The Wolf property — 1998 update: Volcanogenic massive sulphides hosted by rift-related, alkaline, felsic volcanic rocks, Pelly Mountains, Yukon

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ABSTRACT

The Wolf property is situated within the Pelly Mountains, 90 km south of Ross River, Yukon. The Mississippian felsic volcanic and sedimentary rocks which underlie the Wolf property are part of a belt that occurs within the Pelly-Cassiar platform, a miogeoclinal sequence thought to be part of ancestral North America. Much of the bedrock exposure in the region is along the northeastern edges of southwesterly dipping, imbricate thrust sheets. The felsic volcano-sedimentary sequence on the Wolf property is approximately 900 m thick and bounded by two thrust panels of lower Paleozoic platformal carbonate sequences. Volcanic stratigraphy is characterized by high potassium geochemistry, a variety of pyroclastic grain sizes, and high-energy fragmental and low-viscosity flow textures. The chemistry of the volcanic rocks and their tectono-stratigraphic setting indicates deposition within an intra-continental rift.

Volcanogenic sulphide mineralization and exhalative barite occur at four stratigraphic levels within the Wolf property. The Wolf deposit is hosted within a laterally extensive sheet of massive sulphide mineralization at the upper stratigraphic level and has been defined by 30 diamond-drill holes over a 600 m strike length and a 500 m width (down-dip). Thickness of zinc, lead and silver bearing massive sulphide ranges from 2 to 25 m. A bulk of the deposit is contained within a higher grade "keel" that has a strike length of 125 m, a down-dip length of 400 m, an average thickness of 12 m and dips 45 degrees to the south. The deposit has an inferred resource of 4.1 million tonnes grading 6.2% Zn, 1.8% Pb and 84 g/t Ag, and is open along strike and down-dip. Exploration potential of the property has been enhanced by the discovery of the East Slope zone, 1200 m east of the Wolf deposit. Chemical zoning within the mineralization and peripheral alteration, and deposit morphology indicate that stratigraphy may be overturned.

RÉSUMÉ

La propriété Wolf se trouve dans la chaîne St. Cyr des monts Pelly, à environ 90 km au sud de Ross River (Yukon). La propriété repose sur des roches volcaniques felsiques et des roches sédimentaires dévono-mississippiennes. Il y a minéralisation sulfurée et/ou minéralisation en barite massive à bien laminée à quatre niveaux stratigraphiques distincts dans un amoncellement, d'une épaisseur d'environ 900 m, de roches volcaniques trachytiques à teneur élevée en K intercalées de sédiments argileux. Bien que les études de cartographie régionale n'aient pas précédemment permis la documentation à grande échelle des plis couchés de la région, un certain nombre de caractéristiques observées dans des carottes de forages indiquent que la séquence minéralisée pourrait être renversée. Des failles chevauchantes d'orientation nord-est séparant des séquences carbonatées paléozoïques de plate-forme étendues limitent la séquence de roches volcaniques felsiques encaissantes.

Dans la propriété Wolf, la minéralisation s'est formée dans des corps tabulaires de sulfures massifs latéralement étendus renfermant couramment des quantités moindres de dolomie ferrifère et plus rarement de la barite. L'horizon sulfuré supérieur du gisement Wolf a été recoupé par trente et un trous de sonde sur une longueur de 600 mètres dans la direction de la couche et sur jusqu'à 500 mètres vers l'aval-pendage; il présente une épaisseur variant de 2 mètres à plus de 25 mètres. Une «quille» à teneur plus élevée et d'une plus grande épaisseur a été définie sur une largeur approximative de 120 m et elle présente une épaisseur moyenne de 12 m sur plus de 400 m en aval-pendage. Une faille normale fortement inclinée avec rejet vertical de 65 m divise en deux parties égales la quille de l'horizon supérieur. Parmi les textures observées des sulfures, mentionnons : de la pyrite massive à grains fins avec sulfures de métaux communs disséminés, de la sphalérite, de la galène et de la roche carbonatée laminées ainsi que de la sphalérite et de la galène botryoïdes dans une gangue de roche carbonatée de couleur chamois avec Fe-Mg. La chalcopyrite brille par son absence générale dans l'horizon supérieur, bien qu'elle ait été observée dans des petits filons carbonatés de quartz et dans des bandes proximales sous-jacentes aux sulfures massifs.

