep southeast direction. The second case includes the enigmatic graphitic argillite located east of Bell Creek ("graphite marker horizon") where both stratiform and cross – cutting relationships exist. In the area of the "A" Horizon of the Bell Creek Zone the graphitic argillite unit is conformable to the overall strike of the package, and it dips steeply (-80°) to the south. However, in the area from the "B" Horizon of the Bell Creek Zone to a point in the south half of Lot 10 Concession II this unit takes on a cross – cutting northwesterly strike and dips steeply southwest. From there the unit resumes its' conformable attitude as its' strike changes once again to a west-northwest direction.

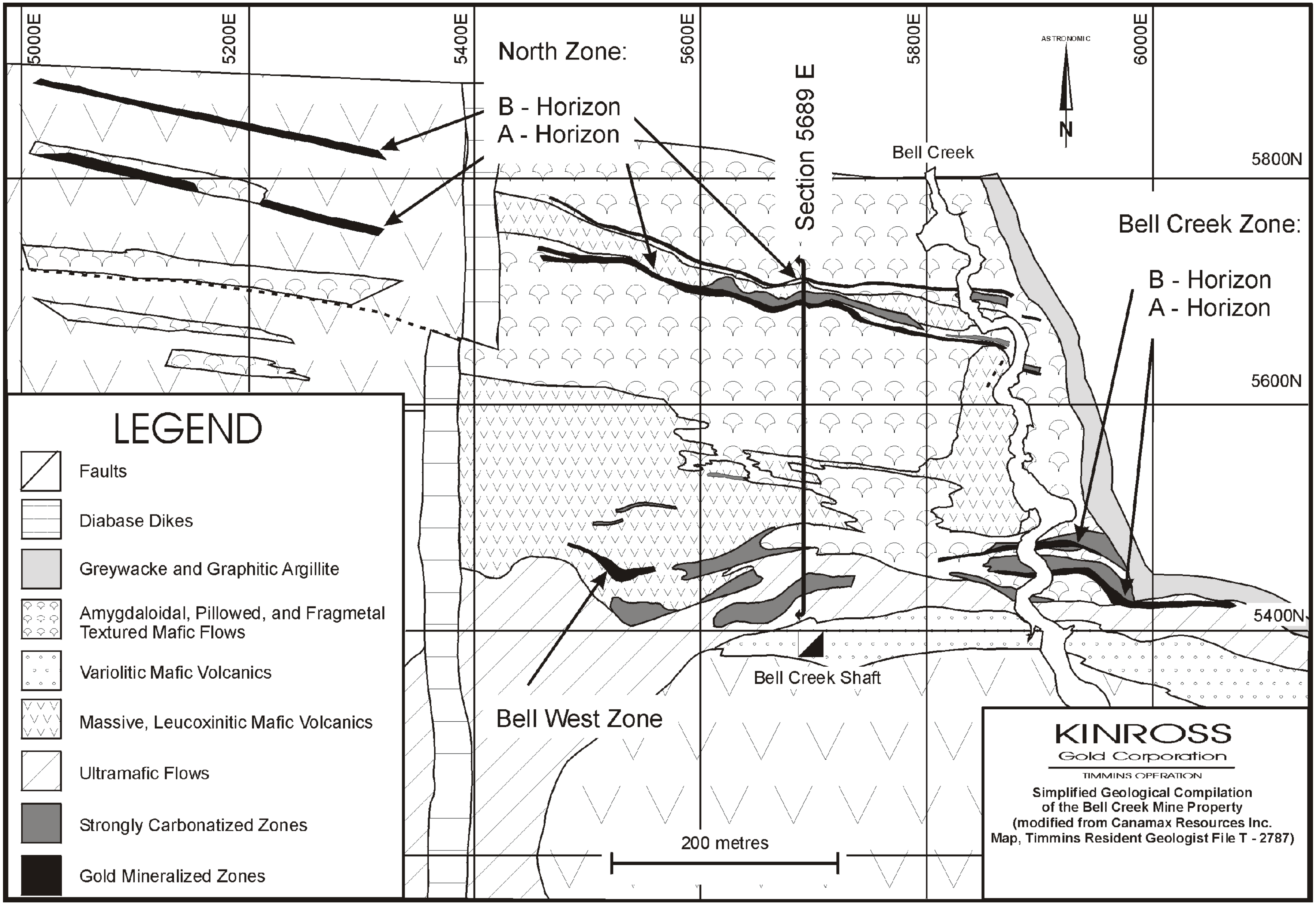

5000E
5200E
5400E
5600E
5800E
6000E
5800N
5600N
5400N
ASTRONOMIC
N
North Zone:
B - Horizon
A - Horizon
Section 5689 E
Bell Creek
Bell Creek Zone:
B - Horizon
A - Horizon
Bell West Zone
Bell Creek Shaft
200 metres
LEGEND
Faults
Diabase Dikes
Greywacke and Graphitic Argillite
Amygdaloidal, Pillowed, and Fragmetal Textured Mafic Flows
Variolitic Mafic Volcanics
Massive, Leucoxinitic Mafic Volcanics
Ultramafic Flows
Strongly Carbonatized Zones
Gold Mineralized Zones
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Geological Compilation of the Bell Creek Mine Property (modified from Canamax Resources Inc. Map, Timmins Resident Geologist File T - 2787)

Figure 5.

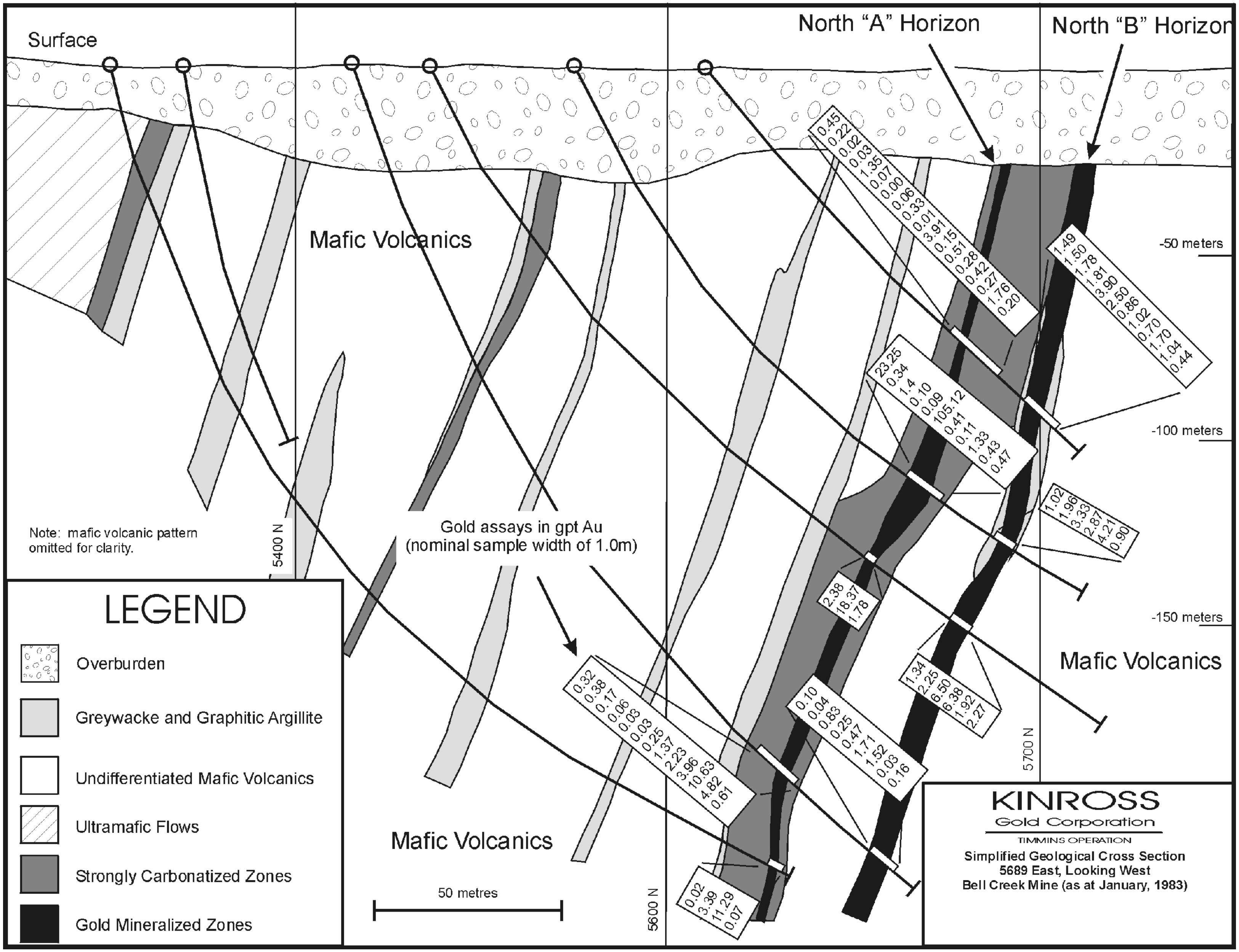

Surface
North "A" Horizon
North "B" Horizon
Mafic Volcanics
Mafic Volcanics
Mafic Volcanics
-50 meters
-100 meters
-150 meters
5400 N
5600 N
5700 N
Note: mafic volcanic pattern omitted for clarity.
Gold assays in gpt Au (nominal sample width of 1.0m)
50 metres
LEGEND
Overburden
Greywacke and Graphitic Argillite
Undifferentiated Mafic Volcanics
Ultramafic Flows
Strongly Carbonatized Zones
Gold Mineralized Zones
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Geological Cross Section
5689 East, Looking West
Bell Creek Mine (as at January, 1983)

Figure 6.

South facing younging directions have been observed in an outcrop of pillowed, variolitic mafic flow located immediately west of the Bell Creek shaft (Phillip 1984), and from an outcrop of pillowed mafic volcanic rocks located in the north half of Lot 11 Concession I, Hoyle Township (Berger 1992). These facing directions suggest that one possibility for the cross cutting relationship for the ultramafic rocks in the area southwest of the shaft is that they mark the nose of a synclinal fold. Interpretations for the distribution of the graphite marker horizon are tenuous at best , however three possibilities include interaction of these sediments with a northwesterly oriented brittle cross fault, and angular unconformity, or disruption by folding. Additional information is required to arrive at an adequate explanation for the distribution of the graphitic argillite unit.

Geological and structural studies by Brisbin (1986), Barclay (1993, and 1994), and Rhys (1996, and 1997) at the Owl Creek Mine, the Hoyle Pond Mine and the Marlhill Mine Project have recognized the presence of two foliations in the region. The first foliation has been described as a penetrative flattening fabric or as a penetrative schistosity, generally striking in an easterly to east-northeasterly direction. The second foliation consists of a spaced fracture cleavage generally striking in a northeasterly direction. Examination of available structural data from surface mapping in the area by Berger (1992), and from the –60 metre level plan at the Bell Creek Mine confirms the presence of two sets of foliations at the Bell Creek Mine (Figure 7). One foliation set (interpreted as S1) has an average orientation of approximately 084/75°S while the other foliation set (interpreted as S2) has an average orientation of approximately 059/75°S. These two orientations are in general agreement with the observations at the Hoyle Pond Mine, the Owl Creek Mine, and the Marlhill Mine Project.

Faults and Shears

No occurrences of Archean-aged shear zones are known to exist on the property. However two younger brittle faults can be deduced from observed offsets of stratigraphic units. The first is an dextral offset in the diabase dike located west of the shaft and the second is also a dextral offset in the North “A” Horizon located northeast of the shaft along Bell Creek. The first fault has been interpreted to have an easterly strike by Phillip (1984) and can be interpreted to be younger than the diabase dike (ie < 2452 Ma). The second fault has been interpreted to have a northeasterly strike by Phillip (1984), however its’ age cannot be deduced. Additional brittle faults have been observed by Kent (1990) who writes:

> “… Late stage brittle deformation occurs along a series of flat faults at the Marlhill and Bell Creek Mines. Displacement of the ore veins varies from a few centimetres to two metres on these flat faults and is accompanied by minor drag folding. Calcite and chlorite coat the flat fractures, which also form planes of weakness in the metavolcanic host rocks.”

ECONOMIC GEOLOGY

Production History

The Bell Creek Mine achieved commercial production status in 1986 and the ore was custom milled locally until mid-1987 when an on-site mill was commissioned with an initial capacity of 385 tons per day. Mining activities continued through the 1986-1991 period until the mine was placed on a care-and-maintenance basis on November 27, 1991 as a result of falling gold prices and rising mining costs. The milled continued operations by milling ore from the nearby Hoyle Pond Mine. Limited production came from the mine during 1992-1994. A total of 576 017 tons were extracted from the mine from the 1986-1994 period, from which a total of 112 739 ounces of gold were recovered at an average recovered grade of 0.196 oz / ton Au. Much of this tonnage was produced from the North “A” Horizon, however an unknown amount was contributed from the Bell West Zone, and from the Marlhill Zone located 900 metres northeast of the Bell Creek shaft. A detailed summary of the annual production is given in Table 2 and a breakdown of the Mineral Inventory is given in Table 3.

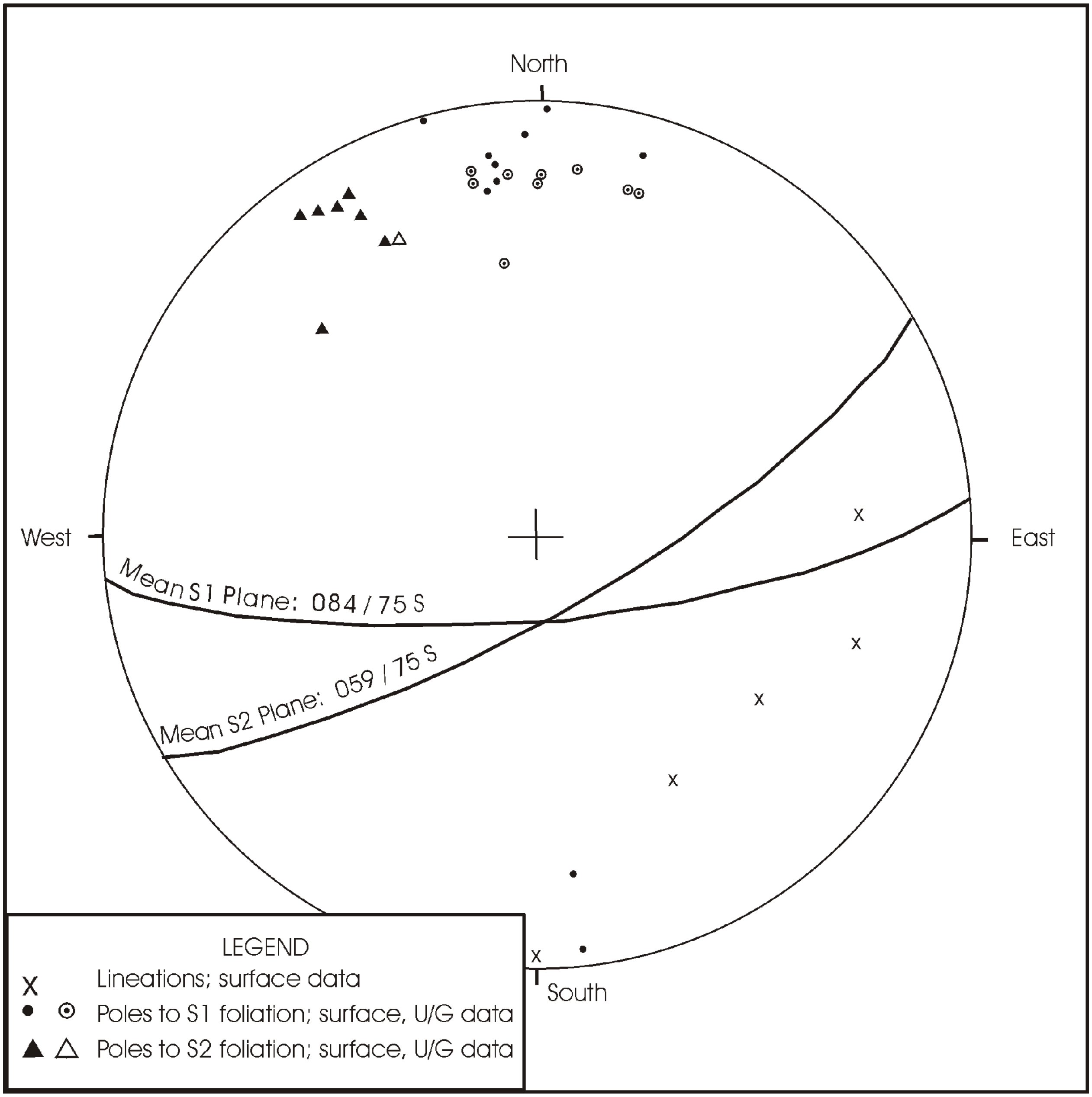


Figure 7. Stereonet projection of selected structural elements from the Bell Creek Mine area. Surface data taken from Berger (1992), and underground data taken from the –60m level plan, Bell Creek Mine.

Table 2. Summary of the Production History at the Bell Creek Mine. Data compiled from Timmins Resident Geologist's Annual Reports, 1987-1994.

Year	Tons Produced	Grade (oz / ton Au)	Recovered Ounces	Remarks
1987	55 180	0.173	9 558	Mill commissioned in July
1988	135 324	0.195	24 648	93.4% mill recovery
1989	146 727	0.203	29 786	94% mill recovery, includes Marlhill ore
1990	66 666	0.206	13 728	Excludes 82 200 tons of Marlhill ore
1991	138 171	0.195	26 880	Includes co-mingled Marlhill ore
1992	5 030	0.223	1 122	
1993	Limited			
1994	33 899	0.207	7 017	
TOTAL	**576 017**	**0.196**	**112 739**	

Table 3. Summary of the Mineral Inventory as at December 31, 1997, Bell Creek Mine (Randy Roussain, Kinross Gold Corporation, written communication, 1998).

Zone	Tonnes	Grade (g / t Au)	Contained Ounces
Reserves (Indicated and Measured): Bell Creek North "A"	144 521	7.22	33 551
Resources (Inferred): Bell Creek North "A" Bell Creek West Zone	190 269 21 911	5.97 8.47	37 676 5 967
TOTAL	**356 701**		**194**

Mining Methods

Access to the North "A" Horizon is via a three compartment timbered vertical shaft to the -60, -120, -180, and -240 metre levels, and by a ramp from the -240 metre to the -300 metre level. Access to the Bell West Zone is provided by the –60, -120, and –180 metre levels (Figures 8 and 9). The current shaft bottom is at a depth of 280 metres. A central pillar is established from surface to the -240 metre level on section 5650 East.

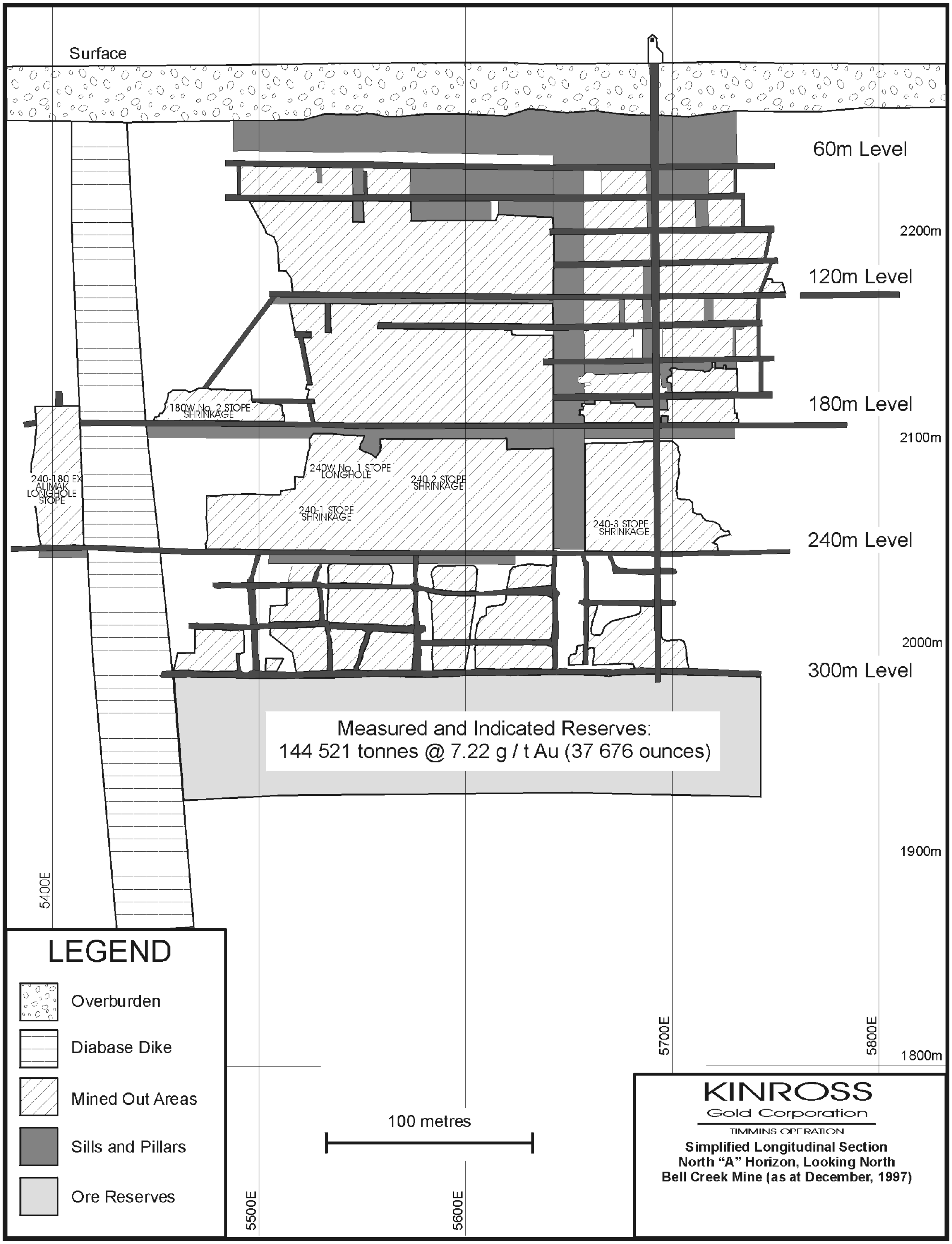
Three principle mining methods (vertical sublevel retreat, longhole stoping, and shrinkage stoping) were employed on the North "A" Horizon. The sublevel retreat methods were employed on the east side of the central pillar from surface to the -180 metre level, and sublevels were established at 15 metre vertical intervals. To the west of the central pillar, both longhole and shrinkage stoping methods were employed, with shrinkage methods being the most widely used. Individual mining blocks varied up to130 metres in length. Longhole methods were exclusively used at the Bell West Zone. All stopes remained open upon their completion, as no backfill was used at the mine aside from selective placement of development waste.

The average mill throughput from commencement of production to August 1991 was 346 tonnes per day (380.6 tons per day) with an average recovery of 93.7% and an average mill head grade of 6.63 g / t Au (0.193 oz / ton Au) (Roussain 1991).

Description of Orebodies

Presently there are 14 gold-bearing zones known on the Bell Creek mine property (North Zones (A and B), the Bell Creek Zones (A and B), the Bell West Zone, NEZ I Zone, NEZ III Zone, 5500 Vein, 5850 Vein, C Zone, D Zone, E Zone, F Zone, and G Zone). Of these, only the North "A" Horizon and the Bell West Zone have seen commercial production. Kent (1990) describes the Bell Creek Zone and the North Zone as:

> Mineralization consists of two to ten percent pyrite and accessory arsenopyrite (typically 100-500 ppm As in ore), pyrrhotite, and chalcopyrite, although minor quartz veins are present. Roughly 90 percent of the gold is associated with the disseminated sulphides, which occur within highly altered quartz-carbonate-sericite-sulphide zones up to 0.5 to seven metres in width. Erratic gold values occur in the quartz veinlets. These veinlets cut the altered rocks at all angles, especially in the hanging wall ultramafic unit. Non-auriferous veins surrounding the sulphide-carbonate gold zone generally occur as gash or en-echelon type structures.



Surface
60m Level
120m Level
180m Level
240m Level
300m Level
2200m
2100m
2000m
1900m
1800m
180W No. 2 STOPE
SHRINKAGE
240-180 EX
ALIMAK
LONGHOLE
STOPE
240W No. 1 STOPE
LONGHOLE
240-2 STOPE
SHRINKAGE
240-1 STOPE
SHRINKAGE
240-3 STOPE
SHRINKAGE
Measured and Indicated Reserves:
144 521 tonnes @ 7.22 g / t Au (37 676 ounces)
5400E
5500E
5600E
5700E
5800E
LEGEND
Overburden
Diabase Dike
Mined Out Areas
Sills and Pillars
Ore Reserves
100 metres
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Longitudinal Section
North "A" Horizon, Looking North
Bell Creek Mine (as at December, 1997)

Figure 8.

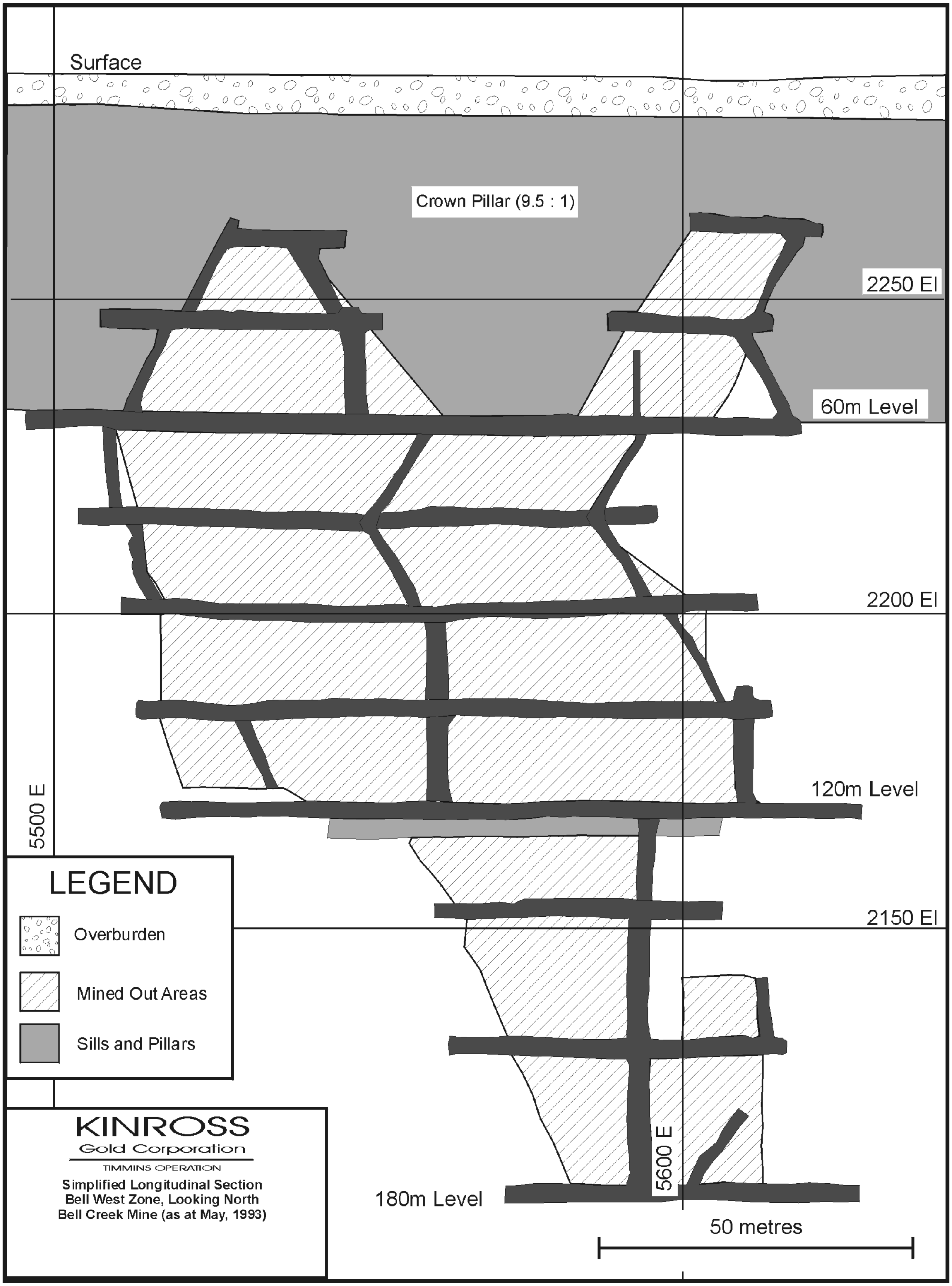

Surface
Crown Pillar (9.5 : 1)
2250 El
60m Level
2200 El
120m Level
2150 El
180m Level
5500 E
5600 E
50 metres
LEGEND
Overburden
Mined Out Areas
Sills and Pillars
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Longitudinal Section
Bell West Zone, Looking North
Bell Creek Mine (as at May, 1993)

Figure 9.

The ore-grade mineralization occurs in pods or lenses not more than 100 metres in strike length and 200 metres vertical extent. The ore lenses appear to plunge steeply to the east. Multiple zones have been located along a strike length of one kilometre at or near the favourable Unit 1 – Unit 2A (ultramafic – basalt) contact. Active carbon occurs in some of the mineralized pods in the form of sheared graphitic interflow sediments and mining is not planned in these areas due to the deleterious affects of the carbon to the recovery of gold.

The North Zone consists of two sub-parallel, west-northwest-striking mineralized bands termed the "A", in the south, and "B" in the north. The two zones are roughly 25 metres apart and dip at 70° to the south.

The mineralized portion of the "A" horizon consists of a quartz marker vein ten centimetres to two metres in width, and averages only 0.5 metres in width (Figure 10). The marker vein parallels the regional schistosity and crosscuts green, fragmental tuff, variolitic basalt, leucoxene-bearing basalt, and narrow beds of graphitic argillite. Bright green hydromuscovite occurs as fracture and slip coatings in the vein and platy, visible gold occurs with the mica. Tourmaline is fairly wide spread within the vein. The "A" zone contains the best gold values, averaging six to ten g/tonne over widths of two to ten metres. Surrounding the central quartz vein is a grey to buf coloured altered zone, which contains five to fifteen percent pyrite and pyrrhotite with accessory chalcopyrite and arsenopyrite. Up to 30 percent of the gold in the North "A" vein system occurs within the alteration halo, in discrete sulphide zones, in vein-brecciated wall rock zones which extend up to five metres from the margin of the core vein.

… Deep drilling has intersected the ore zone at a depth of 400 metres. Current mining is entirely by shrinkage stoping. Long-hole stopes were common until early 1989, when it was realized that a weak hangingwall resulted in excessive dilution.

Gold mineralization in the North "B" zone has been noted in drill holes over a strike length of 100 metres. As in the "A" zone, gold occurs with sulphides in a quartz vein and in a quartz veinlet halo in the adjacent wall rock. Carbonate alteration of the wall rock is only weakly developed. Abundant graphite occurs in the argillaceous host rocks. This zone has an average grade of 2.8 g/tonne across 4.4 metres and is considered to be sub-economic at this time."

The presence of several quartz vein generations is suggested in Figure 10. Overall, the vein system follows the property scale stratigraphic orientations. However, small scale features of the veins show that at least in part the veins are oriented parallel to the strike of the S1 and S2 cleavages (Figure 10, Inset B). This suggests that these veins were either formed at the same time as each of the cleavages, or that they formed during (or after) development of the S2 cleavage and have developed parallel to pre-existing fabrics. An earlier generation of quartz veining is also suggested by the folded nature of some of the minor veins shown in Inset A of Figure 10. A study of polished sections of diamond drill core by Scott (1994) deduced the following paragenetic sequence at the Bell Creek Mine:

Stage	**Mineralogy**
I	Rhyolite (?) + Ti – magnetite
II	Albitization + pyrrhotite (I)
III	Shearing + gray chlorite
IV	Arsenopyrite + pyrite (I)
V	White muscovite (I)
?	
VI	Dolomite + pyrrhotite
VII	Dolomite + pyrrhotite + Au (I)
VIII	Silicification + Au (II) + quartz veinlets
IX	Fracturing + quartz/calcite veins + tourmaline
X	Fracturing + Au (III) + muscovite (pale-green hydromuscovite)
XI	Siderite

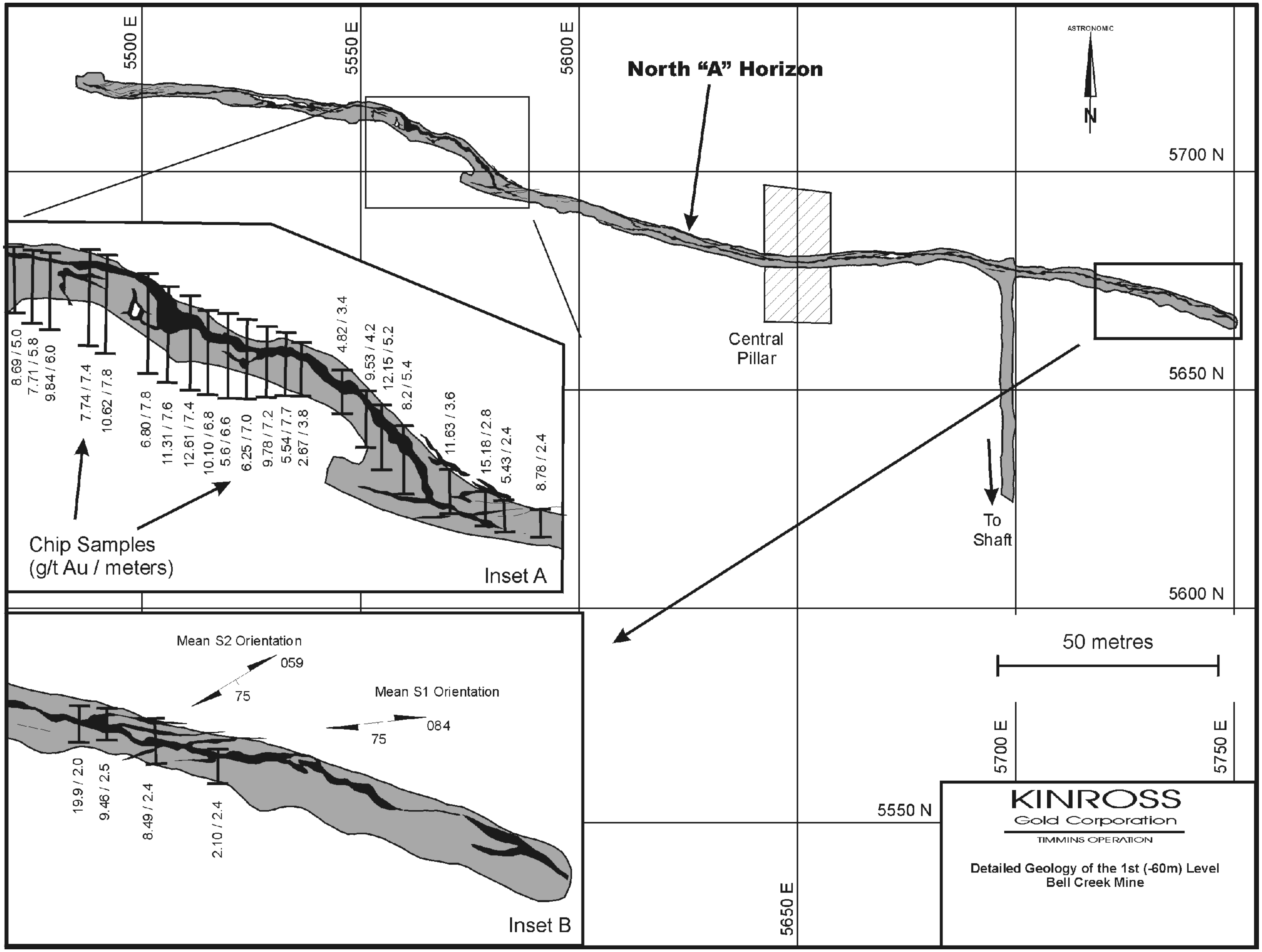

North "A" Horizon
ASTRONOMIC
N
5500 E
5550 E
5600 E
5650 E
5700 E
5750 E
5700 N
5650 N
5600 N
5550 N
Central
Pillar
To
Shaft
50 metres
8.69 / 5.0
7.71 / 5.8
9.84 / 6.0
7.74 / 7.4
10.62 / 7.8
6.80 / 7.8
11.31 / 7.6
12.61 / 7.4
10.10 / 6.8
5.6 / 6.6
6.25 / 7.0
9.78 / 7.2
5.54 / 7.7
2.67 / 3.8
4.82 / 3.4
9.53 / 4.2
12.15 / 5.2
8.2 / 5.4
11.63 / 3.6
15.18 / 2.8
5.43 / 2.4
8.78 / 2.4
Chip Samples
(g/t Au / meters)
Inset A
Mean S2 Orientation
059
75
Mean S1 Orientation
084
75
19.9 / 2.0
9.46 / 2.5
8.49 / 2.4
2.10 / 2.4
Inset B
KINROSS
Gold Corporation
TIMMINS OPERATION
Detailed Geology of the 1st (-60m) Level
Bell Creek Mine

Figure 10.

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Economic Geology and Mineralization at the Detour Lake Mine

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INTRODUCTION

The gold mineralization at Placer Dome North America's Detour Lake Mine is an atypical example of gold deposits in the Abitibi greenstone belt. It can be described simply as pyrrhotite + chalcopyrite + pyrite stringer and vein systems hosted within quartz veins and potassic-dominated (largely micas) alteration zones which are in turn hosted by mafic volcanic rocks.

Exploration activities in the Detour Lake greenstone belt date back to the early 1970's when Amoco Minerals Company conducted exploration for volcanogenic massive sulphide deposits (Wells 1997). An airborne geophysical survey was flown in 1974, with drill testing of the Detour 38 anomaly returning low grade copper values containing significant gold. Campbell Red Lake Mines entered into a Joint Venture agreement with Amoco Minerals in 1977, and continued exploration activities resulted in identification of a sizeable gold resource in the area of the present open pit. Mining operations began with the open pit in 1983, with underground development beginning in 1984 leading to full production in 1988. Current ore reserves as at December 31, 1997 are sufficient for an additional 12-18 months of operations at current rates (R. Hill, personal communication, 1998).

LOCATION, OWNERSHIP, AND CLAIMS

The Detour Lake Mine is located in the Sunday Lake NTS area, some 140 kilometres northeast of Cochrane, Ontario (Figure 1). The land holdings currently consist of approximately 5009 Ha (D. Gliddon, Placer Dome North America Limited, personal communication, 1998) in two properties, namely the Detour Lake Mine (Placer Dome North America Limited), and the Pelangio-Larder Option (Pelangio-Larder Mines Ltd).

REGIONAL GEOLOGICAL SETTING

The supracrustal rocks of the Detour Lake greenstone belt form the western extension of the Northern Province of the Abitibi Subprovince in northwestern Quebec as defined by Chown et. al. (1992). They are bounded to the north by gneissic and plutonic rocks of the Opatica Subprovince and to the west and south by the Hopper Lake granitoid complex (Jackson and Fyon 1991). On a regional scale, these supracrustal rocks consist of steeply dipping, easterly trending bands dominated by mafic metavolcanic rocks and clastic sedimentary rocks which have been sub-divided into three assemblages: the Vandette Assemblage, the Lower Detour Assemblage, and the Detour Lake Assemblage (Figure 2). The metamorphic grade of all three Assemblages has been described as lower amphibolite by Marmont (1987).

The Vandette Assemblage is the southernmost, and is dominated by iron-rich tholeiitic basalt units which contain minor amounts of chemical metasediments and felsic tuff units. Limited data suggest that younging directions in this Assemblage are towards the south. The Lower Detour Assemblage occupies the central portion of the belt and consists of a mixture of polymictic conglomerates, grits, finely bedded wackes, and argillites. On a gross scale the argillites and polymictic conglomerates predominate in the southern portions of the Assemblage while the northern portions are richer in quartzofeldspathic and chloritic wacke – rich sediments. Limited diamond drill hole information suggests the presence of felsic to intermediate metavolcanic flows in the central portions of the Assemblage near the Ontario – Quebec border (Johns 1979). Younging directions in the southern portions of the assemblage are to the north, conflicting with an anticlinal fold axis interpreted by Johns (1982). This assemblage has been tentatively correlated with Cycle 2 sediments of the Northern Volcanic Zone in Quebec (Mueller and Donaldson 1992) which are interpreted to have formed in subaerial to shallow-marine to lacustrine environments in the 2715 – 2705 Ma period. The Detour Assemblage is the northernmost and is similar to the Vandette Assemblage

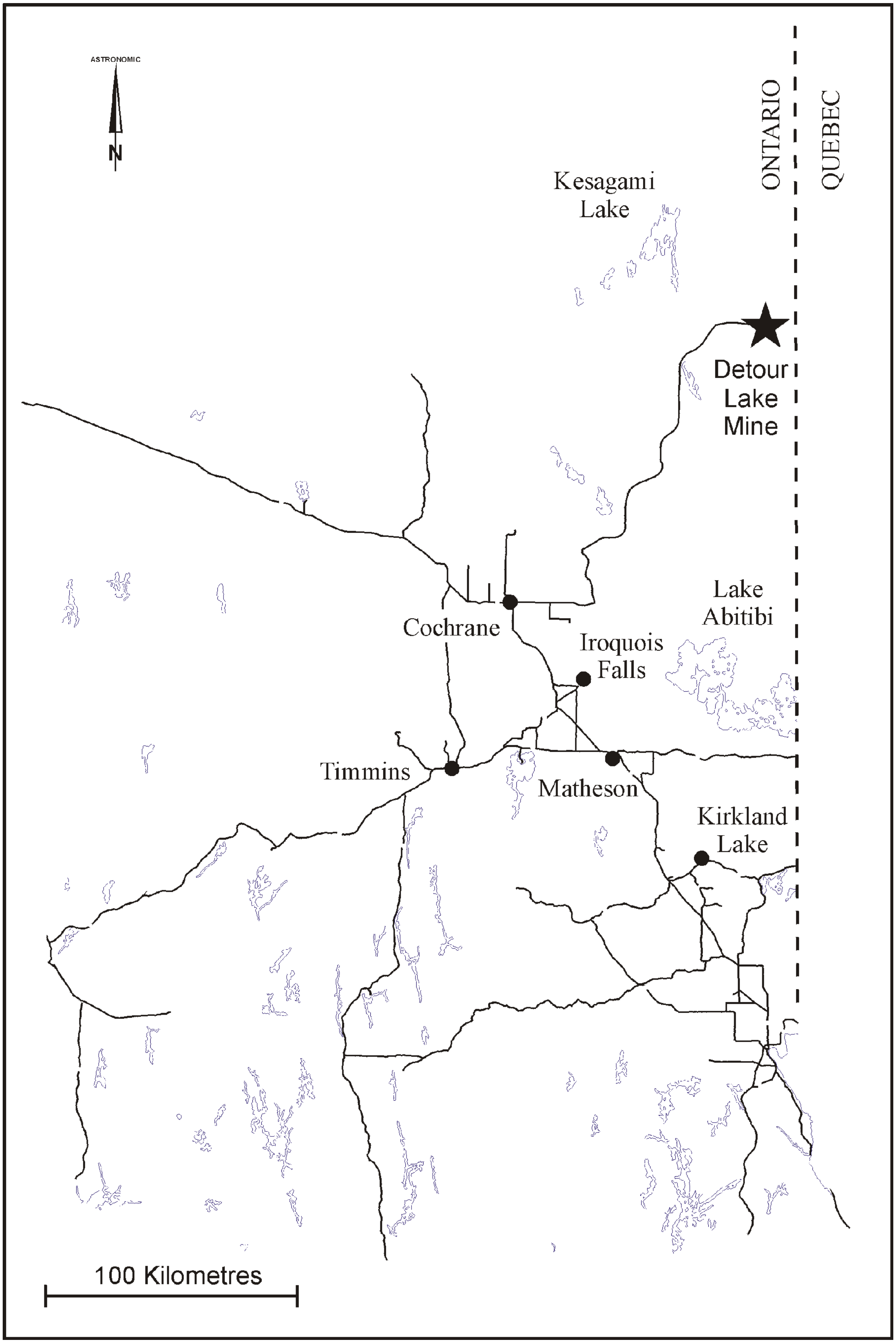

Figure 1. Location map of the Detour Lake Mine.

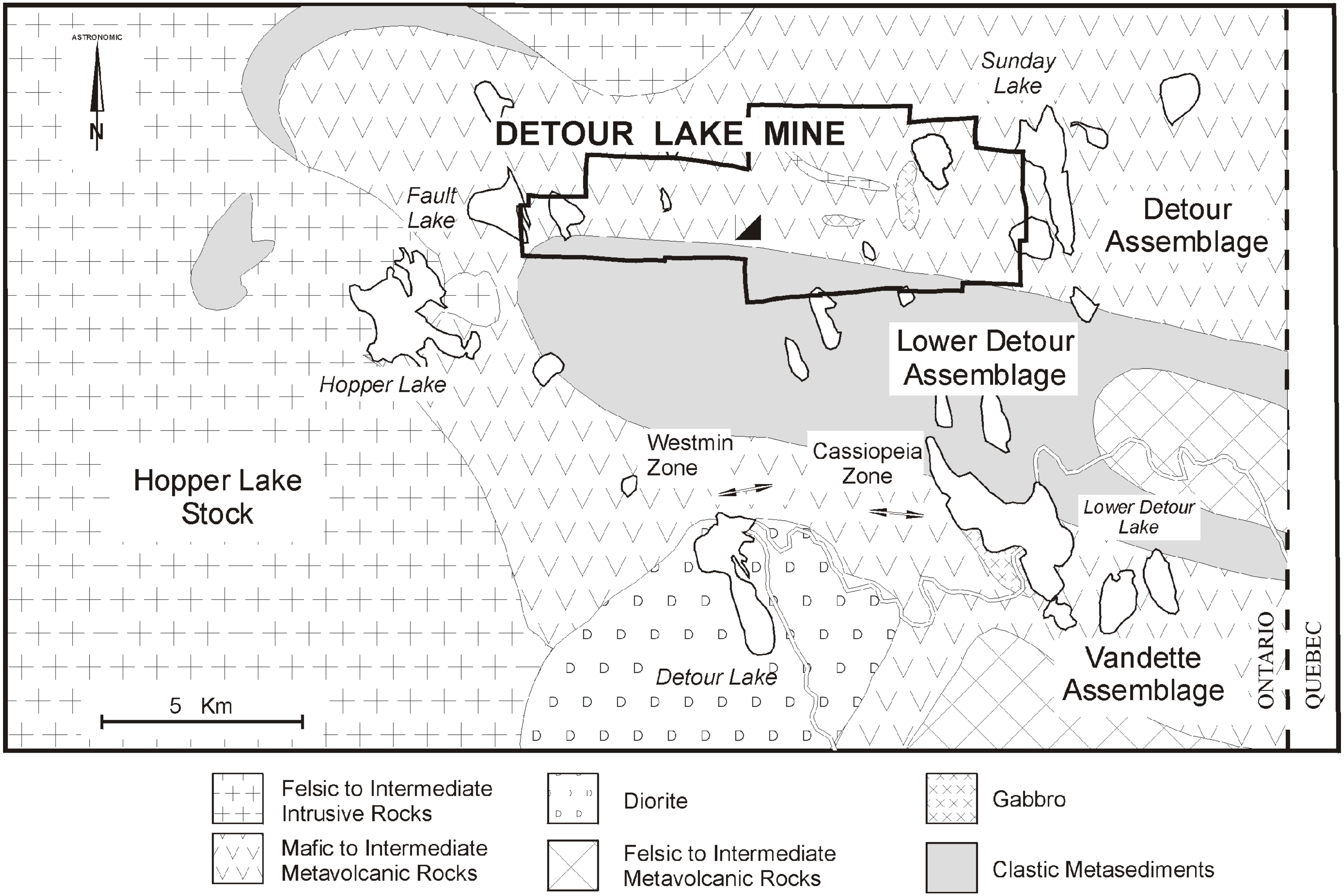

Figure 2. Generalized Regional Geology of the Detour Lake Greenstone Belt (modified from Johns 1981).

in that it is dominated by iron-rich tholeiitic basalts with minor intercalated f chemical metasedimentary rocks and felsic tuffs. However it also contains rare amounts of ultramafic rocks along its southern limit. Both north and south facing units have been observed in this assemblage, suggesting tight folding.

A number of intrusive bodies are found throughout all three assemblages. They are dominantly of mafic to intermediate compositions, and occur mostly as dikes and large stocks. Three of the larger of these consist of a gabbro – diorite – quartz diorite body located on the southwestern shore of Lower Detour Lake, a gabbro – diorite body surrounding Detour Lake, and a complex gabbro – pegmatite – diorite body located to the northeast of the Detour Lake Mine known as the East Lake Gabbro. Felsic intrusions are rare on a regional scale and occur mostly as small dikes. However felsic dikes are more numerous in the area of the Detour Lake Mine, and age dating of one such dike which cuts the tholeiitic flows returned a date of 2722 m. y. (Marmont and Corfu 1988).

Two major structures or deformation zones have been recognized in the Belt by Marmont (1987), namely the Detour Lake Deformation Zone and the Cassiopeia – Westmin Zone. The Detour Lake Deformation Zone is located within the Detour Lake Assemblage, crosscuts the general stratigraphic trend at a low angle, and has been traced along a strike length of approximately 19 km. It is described as a ductile shear zone consisting of a strong penetrative fabric on the order of 2 km in width. The area of highest strain is centered on the Mine area where single high-strain shears are separated by areas of relatively undeformed rocks. A moderately west plunging stretching lineation is a common feature in this Deformation Zone. The Cassiopeia – Westmin Deformation Zone is hosted within the Vandette Assemblage and has been traced only from north of Detour Lake eastwards to Lower Detour Lake, a distance of some 5 km. Heavy overburden cover and a general lack of information have hindered a detailed examination of this deformation zone, but a few outcrop exposures show it to consist of several closely spaced zones of high strain separated by narrow bands of undeformed rock. A series of late, northwest trending brittle faults transect all three assemblages.

PROPERTY SCALE GEOLOGICAL SETTING

Macroscopic Description of Rock Types

The following description of the detailed geological setting and alteration of the Detour Lake Mine is summarized from Hennessey et. al. (1995):

OVERALL DEPOSIT GEOLOGY

The ore zones of the Detour Lake deposit occur at the contact between the Lower Detour and Detour Assemblage within a sequence of mafic to ultramafic volcanic and intrusive rocks which structurally overlie clastic sediments. Very limited facing indications suggest this sequence of rocks is overturned with the sediments to the south being younger.

The stratigraphic sequence from north to south (structural hanging wall to footwall) in the immediate mine area is hanging wall tholeiitic mafic volcanic flows, “chert”, komatiitic sills (volcanic flows ?), footwall tholeiitic mafic volcanic flows, and volcaniclastic and clastic sediments. All of these units are intruded by a variety of crosscutting felsic, intermediate, mafic, and ultramafic intrusives (Figure 3) and are discussed individually below.

THOLEIITIC BASALTS-MAFIC VOLCANIC FLOWS

The structural hanging wall of the orebody is composed of a thick sequence of tholeiitic basalt flows. Both pillowed and massive flows are noted. The thickness of this sequence is unknown, but it is at least 500 m and probably exceeds 1,000 m. Occasional sections of tuffaceous appearance are noted but this unit is usually an equigranular, relatively featureless rock. Pillows are usually hard to distinguish unless looking at altered or weathered areas. Variolitic and amygdaloidal textures are rare but not unknown.

“CHERT”

“Chert” is a mine name for the rock type immediately underneath the hanging wall mafic volcanics. This rock unit is a 0.5 - 3 m thick, fine grained, banded, siliceous looking rock which at first glance resembles a

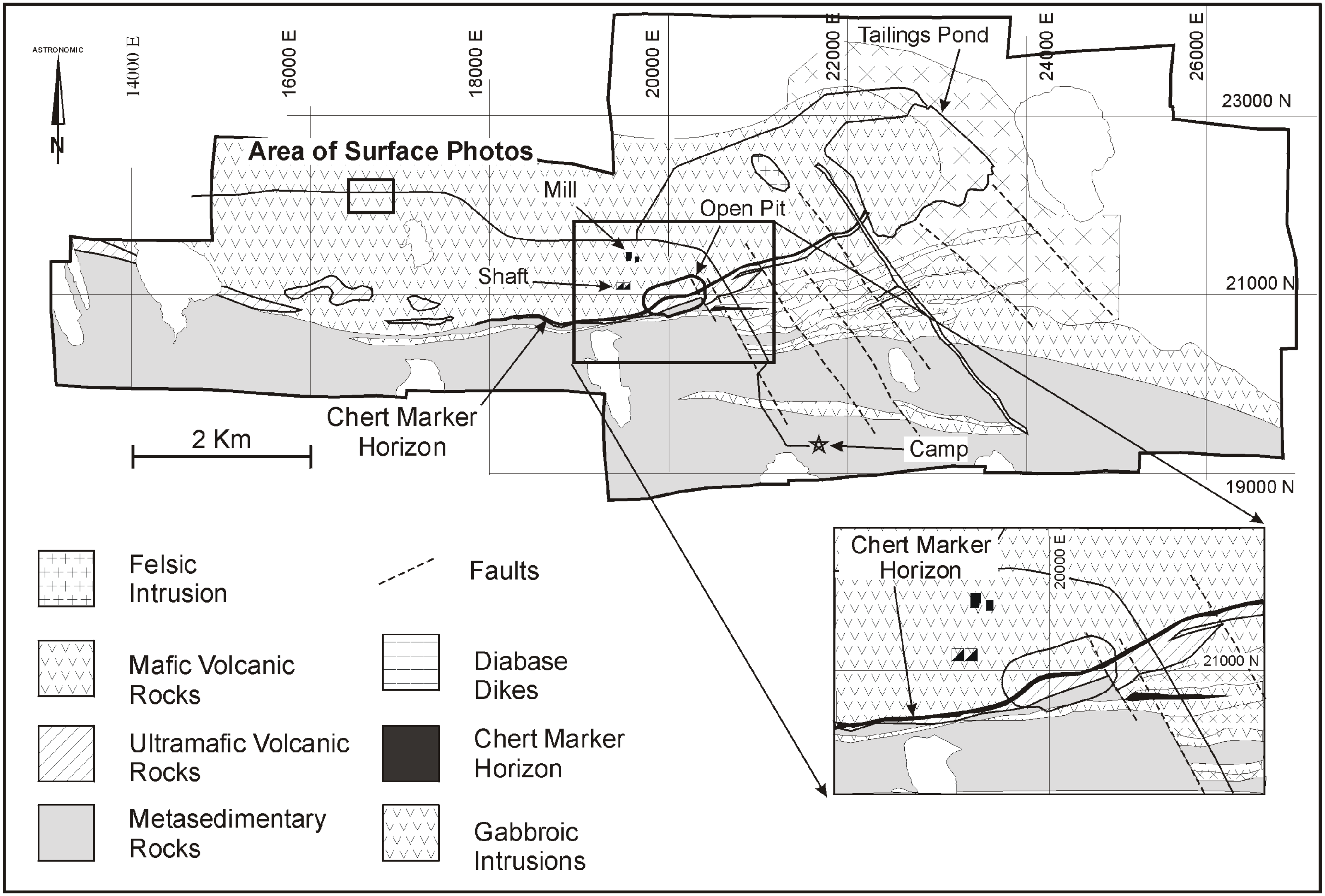

Figure 3. Property Scale Geology of the Detour Lake Mine (modified from Placer Dome North America Limited drawing).

chemical sediment or exhalative layer. In the early exploration of the property, it was called a chert and the name has been retained in the interests of consistancy. It has been interpreted as a mylonite zone at one time, but recent work now suggests it to be a highly strained felsic to intermediate intrusive. The chert forms a useful marker horizon and has been traced over a strike length of several kilometres but is often locally absent as a result, it is believed, of boudinaging.

KOMATIITE

Underneath the chert lies a 5-80 m thick sequence of komatiitic rocks now believed to be intrusive in origin. This sequence grades quickly from a basaltic composition immediately against the chert to ultramafic as one proceeds southwards. The ultramafic rocks are typically strongly altered to chlorite ± talc ± carbonate ± actinolite schists. The komatiitic basalts adjacent to the chert appear less altered but do show some chloritic and patchy potassic alteration. Original volcanic textures such as spinifex and pillows are never seen. Intrusive textures have been recognized to the west, suggesting that these units are actually peridotites.

VOLCANICLASTIC SEDIMENTS

The volcaniclastic sediments or “VC” are typically found adjacent to the talc altered komatiites and may have 1-5 m thick layers of talc-chlorite schist in the upper 10 m. The VC is typically 5-50 m or more in thickness and is characterized by alternating bands or layers of grey-green tuffaceous material and bronzy biotite - coloured altered mafic volcanics. These bands are normally 1-4 cm wide. Although exposed in only two places in the mine workings, the biotite altered layers are believed to represent highly flattened fragments of volcanic rock, hence, the volcaniclastic name.

FOOTWALL THOLEIITE-MAFIC FLOWS

This unit is usually located structurally beneath or within the volcaniclastic unit but can occasionally be found in contact with the altered komatiite. Tholeiitic in composition, its’ fine grained textures, colour and homogenous appearance all closely resemble the hanging wall tholeiitic basalt. Thickness can vary from zero to tens of metres. Slight variations of the unit include a crushed feldspar phenocryst and a garnetiferous phase and these are usually found well away from the talc contact.

CLASTIC SEDIMENTS

South of the “VC” is a thick sequence of interbedded greywackes and siltstones. These rocks are not exposed anywhere in the mine workings but are known from long holes drilled to the south. Limited surface drilling on the property would indicate that this sequence may be more than 1,200 m thick. These sediments comprise the northern portion of the Lower Detour Assemblage.

INTRUSIVE ROCKS

The Detour Lake Mine property has undergone an extremely complex intrusive history which is still being worked out at this time. There are several large felsic and intermediate dykes which have experienced D_2 deformation but pre-date both the quartz veins and the ore (Photo 1). However, there are many fine grained, porphyritic felsic and intermediate intrusives which show no deformation and therefore may be relatively young. Also, the same can be said of mafic intrusives. There are pre-D_2 deformation and post-ore, fine grained, mafic intrusives which appear to be very similar in composition to the hanging wall mafic volcanics.

There is one large intrusive body in the mine workings stratigraphy. This is a 5-20 m thick, intermediate intrusive found within the talc-chlorite schists in the footwall of the Main Zone. It is conformable with the talc altered unit, and is found immediately south of the change in strike of the chert to a northeasterly orientation. It maintains the same dip and plunge as the Main Zone down to the 560 m level. This intrusive has experienced D_2 deformation and shows moderate foliation. It has been broken up into many contiguous slivers and the most heavily altered rock in the mine surrounds this unit.

To the east and northeast of the open pit is a large, polyphase intrusive complex (East Lake Gabbro). It is weakly foliated and contains xenoliths of ultramafic intrusive, feldspar porphyritic intrusive, strongly foliated amphibolite, and pillowed flows. This may be post D_2, but it is not known if it is post-ore. It has been described at various times as a quartz diorite, diorite or gabbro.

Recent drilling on the QK Zone, some three kilometres west of the shaft has intercepted two new intrusive bodies: a large ultramafic intrusive, and multi-phased intrusive of variable composition The multi-phased intrusive typically contains up to 50% xenoliths of foliated footwall volcanics, sediments, and ultramafic intrusive, set in an equigranular gabbroic groudmass. The ultramafic intrusive, interpreted to be a pyroxinite, is situated within the hanging wall volcanics, and its source area is speculated to be the multiphased intrusive at depth. Both the pyroxenite and multiphased intrusive are unfoliated suggesting they are post-D_2 deformation or at the very earliest intruded at the waning stages of the D_2 event. The ultramafic intrusive has been found to have sheared and talc altered boundaries in some sections.

Diabase and granodioritic dikes are also seen on the property and cross cut all rock types.

Several examples of a rock-type mapped as a heterolithic breccia have been identified in underground mapping. These dyke-like structures are seen to crosscut the major volcanic lithologies and contain brecciated fragments of quartz, gneiss, granitic rocks, and metavolcanic rocks, in a fine grained mafic matrix. The matrix shows the foliation of the D_2 event. It is not understood whether these are true magmatic intrusives or are generated through some other mechanism such as tectonic brecciation or explosive degassing of a stock.

Macroscopic Description of Metamorphic/Alteration Types and Assemblages

The main peak metamorphic minerals in the metavolcanic and metasedimentary rocks at the Detour Lake Mine are hornblende and almandine garnet. Combined with the anorthite content of the plagioclase, these minerals indicates a peak metamorphic grade of lower amphibolite facies. This grade is regional in extent and is persistent throughout the mine rocks.

Alignment of hornblende crystals of possible metamorphic origin suggests that peak metamorphism predates or is synchronous with peak ductile deformation (D_2). Peak metamorphism also predates the hydrothermal alteration event seen in the hanging wall tholeiites, as hydrothermally retrograded metamorphic mineral assemblages are noted here (retrograde alteration of hornblende to biotite and chlorite).

Photo 1. Surface exposure of an early mafic intrusive contained within strongly folded massive and pillowed mafic volcanic rocks, Detour Lake Mine. Outcrop located at approximately 16250E 21250N on the mine grid, approximately 3.2 km northwest of the shaft. Note pen (A) points northwards.

Two distinct alteration mineral assemblages are found, one in the hanging wall mafic volcanic rocks and one in the footwall komatiitic rocks:

The hanging wall tholeiitic metavolcanic rocks have been hydrothermally altered to potassic micas, quartz, sericite, and minor chlorite. The potassium alteration is the most dominant alteration style, and results principally in the development of a bronze coloured biotite giving the rock a characteristic purplish brown colour (Photo 2). The silicification, which is usually weak, may overprint the biotite alteration or occur as an intense pinkish halo with associated potassic feldspar flooding. Hydrothermal alteration in the hanging wall occurs principally as halos around quartz veins. Alteration intensity increases southwards, reaching a maximum up against the “chert.” The upper several metres of the volcaniclastic horizon contains a similar alteration mineral assemblage. A mineralized zone, called the Pillow Zone, discovered well out in the hanging wall in 1993, has the same alteration mineral assemblage as the other hanging wall zones, although carbonate alteration is more prevalent there and silicification and biotite development somewhat reduced.

The footwall komatiitic rocks show typical talc-chlorite alteration seen in ultramafic rocks elsewhere in the Abitibi Subprovince. The metamorphic mineral assemblage is chlorite + talc ± calcite ± tremolite/actinolite. In contrast to the hangingwall alteration style, the alteration intensity in this unit increases southwards, away from the chert. This observation suggests that the komatiites may have been structurally emplaced against the hanging wall tholeiitic volcanics.

A new gold zone called the QK Zone has been discovered approximately 3 kilometres west of the headframe. Situated in the hanging wall in close proximity to Main Zone stratigraphy, the QK Zone has similar features to the Main Zone such as quartz veining and fracture controlled sulphides surrounded by biotite, but the zone also contains a significant increase in K-feldspar alteration. Between the QK Zone and the deep multiphased intrusive, the volcanic stratigraphy is hornfelsed from an epidote-almandine to a garnet-amphibole-magnetite mineral assemblage with depth.

Lithogeochemical Data

Detailed lithogeochemical (Pianosi 1994, Thomas 1994, Wells 1994) and petrographic studies (Stanley et. al. 1991, Murck 1992 and 1993) have been done on the Detour Lake Mine stratigraphy, with selected data presented in Table 1.

