GEOLOGICAL ASSOCIATION OF CANADA
NEWFOUNDLAND SECTION

Regional geology and mineral deposits of the Victoria Lake Group

"Tulks Valley '90"

Field Guide and Road Log

for the

October 12-14, 1990

Field Trip

Leaders:

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INTRODUCTION

The Victoria Lake Group (Kean, 1977) consists of thick sequences of Cambrian to Middle Ordovician volcanic and epiclastic rocks that outcrop along the western side of the Exploits Subzone. It is host to a number of important volcanogenic massive sulphide and epigenetic gold deposits. Although most of the central and southern parts of the Victoria Lake Group are not sufficiently accessible to be visited on and excursion such as this, there is an extensive, easily accessible network of roads in the northern part of the area (Figure 1). Outcrops on these roads provide a good overview of the regional geology and access to representative examples of the most important mineral deposit types.

The Victoria Lake Group includes arc-related volcanic and epiclastic rocks of at least three distinct ages (Cambrian, Lower Ordovician and Middle Ordovician), each of which contain volcanogenic massive sulphides. We will visit examples of the Cambrian (Duck Pond), Middle Ordovician (Victoria Mine) and Lower Ordovician (Tulks Hill) VMS deposits.

Gold deposits are a recently recognized feature of Victoria Lake Group metallogeny. Gold occurrences are all epigenetic, and occur in second - and third - order structures apparently related to regional transpression during the Silurian and/or Devonian. The mineralization is hosted by a wide variety of lithologies and is not restricted to any particular age of rocks. We will visit the Bobby's Pond alteration zone, the Road Showing and view drill core from two others; Valentine Lake and Midas Pond.

GEOLOGY AND MINERAL DEPOSITS OF THE VICTORIA LAKE GROUP

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INTRODUCTION

The Victoria Lake Group (Kean, 1977) includes all pre-Caradocian volcanic and sedimentary rocks in the area bounded by Grand Falls in the northeast and King George IV Lake in the southwest, Red Indian Lake in the northwest and Noel Paul's Brook in the southeast (Fig. 1). The group has proven to be very favourable for volcanogenic massive sulphides and significant shear zone hosted lode gold mineralization.

Access to the much of the area is provided by a network of private woods roads from Millertown and Grand Falls. Heavily forested, gently undulating topography covered by extensive glacial till comprise much of the area, resulting in a paucity of bedrock exposure.

GEOLOGY OF THE VICTORIA LAKE GROUP

Regionally, the group can be subdivided into three belts defined by their dominant lithology (Fig. 1) (Kean and Jayasinghe, 1980, 1982; Kean, 1985): 1) the Tulks Hill volcanic belt to the southwest which includes the Victoria Mine sequence; 2) the Tally Pond volcanic belt to the southeast, and 3) a volcanically derived sedimentary belt in the northeast which in part is a lateral equivalent of the volcanic belts. Stratigraphy of the Victoria Lake Group and its adjoining sequences is shown in Table 1.

The Victoria Lake Group has an inhomogeneously developed, regional penetrative foliation defined by the orientation of chlorite and sericite, flattened clasts and elongated crystal augen. The intensity of this foliation, which is subparallel to bedding and axial planar to tight to isoclinal folds, increases to the southwest. The rocks have been metamorphosed to the lower-greenschist facies, except locally along their southern margin where middle-greenschist to lower-amphibolite facies rocks are present.

Volcanic Rocks

Both the Tulks Hill and the Tally Pond volcanics are characterized by linear belts of predominantly felsic pyroclastic rocks with intercalated mafic flows, pillow lava, tuff, agglomerate and breccia. Lithologically the two volcanic belts are similar but mafic flows are more prevalent in the Tally Pond volcanics. Deformation within the Tulks Hill volcanics is more intense than in the Tally Pond volcanics and has largely obliterated primary structures.

Despite their lithological similarity, geochronological studies of the two volcanic belts indicate that they are not the same age (Table 1). The Tally Pond volcanics have been dated as Cambrian (513 +/-2 Ma, Dunning, 1986), the Tulks Hill volcanics at 498 +6/-4 Ma (Lower Ordovician, Evans et al. 1990) and the Victoria Mine sequence, at 462 +4/-2 Ma (Middle Ordovician, Dunning et al. 1987).

Geochemical studies of mafic volcanic rocks in the Victoria Lake Group have revealed a variety of geochemical types representing diverse tectonic environments (Fig. 2). These mafic volcanic rocks appear to fit into three broad groupings (Kean and Evans, 1988):

1) island-arc tholeiites, with locally highly incompatible element depleted refractory lavas. This group is represented by the Beatons Pond-Harmsworth Steady basalts of the Tulks Hill volcanics and by the Lake Ambrose-Tally Pond basalts and the Sandy Lake sequence of the Tally Pond volcanics.

2) calc-alkaline basalts represented by the Victoria Mine sequence.

3) non-arc rocks represented by the Upper, Valley Brook and Tom Joe Brook basalts and the Diversion Lake Group.

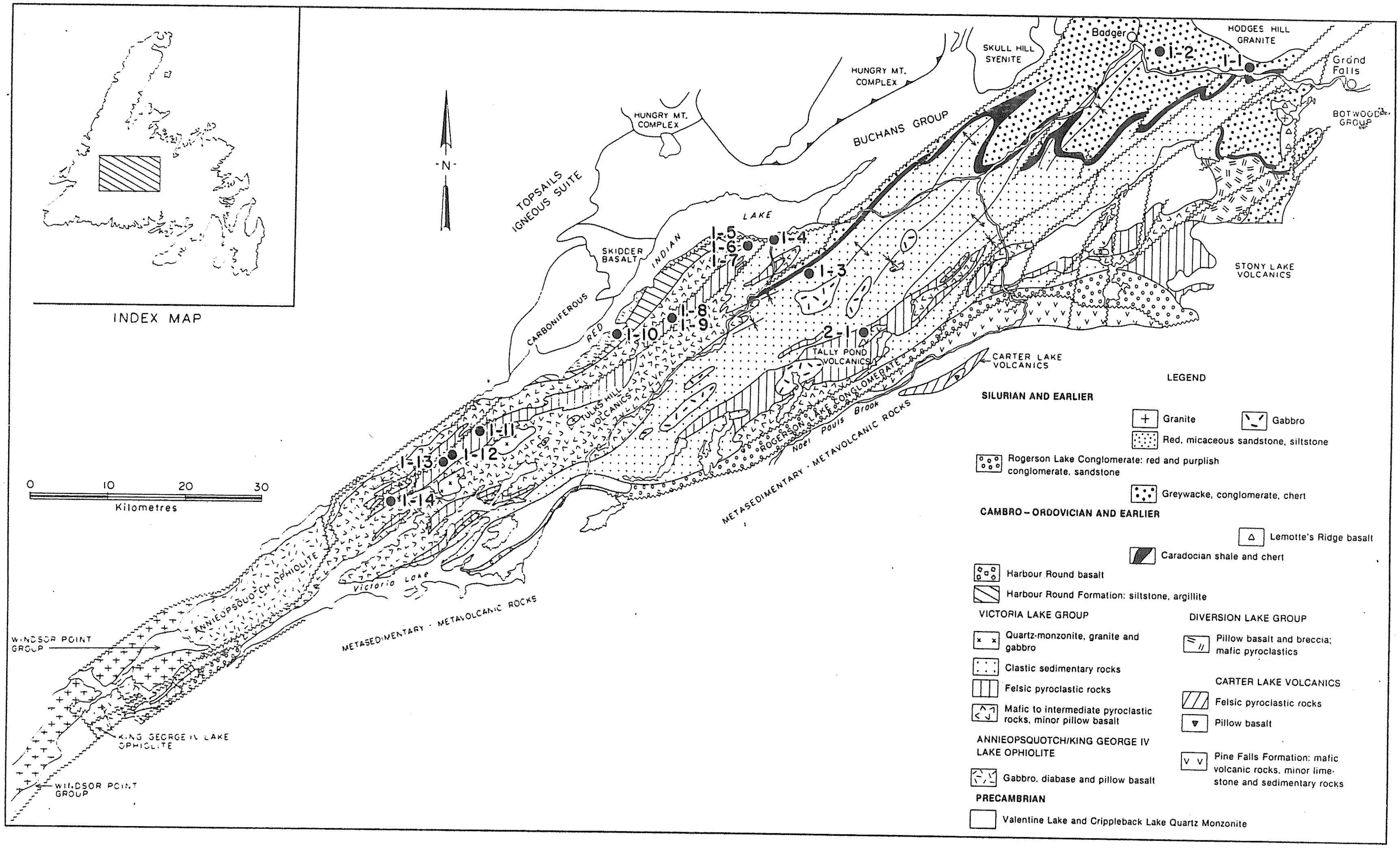

Figure 1. Regional geology and field trip stops, Victoria Lake Group.

Table 1. Simplified stratigraphy and geochronology of the Victoria Lake Group and adjoining sequences (after Evans et al., 1990).

Ma	Period/Epoch		Simplified Stratigraphy of the Victoria Lake Area			
	Silurian					
440	ORDOVICIAN	Ashgillian			Flyschoid Sequences Conformable	Rogerson Lake Conglomerate (?) unconformable upon Tally Pond Volcanics and Valentine Lake Q.M.
450		Caradocian		Harbour Round Formation (?) Conformable	Black Shale and Chert Conformable	
460		Llandeilian		Victoria Mine Sequence 462^{+4}_{-2} Ma (?)	Sedimentary Facies	
470		Llanvirnian			(?)	
480		Arenigian	Annieopsquotch Complex 478^{+3}_{-2} Ma in fault contact with Tulks Hill Volcanics			
490		Tremadocian	Roebucks Q.M. 495 ± 4 Ma	Tulks Hill volcanics 498^{+6}_{-4} Ma (?)		
500 510	Cambrian					Tally Pond Volcanics 513 ± 2 Ma
	Precambrian			Valentine Lake Q.M. 563 ± 2 Ma		Crippleback Lake Q.M. 565^{+4}_{-2} Ma

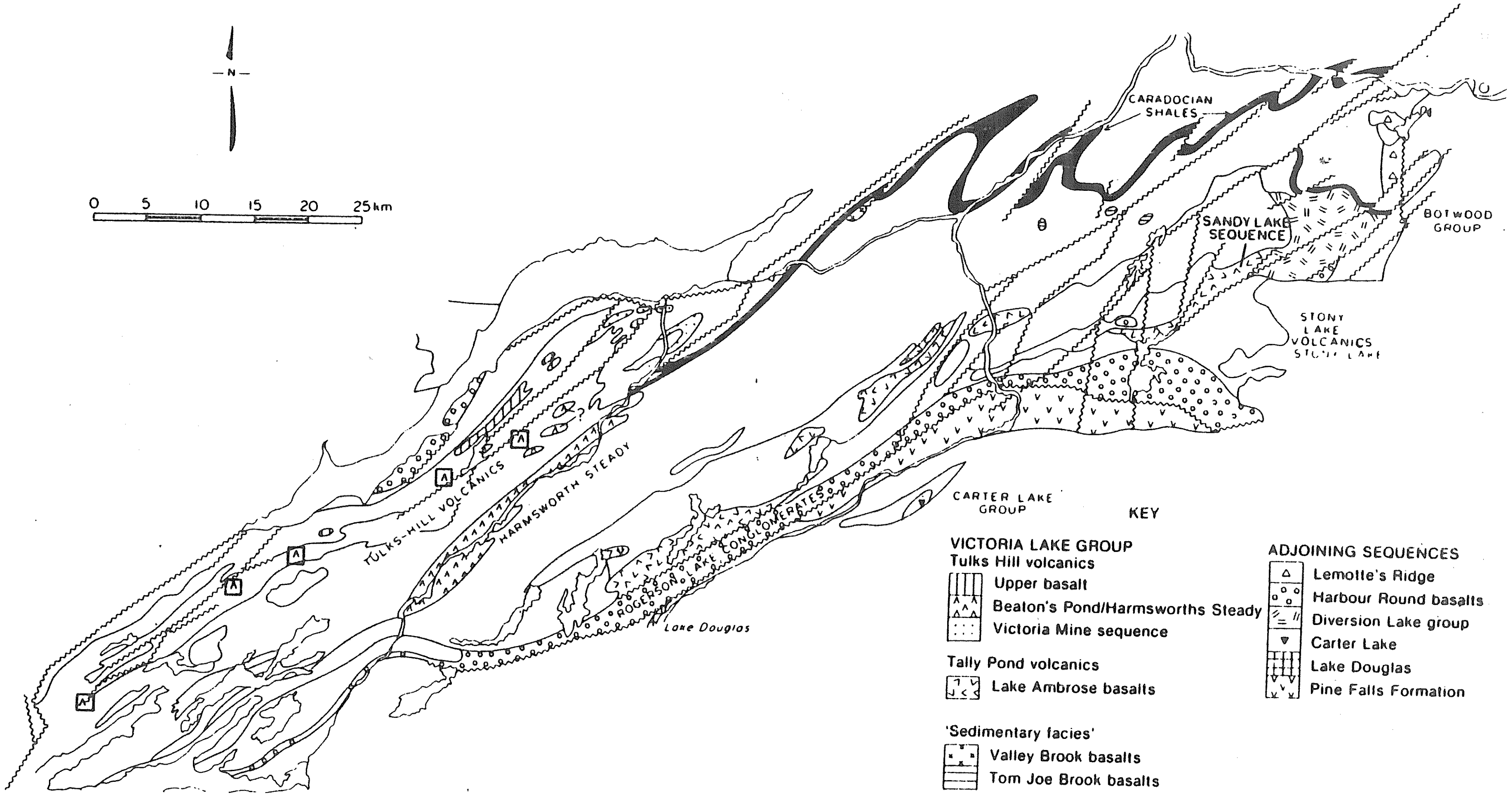

Figure 2. Distribution of major mafic flow units within and adjoining the Victoria Lake Group (modified after Kean and Evans, 1988).

Sedimentary Rocks

Siliciclastic rocks constitute much of the sedimentary belt. These rocks, comprised of greywacke and interbedded siltstone, shale, argillite, conglomerate and rare limestone, are interpreted to represent a shallowing-upward turbidite sequence (Kean and Jayasinghe, 1982).

Volcanic detritus is common in the sedimentary rocks of the Victoria Lake Group and increases in both amount and coarseness towards the volcanic belts. The clastic sedimentary rocks are therefore interpreted to have been derived from the adjacent and underlying volcanic sequences. Small lenses of volcanic rock occur throughout the sedimentary sequence.

Limestone lenses at the mouth of Victoria River near the top of the sedimentary belt have yielded Late Llanvirn to Early Llandeilo conodonts (Kean and Jayasinghe, 1982). Siliceous siltstone and chert are more common near the top of the sequence where the sedimentary rocks pass conformably upwards into Llandeilo-Caradocian chert and shale (Kean and Jayasinghe, 1982; Williams, 1989).

Intrusive Rocks

Linear bodies of medium grained quartz monzonite, minor granite and granodiorite, diorite and gabbro, interpreted to be coeval with the volcanism, intrude the volcanic belts of the Victoria Lake Group. The Roebucks quartz monzonite, which intrudes the Tulks Hill volcanics, is dated at 495 +/-2 Ma, and is therefore coeval with the volcanism (Evans et al. 1990)(Table 1).

The larger plutonic bodies located along the southeastern margin of the Victoria Lake Group (Valentine Lake and Crippleback Lake), have recently been shown to be Precambrian in age (Evans et al. 1990) and are interpreted to have been structurally emplaced.

STRUCTURAL SETTING

Rocks of the Victoria Lake Group have previously been interpreted to occupy a regional, northeast-trending anticlinorium called the Victoria Anticlinorium (Kean, 1985). Regionally, the group dips steeply and faces northwesterly on the north limb and dips gently and faces southeasterly on the south limb; however, there are many second- and third-order folds, resulting in variable facing directions. A paucity of outcrop generally precludes detailed structural interpretations.

Nowlan and Thurlow (1984) suggested that the Buchans Group to the west was thrust southeastwards over the Victoria Lake Group and its adjoining sequences. It is suggested that the style of thrusting observed within the Buchans Group (Calon and Green, 1987) is also present in the Victoria Lake Group (Evans et al., 1990)

Regional studies of colour infrared aerial photography, gradiometer data (Geological Survey of Canada, 1985 a, b, c, d, e; Kean and Evans, 1988) and Synthetic Aperture Radar (C-SAR) imagery have defined a series of northeast, north-northeast and northwest trending linear structures, a number of which are coincident with known faults. The northeast-trending linears (Fig. 3) appear to be the oldest structures and locally these form boundaries between the different lithological and temporal rock groupings within the Victoria Lake Group. These structures are interpreted as southeastward-directed, possibly out of sequence, imbricate thrusts which have produced the regional anticlinal folding (antiformal stack ?) observed within the group (Fig. 4).

