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METALLOGENY OF THE TULKS HILL VOLCANICS, VICTORIA LAKE GROUP, CENTRAL NEWFOUNDLAND

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ABSTRACT

The Tulks Hill volcanics are host to pyritic volcanogenic sulfides and are part of a thick sequence of volcanic and volcaniclastic rocks of the Victoria Lake Group. The group was deposited during the development of an early to middle Ordovician island arc. The volcanic rocks occur within two principal volcanic units, informally termed the Tulks Hill and Tally Pond volcanics. The volcanic rocks consist of intercalcated mafic and felsic rocks that are predominantly pyroclastic; mafic pillow lava is more common in the Tally Pond volcanics than in the Tulks Hill volcanics. The felsic volcanic rocks occur as laterally extensive sheets of crystal and crystal-lithic tuff, breccia and minor flows. Sedimentary rocks consist of sandstone, siltstone, shale, argillite, chert and minor interbedded conglomerate. The clastic sedimentary rocks appear to be derived from the adjacent and underlying volcanic rocks of the Victoria Lake Group.

There are six principal volcanogenic sulfide occurrences in the Victoria Lake Group, four in the Tulks Hill volcanics and two in the Tally Pond volcanics. The Tally Pond (Boundary) deposit and Burnt Pond prospect are both massive sulfides in the Tally Pond volcanics. The Tulks Hill, Tulks East and Victoria deposits are both stratiform, pyritic, Zn-Pb-Cu, massive sulfides in the Tulks Hill volcanics. The Jacks Pond deposit also occurs in the Tulks Hill volcanics, but aside from a zone of transported clastic sulfides, it mostly appears to be a stockwork zone. The mineralization is hosted by felsic crystal tuff, lapilli tuff and breccia, and are enveloped by an alteration halo characterized by silicification, sericitization and chloritization. Disseminated and stringer sulfides are also well developed in this halo.

INTRODUCTION

Metallogenic studies of the pre-Caradocian volcanic sequences of central Newfoundland were begun in July, 1984, concentrating on the Tally Pond volcanics (Kean, 1985). In 1985, studies were begun on the Tulks Hill volcanics. This involved regional rock geochemistry and detailed stratigraphic, structural and geochemical studies in the areas of known mineralization. A regional gold sampling program was also caried out over the Victoria Lake Group.

Access to the area is provided by woods roads from Millertown and Grand Falls. The area is characterized by a heavily forested (fir, spruce), gently undulating landscape with extensive glacial till cover. Consequently, except for the ridge that extends from Tulks Valley to Victoria River, bedrock exposure is poor.

Previous Work

Parts of the field area have been mapped in detail by mineral exploration companies, including ASARCO, Abitibi-Price and Noranda. The first systematic geological mapping was done at 1:250,000 scale by the Geological Survey of Canada (Riley, 1957; Williams, 1970). The Newfoundland Department of Mines and Energy has done 1:50,000 scale regional mapping of the King George IV Lake (12A/4), Victoria Lake (12A/6), Star Lake (12A/11E), Lake Ambrose (12A/16), Noel Paul's Brook (12A/9), Buchans (12A/15), Badger (12A/16) and Grand Falls (2D/13) map areas (Kean, 1977, 1979a,b, 1983; Kean and Jayasinghe, 1980, 1982; Kean and Mercer, 1981).

Brown (1952) proposed the name 'Victoria River Series' for the volcanic and sedimentary rocks in the Lake Ambrose - Victoria River area. Riley (1957) proposed the name 'Strides Group' for similar rocks in the western half of the Red Indian Lake map area. Kean (1977) abandoned these names and proposed and defined the 'Victoria Lake Group' to include all the pre-Caradocian volcanic and sedimentary rocks in this area (Figure 1).