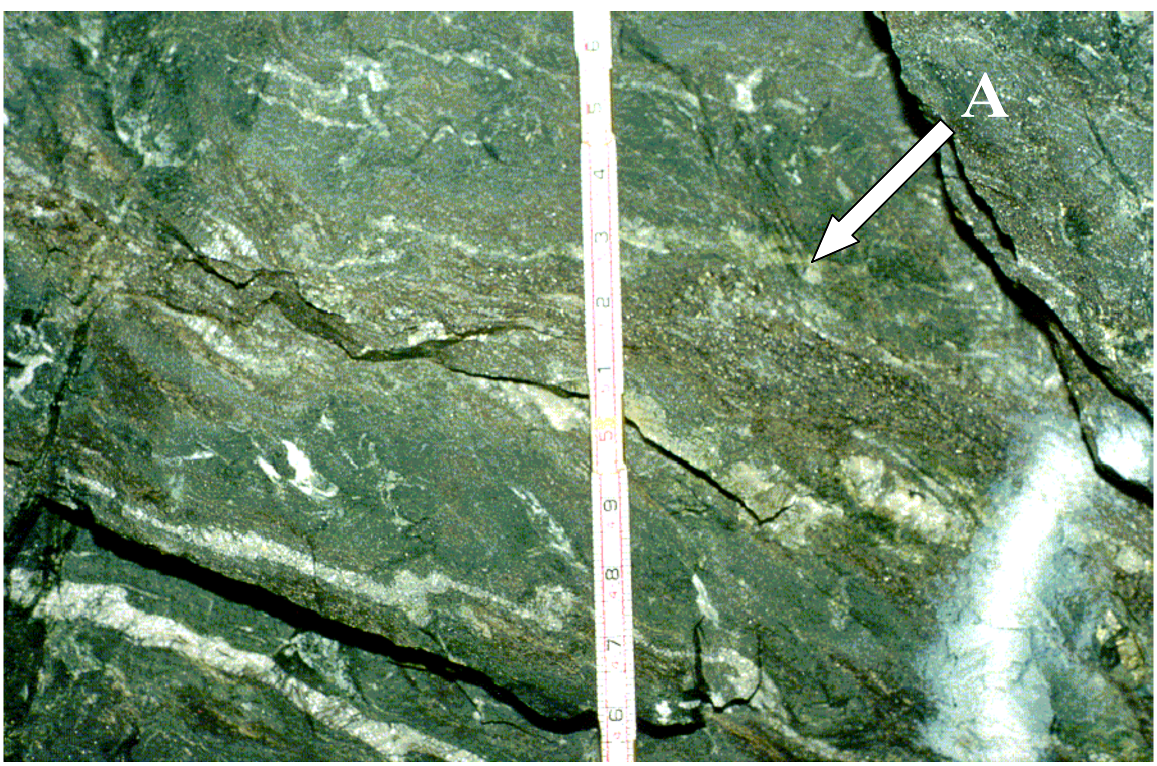

Photo 2. Example of potassic (biotite) alteration(A) of mafic metavolcanic rocks, Main Zone, 17 900E pillar, 785 Heading, Detour Lake Mine. Stick rule is marked in 10ths of a foot.

Table 1. Major and trace element geochemistry of selected samples from the Detour Lake Mine. Data modified from Pianosi (1994), Thomas (1994), and Wells (1994).

Sample	Rock	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	CaO (%)	MgO (%)	Na2O (%)	K2O (%)	P2O5 (%)	LOI (%)	Total	Cr (ppm)	Ba (ppm)	CO2 (%)	As (ppm)
00-021-1	MF	51.49	0.90	14.48	11.26	0.18	10.21	7.04	2.27	0.69	0.09	1.56	100.18	84	84	0.12	0.3
00-021-2	MF	52.78	1.07	14.44	12.00	0.21	9.21	6.04	2.67	0.41	0.09	1.32	100.25	68	53	0.08	0.6
00-021-3	MF	50.73	1.58	13.74	15.56	0.23	8.03	6.46	2.54	0.40	0.11	1.63	101.00	67	82	0.04	0.5
11-435-11	MF	64.35	0.67	15.21	5.94	0.09	5.19	2.27	3.44	1.54	0.13	1.43	100.24	16	408	0.55	1.2
11-435-12	MF	51.83	0.97	13.46	11.09	0.19	10.32	6.14	2.46	0.85	0.10	2.70	100.10	147	155	0.38	0.9
11-435-13	MF	51.26	0.85	14.69	11.35	0.17	8.92	7.17	2.65	0.84	0.06	2.51	100.45	94	96	0.67	0.9
11-435-14	MF	51.45	1.02	16.53	9.67	0.16	8.84	5.26	2.68	0.75	0.23	3.40	99.98	47	156	0.77	1.3
11-435-15	MF	47.95	0.93	13.36	12.67	0.22	10.69	9.53	2.07	0.70	0.25	2.17	100.52	816	89	0.67	0.5
11-435-16	MF	52.74	0.21	15.55	6.53	0.13	8.42	8.78	3.73	1.01	0.10	2.70	99.90	483	199	0.43	2.0
11-435-17	MF	50.85	0.98	13.22	11.24	0.19	10.19	6.09	2.34	0.84	0.08	4.48	100.50	68	73	2.74	1.0
11-435-18	MF	52.29	0.88	13.61	11.55	0.19	9.61	4.90	1.77	1.56	0.08	3.76	100.19	78	134	3.00	2.9
400-MZ-1	MF	50.85	0.75	15.02	10.97	0.16	11.24	7.55	2.11	0.46	0.07	1.45	100.63	104	65	0.33	0.4
400-MZ-2	MF	53.01	0.91	14.53	10.68	0.17	11.34	5.77	1.45	0.40	0.07	2.28	100.62	52	53	0.76	0.5
400-MZ-3	MF	52.04	1.11	13.84	12.78	0.18	9.17	7.10	2.28	0.25	0.07	1.80	100.62	69	26	0.18	0.2
400-MZ-4	MF	54.65	1.67	13.52	15.15	0.25	8.61	4.08	1.58	0.35	0.13	1.06	101.06	66	26	0.37	0.5
464-032-12	MF	51.49	1.09	14.28	12.65	0.14	7.63	7.31	2.17	1.19	0.11	2.57	100.62	70	40	0.46	0.9
464-032-13	MF	52.07	0.92	14.86	11.14	0.16	9.10	6.51	2.45	1.03	0.08	2.20	100.51	57	172	1.08	0.1
464-032-15	MF	47.05	0.77	11.24	11.95	0.24	13.23	10.08	1.61	0.31	0.16	3.71	100.36	1051	30	2.32	4.0
464-032-16	MF	49.48	0.94	13.67	12.19	0.26	9.72	6.33	0.73	1.94	0.09	4.79	100.14	76	131	1.98	2.2
464-032-2	MF	51.79	1.18	14.24	12.59	0.21	8.94	5.31	2.34	1.23	0.10	2.46	100.38	83	109	0.79	0.1
464-032-3	MF	55.09	1.03	13.94	9.88	0.16	8.98	6.05	2.41	0.91	0.10	1.60	100.16	118	74	0.27	0.1
464-032-4	MF	53.96	0.89	13.66	10.73	0.17	10.38	5.89	2.09	0.49	0.07	1.95	100.28	126	58	0.71	0.5
464-032-6	MF	50.50	0.75	13.19	11.37	0.20	10.97	9.46	2.56	0.79	0.17	0.44	100.39	541	175	0.68	0.4
464-032-8	MF	54.13	0.91	14.21	10.72	0.16	10.25	5.91	1.82	0.78	0.09	1.49	100.46	152	97	0.80	0.4
530-10	MF	53.33	1.03	14.62	12.08	0.18	8.13	6.35	1.73	1.10	0.09	1.76	100.39	85	225	0.19	1.5
530-4	MF	52.51	1.10	14.12	12.68	0.19	7.69	7.19	1.22	1.16	0.08	2.57	100.51	86	116	0.29	0.9
530-8	MF	51.47	0.89	13.38	11.72	0.20	9.88	8.13	1.44	0.90	0.16	2.35	100.52	356	95	0.47	0.8
530-9	MF	51.57	0.95	14.28	11.78	0.19	9.74	7.48	1.73	0.57	0.07	2.02	100.38	76	80	0.24	0.5
11-435-19	KMF	50.25	0.99	13.63	11.60	0.20	7.79	5.26	1.60	2.10	0.09	7.01	100.52	68	216	3.04	3.0
400-MZ-5	KMF	59.96	1.20	15.42	10.69	0.09	2.83	2.35	1.64	2.86	0.08	3.27	100.38	80	760	0.08	0.8
400-MZ-6	KMF	57.52	1.13	15.09	12.50	0.10	4.68	3.24	1.04	2.57	0.07	2.57	100.51	78	443	0.05	1.2
400-MZ-7	KMF	57.56	1.22	16.98	9.88	0.13	3.63	2.72	2.45	3.20	0.08	2.50	100.34	70	1054	0.03	0.5
464-032-10	KMF	50.20	0.83	14.08	9.70	0.17	9.66	4.55	1.19	3.05	0.08	7.07	100.59	61	266	3.90	1.6
464-032-17	CMF	50.50	0.93	13.62	11.49	0.21	8.92	5.76	1.85	1.87	0.09	4.66	99.90	97	331	2.54	2.0
464-032-18	KMF	50.69	0.95	14.39	11.15	0.20	9.88	4.83	2.07	1.40	0.09	4.86	100.51	75	99	2.76	2.5
464-032-19	KMF	53.42	1.11	13.66	15.91	0.20	5.68	4.08	0.90	1.96	0.08	4.06	101.05	87	336	1.43	2.9
530-5	KMF	51.05	1.04	14.81	13.04	0.17	7.71	4.87	2.30	2.00	0.08	3.45	100.50	90	221	1.38	2.0
11-435-1	PF	49.48	0.99	14.16	12.56	0.28	9.66	6.38	1.95	1.46	0.09	3.56	100.57	90	122	1.71	2.0
11-435-2	PF	48.57	0.91	13.64	11.09	0.24	10.43	5.58	0.74	2.31	0.08	7.18	100.74	73	153	3.89	3.5
11-435-3	PF	54.04	0.94	14.27	10.57	0.21	9.01	5.14	1.69	1.60	0.08	2.75	100.31	69	119	2.11	1.4
11-435-4	PF	49.54	1.62	14.49	11.13	0.18	9.14	7.03	3.60	0.81	0.43	2.48	100.45	124	162	1.76	3.1

Table 1. Continued

11-435-5	PF	52.85	0.68	12.84	9.46	0.20	9.69	9.89	2.16	0.56	0.14	1.76	100.21	752	34	0.38	1.0
11-435-6	PF	54.02	0.93	14.22	10.48	0.17	9.66	3.62	2.14	1.02	0.07	3.54	99.87	71	124	3.16	0.9
11-435-7	PF	53.42	1.17	13.17	16.20	0.10	4.64	3.69	2.16	1.52	0.07	4.99	101.12	100	239	0.47	2.0
11-435-8	PF	50.74	0.89	13.77	11.29	0.16	10.42	4.55	1.45	1.99	0.08	4.06	99.41	74	193	2.86	12.4
11-435-9	PF	48.53	0.86	13.81	11.42	0.19	10.57	4.84	0.79	2.48	0.08	6.76	100.32	70	430	3.69	2.6
464-032-1	PF	51.77	0.79	14.24	11.34	0.18	10.56	6.68	2.04	0.62	0.05	2.17	100.44	634	80	0.65	0.1
464-032-5	PF	54.51	0.92	14.03	10.49	0.14	7.97	6.04	2.29	1.72	0.09	1.82	100.02	154	122	0.35	0.2
464-032-9	PF	54.05	0.92	14.20	9.84	0.14	9.56	6.53	2.27	0.82	0.10	2.09	100.52	95	82	0.79	0.1
464-032-11	KPF	50.20	0.84	13.24	10.49	0.15	10.77	3.74	2.08	2.05	0.07	6.81	100.42	64	175	5.09	1.3
464-032-14	KPF	48.58	0.95	13.97	12.92	0.26	9.89	5.77	0.79	1.89	0.07	5.64	100.72	82	153	1.76	8.9
400-MZ-10	KB	48.81	0.89	14.01	13.80	0.21	9.38	9.22	0.97	0.44	0.06	3.01	100.79	602	30	0.09	0.4
400-MZ-11	KB	48.88	0.94	13.31	14.32	0.22	8.16	10.07	0.77	0.39	0.06	3.89	100.99	722	71	0.22	1.1
11-435-20	KB	48.19	0.91	13.09	14.03	0.22	7.94	10.29	0.87	1.54	0.06	3.38	100.50	745	156	0.49	2.1
400-MZ-9	KB	49.92	0.88	13.84	13.04	0.23	10.13	8.78	0.84	0.78	0.06	2.18	100.67	546	105	0.08	0.6
400-MZ-14	KB	48.56	0.90	13.76	12.80	0.19	10.55	8.47	1.25	0.66	0.06	3.29	100.48	515	65	0.18	0.7
464-032-21	KB	48.61	0.83	13.97	12.52	0.25	10.14	8.58	1.14	1.62	0.05	2.79	100.50	527	156	0.58	4.7
530-3	KB	49.95	0.90	13.76	12.71	0.28	9.58	9.06	1.17	1.05	0.05	1.95	100.46	585	100	0.16	0.6
530-7	KB	47.31	1.04	13.23	14.43	0.19	9.31	8.61	1.18	1.23	0.03	4.35	100.90	570	114	0.46	2.4
11-435-21	CG	45.63	0.46	7.41	12.46	0.18	9.24	19.32	0.50	0.06	0.06	5.08	100.39	2650	1	1.39	2.5
400-MZ-13	CG	46.85	0.86	13.01	15.43	0.26	6.27	12.03	0.91	0.38	0.04	4.88	100.91	1033	40	0.13	0.3
530-2	CG	46.36	0.84	10.89	14.39	0.31	7.59	14.36	0.99	0.11	0.06	5.01	100.91	1021	15	0.13	1.5
00-021-5	UI	41.02	0.36	3.61	12.63	0.21	7.36	26.32	0.41	0.07	0.02	8.53	100.54	2315	1	2.11	0.9
00-021-6	UI	40.91	0.61	6.86	10.70	0.19	9.67	21.80	0.84	0.14	0.03	8.83	100.57	2291	1	3.92	0.7
464-032-7	UI	50.31	0.45	9.63	9.57	0.18	14.09	11.67	1.60	0.43	0.11	2.20	100.26	902	99	0.71	0.5
00-021-7	TC	37.96	0.35	3.49	12.82	0.21	6.50	24.83	0.24	0.03	0.03	14.28	100.74	2148	0	9.67	0.9
00-021-8	TC	40.08	0.36	3.58	11.56	0.21	8.50	23.01	0.37	0.04	0.02	13.14	100.85	2560	18	9.06	10.2
11-435-22	TC	43.08	0.59	8.64	13.64	0.18	4.60	21.23	0.28	0.03	0.02	8.37	100.64	3140	1	0.99	0.9
400-MZ-12	TC	45.69	0.43	6.17	12.64	0.17	7.33	21.03	0.38	0.03	0.04	6.72	100.63	2284	1	0.41	0.4
464-032-22	TC	49.57	0.49	11.16	8.62	0.13	7.34	15.29	1.78	1.07	0.19	4.64	100.28	1078	398	0.60	4.4
530-1	TC	45.30	0.52	6.59	14.27	0.20	4.74	20.80	0.37	0.03	0.02	8.55	101.38	3013	0	0.26	0.3
120-CH-1	CH	75.33	0.12	11.14	2.42	0.03	1.85	0.98	1.32	4.09	0.03	2.85	100.15	2	393	0.49	0.9
400-MZ-15	CH	82.10	0.12	8.84	2.20	0.02	0.68	0.58	0.62	2.78	0.03	2.02	99.99	3	335	0.13	0.9
400-MZ-8	CH	78.45	0.10	11.84	2.46	0.02	0.72	0.67	0.80	3.39	0.02	2.07	100.52	4	1606	0.07	0.3
464-032-20A	CH	61.66	0.69	11.78	11.96	0.13	3.30	3.35	1.39	2.03	0.06	3.95	100.29	91	371	0.19	4.0
464-032-20B	CH	68.72	0.50	11.14	8.92	0.08	1.52	2.75	1.71	2.37	0.04	2.62	100.37	34	423	0.23	3.0
530-6	CH	83.08	0.06	8.70	1.53	0.04	2.28	1.05	0.41	2.20	0.01	1.60	100.96	1	219	0.19	0.7
260-1	VC	56.60	1.08	13.89	9.18	0.13	7.36	3.60	2.61	1.99	0.19	4.07	100.69	143	224	1.83	0.8
464-021-1	VC	50.10	0.91	15.75	10.90	0.21	11.94	4.69	1.95	1.17	0.05	2.92	100.59	228	197	2.46	0.7
464-032-23	GWE	66.80	0.73	14.39	6.62	0.10	2.53	2.30	4.27	1.58	0.08	0.83	100.23	85	567	0.14	0.5
11-435-23	FI	68.07	0.19	16.53	1.83	0.03	2.35	1.08	6.04	2.25	0.05	2.07	100.51	10	673	0.72	0.8
11-435-24	FMV?	48.82	0.57	13.46	10.24	0.20	9.43	11.10	2.20	1.02	0.10	2.83	99.95	893	345	0.54	0.6

STRUCTURAL GEOLOGY

Stratigraphy

The property scale stratigraphic units, as determined from drill hole and outcrop information, vary in strike from west-northwest in the western part of the property, to east-west in the central parts, to east-southeast in the eastern parts of the property. This overall trend is disrupted in the area of the open pit, where a distinct flexure brings the stratigraphic orientations into a northeasterly direction. A number of gabbroic sills of the East Lake Stock intrude the stratigraphy in a northeasterly attitude to the immediate east of the mine. All rock units generally dip steeply north overall (-80°), but local variations in dips do occur with depth in the mine, such that dips of -60° N are present locally (Figure 4).

Barclay (1993) concluded that the regional structural setting and style of deformation on the Detour Lake Mine property is characterized by close to locally isoclinal folding as a result of predominantly regional flattening of the rock units, with little or no strike-slip movement (Photo 3). Marmont (1987) however proposed that the rocks of the Detour Lake Mine area were affected by a major regional ductile shear zone.

Interference fold patterns observed in outcrop indicate that at least two folding events took place on the property (Photo 4). A third folding event has been recognized recently by mine staff and is attributed to the emplacement of the ultramafic intrusive rocks. This third folding event is observed in the chert unit in the area of Section 17620E where it is compressed upwards and to the north (Photo 5). The intensity of the folding increases from the open pit westwards to the limit of the current mine workings.

Joints

The orientations of joints within the mine affect mining operations only on occassion. Major joint sets have been identified and their properties are shown in Table 2.

Table 2. Summary of Joint Data, Detour Lake Mine. Data provided courtesy of Roger Hill, Chief Geologist, Placer Dome North America Limited.

Area	Joint Orientations	Joint Spacing	Joint Surfaces	Avg. CSIR Rock Mass Classification	Water Flow
Hangingwall and Footwall Units	E-W, dip 90 N-S, dip 90	1 – 3 m	Slightly rough	70%	Rare
Main Zone	E-W, dip 90 N-S, dip 90 Flat (below 660mL)	Verticals: 1-3m Flats: 1m	Slightly rough Clean	65-80% above 660 45-75% below 660	Minor
Talc Zone	E-W, dip 90 N-S, dip 90	0.3 – 1m	Soft gouge to Slickensided	30-60%	Minor
Quartz Zones	E-W, dip 90 N-S, dip 90	1 – 3 m	Slightly rough	65-75%	Minor

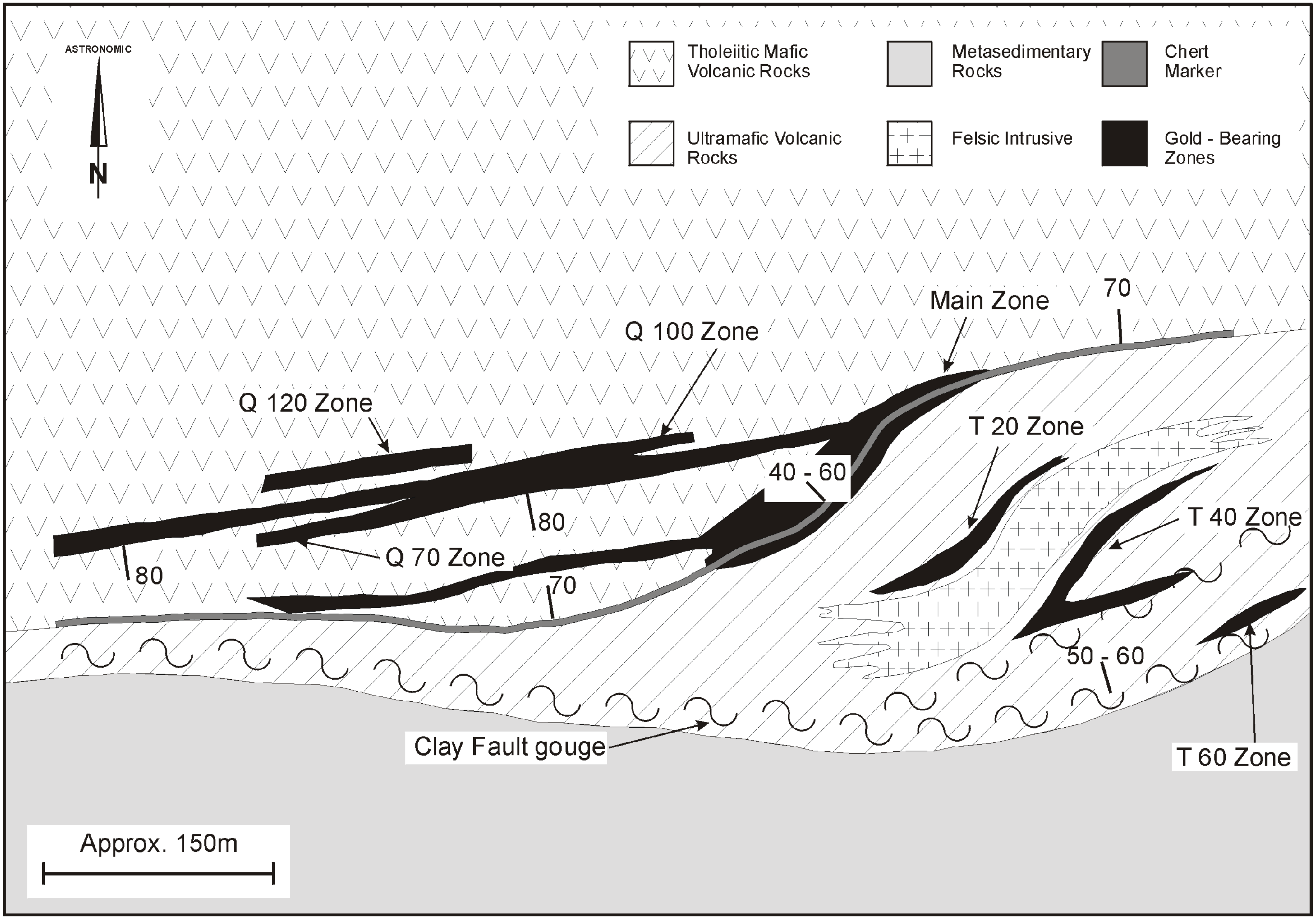

Figure 4. Schematic illustration of the geology and mineralization (~360m L) at the Detour Lake Mine (modified from Barclay 1993). Not to accurate scale.

Photo 3. Surface exposure of a late mafic intrusive dike cross cutting intensely folded pillowed and massive mafic metavolcanic rocks, Detour Lake Mine. Note the south-dipping foliation and distinctive ring structures. Location of Photo 4 as indicated. Outcop is located at approximate mine grid co-ordinates 16250E 21250N, approximately 3.2 km northwest of the shaft. View looking west.

Photo 4. Surface exposure of folded massive and pillowed mafic metavolcanics, Detour Lake Mine. Pen points northwards to approximate azimuth of 010°. Note south dipping foliation and contacts of large ring structure in the channel sample. These ring structures suggest refolded folds in a dome-and-basin, Type I interference pattern. Location as shown in Photo 3.

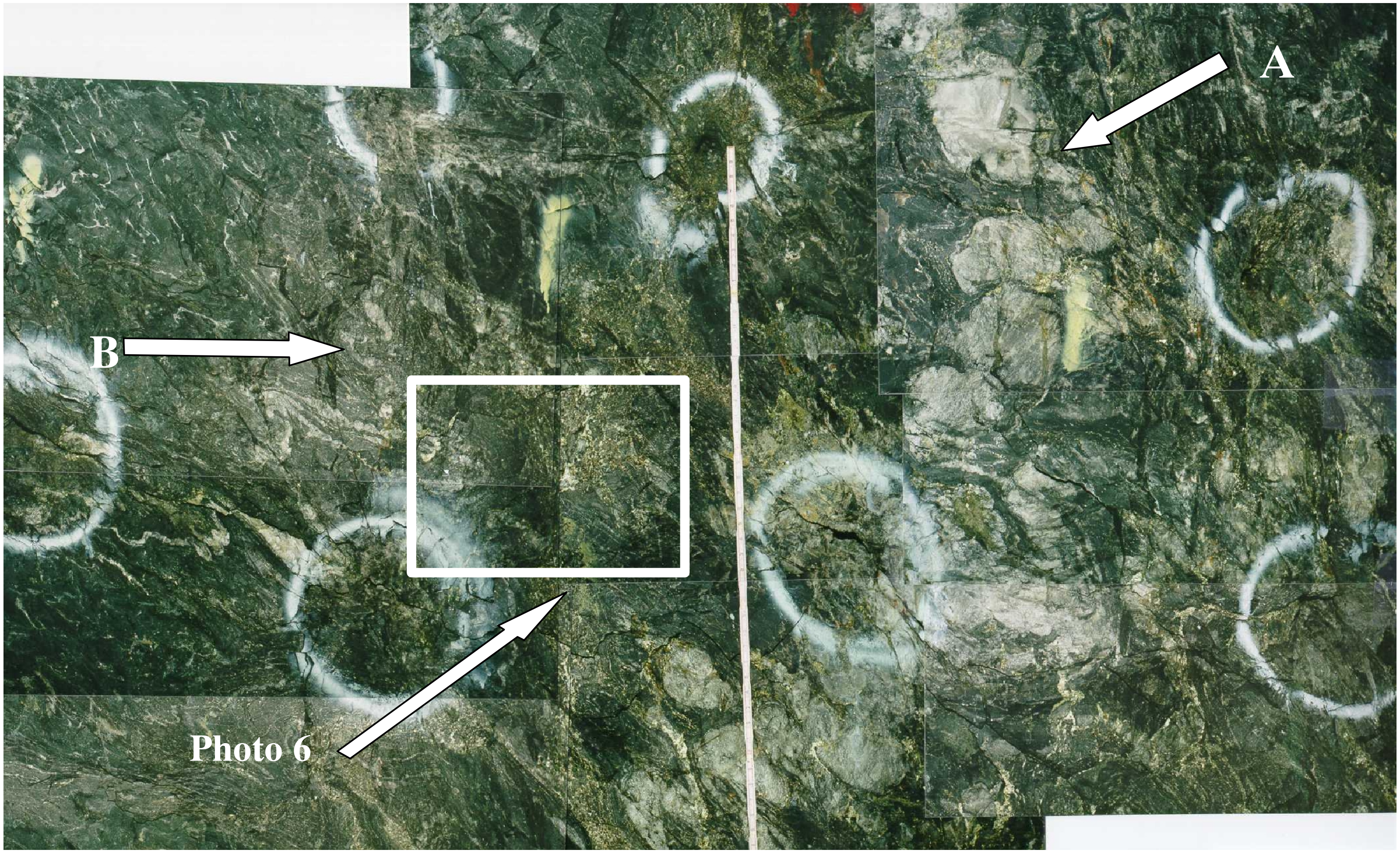

Photo 5. Composite view of Main Zone 785 – 805 Boundary Pillar, 785 Heading, approximately at Section 17900E, looking west, Detour Lake Mine. Note ptygmatically folded and boudinaged quartz vein (A), folded cherts and mafic metavolcanics (B), and cpy+po sulphide stringers and disseminations. Stick rule is 4 feet in length.

Table 3. Summary of Gold Production by Ore Zone for the Detour Lake Mine as at December 31, 1997. Data provided courtesy of Roger Hill, Chief Geologist, Placer Dome North America Limited.

Year	Low Grade Stockpile			Open Pit			Main Zone (UG)			Quartz Zones (UG)			Talc Zones (UG)		
	Tonnes	Grade (g / t)	Oz Au	Tonnes	Grade (g / t)	Oz Au	Tonnes	Grade (g / t)	Oz Au	Tonnes	Grade (g / t)	Oz Au	Tonnes	Grade (g / t)	Oz Au
1983	-	-	-	256 604	2.70	22 275	-	-	-	-	-	-	-	-	-
1984	-	-	-	794 561	3.30	84 301	-	-	-	-	-	-	-	-	-
1985	-	-	-	813 139	3.40	88 886	-	-	-	-	-	-	-	-	-
1986	30 800	1.80	1 782	691 557	3.70	82 266	61 000	5.00	9 806	-	-	-	-	-	-
1987	177 857	1.40	8 006	439 704	2.50	35 342	95 650	4.50	13 838	17 100	5.00	2 749	18 200	5.20	3 043
1988	143 450	1.60	7 379	-	-	-	430 000	5.10	70 507	118 118	5.10	19 368	115 000	5.00	18 487
1989	46 784	1.40	2 106	-	-	-	494 881	5.50	87 509	67 777	6.40	13 946	207 267	5.40	35 984
1990	36 565	1.40	1 646	-	-	-	470 000	5.30	80 087	110 000	5.20	18 390	250 000	4.70	37 777
1991	58 620	1.40	2 639	-	-	-	483 790	5.20	80 882	84 065	5.40	14 595	172 000	5.50	30 415
1992	47 228	1.60	2 429	-	-	-	499 631	4.80	77 105	214 169	5.80	39 937	112 208	5.40	19 481
1993	50 238	1.60	2 584	-	-	-	815 613	4.98	130 667	87 304	5.99	16 802	-	-	-
1994	49 878	1.70	2 726	-	-	-	419 742	4.60	62 077	362 032	5.40	62 854	63 328	3.90	7 941
1995	37 800	1.50	1 823	-	-	-	651 600	4.10	85 893	259 400	5.10	42 533	29 200	3.91	3 671
1996	83 000	1.30	3 469	-	-	-	607 377	4.38	85 531	233 948	5.49	41 294	23 300	4.38	3 281
1997	473 437	1.11	16 904	-	-	-	675 973	3.76	81 634	137 611	6.48	28 669	7 233	2.90	674
TOTAL	1 235 657	1.35	53 493	2 995 565	3.25	313 070	5 705 257	4.72	865 536	1 691 524	5.54	301 137	997 736	5.01	160 753

Faults and Shears

Centred around the ultramafic schist units, the Detour Lake Deformation Zone is the most important structural feature on the property and consists of a wide zone of weakly to intensely developed foliation (penetrative fabric), interpreted as ductile shearing by Marmont (1987). The ultramafic units have been traced from a point immediately east of the mine workings westward to the property boundary.

A number of brittle faults are recognized on the property, especially in the area of the mine workings where the amount of information is the greatest. These faults are oriented in both a northwest-southeast direction as well as sub-paralleling the stratigraphy. They are quite late features, and cross-cut all rock types, alterations, and mineralization. On the whole, the northwesterly faults do not appear to displace units to any great extent and do not pose any significant problems related to the mining operations. The stratigraphy sub-parallel brittle faults (termed the Clay Fault Gouge by mine staff) do however interfere with the mining operations, especially in the western part of the mine. There, the Clay Fault Gouge gradually approaches the Main Zone, and introduces mechanical weaknesses into the rock such that a great deal of spalling and dilution occur at times. In the eastern parts of the mine, the Clay Fault Gouge occurs farther away from the Main Zone and posses less of a concern to the mining operations.

ECONOMIC GEOLOGY

Production History

The production history of the Detour Lake Mine is presented in Table 3, the production totals are presented in Table 4, and the mineral inventory is presented in Table 5.

Table 4. Total Annual Production and Mill Recovery for the Detour Lake Mine as at December 31, 1997. Data provided courtesy of Roger Hill, Chief Geologist, Placer Dome North America Limited.

Year	Tonnes Milled	Head Grade (g / t Au)	Ounces Mined	Mill Recovery (%)	Ounces Produced
1983	256 604	2.70	22 275	87.78	19 553
1984	794 561	3.30	84 301	92.73	78 172
1985	813 139	3.40	88 886	93.59	83 189
1986	783 357	3.73	93 854	94.01	88 233
1987	748 511	2.62	62 978	94.50	59 514
1988	806 568	4.46	115 740	93.32	108 009
1989	816 709	5.31	139 546	93.85	130 964
1990	866 565	4.95	137 901	93.81	131 614
1991	798 475	5.01	128 530	94.65	119 152
1992	873 236	4.95	138 952	93.58	129 497
1993	953 155	4.90	150 053	93.23	141 488
1994	894 980	4.71	135 598	90.41	123 254
1995	978 000	4.26	133 920	91.28	121 393
1996	947 625	4.38	133 575	91.52	120 288
1997	1 294 254	3.07	127 881	92.55	125 556
TOTAL	**12 625 739**	**4.17**	**1 693 989**	**93.26**	**1 579 875**

Table 5. Total Mineral Inventory by Category for the Detour Lake Mine as at December 31, 1997 (Gold Price: $US 340 / oz, exchange rate: $C 1.40 = $US 1.00). Data provided courtesy of Roger Hill, Chief Geologist, Placer Dome North America Limited.

Description	Tonnes	Grade (g / t Au)	Grade (oz / ton Au)	Contained Ounces
Ore Reserves:				
1997 Proven	1 733 000	2.99	0.087	166 421
1997 Probable	283 000	5.98	0.174	54 363
Sub-total, Reserves	2 016 000	3.41	0.099	220 784
Geological Resources:				
1997 Measured	1 055 000	5.12	0.149	173 739
1997 Indicated	1 533 000	6.59	0.192	324 493
Sub-total, Meas.+ Indicated	2 588 000	5.99	0.175	498 232
1997 Inferred	5 369 000	6.21	0.181	1 071 352
Sub-total, Resources	7 957 000	6.09	0.178	1 569 584
Total Mineral Inventory	**9 973 000**	**5.54**	0.162	**1 790 368**

Diamond Drilling To-Date

The amount and distribution of diamond drilling at the Detour Lake Mine is given in Table 6 below:

Table 6. Summary of Diamond Drilling at the Detour Lake Mine. Data provided courtesy of Roger Hill, Chief Geologist, Placer Dome North America Limited.

Year	Operations / Definition (m)	UG Exploration / Delineation (m)	Surface Exploration (m)	Annual Total (m)
1983	-	-	-	-
1984	-	-	-	-
1985	-	-	-	-
1986	-	-	-	-
1987	21 950	-	-	21 950
1988	19 921	-	-	19 921
1989	18 025	-	-	18 025
1990	25 189	-	-	25 189
1991	21 127	-	3 226	24 353
1992	24 265	-	7 949	32 214
1993	27 667	37 301	3 423	68 391
1994	43 812	10 352	2004	56 168
1995	33 195	39 037	26 742	98 974
1996	53 046	37 484	14 609	105 139
1997	32 766	20 856	3 638	57 260
1998 (est.)	9 000			
TOTAL	329 963	145 030	61 591	527 584

Description of Orebodies

Ore bodies at the Detour Lake Mine are categorized into 6 zones depending upon the nature of the mineralization and / or host rock characteristics. Three of these zones have provided the bulk of the tonnage mined to date, these being the Main Zone, Quartz zones and Talc zones (Figure 5). Other recently discovered mineralized zones include the Pillow Zone, Calcite Zone, and QK Zone. The Main Zone strikes easterly to northeasterly, has an average dip of 70°N. It has a plunge of 40°W near surface, flattening out to 0° below the 660 metre level and an irregular hanging wall contact resulting from diverging quartz vein structures. An assay cutoff is used to define the hanging wall stoping limits. The foot wall contact is more regular on strike than the hanging wall contact but undulates locally, thus causing dips varying from 30° to near vertical. The Quartz Zones strike at azimuth 080° with a vertical to near vertical dip, and a plunge of 45°W parallel to the Main Zone.

Ore grade mineralization in each of these three zones is closely related to the amount and type of sulphides present in the rock. Sulphides include pyrrhotite, chalcopyrite, and pyrite and occur as disseminations, stringers, and veins (Photo 6). Gold content correlates principally to the amount of chalcopyrite and pyrrhotite. Volumetrically, pyrrhotite is the most abundant mineral, with chalcopyrite and

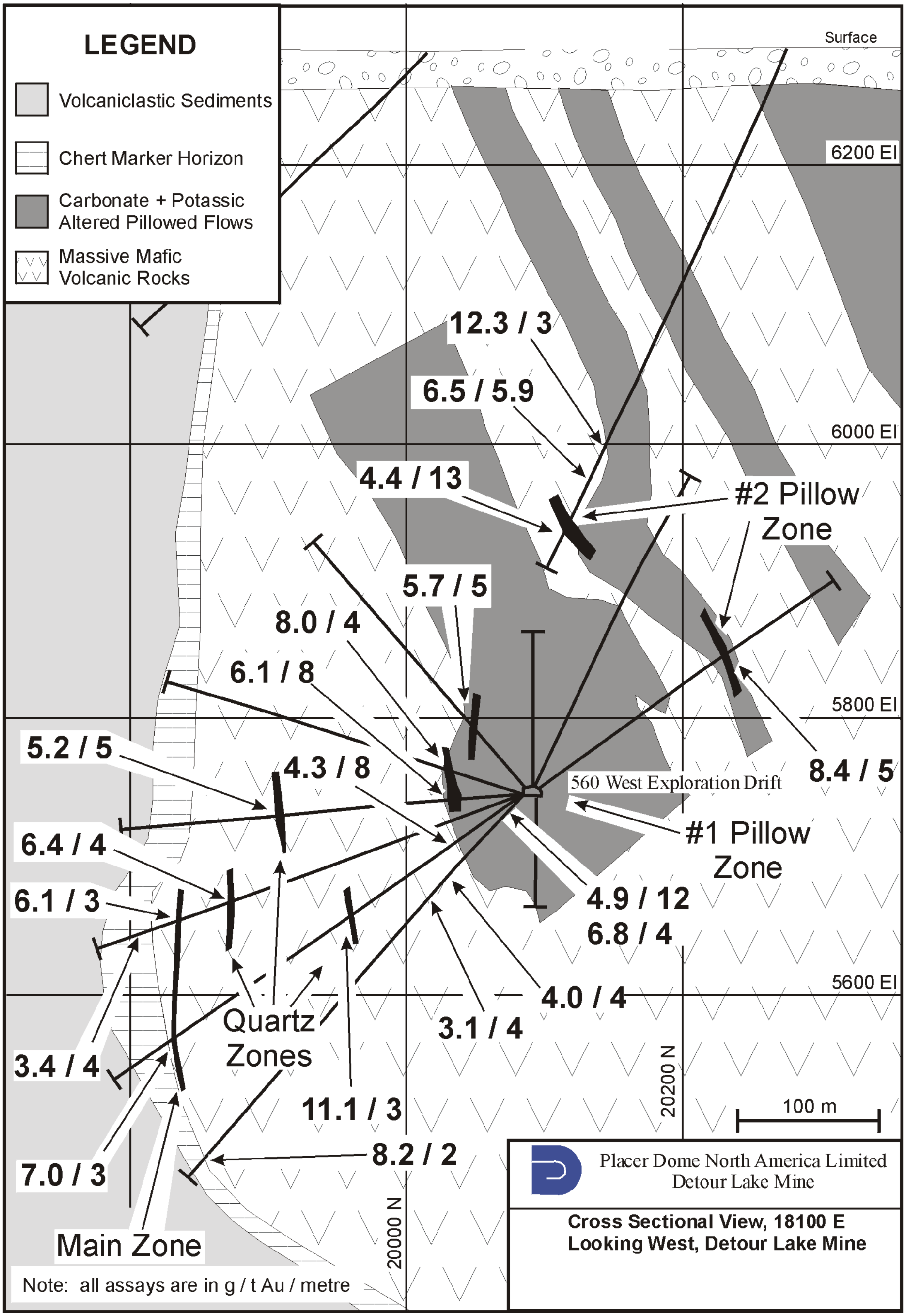
LEGEND
Volcaniclastic Sediments
Chert Marker Horizon
Carbonate + Potassic Altered Pillowed Flows
Massive Mafic Volcanic Rocks
Surface
6200 El
6000 El
5800 El
5600 El
12.3 / 3
6.5 / 5.9
4.4 / 13
#2 Pillow Zone
5.7 / 5
8.0 / 4
6.1 / 8
5.2 / 5
4.3 / 8
560 West Exploration Drift
8.4 / 5
#1 Pillow Zone
6.4 / 4
6.1 / 3
4.9 / 12
6.8 / 4
4.0 / 4
3.1 / 4
Quartz Zones
3.4 / 4
11.1 / 3
20200 N
100 m
8.2 / 2
7.0 / 3
20000 N
Main Zone
Note: all assays are in g / t Au / metre
Placer Dome North America Limited
Detour Lake Mine
Cross Sectional View, 18100 E
Looking West, Detour Lake Mine

Figure 5.

pyrite occurring in lesser and trace amounts in the ore zones, respectively. While volumetrically insignificant, chalcopyrite can locally occur in significant amounts (Photo 7) and correlates with better gold grades. Pyrrhotite most often forms the matrix to veins and stringers, and when a pyrrhotite vein contains rounded fragments of quartz, it is termed to be a “Sulphide Breccia Vein” (SBV) in mine terminology (Photo 8). These sulphide breccia veins contain significant quantities of gold, often in the multi-ounce range (M. Croteau, personal communication, 1998), typically do not exceed 0.3-1.0 m in thickness, and are found in both the Main Zone and Quartz Zones. In cross sectional view these “Sulphide Breccia Veins” cross cut quartz veins of both the Main and Quartz zones and contain fragments of both the country rock and quartz vein. Their orientation changes gradually from being at a low angle to the quartz veins distally to a parallel orientation when the SBV’s are in contact with the quartz vein. When the SBV’s are in contact with the quartz veins, they tend to contain few included wall rock and quartz vein fragments, and the SBV’s become more fragment rich away from the quartz veins. The SBV’s have a similar relationship to the quartz veins in plan view (M. Croteau, personal communication, 1998). While much of the sulphides occur as disseminations and stringers, they are also found as amygdule fillings and located between pillow selveges in the Pillow Zone. Visible gold hosted by quartz veins is present on occasion.

The Main Zone (MZ) has provided two thirds of the proven and probable reserves (Figure 6). Above the 560 metre level, the Main Zone consists of numerous quartz veins splaying north and west off into the hanging wall from the “chert” marker horizon. The zone is typically associated with moderate to intense potassic alteration. It has been mined at widths up to 30 metres but as it plunges below the 560 metre level, the ore body narrows down to 4-8 metres. Below the 560 metre level, quartz veins associated with the Main Zone are fewer and frequently severely boudinaged. The grades in the hanging wall quartz veins decrease as the distance from the “chert” increases northwards. The Main Zone extends to a proven depth of 745 metres, is open to the west along strike, and dips north at an average of 70°.

The Quartz Zones comprise 20% of the proven and probable reserves and are characterized by discreet groups of steeply dipping (predominately north) quartz veins. Generally having widths of 3-5 metres wide, these quartz zones appear to splay off from the chert although in many instances it is difficult to trace these zones directly back to the chert. Potassic alteration may or may not be present associated with these zones.

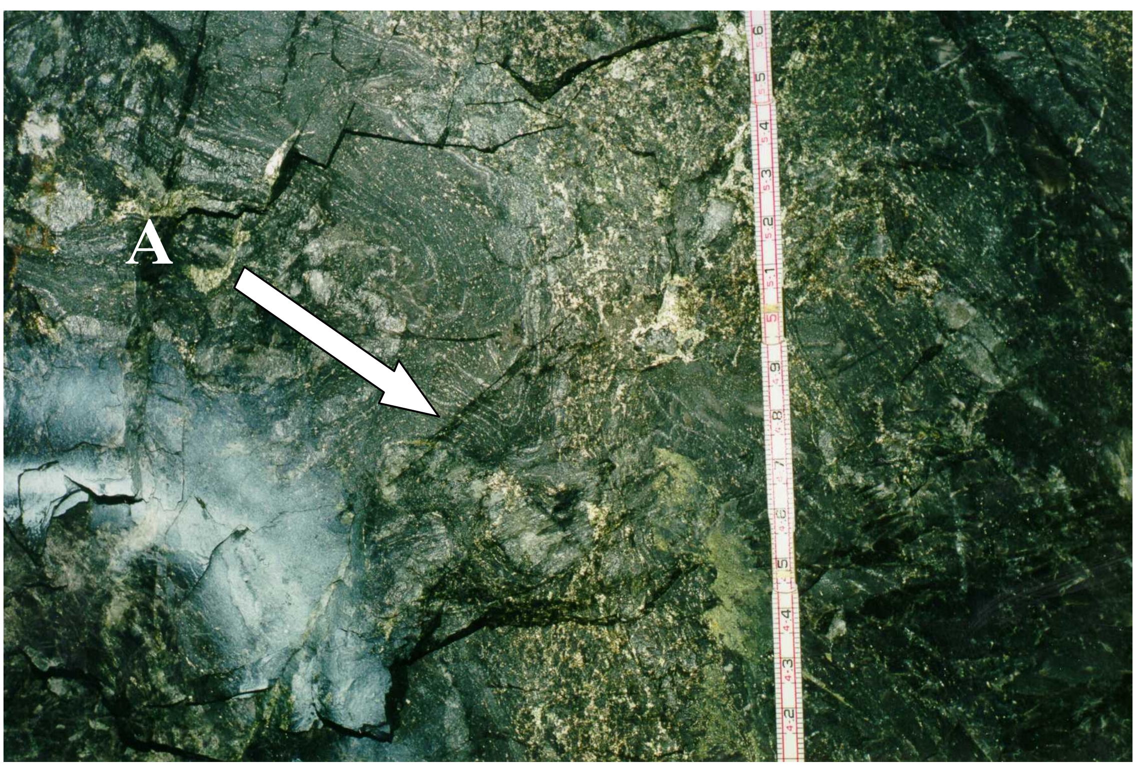

Photo 6. Close-up view of po-cpy stringers as indicated in Photo 5. Note the folded cherts (A) and cross-cutting relationships of the sulphides. Stick rule is marked off in 10ths of a foot.

Photo 7. Hand sample of a cpy-rich sulphide breccia vein from the 280m level, Q70 Zone, Detour Lake Mine. Note the fragments of quartz and mafic wall rocks in a chalcopyrite matrix.

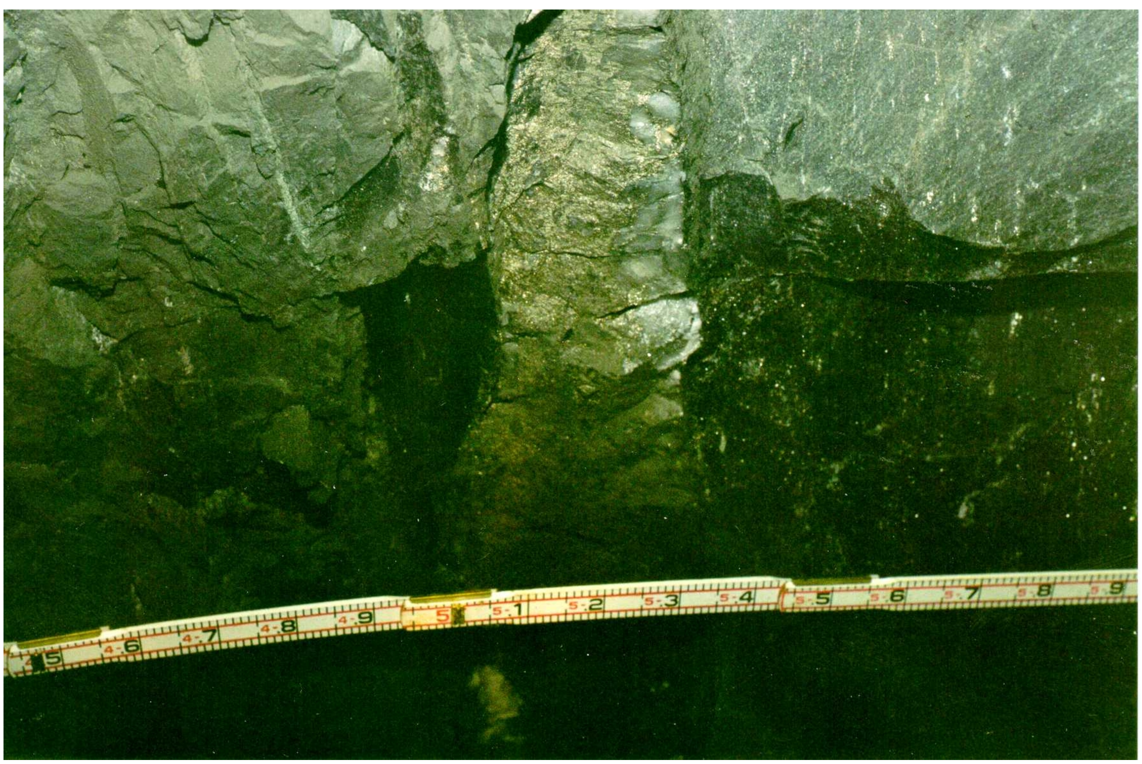

Photo 8. In-situ example of a po-rich sulphide breccia vein in the back of a shrinkage stope on the 330 m level, Q100 Zone, Detour Lake Mine. Stick rule is marked off in 10ths of a foot.

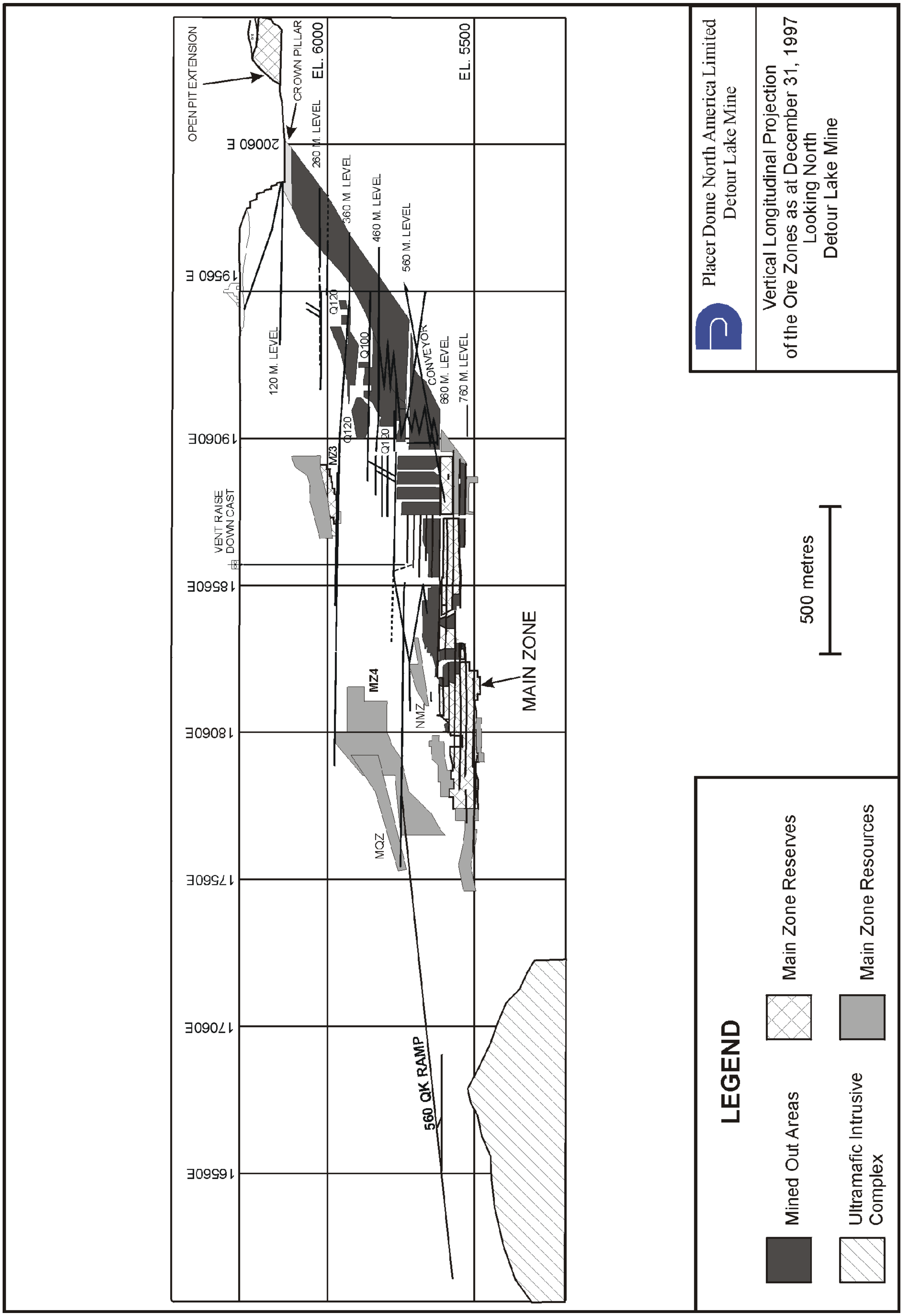
Placer Dome North America Limited
Detour Lake Mine
Vertical Longitudinal Projection
of the Ore Zones as at December 31, 1997
Looking North
Detour Lake Mine
LEGEND
Mined Out Areas
Main Zone Reserves
Ultramafic Intrusive Complex
Main Zone Resources
500 metres
OPEN PIT EXTENSION
CROWN PILLAR
EL. 6000
EL. 5500
20060 E
19560 E
19060E
18560E
18060E
17560E
17060E
16560E
260 M. LEVEL
360 M. LEVEL
460 M. LEVEL
560 M. LEVEL
120 M. LEVEL
660 M. LEVEL
760 M. LEVEL
CONVEYOR
Q120
Q100
MZ3
VENT RAISE
DOWN CAST
MAIN ZONE
MZ4
NMZ
MQZ
560 QK RAMP

Figure 6.

Specific Quartz Zones are frequently characterized by the presence of intermittent, discontinuous “sulphide breccia veins”. These high grade veins consist of brecciated quartz material which tend to be rounded and engulfed in pyrrhotite, and to lesser extent pyrite and chalcopyrite. Visible gold is frequently associated with the sulphide breccia veins and the overall gold grades are proportional to the abundance of sulphides.

Although minor in abundance, the presence of chalcopyrite in the sulphide assemblage usually is an indicator of elevated gold content.

Talc Zones comprise approximately 10% of proven and probable reserves. They are found in the foot wall below the chert and consist of sulphide mineralization hosted by talc-carbonate rich ultramafic rocks with few or no associated quartz veins. Sulphide minerals usually occur along prominent foliation planes within the host rock. These zones vary in width from 4-15 metres and tend to be less continuous than the Main Zone or Quartz zones.

The Pillow Zone is a new zone defined by diamond drill holes and limited exploration drifting. It is hosted by pillowed mafic volcanic flows in the hanging wall of the mine. Mineralization encountered to date consists mostly of sulphide mineralized pillow selvages and occasional sulphide bearing quartz veins. The Pillow Zone usually displays somewhat more carbonate alteration of the host lithology than either the Main Zone or Quartz Zones. The continuity of this zone is poor and consequently only a small percentage has been upgraded into the ore reserve category.

The Calcite Zone is another new mineralized area and is identified only by diamond drilling. It occurs several hundred metres into the hanging wall with no apparent connection to Main Zone. It is a near surface hanging wall quartz zone in massive mafic volcanic rocks but distinguished from other quartz zones by several features including weak potassic alteration, strong carbonate alteration of the wall rocks, and the presence of free carbonate in the quartz veins. All of the gold mineralization contained in this zone to-date is classified as a geological resource only.

The QK Zone is a potassically altered quartz zone. Discovered by surface diamond drilling in 1994, it occurs starting approximately 2.5 kilometres west of the mine site head frame and was the target of an Advanced Exploration program in 1996 and 1997 to verify the grade and continuity of the zone.

ACKNOWLEDGEMENTS

The author wishes to thank Placer Dome North America, Roger Hill, Chief Mine Geologist, and Mark Croteau, Project Geologist at the Detour Lake Mine for their prompt and enthusiastic support, for their openness in providing information and materials for the Project, and for the generous donation of diamond drill core. As well, thanks are extended to Dave Gliddon of Placer Dome North America Exploration Department for providing relevant information on the mine property.

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Appendix I: Geological Legend, Detour Lake Mine.

ROCK NAME	CODE
HANGINGWALL UNITS- THOLEIITIC BASALT	
Mafic Flow (unaltered to weakly altered)	MF
Mafic Tuff	MT
Pillowed Flow (unaltered to weakly altered)	PF
Potassic Mafic Flow (moderate to intense alteration)	KMF
Potassic Pillowed Flow (moderate to intense alteration)	KPF
Carbonatized Mafic Flow (moderate to intense matrix alteration)	CMF
Carbonatized Pillow Flow (moderate to intense matrix alteration)	CPF
Silicified Mafic Flow (moderate to intense matrix alteration)	SMF
Brecciated Pillow Flow (moderate to intense matrix alteration)	BPF
Cherty Mylonite (marker horizon)	CH
Cherty Mylonite Equivalent (laminated qtz vein)	CHQ
Sulphide Brx Vein	SBV
Sulphide Vein	SV
TRANSITION UNITS – KOMATIITIC BASALT	
Komatiitic Basalt (unaltered, weak biotite)	KB
Chloritic Greenstone (greenish chlorite alteration)	CG
Footwall Vein (quartz & sulphides)	FWV
KOMATIITIC/ULTRAMAFIC BASALT	
Komatiitic Flow (unaltered to weakly altered)	KF
Talc Chlorite (mod. to intense chloritic Alt'n)	TC
Talc Carbonate (medium to inter. chl. and carbonate alter.)	TCB
FOOTWALL VOLCANIC UNITS	
Volcaniclastic Biotite Banding, Sheared	VC
Footwall Mafic Volcanic (unaltered)	FMV
Tuffaceous Mafic Volcanic	TMV
Feldspar Porph. Mafic Volcanic	FPV
FOOTWALL METASEDIMENTARY UNITS	
Greywacke	GWE
Sandstone	SNS
Siltstone	SLS
Arkose	ARK
INTRUSIVE UNITS	
Felsic Feldspar Porph. Intrusive, Light Purple	Fl
Intermediate Feldspar Porph. Intrusive, Dark Purple	II
Mafic Intrusive	MI
Gabbro	GB
Hetrolithic Breccia	HBX
Ultramafic Intrusive	UI
Granite	GR
Granodiorite	GD
Diorite	DT
MISCELLANEOUS	
Casing (through overburden)	CAS
Fault Zone (broken core or clay gouge)	FZ
Quartz Veins	QV

Economic Geology and Mineralization at the Hoyle Pond Mine

Reno Pressacco
District Geologist, Timmins Regional Resident Geologist's Office

INTRODUCTION

The gold mineralization at Kinross Gold Corporation's Hoyle Pond Mine is a typical example of the lode gold deposits that have been mined in the Porcupine Camp since 1910. In simple terms, economic gold mineralization is hosted by a system of narrow quartz veins hosted in Mg- and Fe-tholeiitic flows. Three zones are recognized in current mine nomenclature. The 1060 Zone consists of at least 5 main vein structures (the 1060, A, B1, B2, B3, and Porphyry veins), the Sediment Zone consists of at least two veins, and the Main Zone consists of the remaining known veins (the 2, 7, 9, 10, 11, 12, 13, 14, 16, 17, 18, 18 west and 19 veins).

The discovery hole at the Hoyle Pond Mine was drilled by Texas Gulf Sulphur Company Inc. in 1969 with hole DDH 69-17 intersecting 6.5 g / t Au / 3.0m (0.18 oz / ton / 9.8ft). Subsequent drill programs in 1980 and 1982 outlined a deposit containing 199 600 tonnes grading 15.1 g / t Au (97 670 oz Au). Construction of ramp access was completed in 1984, and mining began by Kidd Creek Mines in 1985 with the production of 64 400 tonnes grading 13.0 g / t Au. Mining activities continued through 1989 under Falconbridge Gold Corporation and continued until the purchase of the Falconbridge Gold by Kinross Gold Corporation in 1994.

LOCATION, OWNERSHIP, AND CLAIMS

The Hoyle Pond Mine is located in southeastern Hoyle Township, approximately 18 kms northeast of Timmins, Ontario (Figure 1). The land holdings currently consist of three properties (Hoyle Pond, Owl Creek, and Bell Creek) and include 889 Ha of patented claims, 453 Ha of leased claims, 32 Ha as unpatented mining claims, and 64.6 Ha under a private lease agreement. The main production shaft is located in the northeast quarter of the north half, Lot 4, Concession I, Hoyle Township. All lands are currently registered to Kinross Gold Corporation.

REGIONAL GEOLOGICAL SETTING

The mine is hosted within an easterly striking band of massive to pillowed variolitic mafic metavolcanic rocks which is flanked to the north and south by clastic metasedimentary rocks composed principally of wackes and mudstones (Figure 2). These units are located to the immediate north of the traditional Timmins Camp stratigraphy which has been described in detail by Ferguson et. al. (1968), Pyke (1982), Jackson and Fyon (1991), and Brisbin (1998).

The Tisdale Group consists of: i) a lower portion consisting of mixed ultramafic and Mg-tholeiite mafic metavolcanic rocks that have returned an age date of 2707 Ma, ii) a middle sequence dominated by Fe-tholeiitic basalts capped by two distinctive variolitic units, and iii) an upper consisting dominantly of calc-alkaline felsic pyroclastic rocks (Krist Fragmental, 2698 Ma) with minor amounts of carbonaceous argillite. The Tisdale Group is in fault contact with the older Deloro Group (2727 Ma) to the south across the Destor-Porcupine fault zone. The rock types in the Deloro Group are dominantly calc-alkaline basalts, andesites, rhyolitic and dacitic tuffs, and lapilli tuffs. A sequence of clastic sediments (Porcupine Sediments) conformably overlie the Tisdale Group units, and are in turn overlain by younger clastic sediments of the Timiskaming Group. A schematic illustration of the stratigraphy and age dates for the Timmins Camp is given in Figure 3.

The Destor-Porcupine Fault is the most significant structure in the area and it consists of a number of zones of shearing and ductile deformation focussed mainly within ultramafic flows and intrusions. The

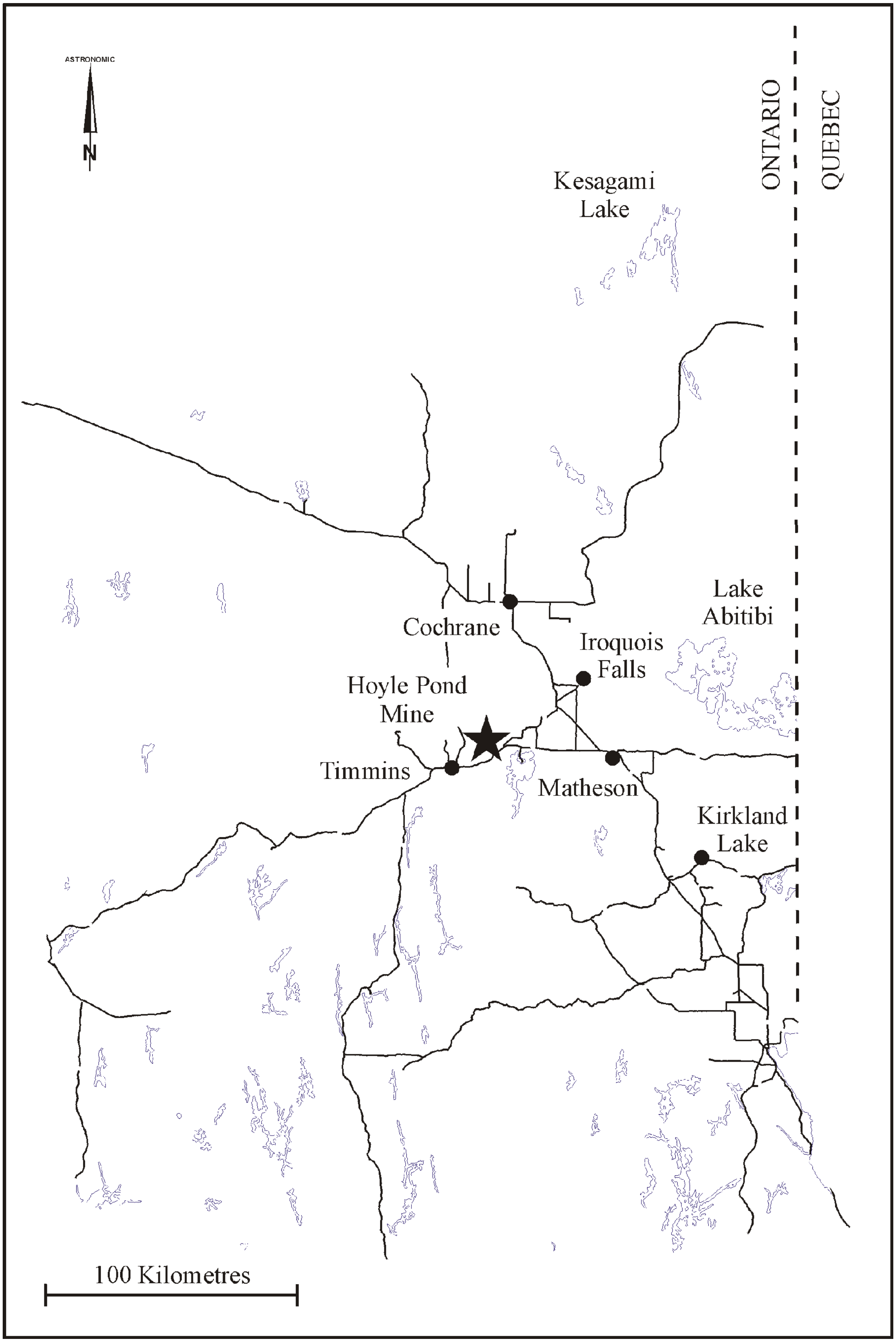


Figure 1. Location map of the Hoyle Pond Mine.