The northeast-trending, southeast-directed thrusts may have been reactivated as transcurrent faults in response to regional sinistral movement. Blackwood (1985) has suggested that a major sinistral shear couple affected most of central Newfoundland as a result of movement along the major boundary fault systems, the Cape Ray-Cabot Fault and the Hermitage Bay-Dover Fault. This model relates the formation of the Hermitage Flexure and other flexures of similar character throughout the Central Mobile Belt to clockwise rotation of the structural elements within the bounding fault system. This flexuring may be represented within the Victoria Lake Group by regional variations in the trend of major geological units and by the shape and orientation of major lakes and river systems (eg. Red Indian Lake).

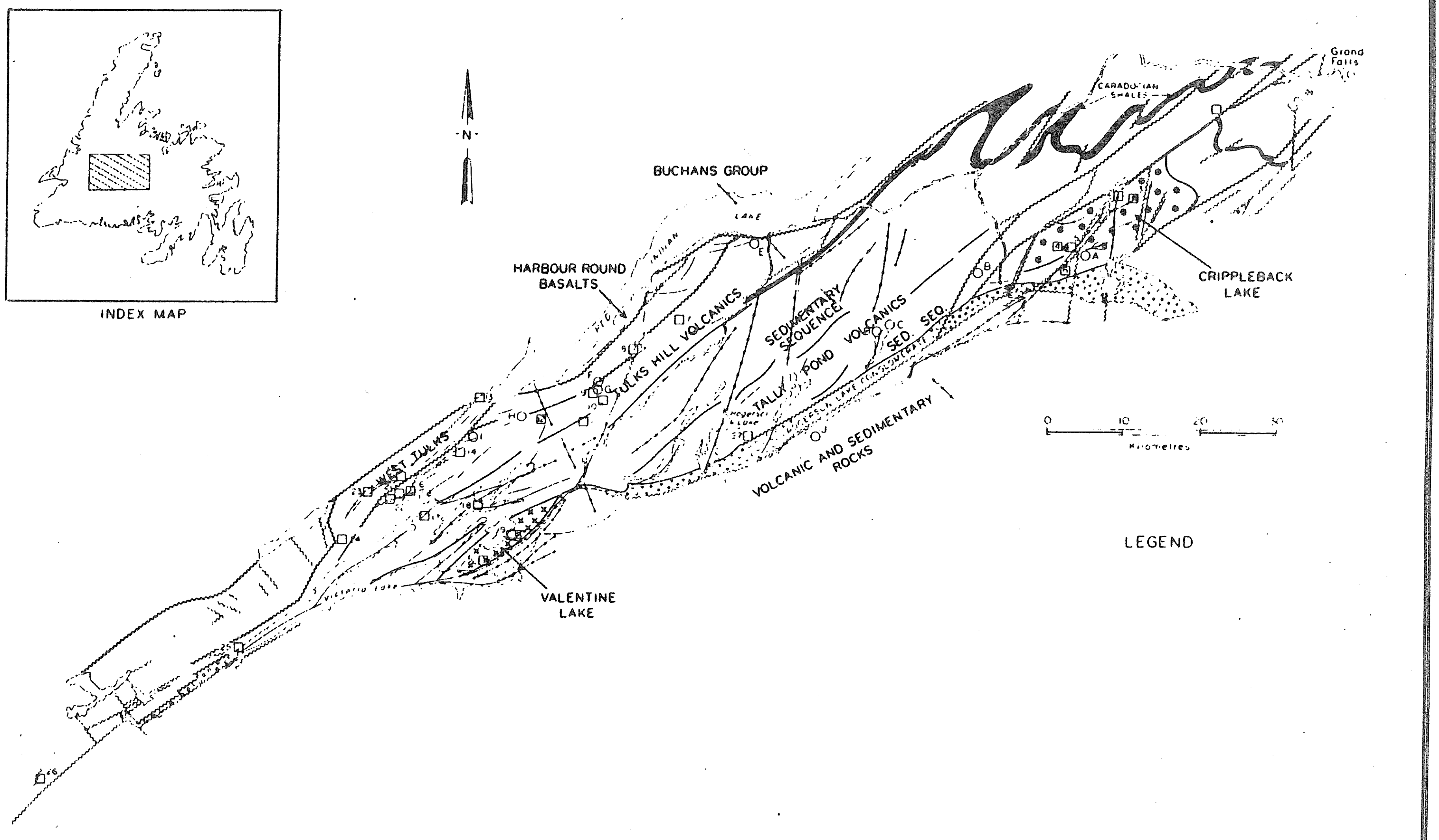

Figure 3. Major northeast-trending structural linears (heavy lines) and the rock packages they define (after Evans et al., 1990).

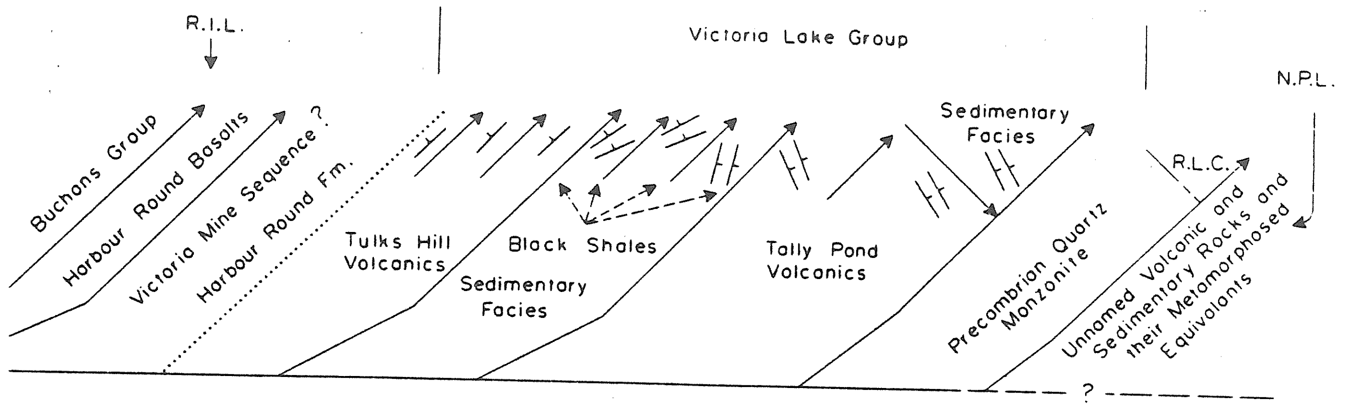

Figure 4. Schematic cross-section showing southeast-directed thrusting within the Victoria Lake Group (after Evans et al.,1990).

Sinistral movement along the major northeast-trending fault systems bounding the Victoria Lake Group (Lloyds Valley fault and the fault along the south eastern margin of the Rogerson Lake Conglomerate) resulted in clockwise rotation of the geological units within the group (Fig. 5). Conjugate, brittle fault systems (north-northeast and northwest structural linears) developed in response to this rotation, particularly within the sedimentary belt and the Tally Pond volcanics where deformation was less intense and of a more brittle nature. Deformation within the Tulks Hill volcanics was much more intense than in the remainder of the Victoria Lake Group with more of the deformation being taken up by the northeast-trending ductile shears.

The north-northeast-trending structures exhibit a dextral sense of offset as is portrayed by the mapped offsets on the Middle Ordovician shales along the Exploits River (Fig. 5). This sense of movement is identical to the sense of movement exhibited by the broken, lensoidal outcrop pattern of the graphitic shales along the northern edge of the Tally Pond volcanics.

The northwest-trending structures are brittle structures which appear to exhibit little movement (Fig. 5). The Bonne Bay-Buchans-Tally Pond-Great Burnt Lake linear (Scott, 1980) is an example of one of these structures.

The age of the last movement along the northwest-trending linears may be approximately 38a Ma to 390 Ma. These dates were obtained from Ar40/Ar39 dating of sericite from alteration zones associated with massive sulphide and gold mineralization (Kean and Evans, 1988). Alternatively these ages may represent the period of regional metamorphism.

MINERALIZATION

Two types of mineralization have been documented within the Victoria Lake Group (Evans and Kean, 1987): (1) volcanogenic massive sulphide (VMS), and (2) epigenetic gold mineralization. The VMS mineralization includes disseminated and massive stockwork, exhalative massive lenses and transported sulphides associated with variably altered felsic volcanic rocks and is the same age as the enclosing felsic volcanic rocks. Hence, there are at least three ages of volcanogenic mineralization within the Victoria Lake Group; Upper Cambrian in the Tally Pond volcanics, Lower Ordovician in the Tulks Hill volcanics and Middle Ordovician in the Victoria Mine sequence. VMS mineralization in the Tulks Hill volcanics appears to be confined to a significant time stratigraphic, locally thickened, horizon of extensive felsic volcanic activity and associated highly-depleted arc-tholeiitic volcanic rocks.

Swinden et al. (1989) suggested that the tectonic environment was a rifting island arc. This rifting event would promote hydrothermal activity leading to VMS formation through a combination of high heat flow and enhanced permeability (Cathles, 1983). Neither the LREE-enriched arc sequences (Harmsworth Steady and Lake Ambrose basalts), nor the non-arc (Upper basalt and Diversion Lake Group) sequences are known to host VMS mineralization.

Gold mineralization occurs in a number of different geological environments. Epithermal-style alteration is developed within a shear zone at Bobbys Pond. Mesothermal shear zone hosted lode gold mineralization and accompanying alteration occurs in a variety of rock types in a number of settings. Lode gold mineralization with associated aluminous alteration is developed within sheared felsic and mafic volcanic rocks at Midas Pond. Similar mineralization, hosted by quartz veins, is developed along a deformed nonconformity between the Silurian (?) Rogerson Lake Conglomerate and the Valentine Lake intrusive suite (Valentine Lake quartz monzonite. There appears to be a spatial relationship between the gold mineralization-alteration and the structural linears (Fig. 5), particularly in the Tulks Hill volcanics and along the southeast margin (major structural break) of the Victoria Lake Group. Narrow, northeast-trending shears with associated carbonate alteration, developed within a gabbro phase of the Valentine Lake intrusive suite along the Victoria River, contain anomalous gold values (585 ppb). Deformation within the Tulks Hill volcanics and along the southern margin of the group is more intense and is of a brittle-ductile nature. It has been suggested (Evans et al. 1990) that the major northeast-trending, deep-seated, ductile shears focused the fluid flow upwards (Fig. 6) into second and third-order brittle-ductile shears where the mineralization-alteration occurred. Similar styles and settings of mesothermal gold mineralization have been well documented from a wide variety of settings (eg. Kerrich, 1989). To date, gold mineralization has not been documented within the less deformed sequences.

If the gold mineralization is related to movement along these structures, and the last movement along these is in the 380 Ma to 395 Ma range (Kean and Evans, 1988), then this provides a tentative upper age limit on the gold mineralizing processes.

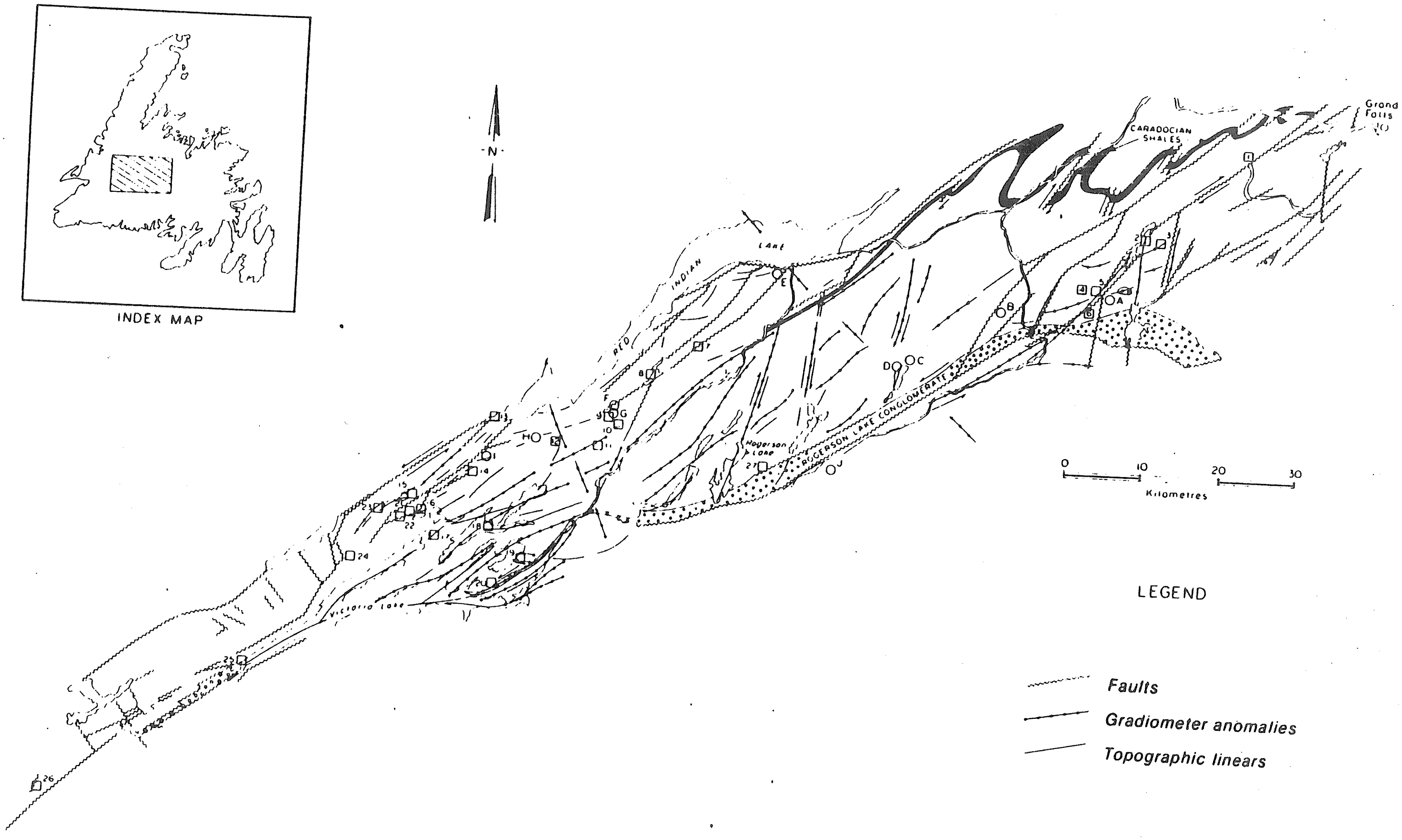

Figure 5. North-northeast and northwest structural linears. Arrows show the direction of movement along the fault systems. Squares represent gold mineralization or alteration; Circles volcanogenic massive sulphide mineralization (modified from Kean and Evans, 1988).