Une nouvelle découverte, la zone East Slope, a été faite pendant la campagne de travaux sur le terrain de 1998. Situés à 1,2 km au sud-est du gisement Wolf dans la direction de la couche, les sulfures rubanés semi-massifs à massifs se présentent du point de vue stratigraphique approximativement à 70 m sous la position de l'horizon du gisement Wolf. Des sulfures massifs ont été recoupés par quatre trous de sonde et des teneurs atteignant jusqu'à 5,7 % en Zn, 2,1 % en Pb et 43,6 g/t d'argent on été relevées sur une épaisseur réelle de 4,6 m.

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INTRODUCTION

The Wolf property is located approximately 90 km southeast of Ross River, Yukon in the Pelly Mountains (Fig. 1). The property lies within NTS map sheets 105G/5 and 6, with the centre of the property at latitude 62°20'N and longitude 131°20'W. The property is best accessed by helicopter.

Owned by YGC Resources Ltd., the property was optioned by Atna Resources Ltd. in 1995 under an agreement which allows for Atna to earn a 65% interest in the claims for expenditures of $1.5 million over a five-year period. Atna has completed its option requirements and the project is now in the joint venture phase. The property presently comprises 23 mineral claims covering an area of approximately 481 hectares.

HISTORY

The Wolf property has been explored intermittently for the last 40 years. From the first recorded discovery of mineralization in 1955, the property has been the subject of numerous exploration programs: Newmont Mining Corp. staked the property and conducted geochemical sampling in 1966; Hesca Resources Ltd. restaked in 1972 and drilled two "x-ray" holes totaling 61 m in 1974; Newmont restaked in 1976 and conducted geochemical sampling, EM and magnetometer surveys, and 528 m of drilling in 1978; Amax of Canada Ltd. conducted a program of additional mapping and soil sampling (Harris, 1982); and Cominco Ltd. carried out more detailed gridding, soil sampling, mapping, and a UTEM ground geophysical survey between 1990 and 1993 (MacRobbie, 1992; Holroyd, 1993). Atna Resources Ltd. optioned the property in 1995 and conducted reconnaissance evaluation (Kallock, 1995), and a program of soil sampling, hand trenching and diamond drilling in 1996 (Schmidt, 1997). The three holes, in 1996, intersected significant, but sub-economic zinc, lead and silver. More drilling by Atna followed, and WF97-07, the fourth hole of the 1997 program, intersected 25.2 m of 6.9% zinc, 2.8% lead, and 139 g/t silver. Eight additional holes were drilled, all of which intersected the upper horizon of massive sulphides of varying thickness and grade (Holbek and Wilson, 1997).