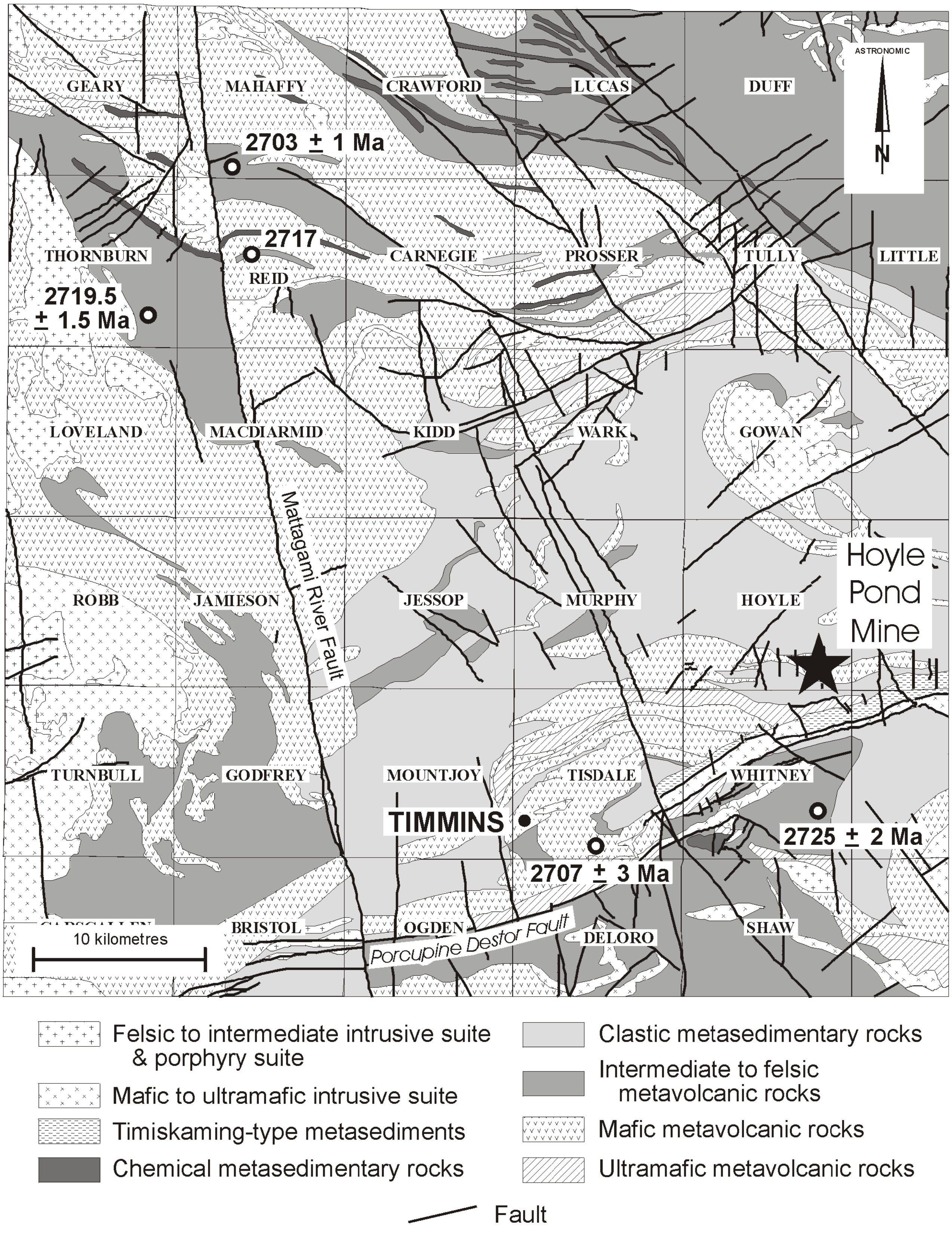


Figure 2. Regional Geological Setting of the Timmins Area (modified from Ayer and Trowell 1998).

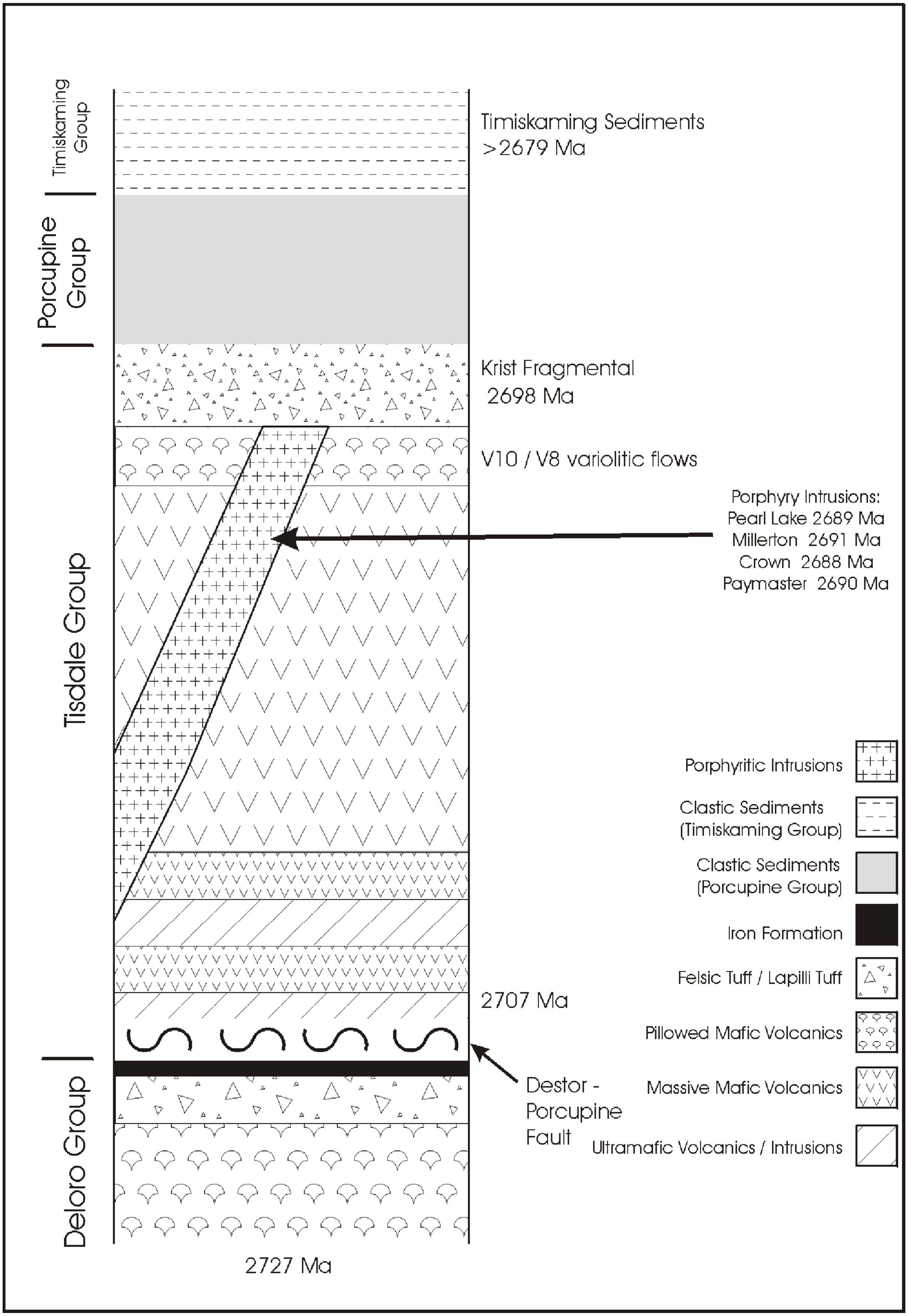


Figure 3. Generalized Stratigraphic Column of the Timmins Camp.

fault is either vertical, or dips steeply to the north, has been traced continuously eastwards through to Val d'Or, Quebec, and has an apparent sinistral sense of movement. A set of brittle faults oriented in a northwesterly direction are present throughout the region. These faults are the youngest structural features in the area and serve to offset all stratigraphic units and older structures. The Hoyle Pond Mine is located in the hangingwall to the Destor Porcupine Fault, approximately six kilometres north of its' surface trace.

PROPERTY SCALE GEOLOGICAL SETTING

Macroscopic Description of Rock Types

The property scale geology of the Hoyle Pond Mine and 1060 Zone area is relatively straightforward. An easterly trending, steeply north dipping band of Mg- and Fe-tholeiitic mafic volcanic rocks and ultramafic volcanic rocks is flanked both north and south by clastic metasedimentary rocks containing minor amounts of intercalated graphic argillite (Figure 4). The ultramafic volcanic rocks are situated in the central portions on this band, mostly to the west of section 101750E on the mine grid, such that a thin interval of Mg-tholeiite mafic volcanic rocks is present between them and the flaking sedimentary rocks. Some Fe-tholeiites have been documented along the southern sedimentary contact by Downes et. al. (1984). The overall easterly trend is maintained throughout the property except in the immediate vicinity of the Hoyle Pond shaft where the Mg-tholeiites are observed to take on an overall Z-shape as a result of either tight folding or a system of northeasterly trending faults / shears.

The sediments are composed of a mixture of carbonaceous argillites and greywackes which become increasingly more argillaceous near the mafic contacts. The argillites exhibit a compositional banding defined by alternating 1 – 2 mm thick dark and light coloured argillaceous layers.   Karelse (1985) determined that these sediments were fine grained turbidites on the basis of preserved Bouma cycles. The sediments contain trace amounts of porphyroblastic and nodular pyrite, and have a pronounced fabric defined by closely spaced fracture cleavage and flattening of the pyrite nodules. In the northern sediments, the intensity of the fabric increases southwards towards the volcanic contact. Rapid changes in facing directions are observed along the strike length of both the northern and southern sediments, suggesting tight folding (Ben Berger, personal communication, 1998).

The central Mg-tholeiitic mafic volcanic unit is approximately 300 – 500 metres in thickness and grades from a thin (3 – 5m) "mixed mafic" unit at its base into a succession of massive and pillowed volcanic flows. The "mixed mafic" unit may be a basal flow feature and contains a mixture of small angular fragments of volcanic and sedimentary clasts hosted in a pyritic, carbonaceous, and carbonate-rich volcanic matrix, with the proportion of sedimentary clasts decreasing away from the sediment contact. Pillowed basalts account for approximately 90% of the remainder of the unit, with the sizes of the pillows ranging from 20 cm to 1.5 m. These pillows can contain 5 – 10 mm amygdules and varioles. Several pillow breccia units occur within the sequence. The breccia units are 1 – 3 m in thickness and have sharp upper and lower contacts with the enveloping pillowed flows. These units consist of 5 – 50cm intact, to weakly fragmented pillows in either a volcanic or sedimentary matrix. Interflow sedimentary material consisting of carbonaceous and pyritic argillite is common, occurring generally as narrow 1 – 3 cm bands between the pillowed flows or within the pillow breccia units. These pillowed Mg-tholeiites are typically massive and generally lack development of a pronounced fabric. However the intensity of the fabric increases towards the contact with the ultramafic volcanic rocks where it develops into a broad zone of shearing (Rye 1987).

The ultramafic volcanic rocks consist of mixed basaltic komatiites and komatiites.

Macroscopic Description of Alteration Types and Assemblages

Two distinct forms of alteration are present in the Hoyle Pond Mine. The first type of alteration is termed "grey zone" alteration (carbonate – sericite - free carbon) and is prevalent in and about the Hoyle Pond vein sets. The second type of alteration is more of a sericitic – pyritic style of alteration and is the dominant alteration type in and about the 1060 Zone, located approximately 500m to the southeast of the shaft. Each of these types will be discussed in detail separately below:

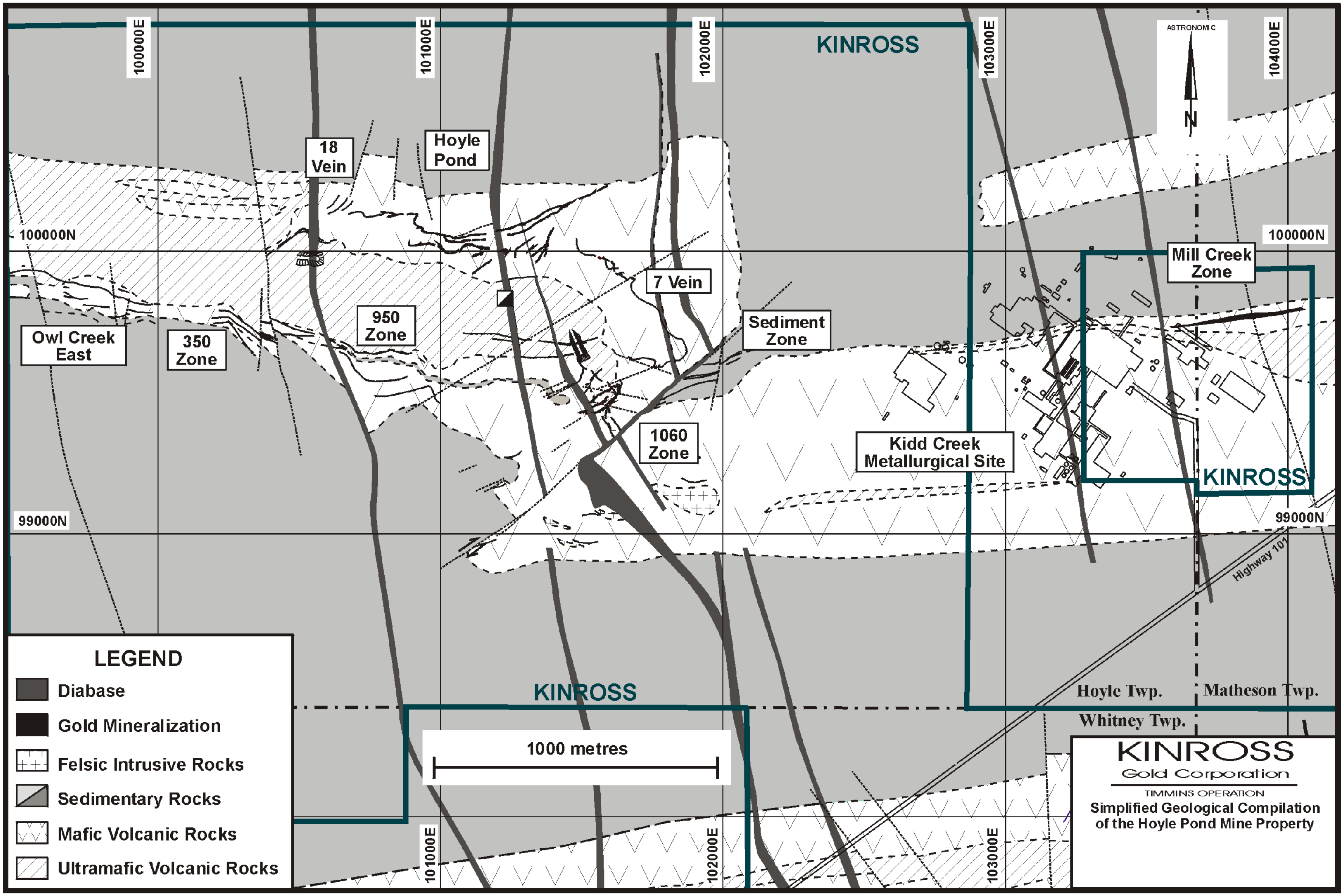

KINROSS
100000E
101000E
102000E
103000E
104000E
ASTRONOMIC
N
18 Vein
Hoyle Pond
100000N
7 Vein
Mill Creek Zone
Sediment Zone
950 Zone
Owl Creek East
350 Zone
1060 Zone
Kidd Creek Metallurgical Site
KINROSS
99000N
Highway 101
LEGEND
Diabase
Gold Mineralization
Felsic Intrusive Rocks
Sedimentary Rocks
Mafic Volcanic Rocks
Ultramafic Volcanic Rocks
KINROSS
1000 metres
Hoyle Twp.
Matheson Twp.
Whitney Twp.
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Geological Compilation of the Hoyle Pond Mine Property

Figure 4.

HOYLE POND "GREY ZONES"

In brief, the "grey zone" style of alteration is closely associated with many of the gold-bearing quartz veins at Hoyle Pond and typically occurs as asymmetrical alteration selvages around a central quartz vein. In places "grey zone" alteration does exist without the presence of a quartz vein, and while elevated gold values may be present in the altered zones, the alteration zones alone do not usually constitute ore (Wally Smith, personal communication, 1998). Downes et. al. (1984) described the "grey zone" alteration from the northeast extension of the 7 Vein system, and Rye (1987) provided a more comprehensive description of the "grey zone" alteration throughout the Mine. Much of the following description is excerpted from these two sources.

The grey alteration zones are recognized chiefly through a variation in the colour of the host rocks from a light green – grey in unaltered host rocks, through a light grey colour on the outer margins of the zones, to a dark grey to black colour as the central portions of the zones are approached. For the most part the alteration zones occur as bands, isolated pods, and at times as anastomosing three dimensional networks which surround lenses of less altered Mg-tholeiites. They trend generally towards an azimuth of 060° and dip vertically. The zones can reach strike lengths on the order of 500m (Wally Smith, personal communication, 1998), and vary rapidly in width from 0.5m to 20m or more along strike or down dip.

On occasion grey zone alteration zones are found along flow contacts. In these instances, one contact between the alteration and host rock is very sharp and the other contact is gradational (Bill MacRae, written communication, 1998). For the most part however, the intensity of alteration increases inwards toward a central core. The margin of an alteration zone is marked first by a subtle colour change from a buff green colour to a grey-green basalt and a noticeable increase in foliation intensity occurring over approximately a 1m interval. These marginal areas lack significant pyrite mineralization or brecciation. Toward the center of the alteration zone, the rock becomes perceptibly darker in colour and becomes enriched in 1 – 5 mm sized grains of recrystallized pyrite in roughly 2 – 5% overall abundance. A fine network of 1 – 2 mm wide carbonaceous fractures and randomly oriented carbonate stringers also become increasingly common, causing a fine brecciation of the host volcanic rocks. The core of the alteration zones are typically jet black in colour, exhibit an intense vertically dipping foliation (as defined by orientation of the long axes of volcanic fragments and the platy minerals), and contain up to 10% brass coloured "buckshot" pyrite porphyroblasts that are 2 – 20mm in size. The progressive increase in the size of the carbonaceous fractures first seen in the margins of the alteration zones eventually results in the development of a matrix-supported breccia in the core of the alteration zone. These breccias typically consist of angular volcanic rock fragments which are surrounded by a soft, black, matrix of chlorite and carbon. Both the clasts and the matrix react strongly to dilute HCl acid, indicating the presence of large amounts of calcitic material. Microscopic study of the volcanic fragments reveals that they are heavily altered and contain carbonate (>70%, species unknown), chlorite (15%), quartz (5%), sericite (5%), and albite (trace). The matrix material consists of carbonate (30%, species unknown), chlorite (species: repidolite, 20%), carbon (10%), sericite (10%), quartz (10%), albite (10%), pyrite (5 – 10%), trace rutile, and comminuted rock fragments. Downes et. al. (1984) conducted a quantitative study of one of these grey alteration zones intersected by a diamond drill hole. Their results are summarized in Table 1 and illustrated in Figures 5 and 6.

1060 ZONE SERICITE – PYRITE ALTERATION

The alteration style associated with the 1060 Zone mineralization differs from the typical "grey zone" alteration elsewhere in the mine in that it is dominated by a sericite – pyrite mineral assemblage (Wally Smith, personal communication, 1998). At the time of writing (July, 1998) no detailed descriptions of this assemblage is available, however documentation of this alteration type is in progress and the results will be released under a separate cover.

Table 1. Summary of Geochemical Data from DDH H-15-29, Grey Zone Alteration at the Hoyle Pond Mine (after Downes, et. al. 1984).

Sample	29	30	31	33	37	42	48	52	55	56
Depth (m)	244.9	259.9	269.9	276.9	283.4	289.2	295.2	300.7	307.7	312.7
Oxide (wt%)										
SiO2	43.00	45.30	46.10	44.00	45.20	39.80	41.00	44.50	45.20	46.20
Al2O3	16.70	16.20	16.20	14.50	16.20	20.30	15.40	15.70	17.30	16.70
CaO	7.50	7.72	7.72	8.08	8.10	7.91	8.30	7.77	7.62	7.62
MgO	8.20	7.56	7.56	7.86	6.41	5.47	8.60	8.02	8.48	8.20
Na2O	1.81	1.83	1.83	1.43	2.05	3.50	2.45	1.49	1.16	1.08
K2O	0.28	0.36	0.36	0.31	0.44	0.44	1.01	0.31	0.24	0.40
Fe2O3	1.20	1.23	2.13	3.67	1.79	2.95	2.54	1.66	1.76	1.80
FeO	7.10	6.10	6.20	6.80	5.60	4.40	6.80	7.00	7.40	7.10
MnO	0.18	0.25	0.20	0.21	0.21	0.16	0.24	0.17	0.21	0.21
TiO2	0.43	0.42	0.41	0.41	0.41	0.53	0.37	0.41	0.44	0.43
P2O5	0.06	0.05	0.06	0.05	0.05	0.00	0.05	0.05	0.05	0.05
CO2	9.64	9.71	9.09	11.18	11.50	11.40	10.81	10.22	5.64	5.39
C	0.06	0.01	0.05	0.09	0.15	0.32	0.18	0.06	0.02	0.01
T. Sul	0.01	0.01	0.01	0.11	0.26	1.24	0.01	0.02	0.00	0.02
Element (ppm)										
Au (ppb)	14.00	1.00	0.50	7.00	3.00	7500.00	13.00	4.00	1.00	1.00
Ni	63.00	75.00	66.00	91.00	82.00	150.00	80.00	80.00	59.00	58.00
Cu	60.00	67.00	57.00	63.00	31.00	92.00	33.00	30.00	56.00	48.00
Zn	22.00	24.00	24.00	25.00	35.00	20.00	27.001	39.00	25.00	25.00
As	73.00	67.00	78.00	62.00	97.00	1000.00	20.0	74.00	62.00	54.00
Sb	0.40	0.80	0.10	1.50	0.50	2.00	0.30	0.50	0.40	0.50
Te	0.05	0.05	0.05	0.05	0.05	0.40	0.05	0.05	0.05	0.05
W				5.00	4.00	79.00	4.00	2.00		
Pb	21.00	19.00	19.00	26.00	24.00		21.00	22.00	18.00	17.00
Bi	0.05	0.10	0.10	0.05	0.10	0.30	0.10	0.05	0.05	0.05
Ce	4.60	4.79	4.79	4.63	4.09	4.81	3.91	3.78	4.54	3.93
Nd	2.85	3.12	2.89	2.62	3.00	3.30	2.85	2.50	2.97	2.45
Eu	0.33	0.41	0.33	0.29	0.34	0.38	0.34	0.31	0.29	0.27
Gd	1.36	1.70	1.04	1.08	0.86	1.29	0.98	1.44	1.36	1.33
Tb	0.29	0.27	0.28	0.25	0.26	0.31	0.26	0.26	0.28	0.26
Yb	2.25	2.10	2.03	2.01	1.95	2.44	1.88	1.93	2.07	2.00
Lu	0.36	0.35	.034	0.34	0.32	0.42	0.33	0.32	0.35	0.32
Th	0.28	0.29	0.24	0.30	0.21	0.22	0.16	0.22	0.22	0.25
Ta	0.11	0.08	0.10	0.08	0.07	0.11	0.05	0.05	0.05	0.07
Ba	37.58	48.36	63.50	51.06	71.29	186.94	41.58	57.38		58.45
Hf	0.72	1.00	0.84	0.68	0.68	1.00	0.60	0.67	0.79	0.73

Lithogeochemical Data

Selected lithogeochemical analyses from the Hoyle Pond Mine are given in Table 2.

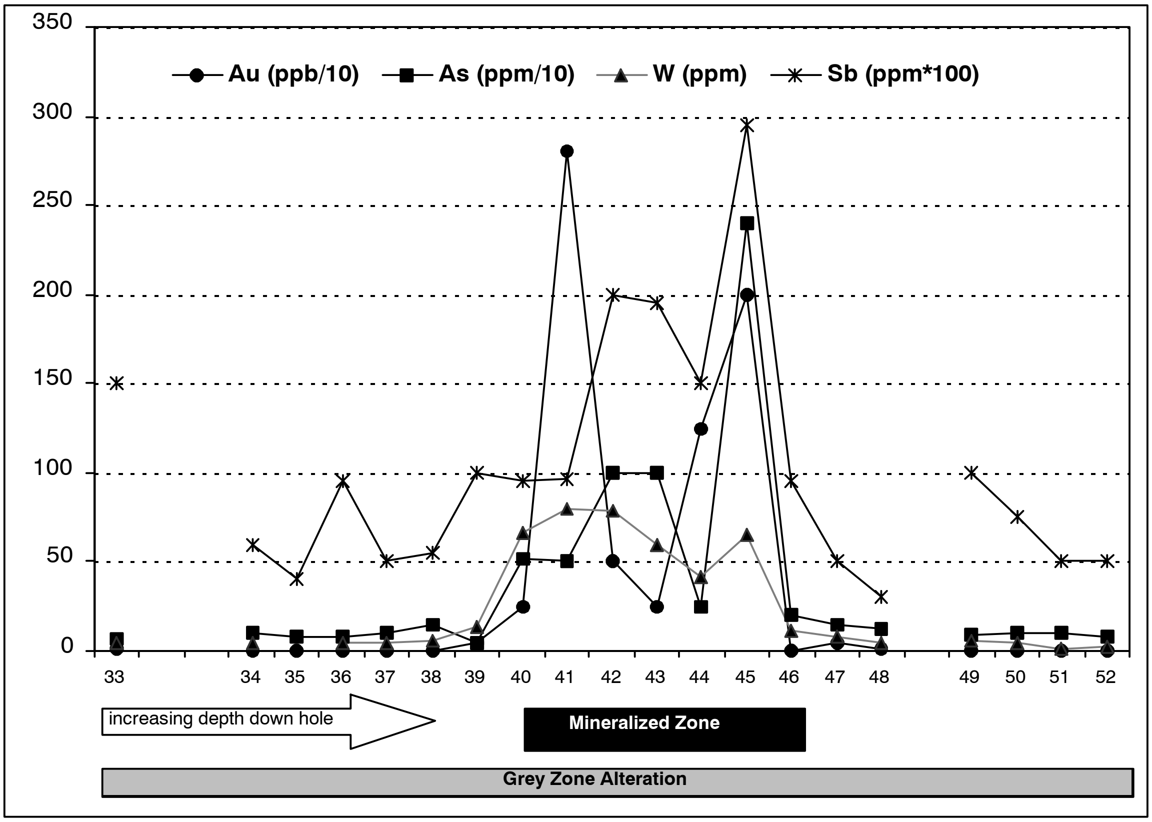


Figure 5. Geochemical profiles (Au, As, W, and Sb) of a grey alteration zone, DDH H-15-29, Hoyle Pond Mine (modified after Downes, et. al. 1984).

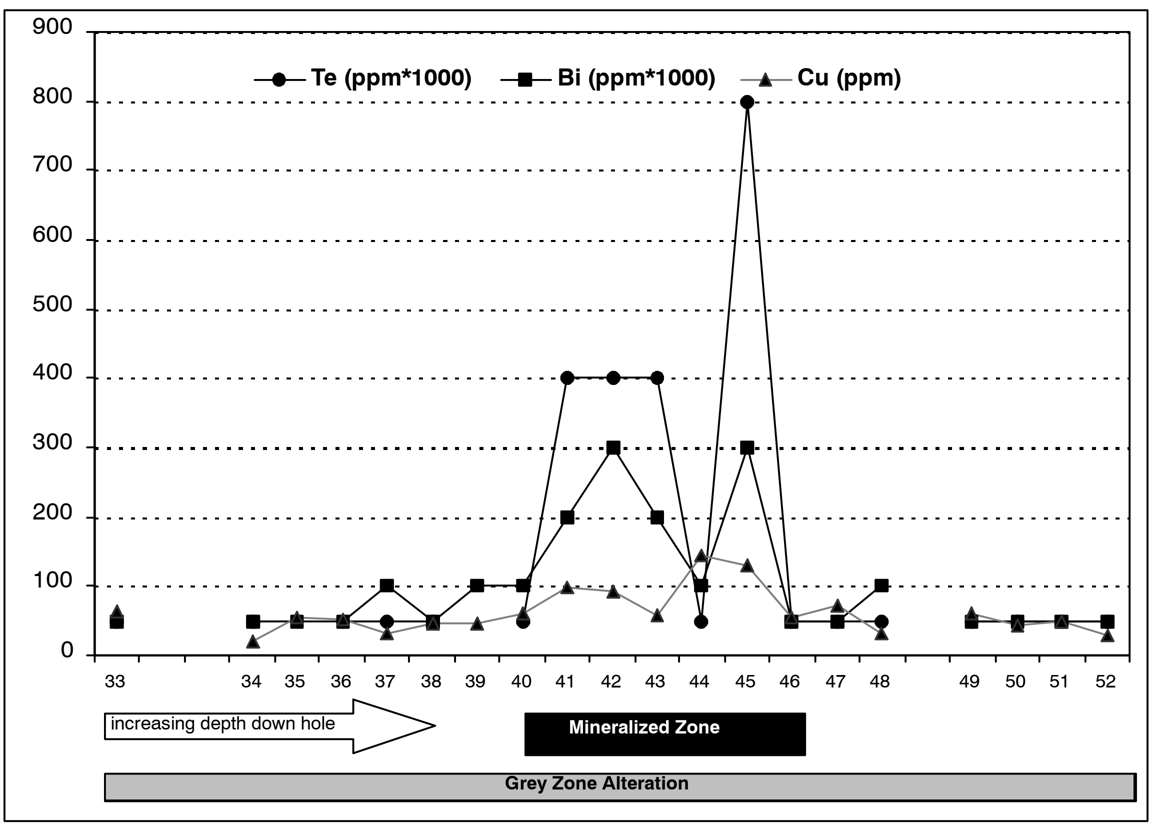


Figure 6. Geochemical profiles (Te, Bi, and Cu) of a grey alteration zone, DDH H-15-29, Hoyle Pond Mine (modified after Downes, et. al. 1984).

Table 2. Major, minor, and trace element abundances from selected samples from the Hoyle Pond Mine (modified after Rye 1987).

Sample	Rock	Easting	Northing	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	CaO (%)	MgO (%)	Na2O (%)	K2O (%)	P2O5 (%)	LOI (%)	Total	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Nb (ppm)	Ba (ppm)	Cr2O3 (%)
G1	Pillowed Basalt	101398	100089	50.9	0.46	19.1	7.56	0.19	9.60	5.31	2.30	0.06	0.05	4.77	100.3	20	50	30		10	70	
G2	Buff Mafic, 2% Py	101406	100042	45.4	0.41	16.1	9.45		6.57	8.18	1.52	0.32	0.05	12.4	100.4	20	50	10		10	100	
G3	Grey Mafic	101324	100129	42.0	0.40	13.5	8.19	0.34	10.6	5.31	2.18	0.48	0.04	16.8	99.9	10	40	20		10	130	
G4	Grey Mafic	101329	100118	43.0	0.43	14.8	7.17	0.27	10.8	5.65	2.00	0.28	0.05	15.9	100.3	10	60	20		10	60	
G5	Massive Mafic, 2% Py	101329	100074	43.9	0.60	16.8	11.7		5.69	9.17	1.70	0.36	0.07	9.47	99.5	20	20	10		10	190	
G6	Grey-green Mafic	101330	100048	46.0	0.42	16.9	9.60		6.84	8.04	1.25	0.14	0.05	10.7	100.0	10	40	20	10	10	90	
G8	Buff Mafic, 2% Py	101330	100035	46.3	0.39	16.2	6.55		8.70	5.37	2.31	0.43	0.04	13.9	100.2	20	70	20	10	20	90	
G9	Buff Mafic, Carb. Stringers	101330	100020	45.0	0.41	16.6	9.32		8.04	7.52	1.30	0.14	0.05	11.6	100.0	20	30	10	10	10	90	
G10	Green Mafic, strng. Foliated	101319	99972	49.2	0.38	16.6	7.66		9.58	3.56	1.81	1.21	0.03	9.77	99.9	50	50	10	10	10	310	
G11	Sheared Mafic	101315	99966	48.1	0.61	15.6	11.3		6.05	7.17	1.67	0.90	0.07	8.62	100.1	30	40	10	20	30	260	
G12	Sheared, chloritic Mafic	101309	99963	51.2	0.62	16.4	12.0	0.21	5.38	7.61	2.77	0.03	0.07	4.31	100.6	10	50	20	30	20	90	
G13	Foliated Grey Mafic	101424	100178	48.7	0.37	16.2	7.66	0.26	9.29	4.26	2.51	0.70	0.04	10.6	100.6	30	40	10	10	10	120	
G14	Ultramafic	100727	99968	28.0	0.26	3.95	8.21	0.28	13.5	17.5	0.10	0.01	0.04	28.2	100.1	20	90	10	20	20	20	
G15	Foliated Buff Mafic	101567	100228	41.3	0.70	12.7	8.65		11.6	5.51	2.27	0.22	0.06	15.6	98.7	20	90	20	10	10	50	
G16	Foliated Grey Mafic	101511	100202	45.6	0.27	15.4	8.45	0.28	9.01	5.08	2.52	0.68	0.03	13.2	100.6	20	60	20	10	10	160	
I12	Buff-green mafic	101330	100104	42.7	0.43	15.4	7.78	0.22	9.69	6.60	1.58	0.43	0.05	15.4	100.3	20	90	10	20	20	120	
I24	Grey mafic	101484	100188	32.4	0.46	16.50	10.2	0.25	10.4	5.95	2.93	1.61	0.05	15.5	96.4	70	60	10	20	10	170	
I26	Grey Zone inclusion in 16 Vein	101484	100190	62.6	0.21	8.61	5.47	0.16	6.76	3.48	0.70	1.23	0.01	9.70	99.0	50	30	10	10	10	180	
5668	Basaltic Komatiite	101286	99930	39.1	0.56	8.67	12.8	0.22	10.2	14.7	0.19	0.01	0.04	13.2	100.0	10	30	10	10	10	40	0.32
5669	Basaltic Komatiite	101289	99933	42.7	0.50	8.01	9.98	0.23	13.2	10.0	0.94	0.01	0.04	13.4	99.3	10	50	10	10	10	20	0.29
5670	Basaltic Komatiite	101294	99936	44.7	0.51	8.63	11.3	0.23	11.9	11.2	1.82	0.03	0.04	8.47	99.1	10	20	10	10	10	10	0.30
5671	Basaltic Komatiite	101299	99941	41.2	0.56	8.84	13.9	0.25	11.2	13.4	0.52	0.01	0.05	9.39	99.7	10	10	10	10	30	40	0.33
5672	Basaltic Komatiite	101302	99944	46.8	0.55	8.58	11.8	0.21	9.23	13.9	0.81	0.01	0.04	7.16	99.4	20	10	10	10	20	20	0.32
5673	Basaltic Komatiite	101306	99948	44.7	0.59	9.29	13.3	0.21	7.63	16.7	0.71	0.02	0.05	5.23	98.8	10	10	10	10	20	60	0.37
5674	Mg Tholeiite	101308	99953	48.0	0.60	15.9	11.4	0.21	4.80	7.61	4.01	0.01	0.06	6.85	99.5	10	40	20	30	20	80	0.01
5675	Mg Tholeiite	101313	99957	47.8	0.66	16.5	11.3	0.19	4.36	7.66	3.91	0.03	0.07	6.62	99.1	10	80	20	40	10	70	0.01
5676	Mg Tholeiite	101315	99961	48.2	0.61	15.2	11.1	0.19	6.34	7.19	1.77	0.80	0.07	9.00	100.5	30	30	20	40	10	280	0.01
5677	Mg Tholeiite	101315	99966	47.4	0.64	15.9	11.1	0.16	5.22	7.66	3.04	0.10	0.07	8.39	99.7	10	70	20	50	10	80	0.01
122	Silicified Mafic, N wall 2-16 vein	101610	100250	33.9	0.78	13.0	9.07	0.24	12.6	5.98	2.24	0.37	0.05	17.8	96.0	20	80	10	40	10	150	0.02
123	2-16 Grey Zone	101610	100250	37.4	0.69	12.9	7.41	0.22	12.7	5.48	2.17	0.40	0.08	19.0	98.5	20	100	10	10	10	200	0.02
124	Chl-sid mafic wall rock, 2-16	101375	100147	28.0	0.26	12.8	8.23	0.26	13.8	8.73	1.02	0.54	0.02	21.8	95.5	30	80	10	10	10	200	0.06

STRUCTURAL GEOLOGY

Stratigraphy

All of the stratigraphic units at the Hoyle Pond Mine and the 1060 Zone (with the exception of the younger diabase dikes) have been affected by deformation events which are manifested as strong cleavage fabrics, lineations, and folds. Rhys (1996) recognized two main stages of deformation, with 2 weak, overprinting crenulation cleavages (Figure 7). Much of the following section is taken from that source.

D1 DEFORMATION

Very little physical evidence is present to document this deformational event, aside from the observation that the symmetric distribution of the Mg-tholeiitic volcanic rocks and clastic sediments about a core of ultramafic volcanics suggests that the stratigraphy at the Hoyle Pond Mine defines an anticlinal fold with a closure in the 1060 Zone area. In agreement with this concept, bedding is overturned and faces outwards from the volcanic rocks in the laminated, graded siltstones and mudstones within the Sediment zone on the 120m Level. In addition, clasts of basalt supported in mudstone within the basal portions of the sediments suggests that the sediments unconformably overlie the basalts and face outwards from them. This probable fold is referred to herein as the Hoyle Anticline. It is the earliest phase of deformation recognized in the mine area and hence is defined here as a D1 structure. While the interpreted axial plane of the Hoyle Anticline trends east-southeast, it has no recognized axial planar cleavage, and its' plunge is unknown due to uncertainties in the 3 dimensional orientation of the stratigraphy in this area.

D2 DEFORMATION

Evidence for a second phase of deformation, D2, includes a steeply north dipping, northeasterly trending slaty cleavage that forms the main cleavage which is visible in the mine (Figure 8). It is developed throughout the Hoyle Pond Mine with variable intensity and has consistent strikes in the 240-255° range. The S2 cleavage is oblique to the east-southeasterly trend of the D1 Hoyle anticline In the 1060 Zone area, the S2 cleavage cuts across the ultramafic / mafic contacts in the core of the Hoyle Anticline. Further along strike to the west at the Owl Creek Mine, the S2 cleavage is also oblique to the bedding attitudes, but is rotated 15-30° clockwise (Brisbin 1986). The oblique nature and crosscutting attitude of this S2 cleavage with respect to the Hoyle Anticline indicates that it postdates the anticline, and represents a separate, younger folding event. Only one D2 anticline / syncline pair has been recognized to date, and these are located in the 1060 Zone area. The S2 cleavage is defined by a strong preferred orientation of platy minerals (chlorite and sericite), and flattening of pillows and other marker features. An elongation lineation (L2) that plunges steeply to the north-northeast on foliation surfaces is observed in various lithologies in the mine, and is defined by stretched phenocrysts and by pressure shadows on pyrite grains. Phenocrysts are commonly stretched to 2-5 times their original size, indicating a substantial stretching event. In general, quartz veins of the Hoyle Pond Mine (No.s 10 to 17 veins) are developed on the north limb of the D2 anticline, and the veins of the 1060 Zone are developed on the south limb. Their attitudes and relative structural timing are discussed.

YOUNGER STRUCTURAL ELEMENTS

Younger structural features present in the mine area include a crenulation cleavage (S3), kink banding (S4), minor brittle faults, and calcite-filled joints. Their average orientations are summarized in Table 3 along with the older structural elements, and are illustrated in Figure 9. The S3 crenulation cleavage is only locally developed, dips shallowly to the west and southwest, and is axial planar to rare, open minor folds of S2 foliation which have amplitudes of less than 0.5metres. The S4 kink bands are the youngest recognized fabrics and occur as a series of moderately to steeply east-southeast dipping kink bands that affect both the S2 and S3 fabrics.

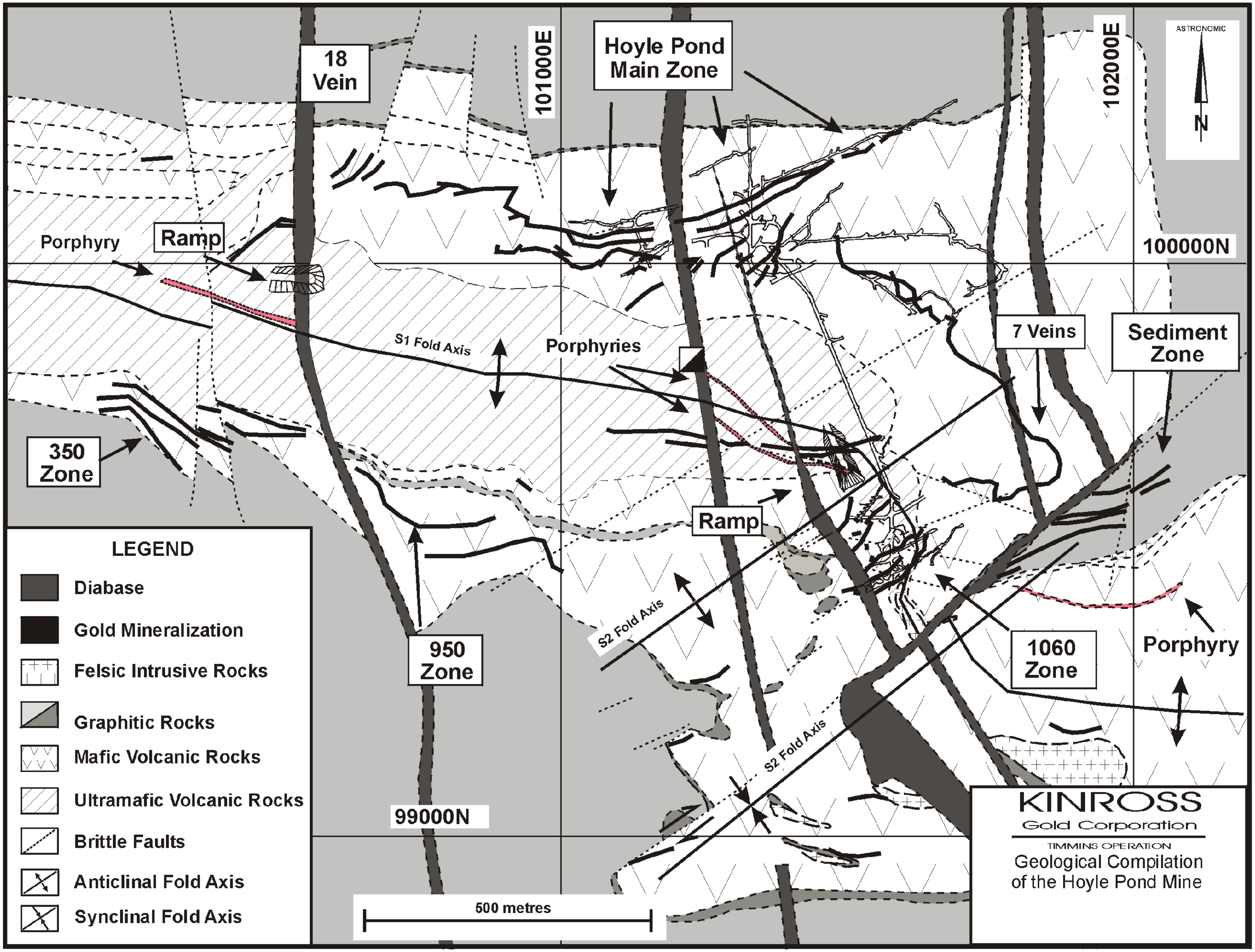

18 Vein
101000E
Hoyle Pond Main Zone
102000E
ASTRONOMIC
N
100000N
Porphyry
Ramp
S1 Fold Axis
Porphyries
7 Veins
Sediment Zone
350 Zone
Ramp
S2 Fold Axis
950 Zone
1060 Zone
Porphyry
S2 Fold Axis
99000N
500 metres
LEGEND
Diabase
Gold Mineralization
Felsic Intrusive Rocks
Graphitic Rocks
Mafic Volcanic Rocks
Ultramafic Volcanic Rocks
Brittle Faults
Anticlinal Fold Axis
Synclinal Fold Axis
KINROSS
Gold Corporation
TIMMINS OPERATION
Geological Compilation of the Hoyle Pond Mine

Figure 7.

Photo 1. White quartz vein with foliation parallel splay exploiting the S2 cleavage (after Rhys 1996). B1 Vein west, 40 level, 1060 Zone, Hoyle Pond Mine, view of the back. Photo provided courtesy of David Rhys.

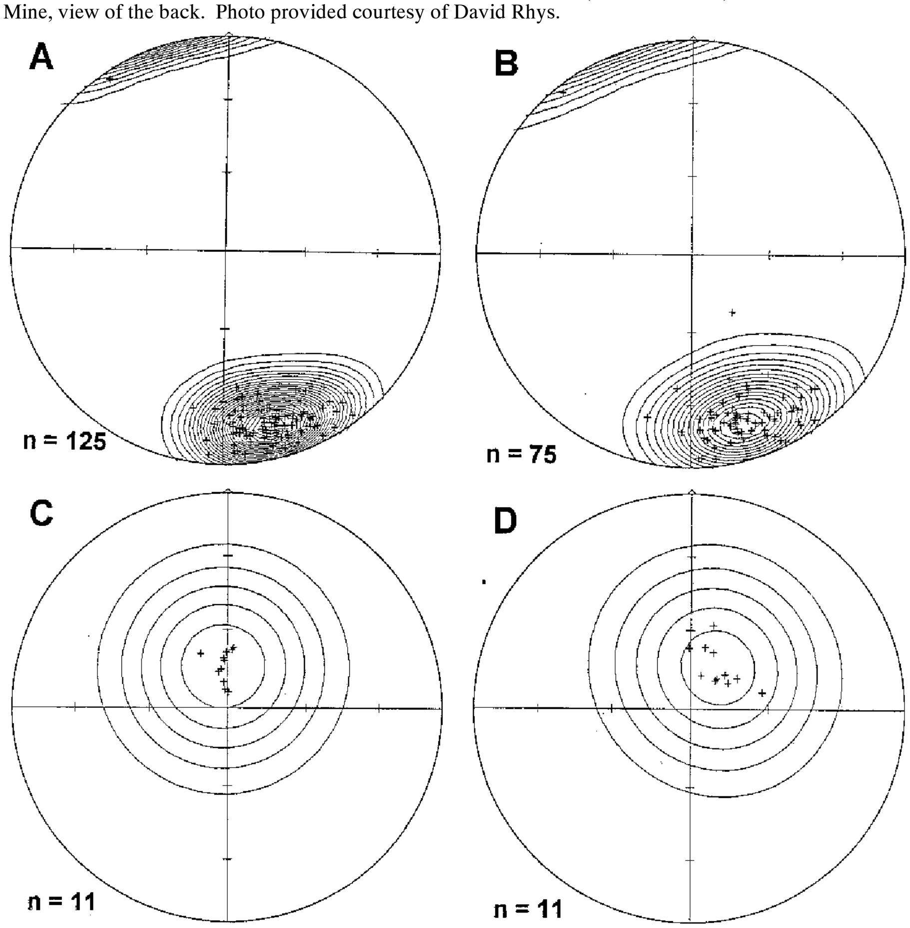


Figure 8. Stereonet projections of selected D2 structural features, Hoyle Pond Mine and 1060 Zone (after Rhys 1996): (A) Poles to S2 cleavage (Avg: 255° / 75°N), B vein, 1060 Zone, 40-200 Levels, (B) Poles to S2 cleavage (Avg: 250° / 72°N), Hoyle Pond mine, 107-650 stope, (C) L2 elongation lineations (Avg: 72° to Az 360°), 1060 Zone and 107-650 stope, (D) Poles to S3 crenulation cleavage (Avg: 117° / 20°S), 1060 Zone and 107-650 stope.

Table 3. Average Orientations of Structural Elements at the Hoyle Pond Mine (after Rhys 1996).

Fabric	Feature	Average Orientation	No. of Measurements	Area where measured
D2	S2 slaty cleavage	255 / 75° N	125	1060 Zone
		250 / 72° N	75	107-650 Stope
	L2 elongation lineation	72° to 360°	11	1060 Zone + 107-650 Stope
D3	S3 crenulation cleavage	117 / 20° S	11	1060 Zone + 107-650 Stope (Barclay, 1993)
	L3 crenulation lineation	13° to 252°		
Younger Structures	S4 Kink Bands	022 / 34° E	13	1060 Zone
	Brittle Faults	284 / 58° N	37	1060 Zone
	Calcite-filled Joints	090 / 18° S	152	1060 Zone
		104 / 19° S	29	107-650 Stope

Joints

A set of very young, shallow dipping joints are developed throughout the mine workings in all lithologies, including the diabase dikes. They are generally oriented at 090 / 18°S in the area of the 1060 Zone and 104 / 19°S in the Hoyle Pond Mine. Both calcite – filled, and unmineralized joints are found. Their orientations are illustrated in Figure 9, C and D.

Faults and Shears

A number of brittle faults occur locally throughout the mine area and affect all of the rock types on the property. These faults generally strike in a northeasterly direction, but north and west-northwest orientations are also observed. Rhys (1996) determined that the average orientation of these faults in the 1060 Zone was 284 / 58°N (Figure 9B, Table 3). The faults are usually filled with 2-10 mm of clay gouge that forms a matrix to rusty-coloured wall rock fragments, with coarse calcite veins filling some faults.

Slickensides, rotation of foliation, and displaced veins indicate a right-lateral, reverse sense of displacement on the structures that ranges from <0.1 to 2 metres. Observation of Figure 7 reveals that the northeast trending brittle fault located immediately southeast of the 1060 Zone both cross cuts and is partially filled by north and northwesterly trending diabase dikes. The orientation of these dikes suggests that they are part of the Matachewan Dike Swarm as described by Osmani (1991) and correlate with the Hearst Dike Swarm that has been dated at 2454 Ma by Heaman, (1988). Personal observations by the author and others (J. Ireland, pers. comm.) have shown that the Matachewan Dikes consist of multiple intrusive events such that several overprinting diabase dikes can be observed on occasion. These observations all provide evidence to suggest that these late brittle faults formed at approximately 2450 Ma.

ECONOMIC GEOLOGY

Production History

The Hoyle Pond mine is a fully equipped underground mine employing some 200 people in 1997, and is capable a mining rate of approximately 1 500 tonnes per day. The mine is serviced by two declines at a grade of –17% to a depth of 225 metres below surface, and a new production shaft completed in 1996 to a depth of 815 metres. The mine currently has six main levels located at 75, 120, 165, 210, 230, and 255 metres below surface. Much of the underground equipment was purchased new in 1986 to 1988, including a then state-of-the-art electric truck haulage system. The mill has been expanded a number of times from 400 tonnes per day to 500 tonnes per day in 1994, to 1,000 tonnes per day in 1995, and most recently to 1,500 tonnes per day by means of addition of a Carbon-in-Pulp circuit in 1997. The mill achieved a 90% recovery in 1997 with 30 to 50% of the total recovery being accomplished by means of gravity circuits. Cash operating costs for the mine are shown in Table 4, and the production and reserve history of the Hoyle

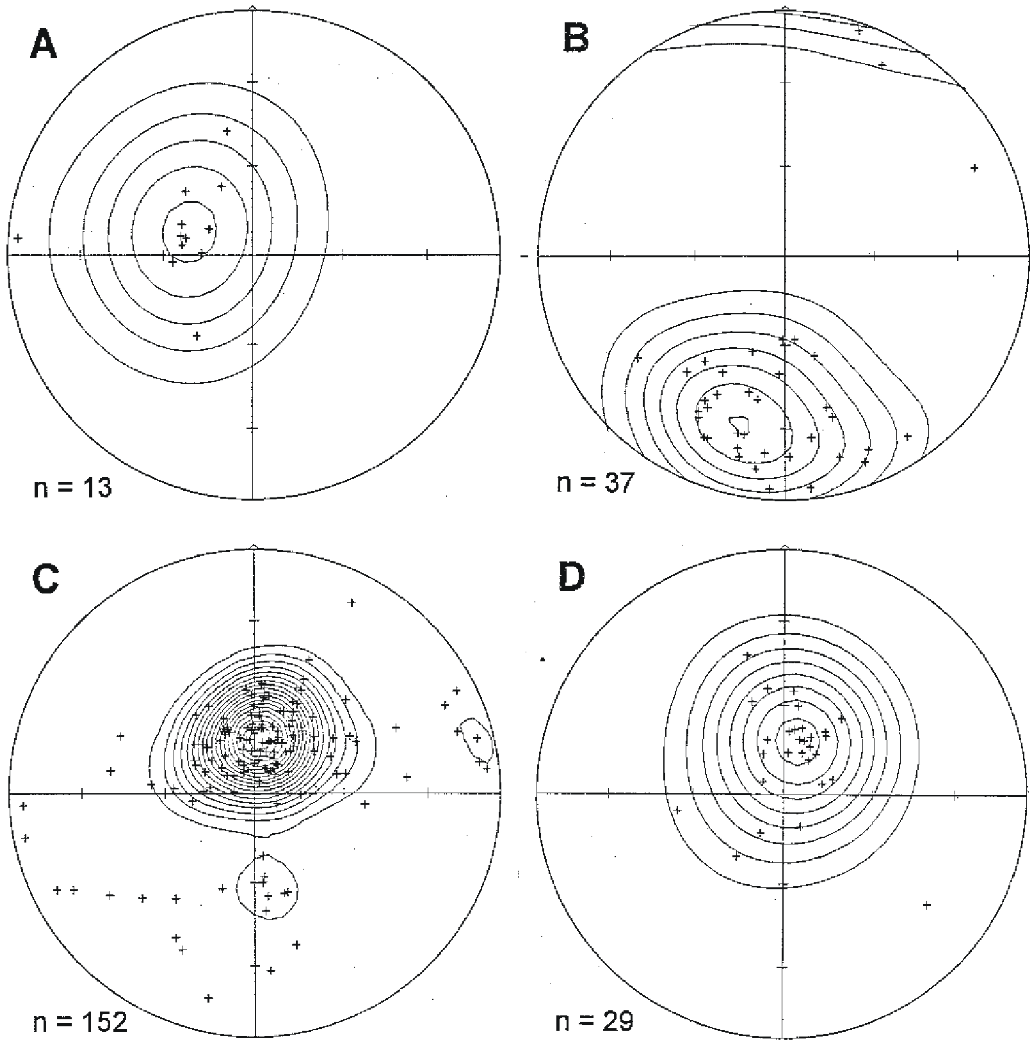


Figure 9. Stereonet projections of selected young structural features, Hoyle Pond / 1060 Zone (after Rhys 1996): (A) Poles to S4 kink bands (Avg: 022° / 34°E), 1060 Zone, 40-200 Levels, (B) Poles to brittle faults (Avg: 284° / 58°N), B Zones, 1060 Zone, 40-200 Levels, (C) Poles to calcite-filled joints (Avg: 090° / 18°S), B Zones, 1060 Zones, 40-200 Levels, (D) Poles to unmineralized joints (Avg: 104° / 19°S), 107-650 stope, Hoyle Pond.

Pond Mine is given in Table 5. The ore reserves shown in Table 5 include all material in the Proven, Probable, and Possible Ore categories on a fully diluted basis. The Mineral Inventory as at December 31, 1997 (including all material in the Resources category) is 15 100 000 tonnes grading 5.9 g / t Au (2 870 000 oz Au). The following economic parametres were used in estimation of the 1997 Mineral Inventory: gold price - $US350 / oz, exchange rate - $US1 = $C1.384, break-even cutoff grade – 3.0 g / t Au, cut grade – 100 g / t Au for the 1060 Zone and 200 g / t Au for the Main Zone.

Table 4. Summary of Kinross Gold Corporation's Average Annual Cash Costs per Ounce of Gold Produced at the Hoyle Pond Mine.

Year	**1993**	**1994**	**1995**	**1996**	**1997**
Cash Cost ($US / oz)	218	187	189	156	186

Table 5. Summary of the Production and Ore Reserve History at the Hoyle Pond Mine. 1998 figures are for the January – April period. Data provided courtesy of Keith Green, Chief Geologist, Kinross Gold Corporation.

Year	**Tonnes Mined**	**Tonnes Milled**	**Milled Grade (g / t Au)**	**Recovered Gold (oz)**	**Ore Reserves (Tonnes, g / t Au)**
1985	64 400	64 400	13.0	27 000	199 637 @ 15.1
1986	86 598	83 596	22.3	56 898	437 000 @ 23.1
1987	89 415	100 690	15.2	47 212	407 000 @ 19.5
1988	86 817	97 223	17.4	51 358	382 900 @ 16.5
1989	107 329	109 995	17.9	58 540	335 624 @ 16.2
1990	109 559	114 995	18.6	64 573	291 367 @ 16.9
1991	100 196	106 859	18.6	54 118	254 009 @ 15.4
1992	106 145	109 234	17.8	58 864	184 640 @ 14.6
1993	77 368	77 368	19.2	47 092	225 644 @ 17.3
1994	97 369	97 369	17.3	55 170	260 000 @ 15.07
1995	200 970	178 653	16.7	91 661	1 163 889 @ 15.46
1996	379 805	377 752	14.9	160 967	4 245 903 @ 13.80
1997	467 446	469 177	13.60	174 317	4 602 126 @ 11.07
1998*	136 456	138 942	14.57	56 863	3 650 833 @ 9.40
Total	**2 109 873**	**2 126 253**	**17.47**	**1 004 633**	

Mining and Milling Methods

Access to the underground workings is by means of two ramps located at either end of the ore body, and a four compartment shaft. The ramps extend to 280 metres below surface, and the deepest mining level in the shaft is at 720 metres below surface. The ramps measure 4 metres high by 4.5 metres wide, and the haulage drifts measure 3 metres high by 3 metres wide. Muck removal is by means of either 6-yard or 2-yard scooptrams, depending on the drift size.

Conventional cut-and-fill, shrinkage, and panel mining methods are typically employed to excavate the higher grade, narrower gold bearing veins which range from 0.20 to 2.0 metres in width. Mucking is accomplished using slushers. Longhole methods with delayed paste backfill are used in the wider stoping areas. Longhole levels are advanced at 60 metre intervals with sublevels being advanced at 20 metre intervals, and drawpoints are driven on 30 metre centers. Mining blocks range from 30 to 50 metres in length, from 1.5 to 7 metres in width, and are 60 metres high. These blocks are mined on a retreat basis. Production drill holes are drilled downwards between the sublevels using the following patterns:

- For widths greater that 4.5 metres, 2.5 inch diametre holes on a 1.5 x 1.5 metre pattern,
- For widths between 1.5 and 3 metres, 2.125 inch diametre holes on a 1 x 1m pattern, and
- For widths less than 1.5 metres, 2.125 inch diametre holes on either a 1.5m or 1.2 metre dice pattern.

Haulage drifts are driven in the footwall to the veins about 12 metres offset from the ore zone. Traditional backfill methods by previous operators employed a combination of rockfill and cemented slag.

Kinross Gold Corporation has replaced the earlier methods by the use of high quality paste backfill delivered through fill holes from surface and distributed through a network of underground pipes. Ground support is maintained using a regular 1.2 x 1.2m pattern of mechanical and / or grouted rebar rock bolts. Swellex and Split Set friction stabilizers, with shotcrete, are used whenever localized ground conditions warrant additional support. Ventilation is upcast through a large raise located over the 1060 Zone.

Description of Orebodies

Gold mineralization on the Kinross land holdings in Hoyle-Whitney-Matheson Twps area occurs in close association to quartz veins with associated wall rock alteration halos. To date, the known mineralization occurs as a number of vein swarms located in several areas such as: the Bell Creek Deposit (past producer), the Blackhawk (Vogel) Zone, the Owl Creek Deposit (past producer), the Owl Creek East Zones (350 Zone and 950 Zone), the Hoyle Pond Deposit (in production), the 1060 Zone (in production), and the Sediment Zone. At the Hoyle Pond Mine, the Main Zone includes a series of veins that strike in a general east to northeast direction. At least 7 of these veins have been of economic significance (7, 10, 12, 13, 14, 16, and 17 veins). The 1060 Zone at Hoyle Pond consists of at least 5 main vein structures (1060, B1, B2, B3, A, and Porphyry Veins).

The individual veins in these swarms appear to either pre-date or be synchronous with the D2 deformational event (Figure 10). They occur either as folded about the S2 axial plane (eg. 7 Vein, Photo 2), as discrete vein sets sub-paralleling the S2 axial plane cleavage (eg. B veins, 1060 Zone), or as flat dipping veins very nearly perpendicular to the S2 axial plane cleavage (eg. Extension veins, 1060 Zone).

In addition to the structural style of the veins, multiple generations of quartz are also present. At least two, and possibly three generations of auriferous quartz veins are observed in the Main Zone and 1060 Zone area (Rhys 1996), and are summarized in Table 6. While all of the rock types in the mine form hosts to the aurferous veins except the diabase dikes, the veins are most abundant, thickest, and most continuous within the basaltic units. The three vein types are:

Grey Quartz Veins: These early grey quartz>albite +/- tourmaline + carbonate + hydromica (hydromuscovite) + carbon veins are commonly surrounded by “grey zone” alteration halos (Rye 1987). These veins are commonly ribboned with dark grey bands of tourmaline, carbon and carbonate that are either discrete aggregates of these minerals, or are pervasively disseminated throughout the quartz (Photo 3). The bands commonly contain, or are spatially associated with, coarse native gold. The banding may represent cyclic opening of the veins in a crack-seal fashion. The veins vary from <0.1m to 3 metres in thickness, but are thicker where later generations of quartz have further dilated the vein. Grey quartz veins are commonly folded and boudinaged by the S2 cleavage (Photo 4).

Table 6. Summary of quartz vein types and characteristics at the Hoyle Pond Mine (after Rhys 1996).

Type	Accessory Minerals	Alteration Minerals	Orientations	Deformation	Examples
Grey Quartz	Ribboned albite, carbonates, tourmaline, hydromica	“Grey Zone”, chlorite, carbonate, carbon, muscovite	Variable, but commonly shallow dips	Variable, but commonly folded and boudinaged by S2	7,8,14,16, and Porphyry vein systems
White Quartz	Ribbons of carbonate, chlorite, muscovite, and pyrite	Disseminated pyrite 0.5-3%	NE trending with subvertical dips, or dilating other orientations of grey quartz veins	Locally intensely boudinaged by S2 in the B vein area, weakly folded	A and B vein systems, 1060 Zone; 10 Vein system, Hoyle Pond
Late Extension Veins	Carbonate selvages	None identified	Shallow to moderate S-SE dips	Locally weakly folded; locally fill boudin necks in older veins	Examples present througout the mine(Porphyry Vein)

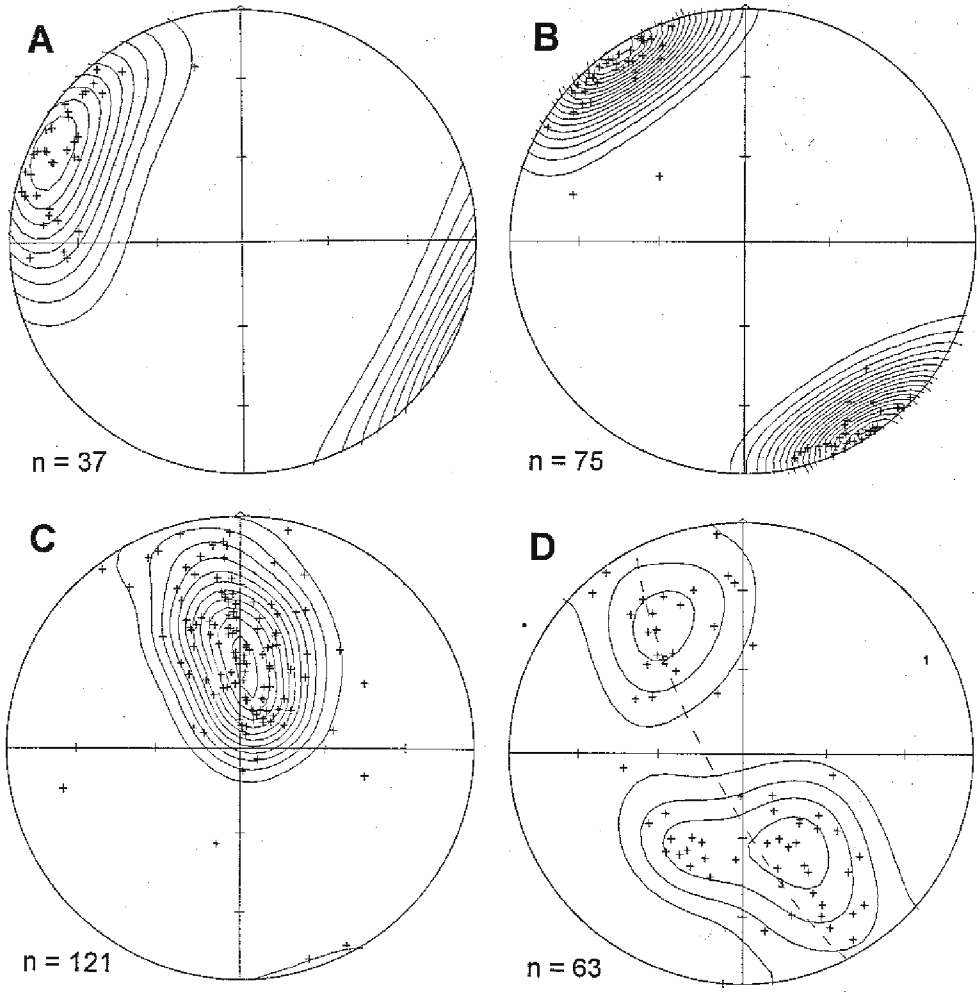


Figure 10. Stereonet projections of selected vein systems at the Hoyle Pond / 1060 Zone (after Rhys 1996): (A) Poles to the Porphyry Vein (Avg: 025°/81°E), 1060 Zone, 4 –200 Levels, (B) Poles to the B veins (B1, B2, and B3) (Avg: 236°/90), 1060 Zone, 40-200 Levels, (C) Poles to the extensional quartz veins (Avg: 090°/42°S), 1060 Zone, 40-200 Levels, (D) Poles to the 7 Vein showing two fold limbs (240°/53°, and 057°/58°), and fold axis (approx. 10° to Az 063°).