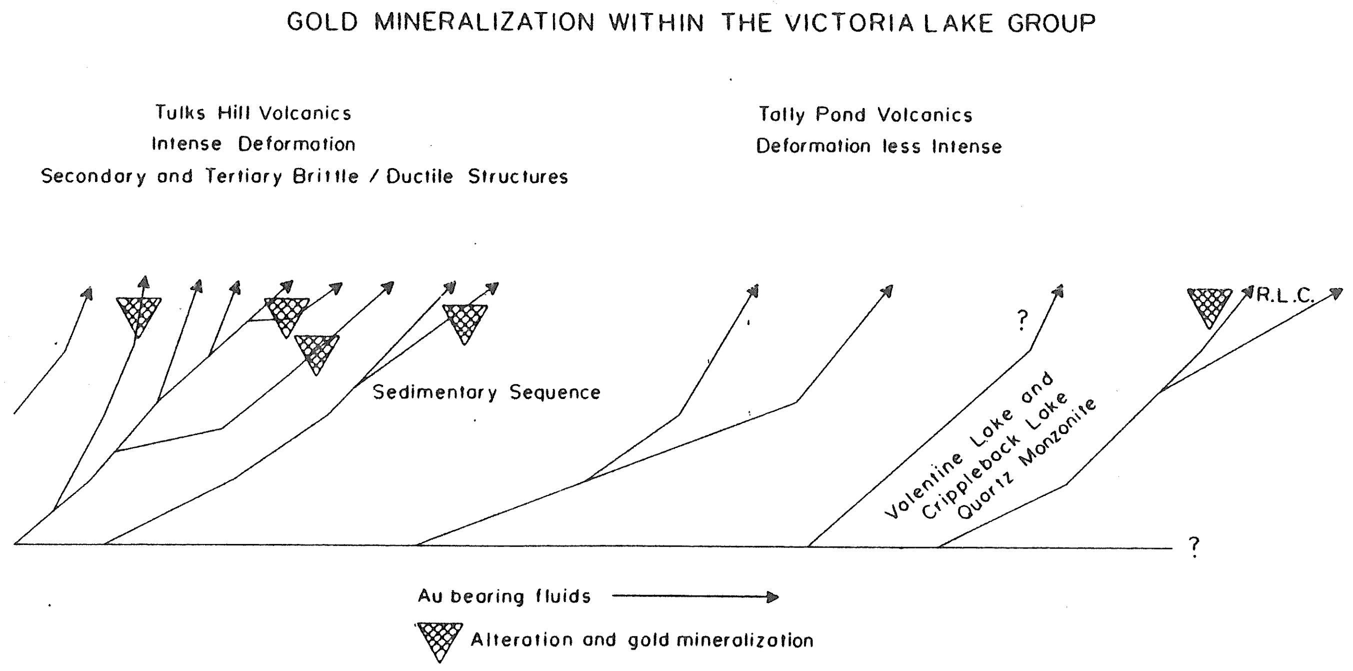

Figure 6. Gold mineralization model within the Victoria Lake Group. Au bearing fluids passed upwards through the ductile shears and were focused into the second- and third-order brittle-ductile structures where the alteration and mineralization developed (after Evans et al., 1990).

VICTORIA MINE PROSPECT

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INTRODUCTION

The Victoria Mine prospect is located approximately 15 kilometres southeast of Buchans, near the mouth of Victoria River. It consists of a number of high-grade Cu-Zn-Pb showings (trenches and/or drill intersections) along an approximately 1 km strike length (Fig. 1).

EXPLORATION HISTORY

Mineralization was first discovered in the early 1900's. Three shallow (approximately 12 m) shafts were sunk, one at the Brook Shaft and two in the Main Shaft area, but no production resulted. Prior to 1980 a total of 38 diamond drill holes totalling approximately 3900 m tested the mineralized zone. Estimates from the mid-fifties as to grade and tonnage were:

Main Zone	10,000 tonnes	6% Cu
Brook Zone	20,000 tonnes	3.5% Cu
"Low Grade Zone"	25,000 tonnes	0.5% Cu, 1.2% Pb, 5.9% Zn

The Victoria Mine area was acquired by BP Resources Canada Limited in 1985. Since that time the prospect has undergone an extensive exploration program consisting of linecutting, geological mapping, core relogging, soil geochemical surveys and geophysical surveys including magnetometer, VLF-EM and UTEM. The geophysical surveys failed to delineate an obvious anomaly associated with the mineralization. Soil sampling outlined a number of significant multi-element anomalies and trenching on one of these uncovered high grade zinc (up to 44% Zn from grab samples) mineralization. Approximately 695 m of diamond drilling has followed-up this discovery.

GEOLOGY

The Victoria Mine area is at the northeast end of the Tulks Hill volcanics, an extensive belt of typically quartz-phyric felsic volcanics which hosts a variety of volcanogenic massive sulphide prospects and showings. In the Victoria Mine area, however, quartz-phyric felsic rocks are not predominant.

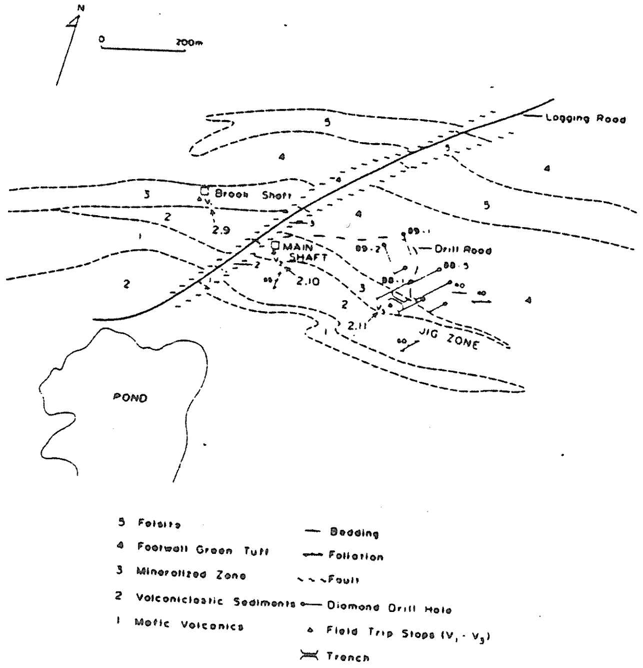

Figure 1. Geology map of the Victoria Mine area showing stop locations 2 - 9 to 2 - 11.

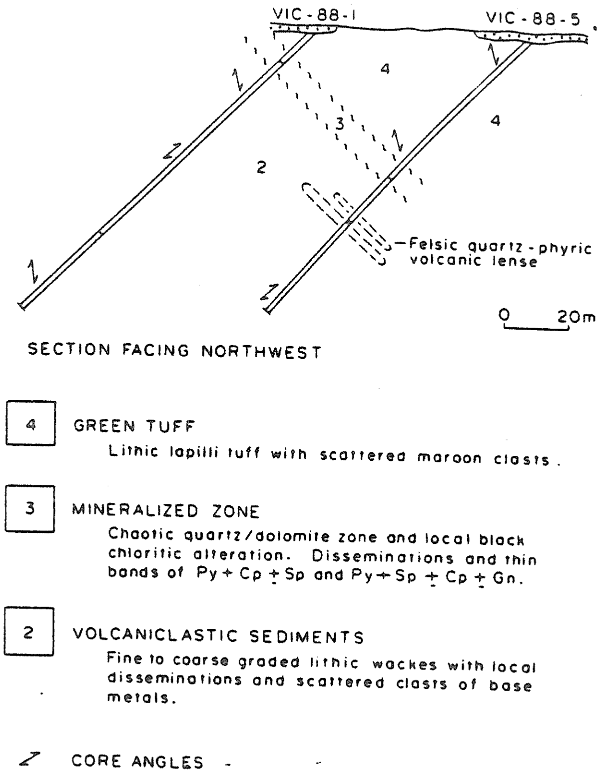

Figure 2. Drill-section through the Jig Zone, Victoria Mine.

Instead the area is underlain by an east-west striking and north-dipping sequence consisting of an aphyric felsite and a distinctive green lapilli tuff in the hanging wall, a felsic mineralized horizon, and mafic volcanics and fine to coarsely graded volcaniclastic sediments in the footwall.

The host rocks to the mineralization consist of a rusty weathering silicic horizon. In the area of the Brook and Main Shafts this horizon appears to be an altered dacitic to felsic tuff and is locally quartz-phyric. In the area uncovered by recent trenching and diamond drilling (Jig Zone) the host appears to be a variably silicified fine grained sediment. Also associated with the mineralization in the latter area is the "chaotic quartz/dolomite" zone, consisting of contorted white quartz/dolomite veins and vein fragments in a dark grey pyritic siltstone. It is typically only a few metres thick but occurs at or near the contact with the hanging wall green tuff (Fig. 2).

Mineralization is fine grained, commonly banded and varies from pyrite dominated to pyrite-chalcopyrite +/- sphalerite or pyrite-sphalerite +/- chalcopyrite +/- galena. The pyrite-chalcopyrite dominated mineralization is typically associated with a black chloritic alteration whereas the pyrite-sphalerite mineralization is associated with the quartz/dolomite zone. Recent drill intersections assayed between 2 to 10.7% Cu in the former and 7 to 15% Zn in the latter over widths of a few metres. However, the mineralization is lensoid in nature and continuity of thicker bands seem limited. Precious metal values are low in all types of mineralization: typically < 25 g Ag and < 0.4 g Au.

Local clasts and disseminations of sphalerite/galena are present in the footwall volcaniclastics up to tens of metres below the main mineralized interval. Interestingly, this sequence seems to consistently young towards this mineralized interval, indicating that the source of these clasts is lower in the footwall volcaniclastic sequence. No significant mineralization has been found in the hanging wall rocks.

STRUCTURE

The Tulks Hill volcanics are characterized by a penetrative NE-SW trending regional foliation, typically developed subparallel to bedding and axial planar to tight to isoclinal folds. In the Victoria Mine area, this fabric is nearly normal to the strike of the various lithologies. It is well developed in the footwall volcaniclastic and mineralized horizons but only weakly developed in the hanging wall tuffs.

The lithological and structural contrasts between the hanging wall and footwall sequences indicate that a fault, possibly a thrust fault may separate these two sequences. The "chaotic quartz/dolomite" zone may record the formation of quartz/dolomite veins and their subsequent brecciation by movement along this same structure. Structural dislocation along this horizon may also explain the discontinuous nature of the mineralization.

Late NE-SW trending sub-vertical faulting cut both hanging wall and footwall sequences with a resulting horizontal displacement of approximately 30 m (Fig. 1).

DISCUSSION

The Victoria Mine prospect has usually been classified as a volcanogenic massive sulphide deposit (Thurlow, 1978; Kean and Evans, 1988). The local geology, mineralization and alteration style support this hypothesis. Recent work indicates that structure may have played an important role in remobilizing this mineralization along faults at the base of the footwall volcaniclastics, as indicated by the presence of mineralized clasts below the possible fault related mineralization.

BOBBY'S POND ALTERATION ZONE

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INTRODUCTION

Bobby's Pond is located approximately 20 km SSE of Buchans. The Bobby's Pond alteration zone is an extensive, though poorly exposed, high-alumina alteration zone characterized by abundant pyrophyllite with lesser but locally abundant alunite, orpiment and native sulphur.

EXPLORATION HISTORY

A number of siliceous boulders containing pyrophyllite ($Al_2Si_4O_{10}(OH)_2$), alunite ($[Na,K]Al_3(SO_4)_2(OH)_6$), orpiment (As_2S_3) and native sulphur were discovered in the Bobby's Pond area in the fall of 1985. The common occurrence of these minerals in epithermal precious metal districts prompted the initiation of a gold exploration program in the area.

Exploration activity to date has consisted of linecutting, geophysical surveying (VLF-EM and magnetic), soil sampling, geological mapping and basal till sampling. Late in 1989 a single drill hole was collared on the northwest side of the zone.

GEOLOGY

The geology underlying the Bobby's Pond area has been divided into three zones with characteristic geology, alteration and structure (Fig. 1). The northwest zone consists of a relatively unaltered sequence of massive weakly foliated plagioclase bearing crystal tuffs, thin aphanitic felsic horizons (ash tuff?), felsic pyroclastics and aphanitic rhyolitic flows. The southeast zone consists of strongly foliated to sheared units including a prominent rusty weathering felsic tuff, a mafic flow/agglomerate and quartz-porphyry. The central or Bobby's Pond zone is poorly exposed. Exposures within this zone, as well as numerous, locally derived boulders, are typically highly altered and sheared siliceous rocks.

Alteration within the Bobby's Pond zone is predominantly silicification and argillization (pyrophyllite-rich) with a thin margin of chloritic alteration on both sides. Heavy disseminations and rare massive pods of pyrite are present in the argillic portions whereas only minor disseminated pyrite (< 2%) is present in the silicified portions. The typical lithology as seen in drill core and outcrop is a strongly foliated, white to grey aphanitic rock composed of vein-like ribbon bands of quartz with numerous, thin pyrophyllite-coated foliation planes. Occurrences of alunite, native sulphur and orpiment are largely limited to boulders scattered about the area.

A few gold grains from the heavy mineral fraction of till samples taken over the alteration zone represents the only significant mineralization discovered to date. Gold values in rock range from <5 to 100 ppb.

DISCUSSION

The alteration types and unique mineral assemblages invite comparison with epithermal precious metal deposit types. Possible analogues include other Paleozoic Au deposits such as the Hope Brook Mine (McKenzie, 1986) and the Haile and Brewer Mines in the Carolina Slate Belt (Worthington et al., 1980 and Butler, 1985).

Although the alteration style and mineralogy are similar to epithermal systems, the degree of structural modification implied by the shear fabrics makes it dangerous to use an epithermal model in isolation from structural considerations. The focused vein system with its associated alteration halo typical of many epithermal systems would have probably been significantly deformed during shearing.

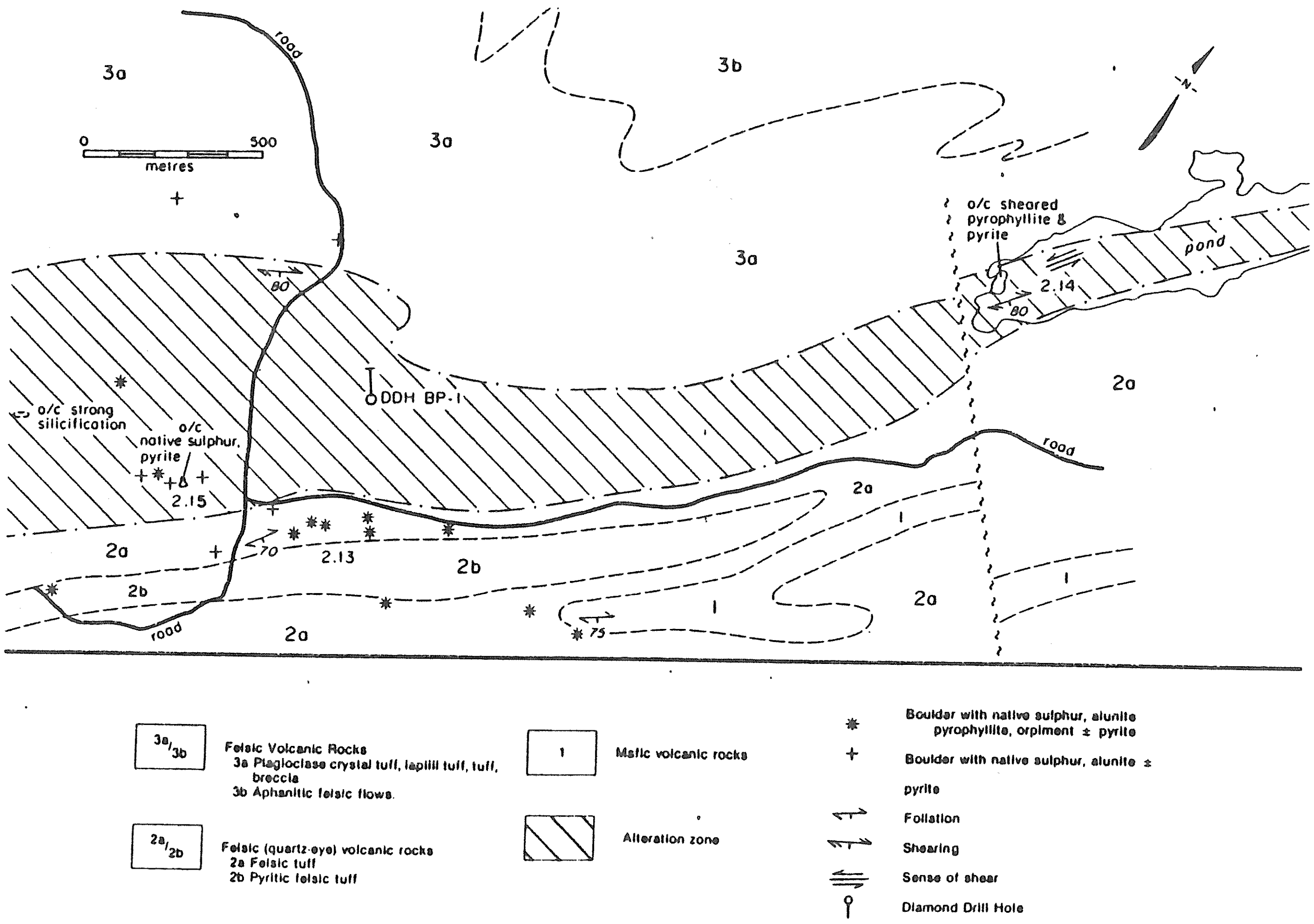

Figure 1. Geological map of the Bobby's Pond area showing stop locations 2 - 13 to 2 - 15.