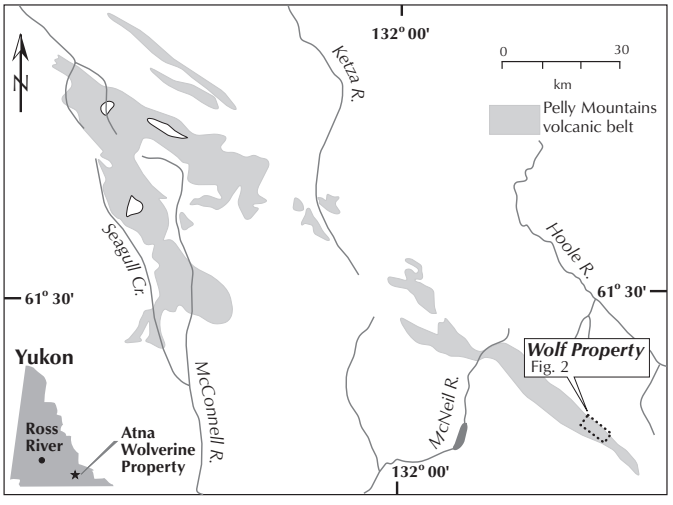

Figure 1. *Location of Wolf property in the Pelly Mountains volcanic belt.*

GEOLOGY

REGIONAL SETTING

The volcano-sedimentary rocks hosting the Wolf deposit form a narrow arcuate belt that extends 80 km along a northwesterly trend (Fig. 1). The volcanic rocks of this belt are characterized by high potassium content and, locally, bedded barite and volcanogenic massive sulphide deposits and showings. The Pelly Mountain Volcanic Belt is early to middle Paleozoic in age and occurs within the Pelly-Cassiar Platform, considered to be part of ancestral North America (Tempelman-Kluit, 1977).

Structure in the region is dominated by the Tintina Fault system and associated trench which is located 12 km east of the Wolf property and runs approximately parallel to the structural grain of the region. Post-late Triassic deformation produced a series of southwest-dipping thrust panels and northeasterly verging folds within the region (Gordey, 1977). Late normal faults crosscut earlier structures and divide the region into numerous fault-bounded blocks that commonly represent different structural levels. Metamorphism and degree of deformation varies from block to block but generally increases in a westerly direction. Metamorphism varies from lower to upper greenschist facies.

The regional tectono-stratigraphic setting, the high potassium geochemistry of the volcanic rocks, and the presence of bedded barite and volcanogenic massive sulphide deposits, indicate that the Pelly Mountain volcanic belt was likely deposited in a continental rift-type environment (Mortensen and Godwin, 1982).

PROPERTY GEOLOGY

The Wolf deposit occurs within an approximately 900 metre thick sequence of trachyte flows, lapilli and crystal tuffs, and lesser intercalated epivolcaniclastic and sedimentary rocks. This sequence of felsic volcanic rocks is bounded by northeasterly directed thrust faults, separating two extensive platformal carbonate sequences interpreted to be of lower Paleozoic age. Thrusts trend northwest and dip moderately towards the southwest. The felsic package strikes northwesterly and dips moderately to steeply (average 45°) to the southwest (Fig. 2).

Surface mapping at Wolf is hampered by weathering of pyritic, Fe-carbonate-altered rocks. Individual lithologies are difficult to identify, as colour and texture are often governed more by degree of alteration and weathering than parent lithology. In any volcanic pile, individual lithologies tend to be highly variable with respect to thickness and areal distribution, due to irregular paleodepositional surfaces, proximity to volcanic vents, and

dynamic to catastrophic local tectonics. Consequently, correlation of individual rock types between widely spaced drill holes and outcrops is difficult. Rock types, therefore, must be grouped into correlatable units, usually representing distinct igneous and/or sedimentary depositional environments. These units, as grouped at the Wolf property, are described below. The present geological plan (Fig. 2) is a simplification of field mapping based on stratigraphic groupings determined from drill core.

STRATIGRAPHY

The oldest rocks on the property are Upper Cambrian to Ordovician platformal carbonate rocks which occur in the uppermost thrust sheet (Unit 1) and consist of limestone to dolomite with interbedded shales and tan to reddish weathering dolostone (Figs. 2 and 3). The next oldest unit is interpreted to be the Upper Silurian to Devonian carbonates in the lower thrust plate on the northeastern edge of the property (Unit 2). The mineralized Upper Devonian to Mississippian volcanic package is bounded by these two carbonate thrust plates, and has been subdivided into eight units (3a-g and 4; Fig. 2).

The volcanic sequence hosting mineralization (Unit 3) was previously thought to be right side-up on the basis that Unit 3g , consisting of polymictic debris flows, lahars, and volcanic conglomerates composed of fragments from almost all of the volcanic sequence, with minor interbedded greywacke and argillite, occurred at the top of the sequence. However, in the Wolf deposit and East Slope areas, a monzonite sill (Unit 4) underlies Unit 3g below a faulted contact. If this sill was emplaced along a thrust fault then Unit 3g may not be in its correct stratigraphic position and cannot be used for a "tops" determination. The following descriptions are therefore based on structural, rather than stratigraphic positions.