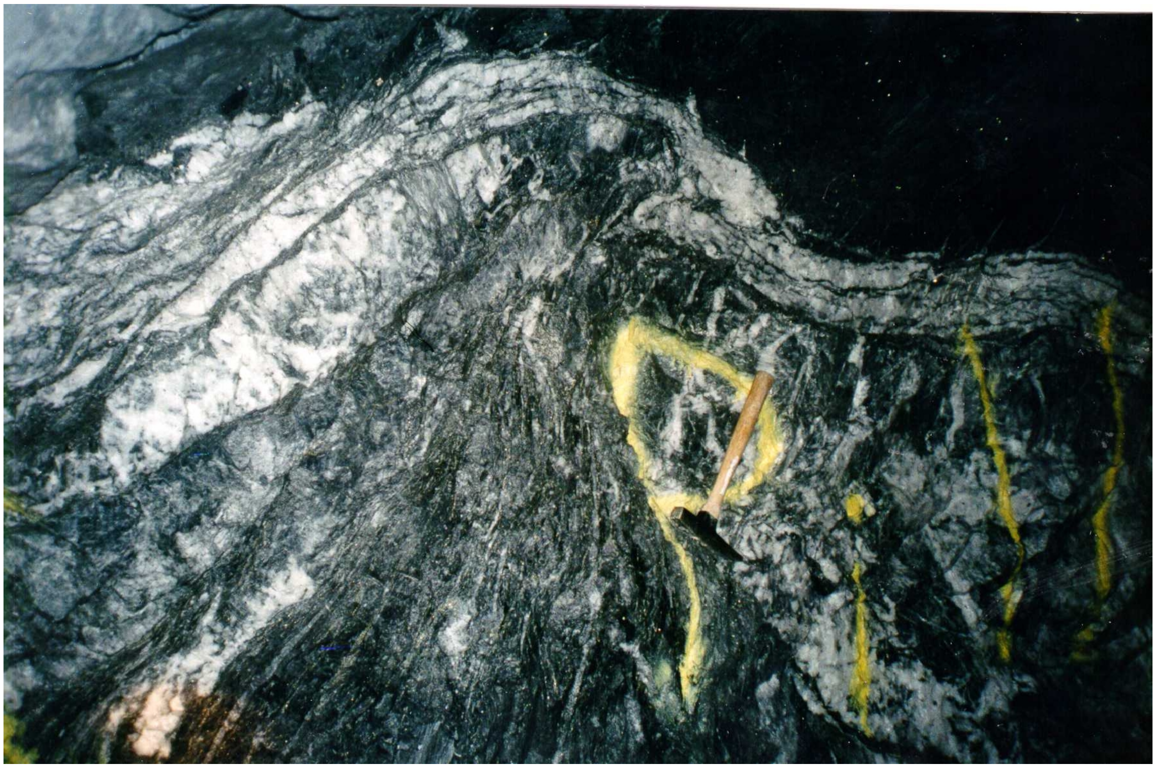


Photo 2. Folded 7 Vein about the S2 cleavage. 575 – 745 area, 120 Level, looking northeast, located at approximately 99621N 101788E (after Rhys 1997). Note hammer for scale. Photo provided courtesy of David Rhys.

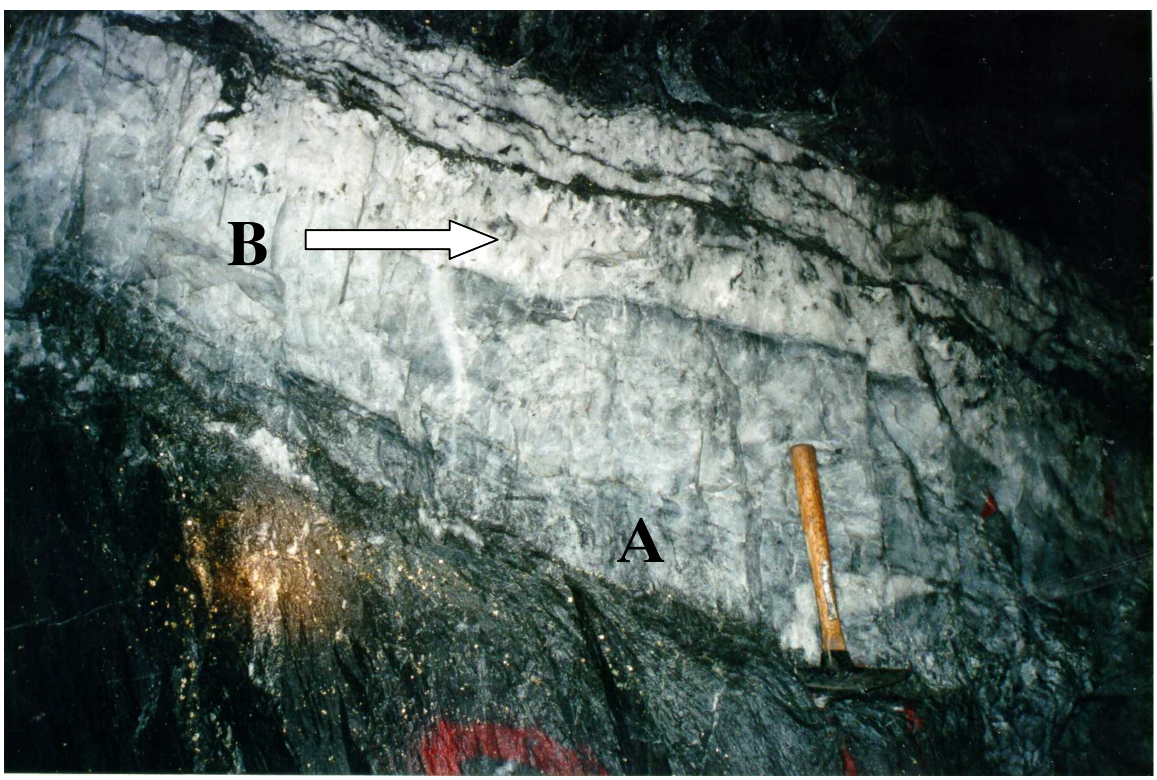


Photo 3. Example of grey quartz (A) cut by later generation ribbon textured white quartz (B) of the 7 Vein. Both generations show laminations parallel to vein walls. Note presence of abundant disseminated pyrite in the wall rocks. Approximate location 99627N 101774E, 120 Level, Hoyle Pond Mine, looking north – northwest (after Rhys 1997). Geological hammer for scale. Photo provided courtesy of David Rhys.

Photo 4. Well developed boudinaged texture of grey quartz in the B3 Vein, 40 Level, 1060 Zone, looking west, Hoyle Pond Mine. Approximate vertical field of view is 2.5 metres. Photo provided courtesy of David Rhys.

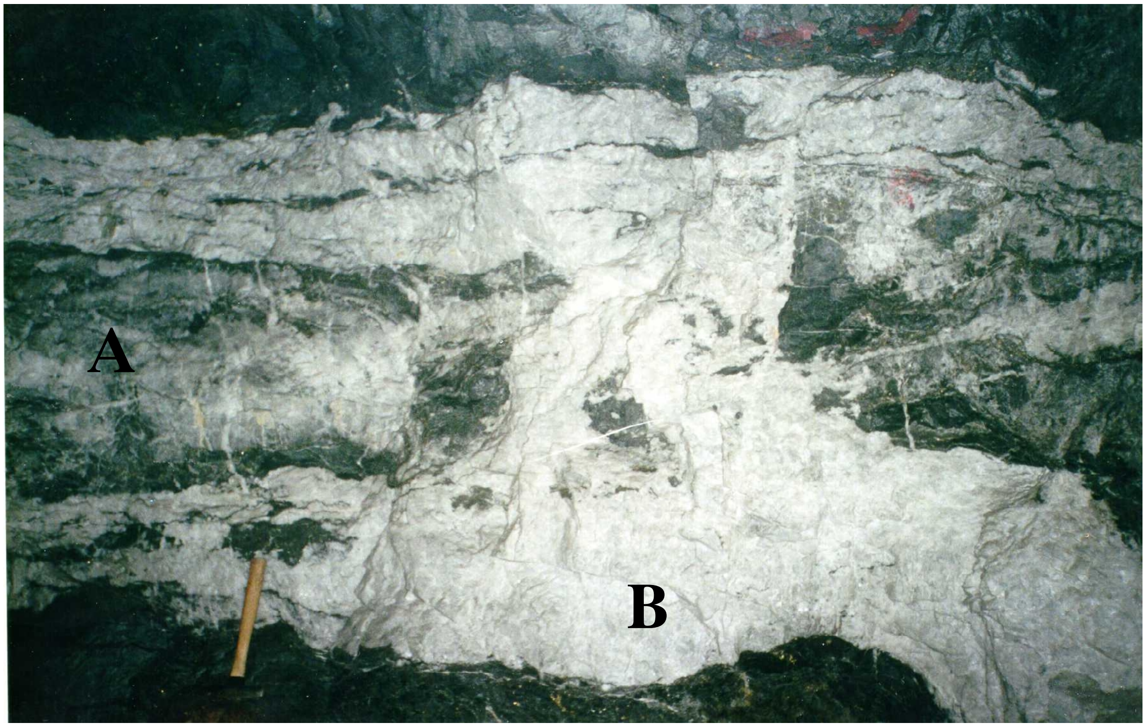


Photo 5. Older grey quartz (A) cross cut and brecciated by younger quartz veining (B) of the 7 Vein, 120 Level, looking northeast, located at approximately 99650N 101807E, Hoyle Pond Mine (after Rhys 1997). Note geological hammer for scale. Photo provided courtesy of David Rhys.

Photo 6. Late extensional quartz veins are preferentially developed in and cross cut older ribboned grey quartz veins of the Porphyry Vein, 80 Level, 1060 Zone, Hoyle Pond Mine (after Rhys 1996). Note the drill jumbo (A) for scale. Photo provided courtesy of David Rhys.

White Quartz Veins: These veins are of intermediate age, and consist of white, milky quartz that contains <1 to 3% ribbons and bands of chlorite, muscovite, carbonate and pyrite that are commonly ribboned in texture. This type of quartz further dilates the older grey quartz veins, often brecciating them (Photo 5). The result is composite veins that contain brecciated fragments of grey quartz, or locally banded areas of grey quartz that are separated by the younger white quartz. In the 1060 Zone area, 0.5-3% disseminated pyrite occurs in the wall rocks to this type of vein. Gold is typically finer grained than in the grey quartz, and is often associated with the pyrite.

Extension Veins: These veins are the youngest set of quartz veins and are developed at a high angle to the S2 cleavage. They are found throughout the Hoyle Pond and 1060 Zone area, are typically 0.5-10 cm thick, 0.2-4m in length, lenticular in shape, and are often developed in shallow south dipping en echelon arrays. The extension veins cross cut the grey quartz veins, and are often preferentially developed within them (Photo 6). The general distribution of some of the veins in the Main Zone is shown in Figure 11. The distribution and folded nature of the 7 Vein system in plan view is shown in Figure 12. The complex branching patterns and vein intersections are shown in Figures 13 and 14, respectively. The vertical distribution and folded nature of the 14 and 16 Veins are shown in Figure 15.

ACKNOWLEDGEMENTS

The author thanks Kinross Gold Corporation, Randy Roussain (Chief Geologist) Hoyle 2000 Group and Keith Green (Chief Mine Geologist) for their enthusiastic participation, openness, and support in providing information and materials for this description. Thanks also go to Ben Berger (Geoscientist, Ontario Geological Survey) for providing copies of lithogeochemical analyses, David Rhys (Panterra Geoservices Inc.) for supplying copies of photographs, and to Jeremy Jeffrey (summer field assistant) for assistance with preparation of the graphics for this description.

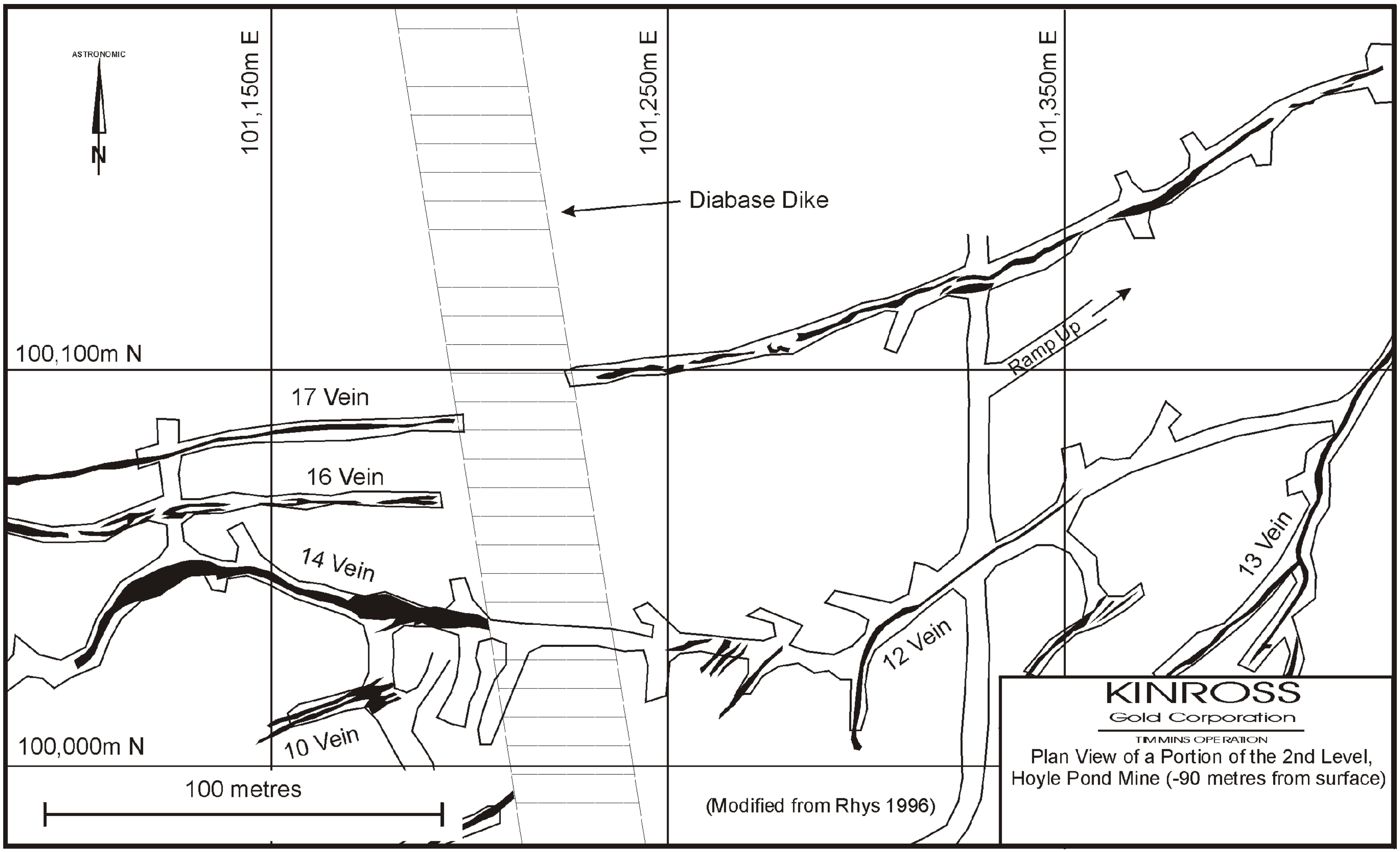
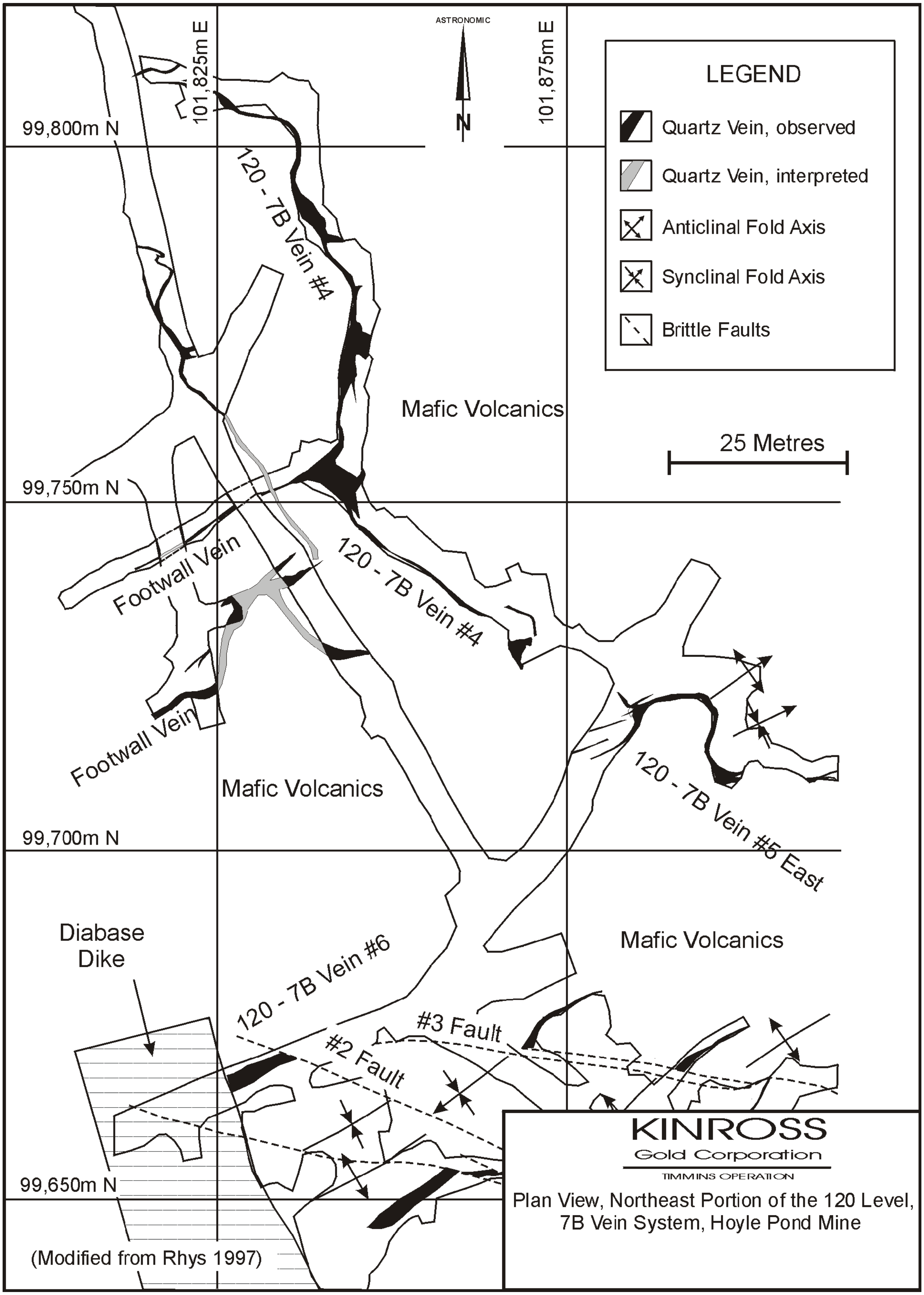


Figure 11. Plan map of selected mine workings and quartz vein locations, 2nd Level (-90 metres from surface), Hoyle Pond Mine.



ASTRONOMIC
N
101,825m E
101,875m E
99,800m N
99,750m N
99,700m N
99,650m N
LEGEND
Quartz Vein, observed
Quartz Vein, interpreted
Anticlinal Fold Axis
Synclinal Fold Axis
Brittle Faults
25 Metres
120 - 7B Vein #4
Mafic Volcanics
Footwall Vein
120 - 7B Vein #4
Footwall Vein
Mafic Volcanics
120 - 7B Vein #5 East
Diabase Dike
Mafic Volcanics
120 - 7B Vein #6
#3 Fault
#2 Fault
(Modified from Rhys 1997)
KINROSS
Gold Corporation
TIMMINS OPERATION
Plan View, Northeast Portion of the 120 Level, 7B Vein System, Hoyle Pond Mine

Figure 12.

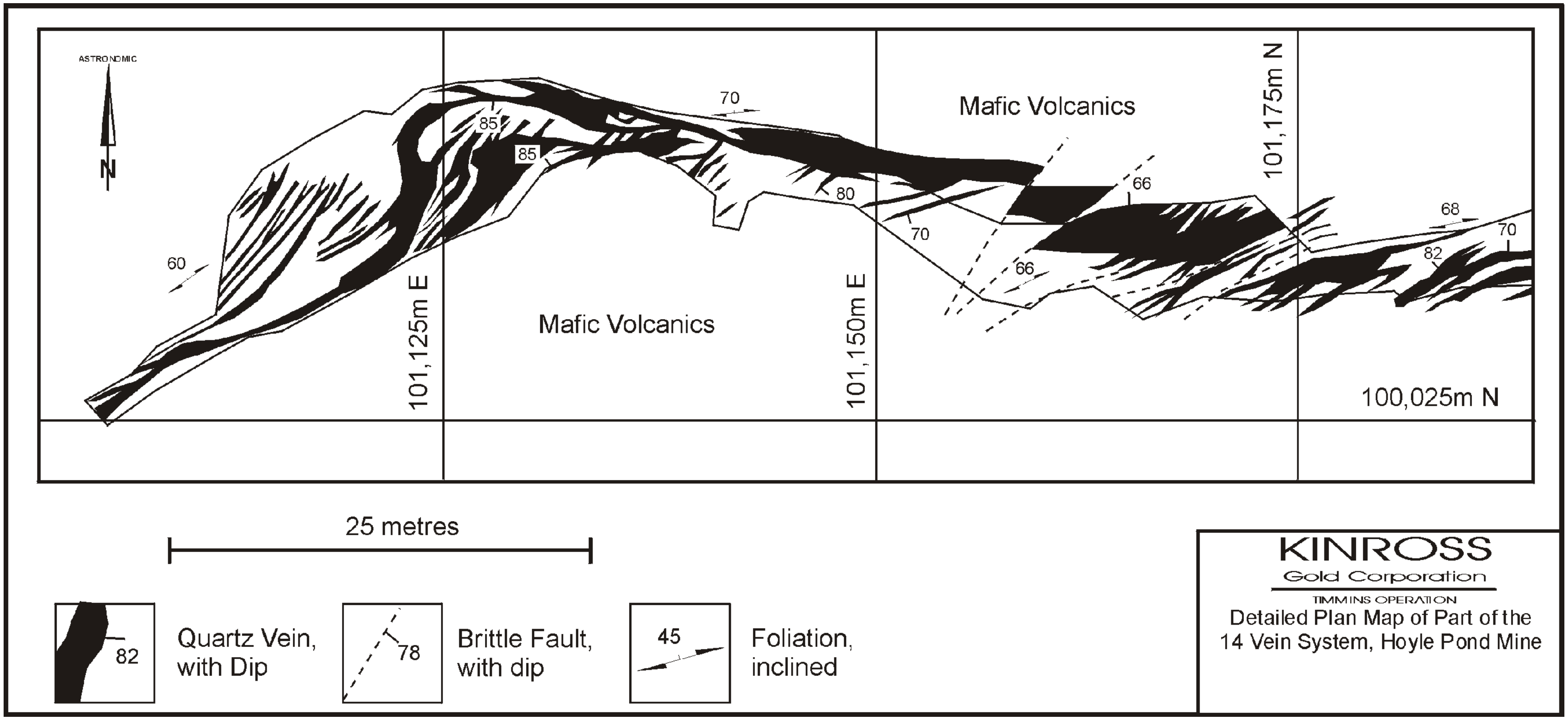


Figure 13. Detailed plan view of a portion of the 14 Vein system, Hoyle Pond Mine. 314 #1 Stope west, lift 4, 1143m elevation (-143 metres from surface). Modified from Rhys (1996).

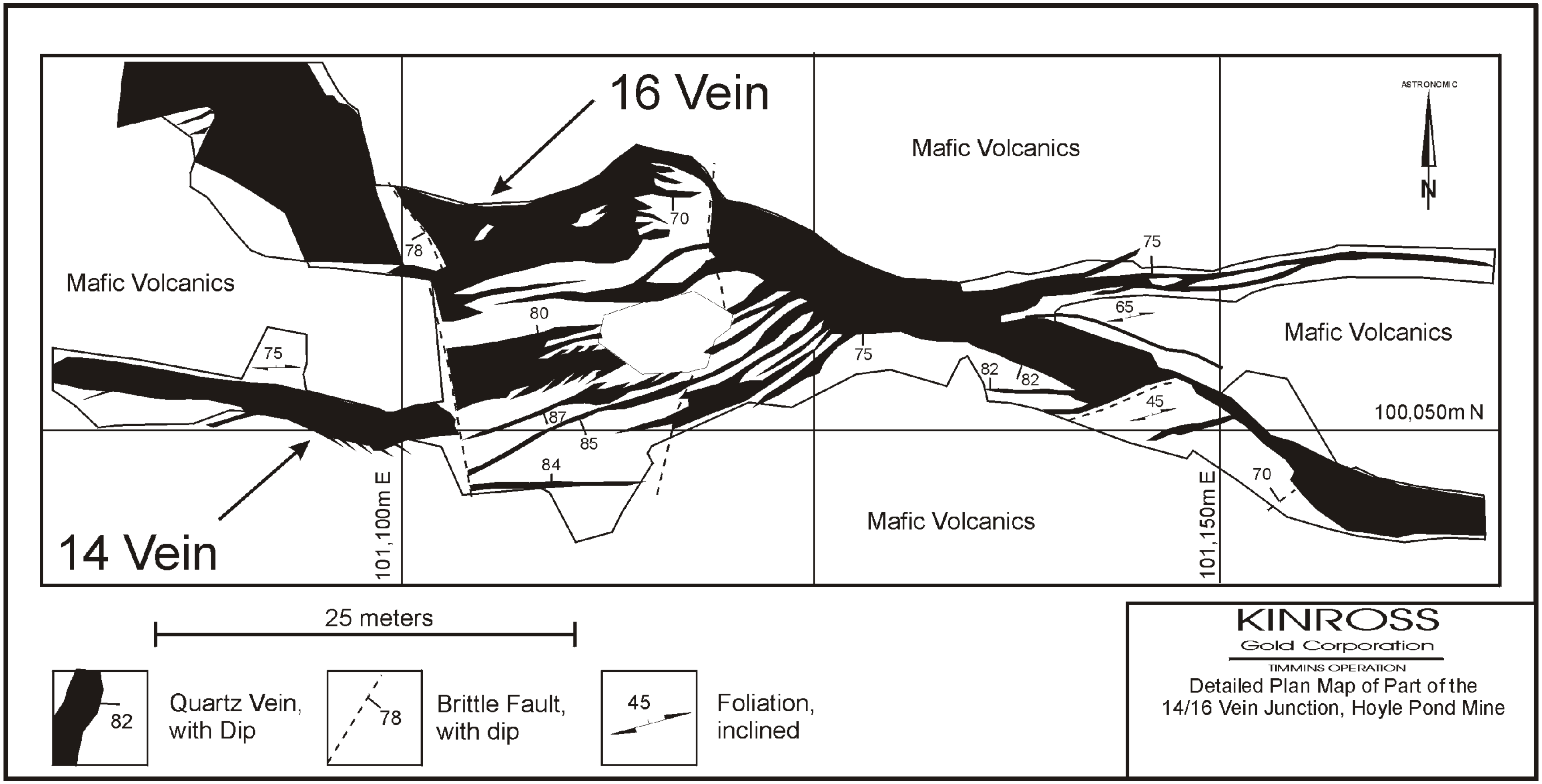


Figure 14. Detailed plan view of part of the 14 / 16 Vein junction area, Hoyle Pond Mine (modified from Rhys 1996). 214 / 216 #1 and #2 stope west, lift 10, 1192m elevation (–94 metres from surface).

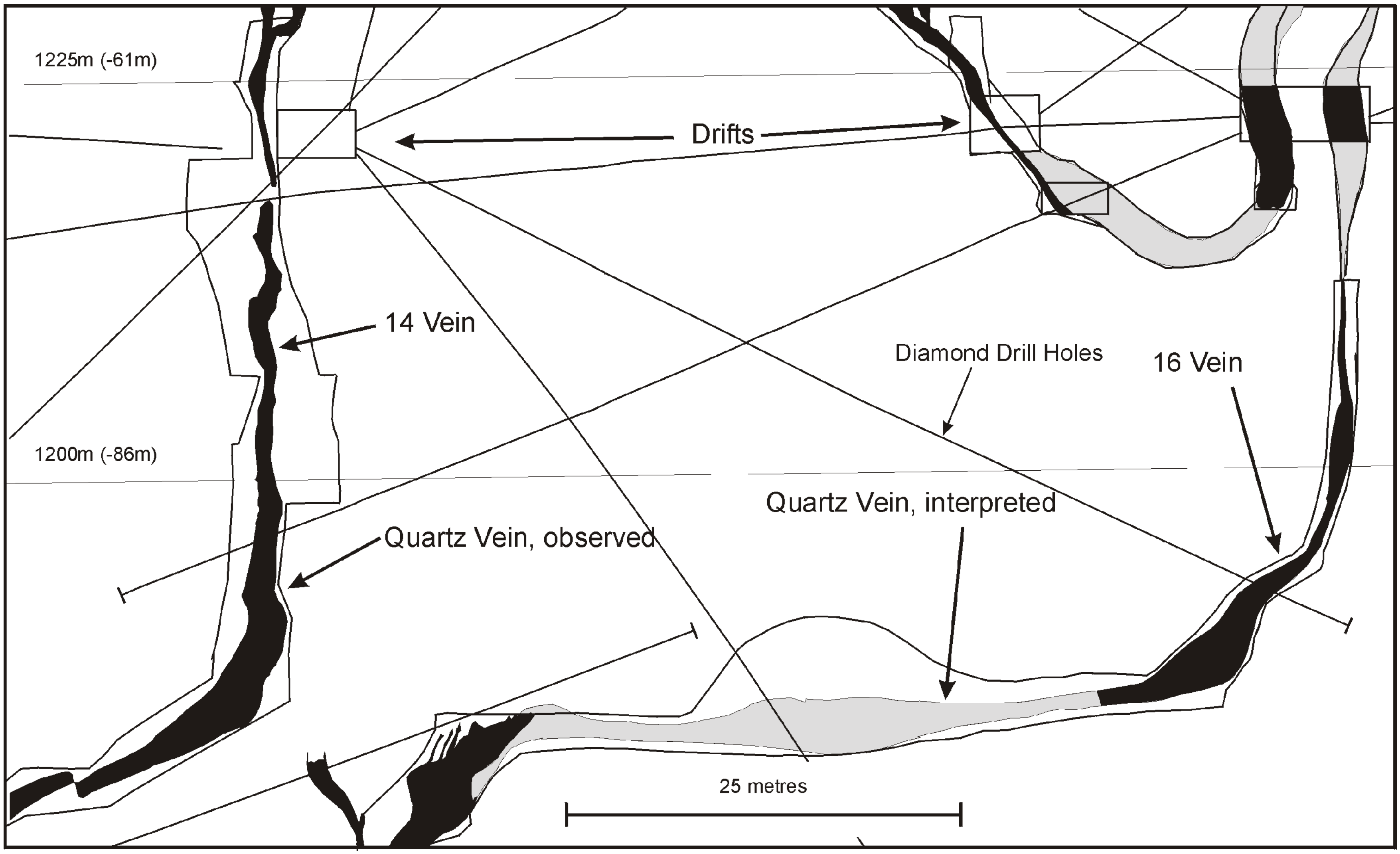


Figure 15. Detailed cross sectional view of part of the 14 / 16 Vein system, Hoyle Pond Mine (modified from Rhys 1996). Non-orthogonal view looking west-southwest. Centre of diagram is located at approximately 101,090E 100,040N on the mine grid.

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Economic Geology and Mineralization of the Marlhill Mine

Reno Pressacco
District Geologist, Timmins Regional Resident Geologist's Office

INTRODUCTION

Lode gold mineralization at Pentland Firth Venture's Ltd. Marlhill Mine Project is contained within a system of quartz veins hosted by Mg-tholeiitic volcanic rocks. They are similar in style and setting to those of other gold mines in this stratigraphy such as the Hoyle Pond Mine (producing mine), the Owl Creek Mine (past producing mine), and the Bell Creek Mine (past producing mine). Together these mines have produced a total of 1 374 700 ounces of gold to-date (Atkinson, et. al. 1998).

The first recorded exploration activity in the area was by Hollinger Consolidated Gold Mines Ltd who conducted a stripping and sampling program on the Johnston Option in the north half of Lots 9 and 10, Concession II, Hoyle Township. They discovered several narrow gold-bearing quartz veins with values of up to $11.80 / ton (0.337 oz / ton Au @ $35 Au) in 1936 (Jones 1936). Additional sampling in 1952 returned a value of $42.00 over a width of 7 inches (1.20 oz / ton Au @ $35 Au). Work by Broulan Reef Mines Limited in 1957 discovered additional quartz veins and stringers in the NW quarter of the south half of Lot 9, Concession II, Hoyle Township and the SW quarter of the north half of Lot 9, Concession II, Hoyle Township. The best assays from that area were 0.12 oz / ton Au over a 30 ft strike length from one trench, and 0.37 oz / ton Au over a 24.5 ft strike length from a second trench (Backman 1958). Canamax Resources Inc. explored the property throughout the 1980's, culminating in test mining and limited commercial production in the 1989 – 1991 period. The mine was dewatered in 1996-1997 to complete an underground diamond drilling program. However changing market conditions caused the program to be deferred and the mine was allowed to flood.

LOCATION, OWNERSHIP, AND CLAIMS

The Marlhill Mine is located in southwestern Hoyle Township, approximately 14 kilometres northeast of Timmins, Ontario (Figure 1). The known limits of the deposit to-date extend from the southeast quarter of the north half of Lot 10 Concession II through the southwest quarter of the north half of Lot 9 Concession II to the northwest quarter of the south half of Lot 9 Concession II. All of these lands are currently registered to Pentland Firth Ventures Ltd.

REGIONAL GEOLOGICAL SETTING

The mine is hosted within a southeasterly striking band of massive to pillowed variolitic mafic metavolcanic rocks which is flanked to the north by clastic metasedimentary rocks composed principally of wackes and mudstones (Figure 2). These units are located to the immediate north of the traditional Timmins Camp stratigraphy which has been described in detail by Ferguson et. al. (1968), Pyke (1982), Jackson and Fyon (1991), and Brisbin (1998).

The Tisdale Group consists of: i) a lower sequence consisting of mixed ultramafic and Mg-tholeiite mafic metavolcanic rocks that have returned an age date of 2707 Ma, ii) a middle sequence dominated by Fe-tholeiitic basalts capped by two distinctive variolitic units, and iii) an upper sequence consisting dominantly of calc-alkaline felsic pyroclastic rocks (Krist Fragmental, 2698 Ma) with minor amounts of carbonaceous argillite. The Tisdale Group is in fault contact with the older Deloro Group (2727 Ma) to the south across the Destor-Porcupine fault zone. The rock types in the Deloro Group are dominantly calc-alkaline basalts, andesites, rhyolitic and dacitic tuffs, lapilli tuffs, and chemical sediments. A sequence of clastic metasediments (Porcupine Group) conformably overlie the Tisdale Group units, and are in turn unconformably overlain by younger clastic metasediments of the Timiskaming Group. A schematic illustration of the stratigraphy and age dates for the Timmins Camp is given in Figure 3.

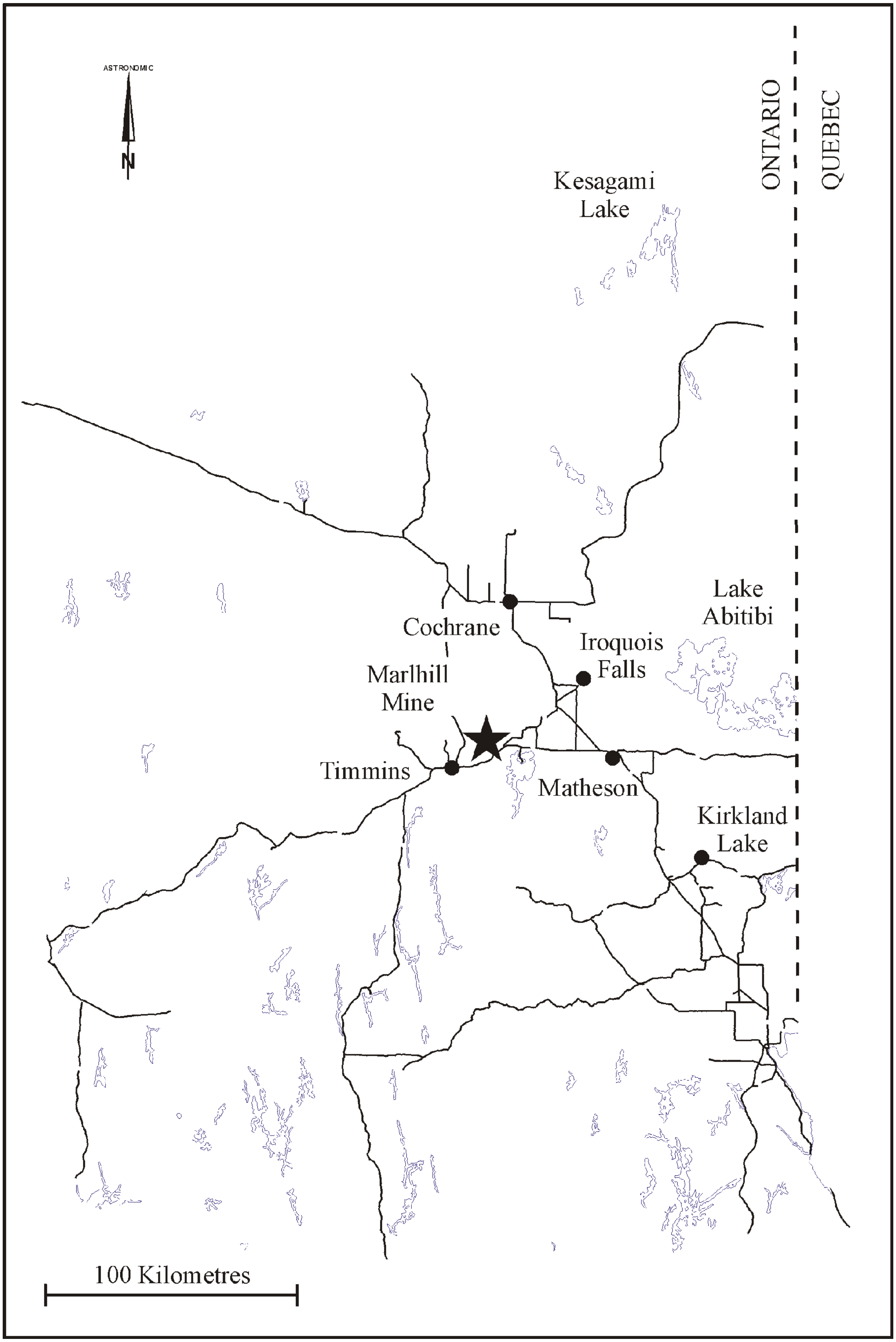


Figure 1. Location map of the Marlhill Mine.

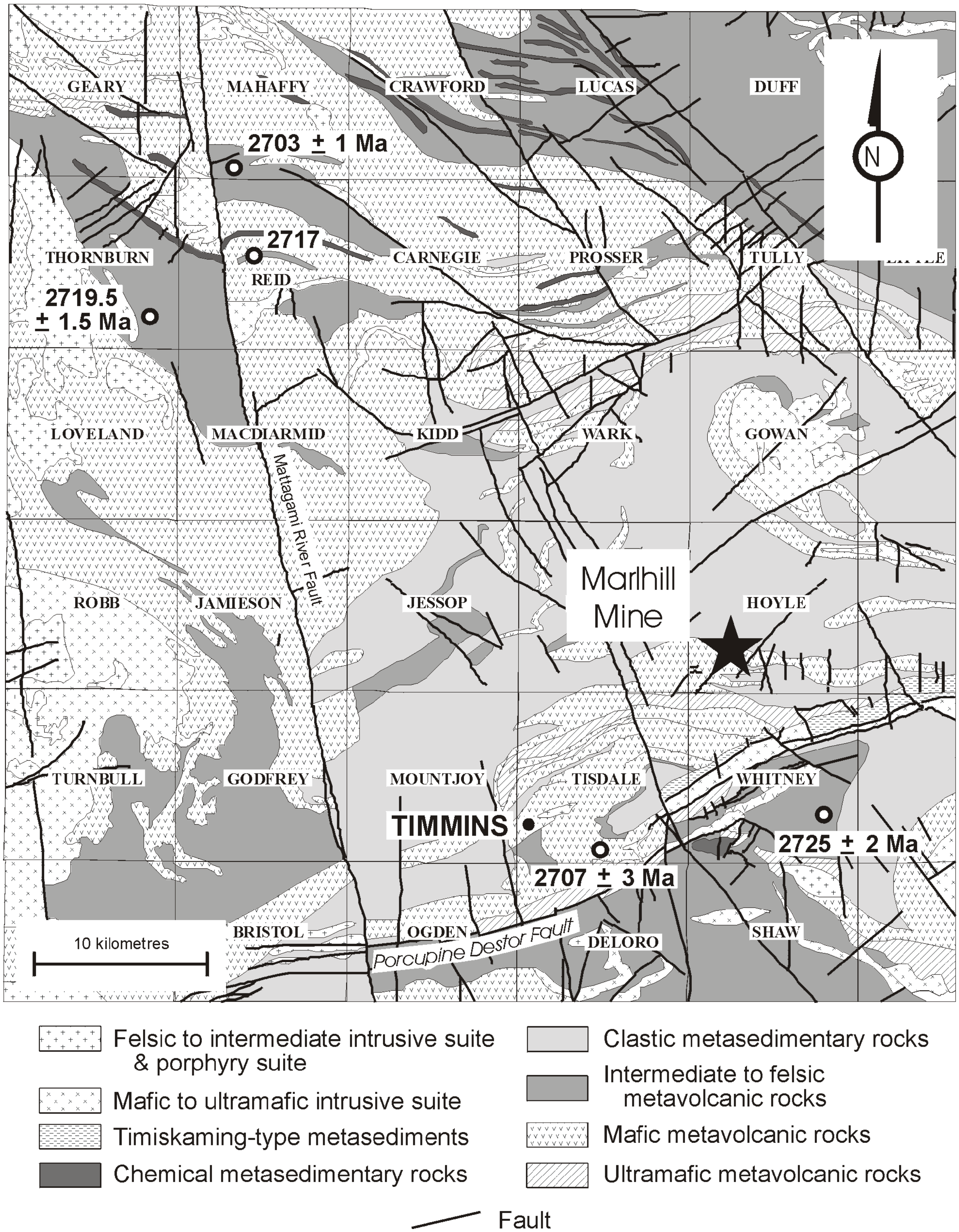


Figure 2. Regional Geological Setting of the Timmins Area (modified from Ayer and Trowell 1998).

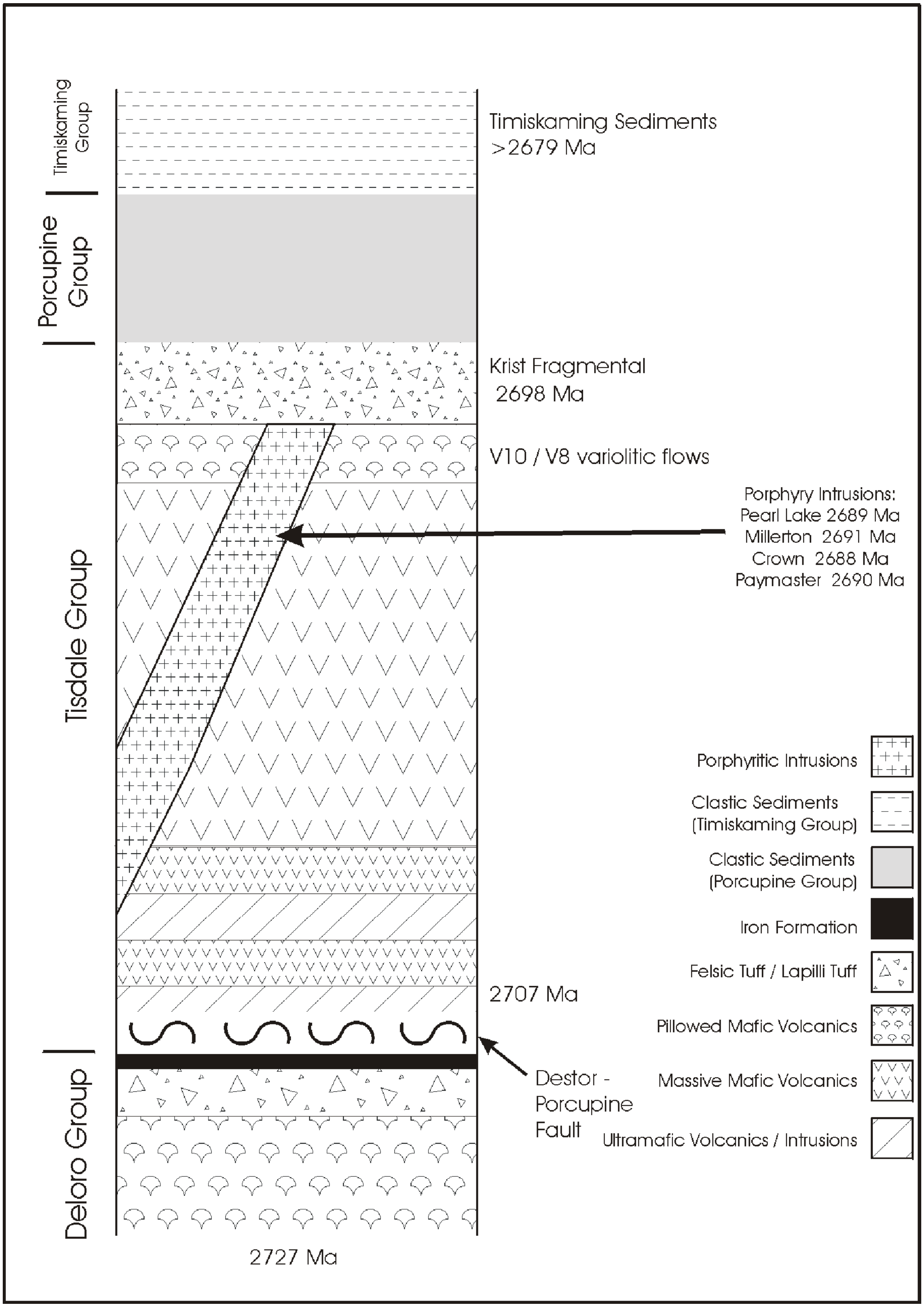


Figure 3. Generalized Stratigraphic Column of the Timmins Camp.

The Destor–Porcupine Fault is the most significant structure in the Timmins area and it consists of a number of zones of shearing and ductile deformation focussed mainly within ultramafic flows and intrusions. The fault is vertical or steeply north dipping, and has been traced continuously eastwards through to the Duparquet, Quebec area where it splits into the east–trending Maneville Tectonic Zone and the southeast–trending Parforu Lake Fault (Couture 1991). The Destor–Porcupine Fault has an apparent sinistral sense of movement in the Timmins area. A set of brittle faults oriented in a northwesterly direction are present throughout the region. The brittle faults are the youngest structural features in the area and serve to offset all stratigraphic units and older structures. The Marlhill Mine is located in the hangingwall to the Destor Porcupine Fault, approximately seven kilometres north of the fault's surface trace.

PROPERTY SCALE GEOLOGICAL SETTING

Macroscopic Description of Rock Types

The property scale geological setting of the Marlhill Mine is straightforward. Gold mineralization is hosted by a number of quartz veins contained within Mg–tholeiitic mafic volcanic rocks that strike northwesterly, dip to the northeast, and are in contact with clastic sedimentary rocks to the north (Figure 4).

The mafic volcanic rocks consist of massive and pillowed flows (Berger 1992). Diamond drilling conducted on the property by Pentland Firth Ventures Ltd. has intersected variolitic textured mafic volcanic rocks (Photos 1 and 2). Amygdaloidal textures were observed in diamond drill core approximately 500m southeast of the portal, but the mafic flows in the immediate vicinity of the portal are more schistose (Photo 3).

The clastic sediments are composed chiefly of interbedded greywacke and mudstone (Kent 1990). Berger (1992) observed opposing facing directions in these sediments. In the central portions of Lot 8 Concession II, Hoyle Township, a northeasterly younging direction very near the mafic volcanic contact was observed in core from one diamond drill hole, and a southwest facing direction was observed in a second diamond drill hole located approximately 200 metres to the northeast. On the basis of the drill core data, a synclinal fold axis is interpreted between the two drill holes. This suggests that the mafic volcanic – sediment contact is situated on the northeastern limb of an anticlinal fold.

Macroscopic Description of Alteration Types and Assemblages

Kent (1990) describes the mineralization and attendant alteration at Marlhill as follows:

> "… mineralization consists of a 0.1 to three metre wide central quartz vein, which contains two to five percent fine–grained pyrite, arsenopyrite, and rarely visible gold. Gold occurs as plates on the surfaces of the sulphide minerals, but shows a preference for arsenopyrite. Significant amounts of brown tourmaline (dravite) occur in all veins. Where white mica and sulphides commonly occur on slips and fractures within the vein, gold tenor generally attains economic values. A sericite–sulphide halo extends up to one metre from the vein. Only about 10 to 20 percent of the gold occurs associated with this wall rock sulphide. Coarse to medium grained cubic pyrite extends farther away from the vein margin, into the host mafic metavolcanic rocks."

Personal observation of selected diamond drill core by the author and discussions with Pentland Firth staff have shown that the alteration style described above is accurate (G. Yule, Pentland Firth Ventures Ltd., personal communication). However a more pervasive, fine–grained sericite–carbonate alteration is commonly present surrounding the veins and vein systems, forming an envelope of incipient to moderate alteration measuring up to 30m in width, with strong sericite–(carbonate) alteration occurring immediately adjacent to the veins (photo 4). Carbonate alteration often displays a typical zonation pattern in the nature of the carbonate species from calcite in the outer reaches of the envelope, changing to ankerite inwards towards the veins (G. Yule, Pentland Firth Ventures Ltd., personal communication). These two alteration minerals cause a color change in the host mafic volcanic rocks from a light to medium green–grey to a dull, waxy, earthy brown colour on the fresh surface, and a medium yellow–brown rusty colour on the weathered surface (Photo 1).

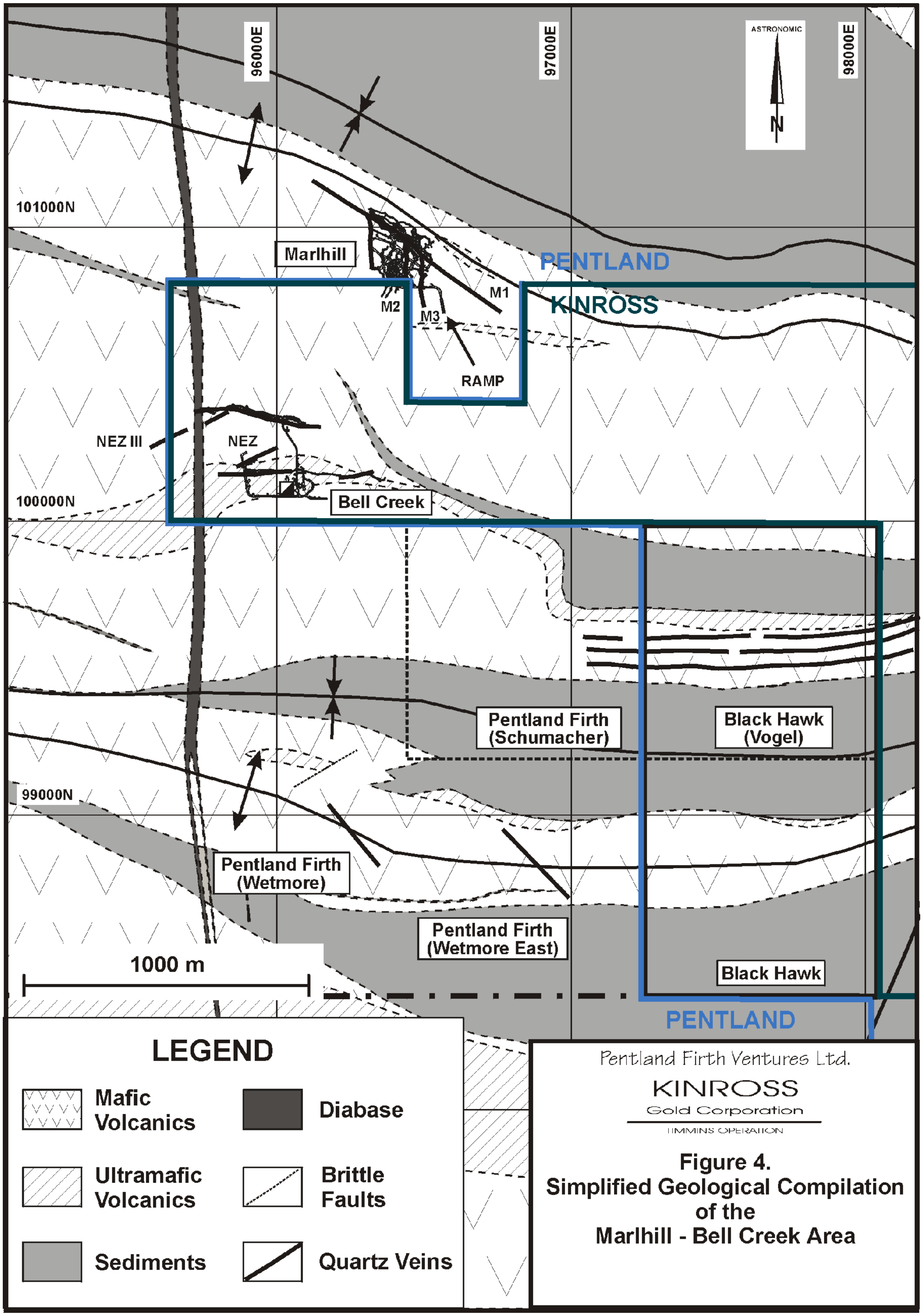


Figure 4.
Simplified Geological Compilation of the Marlhill - Bell Creek Area

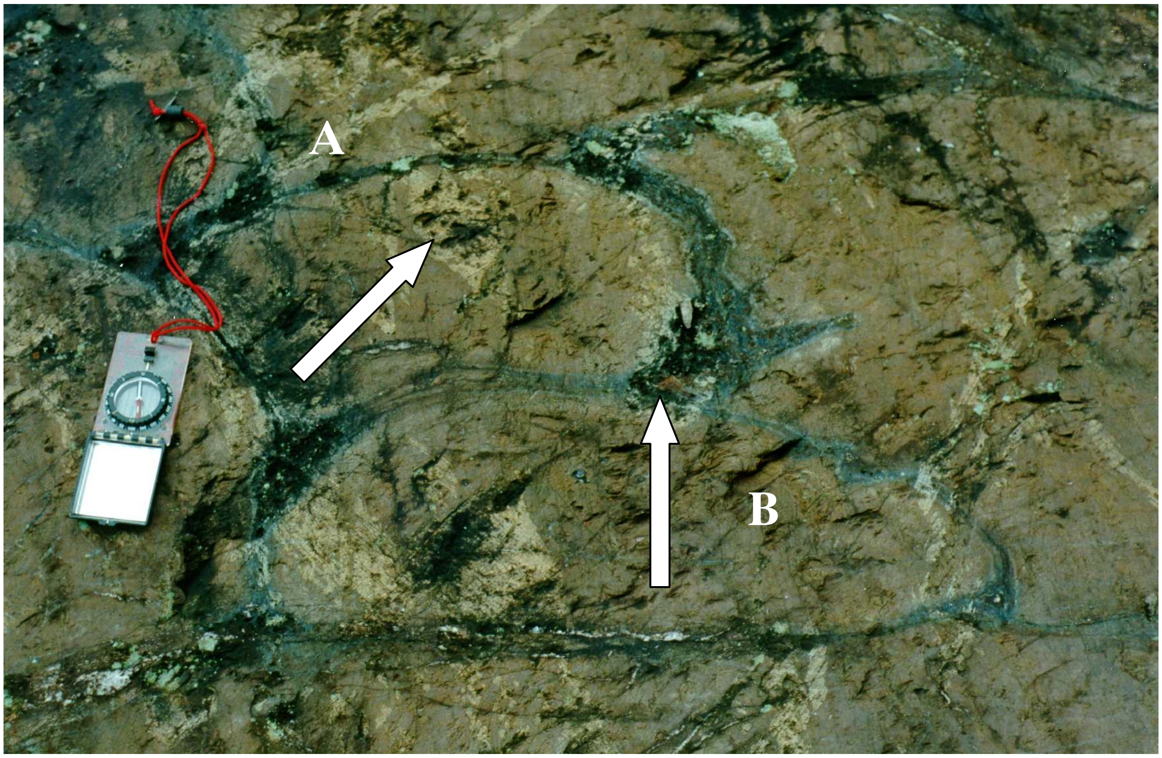


Photo 1. Pillowed mafic volcanics showing south facing younging directions (A and B), Trench 3, Marlhill Mine Project. Compass points to astronomic north.

Photo 2. Diamond drill core intersecting variolitic mafic volcanic rocks from the collection of Pentland Firth Ventures Ltd. Samples from the Marlhill Mine property (A and B, DDH PM-81), and the Bell Creek Mine property (C, DDH KB-396 and D, DDH KB385).

Photo 3. Flattened, pillowed mafic volcanic flows (A), looking west. West portal wall, Marlhill Mine Project. Rebar for scale.

Lithogeochemical Data

Little lithogeochemical data is available from the Marlhill property itself aside from a single outcrop sample taken from the south half of Lot 9 Concession II, Hoyle Township (Table 1).

Table 1. Major Oxide and Trace Element Geochemistry for a Tisdale Assemblage Basalt (Sample 91-BRB-041), Hoyle Township (after Berger 1994). Sample taken at UTM co-ordinates 487750E 5377750N.

Mg #	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3+ (%)	MnO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	P2O5 (%)	CO2 (%)	LOI (%)
54.38	52.46	0.76	13.94	12.45	0.20	7.49	7.90	2.12	2.59	0.07	0.67	1.76

Cr (ppm)	Ni (ppm)	Co (ppm)	Sc (ppm)	V (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	S (%)	As (ppm)
46	55	39	42	231	124	-10	77	0.06	0.00

Au (ppm)	K (ppm)	Rb (ppm)	Ba (ppm)	Sr (ppm)	Li (ppm)	Nb (ppm)	Zr (ppm)	Ti (ppm)	Y (ppm)
0.00	21500	58	255	87	14.28	-5	48	4584	18

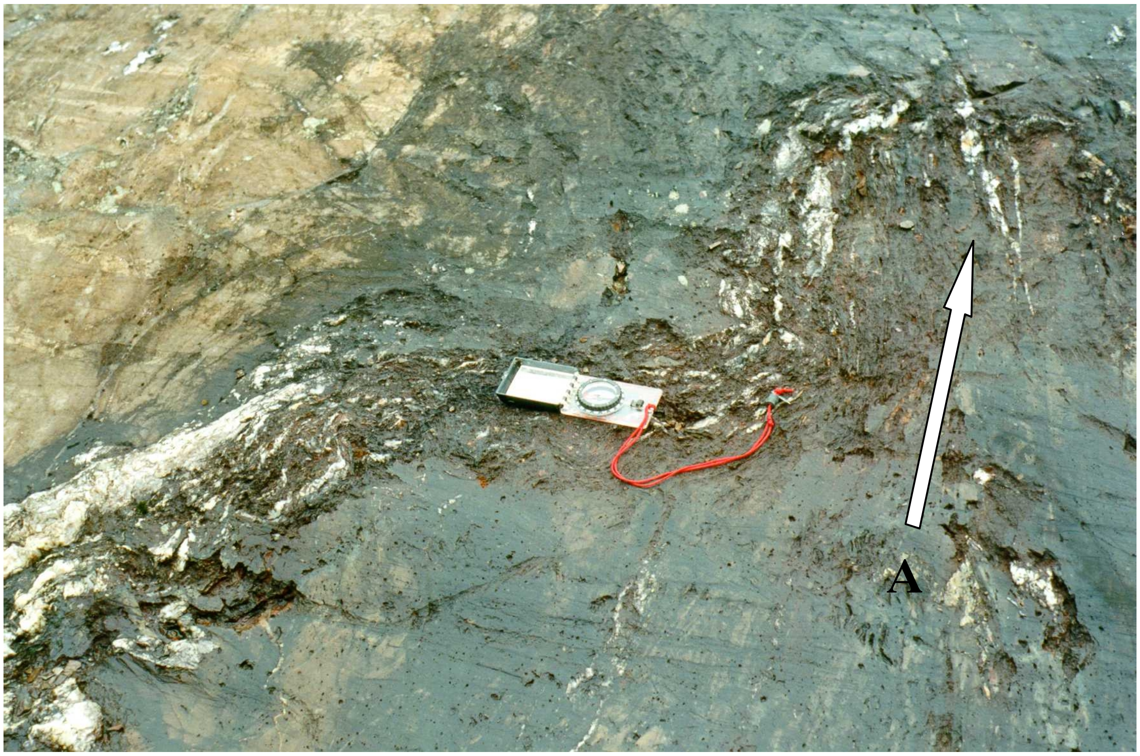


Photo 4. Folded M2 Vein system and attendant sericite-carbonate alteration envelope, Trench 3, Marlhill Mine Project. Note weakly developed quartz veins exploiting S1 axial plane cleavage (A). Compass points towards astronomic north.

STRUCTURAL GEOLOGY

Stratigraphy

The contact between the mafic volcanic rocks and the clastic sediments strikes northwest to west-northwest and dips vertically to steeply north (Figures 5, 6, and 7). On the basis of geological mapping in the area west of the portal, Barclay (1994) concluded that facing directions were towards the southwest from observation of pillowed mafic volcanic rocks. This observation is consistent with mapping by Berger (1992) which indicates that this south facing direction remains consistent from the Marlhill Mine southwards to the north half of Concession I Lots 9, 10, and 11, Hoyle Township. An anticlinal fold axis therefore is herein interpreted to be present between the portal area and the mafic – sediment contact. A synclinal fold axis located in the sediments has been interpreted by Berger (1992) on the basis of facing directions observed in diamond drill core.

In describing the structural elements observed in outcrop, Barclay (1994) states:

"Two foliations are observed in outcrop. The weaker of the two, and the earlier, is a weakly preserved penetrative flattening fabric which is subparallel to the attitude of the pillowed flows. A stereoplot of the measured field data for this foliation (S1), which is correlative with the weak flattening of the pillows, indicates a mean trend and plunge of 18° → 000° for the poles to S1 (Figure 8a). This corresponds to a mean S1 surface for the area of 090° / 72°S. These limited data are principally derived from the westernmost trench.

The stronger planar fabric is a spaced to near-penetrative fracture or solution cleavage which generally is pervasive in outcrop but which is locally intensified in discrete semi-continuous zones. These zones likely result from locally enhanced carbonate and sericite alteration, and have been mis-identified in past mapping as shear zones. This S2 fracture cleavage exhibits a mean attitude in outcrop as determined by field measurements of 063° / 76°SE (Figure 8b). It is oblique to the general trend of the pillowed flows, and is axial planar to minor folds formed along the general WNW-NNE trend of the M2 – type quartz-carbonate veins. It is parallel in strike to S2 at the Hoyle Pond Mine, but dips to the SE rather than to the NW.