MIDAS POND GOLD PROSPECT

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INTRODUCTION

The Midas Pond gold prospect, hosted by extensively sheared and altered felsic and mafic pyroclastic rocks, is located at the southwestern end of the Tulks Hill volcanics to the east of the Tulks Valley fault (Fig. 1). The prospect was discovered by BP-Selco personnel in 1985 as part of a re-evaluation of archived soil samples collected by ASARCO. To date the prospect has been trenched and tested by 19 diamond drill holes. Gold values are sporadic with the best intersection assaying 7.3 grams over 0.9 metres.

GEOLOGY AND MINERALIZATION

The prospect consists of a zone of quartz veining within a northeast-trending, northwest dipping, anastomosing shear zone (Fig. 1). Structurally overlying the mineralized zone is a 70 by 800 metre area of intense pyrophyllite-kaolinite-paragonite-silica alteration. Immediately beneath the quartz veined zone is a banded mafic unit. This rock is interpreted to have originally been a coarse mafic breccia which has been highly deformed within the ductile shear zone. With decreasing distance from the zone of quartz veining the mafic rock becomes more silicious and the pyrite content (with anomalous gold) increases from 2 percent to 5 percent. This change is also accompanied by an increase in the amount of carbonate and by an apparent decrease in epidote. This may reflect the action of CO_2-rich fluids which appear to have been responsible for the deposition of the gold mineralization.

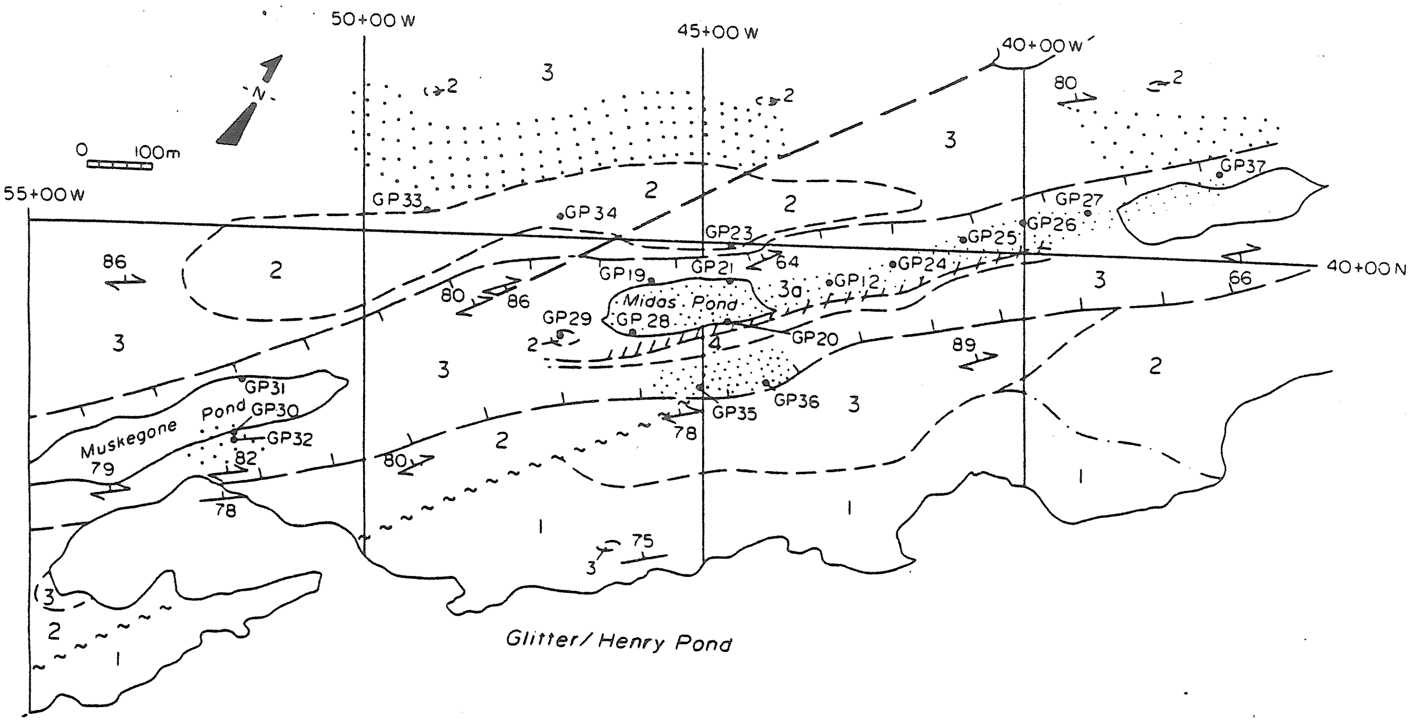
The gold mineralization occurs in a subvertical zone of crosscutting quartz-pyrite-tourmaline-ankerite-paragonite veins developed near the contact between the deformed mafic breccia (banded mafic unit) and the structurally overlying felsic pyroclastic rocks (Fig. 1). The zone has a width of 10 to 15 metres and a strike length of 700 metres. Gold enrichment (> 5 ppb) locally extends th width of the zone for up to 20 metres. Th gold is associated with pyrite an variations in gold grades of the quart veins are reflected in the pyrite content

Three, possibly four, generations o quartz veining are present. The earlies veins are narrow (< 1 cm), pytigmaticall folded veins that are developed at a hig angle to the shear zone fabric. These veins carry no pyrite and no gold.

The second generation of veins, are boudinaged, shear zone parallel veins, that contain pyrite, carbonate, minor tourmaline and anomalous gold. The latest veins, the most abundant type, are undeformed and form a conjugate set developed at an angle of between 39° and 84° to the shear zone fabric. They contain pyrite, ankerite, tourmaline, paragonite and gold and are generally less then a metre thick. They appear to be related to conjugate fractures formed during progressive shear zone development probably during the transition from ductile to brittle-ductile deformation. The best gold values occur in the noses of broad flexures where there appears to be a thickening of the quartz veining. This flexuring can be observed in the outline of both the shear zone and the banded mafic unit.

DISCUSSION

A model for the gold mineralization at Midas Pond (Fig. 2) is fairly typical of shear zone hosted lode gold mineralization. The shear zone, possibly a secondary structure off the major, ductile Tulks Valley fault, provided a conduit for CO_2-rich fluids. A transition from ductile to brittle-ductile deformation produced fractures which formed the loci for quartz vein formation. Competancy, differences between the felsic and banded mafic units may have aided this fracturing. There also appears to have been a lithological control on the actual site of gold



LEGEND

4	*Banded mafic unit*
3	*Felsic crystal tuff, lapilli tuff and minor mafic crystal tuff*
2	*Mafic, feldspar crystal tuff and minor breccia*
1	*Mafic breccia and minor feldspar crystal tuff*
///	*Zone of gold enrichment*
∴∴	*Zone of alumina alteration*
: : :	*Zone of silicification*

SYMBOLS

/ / /	*geological contact (defined, approximate, gradational)*
~ ~ ~	*fault (approximate)*
⊤ ⊥	*shear zone*
— — —	*air-photo lineament*
•GP	*diamond drill hole*
⊥ ⊥	*bedding tops known (inclined)*
⇄	*cleavage (inclined)*

Figure 1. Geological map of the Midas Pond area.

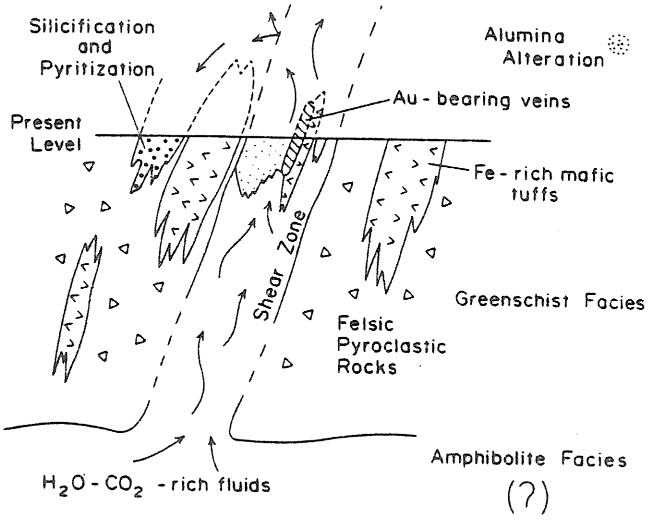


Figure 2. Schematic model for gold mineralization at Midas Pond. The rising CO_2-rich fluids reacted with the iron-rich banded mafic unit forming pyrite and precipitating gold within quartz veins. The veins developed within brittle fractures formed as a result of competency differences between the mafic and felsic volcanic rocks within the larger shear zone.

mineralization. The rising CO_2-rich fluids came in contact with the relatively more iron-rich mafic breccia (banded mafic unit) forming the carbonate alteration and producing pyrite by sulphidation. The gold precipitated out of solution and was deposited along with the pyrite.

VALENTINE LAKE GOLD PROSPECT

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INTRODUCTION

The Valentine Lake gold prospect, located along the southeast margin of the Victoria Lake Group near Victoria Lake, was discovered by BP Resources Canada Limited in 1986. It consists of vein type mineralization hosted by a trondhjemite intrusion and covers an area of approximately fifteen square kilometres. The mineralization was found as the result of follow up of anomalous gold in reconnaissance B-horizon soils. To date twenty-five holes have been drilled on several separate targets on the property. The most explored target has been penetrated by four drillholes, at approximately one hundred metre spacing and includes intersections of 22 metres of 2 g/t gold and 3 metres of 24 g/t gold.

GEOLOGY

The key geological elements in the Valentine area are the Valentine Lake intrusive suite and the nonconformably overlying Rogerson Lake Conglomerate (Fig. 1). The intrusive suite forms an elongate northeast trending body. The northwestern side of this body is dominated by medium to coarse grained equigranular gabbro and diorite with frequent small areas of pyroxenite. Fine to medium grained equigranular to quartz porphyritic trondhjemite occupies the southeast side of the intrusion. Field relationships and lithogeochemistry indicate that the intrusives form a single fractionated igneous suite. The trondhjemite has been dated (U/Pb in zircon) as 562 and 563 ± 2 Ma (Evans et al., 1990).

The Rogerson Lake Conglomerate forms a thin and regionally extensive unit which nonconformably overlies the southeast side of the Valentine Lake intrusive suite Fig. 1). The conglomerate is greenish-gray coloured, unsorted, polymictic and matrix to clast supported. n the project area trondhjemite clasts dominate and quartz crystal fragments form an important matrix component. Other important clast lithologies include mafic igneous rocks, fine grained sedimentary rocks of unknown provenance and clasts of the conglomerate itself. The conglomerate grades upward into a conformable sequence of siltstones and sandstones of similar composition containing thin beds of fine pebble conglomerate. The regionally extensive and uniform thickness of the unit, its unsorted character, its close compositional association to underlying bedrock lithology, and clasts of the conglomerate within the conglomerate, all suggest that the unit was deposited in a high energy environment probably along an active fault scarp.

All of the above rocks are cut by syntectonic fine grained mafic dykes with a preferred orientation sub-parallel to regional fabrics and lithologic trends.

Structure

Rocks in the Valentine area record a single deformational event which is interpreted as a north-northeast to south-southwest directed transpression that predates the nearby Silurian(?) Redcross (Rodeross) Lake mafic/ultramafic intrusion. The deformation is evidenced as a strong penetrative s-fabric associated with prominent flattening/stretching, northeast-trending shearing, small scale folding, and an overturning of the rock units so that the conglomerate-trondhjemite nonconformity dips 60 to 70 degrees northwest underneath the trondhjemite.

Deformational styles vary from mainly brittle in the intrusive rocks to ductile in the conglomerate unit. The conglomerate consists of alternating high and low strain zones with a major zone of high strain occurring along the conglomerate-trondhjemite contact. The high strain zones are areas of shearing

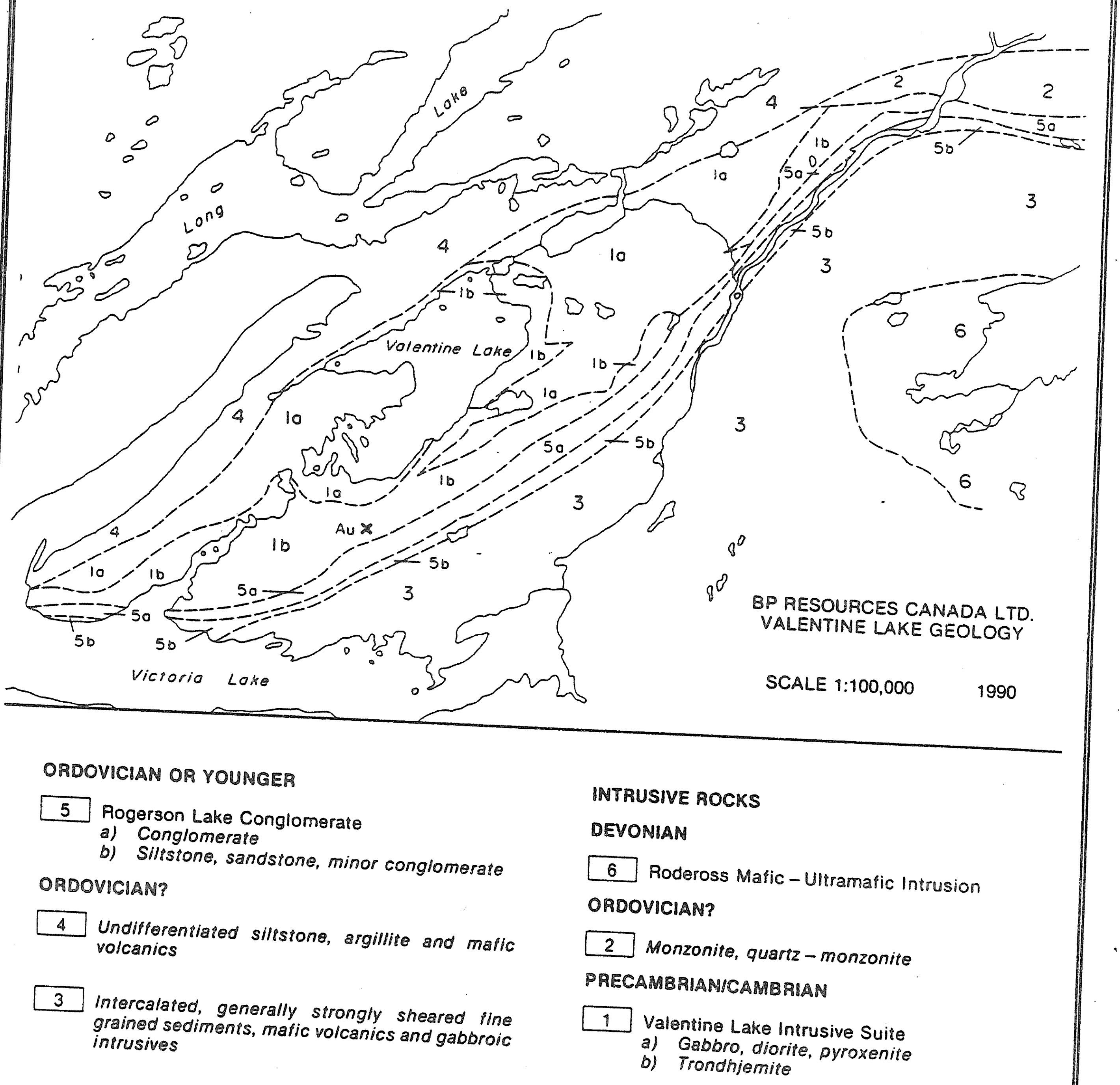

Figure 1. Geological map of the Valentine Lake area.

and/or very strong flattening and stretching and small scale tight to isoclinal folding. Brittle deformation in the trondhjemite is represented by a pervasive network of fracturing and by abundant quartz-tourmaline veining. Fractures are quartz-tourmaline coated with slickenslides that plunge steeply north-northeast. Movement also occurred along rare thin shear zones developed in the trondhjemite, and more importantly along the abundant strongly sheared fabric parallel mafic dykes. Development of c-s fabrics and anticlockwise rotation of clasts in the conglomerate indicate a sinistral sense of shearing.