The lowermost unit (3b) in the volcanic sequence is a poorly defined assemblage of ash tuffs, greywackes, argillite and locally, lapilli tuffs. The lapilli tuffs of this unit are characterized by relatively coarse, elliptical fragments (20 - 40 mm) that are altered to a soft greenish yellow. The matrix appears to be serpentinized or chloritized but chemically, Mg values are low. Further subdivision of this unit may be possible with additional drill data. Unit 3a is a highly pyritic, siliceous (?) felsic breccia/ flow that overlies 3b in the East Slope area but not at the Wolf deposit. Texturally, this unit appears to be vent proximal and may even be part of a flow-dome complex. Directly above Unit 3a is a laminated barite-carbonate-sulphide exhalative unit up to 18 m in thickness. This exhalite likely correlates with the lowermost barite horizon below the Wolf deposit (those exposed in the Newmont trenches) and the massive galena showing at the base of the cliffs on the northwest side of Mt. Vermilion.

Unit 3c hosts the East Slope zone and the middle sulphide horizon in the Wolf deposit area. The unit consists of ash tuffs, epivolcaniclastic rocks, trachyte flows and/or sills, pyritic mudstones and exhalative material, including massive sulphide horizons. The unit is distinct in that the tuffaceous and flow and/or sill rocks commonly contain fine quartz grains. The trachyte flows and/or sills and adjacent tuffaceous units typically display unusual textures formed by fine to coarse disseminated to aggregated elliptical Fe-dolomite nodules. It has been speculated that these textures are a form of pepperite caused by the injection of magma into wet unconsolidated tuffs and volcanic sediments. The percentage of quartz grains in these rocks appears to decrease from southeast to northwest.

Unit 3d hosts the Wolf deposit and consists of altered lapilli and ash tuffs, pyritic ash tuff, mudstone, laminated barite and massive to semi-massive sulphide mineralization. The tuffaceous