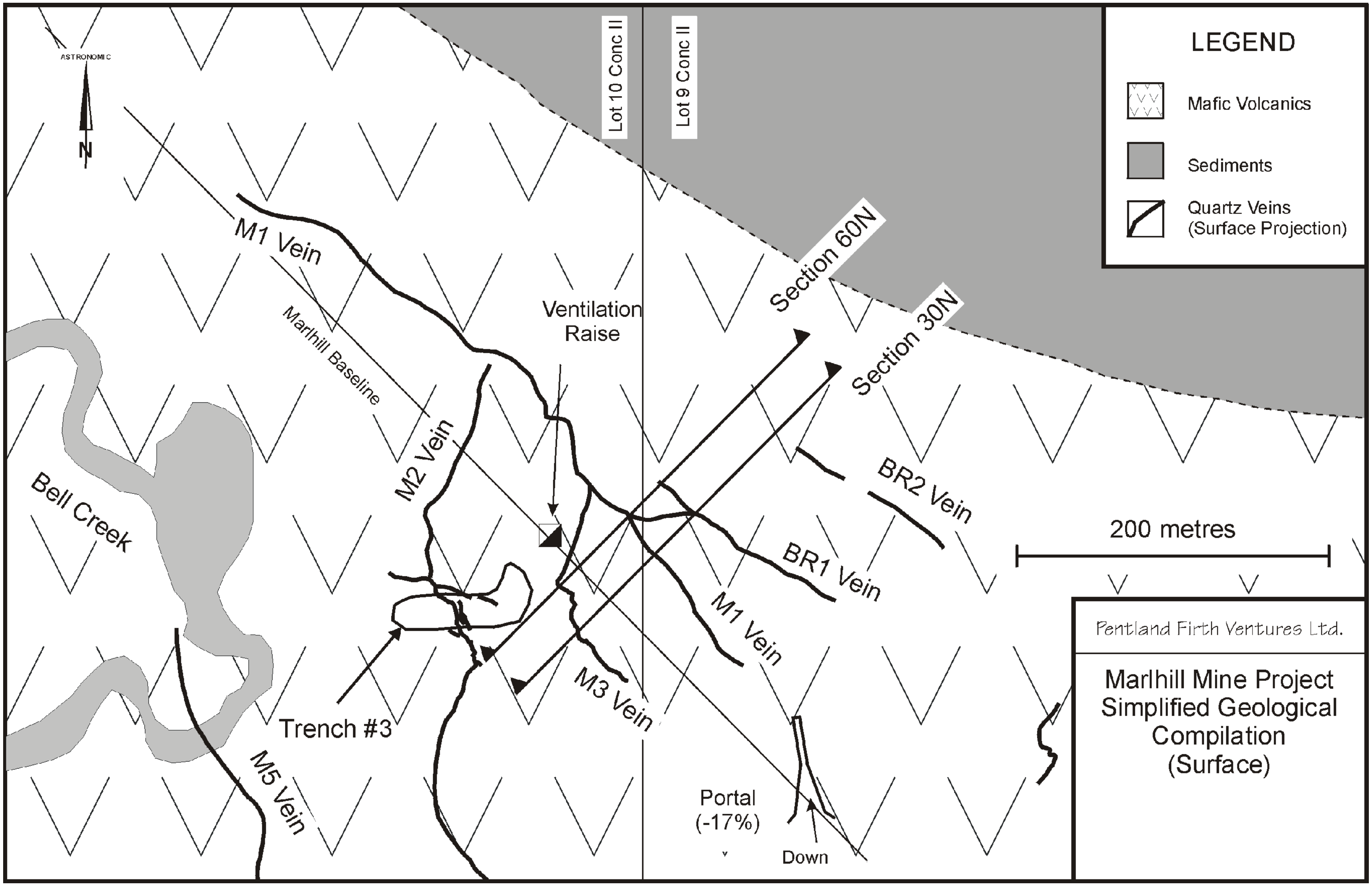

ASTRONOMIC
N
LEGEND
Mafic Volcanics
Sediments
Quartz Veins
(Surface Projection)
Lot 10 Conc II
Lot 9 Conc II
M1 Vein
Marlhill Baseline
Ventilation
Raise
Section 60N
Section 30N
M2 Vein
Bell Creek
BR2 Vein
BR1 Vein
M1 Vein
200 metres
Trench #3
M3 Vein
M5 Vein
Portal
(-17%)
Down
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Simplified Geological
Compilation
(Surface)

Figure 5.

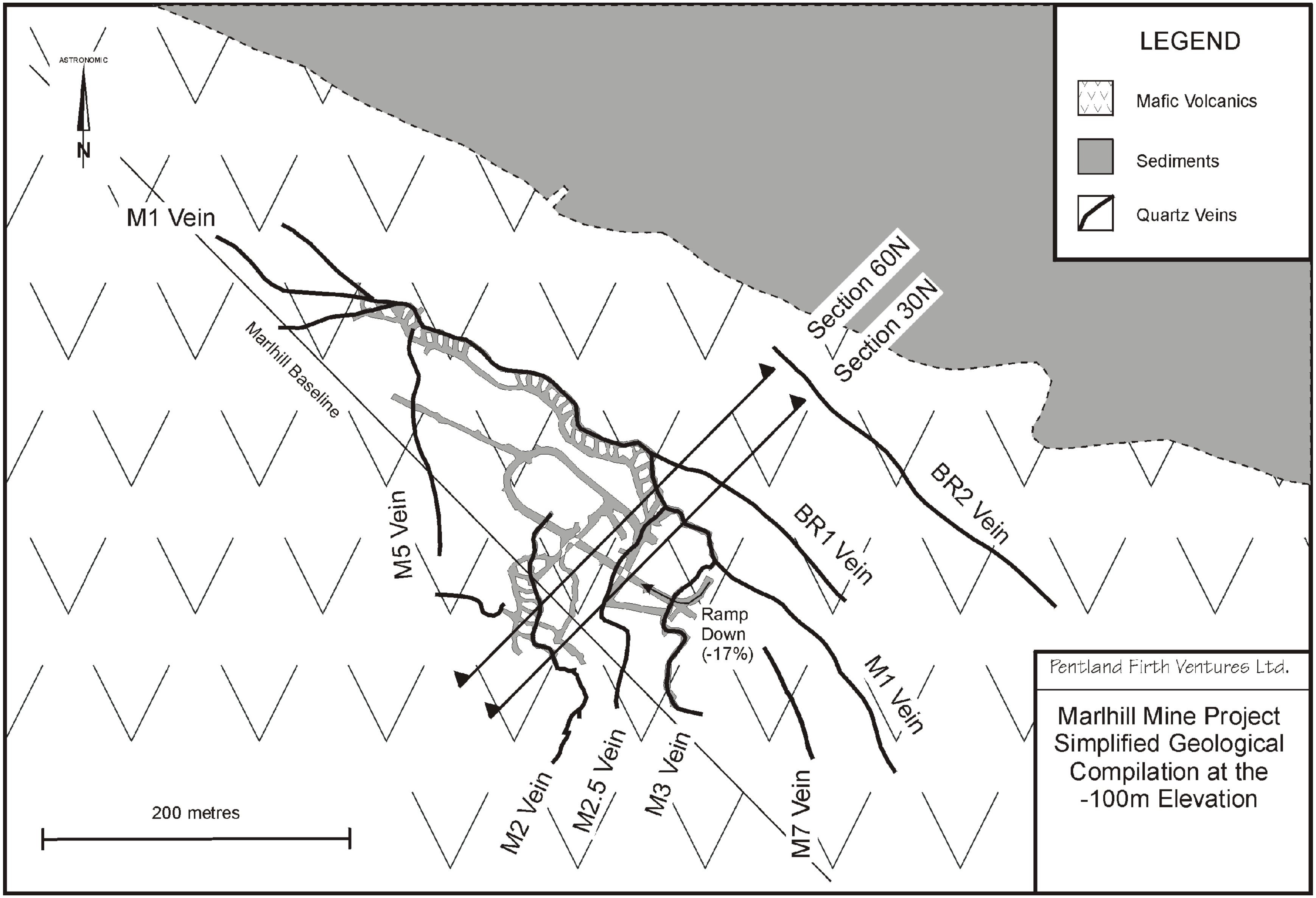

LEGEND
Mafic Volcanics
Sediments
Quartz Veins
ASTRONOMIC
N
M1 Vein
Marlhill Baseline
M5 Vein
Section 60N
Section 30N
BR2 Vein
BR1 Vein
Ramp
Down
(-17%)
M1 Vein
M2 Vein
M2.5 Vein
M3 Vein
M7 Vein
200 metres
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Simplified Geological
Compilation at the
-100m Elevation

Figure 6.

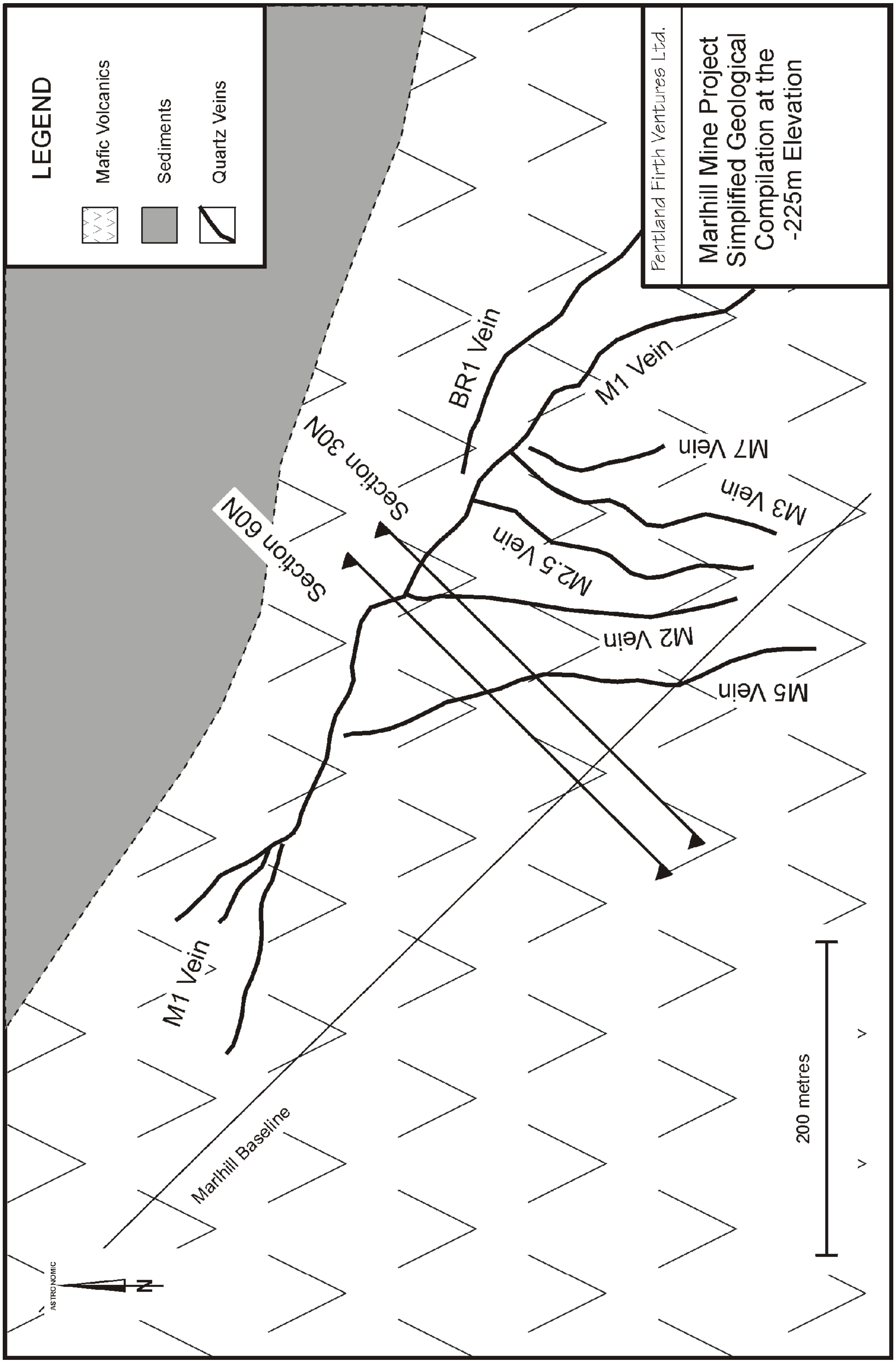

LEGEND
Mafic Volcanics
Sediments
Quartz Veins
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Simplified Geological
Compilation at the
-225m Elevation
BR1 Vein
M1 Vein
M7 Vein
M3 Vein
M2.5 Vein
M2 Vein
M5 Vein
Section 30N
Section 60N
M1 Vein
Marlhill Baseline
200 metres
ASTRONOMIC
N

Figure 7.

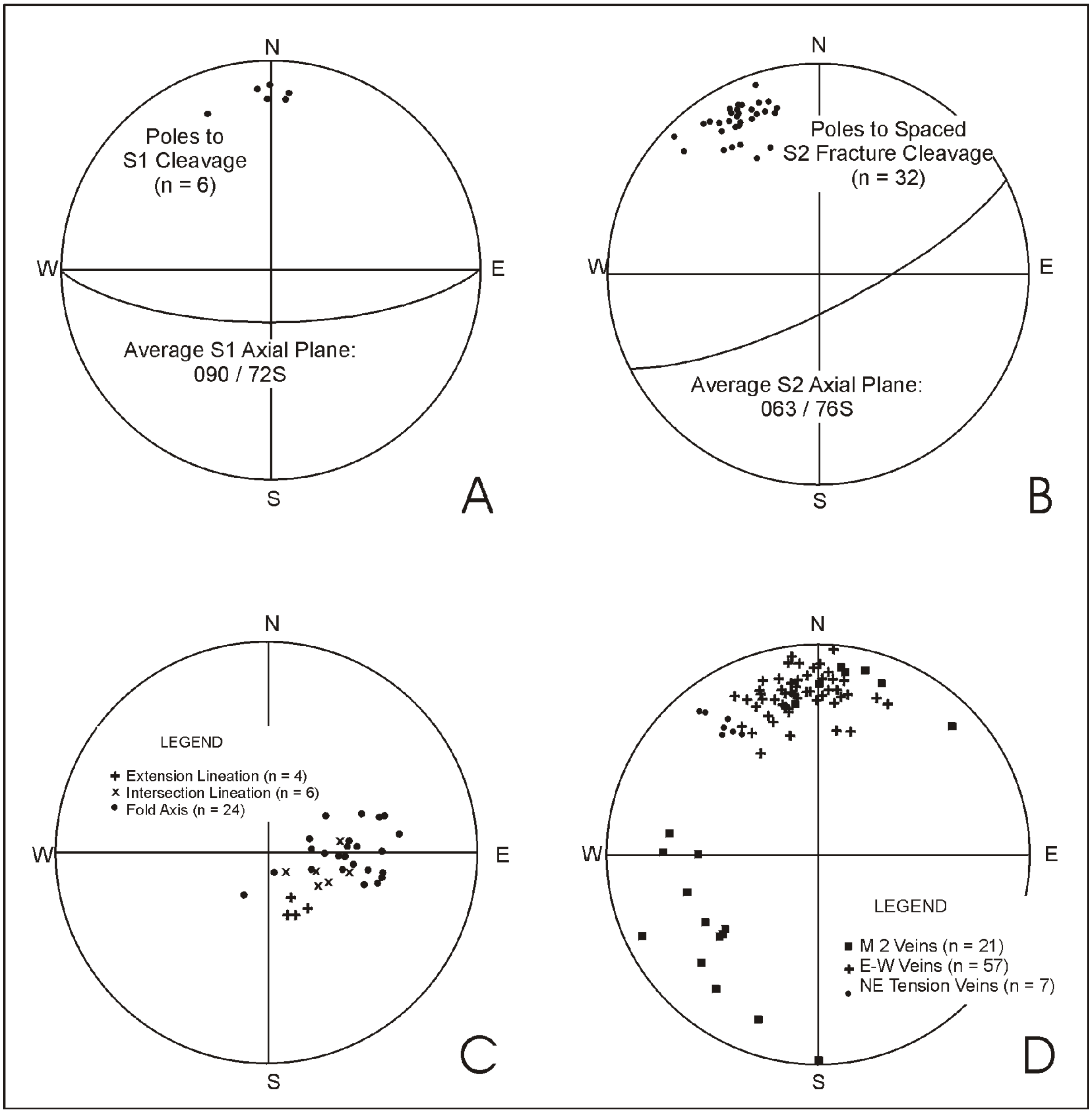


Figure 8. Stereonet projections of selected structural elements, Trench 3, Marlhill Mine Project (modified from Barclay 1994): (A) poles to S1 cleavage, (B) poles to S2 cleavage, (C) selected lineation data, (D) poles to quartz veins.

Where both S1 and S2 are well developed, and exhibit strong parting in outcrop, a weak diamond-shaped pencil cleavage has been produced by the intersection of the two foliations. The long axis of this diamond pattern plunges steeply ESE-SE, parallel to the axes of calculated and directly measured intersection lineations (Figure 8c). The intersections of mean S0 (pillow flow attitude), S1, and S2 orientations all fall at similarly moderate to steep plunges along an ESE trend.

It is important to note that the above observations and data for S1 and S2 derive from areas in outcrop which are not immediately adjacent to strong veins. In such altered margins, both of these planar fabric elements appear locally deflected and rotated, sometimes in an arcuate pattern around minor fold hinge areas.

One occurrence of a weak late crenulation lineation was observed in outcrop. This lineation exhibited a trend and plunge of 30° → 229°. In orientation and morphology it is near identical to the late (L3) crenulation lineation documented at Hoyle Pond (Barclay 1993)."

Faults and Shears

No major faults are known to be present on the Marlhill Mine property, however Berger (1992) has interpreted the presence of a northeast striking brittle fault from limited geological information. This fault extends from Lot 9 Concession I to Lot 3 Concession IV, Hoyle Township. Limited surface mapping west of the portal by Barclay (1994) concluded that:

> “There is no evidence preserved in outcrop here that the pillows are anomalously flattened within local, discrete zones of ductile shearing or intense flattening. Local strain gradients may nevertheless exist, elsewhere, in covered rock. Nor is there any evidence on surface that E-W trending veins and veinlets have been preferentially formed within such zones.”

ECONOMIC GEOLOGY

Production History

Mining activity took place at the Marlhill Mine during the 1989 to 1991 period, during which 141 124 tonnes grading 6.83 g/t Au (30 924 oz Au) were extracted and co-mingled with ore from the nearby Bell Creek Mine. Of this total, 74 000 tonnes grading 5.13 g/t Au were produced in 1990 (Luhta et. al. 1991). Much of this material was extracted from the M1 vein system, with smaller amounts also being taken from parts of the M2 and M3 vein systems. Recent evaluation of available information by Pentland Firth staff have concluded that better gold grades in the mined out sections were associated with the thicker portions of the veins, and that this thickenning was likely a result of the folding history of the area (Crick 1997, G. Yule, Pentland Firth Ventures Ltd., personal communication, Figures 9 and 10). Indeed, Crick (1997) states that:

> “…of the three stoping blocks along the M1 Vein (the West, Central, and East), the Central production results account for 80% of the total tonnes milled from the M1 and 58% of stope production from all sources. Detailed geologic mapping and chip channel sampling reveals the Central Block is comprised of several higher grade shoots that carry intercalated, relatively short, low grade (ie. <3.4 g/t Au) intervals. The vein structure also appears stronger and consistently thicker over a greater strike length in the Central Block. Both the East and West stope blocks are characterized by singular, higher grade shoots, ie. >5 g/t, with 15 – 20 metre strike length, intercalated with larger gaps of <3.4 g/t mineralization. The vein structure in these lower grade areas pinch locally to nothing.”

The most recent mineral inventory is given in Table 2.

Table 2. Summary of Mineral Inventory at the Marlhill Mine as at December 31, 1997, utilizing a minimum mining width of 1.6 – 1.8 metres and a cut-off grade of 3.4 g/t Au (modified from Crick 1997).

Vein	Tonnage and Grade
M1:	
Mineable Reserves (0-150m)	54 206 tonnes @ 7.77 g/t Au (13 543 oz)
Geologic Resources (150-350m)	550 306 tonnes @ 6.90 g/t Au (121 824 oz)
Total, M1 Vein:	604 512 tonnes @ 6.98 g/t Au (135 367 oz)
M2:	
Mineable Reserves (0-150m)	42 969 tonnes @ 5.44 g/t Au (7 515 oz)
Geologic Resources (150-350m)	76 350 tonnes @ 6.87 g/t Au (16 866 oz)
Total, M2 Vein:	119 319 tonnes @ 6.36 g/t Au (24 381 oz)
M3:	
Mineable Reserves (0-150m)	34 885 tonnes @ 5.35 g/t Au (6000 oz)
Geologic Resources (150-350m)	87 315 tonnes @ 5.92 g/t Au (16 619 oz)
Total, M3 Vein:	122 200 tonnes @ 5.75 g/t Au (22 619 oz)
Grand Total, All Veins	**846 031 tonnes @ 6.71 g/t Au (182 367 oz)**

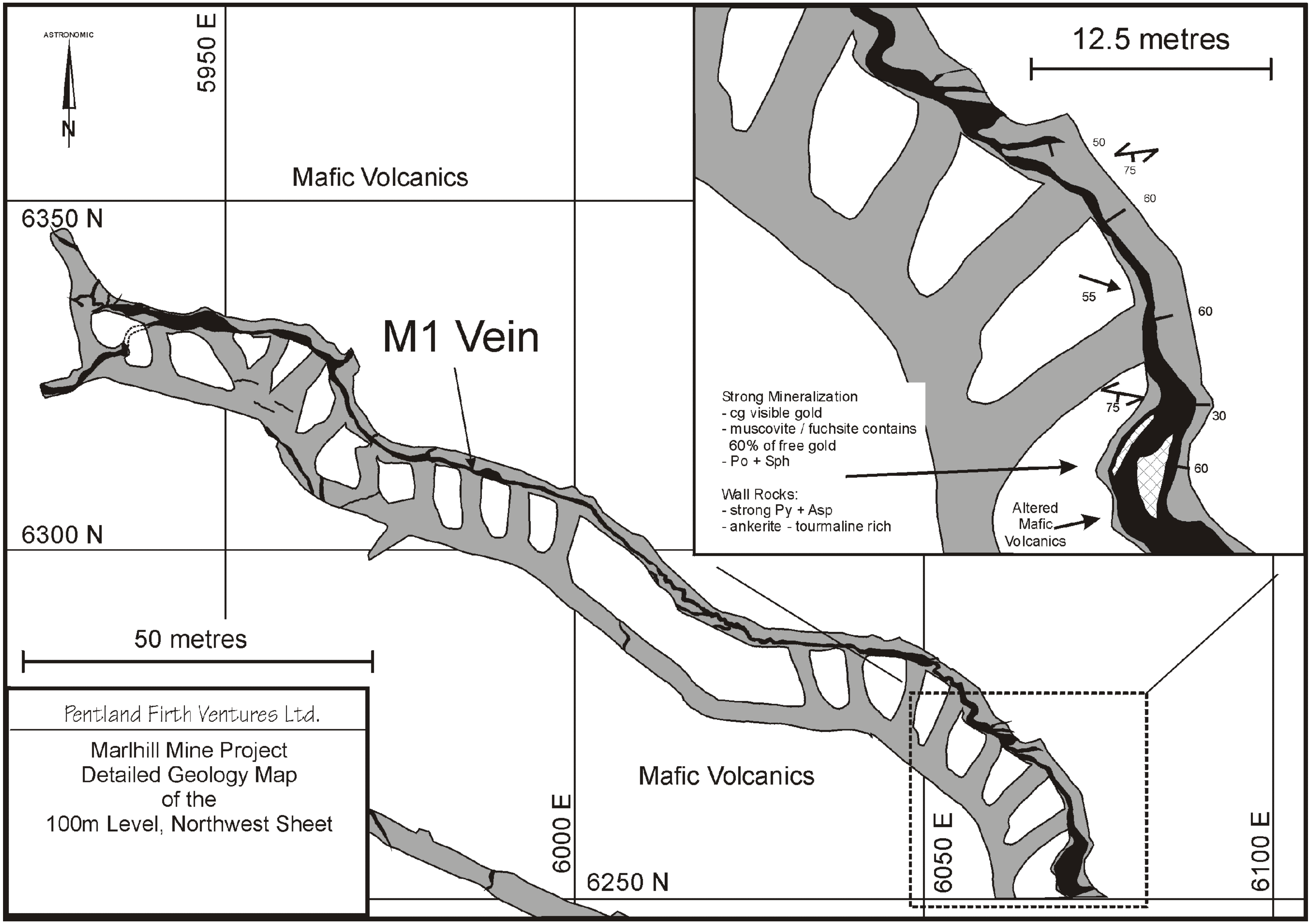

ASTRONOMIC
N
5950 E
Mafic Volcanics
6350 N
M1 Vein
6300 N
50 metres
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Detailed Geology Map
of the
100m Level, Northwest Sheet
6000 E
6250 N
Mafic Volcanics
6050 E
6100 E
12.5 metres
50
75
60
55
60
75
30
60
Strong Mineralization
- cg visible gold
- muscovite / fuchsite contains
60% of free gold
- Po + Sph
Wall Rocks:
- strong Py + Asp
- ankerite - tourmaline rich
Altered
Mafic
Volcanics

Figure 9.

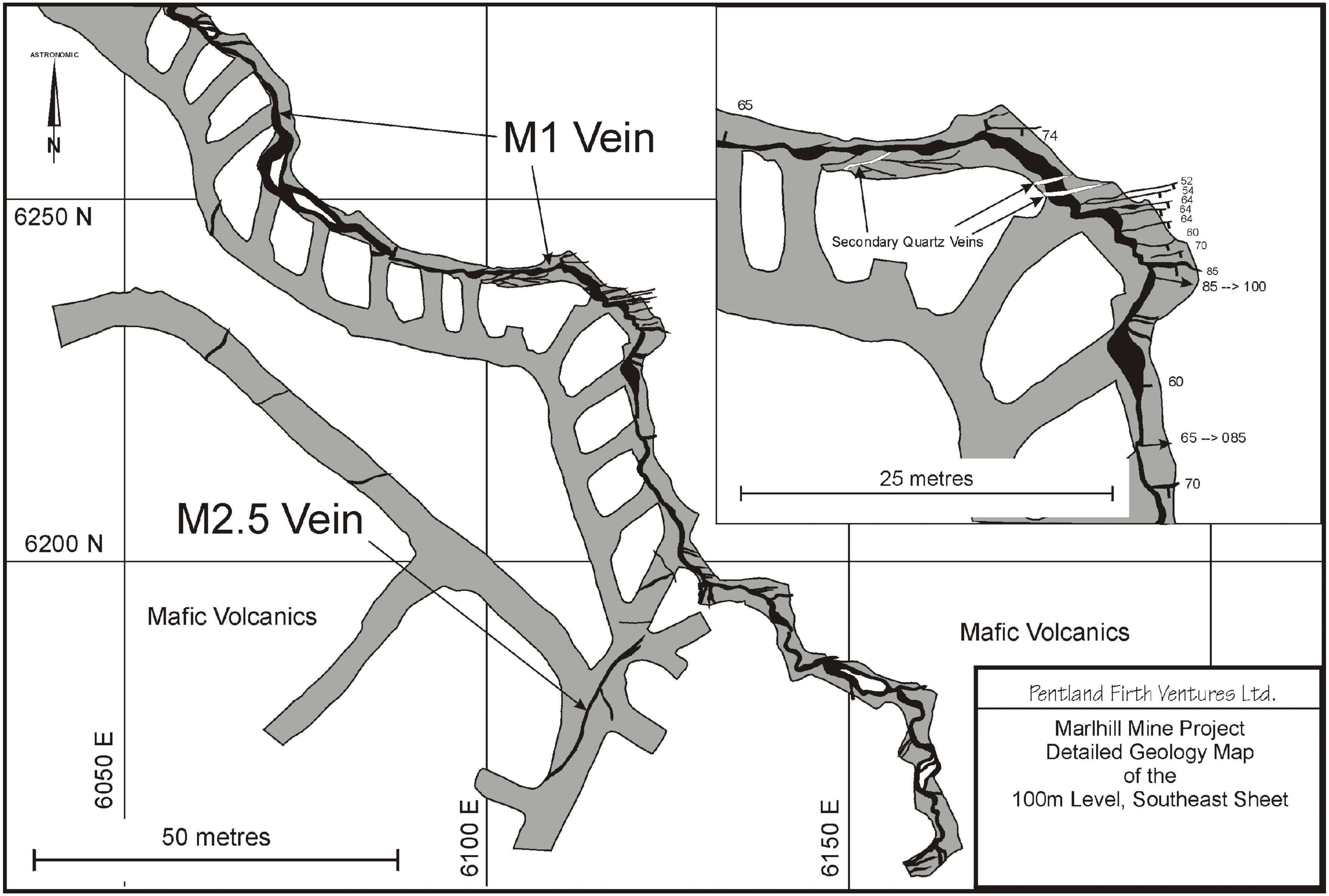

ASTRONOMIC
N
M1 Vein
M2.5 Vein
6250 N
6200 N
6050 E
6100 E
6150 E
Mafic Volcanics
Mafic Volcanics
50 metres
25 metres
Secondary Quartz Veins
65
74
52
54
64
64
64
60
70
85
85 --> 100
60
65 --> 085
70
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Detailed Geology Map
of the
100m Level, Southeast Sheet

Figure 10.

Mining Methods

Underground access to the mine is via a ramp driven at a grade of –17%. Three main production levels were established at the -50m, -100m, and the -150m elevations. Sublevels were established at 25m intervals between levels to provide access to individual stoping blocks. Shrinkage stoping was the only mining method employed at the mine, and the ore was co-mingled with the Bell Creek mine ore. No backfill was used and the stopes remained open upon their completion.

Description of Orebodies

Presently there are 8 known mineralized quartz veins at Marlhill, all of which are hosted within the mafic volcanic rocks. All of these veins strike either in a northwesterly direction (M1, BR1, and BR2 Veins) or in a northerly direction (M2, M2.5, M3, M5, and M7 Veins). All of the veins dip to the northeast and east. The M1 vein dips north at approximately 60° at surface and steepens into a near vertical orientation below the -200 metre level. The remaining veins dip eastward at approximately 40° thereby creating a branching and bifurcating pattern (Figures 11 and 12). All veins have been affected by folding that has thickened the veins in steeply easterly plunging fold closures. Of these veins, the M1 Vein has been the focus of attention and has been traced continuously in mine workings for a minimum strike length of 300 metres, and to a depth of 530 metres by diamond drilling. It attains widths of up to 3.6 metres (Figure 13). In describing the results of his review of the underground geology plans Barclay (1994) writes:

> "At macroscopic scale, the M1, M2, and M3 Veins as presently defined crosscut stratigraphy. They typically splay into branching spurs that may extend from a main through going vein at low or high angles, or may coalesce around large blocks of host rock (Photos 5 and 6). They contain breccia clasts of wallrock which is typically mineralized, as is wallrock immediately contiguous to the veins (Photo 7). These veins, particularly M2 and M3, are cut by a secondary ENE-striking set observed on surface as described below. The veins are further cut by late, often shallow-dipping slips or joints which may be lined with calcite and / or dolomite, or mica.
>
> Locally the veins are described as being highly folded. Fold axes which have been measured underground generally plunge 45 – 60°, ENE – ESE. Plan map traces of the individual veins underground confirm that M1, M2, and M3 all locally roll into metre – scale moderately East – plunging folds. These observations are closely consistent with surface data.
>
> Each of the M1, M2, and M3 Veins reportedly contains tourmaline and ankerite (Photo 8 and 9). Visible gold is commonly noted in assay plans along each of them: indeed it likely elevates background 2 – 4 g/t material into ore. The veins also contain, or are flanked along contact alteration haloes, by disseminated pyrite and arsenopyrite. Minor sphalerite and pyrrhotite and / or hydromuscovite are less commonly reported."

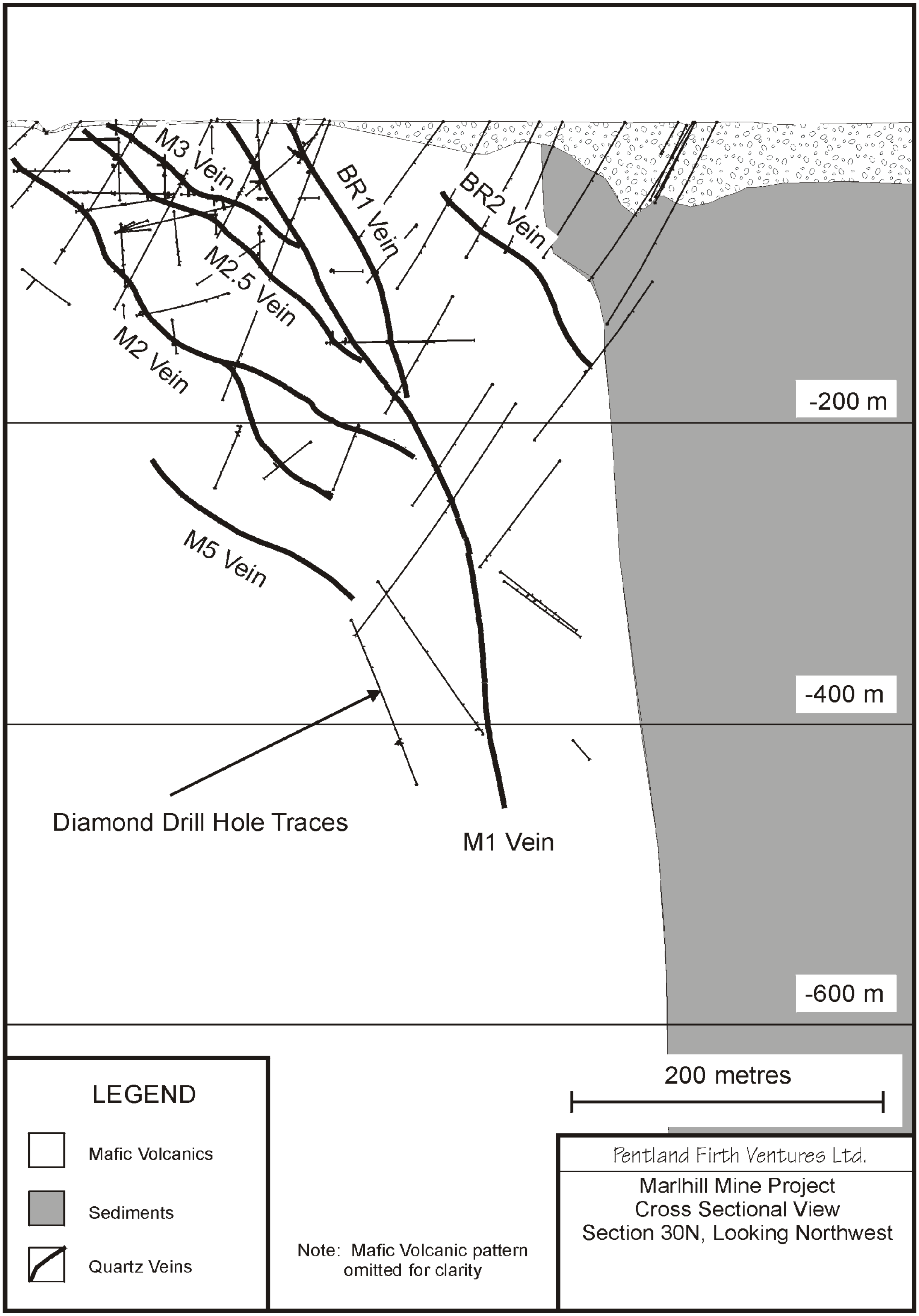
In describing the results of his observations on available surface exposures, Barclay (1994) writes:

> "Many of the previously exposed surface expressions of mineralized veins at Marlhill are now covered. The following observations derive mainly, therefore, from the westernmost of the earlier stripped areas, designated on past maps as Trench 3. This trench now exposes a short strike length only of the M2 Vein and a small outcrop of the M3 Vein, as well as secondary veins which thus far have not proved sufficiently strong to be economic.
>
> In the area of Trench 3, three main vein types can be distinguished on the basis of morphology and orientation; these comprise part of the M2 Vein, a set of ENE-striking quartz +/- carbonate veinlets and, locally, a set of NE-striking quartz tension veinlets (Figure 8d)."

Examination of Figures 8a, b, and d reveals that the E-W veins have variable strikes ranging from northeasterly to easterly, and their dips are consistently steep southeasterly to southerly. These orientations are parallel to both the S1 and S2 cleavages. As well, the NE tension veins also strike northeasterly and dip steeply to the southeast, parallel to the S2 fracture cleavage. These observations suggest that these two vein sets are either directly related to the formation of the S1 and S2 cleavages, or that they post-date the cleavage and have exploited a pre-existing fabric.

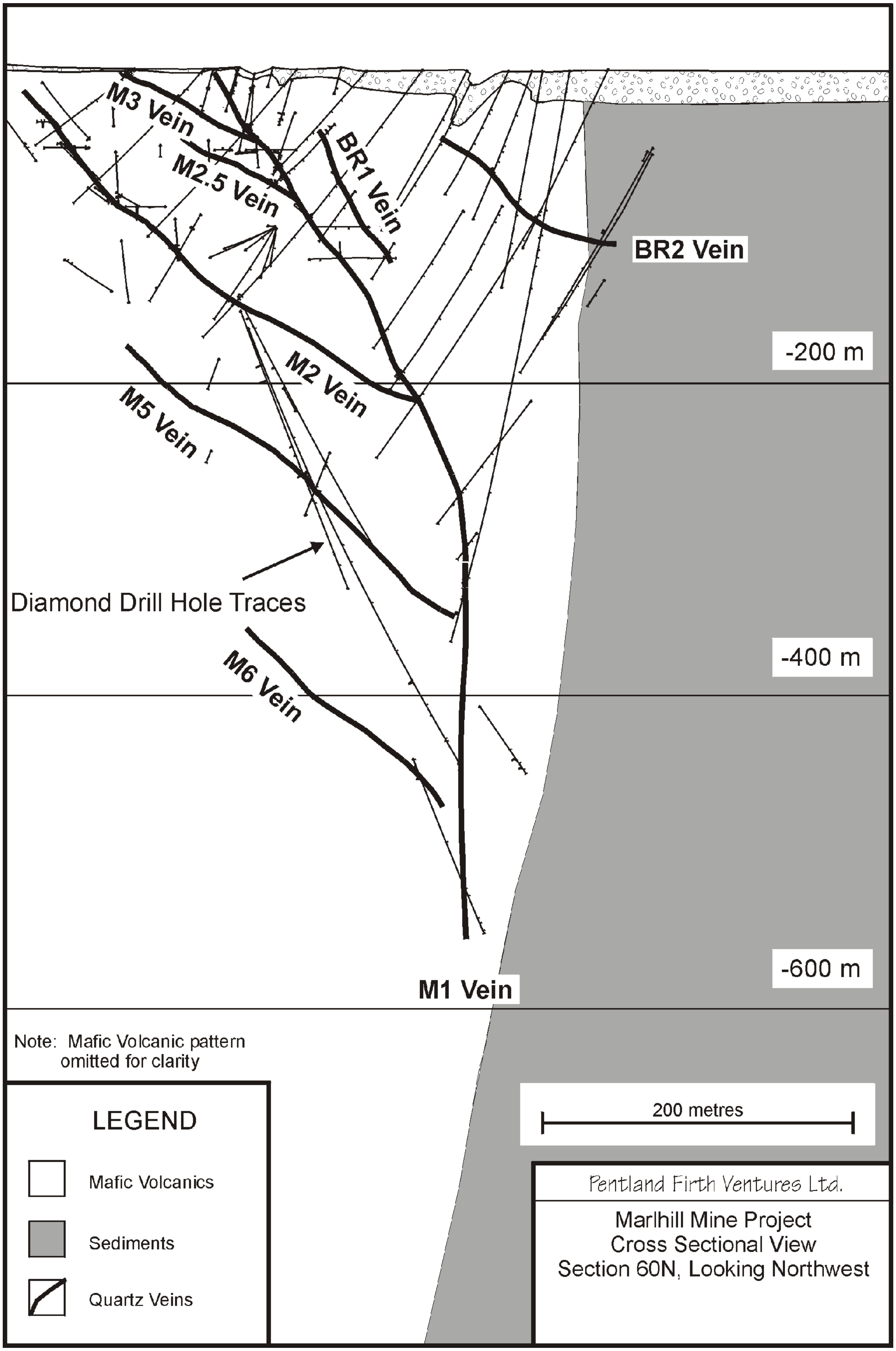
In describing the surface exposure of the M2 Vein system, Barclay (1994) writes:

> "Underground plans demonstrate that the M2 Vein generally strikes N-S, parallel to the M3 Vein. However, its surface exposure in Trench 3 trends generally NW; the exposure represents a dogleg or flexure along the overall main vein, one which is repeated down-dip through the past workings.



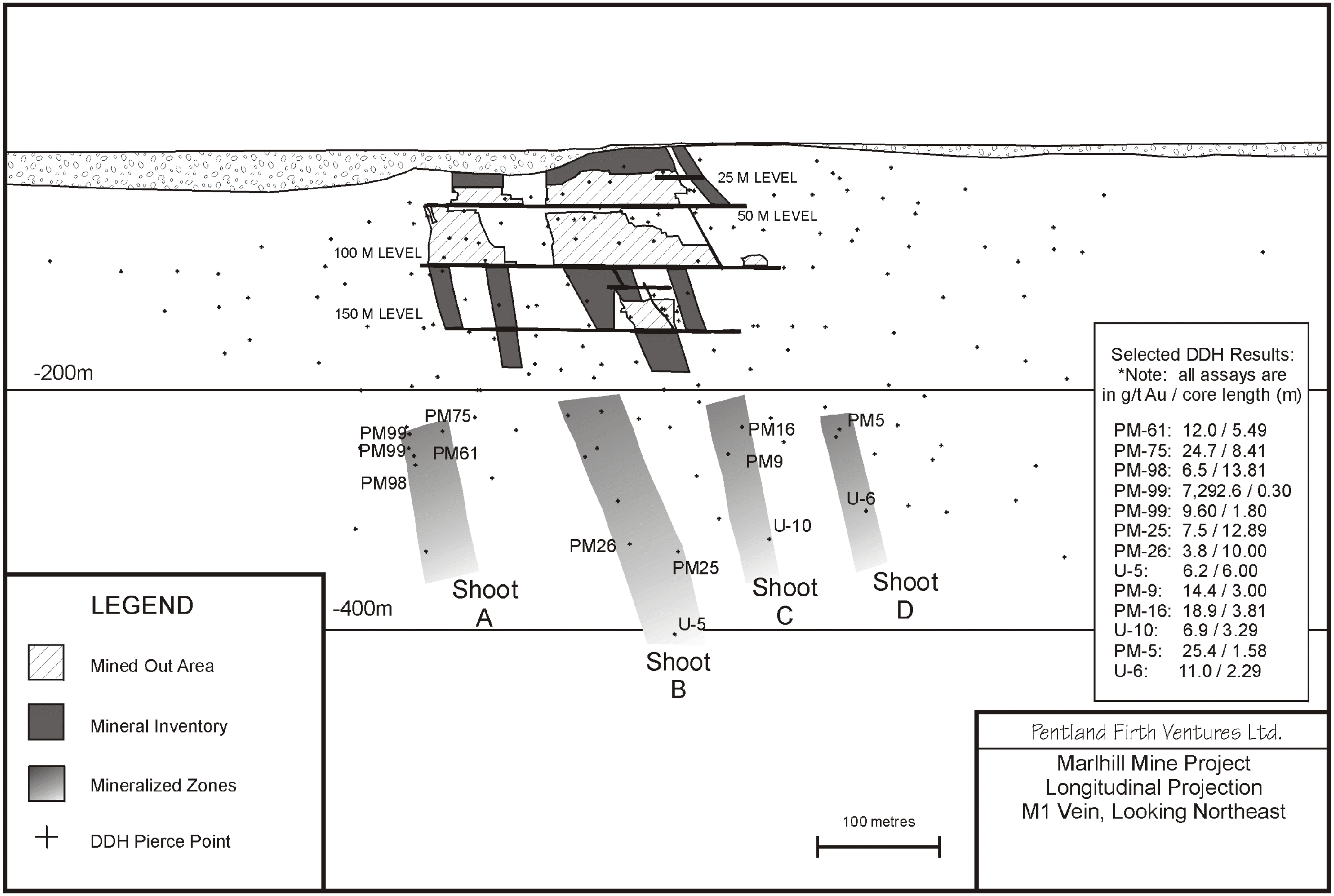
M3 Vein
BR1 Vein
BR2 Vein
M2.5 Vein
M2 Vein
-200 m
M5 Vein
-400 m
Diamond Drill Hole Traces
M1 Vein
-600 m
200 metres
LEGEND
Mafic Volcanics
Sediments
Quartz Veins
Note: Mafic Volcanic pattern omitted for clarity
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Cross Sectional View
Section 30N, Looking Northwest

Figure 11.



M3 Vein
M2.5 Vein
BR1 Vein
BR2 Vein
-200 m
M2 Vein
M5 Vein
Diamond Drill Hole Traces
-400 m
M6 Vein
-600 m
M1 Vein
Note: Mafic Volcanic pattern omitted for clarity
LEGEND
Mafic Volcanics
Sediments
Quartz Veins
200 metres
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Cross Sectional View
Section 60N, Looking Northwest

Figure 12.



25 M LEVEL
50 M LEVEL
100 M LEVEL
150 M LEVEL
-200m
-400m
PM75
PM99
PM99
PM61
PM98
PM26
PM25
U-5
PM16
PM9
U-10
PM5
U-6
Shoot A
Shoot B
Shoot C
Shoot D
LEGEND
Mined Out Area
Mineral Inventory
Mineralized Zones
DDH Pierce Point
100 metres
Selected DDH Results:
*Note: all assays are in g/t Au / core length (m)
PM-61: 12.0 / 5.49
PM-75: 24.7 / 8.41
PM-98: 6.5 / 13.81
PM-99: 7,292.6 / 0.30
PM-99: 9.60 / 1.80
PM-25: 7.5 / 12.89
PM-26: 3.8 / 10.00
U-5: 6.2 / 6.00
PM-9: 14.4 / 3.00
PM-16: 18.9 / 3.81
U-10: 6.9 / 3.29
PM-5: 25.4 / 1.58
U-6: 11.0 / 2.29
Pentland Firth Ventures Ltd.
Marlhill Mine Project
Longitudinal Projection
M1 Vein, Looking Northeast

Figure 13.

Photo 5. Example of the M1 Vein showing a series of quartz veins and altered mafic volcanic wall rocks. Chip sampling returned 17.6 g/t Au / 0.7m. Rock bolt for scale. –150m Level, Marlhill Mine. Photo courtesy of Pentland Firth Ventures Ltd.

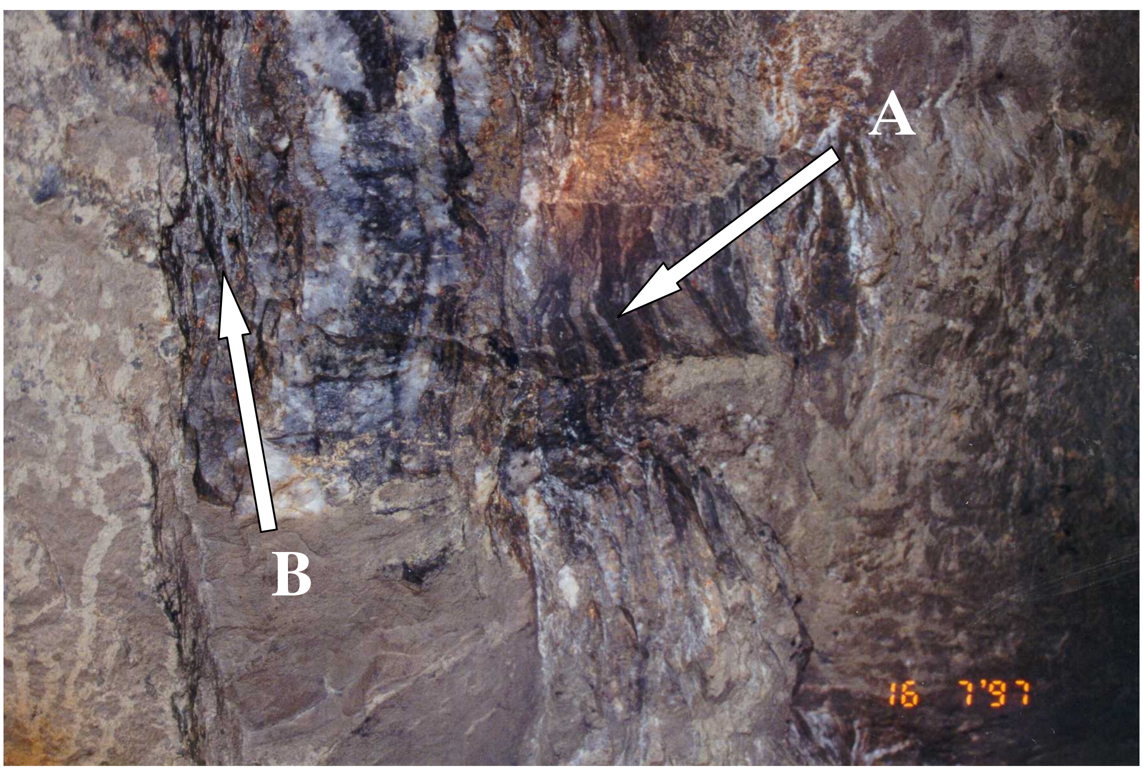


Photo 6. M1 Vein showing well developed banding. Dark material is semi-massive tourmaline occurring in the vein as bands (A) and in the wall rock as stockwork (B). –150m Level, Marlhill Mine. Photo courtesy of Pentland Firth Ventures Ltd.

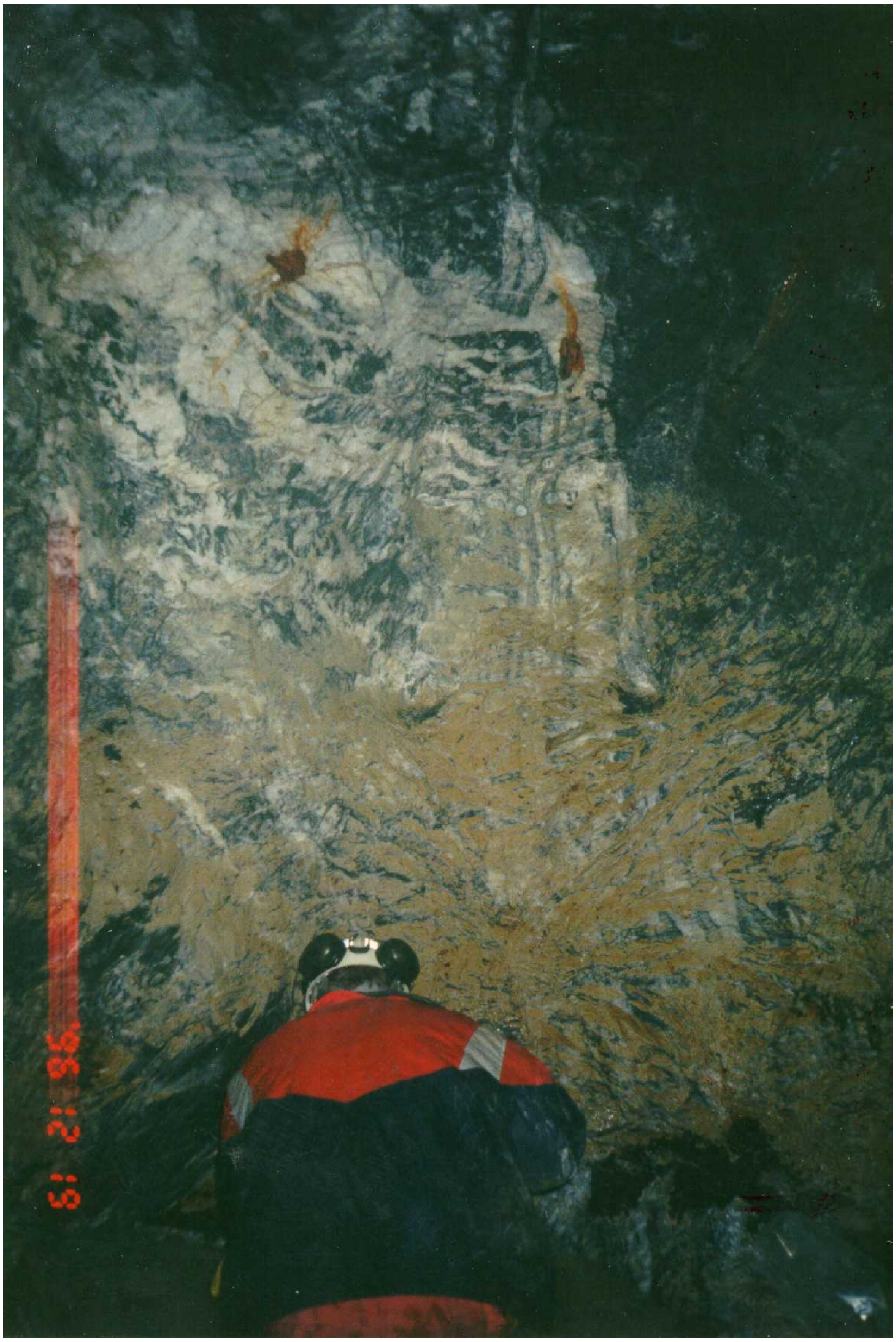


Photo 7. M1 Vein containing brecciated, siliceous mafic volcanic fragments. Chip samples returned <1 g/t Au. Note absence of tourmaline in the vein or vein walls. –100m Level, west end, Marlhill Mine. Photo courtesy of Pentland Firth Ventures.

Photo 8. M1 Vein showing well developed breccia texture defined by tourmaline stockwork. Rock bolt (A) for scale, view of the back. –150m Level, Marlhill Mine. Photo courtesy of Pentland Firth Ventures Ltd.

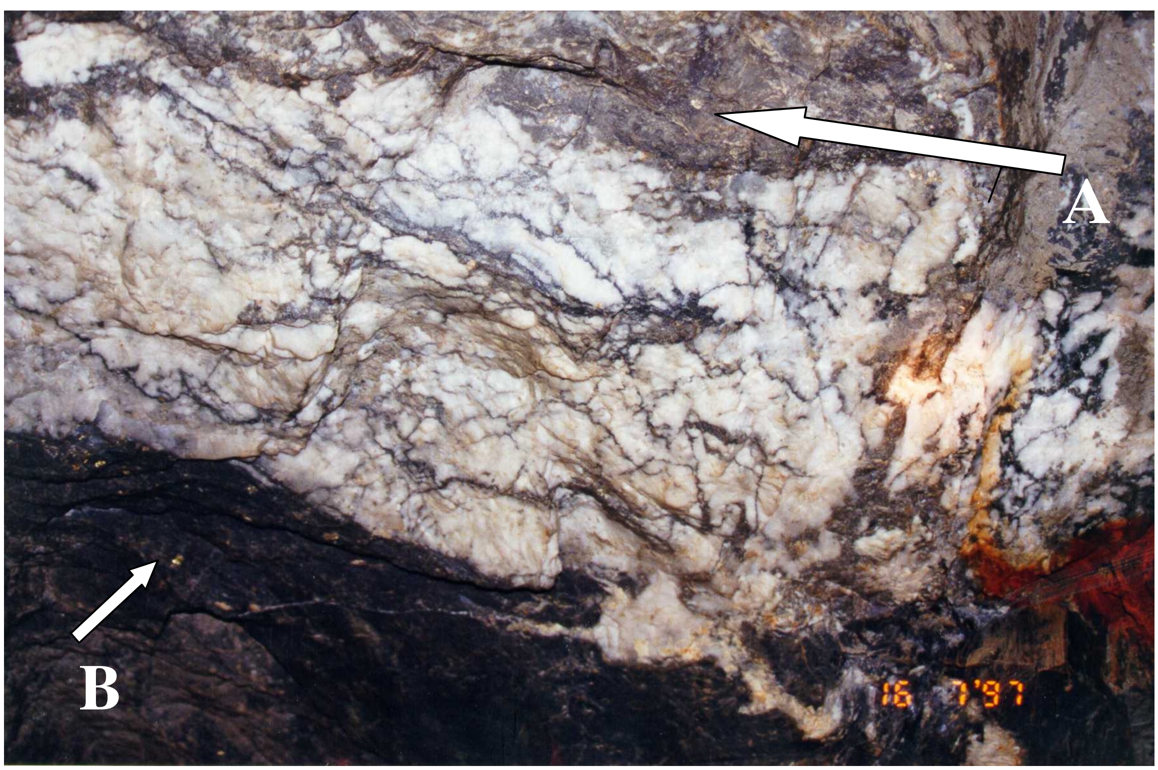


Photo 9. M1 Vein showing tourmaline stockwork and altered mafic volcanic wall rock inclusions (A). Note coarse disseminated pyrite in wall rock (B). –150m Level, view of the back, Marlhill Mine. Photo courtesy of Pentland Firth Ventures Ltd.

“The several splays which are previously designated as part of the M2 system of veins are heavily stylolitic in places, contain abundant Fe–carbonate (ankerite), are continuous across the stripped area, and commonly branch into subsidiary splays of short length at low and high angles to the main veins. They comprise the strongest (broadest) vein system in this trench area; individual veins attain widths of < 20–25cm. They describe an overall broadly curviplaner configuration along a generally NW–SE trend in outcrop here. However, the veins typically are sharply doglegged rather than curviplaner, at m – scale. Individual doglegs strike roughly N–S to WNW–ESE, and generally dip E–NNE. Hence the structural elements which are preserved on surface along this vein (eg. vein attributes, minor fold axes, cleavage relationships) likely are analagous both to the WNW–trending M1 Vein and to the M2–M3 Veins.

Where M2 Veins trend N–S to NW–SE, they are somewhat ptygmatically buckled about cm–scale, open to tight, minor folds, the axes of which generally plunge ESE to NE. The orientations of these fold axes vary systematically with the finite attitude of that dogleg segment within which they have been formed. Where the enveloping surface of a vein segment trends N–S, fold axes plunge E to ESE; along trends which are more NW–SE, fold axes trend more to ENE; for WNW–ESE dogleg segments, the axes exhibit trends which are more to the NNE. Plunge angles are consistently moderate to steep. The stereoplot of measures fold axes indicates a distribution broadly centered along a mean trend and plunge at 58° → 090° (Figure 8c).

The M2 Veins attain their greatest width in N–S and NW–SE trending dogleg segments; WNW–ESE segments tend to be thinner (less dilatent), or have been attenuated by extension subsequent to their formation.

In overall geometry and fold characteristics, the various M2 Veins exposed here closely resemble the 7 Vein system exposed at Hoyle Pond in 307 DR S, 407 DR, and 407 ST (Barclay, 1993). Minor folds in the latter, most of which occur in NW–SE trending segments, plunge moderately NE to ENE, similar to attitudes in dogleg sections of M2 Veins at the same trend. High angle ladder veins such as were observed in the 7 Vein have not thus far been noted in the M2 Vein.

The spaced S2 cleavage is axial planar to the minor folds observed along these M2 Veins, and locally can be observed cutting the buckled veins within their hinge regions. Occasionally, rusty carbonate–rich wallrock inclusions within the veins preserve the S2 fabric. However, the same veins cut the individual pillows and pillow selvages, as well as the penetrative S1 flattening foliation. Hence, M2 Vein emplacement appears to have been prekinimatic, or early synkinematic, with respect to formation of the spaced S2 cleavage. The earlier S1 fabric locally has been refracted in an arcuate pattern about fold hinges.

ENE–WSW Veins

A second set of veinlets is exposed throughout all trenched outcrop exposures in the Marlhill area. These consistently trend E–W , to ENE–WSW. They are uniformly thin (0.5 – 3 cm), discontinuous at m–scale along strike, straight, and (in plan at least) rarely exhibit minor pinch–and–swell structure or local weak boudinage.

These veinlets locally exploit, and elsewhere crosscut, the spaced S2 fracture cleavage. Local minor extension (pinch–and–swell, boudin formation) along their strike lengths suggests that they are emplaced synkinematically with respect to the S2 fabric. Many occurrences show that they emanate from M2 Veins as high angle connected splays but, in several observed instances, they crosscut M2 Veins and, hence, perhaps closely, postdate formation of the M2 Vein set.”

ACKNOWLEDGEMENTS

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Economic Geology and Mineralization of the Nighthawk Mine

P. Harvey, B. O'Connor, B. Kilbride, P. Coad and K. Tyler
Royal Oak Mines Inc.

INTRODUCTION

The Nighthawk Mine was discovered in 1909 when the water level of Nighthawk Lake was artificially lowered in order to enable prospecting to be done on a nearby claim. The lowering of the water level exposed a gold-bearing quartz vein at the southern end of the North Peninsula, and subsequent work included sinking a shaft on the vein in 1917. Some underground lateral work followed and a 200 tpd mill was built on the property in 1923 (Leahy 1971).

Royal Oak Mines Inc. acquired the property in 1990. Recent activity includes major exploration programs, an open pit mine which was in operation during 1994–1995, and an underground operation which started in 1995. Ore from the mine is trucked to the Pamour Mill for processing. The Nighthawk Mine (underground) contributed a mill adjusted 722 274 tons at a grade of 0.135 oz / ton (97 528 ounces) of high grade ore and 62 486 tons at 0.066 oz / ton (4126 ounces) of low grade material to the Timmins Division of Royal Oak from start-up in 1995 through to June 1998.

Gold is spatially associated with quartz veins and/or fine grained disseminated pyrite mineralization.

LOCATION, OWNERSHIP, AND CLAIMS

The Nighthawk Mine is owned by Royal Oak Mines Inc. and is located in Cody Township, about 35km east of Timmins, Ontario (Figure 1). The mine is within the central part of the Nighthawk Lake Project area, where Royal Oak controls a total of about 13 080 acres of mining lands consisting of staked, patented, and leased claims, as well as exploratory licences of occupation.

REGIONAL GEOLOGICAL SETTING

The Nighthawk Lake area is dominated by mafic volcanic rocks with minor felsic flows (Figure 2). Sedimentary units of greywackes and argillite conformably overly the volcanic rocks. Ultramafic rocks intrude the volcanic rocks and are comprised of serpentinized peridotites and carbonatized ultramafics. Felsic intrusions composed of quartz-feldspar porphyry, feldspar porphyry, syenite, aplite, and felsite are occasionally present through the stratigraphy. All units are cut by two separate diabase dike systems, an older set which trends at 070° and a younger "Matachewan" set (Leahy 1971).

The Destor Porcupine Fault crosses the northern Nighthawk Lake area where it appears to separate the Deloro group sediments and volcanic rocks from the younger Three Nations Assemblage (Timiskaming) sediments and volcanic rocks. A splay fault off the Destor Porcupine Fault, referred to as the Nighthawk Lake Break, diagonally crosses the area at about 070°. The Nighthawk Mine occurs on this structural feature, as do several other gold deposits to the northeast.

PROPERTY SCALE GEOLOGICAL SETTING

Macroscopic Description of Rock Types

The mine occurs within a +/– 1000 foot wide subvertical, south dipping, easterly oriented deformation zone localized along the Nighthawk Lake Break which is bounded to the north and south by mafic volcanic rocks (Figure 3). These tholeiitic volcanic rocks form massive, pillowed and variolitic flows.

Rock types within the deformation zone include sediments (argillites and tuffs), unaltered to intensely altered mafic and ultramafic volcanic rocks, scattered relics of felsic intrusions and quartz veins.