MINERALIZATION

Gold is contained mainly in the quartz-tourmaline veining hosted by the trondhjemite phase of the Valentine Lake intrusive suite. The veins occur throughout the whole of the trondhjemite but for the most part do not constitute a significant volume of the rock (Fig. 2). Locally the veins cut the conglomerate, but they tend to die out quickly. Veins are typically 1 to 10 centimetres thick and less than 10 metres long, but may attain a thickness of one metre and a length of 50 metres. They have a preferred strike of 130-140° and dip 40-50° to the southwest. This orientation is orthogonal to the x axis and lies in the yz plane of the strain ellipsoid, suggesting that the veins formed along extensional fractures during the main deformation event. Concentration of veining is related to areas of high strain, particularly the northeast trending shearing. Most of the significant auriferous veining occurs within 500 metres of the nonconformity, along which shear deformation was focused. On a more local scale, areas of vein concentration occur directly adjacent to mafic dykes. In these areas, veins tend to diverge from the preferred orientation, bifurcate, form criss-crossing networks producing a breccia effect, and die out in feathery fashion. This is interpreted as being indicative of the stronger deformation and fluid flow adjacent to the shearing.

Mineralogically the veins consist of massive milky to occasionally clear quartz with varying concentrations of acicular black tourmaline and lesser calcite and chlorite. Pyrite constitutes 1 to 2% of the veins, occurring sporadically as coarse crystals and aggregates. Accessory minerals include rare occurrences of scheelite and tungstite and traces of pyrrhotite, arsenopyrite, galena, chalcopyrite, sphalerite and bornite. Locally the veins display banding of quartz versus, tourmaline, implying more than one episode of opening and mineralization. Vugs are rare. Wallrock alteration is restricted to 20 centimetres from the vein margins and consists of sericitization, albitization, and variable silicification containing tourmaline and pyrite.

Gold is closely related to pyrite within the quartz veins. Coarse gold appears to be a near surface phenomenon related to supergene processes. Surface exposures of veins commonly display spectacularly abundant occurrences of visible gold up to 2 mm in size with grab samples assaying in the ounces per ton range. Petrographic examination of unoxidized drill core suggests that the gold occurs in the pyrite as sub-micron sized inclusions or in solid solution, and less abundantly as up to 10 micron sized inclusions of gold telluride (calaverite?) and elemental gold. Pyrite within the wallrock alteration adjacent to the veins is also auriferous. Silver values in the quartz veins are highly variable with a mean gold:silver ratio of about 5:1.

In addition to the quartz veins, gold has been noted in sheared pyritiferous trondhjemite and in small pyritiferous areas of conglomerate adjacent to the nonconformity. At two localities, gold occurs in sheared and carbonatized sections of the fine grained sediments at the top of the conglomerate sequence. At both these locales, very thin but laterally extensive auriferous quartz veins, occupying the preferred vein orientation, imply a genetic link with the trondhjemite hosted veins.

DISCUSSION

Gold at Valentine Lake occurs in a very extensive quartz vein system measured in terms of square kilometres. Field evidence suggests that the mineralization was intimately associated with the main deformation affecting the area. Trondhjemitic rocks of the Valentine Lake intrusive suite provided the main host for mineralization because of their mechanical properties favouring brittle deformation. Concentration of auriferous veining is spatially related to northeast-trending

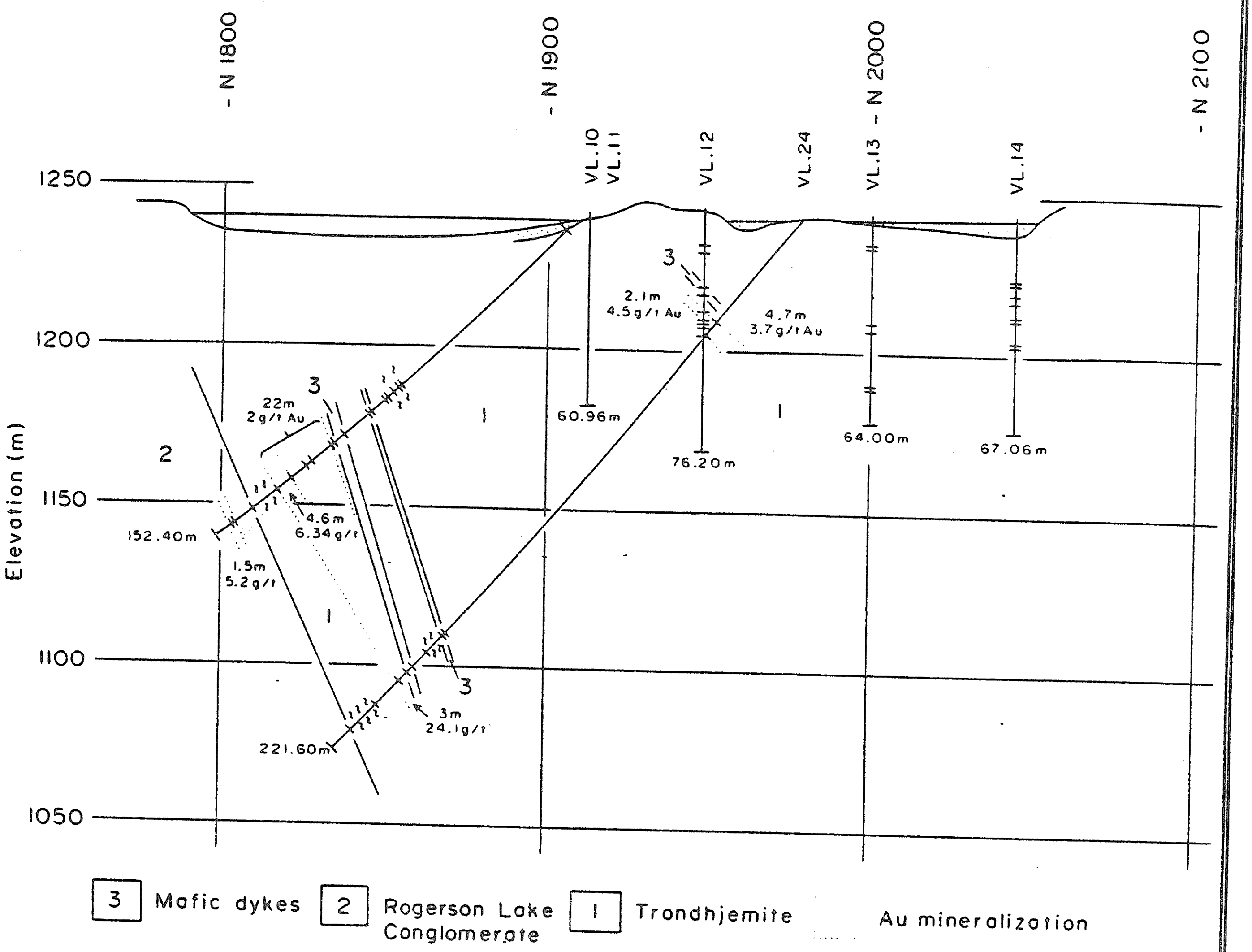

Figure 2. Drill-section Valentine Lake. Section faces southwest.

shear zones, and to the nonconformity between the conglomerate and trondhjemite which was an important site of shear deformation. The Rogerson Lake Conglomerate is interpreted to have formed along a major fault. The fault may have served as the principal conduit for metamorphic and/or other fluids during the deformation. This would explain the spatial relationship of mineralization to the nonconformity and indicates the importance of a major structure in formation of the deposits.

TULKS HILL DEPOSIT

(after Kean and Evans, 1988)

The Tulks Hill deposit, a significant Zn-Pb-Cu volcanogenic, massive sulphide deposit, was discovered by ASARCO personnel in the early 1960s. It is located near the southwest extremity of the felsic pyroclastic rocks of the Tulks Hill volcanics (Figure 1). The deposit consists of four stratiform sulphide lenses (Figure 19.2) with a total of about 750,000 tonnes grading approximately 5-6% Zn, 2% Pb and 1.3% Cu, 41 g/t Ag and 0.4 g/t Au (Kean & Thurlow, 1976; Jambor, 1984; Jambor & Barbour, 1987).

The deposit is marked by gossans and its host rocks are well exposed in Tulks Hill. They are northeast-trending, steeply northwest-dipping sericite schist of greenschist metamorphic grade, derived from felsic lapilli tuff, quartz- (+/- feldspar-) crystal and crystal-lithic tuff. Minor tuffs of intermediate composition and diabase/andesite dykes or sills are intercalated with the felsic rocks. The dykes and sills locally contain quartz and/or carbonate amygdules. Sub-volcanic intrusions of quartz and minor feldspar porphyry and aphanitic rhyolite are also present.

An inhomogeneously developed regional schistosity, coplanar to bedding, is best developed in the host rocks. This penetrative fabric is axial planar to tight to isoclinal folds, and is defined by sericite, chlorite and locally quartz segregations. Volcanic-breccia fragments have undergone moderate flattening within the foliation planes. A fracture cleavage and kink bands constitute less well - developed, later deformation. Faulting generally parallels the regional foliation trend, but minor cross-faulting has also taken place. The northeast-trending Tulks Valley Fault parallels the regional trend of the volcanic rocks and is the major fault in the area, forming the northern boundary of Tulks Hill volcanic unit.

The four sulphide lenses or zones are termed the T_1, T_2, T_3, and T_4 lenses. Since folding in this area is isoclinal, some of the lenses may be structural repetitions of the same horizon. Moreton (1984) interpreted the T_3 and T_4 lenses to be folded equivalents of the same stratigraphic horizon, based on mineral zoning and distribution of alteration. Evidence suggests, however, that reverse mineralogical zoning also occurs at depth in the T_3 lens. Both the hanging wall and footwall display hydrothermal alteration associated with the mineralizing process. Therefore the stratigraphic footwall cannot always be determined on the basis of intensity of alteration.

The lenses are roughly tabular to lensoid in shape, and dip 70° northwest (Figure 19.3). They are predominantly pyritic (about 70%), with sphalerite being the main economic mineral. Lesser galena and chalcopyrite are present in approximately equal amounts. Arsenopyrite,tetrahedrite-tennantite and pyrrhotite are variably distributed accessory sulphide minerals. Minor magnetite occurs in the T_1 and T_2 lenses. Oxidation and supergene alteration minerals include digenite, covellite and anglesite (Jambor, 1984). Most of the silver is attributable to argentian tetrahedrite and tennantite, and nearly all of the gold is native (Jambor, 1984). Dolomite, calcite and barite are either associated with quartz or disseminated among the sulphide.

The pyrite is euhedral to anhedral and generally fine grained, although locally it is coarse grained. No colloform or framboidal textures were observed. The sphalerite is generally brown, fine- to medium-grained and is mostly associated with abundant pyrite. Galena is fine- to medium-grained and occurs as patches in, or at the rims, of sphalerite grains. Sulphide layering is generally well developed, particularly in the sphalerite/pyrite-rich parts; chalcopyrite-sphalerite banding is also locally developed. Chalcopyrite, galena and sphalerite are also present in quartz veins.

The contacts of the massive sulphides with the hanging wall and footwall vary from sharp to gradational. Both the structural hanging wall and footwall are hydrothermally altered; in some areas, however, it appears to be more intensely developed in the structural footwall. Siliceous alteration predominates, characterized by grey silica veinlets, and greenish to yellowish sericite-rich seams in grey to white bleached lapilli tuff and quartz-crystal tuff. Disseminations and stringers of sulphide are variably developed, predominantly rich in pyrite but also chalcopyrite, with lesser galena and sphalerite. Minor chlorite-dominated alteration assemblages are locally developed within the area of siliceous alteration. Moreton (1984) reported that chlorites from the mineralized sequences show a Mg-enrichment trend from the least to most mineralized rock.

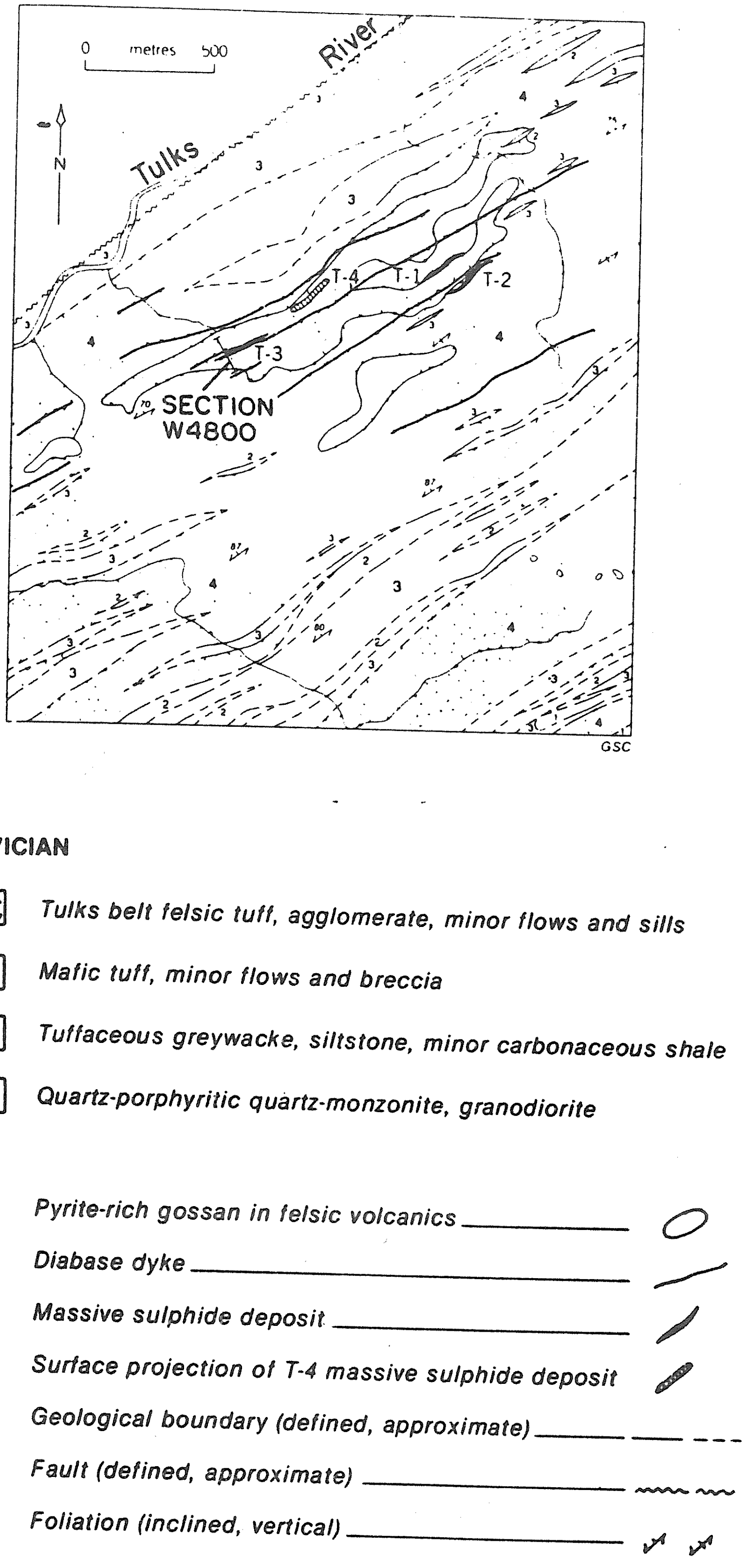

Figure 19.2 General geology of the Tulks (Hill) deposit, appellation of the massive sulphide lenses and location of W4800 cross-section (after Jambor & Barbour, 1987).

