2.3 Project Geology

2.3.1 Introduction

The Wolverine Deposit is a polymetallic, Volcanogenic Massive Sulphide (VMS) deposit that was discovered in 1995 by a Joint Venture between Westmin Resources Limited (Westmin) and Atna Resources Ltd (Atna). Atna staked Quartz Mining claims based upon a conceptual idea presented by Mark Baknes of Equity Engineering Ltd in 1993.

The discovery of the Wolverine Deposit followed the discovery of Kudz Ze Kayah (KZK) in 1994 by Cominco Ltd. (Cominco) and lead to the largest staking rush in the history of the Yukon. The Wolverine deposit is now part of the newest emerging mining camp in Canada and is known as the Finlayson Lake District (FLD). The FLD is also known to host several other base metal deposits including Fyre Lake, GP4F, and Ice (Figure 2.3-1). To date, exploration activities on the Wolverine deposit have revealed an (pre-National Instrument 43-101) Inferred geological resource of 6,237,000 tonnes grading 12.66% zinc, 1.33% copper, 1.55% lead, 370.9 g/t silver and 1.76 g/t gold. The inferred geological resource is based upon drilling data to 1998 and does not contain any of the drilling information from 2000, 2004 and 2005. Since 1998, there was a small drilling program in 2000 as part of the Finlayson Project Pre-Feasibility Study. Between 2001 and 2004 work focused on the Goal Net area and there was relatively little exploration in the vicinity of Wolverine deposit except regionally in the Goal Net area. In 2004, exploration was re-initiated on the Wolverine Deposit and included definition drilling activities, as well as metallurgical analysis for dense media separation technology (DMS). Drilling will continue until early November 2005 when definition drilling will be completed and new resource estimation is undertaken as part of a Bankable Feasibility study on the Wolverine deposit.

As a result of the numerous base metal deposit discoveries in the FLD, both the Yukon Geology Program and the Geological Survey of Canada initiated projects that included:

1. extensive regional geological mapping that commenced in the summer of 1996
2. tectonic and metallogenic studies as part of the NATMAP program
3. a project for the characterization and genesis of the VMS deposits in the FLD