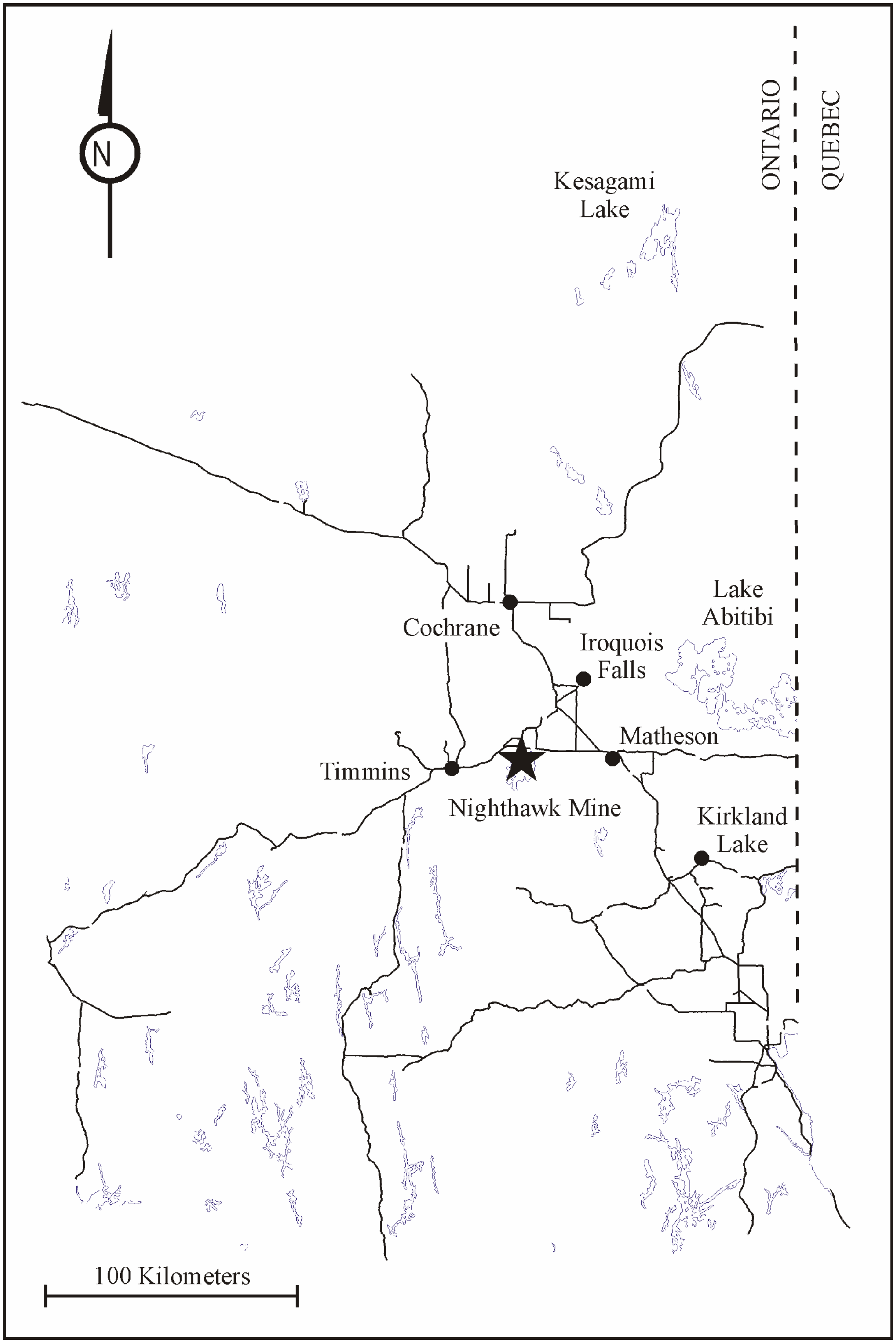
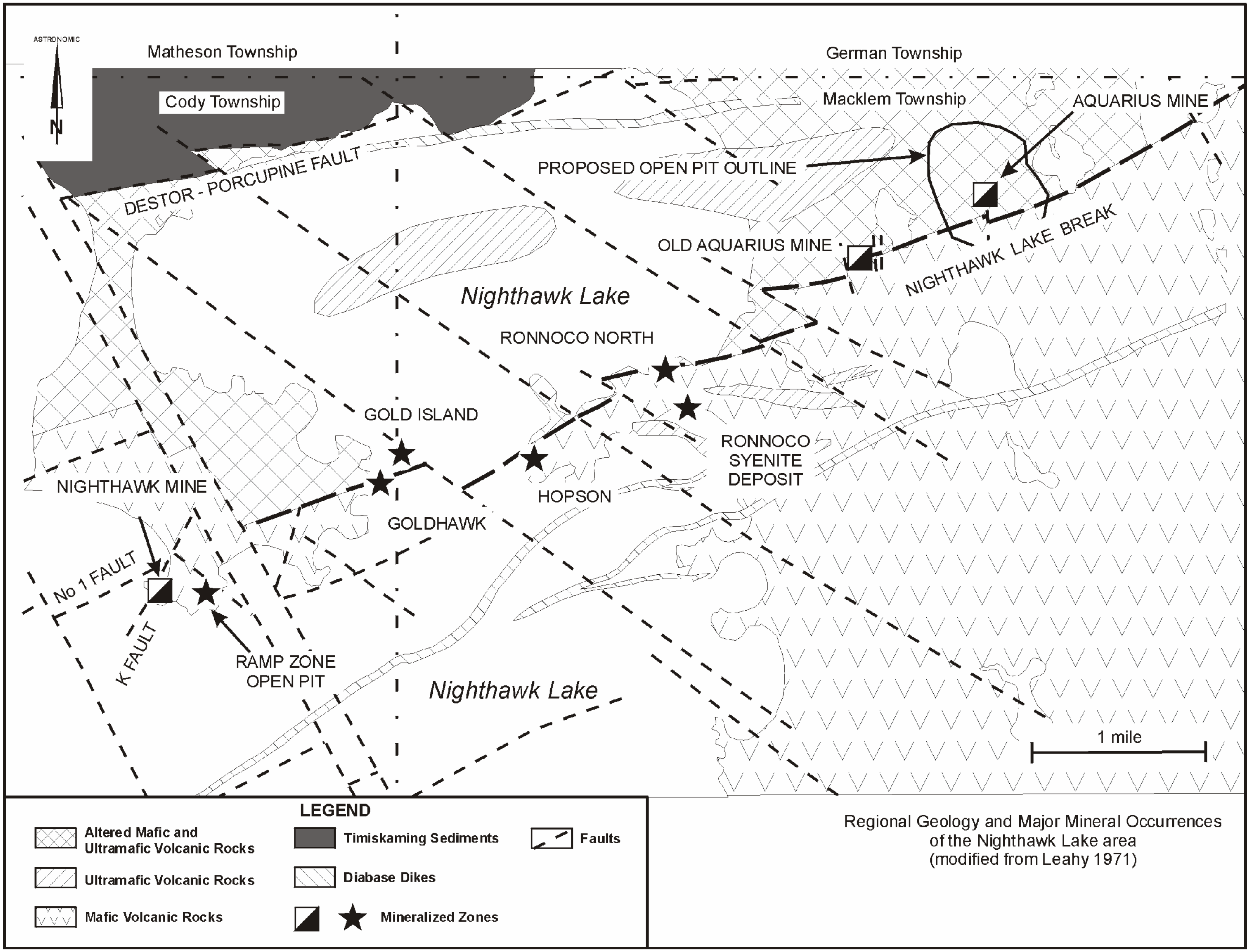


Figure 1. Location Map of the Nighthawk Mine.



Regional Geology and Major Mineral Occurrences of the Nighthawk Lake area (modified from Leahy 1971)

Figure 2.

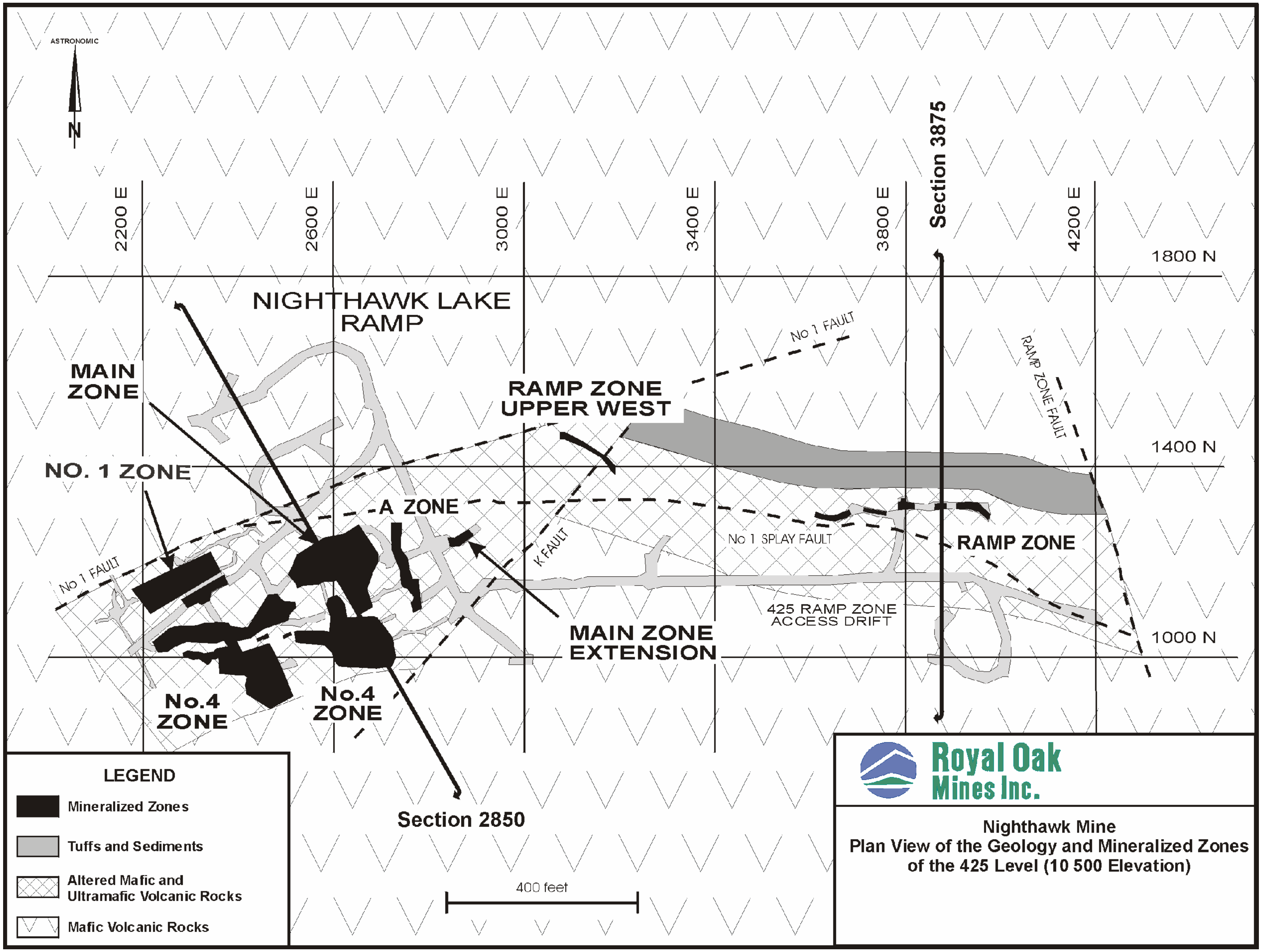

ASTRONOMIC
N
2200 E
2600 E
3000 E
3400 E
3800 E
4200 E
1800 N
1400 N
1000 N
NIGHTHAWK LAKE RAMP
MAIN ZONE
NO. 1 ZONE
No 1 FAULT
RAMP ZONE UPPER WEST
No 1 FAULT
RAMP ZONE FAULT
Section 3875
A ZONE
K FAULT
No 1 SPLAY FAULT
RAMP ZONE
425 RAMP ZONE ACCESS DRIFT
MAIN ZONE EXTENSION
No.4 ZONE
No.4 ZONE
Section 2850
400 feet
LEGEND
Mineralized Zones
Tuffs and Sediments
Altered Mafic and Ultramafic Volcanic Rocks
Mafic Volcanic Rocks
Royal Oak Mines Inc.
Nighthawk Mine
Plan View of the Geology and Mineralized Zones of the 425 Level (10 500 Elevation)

Figure 3.

The sedimentary units generally mark the northern limit of most zones of mineralization within the mine. These units are composed of argillite (thinly laminated and often graphitic) and are commonly adjacent to and/or intercalated with grey volcanic tuffs and lapilli tuffs. The tuffs are banded on a 0.5 inch scale with alternating felsic and mafic layers, are often tightly contorted and vary in colour from pale grey to dark grey. The lapilli tuffs are similar to the grey volcanic tuffs but contain 10-50% felsic lapilli and the units are generally a pale brown colour. When mineralized with 5-10% pyrite, these units may contain gold values between 0.030 to 0.100 oz per ton. The sedimentary units range in thickness from a few feet to several tens of feet and are best developed at the Ramp Zone located at the east end of the mine.

The largest zones of mineralization occur adjacent to, or several 10's to 100's of feet south of the sedimentary units and are hosted in highly deformed and altered mafic and ultramafic volcanic rocks. These rocks are differentiated on the basis of their alteration and are described under "Macroscopic description of alteration types and assemblages".

Randomly scattered through the altered rocks and tuffs are 1-5 foot sized irregular-lensoidal relicts of felsic intrusive rocks of a syenitic or albitic composition. The relicts are generally pale orange-brown, highly fractured and silica flooded and are often well mineralized with 2-10% fine pyrite and may contain significant gold values.

A tabular, laterally continuous quartz vein which is typically 3-5 feet wide occurs at the north-west corner of the underground mine workings and represents the original discovery site of the mine. This vein is referred to as the No.1 Vein. It displays well developed crack-seal textures and was mined out down dip and to the west where it terminated at a fault contact.

Mixed in with, and to the south of the ore zones is an intercalated sequence of mafic and ultramafic rocks which form the structural hanging wall to the deposit. The mafic rocks are generally massive, strongly chloritic, and may be weakly foliated. The ultramafic rocks are often altered to talc-chlorite schists. Carbonate and silica alteration has affected these units in varying amounts. The alteration decreases in strength southward, away from the zones of mineralization.

Macroscopic Description of Alteration Types and Assemblages

Carbonatization (ankerite) is the dominant alteration type throughout the mine, and has affected the mafic and ultramafic rocks which host (and are adjacent to) the zones of mineralization to the point where original protoliths cannot be determined. Occasionally leucoxene can be found, suggesting that the original rock was of mafic composition. Siragusa (1992) refers to these units as "Highly Altered Rocks" and describes them as 'metabasalt carbonatized by discrete ankerite-rich bands parallel to foliation; pervasively carbonatized chlorite-ankerite, and quartz-chlorite ankerite schists; and subordinate, silicified chromium-mica schists of ultramafic derivation'.

Underground mapping by Royal Oak geologists is confined to within the mine area and has resulted in identification of the unaltered rock types described in "Macroscopic Descriptions of Rock Types". The Highly Altered Rocks are differentiated on the basis of their colour as described below. When mineralized with 3-10% pyrite, each of these rock types generally contain gold values in the 0.100-0.500 ounce per ton range.

GREY CARBONATE (GCRB)

This is the most common rock type in the mine. Ankerite is the dominant alteration mineral and this unit varies from dark grey to pale grey in colour, and is banded and/or contorted in appearance due to abundant chlorite which has developed on foliation surfaces. Irregular and tabular centimetre-scale quartz veining of multiple ages dissect the carbonate rock and may form 50% or more of individual samples. Locally this unit contains leucoxene flakes which suggests a high Fe-tholeiite protolith.

BROWN CARBONATE (BCRB)

This unit is texturally similar to Grey Carbonate, however sericite is the dominant alteration mineral, giving the rock a pale brown to yellow-brown colour.

CHLORITIC CARBONATE (CCRB)

The Chloritic Carbonate unit is very similar to the Grey Carbonate, but chlorite is the dominant mineral which gives the unit a dark green colour.

FUCHSITIC CARBONATE (FCRB)

This rock is texturally similar to Grey Carbonate, however the presence of emerald green fuchsite suggests an ultramafic protolith. Additionally, a second type of FCRB, which is massive and cut by barren stockwork type quartz veins, is common in the area of the Ramp Zone located at the east end of the mine.

STRUCTURAL GEOLOGY

Stratigraphy

On a property scale, the stratigraphic units generally strike 070° to 090° and dip steeply to the south, however on a stope scale, abrupt changes in strike and dip by 45–60° over a few feet are common. This suggests that the rocks have undergone a complex structural history. Post–ore block faulting has affected the entire mine. Kink folds, M–style minor folds, crenulations and asymmetric minor folds are common through the mine within the tuffs and carbonate rocks. These features are related to both complex faulting and folding events within the mine stratigraphy.

Joints

Joints are numerous throughout the mine and have not been studied in detail.

Faults and Shears

Faulting is the most obvious structural feature in the mine, all units have been affected by numerous and complex faults. Three dominant sets of faults have been recognized in the mine (Table 1).

Table 1. Description of the dominant fault sets at the Nighthawk Mine (modified from Leahy 1971).

Fault Set	Orientation	Age	Type
1	N70°E / 72°S	pre mineralization	reverse (gouge) ie No.1 Fault
2	N23°W / 45°E	post mineralization	normal
3	N78°E / 75°N	post mineralization	normal

The magnitude of the displacements along these faults has not been determined because suitable marker horizons do not exist.

ECONOMIC GEOLOGY

Production History

A summary of the production history of the Nighthawk Mine is given in Table 2 below:

Table 2. Summary of the production history of the Nighthawk Mine.

Year	Production (tons)	Grade (oz / ton Au)	Recovered Ounces	Remarks
1924 – 1927	99 628	0.320	31 880	Underground
1994 – 1995	59 225	0.071	4 200	Open pit
1995:				Underground
High Grade	14 434	0.125	1 800	
Low Grade	2 393	0.047	110	
1996:				Underground
High Grade	238 283	0.143	34 070	
Low Grade	22 187	0.066	1 460	
1997:				Underground
High Grade	311 997	0.126	39 310	
Low Grade	22 541	0.066	1 500	
1998 (estimate):				Underground
High Grade	329 937	0.139	45 860	
Low Grade	23 000	0.066	1 520	
TOTAL – Royal Oak 1994-1998	**1 023 997**	**0.127**	**129 867**	

Development to Date

The development history of the mine is listed below:

1917	No. 1 Shaft sunk to 90 feet
1921	Shaft deepened to 190 feet, 180 level developed
1922	Shaft deepened to 440 feet, 300 and 425 levels developed
1923	2859 feet of drifting and crosscutting was done200 tpd mill built
1924	525 and 625 levels developed from a winze
1925	Considerable drifting, raising and crosscutting
1926-1927	Underground operations suspended in May, 1926 Production totalled 99 628 tons at 0.32 oz / ton Au.
1945-1948	No.2 Winze established, levels established at 525, 625, 750, 875, and 1000 feet. Three thousand feet of drifting was done on the 1000 Level.
1977	Ramp driven 750 feet long on the Ramp Zone for bulk sample
1986-1987	Mine dewatered, underground drill program, 15 219 feet of diamond drilling
1989	Mine dewatered, underground drill program, 18 514 feet of diamond drilling
1995	5634 feet of development from the ramp
1996	11 251 feet of development from the ramp
1997	7534 feet of development from the ramp
1998	8550 feet (estimate) of development from the ramp

Diamond Drilling

A listing of the amount of diamond drilling performed at the Nighthawk Mine is given in Table 3 below:

Table 3. Diamond drilling history at the Nighthawk Mine.

Year	Amount of Drilling (feet)
1924–1927	17 000
1933–1934	30 000
1947–1948	15 000
1973	7596
1986–1987	15 219
1989	18 514
1993	15 000
1994	650
1995	30 274
1997	41 160
1998	25 083
TOTAL	**215 496**

Mining Method

The mining method currently used is Longhole Retreat open stoping from level and sublevels developed at approximately 50 foot intervals. The stopes are later filled with waste rock from development headings.

Description of Orebodies

NO. 1 ZONE

The No. 1 Zone is located adjacent to and parallels the No. 1 Fault. It extends from surface to below the 750 Level and has a strike length of about 600 feet (Figure 4). An interval of weak mineralization divides the No. 1 Zone into Upper and Lower Zones. The economic mineralization is typically 10 to 20 feet wide. The zone plunges to the east at 70° and dips to the south at 70° to 80°. Local blowouts along the footwall of the zone are up to 50 feet in width. The zone consists of varying degrees of primarily pyrite mineralization within a highly sheared and brecciated 100 foot wide sericite alteration zone (brown carbonate). The economic mineralization lies on the footwall of the alteration zone. The sulphide component is used as a guide in determining the location of the economic mineralization (3 to 8 % pyrite) within the alteration zone (1 to 3 % pyrite).

MAIN ZONE

The Main Zone extends from roughly the 230 Level to the 525 Level, and forms an inverted J-shaped structure with the No. 4 Zone when viewed in Cross Section (Figure 5). It has an elliptical shape formed by north dipping faults and is 150 feet wide at its widest point. It strikes about N70°E, plunges 65° to the east, and is located south of the No.1 Zone. The upper and lower limits of the Main Zone appear to be truncated by north dipping faults. The zone is comprised of well mineralized (3 to 15 % pyrite) grey coloured ankerite alteration (grey carbonate).

NO. 4 ZONE

The No. 4 Zone extends from the 180 Level to below the 750 Level. It strikes at N90°E, dips at 50° south, and has an average width of about 25 feet, however in the area of the 425 Level the zone widens to 50–70 feet. The zone is comprised of a gold-bearing 1 to 2 foot wide crack-seal hanging wall quartz vein and a well mineralized (5 to 15 % pyrite) grey coloured ankerite alteration (grey carbonate) footwall.

RAMP ZONE

The Ramp Zone lies about 500 feet east of the zones described above. It consists of a series of 3 to 15 foot wide, steeply south dipping zones of mineralization which occur over a strike length of about 1000 feet (Figure 6). The strike of the zones changes from an azimuth of 090° at the western and central portion to

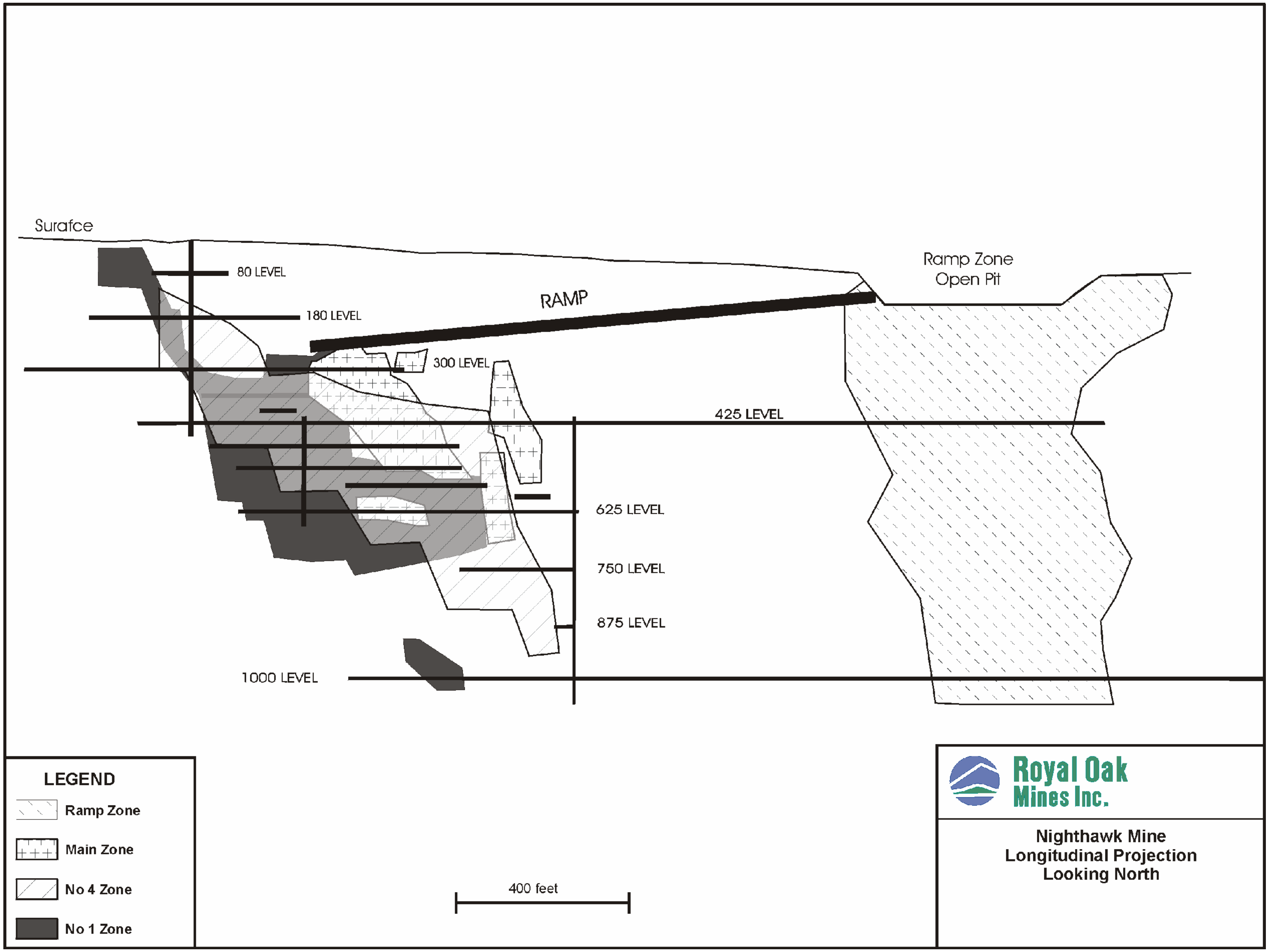

Surafce
80 LEVEL
180 LEVEL
RAMP
300 LEVEL
425 LEVEL
625 LEVEL
750 LEVEL
875 LEVEL
1000 LEVEL
Ramp Zone
Open Pit
LEGEND
Ramp Zone
Main Zone
No 4 Zone
No 1 Zone
400 feet
Royal Oak
Mines Inc.
Nighthawk Mine
Longitudinal Projection
Looking North

Figure 4.

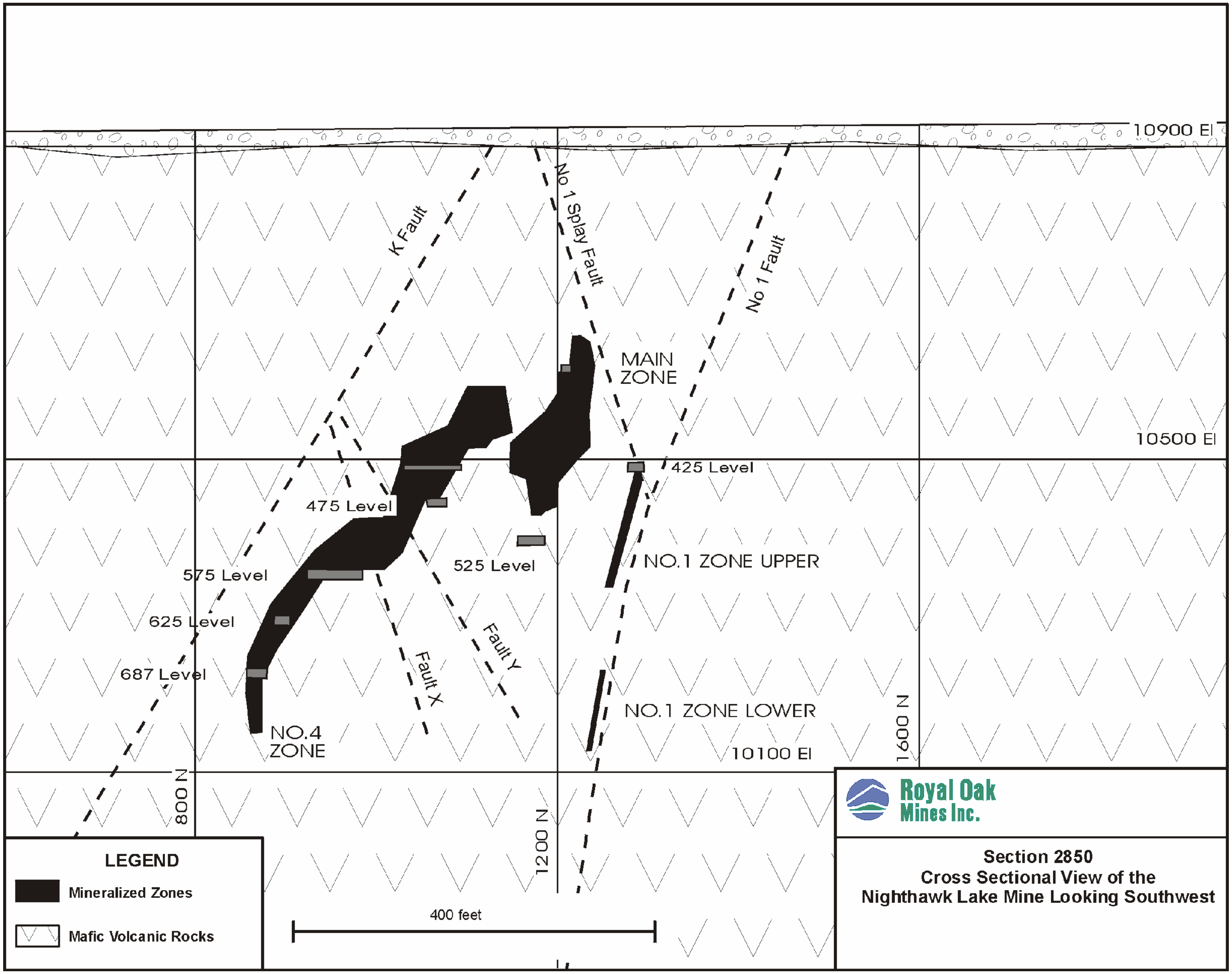

10900 El
10500 El
10100 El
K Fault
No 1 Splay Fault
No 1 Fault
MAIN ZONE
425 Level
475 Level
525 Level
575 Level
625 Level
687 Level
NO.1 ZONE UPPER
NO.1 ZONE LOWER
NO.4 ZONE
Fault X
Fault Y
800 N
1200 N
1600 N
400 feet
LEGEND
Mineralized Zones
Mafic Volcanic Rocks
Royal Oak Mines Inc.
Section 2850
Cross Sectional View of the
Nighthawk Lake Mine Looking Southwest

Figure 5.

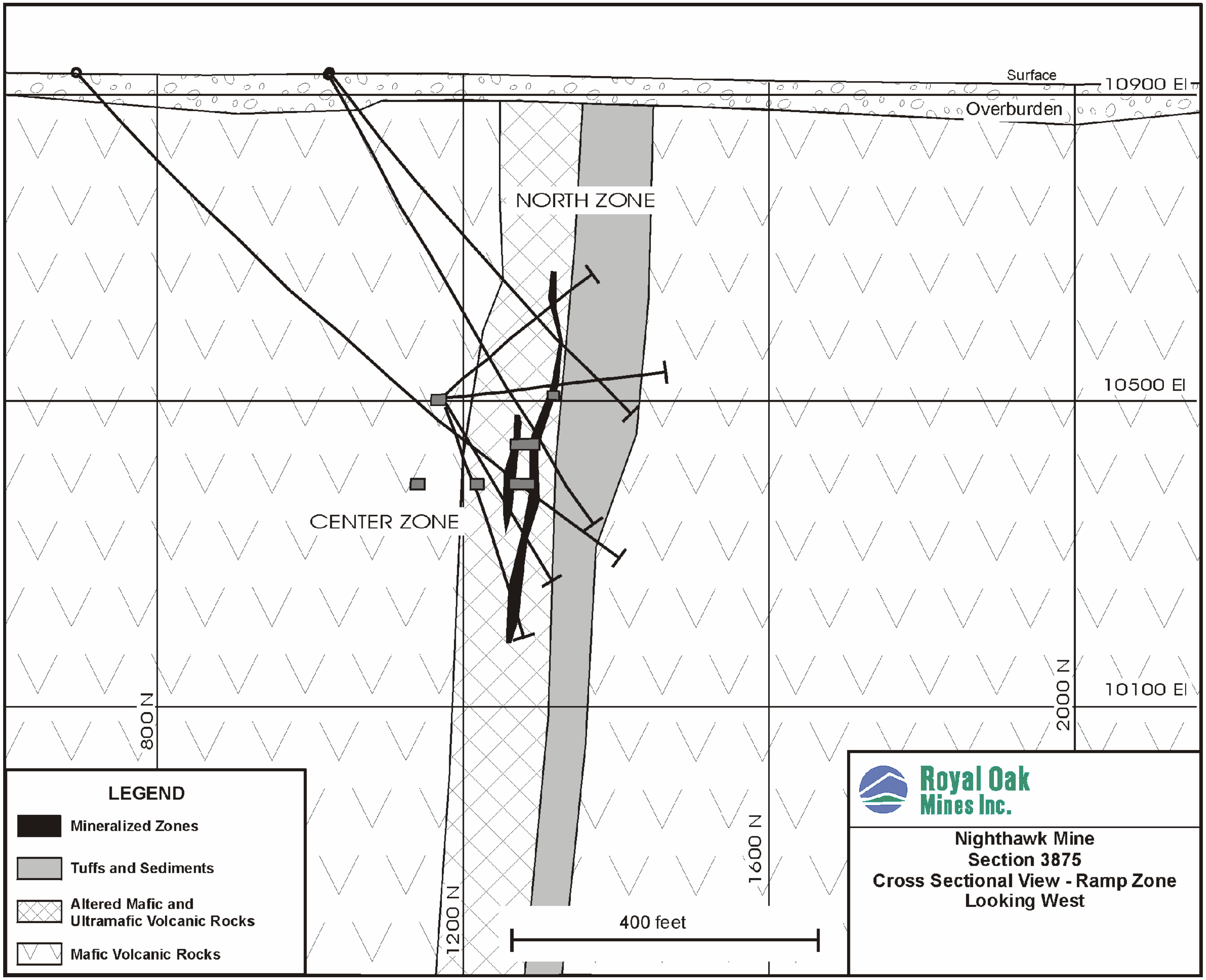

Surface
10900 El
Overburden
NORTH ZONE
10500 El
CENTER ZONE
10100 El
800 N
1200 N
1600 N
2000 N
400 feet
LEGEND
Mineralized Zones
Tuffs and Sediments
Altered Mafic and Ultramafic Volcanic Rocks
Mafic Volcanic Rocks
Royal Oak Mines Inc.
Nighthawk Mine
Section 3875
Cross Sectional View - Ramp Zone
Looking West

Figure 6.

an azimuth of about 130° at the eastern end. Mineralization within these zones is variable, and consists of well mineralized sericite alteration (brown carbonate) within a highly siliceous envelope of lapilli and grey volcanic tuffs, relics of felsic intrusions, and gold-bearing quartz veining.

A ZONE

The A Zone strikes to the north and dips 70° east. It is one of the north-south structures that lie in the 500 foot long interval between the Ramp Zone and three other zones mentioned previously. The A Zone is located approximately 50 feet east of the Main Zone and extends from the 300 Level to the 525 Level. The zone consists of an albite alteration zone enclosed by fuchsitic alteration of the rocks. The zone is unique because it has a north-south orientation and it has significantly higher gold values than other zones of strong sericite alteration.

DEADMAN ISLAND

This area is composed of two zones of mineralization that lie approximately 500 feet east of the Ramp Zone. The economically more important of the two zones is a narrow structure referred to as the South Zone that has an average width of 5.3 feet. This zone dips steeply to the south with dips ranging between 70° and 90°. The mineralization lies directly below an ultramafic contact in a carbonatized shear zone. The second zone (North Zone) lies approximately 100 feet to the north of the first structure. This North Zone outcrops on Deadman Island and extends to a vertical depth of 300 feet. This latter mineralization contains erratic gold values within a larger, 50 foot wide mineralized envelope of green and brown carbonate alteration.

ACKNOWLEGEMENTS

The writers would like to thank Royal Oak Mines Inc. for permission to write this paper and would also like to acknowledge the contributions by all the geologists who have worked at Nighthawk Lake.

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Economic Geology and Mineralization of the Owl Creek Mine

Reno Pressacco
District Geologist, Timmins Regional Resident Geologist's Office

INTRODUCTION

Gold mineralization at Kinross Gold Corporation's Owl Creek Mine is largely contained within disseminated sulphides and quartz veining hosted by a mafic metavolcanic flow that is in fault contact with clastic sediments. This style of gold mineralization is similar to those of other gold deposits in this stratigraphy such as the Hoyle Pond Mine (producing mine), the Bell Creek Mine (past producer), and the Marlhill Mine (past producer). Together these mines have produced a total of 1 374 700 ounces as at December 31, 1997 (Atkinson, et. al. 1998).

The first record of gold discovery in the area was by Jones (1936) who documented the discovery of a number of gold-bearing quartz veinlets in the north half of Lots 9 and 10, Concession II, Hoyle Township on what is now Pentland Firth Ventures Ltd's Marlhill Mine project. Diamond drilling by Hollinger Consolidated Gold Mines in 1941 in the south half of Lot 7, Concession II, Hoyle Township, immediately north of the Owl Creek open pit, intersected mafic volcanic lavas with only sporadic, low gold values (Hollinger Consolidated Mines Hoyle Option 1941). Exploration activities by Canico, a subsidiary of INCO Ltd, consisting of follow-up work on the Owl 9-43 airborne electromagnetic anomaly resulted in drilling of the discovery drill hole in 1967. Additional work on the deposit culminated in a production decision by Kidd Creek Mines Ltd. in 1982, and the mine was in production until its' closure in 1989. The underground workings and the open pit are currently flooded.

LOCATION, ACCESS, AND CLAIMS

The Owl Creek Mine is located in southeastern Hoyle Township, approximately 17 kilometres northeast of Timmins, Ontario (Figure 1), and the open pit is located in the northeast quarter of the north half of Lot 7 Concession II, Hoyle Township. The mine property forms part of Kinross Gold Corporation's extensive land holdings in the area that consists of three properties (Hoyle Pond, Owl Creek, and Bell Creek Mines). In total these three properties comprise 889 Ha of patented claims, 453 Ha of leased claims, 32 Ha of unpatented mining claims, and 64.6 Ha which are under a private lease agreement. All lands are currently registered to Kinross Gold Corporation.

REGIONAL GEOLOGICAL SETTING

The Owl Creek Mine is hosted within a mixed assemblage of mafic and ultramafic volcanic rocks containing interbedded clastic and graphitic sediments that strike in an overall easterly direction and dip steeply south (Figure 2). These units are located to the immediate north of the traditional Timmins Camp stratigraphy which has been described in detail by Ferguson, et. al. (1968), Pyke (1982), Jackson and Fyon (1991), and Brisbin (1998).

The Tisdale Group consists of: i) a lower portion consisting of mixed ultramafic and Mg-tholeiite mafic metavolcanic rocks that have returned an age date of 2707 Ma, ii) a middle sequence dominated by Fe-tholeiitic basalts capped by two distinctive variolitic units, and iii) an upper sequence consisting dominantly of calc-alkaline felsic pyroclastic rocks (Krist Fragmental, 2698 Ma) with minor amounts of carbonaceous argillite. The Tisdale Group is in fault contact with the older Deloro Group (2727 Ma) to the south across the Destor-Porcupine fault zone. The rock types in the Deloro Group are dominantly calc-alkaline basalts, andesites, rhyolitic and dacitic tuffs, and lapilli tuffs. A sequence of clastic sediments (Porcupine Sediments) conformably overlies the Tisdale Group units, and is in turn overlain by younger clastic sediments of the Timiskaming Group. A schematic illustration of the stratigraphy and age dates for the Timmins Camp is given in Figure 3.

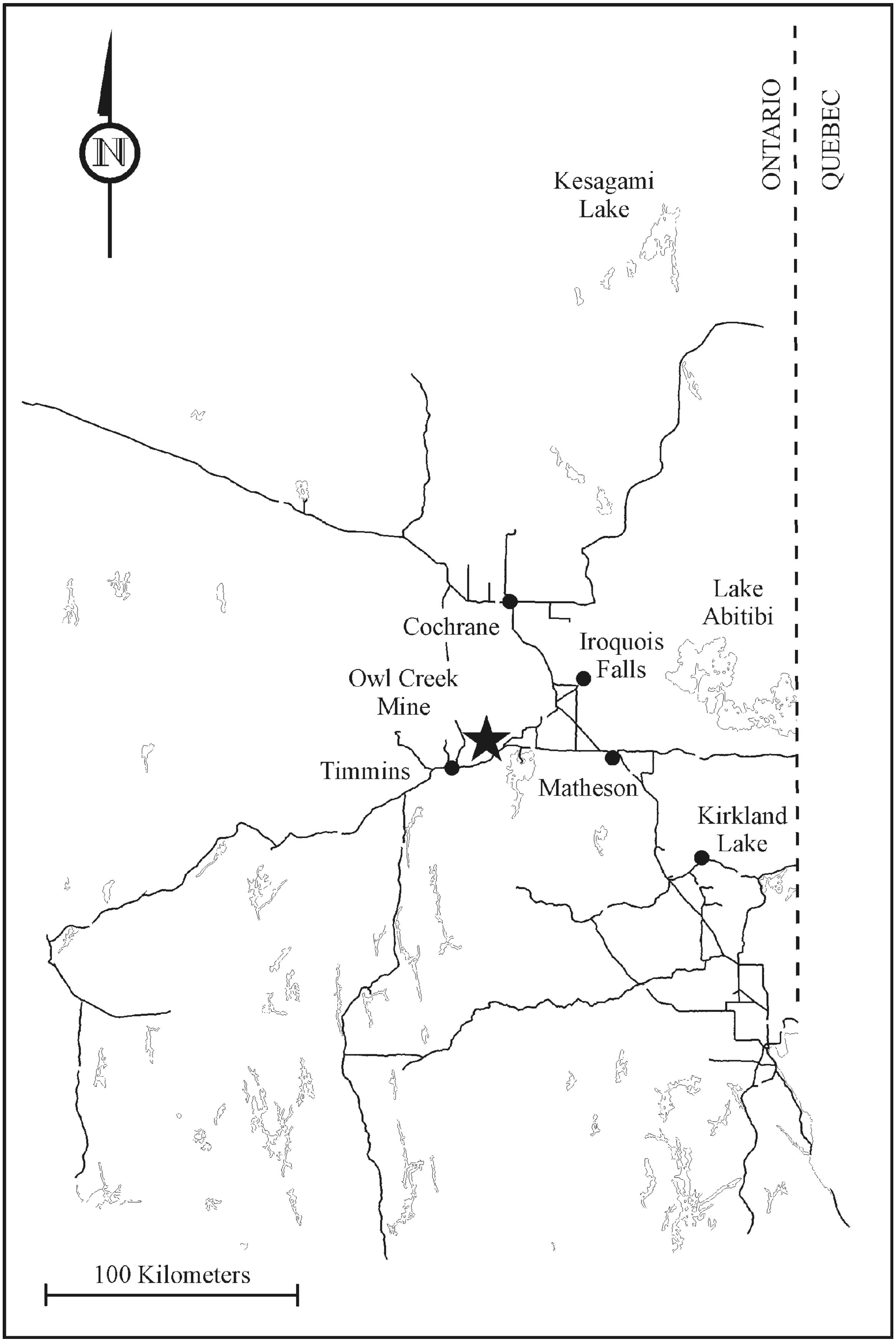


Figure 1. Location map of the Owl Creek Mine.

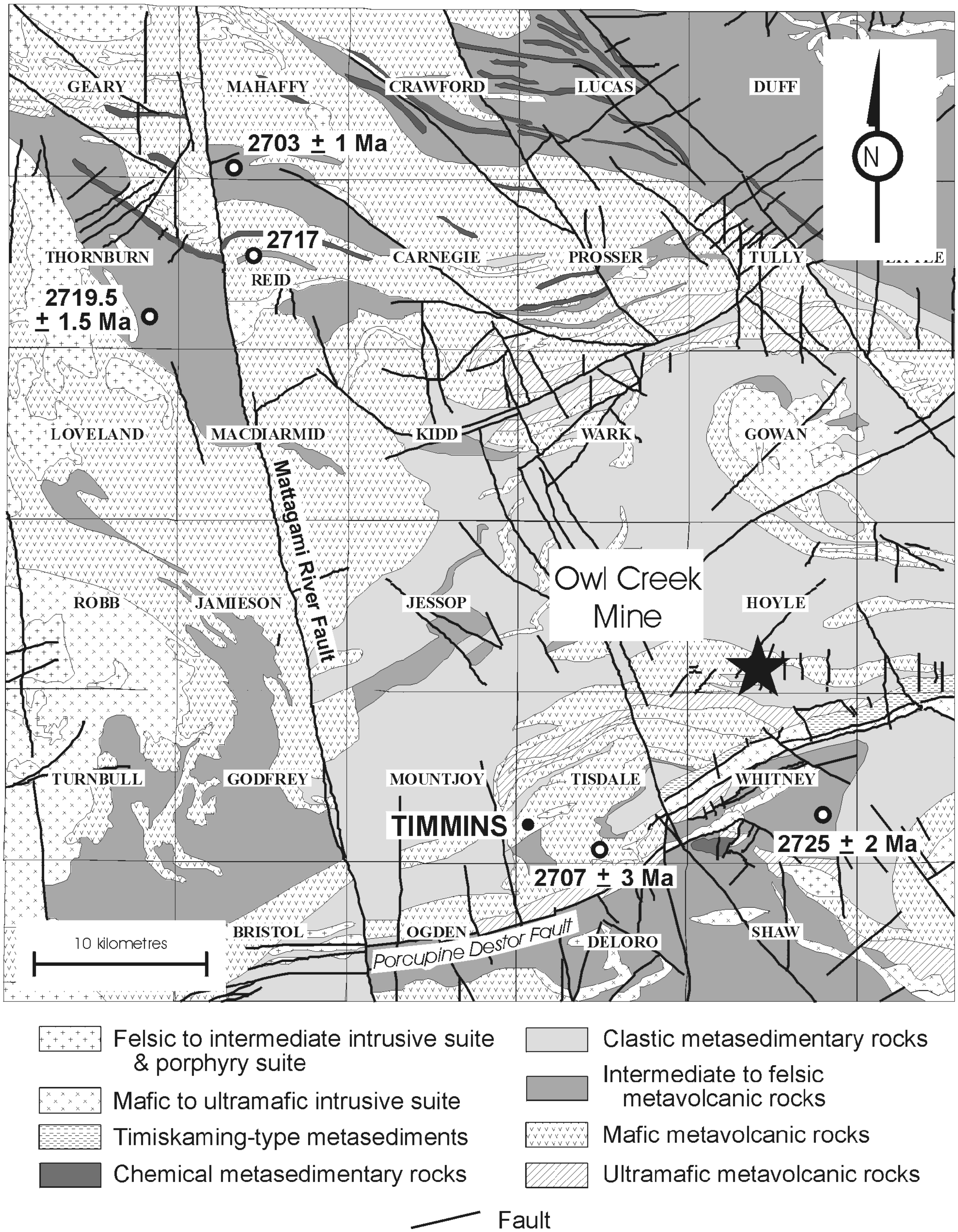


Figure 2. Regional Geological Setting of the Timmins Area (modified from Ayer and Trowell, 1998).

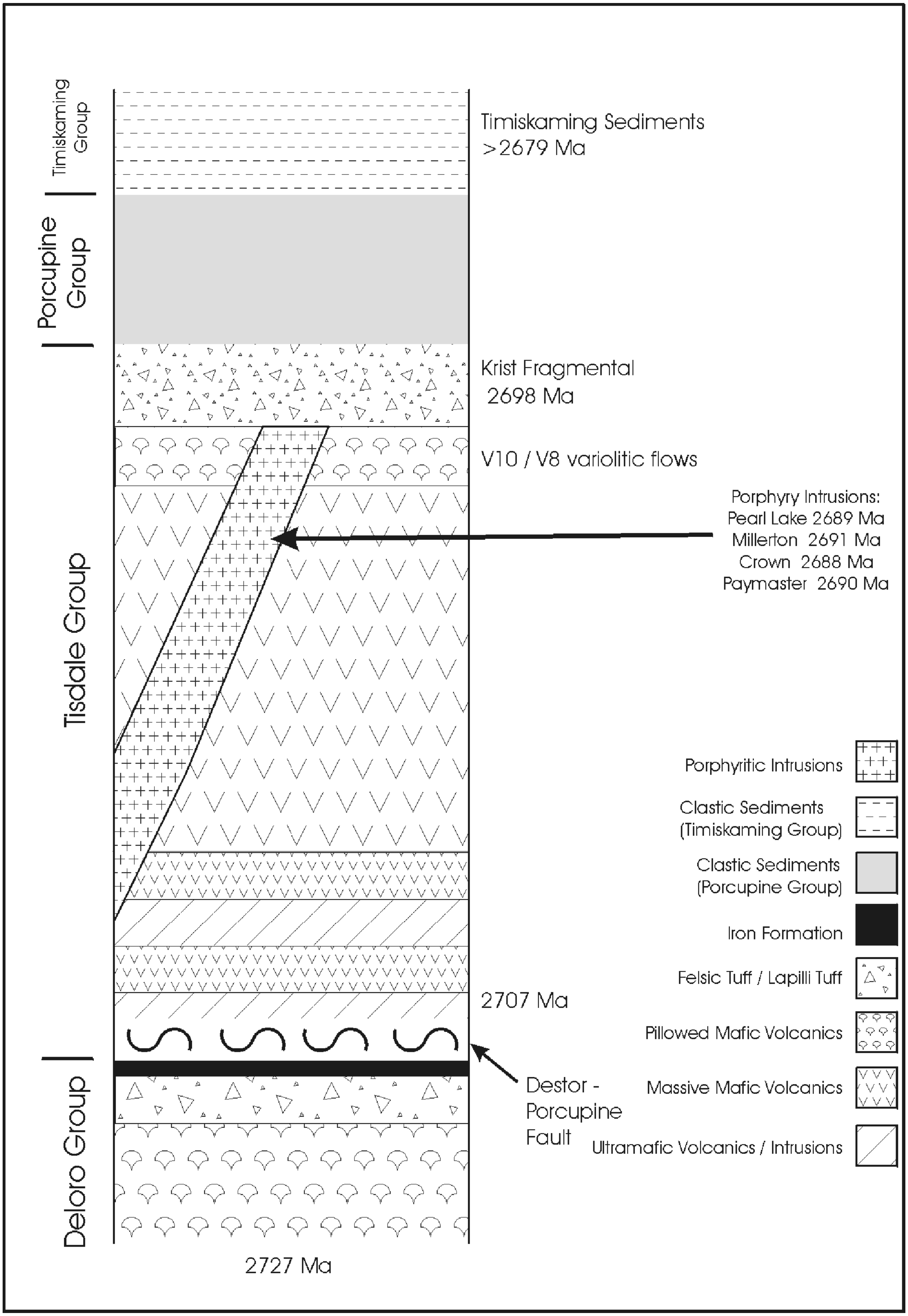


Figure 3. Generalized Stratigraphic Column of the Timmins Camp.

The Destor–Porcupine Fault is the most significant structure in the area and it consists of a number of zones of shearing and ductile deformation focussed mainly within ultramafic flows and intrusions. The fault is either vertical, or dips steeply to the north, has been traced continuously eastwards through to the Duparquet, Quebec area where it splits into the east–trending Maneville Tectonic Zone and the southeast–trending Parforu Lake Fault (Couture 1991). The Destor–Porcupine Fault has an apparent sinistral sense of movement in the Timmins area. A set of brittle faults oriented in a northwesterly direction are present throughout the region. These faults are the youngest structural features in the area and serve to offset all stratigraphic units and older structures. The Owl Creek Mine is located in the hangingwall to the Destor Porcupine Fault, approximately five kilometers north of the fault's surface trace.

PROPERTY SCALE GEOLOGICAL SETTING

Macroscopic Description of Rock Types

Gold mineralization at the Owl Creek Mine is hosted mainly within a 50 – 100 metre thick band of east–northeasterly striking mafic volcanic rocks that is flanked along its' north and south contacts by graphitic (carbonaceous) argillites and greywackes (Figure 4). These units are part of a more regionally extensive sequence of rocks that include komatiitic flows (Photo 1) and ultramafic intrusive rocks, strike in a general east–west direction and extend for a distance of 22 kilometres from south–central Matheson Township to southwestern Murphy Township (Ayer and Trowell, 1998).

The mafic volcanic rocks at Owl Creek were determined to be composed of Mg–tholeiitic basalts by Brisbin (1984). Stratigraphic tops are towards the south, as determined from diamond drill core data and surface mapping of the pre–stripped open pit. Their textures are dominated by massive to pillowed flows with locally developed variolitic and amygdaloidal textures. These basalts have all been variably altered by an assemblage of carbonate and sericite resulting in a light grey to buff colouration (Brisbin 1986). Geological mapping by Kingston (1987) confirmed Brisbin's observations and also noted that while the buff coloured basalts can have either a massive or intensely sheared texture, the grey coloured basalts are always intensely sheared.

The greywacke units are in fault contact on both the north and south contacts of the basalt flows, with a unit of strongly sheared carbonaceous argillite marking the fault contact (Photos 2 and 3). The greywackes have been described by Brisbin (1986) as follows:

> "Greywackes are the dominant sedimentary rock type throughout the study area and are lithologically identical to greywackes of the Porcupine Group. The greywackes in the study area are composed of interbedded light to medium grey arkosic wackes and darker grey argillite typical of distal turbidities within a submarine fan (Downes et. al., 1982). Individual beds range in thickness from a few millimeters to 50 centimeters. Gradded bedding and minor scour features indicate stratigraphic facings to the south at both Owl Creek and Hoyle Pond. Greywackes intersected in diamond drilling west of Owl Creek, on the west side of the Jocko Creek Fault, show similar features indicating facings to the north (Coad, per. com., 1985). Locally greywackes may have a dark grey colour, reflecting an increase in carbon content. These carbonaceous greywackes tend to contain higher concentrations of pyrite than their lighter grey counterparts. Carbonaceous argillites, locally with minor gold values, are common south of the "graphite" at Owl Creek, and are the ore host in the east end of the Owl Creek Pit, east of where the Owl Creek basalts are truncated by a northwest striking fault. In the latter location quartz veins, darkening due to carbon content, higher pyrite content and gold mineralization similar to those present in ore–bearing basalts to the west, are present in greywacke.
>
> Pyrite content in unmineralized greywackes is commonly limited to less than 1% disseminated pyrite cubes, 5 to 10mm in size. These cubes overgrow both bedding and schistosity and thus appear to be post–ore. Pyrite concentrations of up to 10% euhedra, 1 to 3mm in size in light grey arenaceous layers within "darkened" carbonaceous zones described above usually conform to bedding (Photo 4). This pyrite may be diagenetic or hydrothermal. Pyrite clasts, 2 to 10cm long by 0.5 to 2cm thick, flattened parallel to schistosity, have been mapped locally in greywacke on the south side of the Owl Creek pit. Local lenses of semi–massive to massive pyrite have also been noted in the carbonaceous argillites immediately north, ie. underlying, these greywackes. Also, lenses of massive, apparently syngenetic, pyrite are common in carbonaceous sediments throughout the Abitibi. It is therefore likely that the pyrite clasts in the greywacke are detrital, having been eroded from pyrite lenses and redeposited in these turbiditic sediments (i.e. greywackes)."

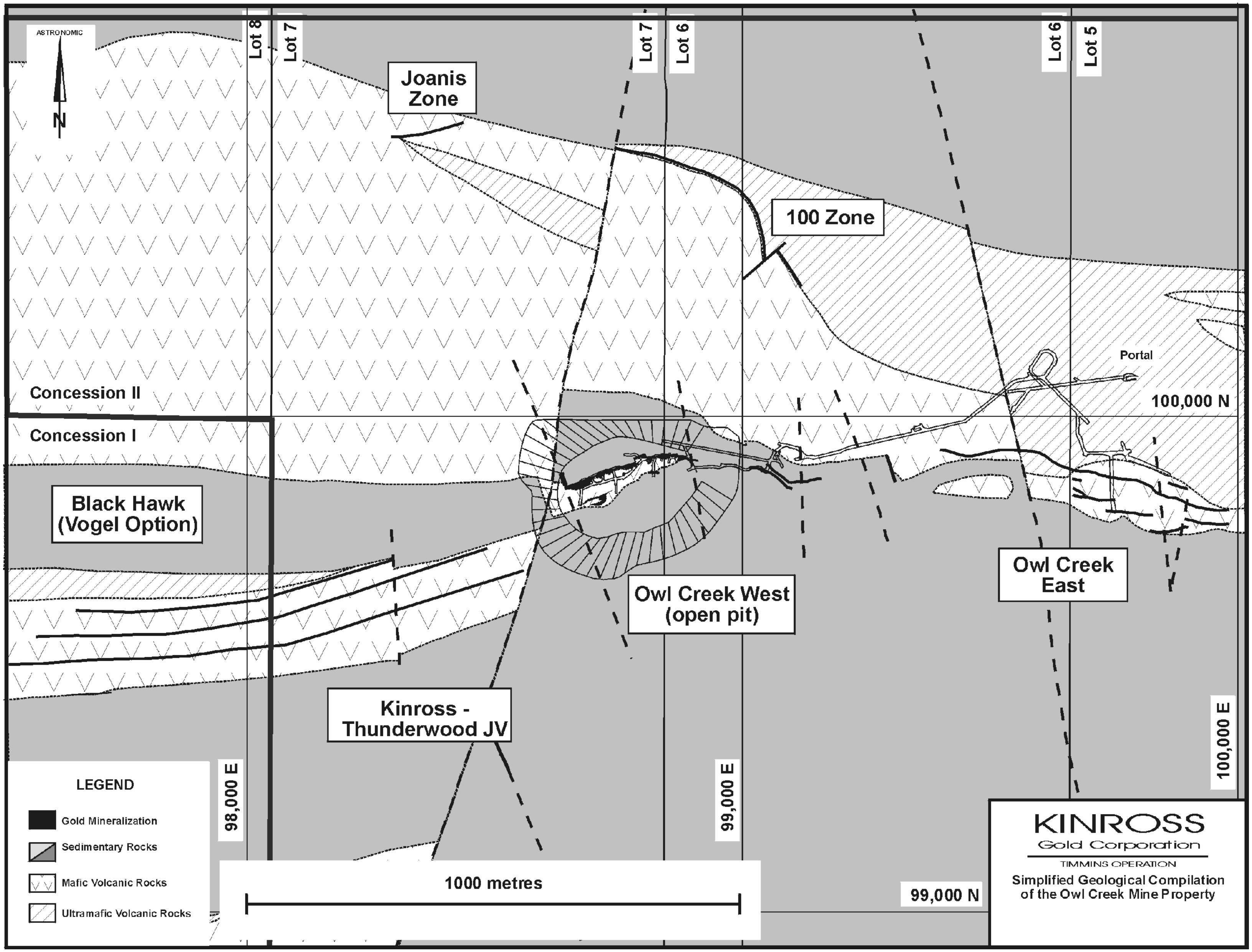

ASTRONOMIC
N
Lot 8
Lot 7
Lot 7
Lot 6
Lot 6
Lot 5
Joanis Zone
100 Zone
Portal
100,000 N
Concession II
Concession I
Black Hawk (Vogel Option)
Owl Creek East
Owl Creek West (open pit)
Kinross - Thunderwood JV
LEGEND
Gold Mineralization
Sedimentary Rocks
Mafic Volcanic Rocks
Ultramafic Volcanic Rocks
98,000 E
99,000 E
100,000 E
1000 metres
99,000 N
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Geological Compilation of the Owl Creek Mine Property

Figure 4.

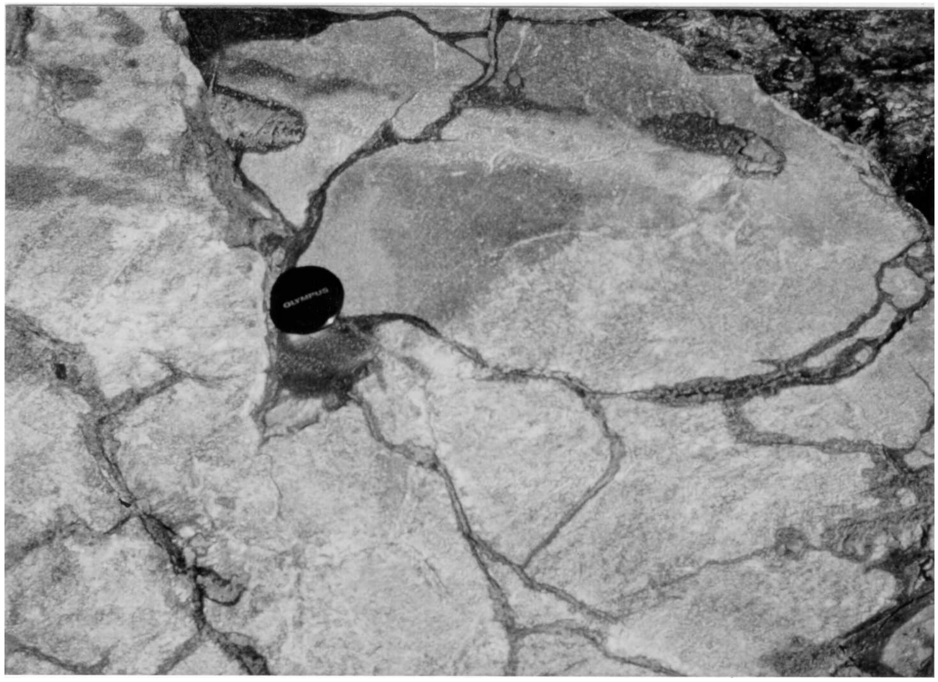


Photo 1. Example of pillowed komatiitic flows located at the portal of the Owl Creek ramp. Photo provided courtesy of Dan Brisbin.

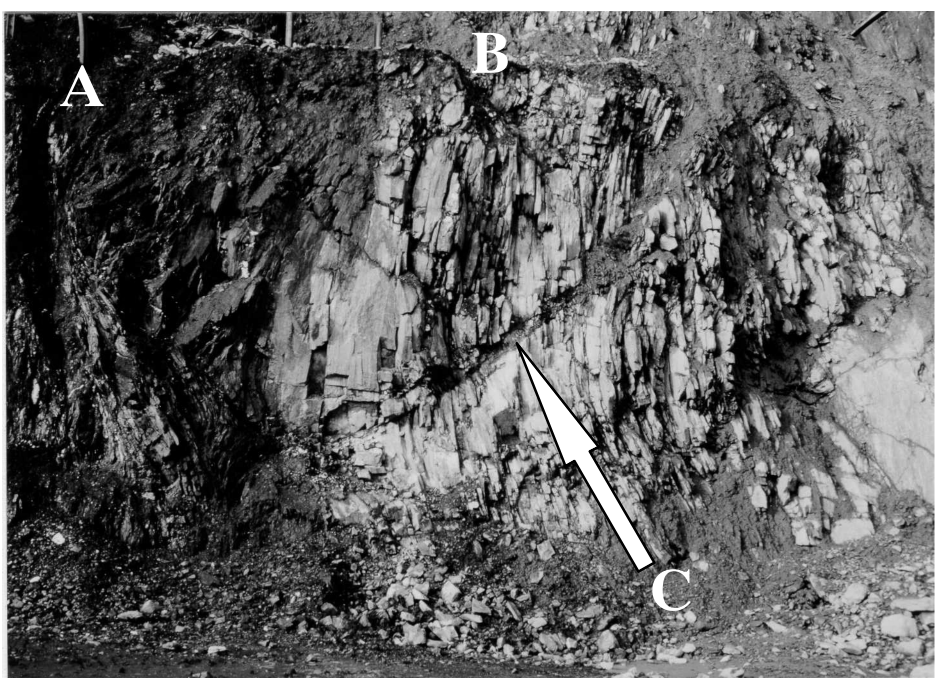


Photo 2. Contact between strongly schistose graphitic argillite (A) and basalt (B). Note the moderately north dipping gouge-filled fault cross cutting the schistosity in the basalts (C). Looking east, 2 Bench, Owl Creek open pit. Photo provided courtesy of Dan Brisbin.

Photo 3. Contact between basalt (left) and graphitic argillite, Owl Creek East Zone, 725 crosscut south, looking west. Note presence of disseminated pyrite in basalt. Photo courtesy of Dan Brisbin.

Photo 4. Dark grey coloured carbonaceous greywacke containing disseminated euhedral pyrite along bedding planes. Looking east, 2 Bench, Owl Creek open pit. Diameter of lens cap is approx. 5 cm. Photo provided courtesy of Dan Brisbin.

Graphitic (carbonaceous) argillites are the least abundant rocks in the Owl Creek open pit, and their distribution is confined to both the north and south contact of the basalt where they typically contain a sheared texture. The northern graphitic argillite is highly sheared and is the locus of some of the quartz veining present in the open pit. These graphitic argillites are black, soft, friable, strongly schistose, and contain minor intercalations of greywacke (Brisbin 1986). Sulphides in the form of pyrite are commonly present in these units and are described by Brisbin (1986) to be:

> "Carbonaceous / graphitic sediments typically contain less than 1% pyrite / marcasite nodules ranging from a few mm to 30mm in diameter. The nodules display internal radial textures with a surface coating of euhedral pyrite and often show flattening and extension in the plane of the S1 schistosity. Pyrite is locally concentrated in semi-massive to massive lenses up to 1m thick in the "graphite" unit exposed in the Owl Creek pit. This pyrite occurs as spherical to ovoid nodules and "worm-like" pyrite forms. Thin grained pyrite is also present in laminae 1 to 5mm thick, containing up to 30% pyrite at both Owl Creek and Hoyle Pond. The nodular pyrite does not host significant Au, and is likely syngenetic and/or diagenetic."