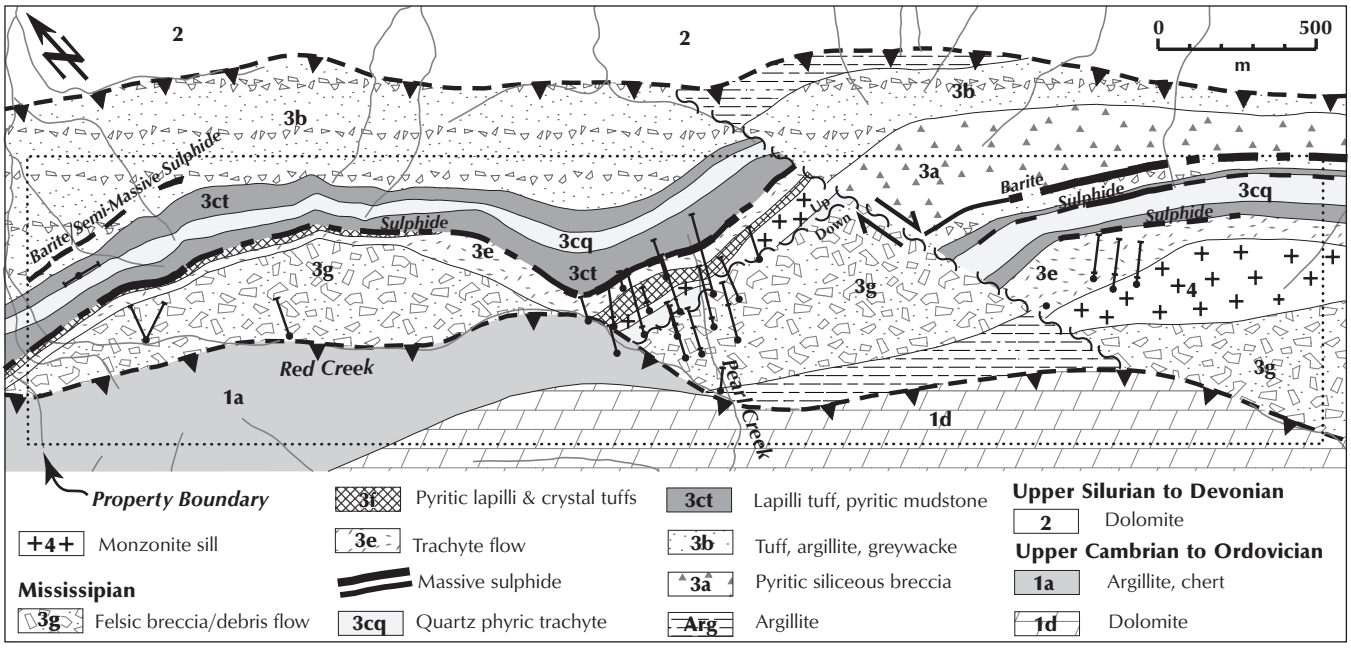

Figure 2. *Geological plan of the Wolf property.*

rocks of this unit are similar to those of 3f and are only different units due to separation by the trachyte flows of unit 3e. The pyritic-lapilli tuff unit overlies the mineralization and is laterally extensive. This lithology is laterally extensive and conspicuous due to strong sericite alteration and the presence of 10 to 20%, 3 to 15 mm fragments of massive pyrite and rarely, other sulphide minerals. There is no discernible zonation with respect to size and abundance of the sulphide fragments at the property scale, suggesting that the sulphide fragments originated in vent proximal mineralization caught in a phreatomagmatic explosion.

The trachyte flows of Unit 3e are the most continuous lithology in the sequence. They are present almost everywhere in the belt and are easily recognizable due to the propensity to form both cliffs and, with 5 to 20% finely disseminated pyrite, gossans. These units may be partly intrusive but most of the textures seen in drill core, including amygdules, flow-top breccias, and rare pillows, support a flow origin. Although felsic in composition, the high potassium content lowers the viscosity of the magma to the point where features more commonly associated with flood basalts occur in this unit. In the vicinity of the Wolf