Volcanogenic sulfide mineralization in the rocks presently assigned to the Victoria Lake Group was first discovered in the early 1900's near the mouth of the Victoria River and is known as Victoria Mine or the Victoria prospect. Subsequently, five other significant, volcanogenic, base-metal occurrences have been discovered: the Jacks Pond, Tulks East and Tulks Hill deposits in the Tulks Hill volcanics, and the Tally Pond (Boundary) deposit and the Burnt Pond prospect in the Tally Pond volcanics.

Regional Geology

The Victoria Lake Group underlies that part of the Dunnage Zone (Williams, 1979) of central Newfoundland which extends from Grand Falls in the northeast to King George IV Lake in the southwest, and from Red Indian Lake in the north to Noel Paul's Brook in the south.

The Ordovician geological development of the Dunnage Zone is recorded in three very broad geologic sequences:

(1) ophiolitic rocks which are interpreted to have formed as oceanic crust; where contacts are preserved,

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these are always the stratigraphically lowest units and they are believed to represent basement to most of the younger rocks in the Dunnage Zone;

(2) tholeiitic and calc-alkaline volcanic and subvolcanic rocks, and related volcaniclastic rocks; these rocks stratigraphically overlie the ophiolites and range up to 8 km in total thickness. The volcanic units consist of mafic and felsic, dominantly submarine, volcanic and volcaniclastic rocks, and are generally interpreted to represent the remains of early to middle Ordovician island arcs and back-arc basins;

(3) post island-arc shale and chert, and a flyschoid sequence of argillite, greywacke, and conglomerate; these rocks stratigraphically overlie many of the island-arc sequences and are in part derived from them. The sedimentary rocks range in age from Middle Ordovician to Early Silurian and are succeeded by younger Silurian rocks consisting of subaerial, mainly felsic, volcanic rocks and terrestrial sedimentary rocks.

In the south-central part of the Dunnage zone, the ophiolitic sequences are represented by the King George IV Lake, Annieopsquotch, Star Lake and Shanadithit Brook complexes. The King George IV Lake and Annieopsquotch complexes are faulted against the early to middle Ordovician island-arc sequences of the Victoria Lake Group to the southwest of Red Indian Lake, but are interpreted to have been originally in stratigraphic continuity (Herd and Dunning, 1979).

In the northeast, the Victoria Lake Group is conformably overlain by Caradocian black shales and cherts which in turn are conformably overlain by Middle Ordovician to Early Silurian flysch, argillite and conglomerate. Siltstone and tuffaceous sandstone of the Harbour Round Formation overlie the Victoria Lake Group in the Red Indian Lake area. This assemblage of rocks is in fault contact to the northwest with the Buchans Group and the Southwest Brook Complex along the Lloyds River - Red Indian Lake fault system.

The Rogerson Lake Conglomerate unconformably overlies the Victoria Lake Group along the group's southern and southeastern boundary. The contact, however, is generally fault modified. The Rogerson Lake Conglomerate is separated by a fault along its southeastern boundary from mafic volcanic rocks of the Pine Falls Formation and unnamed volcanic, sedimentary and metamorphic rocks south of Noel Paul's Brook.

Rocks of the Victoria Lake Group occupy a regional northeast-trending anticlinorium (Victoria Anticlinorium). Regionally, the sequence youngs northwesterly on the north limb and southeasterly on the south limb; however, there are many smaller scale, first order and second order folds resulting in variable facing directions. Unfortunately, poor exposure generally precludes deciphering the detailed structure.

GEOLOGY OF THE VICTORIA LAKE GROUP

The Victoria Lake Group can be divided into two major regional facies (Figure 1):

(1) volcanic rocks in the southwest (Tulks Hill volcanics) and along the southeastern margin (Tally Pond volcanics), comprising approximately 60 percent of the group, and

(2) a predominantly sedimentary facies to the northeast which is laterally equivalent to, and derived from, the volcanic rocks.