Macroscopic Description of Alteration Types and Assemblages

Descriptions of the stratigraphic units in the Owl Creek open pit by Brisbin (1984, and 1986) and Kingston (1987) reveal that while the central basalt unit is variably altered by a sericite dominated alteration assemblage, development of alteration in the flanking sedimentary units is conspicuously absent. In describing the results of petrographic work on the alteration assemblage of the basalt, Brisbin (1986) writes:

> "Examination of thin sections reveals that basalts at Owl Creek and Hoyle Pond are composed predominantly of very fine-grained (<0.1mm) sericite and anhedral grains of carbonate <0.01 to 0.05mm in size. Staining of cut slabs with potassium ferricyanide identified this carbonate as ferran dolomite and/or ankerite. Lesser amounts of very fine-grained (<0.03mm) quartz and chlorite, along with rare, partially altered plagioclase, are also present. Darkening of mineralized basalts which Downes et. al. (1982) termed "grey zone alteration" is due to carbon and chlorite, very finely disseminated throughout the darkened basalts. Carbon and chlorite also occur as fillings in fine (<0.5mm thick) irregular fractures comprising a "crackle-breccia" texture. … This texture is visible in both hand specimen and thin section as randomly oriented fractures less than 0.5 mm thick and black in colour as a result of their filling with carbon and chlorite. In thin section quartz veinlets are observed to cut these features, indicating that this "crackle-brecciation" predates quartz veining.
>
> Schistosity in the basalts is due to aligned sericite, and to a lesser extent, chlorite and carbonaceous material. Although common as a sooty, opaque, amorphous material recognized in thin sections of Hoyle Pond basalts, carbonaceous material appears to be only a minor component of basalts examined from Owl Creek, showing only local concentrations.
>
> Sericite makes up 20 to 40% of altered basalts at Owl Creek and is a minor component of quartz-carbonate veins, filling fractures. Sericite grains are 0.01 to 0.03 mm long. Sericite and chlorite are unoriented to strongly oriented parallel to S1 depending upon the intensity of the schistosity. Locally sericite grains oriented parallel to S1 crosscut minor quartz veinlets at both Owl Creek and Hoyle Pond.
>
> Chlorite occurs intergrown with sericite in altered basalts, and with carbon, filling irregular fractures <0.5 mm thick. A magnesium-rich composition of chlorite is indicated by its very pale green colour in plane light. It varies in abundance from 5 to 20%.
>
> Carbon content of altered basalts is variable. At Owl Creek it appears to comprise <1% of the darkened basalts. The combination of small amounts of finely disseminated carbon along with chlorite present as part of the alteration assemblage has resulted in a marked darkening of more intensely veined and pyritized basalts in which ore-grade gold is hosted. As massive, light grey basalts with only minor pyrite and quartz veining host only minor gold values; darkening, pyritization and veining of basalts are used as guides to ore at Owl Creek.
>
> Pyrite content of basalts at Owl Creek varies from nil to 10% fine (<3mm), euhedral, disseminated grains. Higher pyrite contents are generally in areas of denser quartz veining and more strongly developed darkening of the basalt. Minor amounts of coarse (up to 10 mm), euhedral, disseminated pyrite are also present locally. In thin section, carbonate, sericite and quartz are observed as pseudomorphs of portions of coarse pyrite grains indicating that formation of some coarse pyrite predated hydrothermal mineralization and alteration."

Lithogeochemical Data

Selected analytical results of lithogeochemical analyses performed by Elliot (1984), and Kingston (1987) are presented below in Tables 1 and 2, respectively.

Table 1a. Major oxide geochemistry of altered, gold mineralized basalts from the Owl Creek open pit (modified from Elliot 1984). All samples are of grey altered basalt / ore zone except OWL-11 and OWL-14 which are marginal to the grey altered basalt / ore zone. Note that TiO_2, MgO, and CaO values suggest that sample OWL-14 is possibly a misidentified sedimentary rock.

Sample ID	SiO2 (%)	TiO2 (%)	Al2O3 (%)	FeTotal (%)	MnO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	P2O5 (%)	CO2 (%)	C organic (%)
OWL-07	42.00	0.68	13.60	5.54	0.29	4.82	10.70	2.44	0.69	0.17	15.88	0.12
OWL-08	34.60	0.75	14.00	5.54	0.26	6.02	12.10	1.82	1.29	0.05	18.64	0.41
OWL-09	45.00	0.83	12.00	5.76	0.31	4.21	9.20	2.63	0.61	0.10	14.12	0.52
OWL-10	41.30	0.98	13.40	6.50	0.29	4.10	8.30	3.20	0.71	0.03	12.90	1.26
OWL-11	40.00	0.91	13.30	6.99	0.35	4.70	10.80	2.13	0.70	0.21	16.46	0.31
OWL-12	54.20	0.52	8.94	5.17	0.27	3.90	7.95	1.44	0.40	0.17	12.20	0.35
OWL-13	52.30	0.69	11.00	5.05	0.16	3.82	6.80	1.99	0.51	0.07	10.62	0.19
OWL-14	49.60	0.39	15.20	2.68	0.01	0.39	0.39	0.73	1.95	0.15	0.26	14.30
OWL-28	43.60	0.88	12.40	7.48	0.31	3.95	9.17	3.38	1.24	0.15	12.42	0.19
OWL-29	43.70	1.07	14.20	7.41	0.29	3.54	6.49	3.28	0.91	0.12	9.54	0.66

Table 1b. Trace element geochemistry of altered, gold mineralized basalts from the Owl Creek open pit (modified from Elliot 1984). All samples are of grey altered basalt / ore zone except OWL-11 and OWL-14 which are marginal to the grey altered basalt / ore zone.

Sample ID	Zn (ppm)	Cu (ppm)	Pb (ppm)	Ni (ppm)	Co (ppm)	Ag (ppm)	Mo (ppm)	Sb (ppm)	As (ppm)	Au (ppb)
OWL-07	167	149	119	146	78	<5	14	2.0	313	465
OWL-08	217	94	25	129	80	<5	16	3.3	566	9280
OWL-09	127	140	18	144	44	<5	15	4.7	616	950
OWL-10	139	36	19	143	78	<5	17	5.3	1025	15000
OWL-11	123	94	15	137	77	<5	15	2.7	540	2340
OWL-12	182	261	31	94	58	<5	12	2.0	268	5020
OWL-13	202	138	17	144	99	<5	12	1.3	268	140
OWL-14	4150	140	13	389	119	<5	22	7.3	4698	1810
OWL-28	186	83	13	122	81	6.2	16	4.0	363	75
OWL-29	198	140	15	145	86	<5	15	4.0	616	410

Table 2a. Major oxide geochemistry of selected samples from the Owl Creek open pit (modified from Kingston 1987). All samples are of basalts from the open pit.

Sample ID	SiO2 (%)	TiO2 (%)	Al2O3 (%)	Fe2O3 (%)	MnO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	P2O5 (%)	CO2 (%)	C (%)
86-10	48.4	0.62	12.7	7.99	0.24	5.94	8.33	2.96	0.33	0.07	12.4	0.1
86-11	44.8	0.88	13.8	11.0	0.23	3.84	8.61	2.69	0.89	0.07	13.0	0.0
86-40	45.9	0.69	12.4	8.98	0.22	5.09	9.45	2.10	0.75	0.06	12.8	0.1
86-47	54.8	0.96	17.2	11.0	0.11	4.50	1.81	1.48	2.47	0.12	2.0	0.3
86-48	42.2	0.81	13.9	13.1	0.19	5.86	6.82	1.25	1.82	0.06	10.1	0.0
86-51	46.9	0.61	12.5	8.49	0.20	5.93	7.82	2.99	0.46	0.04	10.5	0.0
86-52	45.8	0.54	11.8	7.96	0.20	5.58	9.70	2.98	0.49	0.05	13.4	0.0
86-53	41.1	0.56	12.6	6.92	0.16	4.84	11.9	2.37	0.75	0.04	16.7	0.0
86-54W	43.5	0.66	12.0	8.81	0.24	5.26	8.97	3.19	0.94	0.05	13.6	0.0
86-67	46.6	0.66	14.5	5.43	0.23	5.13	1.11	1.88	0.98	0.07	15.5	0.1

Table 2b. Trace element geochemistry of selected samples from the Owl Creek open pit (modified from Kingston 1987). All samples are of basalts from the open pit.

Sample ID	Ba (ppm)	Ag (ppm)	Be (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	La (ppm)	Ni (ppm)	Pb (ppm)
86-10	20	- -	0.4	34	140	88	3	53	0
86-11	180	- -	0.6	45	80	130	3	65	1
86-40	80	1	0.7	45	98	100	3	65	7
86-47	340	0	1.1	45	130	71	18	130	2
86-48	190	0	0.6	49	34	120	3	67	0
86-51	20	0	0.4	25	110	97	3	80	4
86-52	50	1	0.3	27	120	98	3	61	0
86-53	60	1	0.4	39	100	72	3	80	6
86-54W	80	1	0.4	43	100	97	3	81	7
86-67	170	1	0.5	46	95	120	2	82	3
Sample ID	V (ppm)	Yb (ppm)	Zn (ppm)	Au (ppb)	B (ppm)	Mo (ppm)	W (ppm)	As (ppm)	Sb (ppm)
86-10	190	1.4	87	89.3	15.3	0.8	9.0	56.4	<0.5
86-11	240	1.8	130	471.2	50.1	1.4	17.0	188.3	1.1
86-40	220	1.3	49	649.3	36.7	0.5	29.5	290.8	1.3
86-47	210	2.0	130	43.5	205.1	1.1	5.4	80.6	<0.5
86-48	270	1.7	120	4.4	571.0	<0.5	2.7	82.7	0.9
86-51	210	0.9	55	8.1	15.3	<0.5	4.9	31.2	0.5
86-52	190	1.1	46	2.2	18.2	<0.5	2.2	58.8	<0.5
86-53	190	1.0	31	7.8	41.6	0.7	2.1	58.7	<0.5
86-54W	210	1.0	56	20,949.1	17.7	<0.5	18.8	985.3	1.1
86-67	220	1.4	50	67.2	42.1	0.5	1.2	294.5	0.8

STRUCTURAL GEOLOGY

Stratigraphy

All of the stratigraphic units at Owl Creek strike in an east-northeasterly direction, and while local reversals are present, the units dip variably to the north ranging from 45° to 90°. Initial work by Canico in the open pit area suggested that the stratigraphic units were part of a homoclinal sequence dipping to the north and younging to the south (Figure 5), however reversals in younging directions to the west of the open pit suggested the presence of folding (Brisbin 1986). Subsequent exploration and development work has confirmed this original suspicion of folding and has shown that the basaltic rocks located within the open pit are indeed the folded equivalents of the larger band of mafic – ultramafic volcanic rocks that host the Hoyle Pond orebodies (Figure 6). As well, the fold patterns observed in Figure 6 are consistent with the expression of a D1 fold event resulting from a predominately north-south compression.

This D1 event is expressed as a penetrative fabric observed by Barclay (1994) at the Marlhill Mine Project, and as the Hoyle Anticline as described by Rhys (1996) at the Hoyle Pond Mine. A well developed foliation is present in all rock types in the open pit and is described by Brisbin (1986) as:

> "A pervasive schistosity (S1) is developed at 070/85°N throughout the area. Its oblique orientation to bedding (S0) is apparent in greywackes where the intersection of these two fabrics causes the greywacke to break into wedge-shaped pieces. Thin section examination of basalts from both deposits reveals that schistosity in the basalts is defined by orientation of sericite, which along with carbonate, comprises the bulk of the altered basalts. Development of S1 schistosity post-dating or synchronous with sericitization is implied."

A stereonet plot of structural data obtained by Brisbin (1986) from the 2 Bench of the Owl Creek open pit (Figure 7) shows that although there are some variations in the overall trends, the general orientation of bedding in the sedimentary units is approximately 084 / 74° N. Although a fair degree of scatter is present in the data, it is clear that the foliations that developed predominantly in the basalt unit are clustered about an approximate orientation of 062 / 84° N. A closer examination of the foliation data reveals a crude but systematic variation in the scatter that suggests the presence of a second folding event resulting from an east-west compression with a steeply north plunging fold axis.

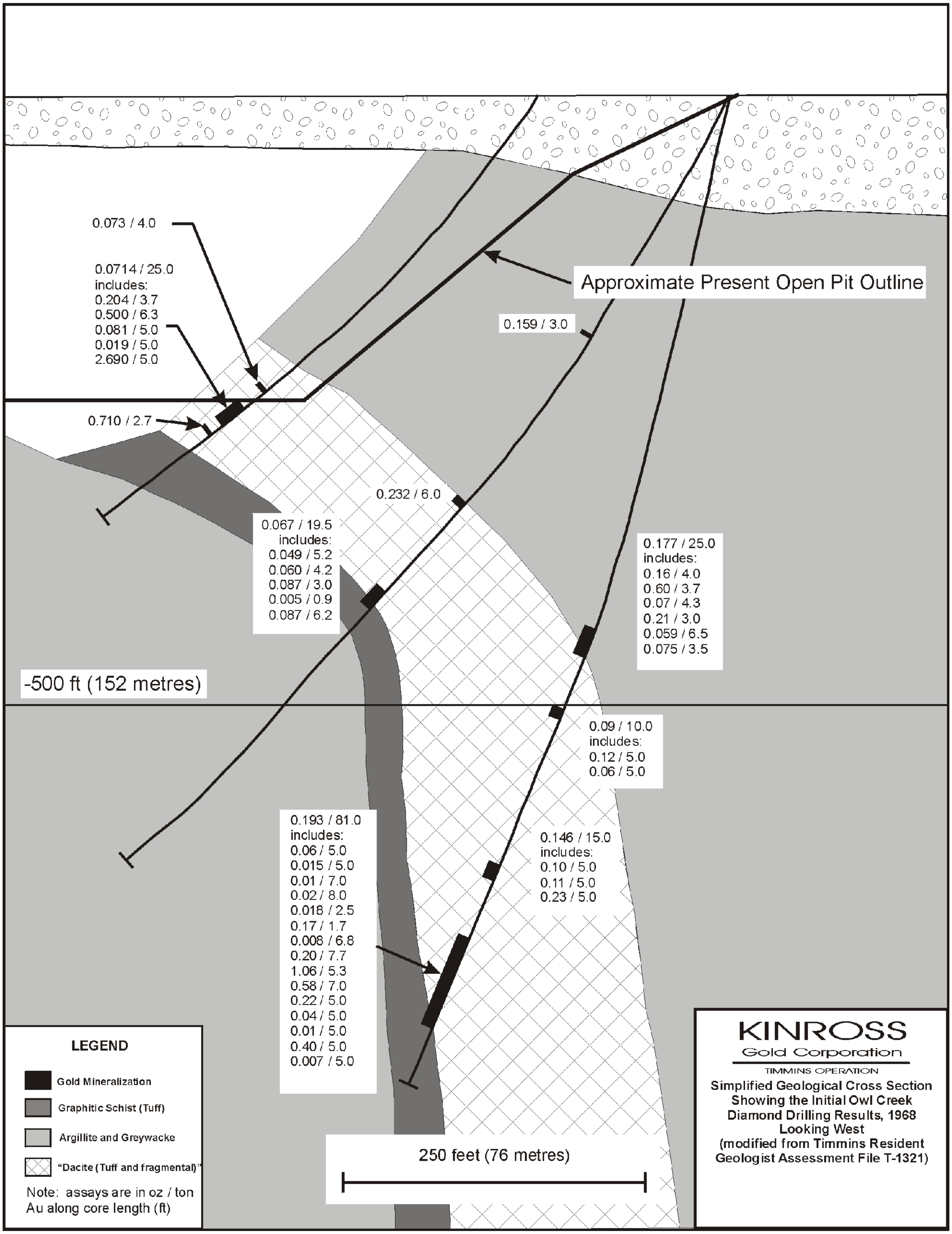

0.073 / 4.0
0.0714 / 25.0
includes:
0.204 / 3.7
0.500 / 6.3
0.081 / 5.0
0.019 / 5.0
2.690 / 5.0
Approximate Present Open Pit Outline
0.159 / 3.0
0.710 / 2.7
0.232 / 6.0
0.067 / 19.5
includes:
0.049 / 5.2
0.060 / 4.2
0.087 / 3.0
0.005 / 0.9
0.087 / 6.2
0.177 / 25.0
includes:
0.16 / 4.0
0.60 / 3.7
0.07 / 4.3
0.21 / 3.0
0.059 / 6.5
0.075 / 3.5
-500 ft (152 metres)
0.09 / 10.0
includes:
0.12 / 5.0
0.06 / 5.0
0.193 / 81.0
includes:
0.06 / 5.0
0.015 / 5.0
0.01 / 7.0
0.02 / 8.0
0.018 / 2.5
0.17 / 1.7
0.008 / 6.8
0.20 / 7.7
1.06 / 5.3
0.58 / 7.0
0.22 / 5.0
0.04 / 5.0
0.01 / 5.0
0.40 / 5.0
0.007 / 5.0
0.146 / 15.0
includes:
0.10 / 5.0
0.11 / 5.0
0.23 / 5.0
LEGEND
Gold Mineralization
Graphitic Schist (Tuff)
Argillite and Greywacke
"Dacite (Tuff and fragmental)"
Note: assays are in oz / ton
Au along core length (ft)
250 feet (76 metres)
KINROSS
Gold Corporation
TIMMINS OPERATION
Simplified Geological Cross Section
Showing the Initial Owl Creek
Diamond Drilling Results, 1968
Looking West
(modified from Timmins Resident
Geologist Assessment File T-1321)

Figure 5.

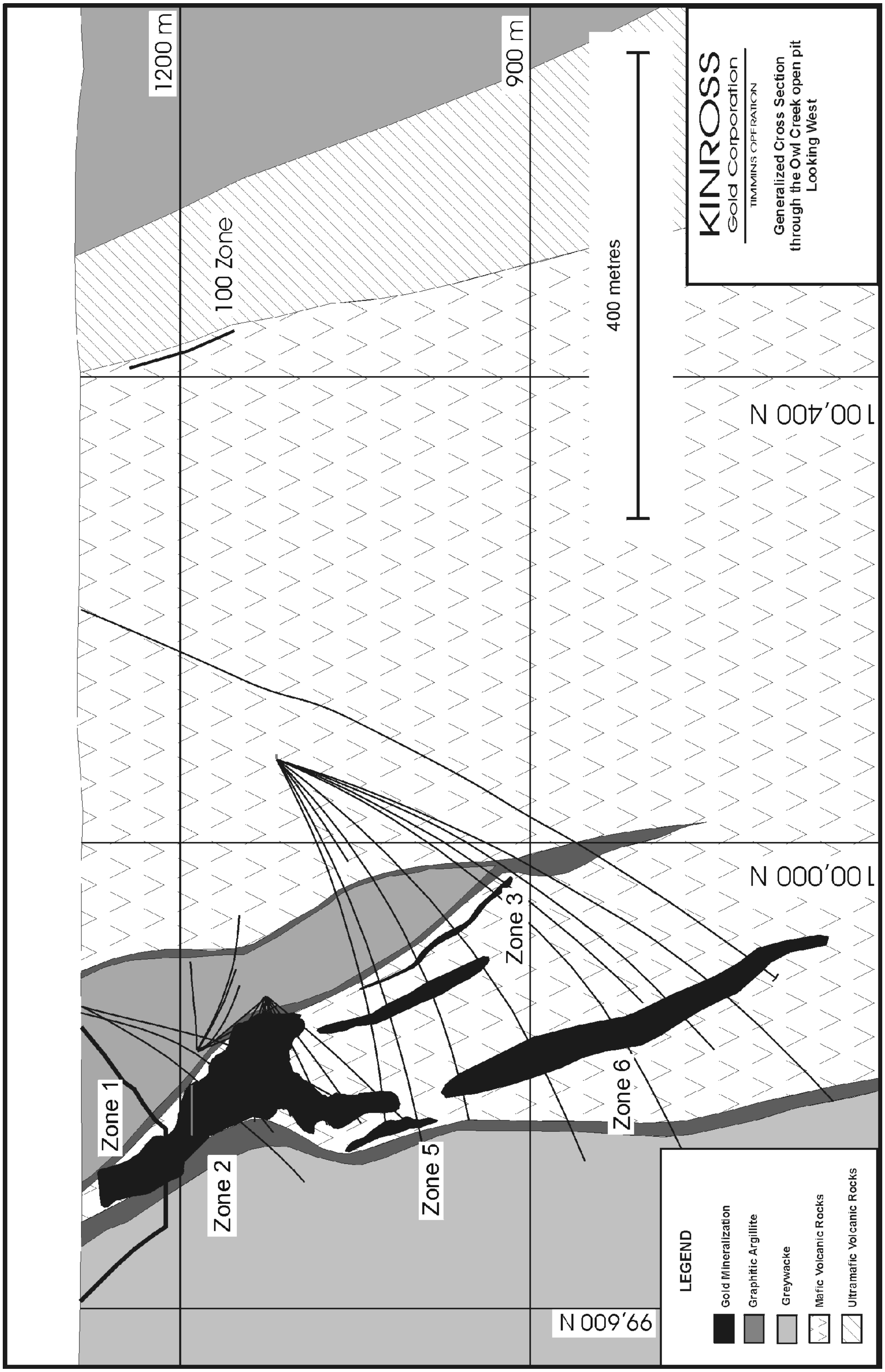

1200 m
900 m
100 Zone
400 metres
KINROSS
Gold Corporation
TIMMINS OPERATION
Generalized Cross Section
through the Owl Creek open pit
Looking West
100,400 N
100,000 N
99,600 N
Zone 1
Zone 2
Zone 3
Zone 5
Zone 6
LEGEND
Gold Mineralization
Graphitic Argillite
Greywacke
Mafic Volcanic Rocks
Ultramafic Volcanic Rocks

Figure 6.

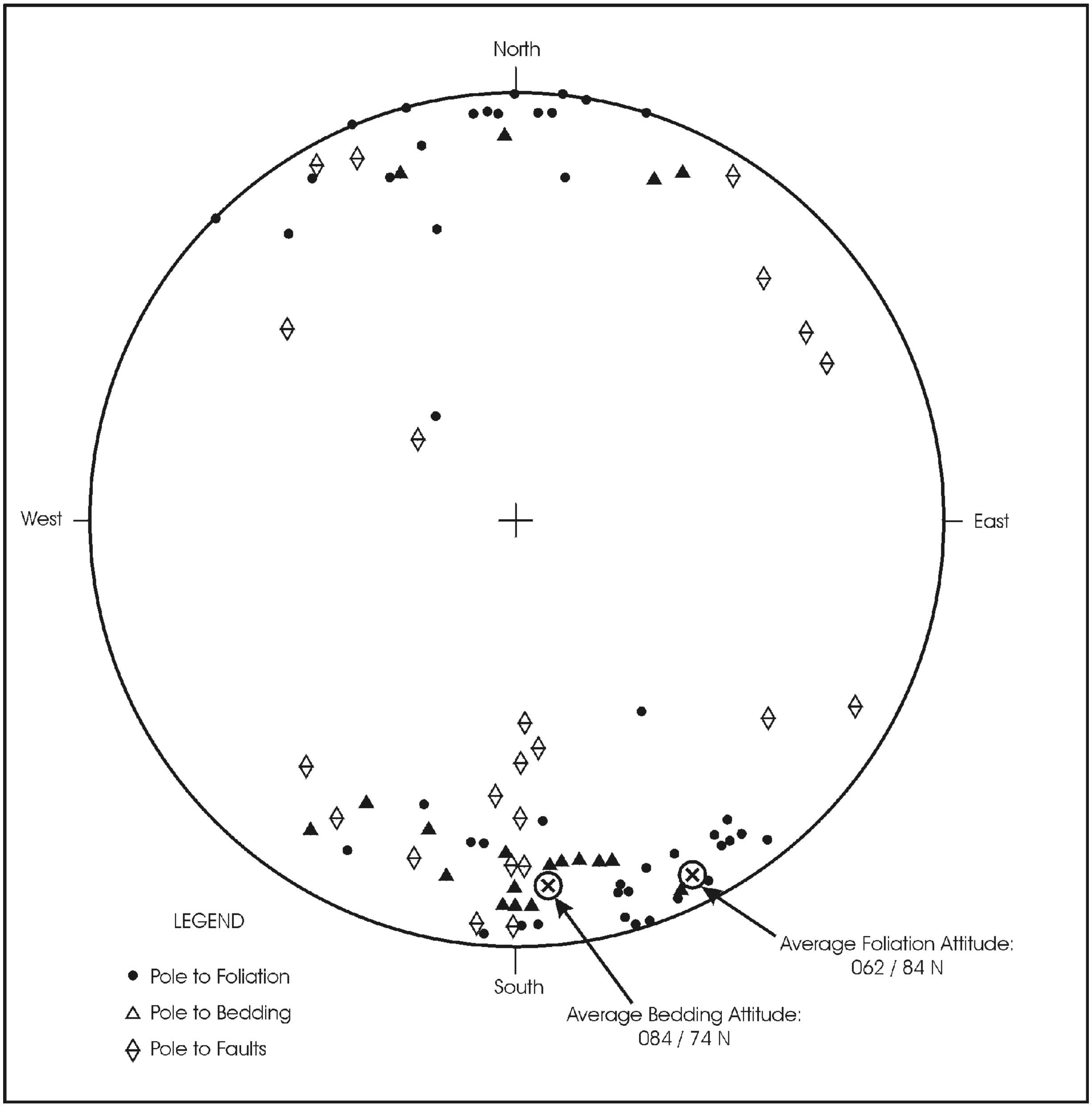


Figure 7. Stereographic projection of selected structural data from the 2 Bench of the Owl Creek open pit mine (data from Brisbin 1986).

Faults and Shears

Two generations of faults and shears are present in the Owl Creek open pit. The oldest of these structures is a shearing event that has most severely impacted the graphitic sediments, and the younger event is a system of northeasterly and northwesterly oriented brittle cross faults. These younger faults have an important control on the distribution of gold mineralization in that they control the distribution of the favourable basalt host unit (Figures 8 and 9). Brisbin (1986) describes these faults and shears as follows:

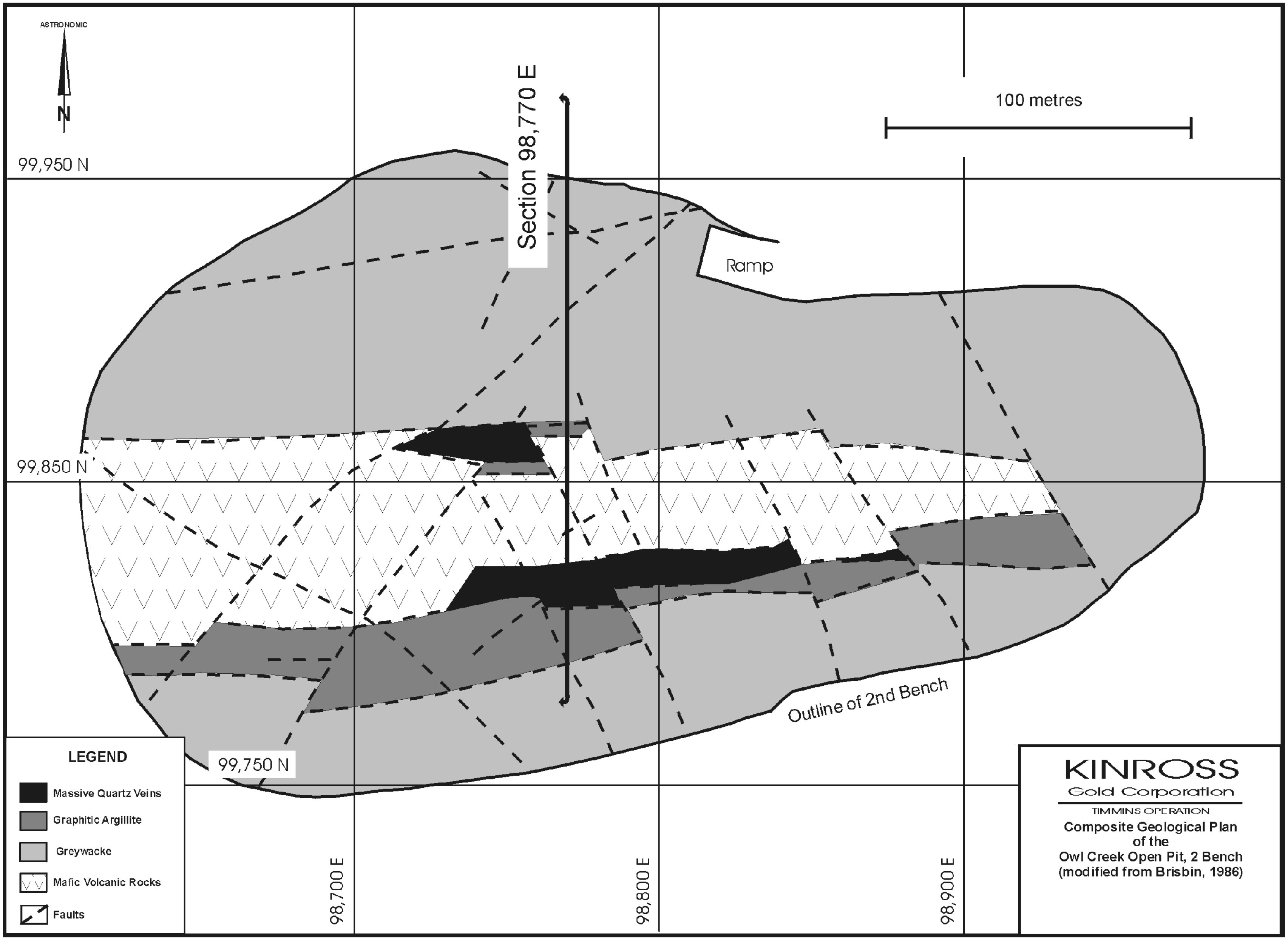
> "At Owl Creek both lithologic contacts are strongly sheared. The shearing, defined by the development of an intense schistosity parallel to the lithologic contacts (with an average distribution of 090/80°N) is most strongly expressed in carbonaceous argillites or "graphites" along those contacts. A zone of schistose "graphite", up to 25m wide, is present along the south contact in the pit. A similar unit is discontinuously developed and generally only 0.5 to 1.0 m wide along the north contact in the pit. On the 105 m underground level schistose "graphites" are well developed on the northern contact and, indeed, presented ground problems during the underground development.
>
> Veins and lithologic contacts have been offset along steeply dipping northwest to northeast-striking faults present throughout the map area. Mapping at Owl Creek has revealed that these crosscutting faults are abundant. Displacement along these structures is unknown but both strike-slip and dip-slip displacements are observed …, the latter evidenced by sudden changes in the thicknesses of lithologic units on either side of a fault. Horizontal displacement on many of the cross-faults in the Owl Creek pit is only in the order of a few metres. Significant strike-slip offsets, in the order of 50 m appear to be limited to a few northwest-striking faults spaced at a 300 to 500 m interval … . Strike-slip displacement is right-handed on the northwest-striking faults. Variable offset of units along the strike of crosscutting faults at Owl Creek … indicates a scissor-like movement of these structures."

ECONOMIC GEOLOGY

Production History

Following the initial discovery of gold by Canico in 1967, two zones of gold mineralization were located hosted by pyrite-bearing, quartz veined mafic volcanic rocks. The western of these two zones would eventually be mined by open pit methods, and the eastern zone is currently termed the "Owl Creek East" zone by Kinross Gold Corporation. An agreement to develop the property was signed with Kidd Creek Mines Ltd. in 1979. Kidd Creek Mines Ltd. subsequently created Falconbridge Gold Corporation in 1987. Falconbridge Gold Corporation was then purchased by Kinross Gold Corporation in 1994.

A surface and underground exploration program was conducted in the 1981-1982 period whereby a decline was advanced into both the West and East zones, and a bulk sample was taken from the –105m level from the West Zone. Open pit operations began in 1982 and continued through to closure in 1989, with some gold being produced from processing of stockpiled ore in 1990. A detailed summary of the annual gold production is given in Table 3, and a tabulation of the Mineral Inventory as at December 31, 1997 is given in Table 4.



ASTRONOMIC
N
Section 98,770 E
100 metres
99,950 N
Ramp
99,850 N
Outline of 2nd Bench
99,750 N
98,700 E
98,800 E
98,900 E
LEGEND
Massive Quartz Veins
Graphitic Argillite
Greywacke
Mafic Volcanic Rocks
Faults
KINROSS
Gold Corporation
TIMMINS OPERATION
Composite Geological Plan
of the
Owl Creek Open Pit, 2 Bench
(modified from Brisbin, 1986)

Figure 8.

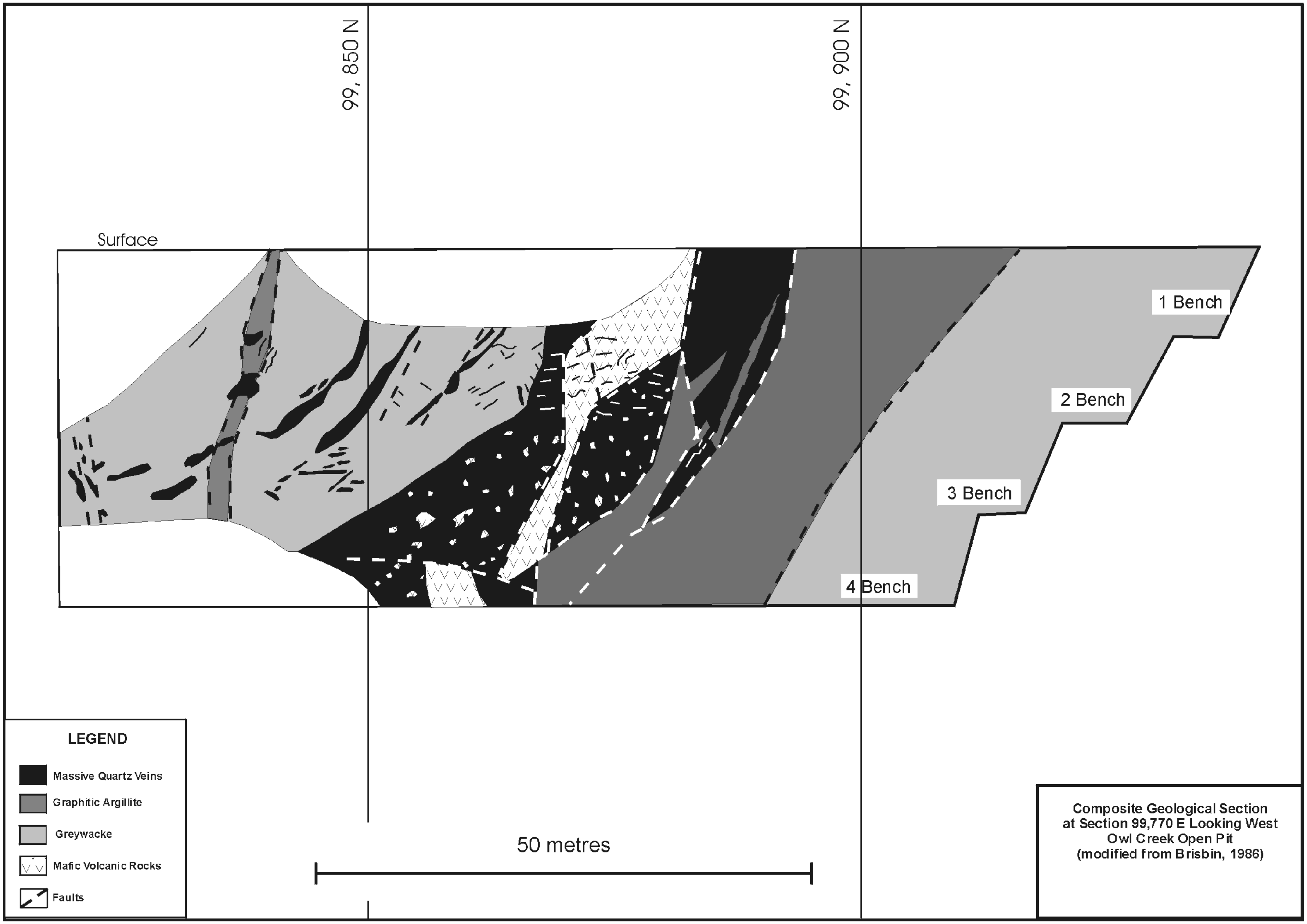

99, 850 N
99, 900 N
Surface
1 Bench
2 Bench
3 Bench
4 Bench
LEGEND
Massive Quartz Veins
Graphitic Argillite
Greywacke
Mafic Volcanic Rocks
Faults
50 metres
Composite Geological Section
at Section 99,770 E Looking West
Owl Creek Open Pit
(modified from Brisbin, 1986)

Figure 9.

Table 3. Summary of the Production History at the Owl Creek Mine. Data compiled from Timmins Resident Geologist's Annual Reports and corporate annual reports and prospectus.

Year	Tonnes Milled	Average Grade (g/t Au)	Recovered Ounces	Recovery (%)	Cash Cost (US $ / ounce produced)
1982	250 000	4.1	32 958		
1983	239 000	4.1	31 508		
1984	280 000	4.0	36 013		
1985	280 000	3.9	35 113		
1986	150 979	5.8	21 707	76.9	213
1987	175 444	5.3	25 886	86.9	196
1988	99 996	5.4	16 384	93.6	290
1989	158 645	4.7	19 866	83.3	250
1990	151 904	4.1	17 445	88.2	
TOTAL	**1 785 968**	**4.12**	**236 880**		

Table 4. Summary of the Mineral Inventory of the Owl Creek Mine area. Data from Kinross Gold Corporation 1997 Annual Report.

Zone	Tonnes	Grade (g/t Au)	Contained Ounces Au
Owl Creek (West)			
– above –200 meters	5 709 954	2.31	424 116
– below –200 meters	821 000	9.79	258 443
Subtotal	6 530 954		682 559
Owl Creek East	3 019 685	7.17	696 371
Kinross-Blackhawk-Thunderwood JV	327 230	7.14	75 126
Vogel Property (Blackhawk Option)	1 706 570	8.38	459 678
TOTAL	**11 584 439**		**913 734**

Mining Methods

Mining operations at Owl Creek were done using open pit mining methods. Individual benches were on the order of 10 metres in height, with the overall slope angle being approximately 44°. The pit bottom is at a vertical depth of approximately 90 metres and the pit is currently flooded. Underground access to both the Owl Creek (West) and Owl Creek East zones is via a ramp driven at a grade of –17%. Three levels have been established to allow examination of the mineralization present beneath the open pit (Falconbridge Gold Corporation 1992). A ventilation raise connects the One Level to the open pit (Figure 10).

Description of Orebodies

The gold present in the Owl Creek orebody occurred in two styles: 1) as microscopic grains associated with pyrite mineralization (Photo 5), and 2) as native gold hosted within quartz veins.

Pyrite mineralization was best developed associated with quartz veins and stockworks within the central basalt unit (Photo 6), however disseminated pyrite containing sub-economic to economic gold values is hosted locally within the greywacke and carbonaceous argillite units. In describing the character of this gold-bearing pyrite, Brisbin (1986) writes:

> "Fine grained, disseminated, subhedral to euhedral pyrite comprises <1 to 10% of altered basalts at Owl Creek. Pyrite content decreases in less intensely veined basalts but pyrite abundance has no correlation with the size of the vein. Pyrite varies in size from <0.001mm to 5mm, but the bulk of the pyrite comprising a portion of the alteration assemblage is <0.2mm. This mode of occurrence of pyrite appears to be late in the alteration / mineralization history as it is present as well-formed grains which locally contain inclusions of quartz, sericite and carbonate. Pyrite is rare or only present in minor amounts in the actual veins. Fine-grained, disseminated pyrite comprises approximately 10% of the angular dark basalt inclusions which make up 10 to 40% of "milled zone" quartz veins which parallel sedimentary/volcanic contacts at Owl Creek.

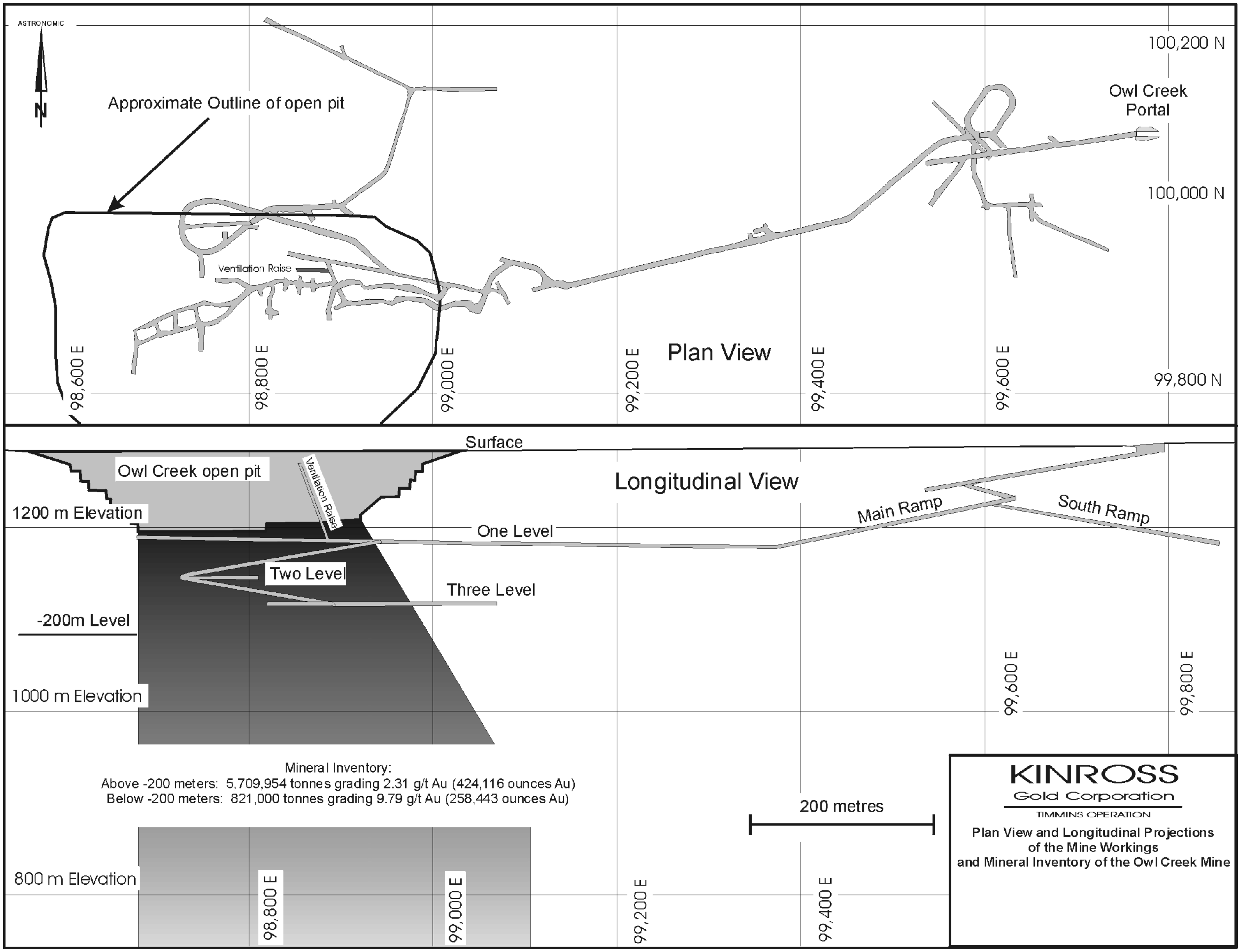

ASTRONOMIC
N
Approximate Outline of open pit
Ventilation Raise
Owl Creek
Portal
100,200 N
100,000 N
99,800 N
98,600 E
98,800 E
99,000 E
99,200 E
99,400 E
99,600 E
Plan View
Surface
Owl Creek open pit
Ventilation Raise
Longitudinal View
1200 m Elevation
One Level
Main Ramp
South Ramp
Two Level
Three Level
-200m Level
1000 m Elevation
99,600 E
99,800 E
Mineral Inventory:
Above -200 meters: 5,709,954 tonnes grading 2.31 g/t Au (424,116 ounces Au)
Below -200 meters: 821,000 tonnes grading 9.79 g/t Au (258,443 ounces Au)
200 metres
800 m Elevation
98,800 E
99,000 E
99,200 E
99,400 E
KINROSS
Gold Corporation
TIMMINS OPERATION
Plan View and Longitudinal Projections
of the Mine Workings
and Mineral Inventory of the Owl Creek Mine

Figure 10.

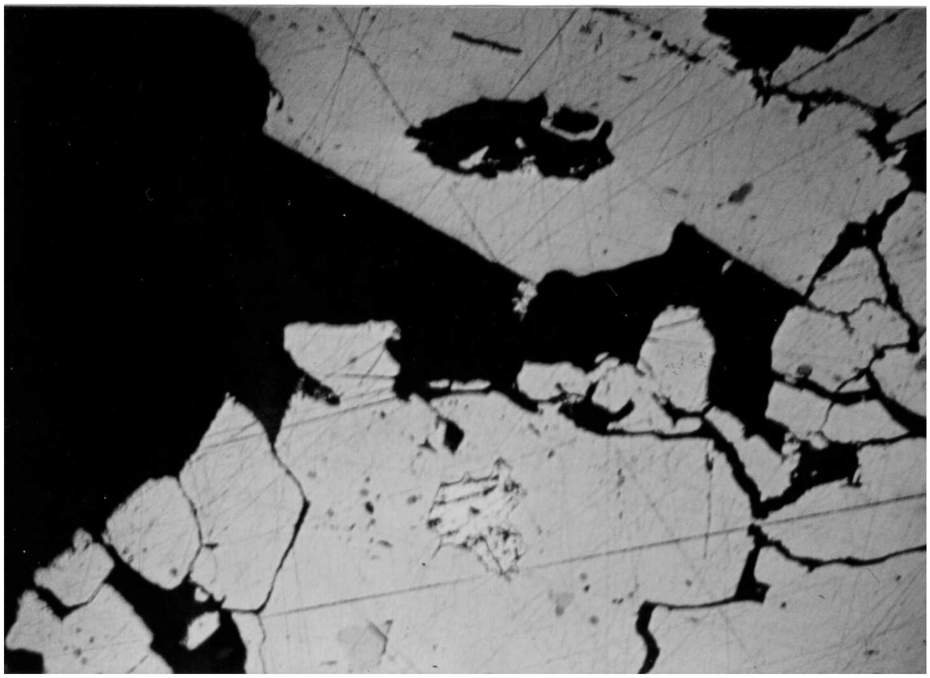


Photo 5. Polished thin section showing gold occurring as inclusions within pyrite, and along pyrite-gangue grain boundaries. Reflected light, field of view is 0.6mm, Owl Creek open pit. Photo provided courtesy of Dan Brisbin.

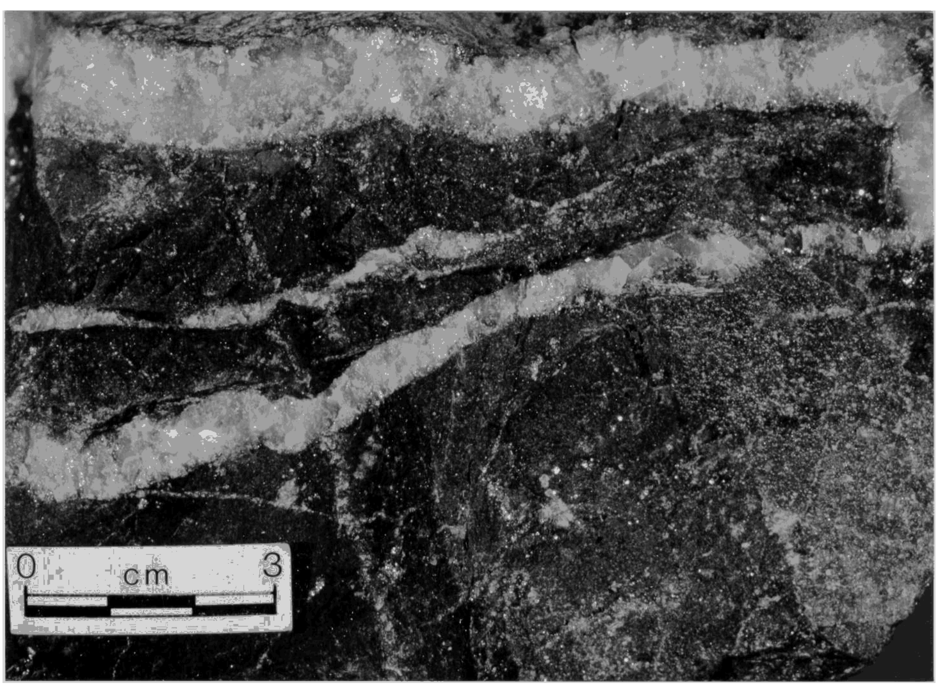


Photo 6. Example of quartz veining, disseminated pyrite, and alteration from the Owl Creek open pit. Photo provided courtesy of Dan Brisbin.

The bulk of the gold at Owl Creek is hosted as inclusions in the fine euhedral pyrite documented as part of the alteration assemblage adjacent to quartz-carbonate veins. Occasionally, visible gold is observed along carbon/quartz contacts in veins in which carbon is present, and along vein margins and within fractures in the quartz (Photo 7). Pyrite and gold appear to have been deposited late in the sequence of veining and alteration as evidenced by inclusions of quartz, sericite and carbonate in pyrite grains which show none of the replacement by the above minerals present in the earlier, coarser pyrite. Free gold occurs in fractures within quartz veins and as such is obviously deposited at a late stage in vein development. Veining, alteration and pyritization are most intense and gold grades highest in basalts adjacent to contacts with sedimentary rock to the north and south (Figure 11). In general the central portion of the basalt units is light grey, massive and hosts minor amounts of quartz veining, pyrite, and gold. Gold is also hosted in fine pyrite within greywacke-hosted ore in the east end of the pit. Ore and near-ore grades have also been obtained over narrow widths in pyritic, carbonaceous sediments south of the main orebody."

The pyrite contained within the greywacke and carbonaceous argillite units occurs in two principle forms: 1) as nodular pyrite hosted principally by carbonaceous argillite units, and 2) as disseminated euhedral pyrite hosted by both the greywackes and carbonaceous argillites. Part of the study done by Elliot (1984) examined the sulphur isotopic distribution and trace element variations associated with the gold mineralization at the Owl Creek Mine. As summarized in Figure 12, it is clearly apparent that the sulphur contained within the nodular pyrite is separate and distinct in it's δS^{34} signature from the gold – bearing pyrite contained within the basalt unit. It is also clear that all of the samples of gold – bearing pyrite contained within the basalt unit have positive δS^{34} signatures that range in value from +1.8 to +3.3 per mil, suggesting a unique isotopic signature for the hydrothermal pyrite at Owl Creek. While this concept holds true in general, in detail one can see that the sulphur isotopic compositions from pyrites contained within the greywackes and carbonaceous argillites range in value from –2.2 to +4.3 per mil. These samples also have a range in gold and arsenic abundances such that no clear pattern emerges. Unfortunately, no description of the nature of the pyrite (ie. euhedral / disseminated or nodular) was given for these samples. Observations of the textural variations of the hydrothermal pyrite by Brisbin (1986) indicated that at least some of the hydrothermal pyrite post-dates development of the sericite-carbonate alteration minerals. This observation is reinforced by a mineralogical study by Scott (1994) of polished thin sections of selected diamond drill core who determined the following paragenetic history at Owl Creek:

Stage	Mineralogy
I	Andesite (?) + Ti-magnetite
II	Albitization + pyrite (I)
III	Shearing + Gray Chlorite
IV	Pyrite (II)
V	Silicification + Arsenopyrite + Au (I) + Pyrite (III)
VI	Dolomite + Pyrrhotite
VII	V5 Quartz Veinlets + Au (II)
VIII	Fracturing + Quartz/Calcite Vein + Tourmaline
IX	Fracturing + Au (III) + Muscovite (pale-green hydromuscovite)
X	Pyrite (IV)

Quartz veining at Owl Creek was best developed within the basalt host unit, but veins were also present in the greywackes and carbonaceous argillites. Brisbin (1986) describes these quartz veins as follows:

"At Owl Creek, wide zones of barren, white quartz including angular inclusions of pyritized, altered basalt and larger irregular inclusions of deformed "graphite" are present in the pit) and at the 105m level on the south and north basalt/"graphite" contacts respectively (Photos 8, 9, and 10). The vein exposed along the southern basalt/graphite contact in the pit varies in thickness and in abundance of contained fault-bounded, deformed, "graphite" lenses due to dissection by post-vein faulting and shearing. The vein is an average of 5 m thick but is locally absent and locally up to 20 m thick.

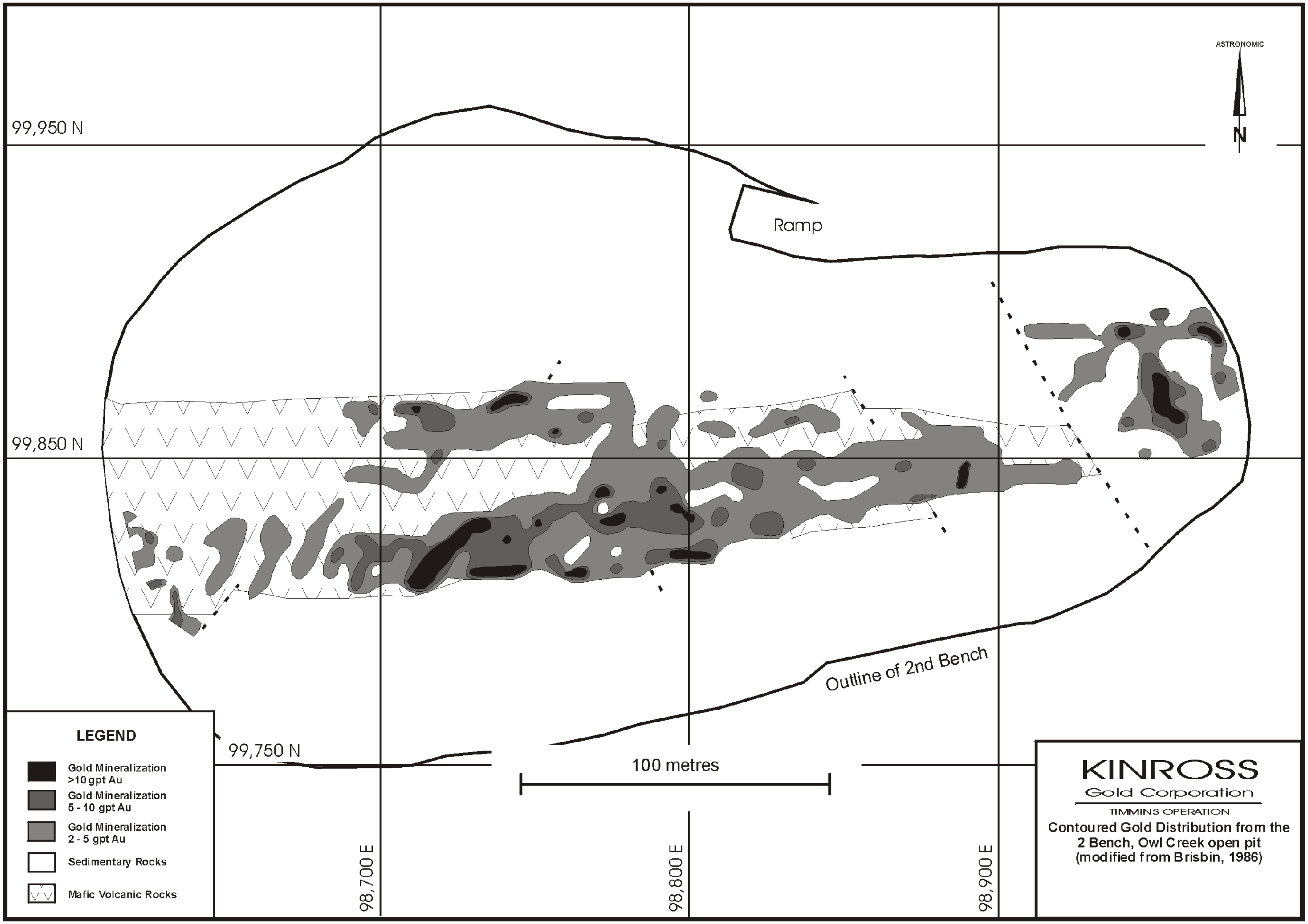
… Within the basalt unit itself at Owl Creek white quartz veins, with or without ankerite, fill gently to moderately dipping fractures (Photo 11). Quartz veins are also present but less abundant parallel and subparallel to schistosity. Gently to moderately dipping "flat veins" are locally up to 2 m thick but are commonly less than 20 cm thick. Veins parallel or subparallel to schistosity are generally less than 20 cm thick. Both vein sets have been deformed.

… Veins at a high angle to schistosity, i.e. "flat veins" are characterized by shortening (Photo 12). This is typified by a long wavelength rolling attitude in the pit. Tighter folding is locally present, particularly adjacent to major structures. These veins are typically dragged into and offset by east to northeast striking faults and shear zones.

Veins parallel or subparallel to S1 have undergone extension or show little deformation. Elongation fabrics include boudinage of the veins and wrapping of the S1 schistosity around the boudins.

A plunge averaging 20°→ 070° is present in Owl Creek West Zone (pit) defined by elongation of quartz boudins. This plunge is also apparent by the progressive change in location of areas of high grade gold mineralization towards the northeast with depth on contoured grade plans for the first four benches at Owl Creek. In detail, plunge reversals to the west have been mapped in the Owl Creek pit. These are thought to be the results of tilting of blocks during movement on crosscuting faults. A moderate plunge to the west in folded veins of Owl Creek East Zone is likely the result of the same process."

Photo 7. Native gold associated with graphitic inclusions in quartz vein. Photo from the display case of Kinross Gold Corporation.


ASTRONOMIC
N
99,950 N
99,850 N
99,750 N
Ramp
Outline of 2nd Bench
100 metres
98,700 E
98,800 E
98,900 E
LEGEND
Gold Mineralization >10 gpt Au
Gold Mineralization 5 - 10 gpt Au
Gold Mineralization 2 - 5 gpt Au
Sedimentary Rocks
Mafic Volcanic Rocks
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TIMMINS OPERATION
Contoured Gold Distribution from the
2 Bench, Owl Creek open pit
(modified from Brisbin, 1986)

Figure 11.

Sample No.	Rock Type	Pyrite Type	Au (ppb)	As (ppm)	δS^{34} (per mil)
OWL - 1	Greywacke		<5	62	1.2
OWL - 2	Greywacke		10	17	2.8
OWL - 3	Greywacke		<10	52	0.4
OWL - 4	Greywacke		5	4	3.2
OWL - 5	Greywacke		205	156	2.2
OWL - 6	Greywacke		290	115	2.7
OWL - 15	Greywacke		<10	179	-1.0
OWL - 16	Greywacke		35	112	-1.4
OWL - 17	Greywacke		1740	223	2.2
OWL - 7	Basalt/Ore Zone		465	313	2.5
OWL - 8	Basalt/Ore Zone		9280	566	2.1
OWL - 9	Basalt/Ore Zone		950	616	1.9
OWL - 10	Basalt/Ore Zone		>15,000	1025	2.9
OWL - 11	Basalt/Ore Zone		2340	540	1.8
OWL - 12	Basalt/Ore Zone		5020	268	1.8
OWL - 13	Basalt/Ore Zone		140	268	3.3
OWL - 14	Basalt/Ore Zone		1810	4698	3.5
OWL - 28	Basalt/Ore Zone		75	363	2.0
OWL - 29	Basalt/Ore Zone		410	616	2.3
OWL - 18	Shale		505	1053	-0.6
OWL - 19	Shale		615	515	-2.7
OWL - 20K core	Shale	Nodular			-1.9
OWL - 20K rim	Shale	Nodular			-3.8
OWL - 20F core	Shale	Nodular			1.9
OWL - 20F rim	Shale	Nodular			-2.3
OWL - 20L core	Shale	Nodular			-5.0
OWL - 20L rim	Shale	Nodular			-4.5
OWL - 20L middle	Shale	Nodular			-1.7
OWL - 21	Shale		205	223	2.3
OWL - 22	Shale		100		-2.2
OWL - 23	Shale		140	290	2.7
OWL - 24	Shale		245	414	0.1
OWL - 25	Shale		310	540	-1.5
OWL - 26	Shale	High content	2470	616	2.8
OWL - 27	Shale	High content	2420	515	2.9
OWL - 30	Shale		195	643	-0.7
OWL - 31	Shale	Massive	2020	464	4.3

Note: Data taken from Elliott, 1984

KINROSS
Gold Corporation
TIMMINS OPERATION
Summary of Sulphur Isotopic Data, Owl Creek Mine

Figure 12.

Photo 8. View of a “milled zone” quartz breccia located along the southern basalt contact. east, Owl Creek open pit. Photo provided courtesy of Dan Brisbin.Looking

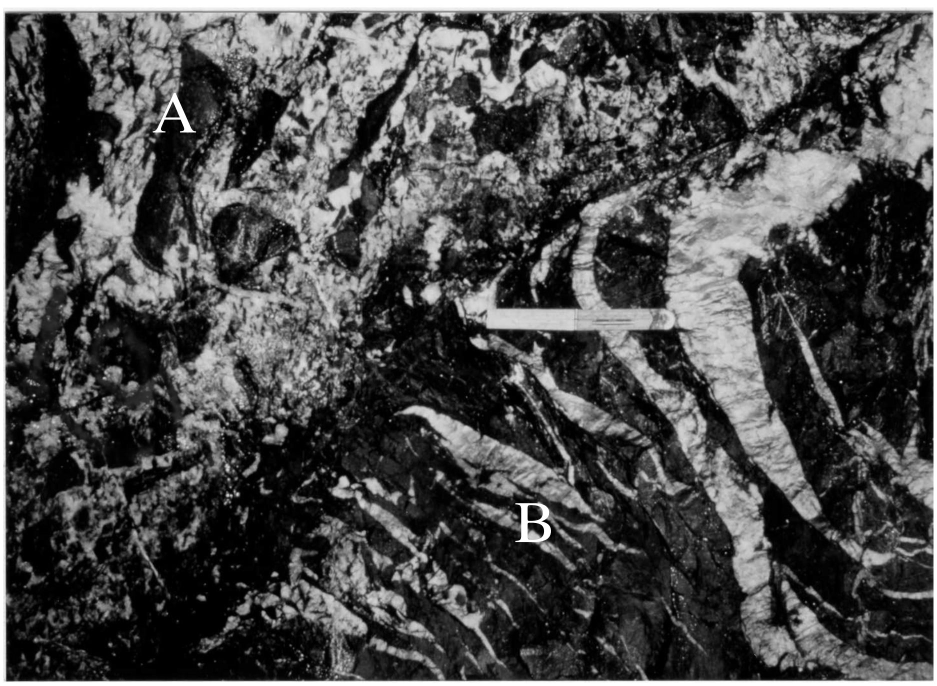

Photo 9. Contact between a “milled zone” quartz breccia vein (A) and basalt (B) located along the northern basalt contact. Looking east, -105 meter level, Owl Creek West Zone. Folding rule is 1 foot in length. Photo provided courtesy of Dan Brisbin.

Photo 10. Ribbon textured quartz vein developed parallel to the basalt/graphitic argillite contact, Owl Creek West Zone, 105 Level, 99,920N 99,870E, looking west. Folding rule is 1 foot in length. Photo provided courtesy of Keith Greene.

Photo 11. Well developed "flat veins" hosted in basalt. Safety vest for scale. Looking south, 1 Bench, Owl Creek open pit. Photo provided courtesy of Dan Brisbin.

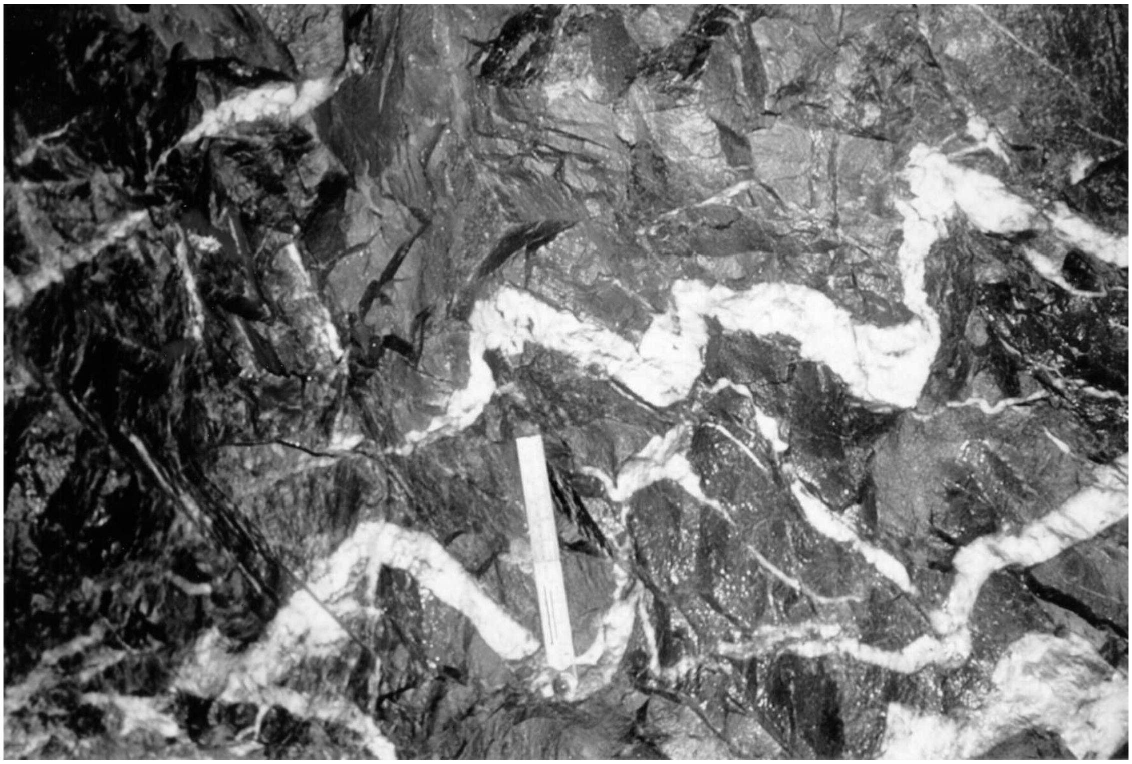

Photo 12. Example of gently dipping quartz veins affected by shortening, Owl Creek West Zone, 104-8-W-DR, looking east, 99,880N 99,720E. Notice development of moderate pervasive sericite alteration of the host basalt unit. Folding rule is 1 foot in length. Photo provided courtesy of Dan Brisbin.