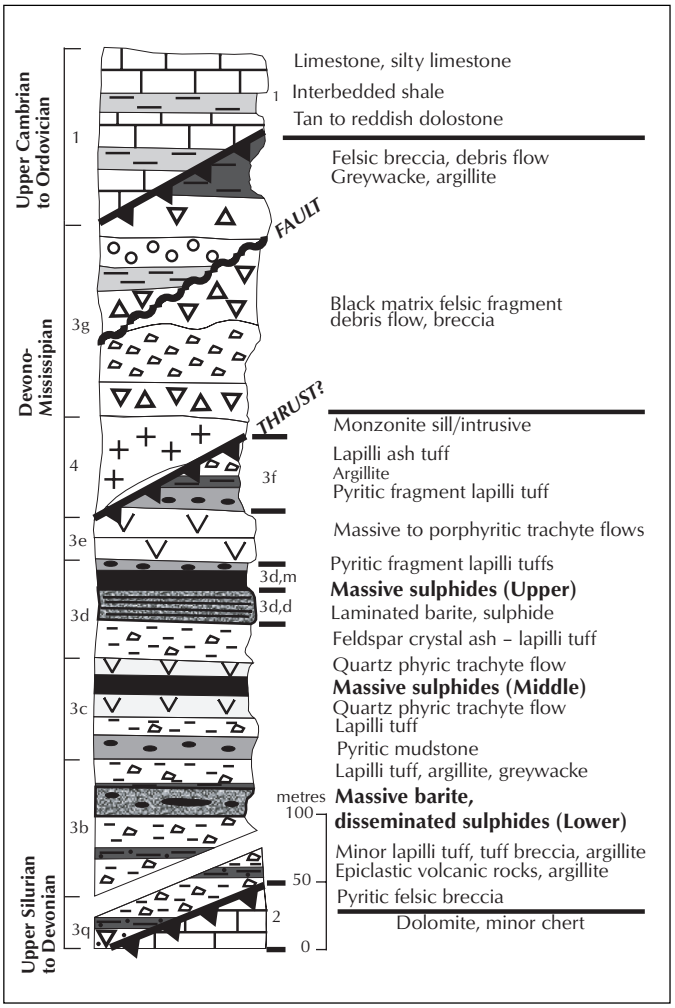

Figure 3. *Schematic stratigraphy of Wolf deposit.*

deposit the thickness of trachyte is variable and appears to be in an inverse relationship to the thickness of the sulphide mineralization (thin trachyte over thick sulphides and vice-versa). Commonly, but not always, the massive sulphide mineralization is separated from the trachyte flows by pyrite-lapilli tuff and/or a thin layer of argillite.

Unit 3g, as described above, consists of lahars and/or debris flows and volcanic conglomerates interbedded with minor greywacke and argillite. The fragments are dominantly trachytic but other volcanic and sedimentary lithologies also occur. The matrix commonly consists of fine-grained black chlorite (hence the field term: black matrix breccia) although, locally, the matrix can be bleached. Disseminated pyrite occurs locally, both within the trachytic fragments and also in the matrix, and rare patches of orange sphalerite are also observed. The presence of sulphides, particularly sphalerite, in the matrix of this unit is enigmatic. Drilling has encountered up to 190 m true thickness of this unit.

Fine- to coarse-grained, equigranular to weakly porphyritic monzonite forms Unit 4. Chemically, this unit is distinct from the other igneous lithologies in that the potassium and sodium contents are approximately equal (in most other rocks on the property, the ratio is 8 or 9:1). In drill core, this unit commonly appears altered and locally, intensely chloritized, however, the outcrops on the southern end of the property, mapped as syenite by Gordey (1977) and others, appear to be relatively fresh.

STRUCTURE

The structure of Wolf property is predominately influenced by the thrust panels which bound the volcanic succession, and dip moderately to the southeast. The lower thrust fault has previously been described as an unconformity (Gordey, 1977; Hunt, 1997), however, the thrust interpretation is retained herein for the following reasons: first, although the actual volcanic-carbonate contact is rarely exposed, the volcanic rocks near the contact commonly display evidence of tectonic disruption including folding of foliation; second, the contact cuts across the volcanic stratigraphy at a shallow angle.

A weak to strong, bedding parallel, foliation is developed in most volcanic and sedimentary units. Diversion of bedding and foliation planes, indicative of folding, has only been observed on the northern end of the property. Small-scale minor folds are common in drill core but megascopic folds in outcrop are rare. However, regional scale nappe structures are observed in the Pelly Mountain Volcanic Belt at the MM property (Mortensen, 1979) and in other rocks of the Pelly Cassiar Platform, immediately south of the Ketza River, and are consistent with the regional tectonic history. The homoclinal stratigraphic sequence of the Wolf property is likely part of a limb of a large fold. Additional limbs may be present north of the Wolf property where the width of the volcanic belt increases substantially.

Late stage faulting is evident on the property in a number of locations. The most prominent is a north-trending, steeply dipping fault that displaces stratigraphy for 700 m in a right

lateral direction (Fig. 2). A less prominent, but economically significant, fault is the easterly trending fault that down-drops the southern part of the Wolf deposit (Fig. 4).

MINERALIZATION

The Wolf deposit was discovered in 1997 by the fourth drill hole of a planned four-hole program. The discovery hole, WF97-07, intersected a true thickness of 25.2 m grading 6.9% zinc, 2.8% lead and 138.6 g/t silver (Fig. 4). Mineralization occurs as stratiform pyrite, carbonate, sphalerite, galena and barite, with rare specular hematite and chalcopyrite.