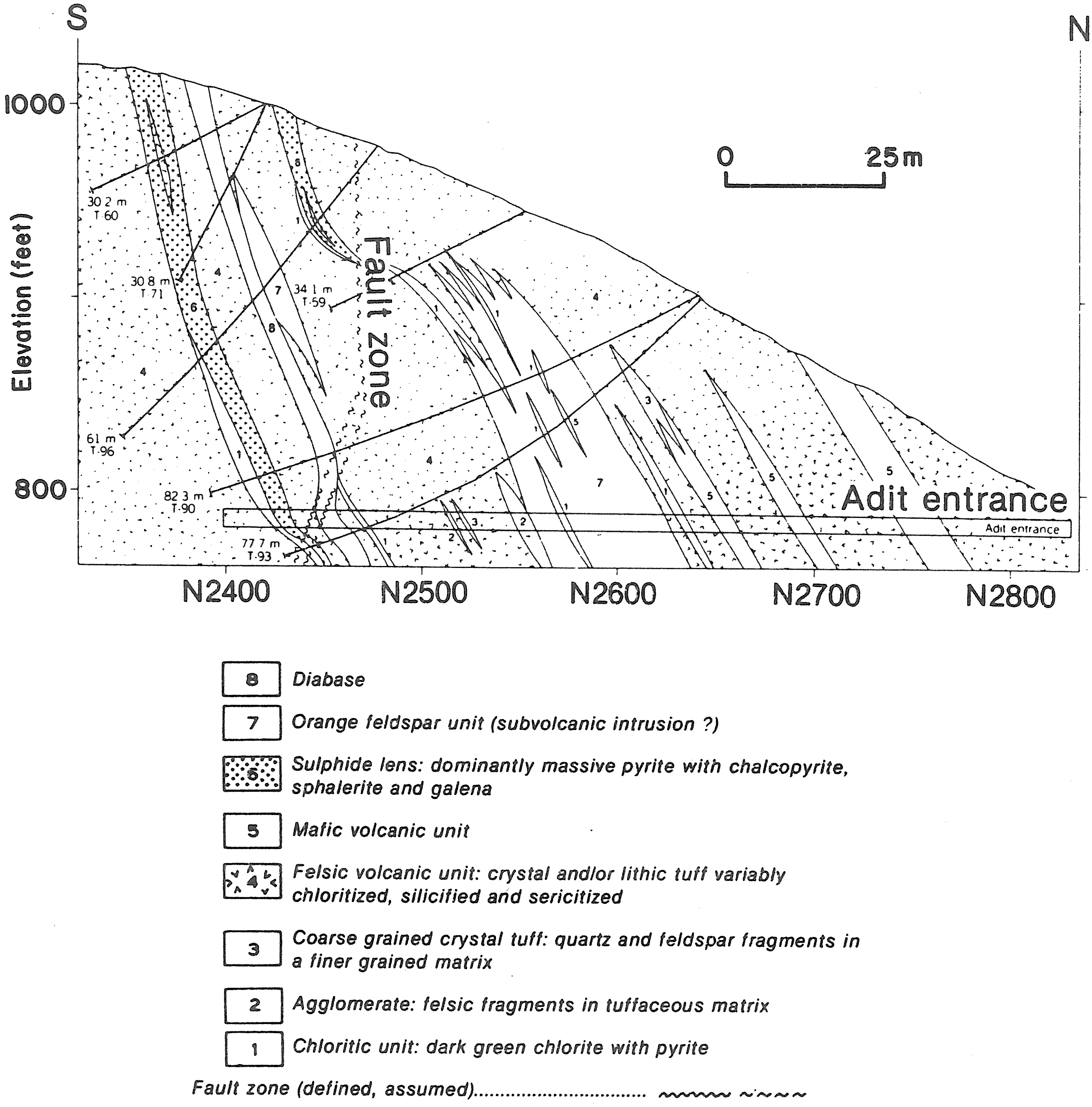

Figure 19.3 *North-south cross-section (W4800) through the T_3 lens, Tulks (Hill) deposit* (after *Jambor & Barbour, 1987*). Grid co-ordinates and elevations are in feet.

GEOLOGY AND GENESIS OF THE DUCK POND VOLCANOGENIC MASSIVE SULPHIDE DEPOSIT

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INTRODUCTION

In May of 1987, after 13 years of continuous exploration in the Tally Pond Volcanic Belt, the Noranda Exploration Company Limited (60%) and BP Resources Canada Limited (40%) Joint Venture, intersected 55m of massive sulphide mineralization at Duck Pond. Subsequent diamond drilling has outlined a major massive sulphide deposit, and produced several new discoveries in the immediate area.

The Duck Pond Deposit consists of two polymetallic sulphide lenses (Upper Duck and Lower Duck) that have an aggregate tonnage of more than 15,000,000 tonnes of massive sulphide. The sulphide lenses occur in moderately to highly chloritized and sericitized felsic volcanics.

The Upper Duck lens has an average ore thickness of 18m and consists of variably tectonized clastic pyrite, chalcopyrite and sphalerite - rich ore. Within the massive sulphide lens an ore grade core contains geological ore reserves of 4,278,000 tonnes grading 3.58% Cu, 1.05% Pb, 6.63% Zn, 68.31 g/t Ag & 1.00 g/t Au.The Lower Duck lens, interpreted to be a faulted continuation of the Upper Duck lens, is located several hundred metres east of and 300m below the Upper Duck, is generally flat-lying, and ranges from 3-15 m in thickness. This deposit is only partially delineated and inferred geological reserves to date are 500,000 to 1,000,000 tonnes of similar grade to the Upper Duck Lens.

At depths of 50-100m stratigraphically beneath the Upper Duck lens, three small, poorly delineated, Zn-rich pods of stringer to massive ore grade sulphide (Sleeper Zones) contain presently-delineated reserves of ~300,000 tonnes grading ~15% combined base metals.

LOCATION AND ACCESS

The Duck Pond property is located ~30 km southeast of Buchans and 90 km southwest of Grand Falls. Access to the area is gained via a network of logging roads established and maintained by Abitibi-Price Co. Ltd. The logging roads originate at Millertown on Red Indian Lake, from where the provincial highway system provides easy access to major airports and service centres. A semi-permanent camp has been established in the area, ~4 km NW of the Duck Pond Deposit.

GENERAL GEOLOGY

The Duck Pond area (Fig. 1) is underlain by the Tally Pond volcanics, a belt of Upper Cambrian, arc-related, volcanics that form part of the Victoria Lake Group. The Tally Pond Volcanics outcrop in an approximately 3 x 100 km, NE-trending linear belt consisting mainly of pillowed basalt and rhyolite flows and their associated pyroclastic and sedimentary products. The volcanic sequences are structurally and stratigraphically overlain by and intercalated with graphitic argillite and siliciclastics.

Deformation in the region has primarily been attributed to the development of open folds with northeasterly trending axes, normal faulting and less important thrust faulting. This folding is associated with a primary penetrative axial planar cleavage and is cut by a number of cross-cutting faults which generally strike in a northwest to westerly direction and appear to displace the limbs of some folds up to several hundred metres.

A significant recent development, resulting from logging of drill core, field mapping and geophysical interpretation, has been the recognition

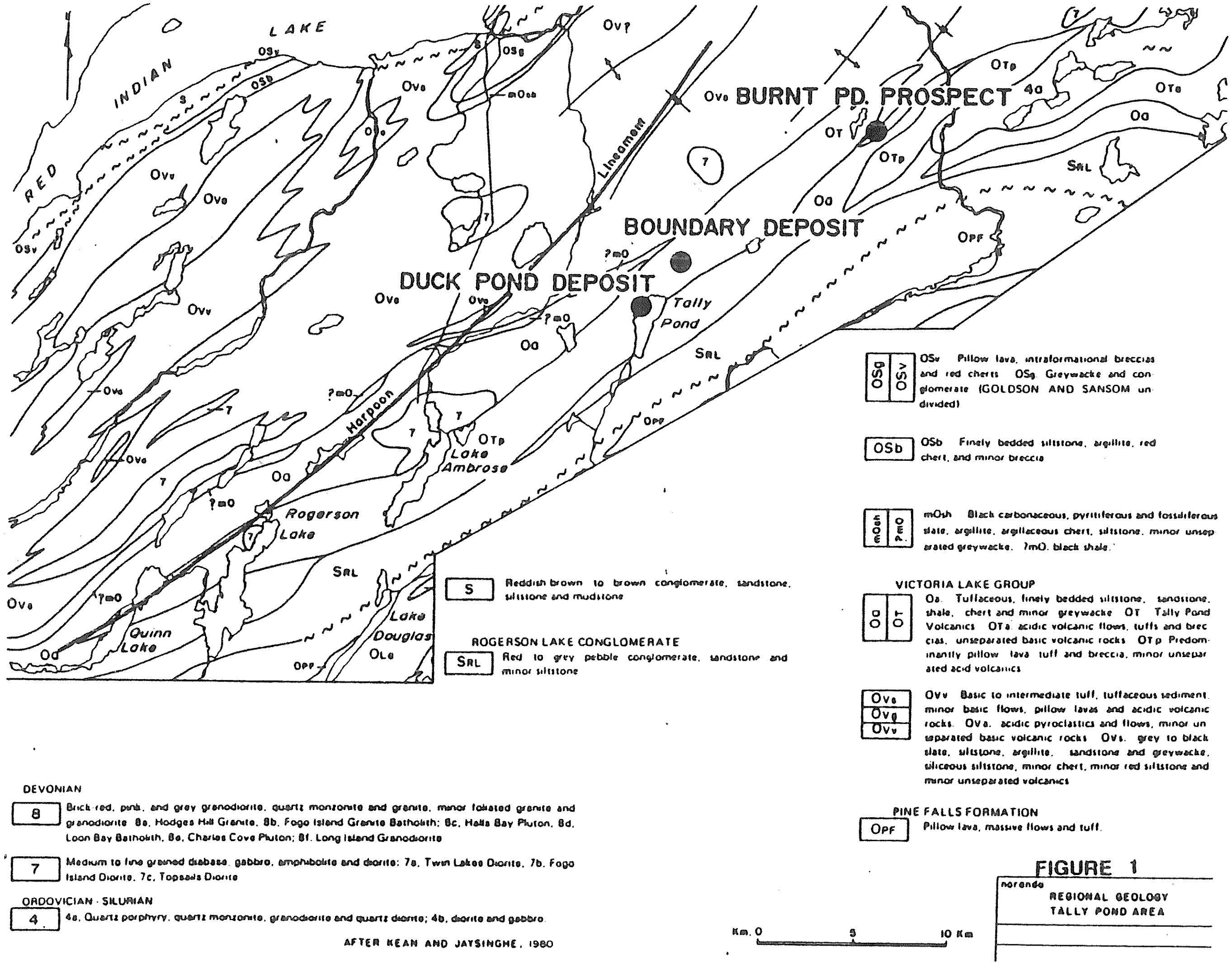


Figure 1. Regional geology of the Tally Pond area including locations of volcanogenic massive sulphides in the Tally Pond volcanic belt (solid dots).

that many of the previously mapped NE-trending graphitic sediment/volcanic contacts are structural rather than stratigraphic, as previously interpreted. Major SE-dipping thrusts in the Duck Pond area are well documented examples. Although these thrusts are crudely parallel to interpreted fold axes, they are clearly the dominant feature in the region and are largely responsible for the attitude, extent and interrelationships of lithologies in the Tally Pond area.

DISCOVERY

The Duck Pond deposit is a blind discovery, found during a systematic, stratigraphic diamond drill program that was testing the down-dip continuation of an altered felsic horizon which contained significant stringer and locally massive pyrite at depth.

Initial work which eventually led to the discovery of the Duck Pond Deposit resulted from reconnaissance surveys stemming from the 1971 Noranda/Nalco Joint Venture discovery of the low grade 18 million tonne Point Leamington volcanogenic massive sulphide (VMS) deposit (Walker and Collins, 1988). Reconnaissance mapping south of Point Leamington focussed on a relatively unexplored belt of felsic and mafic volcanics, the Tally Pond volcanic belt (TPVB). In 1974, the Burnt Pond Prospect (Fig. 1), the first massive sulphide occurrence in the TPVB, was discovered. Over the next five years, Noranda prospectors discovered mineralized outcrop and numerous ore grade boulders (up to 10% Cu and 15% Zn) further to the SW in the TPVB. Also during this period, airborne geophysics and some diamond drilling was carried out.

At this time, much of the TPVB was contained within Abitibi-Price-held leased ground. Subsequently (in 1979), Noranda and Abitibi-Price entered into a Joint Venture Agreement over lands encompassing much of the favourable felsic stratigraphy of the area (BP Canada purchased Abitibi's mineral rights in 1985).

In 1981, the near surface Boundary Deposit was discovered by drilling 15 km SW of Burnt Pond (Fig. 1), after initial prospecting, mapping, geophysics and geochemistry had delineated a significant anomalous target area. By 1983, 500,000 tonnes of 3.5% Cu, 4.0% Zn and 34 g/t Ag had been outlined as three discrete massive sulphide lenses (MacKenzie, 1988). Subsequent to the Boundary discovery, data on the TPVB were compiled and three 1976 anomaly drill holes 4 km to the southwest in the Duck Pond area were relogged. Lithogeochemical anomalies (particularly Ba enrichment), favourable alteration, and significant pyrite mineralization encountered in felsic stratigraphy directly underlying a moderately dipping graphite sediment unit were recognized as comparing favourably with similar features at the Boundary Deposit and other classic VMS environments. Subsequent follow-up drilling down-dip of these intersections cut significant massive pyrite mineralization and culminated in the intersection of 55m of massive sulphide, 20m of which was ore grade, in Hole DP-87-95 in the spring of 1987. The shallowest level of the now delineated Upper Duck lens lies at 250m depth.

GEOLOGY OF THE DUCK POND AREA

Stratigraphy

A complex history of submarine bimodal volcanism and sedimentation, commonly overprinted by intense alteration, and further complicated by structural deformation and dislocation, has been documented by diamond drilling in the immediate Duck Pond area.

Three lithologically distinct, structurally juxtaposed, stratigraphic sequences have been delineated (Fig. 2 and 3). This tripartite package forms a NE-trending structural window of Late Cambrian volcanics and sediments in an overthrust sequence of Ordovician graphitic, argillaceous and siliciclastic sediments (Fig. 2). The stratigraphy is further structurally complicated by NW-SE-trending, moderately to steeply dipping thrusts and wrench faults with net displacements of 500m to 1 km.

Sequence I - The Upper Unmineralized Block

This sequence consists of a >500m thick, shallow-dipping submarine assemblage of cyclic mafic and felsic flows and pyroclastics, intercalated with local graphitic sediments and reworked tuffs. This stratigraphy is cut by several gabbro and porphyry dykes and sills that have been emplaced along minor reverse faults of 100-200m displacement.