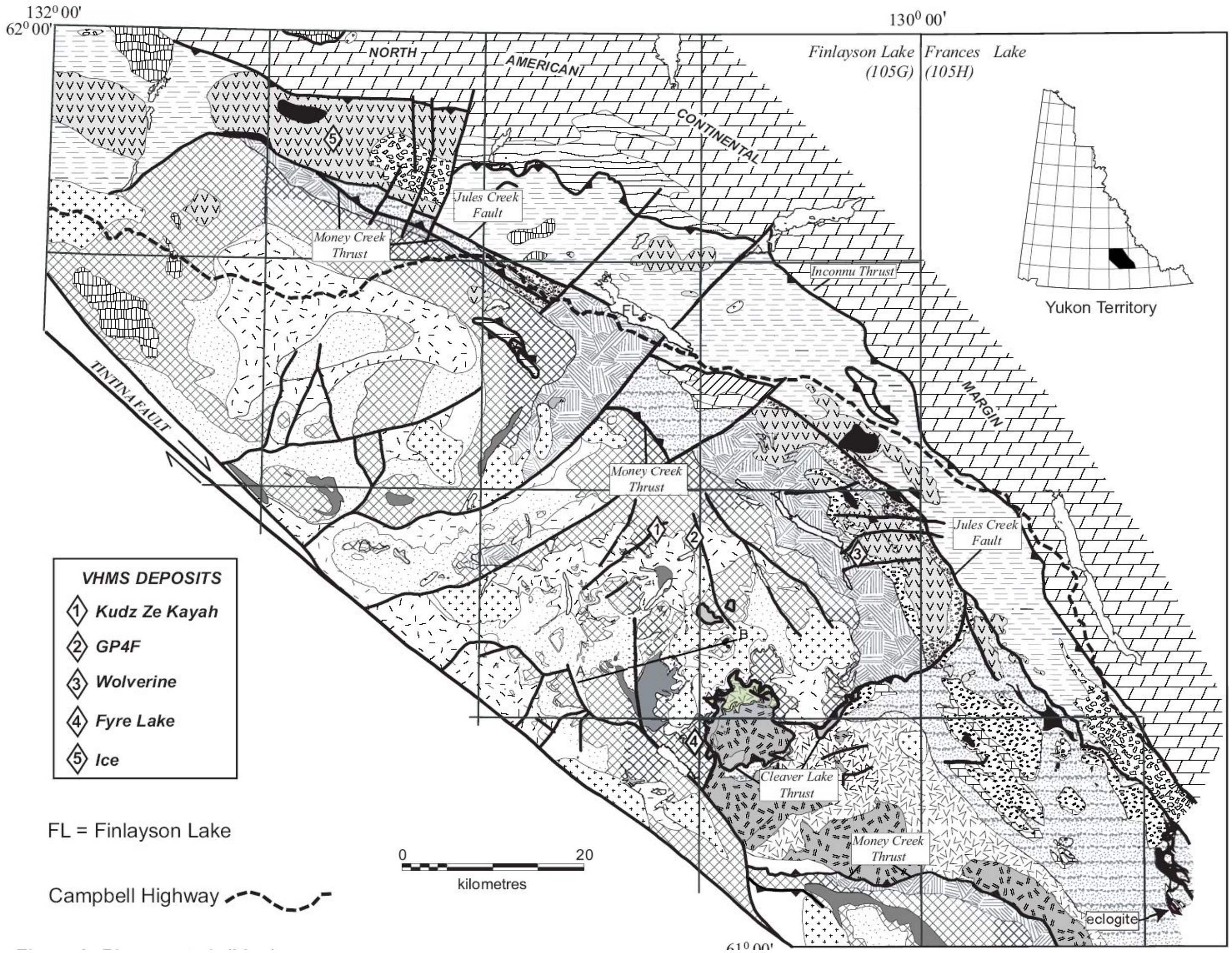
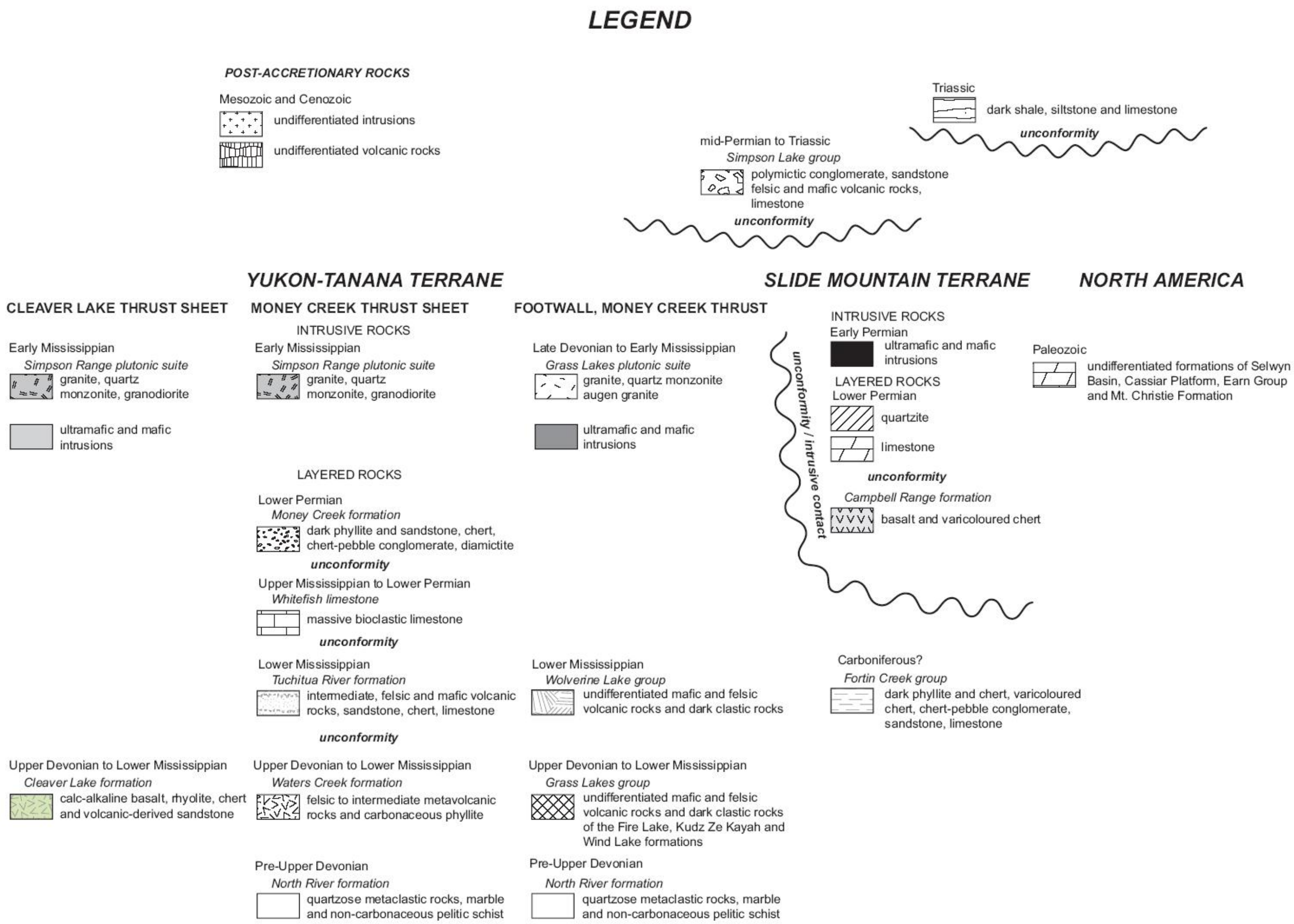