Although conclusive evidence is lacking, it appears the stratigraphy at Wolf may be an overturned limb of a recumbent fold. The mineralogical sequence appears inverted so that stringer mineralization occurs above the massive sulphide deposit and an extensive barite-carbonate exhalite occurs below it. Argillite and other sediments increasingly dominate the stratigraphy over volcanic rock below the lowermost mineralized horizon. If the stratigraphy were inverted these sediments could represent a period of quiescence and sedimentary deposition after a period of active volcanism. Intensity of alteration does not appear to be a conclusive guide because highly altered rocks have been intersected above and below the mineralized horizons. However, the concentration of disseminated to massive pyrite, quartz stringers, and carbonate alteration does appear more prevalent in the trachytic flows directly above the Wolf deposit than in rocks below.

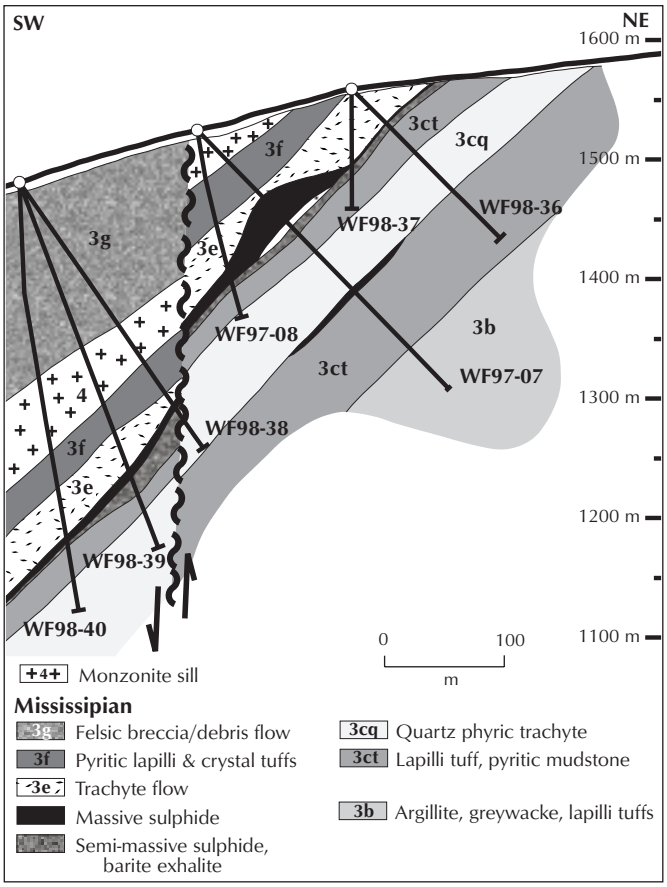

Figure 4. *Geological cross section of Wolf deposit.*

A total of 31 holes have intersected and defined the Wolf deposit which occurs as a tabular massive sulphide horizon across a 600 metre strike length, and approximately 500 m in the down-dip direction. A higher grade, thicker "keel" to this horizon, which is open at depth, was defined over a 120 m width, 12 m average thickness, and 400 m down-dip extent. A thrust fault is interpreted to have terminated the mineralization towards the northwest. The Wolf deposit is still open to expansion along strike to the east and down-dip. The massive sulphide mineralization consists primarily of fine-grained pyrite with bands of amber-coloured sphalerite and fine-grained, steely-grey galena. Also present is medium-grained botryoidal sphalerite and galena within a gangue of buff-coloured Fe-Mg carbonate and more rarely barite. Generally, sulphide intersections within the upper horizon grade from banded galena/pyrite to variably textured medium-grained sphalerite-pyrite. An extensive semi-massive barite/carbonate exhalite occurs immediately below the massive sulphide (Fig. 4). The barite/carbonate hosts disseminated to semi-massive sulphides in a banded, well-foliated fine-grained matrix which generally maintains a relatively uniform thickness of three to five metres throughout the Wolf deposit area. The baritic exhalite occurring on the bottom of the massive sulphide, and the upward doomed shape caused by increase in thickness of the mineralization, as indicated by the upper part of the hole WF98-07, are consistent with the interpretation of an overturned sequence.