Acknowledgements

The author thanks Kinross Gold Corporation, Randy Roussain (Chief Geologist, Hoyle 2000 Group), Keith Greene (Chief Geologist, Hoyle Pond Mine), and Sandra Young (Digital Centre) for their openness, support, and assistance in providing access to information and graphical materials for this description. Thanks also go to Dan Brisbin for his patience, support, and consent for allowing this description to draw heavily from his work at the Owl Creek Mine.

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Economic Geology and Mineralization of the Pamour Mine

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B. Kilbride, P. Coad and P. Harvey
Royal Oak Mines Inc.

INTRODUCTION

Land was first staked in the vicinity of the present day Pamour Mine in 1910. Gold was discovered that year in the vicinity of the Pamour Mine by the Three Nations Mining Co. Ltd. and the following year by La Palme Porcupine Mines Ltd., the two fore–runners of the present day Pamour Mine. A small amount of production was achieved from 1911 to 1914, however the property remained idle from 1914 to 1923. Various exploration activities were carried out by several mining syndicates until the property was acquired by Noranda in 1935. The Pamour Mine commenced full operations in 1936 and has produced almost 4 million ounces of gold from 44 million tons of ore at a recovered grade of 0.091 oz / ton to the end of 1997 (includes approximately 3 million tons and 229 000 ounces from the Hoyle South Property which is operated under a mining lease agreement with Kinross Gold Corporation).

The Pamour is the second oldest continuously operating gold mine in the Timmins camp and is the fourth largest historic producer of gold with about 8% of the camp total. It is also the shallowest of the four with the shaft extending to a depth of 3 100 feet below surface. The Pamour claims cover over 2.1 miles of the 7 mile strike length which makes up the Broulan Reef–Hallnor–Pamour–Hoyle complex.

LOCATION, OWNERSHIP AND CLAIMS

The Pamour Mine is located at the east end of the Porcupine gold camp in Whitney Township (Con. V–VII, Lot 3–6), in the District of Cochrane approximately 12 miles east of Timmins, Ontario (Figure 1). The property consists of 38 contiguous patented mining claims. Additional claims have been added to the property in recent years.

The mine was operated from 1936 to1986 by Pamour Porcupine Mines Ltd. (a Noranda Inc. subsidiary). The operation was sold in 1986 to Jimberlana Minerals and subsequently taken over by Giant Resources Limited, both of Australia. A mining lease agreement for the Hoyle Mine was negotiated with Falconbridge Gold Ltd. (now Kinross Gold Corp.) in 1989. Royal Oak Mines Inc. acquired the Pamour and Hallnor mines in 1990. The contiguous Broulan Reef property was acquired by Royal Oak in 1991.

REGIONAL GEOLOGY

The Pamour Mine is located along the Keewatin–Timiskaming unconformity where older Keewatin mafic and ultramafic metavolcanic rocks to the north ("Tisdale Group"; Pyke 1982), structurally overlie younger Timiskaming metasediments to the south ("Porcupine Group"; Pyke 1982) (Figure 2). The property covers slightly over 2 miles of this angular unconformity which dips steeply north at approximately 72° and has a strike of approximately N78°E. The angle between the unconformity and contacts within the volcanic stratigraphy ranges from 0° in some places to 30° in others. The unconformity is subparallel to, and about 1/2 mile north of the north dipping Destor Porcupine Fault zone.

LOCAL GEOLOGY

Stratigraphy

Progressing across the property from north to south (i.e. oldest to youngest), the principal lithologies are: mafic and ultramafic metavolcanic flows of Keewatin age, overlain by agglomerate and younger

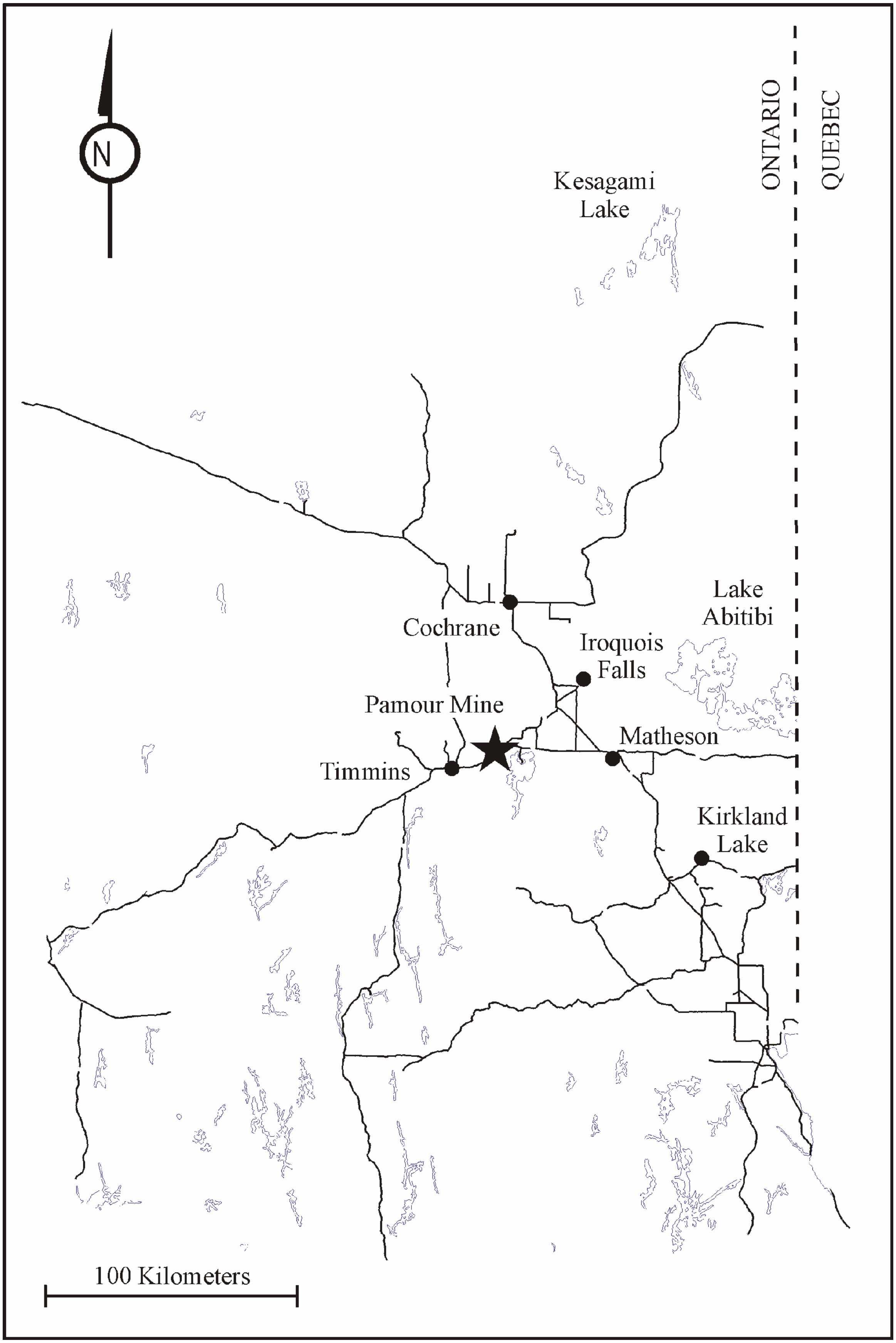
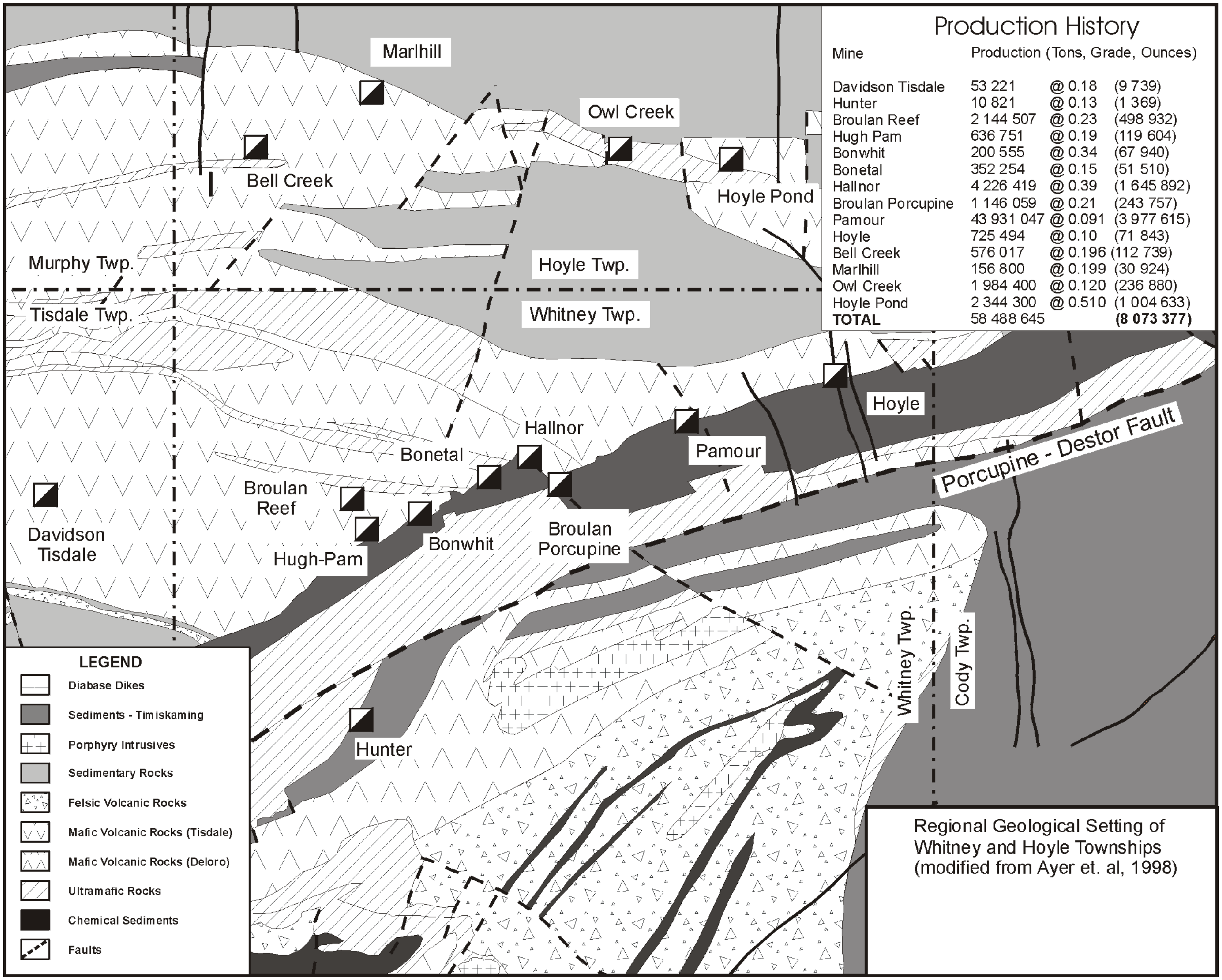


Figure 1. Location Map of the Pamour Mine.



Mine	Production (Tons, Grade, Ounces)		
Davidson Tisdale	53 221	@ 0.18	(9 739)
Hunter	10 821	@ 0.13	(1 369)
Broulan Reef	2 144 507	@ 0.23	(498 932)
Hugh Pam	636 751	@ 0.19	(119 604)
Bonwhit	200 555	@ 0.34	(67 940)
Bonetal	352 254	@ 0.15	(51 510)
Hallnor	4 226 419	@ 0.39	(1 645 892)
Broulan Porcupine	1 146 059	@ 0.21	(243 757)
Pamour	43 931 047	@ 0.091	(3 977 615)
Hoyle	725 494	@ 0.10	(71 843)
Bell Creek	576 017	@ 0.196	(112 739)
Marlhill	156 800	@ 0.199	(30 924)
Owl Creek	1 984 400	@ 0.120	(236 880)
Hoyle Pond	2 344 300	@ 0.510	(1 004 633)
TOTAL	58 488 645		**(8 073 377)**

Figure 2.

Timiskaming age north greywackes, conglomerate, and south greywackes (Figure 3). Sediments located along the extreme north boundary of the property may also be of Timiskaming age as they are locally marked with medium grained quartz rich greywackes and lapilli-sized clasts. A red jasper fragment was observed in a recent exploration hole from this unit.

KEEWATIN METAVOLCANIC ROCKS

The metavolcanic assemblage belongs to the lower portion of the Tisdale Group of the Keewatin Series. It consists predominantly of a series of high Mg-tholeiitic basalts intercalated with thick units of ultramafic talc-carbonate rocks of komatiitic or basaltic-komatiitic composition. High Fe-tholeiitic basalts are known to occur but are not extensive. Both massive and pillowed flows occur in the Pamour stratigraphy, however massive flows predominate.

The agglomerate unit is situated stratigraphically between the underlying Keewatin metavolcanic rocks and the Timiskaming metasediments, and marks the unconformity between them. It is doubtful that it is a true agglomerate but rather it is probably either a basal metavolcanic breccia (Aitken 1990), a flow top breccia, or a remnant erosional regolith. It is laterally and vertically discontinuous and locally occupies depressions along the paleo-topographic surface of the underlying metavolcanic rocks. It is a dark green, chloritic rock hosting predominantly angular to sub-angular clasts of metavolcanic origin and averages 20 to 30 feet in thickness.

TIMISKAMING METASEDIMENTS

The metasediments above and south of the unconformity are part of the Timiskaming assemblage ("Three Nations Lake Formation", Pyke 1982). Timiskaming sediments consist of several sequences of greywacke-turbidite and conglomerate.

The "North Greywacke" occurs between the unconformity to the north and the conglomerate to the south. It is a discontinuous silty turbidite sequence consisting of intercalated greywackes and slates that show a tendency to pinch and swell in some locations. Stratigraphically, it is located directly above the Timiskaming unconformity and below the Pamour conglomerate. The turbidite sequence in places may reach up to 60 feet in thickness.

The Pamour Conglomerate is generally clast supported, polymictic, and unsorted with pebble compositions varying from chert to porphyry. Individual clasts range from pebble to boulder size. The matrix is generally dark and muddy and its proportion to the clasts it hosts varies considerably. The conglomerate unit is lensoidal in shape which is characteristic of a submarine fan depositional origin. It is up to 60 feet thick and thins out at its margins at depth and to the east. The Pamour Conglomerate is harder and more prone to brittle failure than any of the other ore bearing rock types in the area, hence it was more amenable to hydrothermal solutions, and consequently contains more consistent gold mineralization than other rock types. Much of the Pamour Conglomerate has been mined by underground mining methods for decades.

The south greywacke lies stratigraphically above the Pamour Conglomerate and is in sharp contact with it. It is a sandy turbidite sequence consisting of a series of well-bedded intercalated slates and medium grained greywacke beds which locally possesses good metasedimentary structures. The unit averages 800 feet in thickness.

A second conglomerate unit which occurs in the metasedimentary sequence is a coarse grained, matrix supported rock with a minor amount of pebbles. It grades into an interbedded quartzite-greywacke sequence and is poorly sorted. In places it has minor pyrite and sub-economic gold mineralization. This unit locally contains fuchsitic ultramafic clasts and locally is marked by fine to medium grained biotite alteration.

INTRUSIVES

The only major intrusive rocks identified to date are Matachewan diabase dikes. Two such dikes occur at the east end of the property. They cross cut and post date all other structures. They dip steeply to the east,

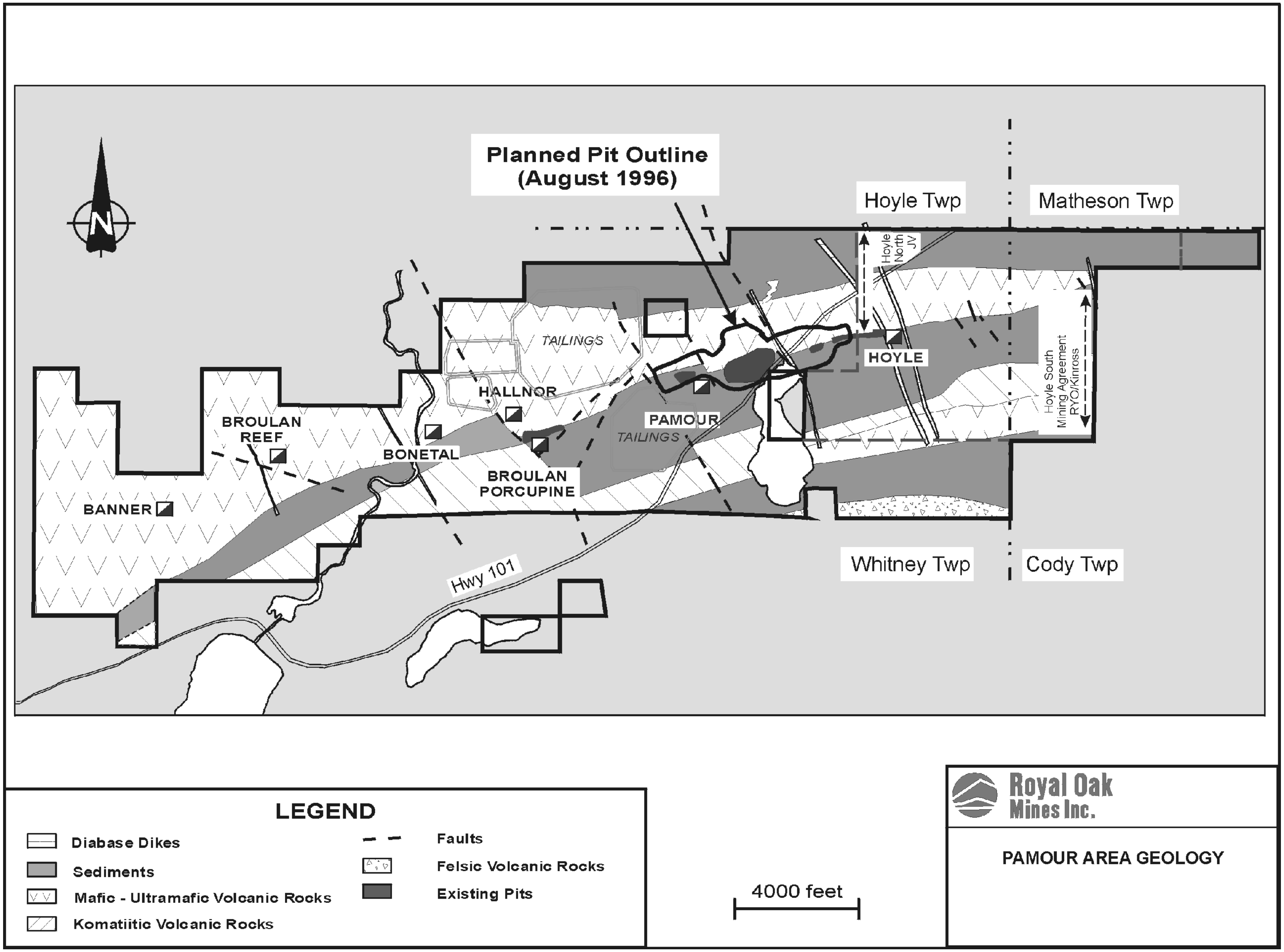

Planned Pit Outline
(August 1996)
Hoyle Twp
Matheson Twp
Hoyle North JV
Hoyle South Mining Agreement RYO/Kinross
TAILINGS
HALLNOR
BROULAN REEF
BONETAL
PAMOUR
TAILINGS
HOYLE
BROULAN PORCUPINE
BANNER
Whitney Twp
Cody Twp
Hwy 101
LEGEND
Diabase Dikes
Sediments
Mafic - Ultramafic Volcanic Rocks
Komatiitic Volcanic Rocks
Faults
Felsic Volcanic Rocks
Existing Pits
4000 feet
Royal Oak Mines Inc.
PAMOUR AREA GEOLOGY

Figure 3.

strike northwest, and vary in thickness from 10 feet to 100 feet wide. Unlike other lode gold deposits in the Porcupine camp, a porphyritic felsic intrusive has yet to be discovered at the Pamour.

Alteration

The metavolcanic assemblage is pervasively metamorphosed to lower greenschist facies. Detailed investigations of the nature of alteration assemblages have been made by Duff (1982), Aitken (1990), and Fan and Kerrich (1991). A composite of their observations are noted below:

At the mine scale a large halo of carbonate alteration occurs. Alteration is also characterized by additions of CO_2, K, Rb, Ba, and variable gains or losses of Na. In general, gold assays correlate well with increased albite/muscovite alteration, however the alteration halo is much larger than the gold content alone. Gold distribution does not appear to be controlled by the Fe/ (Fe + Mg) ratio of host rocks, but rather by alkali metal metasomatism. Generally, higher gold values correlate with increasing alteration intensity (Fan and Kerrich 1991).

Hydrothermal alteration in the metavolcanic wallrock is characterized by the dominant iron-rich carbonatization and chloritization, less abundant albitization and silicification, and minor sericitization and pyritization. Zonation is asymmetrical and discontinuous around hydrothermal centres, and forms separate inner and outer alteration assemblages. The inner assemblage may be under 100 feet thick, and is characterized by the presence of albite, quartz, pyrite and +/- talc. The outer assemblage is characterized by the reduction of albite and quartz, and the introduction of sericite. It may be several hundreds of feet thick (Aitken 1990). Trace sphalerite, galena and chalcopyrite are confined to quartz veins. Where narrow quartz veins break up into stockwork extension veins (eg. bulk ore hosted by mafic metavolcanic rocks) proximal to impervious lithologic contacts, increased silicification and pyritization of the wallrock occurs.

Hydrothermal alteration of the metasediments is more intense, pervasive, and penetrative than that observed in the metavolcanic rocks. Inner zonation in the extension vein bulk ore zones is dominated by quartz + carbonate + albite+sericite + pyrite (Aitken 1990), with minor arsenopyrite, sphalerite, and galena. Wallrock sulphidation of between 3% and 8% occurs around ore zones. Increased pyrite content correlates with increased gold content. Increased amounts of sphalerite and galena, although restricted to quartz vein filling material, also correlate with increased gold content. The outer alteration assemblage is characterized by reduced quartz, albite, pyrite, and sericite, as well as increased carbonate and the introduction of chlorite.

Sedimentary fault veins (eg. TN veins, see Section “Metasediment hosted fault - vein orebodies (TN veins)”) are less extensive in volume (ie. width) than their extension vein stockwork counterparts. The extent of penetrative alteration is therefore also less in the fault veins. Arsenopyrite becomes more dominant as a penetrative wallrock sulphide in the fault veins, as well as increased sphalerite content of the vein material.

In general, an increase in the pyrrhotite/pyrite ratio is indicative of an increase in the gold content.

Lithogeochemical Data

A tabulation of major and trace element geochemical abundances of selected representative samples from the major rock units at the Pamour Mine is given in Tables 1a and 1b below.

Table 1a. Major oxide geochemistry of selected samples from the Pamour Mine. Raw data taken from Fan and Kerrich (1991).

SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	LOI	Sum
Komatiites (Pyroxenitic to Peridotitic):											
35.1	0.36	5.66	9.58	0.28	14.4	12.0	0.005	0.005	0.03	22.8	100.5
31.2	0.37	6.24	11.30	0.26	12.4	14.16	0.005	0.005	0.03	23.8	100.2
34.0	0.52	8.61	13.80	0.43	16.0	6.81	0.03	0.005	0.04	19.4	99.8
36.6	0.35	5.09	9.67	0.16	18.5	5.90	0.13	0.005	0.03	23.5	100.2
31.5	0.30	4.30	9.37	0.22	18.4	9.43	0.03	0.005	0.02	26.5	100.3
36.9	0.37	5.37	9.73	0.14	18.0	5.94	0.04	0.005	0.02	22.8	99.7
23.9	0.45	5.67	11.10	0.14	20.5	9.24	0.05	0.005	0.02	28.0	99.5
29.6	0.21	2.94	8.47	0.22	19.6	9.78	0.05	0.005	0.02	29.2	100.3
33.7	0.39	5.52	9.34	0.15	19.0	6.38	0.64	0.005	0.02	24.2	99.7
41.6	0.32	5.34	9.94	0.11	20.5	5.27	0.22	0.005	0.03	16.5	100.2
36.5	0.26	3.52	9.11	0.32	19.4	10.80	0.12	0.005	0.03	19.3	99.6
47.0	0.39	5.85	10.70	0.07	23.6	1.94	0.52	0.005	0.03	8.8	99.2
37.2	0.33	4.90	9.90	0.24	23.0	7.46	0.13	0.005	0.03	16.1	99.6
39.8	0.31	4.39	9.13	0.14	25.9	4.57	0.06	0.005	0.02	15.1	99.8
33.7	0.29	4.31	7.31	0.17	16.7	11.10	0.05	0.25	0.03	26.2	100.36
39.8	0.34	4.53	7.96	0.14	20.1	3.30	0.24	0.005	0.02	23.2	100.0
37.3	0.41	5.38	11.00	0.13	21.0	1.55	0.04	0.005	0.03	22.6	100.0
35.9	0.33	4.36	9.25	0.24	14.5	11.80	0.80	0.005	0.04	22.8	100.3
46.8	0.55	8.61	13.50	0.24	15.2	8.25	0.83	0.07	0.04	5.1	99.5
Komatiites (Basaltic):											
43.5	0.53	8.82	13.8	0.34	6.7	9.71	0.07	1.03	0.03	15.5	100.14
51.7	0.48	8.89	7.8	0.33	4.0	9.53	2.24	1.24	0.04	13.5	100.15
39.1	0.41	7.20	14.0	0.47	9.7	10.50	0.005	0.04	0.03	18.4	99.85
46.8	0.51	8.28	13.3	0.45	6.9	10.60	0.02	0.005	0.04	12.4	99.80
43.1	0.38	7.06	11.7	0.28	11.7	12.20	0.03	0.005	0.03	13.2	100.06
47.3	0.57	8.28	10.4	0.36	4.6	13.90	1.22	0.02	0.04	13.1	100.2
54.3	0.62	10.6	13.1	0.31	6.2	7.40	2.59	0.05	0.03	3.7	99.46
High Mg-Tholeiites:											
45.7	0.47	15.0	9.09	0.18	7.03	5.40	6.10	0.02	0.05	11.3	100.50
39.3	0.23	16.5	8.10	0.19	11.50	6.97	1.41	0.90	0.03	15.0	11.19
44.2	0.42	12.6	12.00	0.22	8.68	9.23	0.35	0.02	0.04	12.5	100.3
45.5	0.51	16.1	9.93	0.15	7.46	7.19	1.57	1.07	0.05	10.3	99.89
43.3	0.37	11.9	7.82	0.18	7.29	9.77	1.90	1.43	0.04	16.2	100.27
49.3	0.50	16.0	9.92	0.15	7.60	4.90	3.52	0.12	0.05	8.1	100.19
43.5	0.51	15.8	10.10	0.19	8.39	3.68	5.86	0.04	0.05	11.0	99.18
39.1	0.51	12.4	12.30	0.27	9.65	7.29	3.23	0.04	0.03	14.4	99.41
44.8	0.47	15.0	9.60	0.20	7.29	5.42	5.71	0.03	0.04	11.5	100.10
46.0	0.47	15.5	10.10	0.20	7.82	3.47	5.76	0.04	0.05	10.6	100.06
45.2	0.49	14.8	9.77	0.14	7.76	5.91	4.01	0.21	0.05	11.6	99.99
49.3	0.51	14.8	9.16	0.17	7.37	4.70	2.64	1.25	0.05	10.1	100.16
47.0	0.32	14.2	10.80	0.17	8.61	7.07	1.52	0.12	0.04	10.4	100.30
40.0	0.30	16.3	14.60	0.17	10.40	6.24	0.97	0.02	0.03	11.0	100.06
53.0	0.31	15.0	9.59	0.12	7.53	4.19	2.76	0.14	0.03	7.3	100.02
44.3	0.32	15.2	8.56	0.19	9.15	9.58	1.55	0.16	0.04	11.3	100.40
45.9	0.27	13.7	7.33	0.16	7.80	10.40	0.77	0.91	0.03	13.2	100.50
51.5	0.35	16.8	8.12	0.14	9.16	2.30	3.75	0.55	0.04	7.5	100.30
49.8	0.42	18.8	8.16	0.15	7.50	3.99	4.57	0.38	0.04	6.2	100.10
43.4	0.32	16.5	9.45	0.18	9.13	7.38	2.02	0.71	0.04	10.2	99.40
50.3	0.40	19.6	7.99	0.15	7.91	4.74	3.92	0.005	0.04	4.5	99.64
41.4	0.28	16.7	9.08	0.18	8.19	6.80	3.50	1.28	0.02	11.7	99.19
42.8	0.50	13.2	9.95	0.32	8.31	7.94	2.64	0.69	0.05	13.4	99.85
44.9	0.50	16.5	9.55	0.14	6.12	5.96	1.81	2.87	0.05	11.6	100.07
45.3	0.49	15.6	9.36	0.16	6.74	5.85	3.89	1.15	0.03	10.5	99.15
46.3	0.23	14.3	7.37	0.21	7.08	7.30	1.08	2.76	0.03	13.5	100.21
41.8	0.81	13.3	7.04	0.25	5.81	9.42	3.91	1.49	0.06	15.3	99.27
47.5	0.83	13.5	9.36	0.19	6.45	6.35	1.99	1.92	0.07	12.2	100.44
50.8	0.82	13.7	14.30	0.19	5.28	4.97	2.81	0.02	0.08	6.5	99.48
54.3	0.84	13.5	13.70	0.21	5.02	5.99	3.77	0.04	0.08	2.7	100.19
54.6	1.23	14.3	7.74	0.20	4.13	6.31	4.73	0.06	0.09	7.0	100.44
55.2	1.20	13.4	7.24	0.18	3.69	7.56	4.76	0.01	0.09	6.9	100.22
48.6	1.13	12.9	8.96	0.24	4.74	8.15	4.55	0.08	0.09	10.6	100.09
51.6	1.11	13.5	8.51	0.17	4.11	5.94	5.73	0.02	0.09	9.4	100.22
51.7	1.15	13.7	6.72	0.15	3.95	5.96	6.72	0.27	0.08	8.6	99.07

High Fe-Tholeiites:											
57.1	1.17	13.5	10.30	0.22	4.57	6.40	4.57	0.05	0.10	2.2	100.19
50.5	1.13	13.4	9.55	0.23	4.79	7.31	4.33	0.03	0.09	8.4	99.80
53.1	1.21	14.6	9.49	0.24	4.57	8.24	3.34	0.02	0.10	5.3	100.27
55.2	1.21	14.3	8.96	0.22	4.42	6.97	3.31	0.01	0.10	5.8	100.57
47.1	1.20	13.6	9.74	0.25	4.61	6.89	3.32	0.18	0.10	9.5	98.28
52.9	1.13	12.3	10.40	0.21	3.66	7.89	3.16	0.07	0.09	8.2	100.09
Sediments:											
55.9	0.71	21.8	4.92	0.03	3.40	0.64	2.04	5.18	0.18	5.31	100.30
64.1	0.57	14.7	4.96	0.07	2.76	1.89	2.05	3.06	0.12	5.00	99.42
68.0	0.43	12.6	4.28	0.12	2.63	2.29	2.14	2.26	0.10	4.77	99.74
69.4	0.50	14.3	4.83	0.04	2.52	0.51	3.42	1.65	0.11	2.47	99.88

Table 1b. Trace element geochemistry of selected samples from the Pamour Mine. Note that samples are in the same order as those in Table 1a. Raw data taken from Fan and Kerrich (1991).

Pb (ppm)	Sr (ppm)	Ba (ppm)	Y (ppm)	Zr (ppm)	Nb (ppm)	Cr (ppm)
Komatiites (Pyroxenitic to Peridotitic):						
30	67	62	20	22	14	2000
5	51	24	5	5	5	2170
15	19	90	13	66	10	3360
5	10	88	5	16	11	2060
11	24	86	5	5	19	1740
22	30	69	5	20	12	2360
5	65	66	5	27	17	2800
15	45	68	18	13	5	1330
31	32	79	5	5	5	2280
27	22	81	5	12	12	2330
5	71	54	29	16	5	1410
5	12	90	11	5	11	2440
11	30	23	14	27	5	2190
5	26	44	5	5	16	2180
19	66	102	5	18	5	1570
16	22	85	5	5	5	2150
5	5	118	5	27	18	2440
14	110	66	5	24	21	1870
17	5	98	5	5	5	2240
Komatiites (Basaltic):						
38	5	273	18	13	5	3210
42	18	331	5	23	20	2890
27	30	74	5	43	5	2620
19	26	52	5	20	27	3210
5	23	38	5	15	5	2520
5	49	38	5	26	24	3400
10	13	57	5	33	23	3840

High Mg-Tholeiites:						
16	52	71	13	43	16	269
16	48	178	5	20	11	193
5	5	66	14	40	17	199
21	39	182	22	30	5	196
36	46	190	5	20	20	139
5	43	97	5	21	5	178
15	42	124	23	43	5	201
21	29	85	5	29	18	1180
5	36	88	12	34	15	188
17	37	98	13	39	14	194
5	38	103	22	39	16	186
18	24	246	15	38	5	468
11	63	107	23	27	16	117
15	35	69	5	18	14	108
16	77	111	5	15	5	120
5	37	60	22	30	5	217
21	39	123	12	23	21	169
19	17	160	17	25	5	233
29	61	145	15	23	18	276
25	46	144	18	29	18	216
5	54	78	5	39	5	267
42	45	223	5	33	25	88
10	34	112	33	42	19	139
66	5	313	22	43	5	187
27	69	278	25	38	5	176
67	43	176	5	15	5	96
33	105	212	13	54	10	170
55	46	301	20	52	11	179
5	14	111	39	82	16	51
13	56	99	29	58	5	50
16	68	111	15	85	5	127
16	52	61	33	74	5	104
30	57	79	12	69	18	88
14	68	101	15	71	5	104
18	57	167	22	60	5	103
High Fe-Tholeiites:						
15	44	93	26	79	13	113
20	92	113	34	74	5	99
14	138	80	5	70	17	108
5	81	84	27	60	5	99
14	75	96	45	70	5	97
20	88	80	24	70	5	74
Sediments:						
117	48	1050	5	173	19	208
77	81	607	11	170	10	176
64	120	480	13	157	5	162
55	214	476	23	141	5	173

STRUCTURAL GEOLOGY

Regional Structure

The Central Tisdale Anticline is to the north of the property. The mine is located on the north limb of an overturned syncline. Pillow tops in the Keewatin metavolcanics and bedding structures in the metasediments locally face south and are overturned. The axis of the syncline dips north at an angle that is slightly less steep than the unconformity, approximately at 70°, and strikes approximately N78°E. The south limb of this syncline is interpreted to have been faulted away by the Porcupine-Destor Fault, which is located to the south of the mine property.

Mine Scale Structure

Aitken (1990) has identified three fold generations at the Pamour No. 1 mine as follows:

F1 folds are restricted to the volcanic rocks. They are the oldest known folds and pre-date mineralization. The F1 folding event is interpreted to be related to the formation of the North Tisdale Anticline (Ferguson 1968).

F2 folds occur in both volcanic and sedimentary rocks, and also pre-date mineralization. The F2 folds are more prevalent in the area of the "west end" of the mine (between 2,500 ft west of the No.3 shaft and the Hallnor fault). This folding is much tighter than F1 folds with amplitudes ranging between inches and a hundred feet or more.

The youngest F3 folds post-date mineralization, occur in both rock types, and are only weakly developed.

Faults and Shears

Faulting related to mineralizing events are explained in more detail below (section "Description of Orebodies"). Several nested conjugate sets of reverse faults which occur on either side of the unconformity produce the volcanic and sedimentary narrow vein orebodies. These strike east - west and dip steeply to the north and south respectively. In section, the axis of the conjugate set plunges approximately 30° to the east and is vertically repetitive at intervals of about 400 feet. When fault veins come in contact with rock types of differing competence, sheeted extension (ladder) veins are produced. These commonly occur on the footwall side of the primary vein structures. The sheeted veins themselves strike northeast and dip between 30°-60°. The most prolific occurrence of extension veins occur at the axes of the conjugate sets where they are coincident with the unconformity.

The fortuitous presence of the conglomerate at the unconformity, being a more brittle unit than its counterparts, provided much permeability for ore emplacement. Approximately 80% of the historic ore production comes from the structural juncture of the conjugate fault vein axis, the unconformity, and the conglomerate.

Two major post-ore dextral faults, the Hallnor and Pamour faults, strike north to north west, dip 60° east, and offset the stratigraphy by as much as 1 200 feet.

Additionally, there are two systems of less pronounced faults which form a conjugate set. The major set strikes northwest and has dextral displacements of up to 50 feet. Faults of the minor set strike northeast and have sinistral displacements of the same magnitude. These two fault systems appear to be more persistent in the metasedimentary rocks than in the metavolcanic rocks, in part due to a lack of a marker in the latter system (West et. al. 1990). Both sets dip near vertically. The faults are interpreted to be extensional as evidenced by down dropping of blocks between sets.

Flat-lying reverse faults occur and are more pronounced in the metasediments on the west end of the property. Dip angles of the faults average 5°-10° to the south and their strike is generally east-west. Flat faults are truncated by the vertical, northerly striking faults noted above.

A talc-chlorite schist zone on the southern property boundary is interpreted to demarcate the Porcupine Destor Fault zone.

ECONOMIC GEOLOGY

Production History

A tabulation of the production history of the mine to the end of 1997 is given in Table 2 below.

BULK AND NARROW VEIN UNDERGROUND: 1936-1975

During the early years, Pamour Mine production was derived from low tonnage, high grade narrow vein sources. Of the 3.2 million ounces produced to date from the Pamour, 880 000 ounces of gold from

5.5 million tons of ore has been mined from high grade narrow vein sources between surface and the 2 200 foot level. Although many targets remain open along strike and at depth, they have remained untested over the years.

The Pamour Mine production has evolved through time by increasing tonnage provided by lower grade underground bulk minable sources. A significant amount of production from the mine (62%), has been from lower cost bulk mining methods such as longhole stoping, open blasthole stoping, sublevel cave, sublevel retreat, and modified vertical crater retreat techniques. The diamond drilling philosophy in the early years was focused on higher grade sources and little attention was paid to the pervasive low grade gold-bearing halo surrounding these high grade veins. It became a typical occurrence that many of these bulk stopes were over pulled by as much as 200%, as the sloughed material (dilution) contained lower, yet economic, grade ore.

OPEN PIT MINING: 1976

In 1976 open pit mining was introduced to remove crown pillars and eventually exploited the lower grade gold-bearing haloes surrounding the higher grade bulk and narrow vein stopes. The original pit life in 1976 was not expected to last more than a few years. During the ensuing years, pit reserves were replaced as they were mined out the same way that the underground reserves were replaced.. Open pit mining has since contributed 7.6 million tons of ore and 450 000 ounces of gold at an average head grade of 0.059 oz / ton from five open pits. The No.3 pit is currently 2 500 feet long and 640 ft deep with pit slopes averaging 50°.

PIT EXPANSION PROJECT: 1995

During 1995 and 1996, over 255 000 feet of surface and underground drilling was completed by the exploration and mine site groups. This new data was incorporated with the older data acquired over the sixty year history of Pamour. In total, 2 042 000 feet of diamond drilling in over 9 724 drill holes was used for the pit evaluation out of the total database of 15 823 drill holes. Results of this work provided the basis for a preliminary pit design that measured 6 200 feet long, 2 600 feet wide and 1 100 feet deep. This pit is referred to as the 60 Pit to recognize the sixty years of continuous mining at Pamour.

Development

The underground portion of the Pamour Mine is accessed by the No.3 shaft which extends to a depth of 3 100 feet from surface. Working levels extend laterally along strike from the shaft at approximate 200 foot intervals. The longest lateral level is the 1400 level which extends 6 200 ft west and 7 200 ft east of the No. 3 shaft. Secondary access is from the Hoyle ramp which extends to 2 100 ft (vertical) from surface. The ramp is connected to the main Pamour orebody on the 400 foot, 1400 foot and 1600 foot levels. An inactive internal winze is located in the Pamour “west end” between the 525 foot level and the 2 400 foot level at 4 800 ft west of the No. 3 shaft.

Table 2. Tabulation of Total Gold Production and Diamond Drilling at the Pamour Mine.

Year	Tons Milled	Recovered Grade (oz / ton Au)	Recovered Ounces	Diamond Drilling (Surface)	Diamond Drilling (Underground)	Total Diamond Drilling
1936	138 200	0.423	58 500			
1937	276 200	0.409	113 000			
1938	515 200	0.182	94 000			
1939	585 400	0.120	70 500			
1940	576 000	0.123	70 800			
1941	580 000	0.119	66 870			
1942	575 000	0.106	60 800			
1943	525 000	0.103	54 100			
1944	470 500	0.089	41 700			
1945	418 000	0.093	38 800			
1946	387 000	0.091	35 400			
1947	300 000	0.091	27 300			
1948	412 000	0.092	38 000			
1949	584 000	0.098	57 000			
1950	605 000	0.096	58 000			
1951	582 000	0.096	55 600			
1952	611 000	0.092	56 400			
1953	627 400	0.093	58 400			
1954	637 000	0.088	55 800			
1955	636 000	0.082	52 200			
1956	619 000	0.082	50 500			Prior to 1960:
1957	628 000	0.082	51 300			
1958	647 000	0.093	60 300			1 053 698
1959	637 400	0.097	61 600			
1960	646 000	0.097	62 700		57 310	57 310
1961	648 000	0.092	59 800	2 215	62 092	64 307
1962	633 000	0.098	62 000	697	58 101	58 798
1963	628 000	0.104	65 000		63 062	63 062
1964	602 000	0.118	71 000		67 392	67 392
1965	584 500	0.109	63 600		59 465	59 465
1966	612 500	0.105	64 500		45 526	45 526
1967	610 000	0.105	64 000		34 464	34 464
1968	624 000	0.114	71 400		38 378	38 378
1969	622 000	0.139	86 400		41 683	41 683
1970	634 000	0.128	79 800		31 992	31 992
1971	690 000	0.123	85 000		35 678	35 678
1972	692 000	0.130	89 900	441	20 986	21 427
1973	642 055	0.114	73 373	7 126	22 373	29 499
1974	601 245	0.096	57 689	1 180	26 141	27 321
1975	679 034	0.094	64 088	160	24 485	24 645
1976	870 341	0.094	81 724		19 326	19 326
1977	782 549	0.083	65 138	235	8 413	8 648
1978	782 549	0.083	65 218	3 785	9 134	12 919
1979	618 172	0.093	57 335		11 135	11 135
1980	621 549	0.080	49 797	3 537	23 617	27 154
1981	590 503	0.073	43 109	6 252	36 872	43 124
1982	633 275	0.078	49 213	946	33 654	34 600
1983	486 781	0.079	38 491		35 344	35 344
1984	649 252	0.062	40 527	8 577	46 572	55 149
1985	837 847	0.062	52 222		19 799	19 799
1986	1 120 760	0.059	66 560	37 869	52 089	89 958
1987	1 324 922	0.056	73 825	28 906	31 744	60 650
1988	1 325 569	0.054	71 587	16 311	29 526	45 837
1989	1 061 440	0.066	69 675	11 472	23 325	34 797
1990	1 081 125	0.070	75 914	63 760	54 411	118 171
1991	1 219 962	0.075	91 862	23 693	44 157	67 850
1992	1 224 797	0.080	98 218	14 208	37 385	51 593
1993	1 305 493	0.065	84 310	10 695	53 599	64 294
1994	1 291 674	0.062	79 809	11 783	62 758	74 541
1995	1 254 652	0.061	76 924	85 429	108 549	159 319
1996	1 115 889	0.065	72 654	159 033	124 215	283 248
1997	1 031 312	0.064	66 382	15 000	90 800	105 800
TOTAL	**43 931 047**	**0.091**	**3 977 615**	**513 310**	**1 645 552**	**3 177 901**

Diamond Drilling to Date

Diamond drilling on the Pamour property totals 3 178 000 feet, (602 miles) in over 15 823 holes. A detailed tabulation of the diamond drilling is given in Table 2, and is summarized in Figure 4.

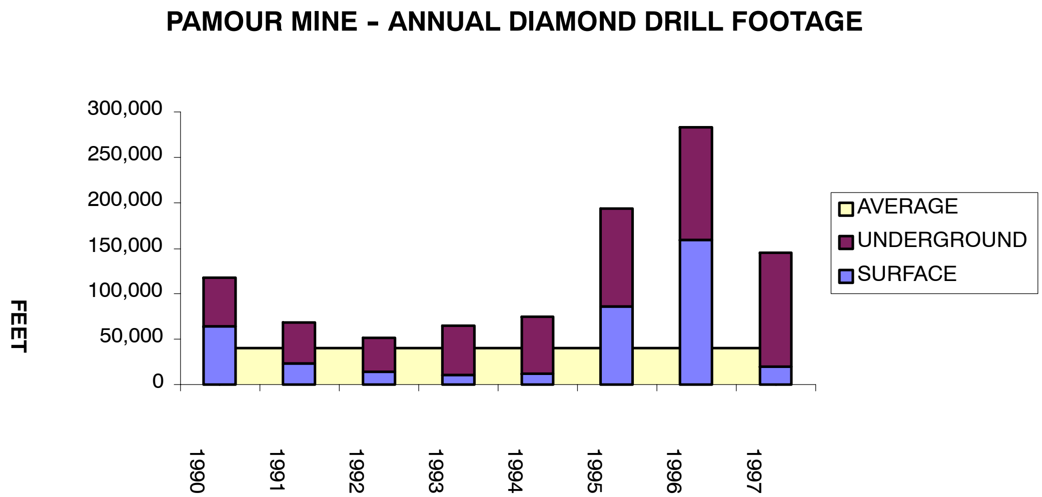


Figure 4. Summary of the Annual Diamond Drilling at the pamour Mine, 1990-1997.

Mining Methods

A variety of underground mining methods have been employed at the Pamour Mine over its' 60 year history. Conventional jackleg panel mining, longhole stoping, shrinkage stoping and sublevel retreat have been used in the higher grade narrow vein ore zones. Underground bulk mining is done traditionally by a modified Vertical Crater Retreat method, however sublevel cave and sub level retreat have also been utilized. Open pit mining commenced in 1976. A summary of the amount of gold produced by mining method is given in Table 3.

Table 3. Historical Detailed Breakdown by Mining Method

Mining Method	Contribution by Total Tons (%)	Contribution by Total Ounces Gold (%)
Bulk Underground	61	62
Open Pit	34	23
Metavolcanic Narrow Veins	5	15
TOTAL	100	100

Open pit production currently contributes about 37% of the 3 800 tons per day mill feed.

Description of Ore Bodies

There are three distinctive orebody types at the Pamour. In progressive order from north to south they are:

1. Metavolcanic-Hosted Fault-Vein Orebodies (Narrow Vein),
2. Extension-Vein (Bulk) Orebodies, and
3. Metasediment-Hosted Fault-Vein Orebodies (TN Veins), (Aitken 1990).

The simplified model in Figure 5 shows the type "1" narrow vein orebodies propagating at depth from the north, rolling over at the Unconformity, breaking up into type "2" bulk orebodies, then dipping steeply to the south as type "3" TN narrow vein orebodies.

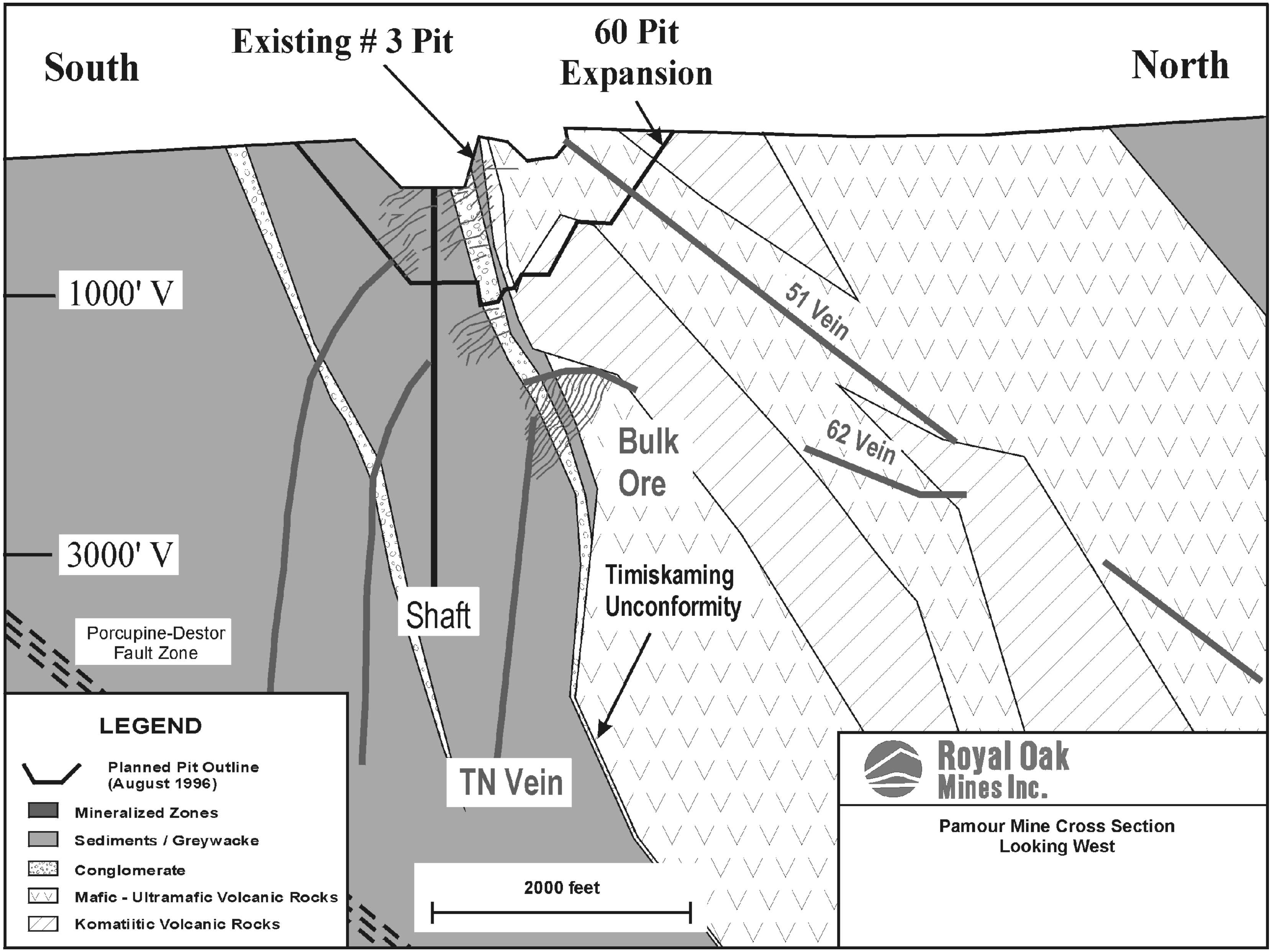

South
Existing # 3 Pit
60 Pit
Expansion
North
1000' V
3000' V
Porcupine-Destor
Fault Zone
Shaft
TN Vein
Bulk
Ore
Timiskaming
Unconformity
51 Vein
62 Vein
2000 feet
LEGEND
Planned Pit Outline
(August 1996)
Mineralized Zones
Sediments / Greywacke
Conglomerate
Mafic - Ultramafic Volcanic Rocks
Komatiitic Volcanic Rocks
Royal Oak
Mines Inc.
Pamour Mine Cross Section
Looking West

Figure 5.

Although the orebody types are genetically and spatially linked, the extension-vein bulk orebodies are the dominant open pit ore type. The bulk type mineralization occurs in the conglomerate and greywackes as sheeted quartz veins or stockwork stringers where the two types of narrow vein structures come together. The resulting "inverted horseshoe" of orebodies plunge at about 30° to the east. The model is vertically repetitive at about 200 to 400 foot intervals.

METAVOLCANIC-HOSTED FAULT-VEIN OREBODIES (NARROW VEIN)

These orebodies progress at depth from the north, up through the metavolcanic suite of rocks, towards the angular unconformity to the south. The veins can extend over 2 000 feet in strike and dip. The mineralogy within the veins varies considerably from place to place. They cross-cut stratigraphy and generally are found in the more competent basaltic lavas. The veins do not manifest themselves in the ultramafic talc units, but rather propagate through them and continue on the other side. Similarly, the veins manifest in the carbonate zones but are barren of gold mineralization as they propagate through them. The metavolcanic-hosted fault-vein orebodies dip northwards from 30° to 50°N. Their strike is slightly more southerly than the unconformity at about 75° to 80°. They vary from inches to several feet and average 2 to 3 feet in thickness. Alteration is pervasive, but not as strongly developed as in the metasediments. Veins are quartz-albite-calcite filled with minor amounts of tourmaline, chlorite, sulphides and gold. Pyrite and sphalerite are the two most common associated sulphide minerals. Where the highest grade mineralization occurs within the metavolcanic narrow veins, chalcopyrite is also known to be associated. Tourmaline, where found occasionally in pockets within the vein material, is indicative of localized nuggety gold distribution. Gold is found free, dominantly in the quartz vein filling, and often displays a strong spatial relationship with sphalerite. Dominant wallrock alteration in the metavolcanic rocks is carbonate, commonly in the form of ankerite. Fuchsite alteration is known to occur but is not abundant.

EXTENSION-VEIN (BULK) OREBODIES

Occasionally pyritiferous "tension gash" or extension-vein style mineralization is found extending from the footwall of the metavolcanic-hosted fault-veins where it has been bulk mined in the past. As the metavolcanic-hosted fault-vein orebodies approach and abut against a geologic contact, the vein breaks up, may roll over, and the footwall extension veins commence to dominate. Depending on the competence of the interfacing strata (i.e. slates), the veins may manifest initially as hydrothermal breccia. It is evident in places (i.e. the north greywacke) that fluids under pressure passing through the more porous basaltic rock migrated along, and pooled up against, a non-porous barrier such as slate or talc. The fluids sought a weak point at the contact which abruptly ruptured. Gold, pyrite, pyrrhotite, sphalerite and galena were deposited as pressure rapidly decreased in the metasediments side. On the metavolcanic side of the interface, pyrite and heavy carbonatization is evident, yet for a short distance away from the contact the mineralization is abruptly devoid of gold (i.e. the MK zone).

The area about the unconformity is the point of refraction, or "hinge" of the mineralized structures. Extension-vein orebodies dominate south of this point. Gold is typically associated with finely disseminated pyrite and pyrrhotite around a series of narrow (1 inch to 3 inches thick), stacked sheets of quartz stringers that dip gently to the southeast. Sphalerite and galena occur in minor to trace amounts overall. Where they occur in greater amounts, coarse free gold usually also occurs. The quartz stringers transgress from the north greywackes through the Pamour conglomerate and into the south greywackes. They are restricted to shoots that plunge at approximately 30° to the east. Coarse visible gold occurs in minor amounts in the quartz stringers. Pyrite and pyrrhotite usually comprise up to 3% of the host rock. Moderate to strong alteration normally accompanies the development of ore and is characteristically sericitic and albitic in nature, giving the host rock a bleached appearance. Ore shoots are typically 100 to 200 feet high, 100 to 150 feet wide and may be up to 4 000 feet in length along their plunge.

The conglomerate units forms the most consistent and highest grade of the bulk ore mined at the Pamour Mine.

METASEDIMENT HOSTED FAULT-VEIN OREBODIES (TN VEINS)

The name "TN" is of local derivation and is an acronym for "Three Nations". The Three Nations Mine was a short lived fore-runner of what would eventually become the Pamour Mine. Three Nations Lake is just south of the mine property. These veins are generally steeply south dipping and strike slightly more northerly than the strike of the stratigraphy (Figure 3). They are the conjugate set of the north dipping metavolcanic-hosted variety. Typically, the vein zones are 1 to 15 feet wide, up to 1 500 feet in strike and 2 000 feet in dip length. They are usually enveloped by an albite-sericite alteration halo containing significant amounts (up to 6%) of pyrite, pyrrhotite, arsenopyrite, sphalerite, and galena. In most cases, the zone makes ore over the complete width of the halo. Gold occurs both as free, nuggety clusters in the quartz, and as very minute inclusions within disseminated pyrite and pyrrhotite in the wall rock.

Ore Mineralogy

The majority of gold occurs in two principal modes. The first is as free gold associated with narrow, quartz-ankerite extension-veins along with traces of sphalerite, galena, and locally arsenopyrite. Historically between 15 to 20% of the gold at Pamour Mine is free milling. Pyrite and pyrrhotite also occur within the quartz veins but more commonly occur as disseminated grains in the bleached and altered wallrock.

The second mode of gold mineralization is recovered as float concentrate comprised mainly of pyrite associated gold. It occurs as a pervasive, lower grade, disseminated pyrite-gold mineralization associated with the alteration halo surrounding the quartz vein stockworks. Locally, in order of decreasing abundance, arsenopyrite, sphalerite and galena may occur in minor amounts.

Gold occurs as electrum, an amalgam of gold and silver. Gold to silver ratios are currently 5:1.

SUMMARY

During the period 1936 to 1975 the Pamour ounce production was derived 73% from underground bulk, and 27% from narrow vein sources. By taking advantage of the widely dispersed low grade gold-bearing halo around the higher grade stopes, the Pamour Mine has evolved into a 33% open pit, 53% underground bulk, and 14% underground narrow vein operation. The mine will continue to evolve by taking further advantage of the large low grade open pit potential and economies of scale (Figures 6 and 7).

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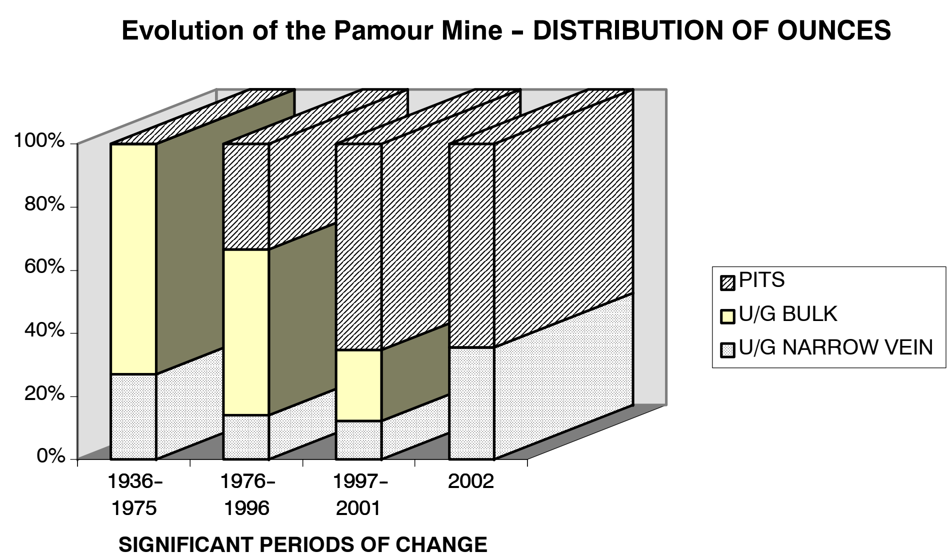

Figure 6. Evolution of the Ore Sources at the Pamour Mine.

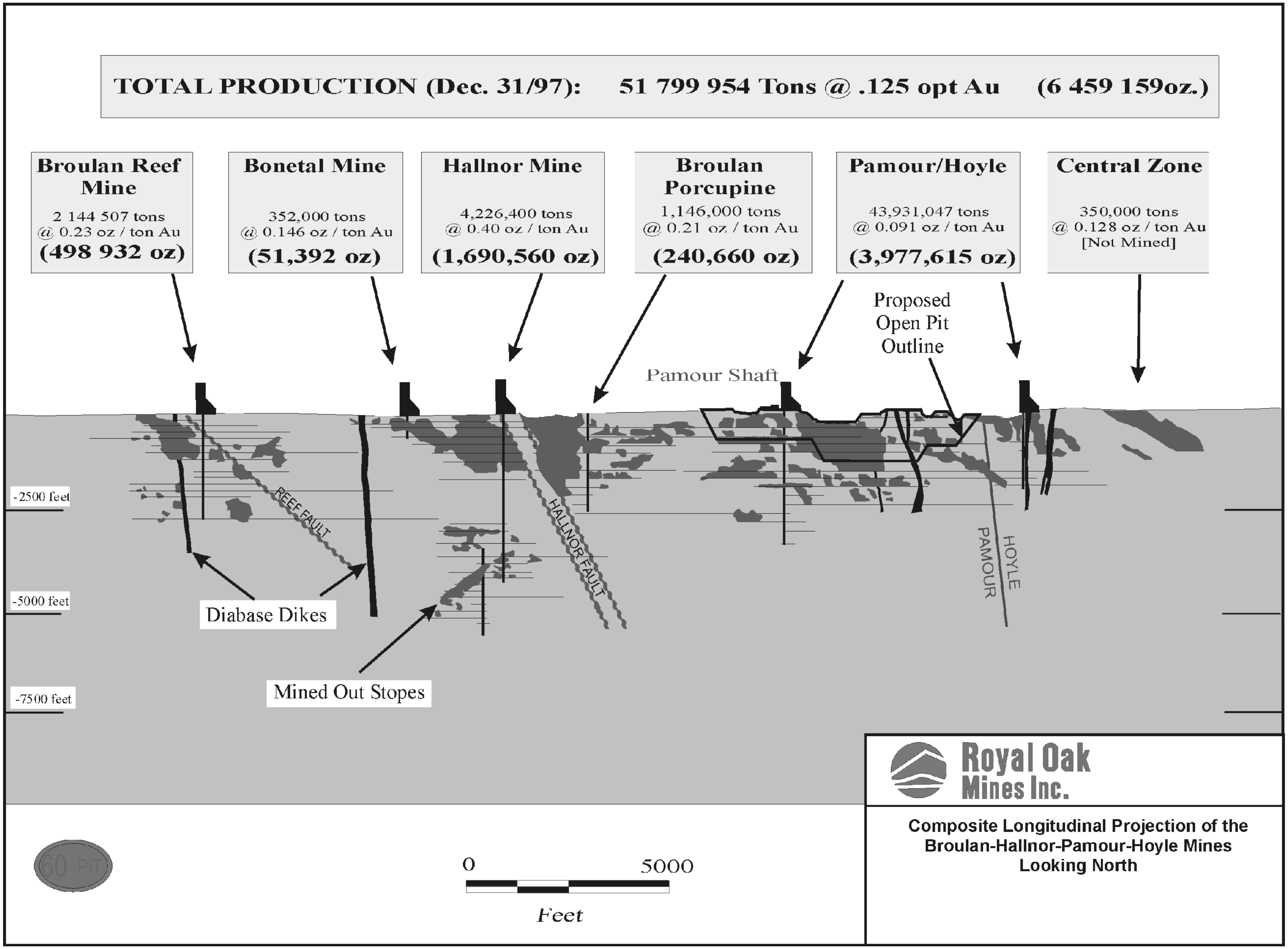
TOTAL PRODUCTION (Dec. 31/97): 51 799 954 Tons @ .125 opt Au (6 459 159oz.)
Broulan Reef Mine
2 144 507 tons
@ 0.23 oz / ton Au
(498 932 oz)
Bonetal Mine
352,000 tons
@ 0.146 oz / ton Au
(51,392 oz)
Hallnor Mine
4,226,400 tons
@ 0.40 oz / ton Au
(1,690,560 oz)
Broulan Porcupine
1,146,000 tons
@ 0.21 oz / ton Au
(240,660 oz)
Pamour/Hoyle
43,931,047 tons
@ 0.091 oz / ton Au
(3,977,615 oz)
Central Zone
350,000 tons
@ 0.128 oz / ton Au
[Not Mined]
Proposed Open Pit Outline
Pamour Shaft
REEF FAULT
HALLNOR FAULT
HOYLE
PAMOUR
-2500 feet
-5000 feet
-7500 feet
Diabase Dikes
Mined Out Stopes
0
5000
Feet
Royal Oak Mines Inc.
Composite Longitudinal Projection of the Broulan-Hallnor-Pamour-Hoyle Mines Looking North

Figure 7.

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Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

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

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