Figure 2.3-1 Finlayson Regional Geology

Legend follows


LEGEND
POST-ACCRETIONARY ROCKS
Mesozoic and Cenozoic
undifferentiated intrusions
undifferentiated volcanic rocks
Triassic
dark shale, siltstone and limestone
unconformity
mid-Permian to Triassic
Simpson Lake group
polymictic conglomerate, sandstone felsic and mafic volcanic rocks, limestone
unconformity
YUKON-TANANA TERRANE
SLIDE MOUNTAIN TERRANE
NORTH AMERICA
CLEAVER LAKE THRUST SHEET
MONEY CREEK THRUST SHEET
FOOTWALL, MONEY CREEK THRUST
INTRUSIVE ROCKS
Early Mississippian
Simpson Range plutonic suite
granite, quartz monzonite, granodiorite
ultramafic and mafic intrusions
Early Mississippian
Simpson Range plutonic suite
granite, quartz monzonite, granodiorite
Late Devonian to Early Mississippian
Grass Lakes plutonic suite
granite, quartz monzonite augen granite
ultramafic and mafic intrusions
unconformity / intrusive contact
INTRUSIVE ROCKS
Early Permian
ultramafic and mafic intrusions
LAYERED ROCKS
Lower Permian
quartzite
limestone
unconformity
Campbell Range formation
basalt and varicoloured chert
Paleozoic
undifferentiated formations of Selwyn Basin, Cassiar Platform, Earn Group and Mt. Christie Formation
LAYERED ROCKS
Lower Permian
Money Creek formation
dark phyllite and sandstone, chert, chert-pebble conglomerate, diamictite
unconformity
Upper Mississippian to Lower Permian
Whitefish limestone
massive bioclastic limestone
unconformity
Lower Mississippian
Tuchitua River formation
intermediate, felsic and mafic volcanic rocks, sandstone, chert, limestone
unconformity
Lower Mississippian
Wolverine Lake group
undifferentiated mafic and felsic volcanic rocks and dark clastic rocks
Carboniferous?
Fortin Creek group
dark phyllite and chert, varicoloured chert, chert-pebble conglomerate, sandstone, limestone
Upper Devonian to Lower Mississippian
Cleaver Lake formation
calc-alkaline basalt, rhyolite, chert and volcanic-derived sandstone
Upper Devonian to Lower Mississippian
Waters Creek formation
felsic to intermediate metavolcanic rocks and carbonaceous phyllite
Upper Devonian to Lower Mississippian
Grass Lakes group
undifferentiated mafic and felsic volcanic rocks and dark clastic rocks of the Fire Lake, Kudz Ze Kayah and Wind Lake formations
Pre-Upper Devonian
North River formation
quartzose metaclastic rocks, marble and non-carbonaceous pelitic schist
Pre-Upper Devonian
North River formation
quartzose metaclastic rocks, marble and non-carbonaceous pelitic schist