The massive sulphide intervals are geochemically anomalous in copper (100-600 ppm), with individual assays up to 0.1%. Copper values in the massive sulphides do not appear to vary significantly between horizons or zones. Although generally absent, chalcopyrite has been observed occurring within mineralized quartz-carbonate stringers in two drill holes below the upper horizon (Wolf deposit). In drill hole WF98-24, the stringers formed a zone 7.1 m thick averaging 0.1% Cu within a trachyte flow. A narrow, high grade massive sulphide horizon directly below the stringer zone assayed 1.4% Cu, 9.8% Zn, 1.1% Pb and 11.3 g/t Ag over 0.5 m. The association of chalcopyrite rich stringers above this copper-enriched massive sulphide horizon is suggestive of an overturned sequence of stringer (feeder?) zone stratigraphically "below" a sulphide horizon.

EAST SLOPE ZONE

A total of six holes were successfully completed on the East Slope target in 1998 encompassing 1292 m of diamond drilling. After two failed previous attempts, the first hole completed on the East Slope target, WF98-33, intersected a 3.9 m true width of massive and semi-massive sulphides grading 4.6% Zn, 2.1% Pb and 30.0 g/t Ag. An approximately 80 m thick sequence of disseminated lead-zinc mineralization was intersected in the

new discovery area. Within this sequence, mineralization is concentrated along five narrow massive sulphide horizons. The last hole of the 1998 program, WF98-45, intersected 4.6m true width of massive, semi massive, mostly bedded sulphide, siliceous exhalite, and mineralized lapilli tuff grading 5.7% Zn, 2.1% Pb, and 42.6 g/t Ag at the same stratigraphic level as hole WF98-33, interpreted to be roughly 70 m below the Wolf deposit upper horizon. The lowermost horizon is comprised of a bedded barite, carbonate, pyrite exhalite horizon with minor amounts of disseminated sphalerite and galena. This exhalite horizon, which attains a true thickness of up to 18 m in drill core, likely correlates with the lower (baritic) horizon in the Wolf deposit and Mt. Vermilion areas. Below the lower exhalite horizon, a pyritic, siliceous, felsic breccia/fragmental/flow unit was intersected in five out of six East Slope drill holes (Unit 3a). None of the holes have yet to drill through the unit, which is greater than 80m in true thickness. Up to 2% combined disseminated sphalerite and galena are present in Unit 3a along with the 15% widespread disseminated to interstitial pyrite.

CONCLUSIONS

The 1998 exploration program followed up the 1997 discovery and located the down dip extension to the keel of the mineralized upper horizon. Through diamond drilling, the geology of the property has become much better understood, previous surface mapping having been hampered by supergene alteration related to pyrite and Fe-carbonate rich rocks.

The primarily trachytic felsic volcanic package hosts at least four separate horizons of volcanogenic massive sulphide mineralization. Mineralization seems to be laterally extensive as the East Slope area was drill-tested and found to contain massive sulphide mineralization; the thickest horizon located at a stratigraphic level approximately 70 m below the Wolf deposit. Potential is high to expand known deposits and zones of mineralization, and to locate new deposits.

Faulting has proven to be a significant factor in locating massive sulphide horizons at the Wolf property. A normal fault with unknown, but limited, strike-slip movement has down-dropped the south side of the Wolf deposit by 65m.

It is postulated that the volcanic sequence hosting the Wolf deposit may be overturned. Although little evidence exists from regional mapping to support the presence of a recumbent fold, observations from drill core which support an inverted VMS mineralized environment include: mineralized stringer zones above massive sulphide horizons; an irregular upper contact and a relatively “flat” lower contact of the massive sulphides; an extensive barite-carbonate horizon spatially below the Wolf deposit massive sulphides; and pyrite rich and highly carbonate-altered trachyte flows spatially above the upper horizon.

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