Limestone lenses near the top of the sedimentary facies and Tulks Hill volcanics have yielded late Llanvirn to early Llandeilo conodonts (Kean and Jayasinghe, 1982) and this is the only direct evidence as to the age of the Victoria Lake Group. Unpublished radiometric age dates on the Tally Pond volcanics indicates it is much older than this (Dunning, personal communication, 1985). This may necessitate the removal of the Tally Pond volcanics from the Victoria Lake Group. The sedimentary sequence is also conformably overlain by Caradocian graptolitic shale and chert (Kean and Jayasinghe, 1982). The thickness of the Victoria Lake Group cannot be estimated with any degree of certainty because of folding and poor exposure.

The Victoria Lake Group has an inhomogeneously developed, regional, penetrative foliation defined by chlorite, sericite, flattened clasts and crystal augen. This foliation is axial planar to tight to isoclinal folds. The rocks have been metamorphosed to the lower greenschist facies.

Volcanic Rocks

Volcanic rocks predominate in the southwestern part of the Victoria Lake Group, as well as along its southeastern margin. Two principal volcanic units, informally termed the Tulks Hill volcanics in the north and the Tally Pond volcanics in the southeast, occupy the north and south limbs of the Victoria Anticlinorium respectively. Both units are characterized by linear belts of predominantly felsic volcanics, in particular pyroclastics. Mafic flows are common in the Tally Pond volcanics but minor in the Tulks Hill volcanics. Small intercalations or lenses of volcanic rocks also occur within the clastic sedimentary rock facies of the Victoria Lake Group to the northeast.

Tulks Hill volcanics. The numerous bands and lenses of volcanic and volcaniclastic rocks that occur in a belt extending from Pat's Pond in the Victoria Lake map area to Victoria River on the southeastern shore of Red Indian Lake in the Lake Ambrose map area were defined by Kean and Jayasinghe (1980) as the Tulks Hill volcanics. The best exposures of these volcanic rocks occur at Tulks Hill in the Star Lake area. The Tulks Hill volcanics consist of predominantly felsic pyroclastic rocks and minor mafic volcanic rocks that are intercalated with well bedded, mafic to silicic, volcaniclastic rocks (including epiclastic / sedimentary rocks).