2.3.1.1 Definition of Volcanogenic Massive Sulphide Deposit

Volcanogenic massive sulphide (VMS) deposits are defined as stratabound to stratiform occurrences of sulphide minerals that have accumulated either through contemporaneous precipitation on the seafloor from a buoyant plume or as the result of replacement sub-seafloor during volcanic activity (Frankin et al, in preparation). Numerous authors such as Franklin et al. (1981), Barrie and Hannington (1999), and Large et al. (2001) have written extensively on VMS deposits from around the world where they note that a VMS deposit consists of two parts: (1) a concordant massive sulphide lens with typically more than 60% sulphide minerals and (2) discordant stringer Zone in the footwall.

2.3.2 Exploration History of the Wolverine Deposit

Prior to being known as the FLD, the Wolverine Lake area was explored during the 1970's and early 1980's by a Syndicate known as the Finlayson Joint Venture that was managed by Archer, Cathro & Associates (1981) Limited. Exploration activities identified several strong, multi-element soil geochemical anomalies that were directly associated with a kill zone that became known as the Fetish showing. This kill zone area was successfully cored by two small diameter drill holes in 1974. Both drill holes intersected low-grade copper and zinc sulphide mineralization; however, both drill holes were terminated above the favorable unit hosting the massive sulphide mineralization of the Wolverine deposit. Despite the presence of sulphide mineralization in the two drill holes, the Quartz Mining claims were subsequently allowed to lapse (Tucker et al., 1999).

In 1993, Equity Engineering Limited (Equity) concluded that the area held promise for VMS mineralization, based on favorable stratigraphy and the presence of surficial geochemical anomalies. On behalf of Atna, Equity staked claims over the deposit area and carried out a field exploration program consisting of geological mapping, prospecting, and sampling. In 1995, Westmin optioned the property from Atna (the "Wolverine Joint Venture") and commenced a vigorous exploration program designed to evaluate the mineral potential of the more than 10 kilometers of strike length of favorable volcanic stratigraphy. Exploration consisted of detailed geologic mapping and systematic grid soil sampling, which lead to the definition of several multi-element geochemical anomalies. The strongest anomaly occurred in the area of the original Fetish showing, subsequently termed the "Wolverine Zone".

Westmin commenced diamond drilling activities in August 1995 and the first hole into the Wolverine Zone intersected massive sulphide mineralization in what is now known as the Wolverine zone. The fourth drill hole was down-dip of the first drill hole and intersected one of the highest grade intercepts on the property, 8.4 m of massive sulphide grading 7.63 grams per tonne gold, 1358.3 grams per tonne silver, 0.56% copper, 3.45% lead and 14.22% zinc. This discovery led to a decision by the Wolverine Joint Venture to conduct extensive drilling in the fall of 1995, as well as in both 1996 and 1997. After concluding the 1997 exploration program, 71 drill holes successfully defined the deposit and Westmin calculated an Inferred geological resource of 6,237,000 tonnes grading 12.66% zinc, 1.33% copper, 1.55% lead, 370.9 g/t silver and 1.76 g/t gold in January of 1998. The deposit was defined over a strike length of approximately 750 m and remained open downdip to the northeast where it crossed onto the WOL claims owned by Cominco.

Also in 1996, Westmin commenced metallurgical testing on the Wolverine deposit and by late 1997, it was discovered that the concentrates from the Wolverine deposit contain unusually high levels of selenium; which at the time, was a deleterious contaminant that could significantly impact the marketability of the concentrates to smelters around the World. Further investigation of the metallurgical problem ended abruptly as a result of the take-over of Westmin by Boliden Limited (Boliden) in early 1998. Subsequent to the take over of Westmin, Expatriate Resources Ltd (now Yukon Zinc Corporation – “Yukon Zinc”) concluded a letter agreement in May 1998 for the purchase of Boliden’s 60% interest in the Wolverine deposit. As a result, in June 1999 a new Wolverine Joint Venture (60% Expatriate and 40% Atna) announced that it was beginning an evaluation of alternative metallurgical methods for processing the concentrates from the Wolverine deposit.