Hydrothermal alteration and

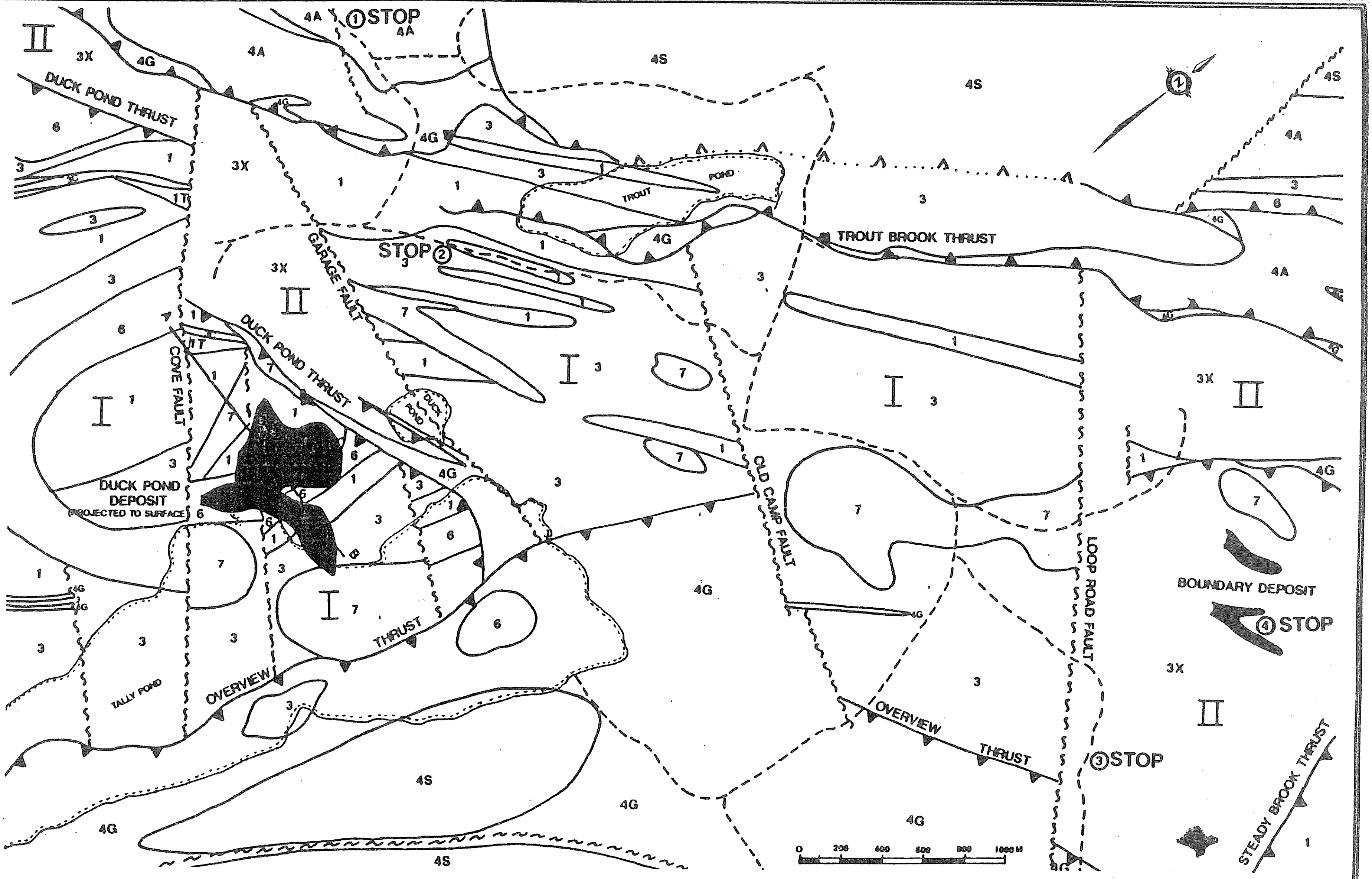
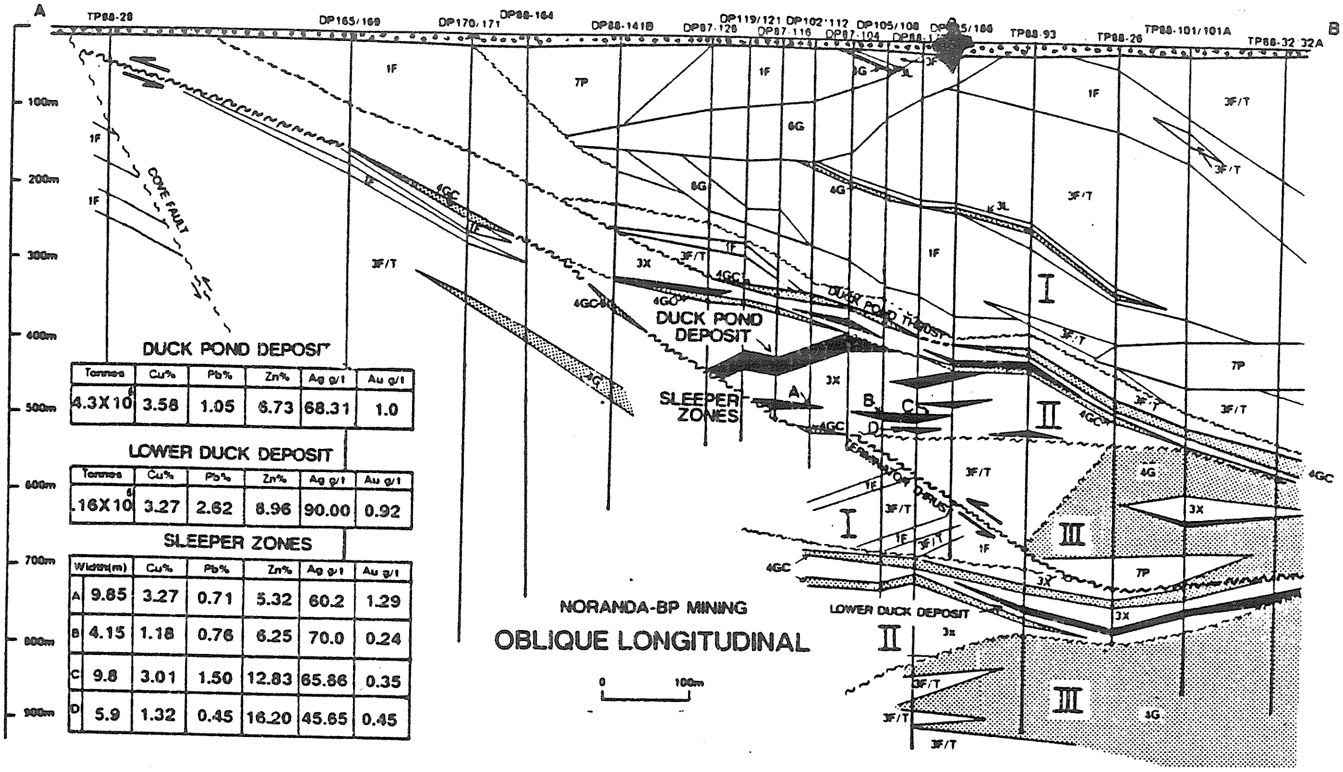


Figure 2. Detailed geology of the Duck Pond-Boundary area.
LEGEND: 1-mafic volcanic rocks (undivided); 1F-mafic flows; 1T-mafic tuff; 3F/T-unmineralized rhyolite and felsic tuffs; 3-undivided felsic volcanic rocks; 3X-altered and mineralized rhyolite rhyolite and felsic tuffs (Sequence II); 3L-lapilli tuff; 3C-felsic crystal tuff (marker); 4A-argillite-dominated clastic sediments; 4GC-graphitic cataclasite (sheared remnants of sediment unit); 4G-graphitic sediment (weakly deformed); 4S-siliciclastic rocks; 6-gabbro; 7P-Porphyritic felsic intrusives.

Upper Duck massive sulphides (surface projection) are in black, line A-B is line of section in Figure 3. I, II, III indicate fault blocks of Sequences I, II and III, respectively described in text. Stop locations are indicated by circled numbers.



DUCK POND DEPOSIT

Tonnes	Cu%	Pb%	Zn%	Ag g/t	Au g/t
4.3×10^6	3.58	1.05	6.73	68.31	1.0

LOWER DUCK DEPOSIT

Tonnes	Cu%	Pb%	Zn%	Ag g/t	Au g/t
$.16 \times 10^6$	3.27	2.62	8.96	90.00	0.92

SLEEPER ZONES

	Width(m)	Cu%	Pb%	Zn%	Ag g/t	Au g/t
A	9.85	3.27	0.71	5.32	60.2	1.29
B	4.15	1.18	0.76	6.25	70.0	0.24
C	9.8	3.01	1.50	12.83	65.86	0.35
D	5.9	1.32	0.45	16.20	45.65	0.45

FIGURE 3

Figure 3. Oblique longitudinal section through the Duck Pond deposit with grade and tonnage estimates for the various lenses. Legend and symbols as for Figure 2. Vertical lines are drill holes. Stipple indicates graphitic sediments.

mineralization in this block are absent or poorly developed. The base of this unit is highly deformed and carbonatized, and zones of mylonite and fault gouge are common. These zones of deformation mark the presence of the E-W trending, Duck Pond Thrust, which dips south at 45^0 and juxtaposes Sequence I above Sequence II. Movement along this thrust is a minimum of several kms.

<u>Sequence II - The Duck Pond/Tally Pond Mineralized Block</u>

Due to the convergence of its bounding faults, this sequence is crudely wedge-shaped. It predominantly consists of flat-lying felsic flows and pyroclastics, with subordinate mafic flows and both mafic and felsic dykes with a maximum thickness of more than 500m. The upper portion of this block (which lies within the Duck Pond Thrust Zone) contains deformed remnants of graphitic and argillaceous sedimentary units that appear to have been structurally entrained along the Duck Pond Thrust. The felsic portion of this block hosts significant accumulations of both ore grade and barren exhalative massive sulphides that, though of restricted extent, form the only intact marker unit in the sequence.

The stratigraphy is generally highly altered, being variably chloritized, sericitized, silicified or carbonatized. Commonly the protoliths and primary textures are entirely obliterated by this alteration. Mineralization is pervasive and consists mainly of pyrite, which ranges in concentration from 5% to local massive sulphide proportions.

The mineralized block is pervasively highly deformed. The main style of deformation is moderately south-dipping, sub-parallel, apparently south-directed thrusting, which is manifested as 1 to 5m thick mylonitic to cataclastic shear zones. These shear zones disrupt the internal alteration and ore stratigraphy. Details of the deformation, alteration and mineralization of this sequence will be discussed in a following section.

Sequence III - The Lower Sedimentary Block

The mineralized sequence is structurally underlain by a >200m thick sequence of interbedded, submarine graphitic and argillaceous sediments that drill core show to be complexly folded. This folding is likely a local response of the incompetent, graphite-dominated, sediments to the compressive structural regime. It does not accurately reflect the regional deformational style which appears to be thrust and fault dominated. This sequence, if of a similar age to the volcanics, was probably distal to the main focus of volcanism and mineralization represented by Sequence II, and probably represents off-arc turbiditic and pelagic sedimentation.

Additional Structural Modification to the Duck Pond Stratigraphy

Subsequent to the juxtapositioning of the three structural blocks, a later southwest-directed, moderately north-dipping thrust of about 1 km displacement, the Terminator Thrust (Fig. 3), has disrupted and stacked this tripartite structural sequence upon itself. The primary result is that in the Duck Pond area, there are now two principal mineralized horizons. The Upper Duck horizon occurs at ~350m depth, while the Lower Duck horizon occurs at ~750m depth further to the east (Fig. 3 and 4). Finally, at least four NW-SE trending, near vertical "wrench" faults have ben identified which offset the volcanic stratigraphy vertically and laterally by about 500m. They are the Cove, Garage, Old Camp and Loop Road Faults, (Fig. 2). The sense of lateral displacement is dextral for some faults but sinistral for others, implying that they may be of different ages. These structural modifications have significant ramifications for further ore potential in the Duck Pond area. That is, exploration drilling to date south of the Duck Pond Deposit and between the Duck Pond and Boundary Deposits has not been deep enough to test Sequence II mineralized stratigraphy. In these areas, the "wrench" faulting is interpreted to have dropped Sequence II stratigraphy below the 500m penetration of the initial stratigraphic drilling screen.

Mineralization, Alteration, Structure and Genesis of the Duck Pond Mineralized Sequence

The Duck Pond stratigraphy in the mineralized sequence contains the major elements of a classic volcanogenic exhalative massive sulphide (VMS) deposit. These elements are (i) submarine, hydrothermally-altered, felsic pyroclastics that host a large massive sulphide deposit and several smaller sulphide bodies; (ii) undeformed parts of the Duck Pond ore body record rhythmic sedimentary sulphide layering and debris flows of polylithic sulphide conglomerate, which indicates submarine deposition of the sulphides. However, much of the original stratigraphy has been modified by subsequent structural disruption and redistribution of this classic VMS stratigraphy (e.g. Fig. 3). Further discoveries will depend heavily on piecing together the structural puzzle of the area.

The Upper Duck lens is 500 m x 500 m in diameter (Fig. 3 and 4), and ranges from 1 to 65 m, averaging 18 m, in thickness. It exceeds 15 million tonnes of total sulphide.

Prior to its structural modification, the deposit appears to have consisted mainly of a base metal-rich "clastic" ore, that likely formed in a high relief marine basin affected by frequent syn-depositional faulting and re-sedimentation. Polylithic sulphide conglomerates with felsic clasts attest to the dynamic nature of sedimentation, in which gravity sliding triggered by seismic activity was probably the main mechanisms of transport. Transport distance may not have been great, as is evidenced by interstitial mineralization in the sulphidic comglomerates and by the complete and intimate replacement of intercalated sediments (originally argillaceous) by sulphides. These features indicate that the "transported" ores were not carried beyond the area of ore-forming hydrothermal activity that produced "in situ" sulphides. The dominantly stringer nature of the ore grade sleeper zones beneath the southeast portion of the Upper Duck lens may indicate that these ore "pods" are part of that feeder system.

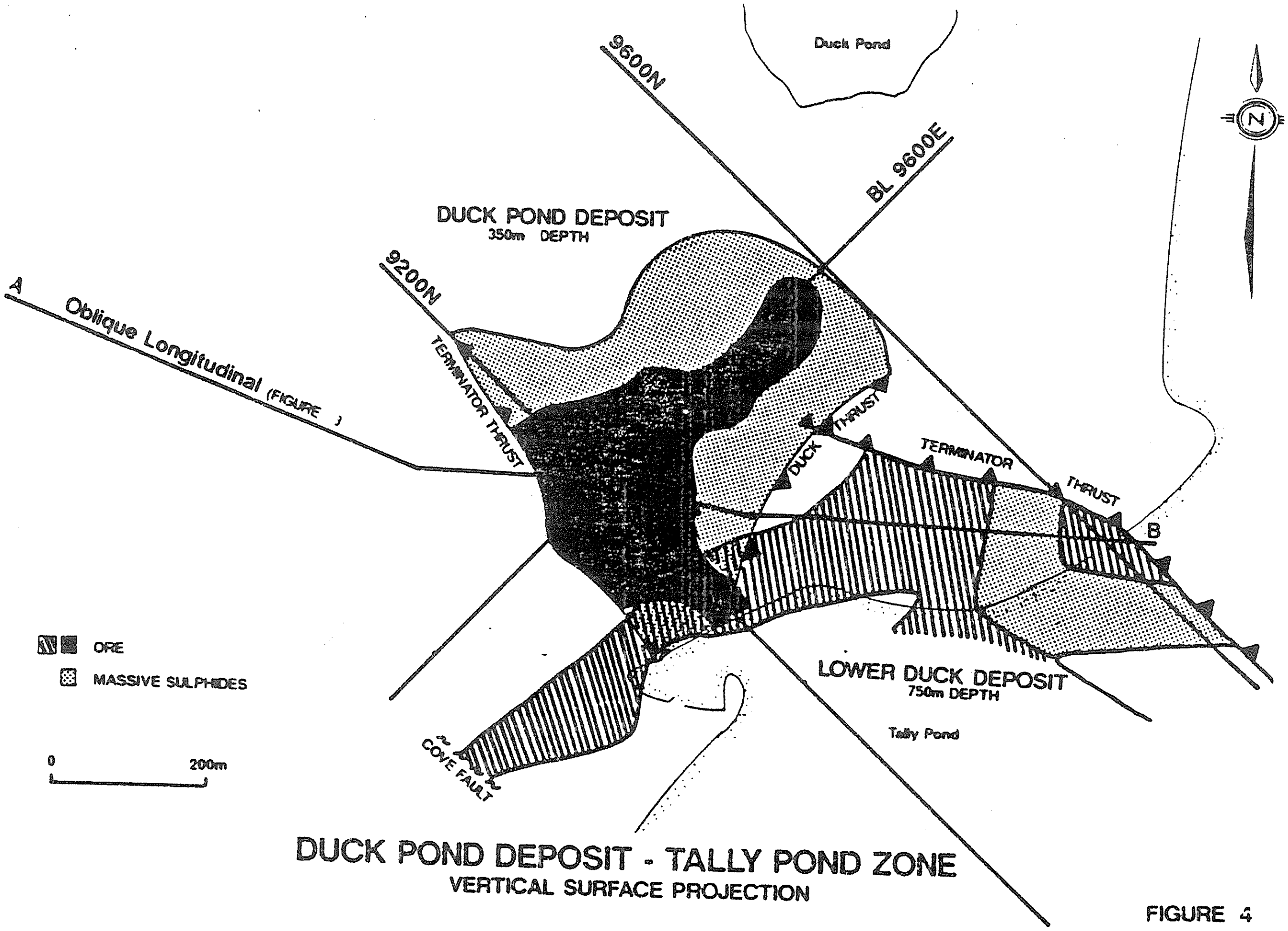


FIGURE 4

Figure 4. Vertical surface projections of the Upper Duck (labeled 'Duck Pond Deposit' on this figure) and lower Duck lenses. Light line with stipple is shore of Tally Pond. Upper Duck ore is black, Lower Duck ore is diagonally hatched.

Subsequent to the deposition of the base metal-rich "clastic" ore, the depositional environment appears to have changed, at least physicochemically. Approximately 65% of the Upper Duck lens consists of coarse grained massive pyrite. This pyrite is stratigraphically distributed above, below, locally within and lateral to the main ore grade core. The lack of sedimentary features in the massive pyrite, together with its coarse grained nature, lateral gradation in ore textures from massive to veins, and its invasion of the adjacent host rock as veins and coarse disseminations, indicate that deposition of this part of the sulphide body occurred within, rather than upon, the felsic stratigraphy. Such a situation may have been the result of rapid burial of the deposit by renewed volcanism or a sudden influx of detritus from up slope during a seismic event. This burial could not have been so deep however as to shut down the hydrothermal system, because at least another 10 million tonnes of massive pyrite is inferred to have formed after this event. One consequence of this event however would be to prevent the formation of iron formation-type cap rocks, which are conspicuously lacking at Duck Pond.