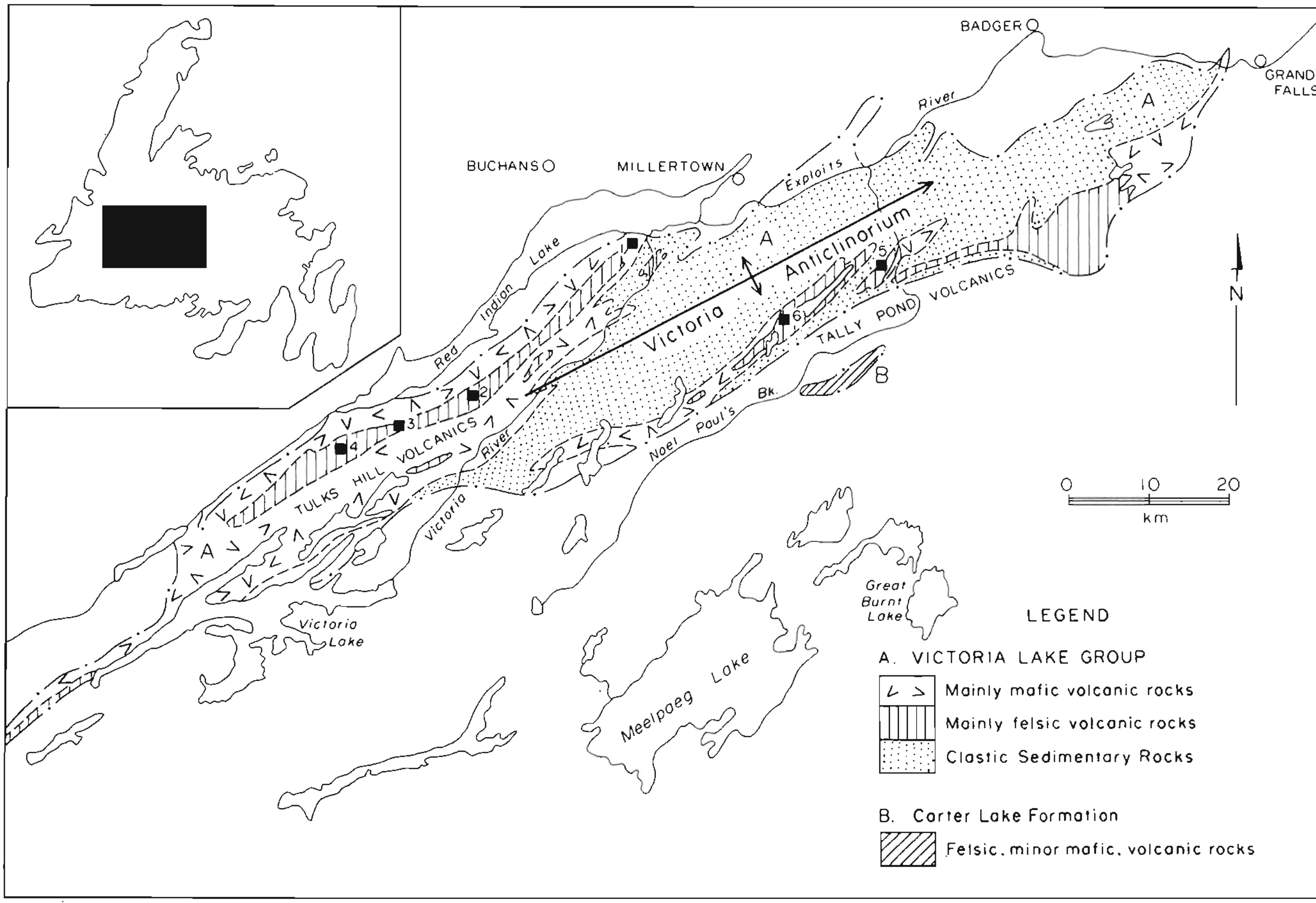

Figure 1: *Early to middle Ordovician volcanic-dominated island-arc sequences and massive sulfide deposits (solid squares) in central Newfoundland. Massive sulfide deposits: 1. Victoria Mine; 2. Jacks Pond; 3. Tulks East; 4. Tulks Hill; 5. Burnt Pond; 6. Tally Pond (after Swinden and Thorpe, 1984).*

The felsic volcanic rocks occur as laterally extensive sheets of crystal and crystal-lithic tuffs, breccias, porphyritic flows and shallow intrusives. The silica content of most of these rocks (unpublished chemical analyses) place them in the high dacite - low rhyolite range. Grayish, green and white quartz-crystal and crystal-lithic tuffs predominate. The quartz crystals range up to 1 cm across and are commonly blue. Locally, feldspar crystals are present. Flow-banded rhyolite occurs in places, especially west of Bobby's Pond. Locally, in the Jacks Pond area, the rocks have a granitic appearance and contain quartz, plagioclase, minor potassium feldspar, and a chloritized mafic mineral.

Pyroclastic breccias are also well developed in the felsic volcanic rocks. They contain angular to subrounded clasts, ranging from 0.5 to 45 cm in length, of green, felsic volcanic and rare mafic volcanic and sedimentary rock. Fine grained, greenish, felsic tuff constitute the matrix to the clasts. Locally the matrix is chloritic and has an intermediate composition.

The Victoria, Jacks Pond, Tulks East and Tulks Hill deposits are hosted by the felsic pyroclastic rocks of the Tulks Hill volcanics. Zones of silicified volcanic rocks occur in areas of hydrothermal activity associated with sulfide mineralization.

The mafic volcanic rocks are mainly pyroclastic, comprising mafic to intermediate aquagene tuff, lapilli tuff, agglomerate and breccia. Mafic lavas are mostly pillow lavas that generally exhibit small, commonly flattened, pillows with thin selvages and minor interpillow material. Pillow breccias occur locally. Massive unpillowed lavas are rare; some rocks mapped as such may actually be sills. The lavas are vesicular, contain calcite amygdules, and locally are variolitic; minor feldsparphyric phases are also present.