In March of 2000, Expatriate announced that the Company had reached an agreement with Cominco to purchase all of Cominco’s Finlayson Lake District assets that included the down-dip WOL claims adjacent to the Wolverine deposit. In May 2000, Expatriate commenced a drill program in order to expand the existing resource and further define the known mineralization; however, by October, the agreement with Cominco had been terminated and Expatriate had to stop work on the Pre-Feasibility Study that was examining the joint development of Wolverine with KZK.

Exploration ceased on the Wolverine property until the summer of 2004 when Expatriate commenced a large-diameter drilling program to accomplish both infill on the known inferred geological resource and collection of samples for DMS. In total, 1758.4 m were cored with ¼ of the massive sulphide drill core sampled for assay analysis at ALS Chemex Laboratories in North Vancouver, British Columbia and the remaining ¾ of the massive sulphide drill core sampled for DMS at SGS Lakefield in Lakefield, Ontario. Use of DMS technology is common in the metals, industrial minerals, and coal industries where there is significant density contract between the materials being recovered and waste materials. The sample material from the pre-2004 drill core was mixed on the basis of 30% hanging wall argillite, 50% massive sulphide, and 20% footwall argillite to form a blended sample. The results achieved a fifty percent weight rejection to the Float (waste) fraction. The loss of metals to the waste material was less than two percent of zinc, copper, and lead and approximately five percent for silver and gold. The DMS testing indicates that the samples tested were very amenable to heavy media separation; achieving a fifty percent weight rejection to the float fraction. In a full scale plant, the combined “sink” and “fines” products from the DMS plant feed would require further processing by conventional grinding and flotation processes, while the nearly barren ‘float” product from DMS would be discarded.

2.3.3 Regional Geological Framework

The Finlayson Lake District (FLD) has been studied by numerous researchers including but not limited to Tempelman-Kluit et al. (1976), Mortensen and Jilson (1985), Hunt (1998) Murphy (1998), Murphy et al. (1999a), Murphy et al. (1999a), Piercey et al. (2001), Hunt (2001), Piercey et al. (2002), Piercey et al. (2003), Piercey et al. (2004), and Murphy et al. (in preparation). The FLD comprises the dominant portion of the isolated outlier of Yukon-Tanana (YTT) and Slide Mountain (SMT) Terranes northeast of the Tintina Fault (Figure 2.3-2). The FLD also lies near the inner, eastern margin of the outlier, where pericratonic rocks of YTT and basinal oceanic rocks of Slide Mountain Terrane are juxtaposed directly against rocks of the North American continental margin along the post-Late Triassic Inconnu Thrust (Figure. 2.3-2).