A second line of evidence indicating the activity of fluids within the felsic pile is the existence of a carbonate halo which mantles the Upper Duck massive sulphide body. Generally, this carbonate halo is found immediately above, below, locally within and up to 200m lateral to the massive sulphides. It consists of contorted "veins" of calcite (with minor disseminated fluorite) which replace an intensely chloritized host rock. The intimate relationship of this "chaotic carbonate" halo with the massive sulphide deposit indicates its genetic relationship to the ore forming process. Its textural and paragenetic relationship to the sulphide body indicates precipitation during the waning stage of the hydrothermal system.

The northern and western margins of the Upper Duck lens are generally undeformed and exhibit the relationships described above. However, the eastern and southern margins of the Upper Duck lens, as well as most of the Lower Duck lens, are highly deformed. The typical ore textures in these parts of the deposit exhibit ductile deformational features and in extreme instances are mylonitic, with very fine grained laminae chalcopyrite, sphalerite and pyrite. Generally more pyritic zones in these deformed areas do not exhibit such textures, probably due to the ease of pyrite recrystallization with tectonism (coarse pyritic lenses in the overlying Duck Pond Thrust actually appear to be examples of tectonically - induced sulphide remobilization and recrystallization). The main deformation of the ore appears to be related to the tectonic event or events which structurally juxtaposed Sequences I, II and III.

The Upper Duck lens abruptly terminates to the south in ore grade sulphides, where the massive sulphide lacks the lateral pyrite halo. In addition to being deformed during the juxtaposition of the tripartite structural package, this southern margin has been truncated by the previously described Terminator Thrust, which now separates the Upper Duck and Lower Duck lenses (Fig. 3 and 4).

Reconstruction of the alteration paragenesis in the host rhyolites surrounding the Duck Pond deposit indicates that silicification ("curdy rhyolite") and sericitic alteration were a widespread and distal manifestation of the ore-forming hydrothermal alteration halo, the complete extent of which is presently unknown. Within about 100m of the ore body, the main alteration is strong to intense chloritization with ubiquitous disseminated and stringer pyrite ranging 5% to locally massive in volume. It is assumed that the morphology of this zone was pipe-like for several hundred metres beneath the ore deposit and may also have had a limited extention above and lateral to the main sulphide body. As previously mentioned, the last hydrothermal event during the formation of the Duck Pond Deposit appears to have been the "chaotic" carbonate zone, which haloes the massive sulphide body.

Because of the structural dislocations that have affected the mineralized horizon, the presumed chloritic feeder pipe does not occur in situ beneath the Duck Pond deposit (or has not been found to date). The most altered rocks are in the present hanging wall and the least altered rocks are in the present footwall. The fault bounded nature of the main Duck Pond deposit indicates that this reversal in stratigraphy may be the result of structural stacking, wherein the stratigraphic footwall chloritization has largely been thrust over the ore body and the less altered rocks of Sequence I have been thrust under the ore body by the Terminator Thrust.

The Sleeper Zones lie immediately beneath the Upper Duck lens within Sequence II. These mineralized pods suggest the existence of stratigraphically stacked ore grade mineralization and enhance the potential for finding further ore deposits at various levels within Sequence II. In the Lower Duck lens, interpreted to be the structurally offset extension of the Upper Duck Pond lens (Fig. 3 and 4), more tectonized textures predominate, indicating a more structurally attenuated mineralized horizon. The host felsic package to the Lower Duck lens is also much thinner and to date has not been found to exceed 50m in thickness. The Lower Duck lens is generally flat-lying, has a continuous massive sulphide strike length of about 900m, is 50-200m wide and averages about 5m in thickness.

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ROAD LOG FOR THE VICTORIA LAKE EXCURSION

DAY 1

STOP 1-1: *MIDDLE ORDOVICIAN "CARADOC" SHALE AND CHERT: THE RED CLIFF SECTION*

Stop and park just west of the Red Cliff Overpass.

A highly folded and faulted section of mid-Ordovician chert and shale is exposed in two large roadcuts on the Trans Canada Highway immediately west of the Red Cliff overpass. The section exposed on the south side of the highway was sampled and described in a 1981 lithogeochemical study of mid-Ordovician cherts and shales in Central Newfoundland (Dean & Meyer, 1982). The conformably overlying Sansom Greywacke is exposed 500 m to the west. Immediately to the east, the northeast-trending Northern Arm Fault separates Silurian red sandstones and subaerial volcanics of the Botwood Group in the east from Ordovician rocks in the west.

The structurally complex Red Cliff overpass roadcut exposed thin, regularly interbedded, black carbonaceous and graptolitic chert and shale. Iron staining and yellow to white sulphur staining is present on many horizons. Thin beds of fine to medium grained volcanogenic sandstone occur in the eastern half of the roadcut, and thicker beds at the centre of the roadcut form competent units within the cores of folds. Thickly bedded to massive chert and argillaceous chert dominate the west half of the section where bedding is less pronounced. These beds contain banded, disseminated, and fracture-controlled pyrite. Banded pyrite and pyrite nodules are present in some of the shale horizons, and fluorapatite nodules (2.6% P_2O_5, 2.6% Fe, 26% Ca) up to 4 cm in diameter have been identified. The section is intruded by fine- to medium-grained porphyritic intermediate dykes 1-3 m wide.

At least 20 species of graptolites were identified at this locality by Bergstrom *et al.* (1974), who considered the assemblage to be a typical *Nemagraptus gracilis* Zone fauna, correlative with other mid-Ordovician shales in Central Newfoundland. However, *N. gracilis* graptolites were not identified from this section, and the abundance of *Climacograptus bicornis* and *Corynoides* from this and similar sections several km to the west, suggest that it records a transition into the younger *Diplograptus multidens* Zone.

STOP 1-2: *SANSOM GREYWACKE/GOLDSON CONGLOMERATE TRANSITION*

At this locality, shale, argillite and chert are overlain by and interbedded with Late Ordovician-Early Silurian Sansom Greywacke. Conglomerates, containing clasts of shale, argillite, chert, granite and plutonic rocks and quartz, that overlie this sequence are assigned to the Goldson Conglomerate.

Limestone nodules and clasts are also present at this locality.

REGIONAL GEOLOGY, NORTHERN VICTORIA LAKE GROUP

STOP 1-3: *SEDIMENTARY SEQUENCE, VICTORIA LAKE GROUP.*

This outcrop comprises tuffaceous sandstone interbedded with medium to coarse grained greywacke, typical of the Victoria Lake Group turbidites. The greywacke contains abundant felsic volcanic fragments and broken quartz phenocrysts. These rocks are typical of those which underlie the southern portion of the sedimentary sequence. Stratigraphically, these rocks underlie the Middle Ordovician black shale and chert which outcrop along the road to the northwest. The sedimentary sequence comprises turbidites which exhibit all the elements of the Bouma model (Bouma, 1962). The rocks can all be described using the submarine fan model of Walker (1979).

STOP 1-4: *VICTORIA MINE*

Upstream from the bridge are exposed tuffaceous sedimentary rocks which are intruded by a sub-volcanic rhyolite porphyry, dated at 462 +4/-2 Ma (Dunning et al. 1987). Downstream from the bridge are limestone lenses, interbedded with the tuffaceous sedimentary rocks, which contain crinoid fragments and Llanvirn-Llandeilo conodonts. These rocks are significantly younger than the other volcanic sequences within the Victoria Lake Group.

VICTORIA MINE

***** BEWARE OF OLD SHAFTS *****

This section will be led by personnel of B.P. Mining.

STOP 1-5: *BROOK SHAFT*

Approximately 200 m west of the main shafts, across a small bog at the north end of a small pond, is an old shaft, dump and mining equipment (Fig. 1). The dump contains excellent samples of massive, disseminated and stringer pyrite-chalcopyrite mineralization. West of the shaft, forming a narrow ridge, is an exposure of pyritized sericite schist, containing quartz crystals and lithic lapilli, which are host rocks to the Victoria Mine.

STOP 1-6: *MAIN SHAFTS*

Samples of massive pyrite-chalcopyrite, disseminated and stringer pyrite-chalcopyrite in black chlorite, and banded lead-dolomite ore are abundant on the mine dumps.

STOP 1-7: *JIG ZONE*

From the main shafts area follow a drill road east for approximately 300 m to the site of a number of trenches. Near one of the drill hole collars is an exposure of the hanging wall green tuff, here represented by a heterolithic lapilli tuff with a few maroon (chert?) clasts. Note also the attitude of the weakly developed fabric. A pod of massive sphalerite is exposed in the main large trench. Still in the trench on the footwall side of the mineralization is an example of the chaotic quartz/dolomite rock. On the far side of the trench, the rusty weathering silicic host to the mineralization is exposed. Note the intensity and orientation of the foliation here as compared to the green tuff exposure.

BOBBY'S POND

From the main logging road which parallels Red Indian Lake, turn right at the Bobby's Pond turn off (est. 20 km from Millertown Dam). Follow old logging road for 4.7 km. then turn left at intersection. Proceed for 300 m.

STOP 1-8: *DISCOVERY BOULDERS*

*****PLEASE DO NOT HAMMER*****

Walk to the large white boulder approximately 100 m east of road. This boulder is one of the largest of numerous highly altered boulders scattered throughout the area. The boulder is predominantly silica with abundant pyrophyllite, alunite (pinkish coloured mineral), native sulphur and minor pyrite. Orpiment occurrs as bright orange flexible prismatic crystals typically in vugs. Most seem to have been removed! The scattered orange spots may represent realgar (AsS) which is known to disintegrate on long exposure to light.

STOP 1-9: *NATIVE SULPHUR OUTCROP*

This outcrop represents the only exposure of material similar to the discovery boulders. The outcrop is characterized by a vertical planar fabric trending 100-129° which is locally strongly crenulated. The dominant planar fabric is defined by thin layers of pyrophyllite +/- alunite. Yellow native sulphur bands parallel this fabric and are locally contained within a massive dense siliceous rock.

STOP 1-10: *BP CAMP HARBOUR ROUND*

Display of diamond drill core from the Valentine Lake and Midas Pond gold occurrences.

STOP 1-11: *TULKS HILL DEPOSIT (Depending on the water level of Tulks Brook).*

PLEASE DO NOT ENTER THE ADIT.

Park on the main road. Exposed in the cliff across the valley are large gossanous zones which mark the four massive sulphide lenses. The adit, which was driven into the T-3 lens to remove a bulk sample, can also be seen. Proceed along the washed out access road which leads across the valley, approximately a 15 minute walk. Rubber boots will be required for crossing Tulks Brook.

Abundant massive sulphide boulders are present on the dump, as are samples of the host sericitic felsic volcanic rocks. Exposed at the entrance to the adit is the Raven rhyolite (Moreton, 1984). The rhyolite is a small sub-volcanic porphyry that has yielded a U/Pb zircon age of 498 +/-6 Ma. (Evans et al. 1990).

STOP 1-12: *MUG UP SHOWING*

The showing was discovered while "boiling up" during a snow squall in November 1988. The mineralization comprises small patches, disseminations and stringers of base metal sulphides hosted by deformed, sericitic felsic quartz crystal tuff. Intermediate tuff is exposed on either side of the showing. Late barren quartz veins cut the showing. Pyrite and galena bearing quartz veins are exposed in the road cut along the hill to the southwest.

Assays (in ppm)

Sample	Mineralized tuff			Quartz vein
	3317	3318	3319	3321
Au(ppb)	14	5.9	<3	<2
Ag	<2	<2	<2	<5
Cu	48	133	266	24
Zn	299	2140	718	115
Ba	300	240	300	
Cr	<20	270	240	
Ni	<10	42	14	

STOP 1-13:

Deformed, coarse felsic pyroclastics, typical of the Tulks Hill volcanics are exposed here.

STOP 1 - 14: *ROAD OR CAMP SHOWING*

Galena, sphalerite and pyrite-bearing quartz veins, hosted by sericitic and carbonate altered felsic crystal tuff of the Tulks Hill volcanics, are exposed along the main road. Grab samples of these veins assayed 5500 ppb Au. Abundant 1-2 mm pyrite cubes are present in the wall rock to these veins.

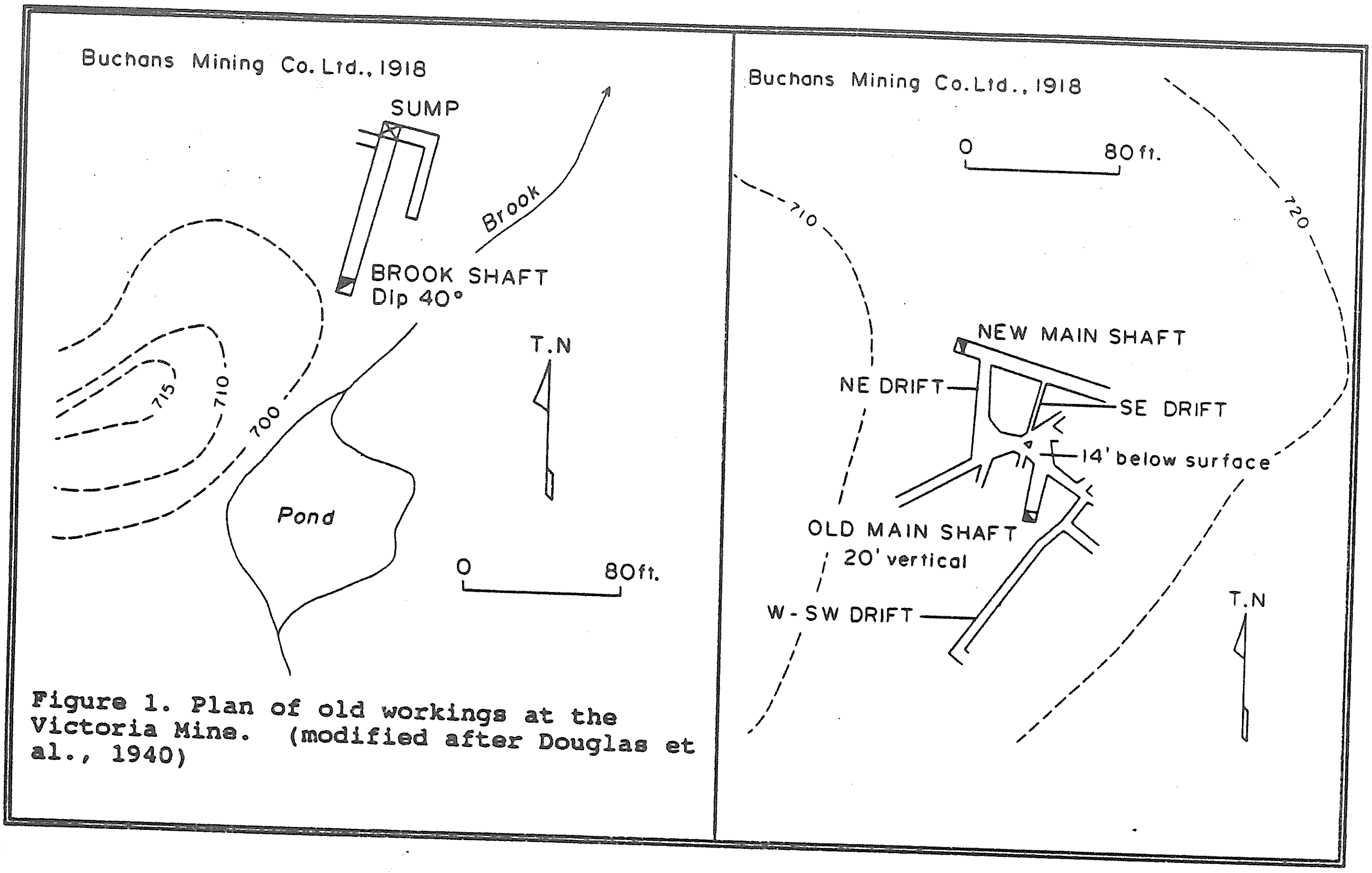

Figure 1. Plan of old workings at the Victoria Mine. (modified after Douglas et al., 1940)

DAY 2: VICTORIA STOP DESCRIPTIONS DUCK POND AREA

STOP 2 - 1: *DUCK POND EXPLORATION CAMP*

Outcrop in the area is sparse, so the only stop will be at the Noranda Camp (25 km south of Millertown) where selected core from the Duck Pond massive sulphide deposit will be on display. As well, a selection of maps and sections will be displayed, and an overview of the area geology will be given by the Noranda Project Geologist.

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