The host to these felsic and mafic volcanic rocks is a well-bedded sequence of volcaniclastic rocks. The unit consists of bedded, waterlain, reworked mafic to silicic tuffs, tuffceous sandstones, argillite and shale.

Tally Pond volcanics. The Tally Pond volcanics were defined by Kean and Jayasinghe (1980) as a belt of intercalated mafic and felsic volcanic rocks that extend from Quinn Lake in the southwest to Sandy Lake in the northeast. The mafic volcanic rocks comprise vesicular and amygdaloidal, generally pillowed, flows and mafic to andesitic tuff, agglomerate and breccia. Mafic pillow lava is more common in the Tally Pond volcanics than in the Tulks Hill volcanics. The pillows are generally small and have minor interpillow material; where present, the latter consists of mafic tuff (probably hyaloclastite) and minor green chert. The breccias contain mafic volcanic rock fragments that range up to 20 cm across. Some of the breccias contain pillow fragments and are interpreted as pillow breccias.

The felsic volcanic rocks, which are host to the Tally Pond deposit and Burnt Pond prospect, consist of tuff, lapilli tuff and breccia. Flow-banded rhyolite and rhyolitic breccia are locally present. Black, subvolcanic, quartz-feldspar porphyries are common. The lapilli tuff consists of subangular to rounded clasts of white, gray and green dacite and rhyolite, locally flow banded, in a fine grained to locally vitric, tuffaceous matrix. The breccias contain angular felsic volcanic fragments ranging from 3 to 45 cm in length in a tuffaceous matrix. Locally, gas breccias are developed which consist of flow-aligned, gas brecciated clasts in an aphanitic to vitric, siliceous matrix.

Sedimentary Rocks

Clastic sedimentary rocks constitute most of the northeastern facies of the Victoria Lake Group (Kean and Jayasinghe, 1982). This facies consists of sandstone (graywacke) with interbedded siltstone, shale, argillite, conglomerate and rare limestone. Siliceous siltstone and chert are more common near the top of the sequence. Locally, thin intercalations of mafic volcanic rocks are present.

The sedimentary sequence generally displays cyclic bedding. A typical cycle consists of a lower unit of conglomerate and pebbly sandstone constituting approximately 40 percent of the cycle. It generally has erosional bases with scour and fill structures, load casts and flame structures, and grades upwards into sandstone, which forms about 50 percent of the cycle. The sandstone grades from coarse at the bottom to fine towards the top, where faint laminations, cross-laminations or convolute laminations may be developed. The sandstone layer is overlain by thinly laminated siltstone, argillite or shale. The contact between the siltstone and underlying sandstone is sharp and free of erosional features. The cycles mainly include ABCE and ABE Bouma divisions and locally CE divisions (Bouma, 1962).

These clastic sedimentary rocks contain abundant volcanic detritus and both the amount and the coarseness of pyroclastic and epiclastic material increase towards the volcanic rocks of the Victoria Lake Group to the southwest. This suggests that the clastic sedimentary rocks were derived from the adjacent and underlying volcanic rocks of the Victoria Lake Group.

Intrusive Rocks

The Victoria Lake Group is intruded by linear bodies of medium grained quartz monzonite, minor granite and granodiorite, interpreted to be related to the volcanism (Kean and Jayasinghe, 1980, 1982). Fine to medium grained diorite and gabbro, including rare coarse grained phases, occur as small plugs and large bodies throughout the Victoria Lake Group.

Volcanogenic Sulfides

There are four principal volcanogenic base metal sulfide occurrences in the Tulk Hill volcanics, namely the Victoria, Jacks Pond, Tulks East and Tulks Hill deposits. The locations of these deposits and prospects are shown on Figure 1. The Tulks East and Tulks Hill deposits will be briefly discussed here. The Jacks Pond deposit is discussed by Evans and Kean (this volume); the Victoria prospect was not included in this study.