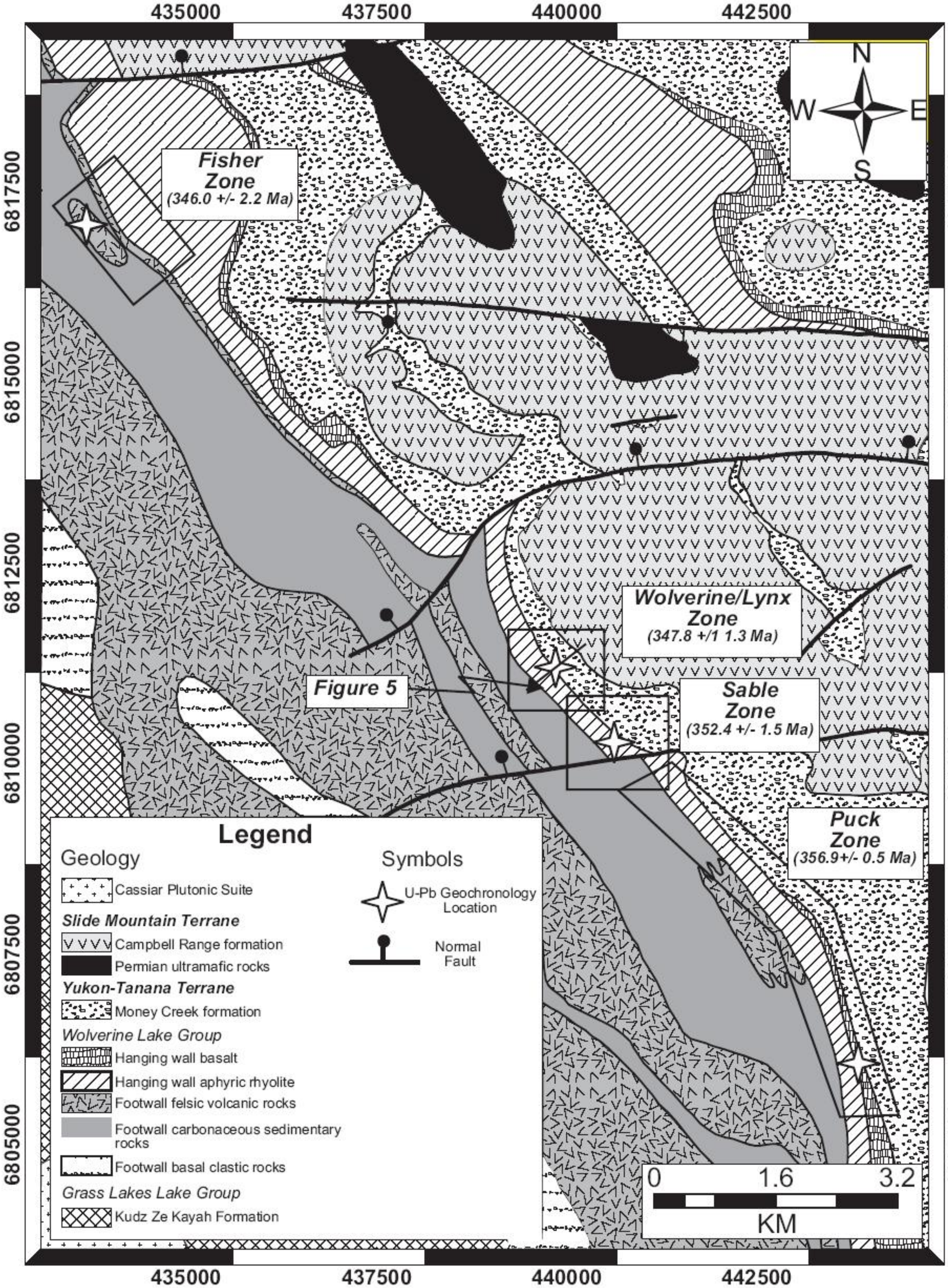


Figure 2.3-2 Wolverine Regional Geology

The YTT and SMT in the Finlayson Lake massive sulfide district comprise variably deformed and metamorphosed lower greenschist to amphibolite facies sedimentary and volcanic rocks and affiliated plutonic suites. Although the rocks of the terrane are ubiquitously foliated and variably folded, regionally extensive stratigraphic units have been defined by mapping and drill core logging and protoliths have been determined from locally well preserved primary features and geochemical characteristics.

Using all of the newly acquired data, Murphy et al. (in preparation) have noted that the YTT and SMT in the FLD can been subdivided into several provisionally named fault- and unconformity-bound groups and formations. It should also be noted that the reconstruction of the FLD has done by researchers including Murphy and Piercey (2000), Murphy (2001), Murphy et al. (2002) and Murphy et al. (in preparation). According to the researchers, the structurally lowermost rocks that are definitely part of the YTT are footwall to the Money Creek Thrust and include the mafic and felsic volcanic and sedimentary rocks of Upper Devonian and older Grass Lakes Group, Late Devonian to early Mississippian granitic plutonic rocks of the Grass Lakes Plutonic Suite and sedimentary and mafic and felsic volcanic rocks of the unconformably overlying lower Mississippian Wolverine Lake Group (Figure 2.3-2). It should be noted that the Grass Lakes Group is host to the Fyre Lake, Kudz Ze Kayah, and GP4F deposits, whereas the Wolverine Lake group hosts the Wolverine deposit.

The hanging wall of the Money Creek Thrust is composed of the metasedimentary and felsic to intermediate metavolcanic rocks of the Upper Devonian to lower Mississippian Waters Creek and Tuchitua River Formations, affiliated granitic to granodioritic metaplutonic rocks of the Simpson Range plutonic suite (Mortensen, 1992b and references therein), the upper Mississippian to Lower Permian Whitefish limestone and, locally, dark grey basinal clastic rocks of the basal Lower Permian Money Creek Formation (Figure 2.3-2). These latter rocks are overlain by rocks of an upper thrust sheet which comprises undeformed, predominantly mafic Late Devonian volcanic rocks of the Cleaver Lake Formation, spatially associated and probably co-magmatic felsic, mafic and ultramafic metaplutonic rocks and a cross-cutting early Mississippian pluton of the Simpson Range plutonic suite. Rare coarse-grained metamorphic rocks with early Mississippian metamorphic cooling ages inferred to be highly retrogressed eclogite (Erdmer et al., 1998) and mélange-like dark chert, chert-pebble conglomerate, argillite, and greywacke similar to, and locally mapped as part of, the Money Creek Formation are provisionally included in the upper sheet. None of these rocks units has yielded significant accumulations of VMS mineralization.

To the north and east, the imbricated rocks of YTT are juxtaposed against rocks of SMT along the Jules Creek Fault. In this area, SMT comprises the probably Mississippian to Lower Permian Fortin Creek group, a primarily dark grey argillite and chert succession with locally important variegated chert and phyllite, quartzofeldspathic sandstone, chert-pebble conglomerate, felsic and mafic metavolcanic rocks, barite and dark grey limestone. SMT also includes pristine to weakly foliated Lower Permian basalt and chert of the Campbell Range Formation and presumably co-magmatic Early Permian mafic and ultramafic meta-plutonic rocks that lie within a ca. 20 km-wide magmatic corridor that straddles the Jules Creek Fault. As the Campbell Range Formation unconformably overlies, and the mafic and ultramafic metaplutonic rocks intrude, older rocks on both sides of the fault, they link the two terranes in the Early Permian. The mafic rocks of the SMT are host to the Ice VMS deposit.

2.3.4 Deposit Geology

2.3.4.1 Introduction

The stratigraphic sequence that hosts the deposit (hereafter referred to as the “Wolverine stratigraphy”) is defined in this paper as those rocks 400 m above and 70 m below the massive sulphide mineralization for which there are sufficient data from drill core to confidently establish a coherent stratigraphy that is consistent throughout the entire area of the deposit. The lithologies forming the immediate host rocks to the deposit are described below. The surface geology of the Wolverine deposit and deposit drilling are presented in Figures 2.3-2 and 2.3-3, respectively.

2.3.4.2 Metamorphism and Structure

All the rocks in the Wolverine stratigraphy have been metamorphosed to middle to upper greenschist grade, based on the characteristic minerals chlorite, actinolite, albite, sphene, carbonate and, in places, biotite. The rocks have undergone a single recognized major deformational event, which has obliterated most primary volcanic and sedimentary textures and forms a prominent S1 foliation which trends consistently northwest and dips gently to the northeast. This fabric is a curviplanar preparationure-solution foliation that is defined by millimetre to centimetre scale seams of fine micaceous minerals that are more widely spaced in the more siliceous units (Murphy, 1998).

Folds in the region of the deposit are consistently northwest verging, tight, highly asymmetric, and are “S” shaped when viewed to the northwest along the fold axes. The scale of these folds ranges from the millimeter-scale (e.g., drag folds in tuff observed in drill core) to meter scale folds that are geometrically identical and observed in outcrop. The tight asymmetric nature of the folding permits the easy correlation of meter-scale units between drill holes on the same section, (i.e., on the scale of about one half kilometer). Correlation between adjacent drill cores in certain cross sections indicates that there has been some thickening and/or structural repetition of units near fold hinges.

In rare cases where primary compositional layering is visible, the intersection of the S1 foliation with bedding (S0) forms a lineation which parallels the orientation of the fold hinges. The compositional layering and S1 foliation are essentially co-planar except near the vicinity of fold hinges.

Layer-parallel or horizontal thrust faults may have resulted in extensive gouge Zones in the more ductile and/or hydrothermally altered rocks. However, even with faulting being present and distinguishable both on surface, as well as through drill core, there has been no significant offset recognized in either cross-section or plan map. Most faults in the Wolverine stratigraphy are interpreted as being related to a major deformation and despite greenschist metamorphism; it is still possible to recognize volcanic and sedimentary protolith rock-types in the stratigraphy hosting massive sulphide mineralization.