Tulks Hill deposit. The Tulks Hill deposit, a significant Zn-Pb-Cu, volcanogenic, massive sulfide deposit, located near the southwestern extremity of the felsic pyroclastic rocks of the Tulks Hill volcanics, was discovered by ASARCO personnel the early 1960's. The deposit consists of four stratiform sulfide lenses with a total tonnage of approximately 750,000 tonnes grading approximately 5 to 6 percent Zn, 2 percent Pb and 1.3 percent Cu, 41 g/t Ag and 0.4 g/t Au (Kean and Thurlow, 1976; Jambor, 1984).

The host rocks to the deposit are well exposed in Tulks Hill and the deposit is surficially marked by gossans. The mineralization occurs within northeast trending, steeply northwest dipping, felsic volcanic rocks of greenschist metamorphic grade. The host volanic rocks are sericite schist derived from felsic lapilli tuff, quartz (± feldspar) crystal and crystal-lithic tuff. Minor tuffs of intermediate composition and diabase/andesite dikes or sills are intercalated with the felsic rocks. The dikes 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 pyroclastic 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; however, minor cross-faulting also has 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.

The four sulfide 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. Morton (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. However, evidence from this study suggests that reverse mineralogical zoning also occurs at depth in the T_3 lens. Both the hangingwall and the footwall display hydrothermal alteration associated with the mineralizing process, and it is not everywhere demonstrable which is the stratigraphic footwall on the basis of intensity of alteration.

The lenses are roughly tabular to lensoid in shape and dip 70° to the northwest. They are predominantly pyritic (approximately 70 percent) 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 sulfide minerals. Minor magnetite occurs in the

Table 1. Grade and tonnage data for the Tulks East deposit (from Barbour and Thurlow, 1982)

ZONE	TONNAGE	GRADE				
		Au g/t	Ag g/t	Cu %	Pb %	Zn %
A-Zone	4,500,000+	Tr.	8.5	0.24	0.12	1.50
B-Zone	200,000	0.14	58.7	0.66	1.26	8.69
C-Zone	900,000	Less than 1 percent combined base metals				

T_1 and T_2 lenses. Oxidation and supergenic 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 occurs as native gold (Jambor, 1984). Dolomite, calcite and barite are either associated with quartz or disseminated among the sulfides.

The pyrite is euhedral to anhedral and generally fine grained, although locally it is coarse grained. No colloform or fromboidal textures were observed. The sphalerite is generally brown and 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. Sulfide 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 sulfides with the hangingwall and footwall vary from sharp to gradational. Both the structural hangingwall and footwall are hydrothermal altered; however in some areas it appears to be more intensely developed in the structural footwall. Siliceous alteration characterized by gray silica veinlets, and greenish to yellowish sericite-rich seams in gray to white, and bleached, lapilli tuff and quartz-crystal tuff is the predominant alteration type. Disseminations and stringers of sulfides, predominantly pyrite-rich but also chalcopyrite-rich, with lesser galena and sphalerite, are variably developed. Minor chlorite-dominated alteration assemblages are locally developed within the overall area of siliceous alteration. Morton (1984) reported that chlorites from the mineralized sequences show a Mg-enrichment trend from the least to most mineralized rock.

Tulks East deposit. The Tulks East deposit, a low grade Zn-Pb-Cu, volcanogenic, massive sulfide deposit, is located in the Tulks Hill volcanics approximately eight kilometres northeast of the Tulks Hill deposit. It was discovered in 1977 by personnel from the Mineral Resources Division of Abitibi-Price. It consists of three stratiform massive sulfide lenses termed the A, B and C zones which contain approximately 5,600,000 metric tonnes of pyritic massive sulfides with low base metal values (see Table 1). The host rocks to the deposit are poorly exposed and the mineralization is best studied in drill core.

The mineralization occurs in steeply northeast trending, northwest dipping, felsic, fine grained tuffs and breccias which have been metamorphosed to lower greenschist facies. The host rocks contain an inhomogeneously developed, regional penetrative foliation which is axial planar to tight to isoclinal folds. The foliation is defined by sericite, chlorite and flattened clasts and the rocks are in places sericite schists. However, overall the rocks of this area are not as deformed as the rocks hosting the Tulks Hill deposit. The host sequence is bounded along its northwestern side by the Tulks Valley fault, which juxtaposes it against an interbedded sequence of felsic pyroclastics, mafic tuffs and fine grained clastic sedimentary rocks (black shale, siltstone and mudstone).

Host rock types to the mineralization are predominantly quartz-crystal and crystal-lithic tuffs, lapilli tuff and locally breccia. Green, aphanitic, dacite dikes containing quartz phenocrysts occur locally. An alteration zone of pyritization, sericitization, bleaching and silicification is developed in the host rocks. Minor quartz, quartz-carbonate, and dolomite veins are locally present. Barbour and Thurlow (1982) estimated the surface dimensions of this alteration halo to measure approximately 1600 m along strike and 200 m across strike. Minor mafic tuffs and widespread andesitic to diabasic dikes and sills occur within the felsic rocks. Locally they contain quartz and/or calcite amygdules.

The lenses are tabular to lensoid in shape, dip 70° to the northwest and plunge 45 to the north (Barbour and Thurlow, 1982). The B-zone is situated 15 m stratigraphically above the A-zone, and the C-zone is situated 250 m east of the A and B-zones within the same stratigraphic unit. The lenses consist predominantly of fine to coarse grained, saccharoidal pyrite with varying amounts of sphalerite, galena, chalcopyrite and gangue of quartz, chlorite, calcite and dolomite. The sulfides consist of massive non-banded and banded varieties. The banding is primarily defined by alternating sphalerite and pyrite layers. Chalcopyrite locally forms layers, but generally occurs as blebs within the pyrite. Galena occurs both as blebs within sulfides and as galena and galena/quartz veins. Locally developed mineralogical zoning within the sulfides display both normal and reverse sequences in what appears to be a non-systematic pattern; however, at this stage it is difficult to interpret the meaning of this. Brecciation textures are locally well developed in the sulfides and are interpreted to be tectonic. The contacts with the host rocks are generally sharp with narrow margins of profuse sulfide dissemination. The lower contact, however, is locally gradational over a few meters.

Both A and B zones appear to be richer in base metals in their northeastern ends. The B-zone contains the lowest tonnage and highest grade (see Table 1).

The hangingwall and footwall rocks display evidence of hydrothermal alteration associated with the mineralization process. Sericitic to chloritic, gray to green pyroclastics, and intermediate dikes and sills, constitute the hangingwall. Mineralization includes disseminated and stringer pyrite with lesser sphalerite and chalcopyrite; minor quartz and dolomite veins are also present. The footwall is generally more silicified and sericitized and commonly has a bleached appearance. Chloritization is sporadically developed, except for the C-zone where it is the predominant alteration. The silicification occurs both as a pervasive replacement by silica and as narrow, gray silica veinlets. Pyrite and minor sphalerite and chalcopyrite occur as disseminations and stringers. Dolomite is dispersed throughout the rocks and also forms veins.

SUMMARY AND CONCLUSIONS

The Tulks Hill volcanics represent a major volcanic complex in the southwestern part of the Victoria Lake Group. Felsic volcanic rocks of the Tulks Hill volcanics represent a significant time-stratigraphic horizon of extensive felsic volcanic activity within a dominantly mafic to intermediate volcaniclastic sequence. The felsic rocks appear to have been deposited near a number of volcanic edifices located along a fissure or fault-controlled lineament. This volcanic activity was accompanied by hydrothermal activity which resulted in deposition of metallic elements, mainly Zn, Pb and Cu, near the stratigraphic top of the felsic volcanic rocks.

Exhalative sulfides are well developed as the Tulks Hill and Tulks East deposits and stockwork alteration and mineralization underlie these as well as being the predominate type of mineralization at Jacks Pond. There is excellent potential for more massive sulfides, as well as gold minerlization, in the belt.

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