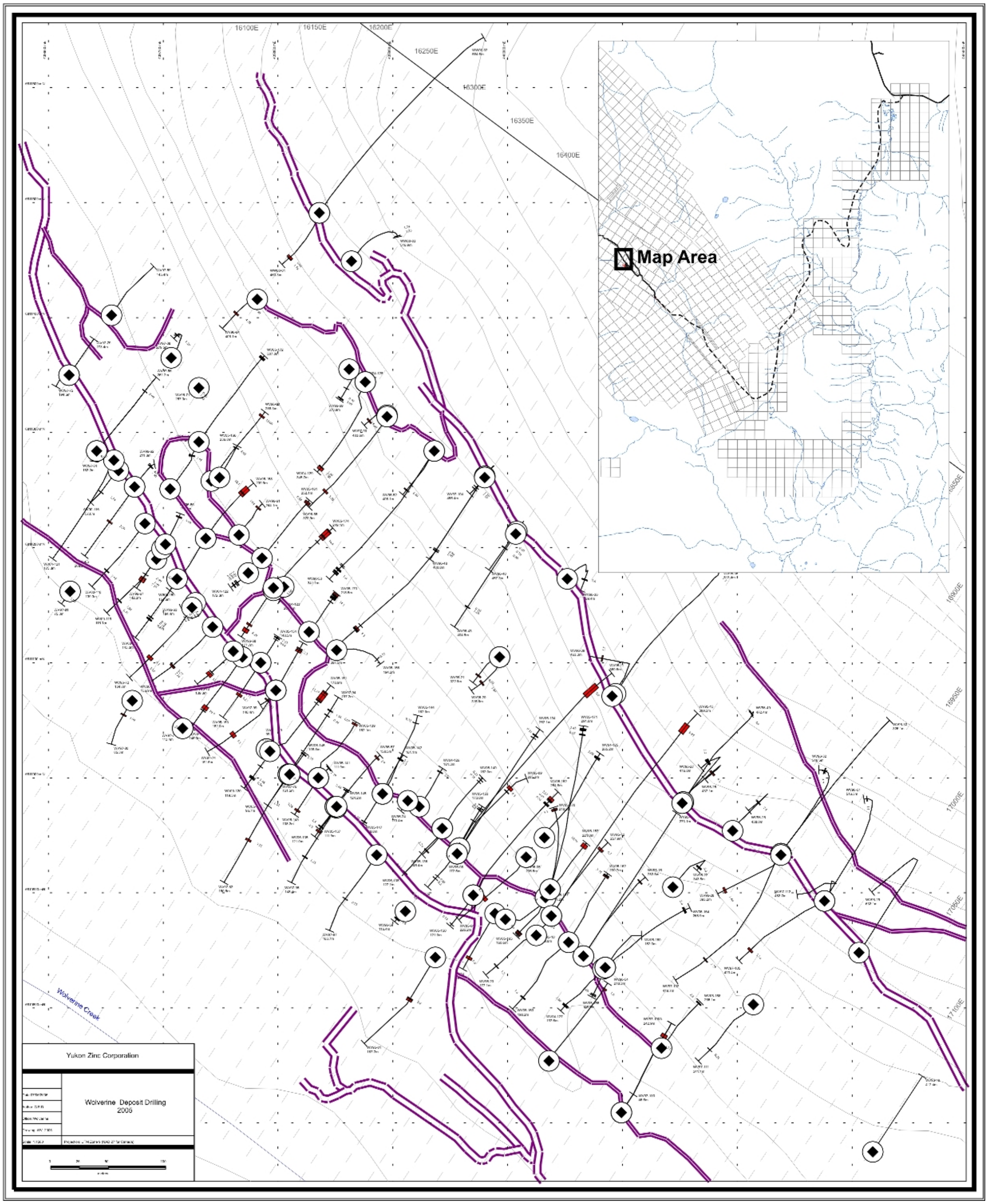


Figure 2.3-3 Wolverine Deposit Drilling

2.3.4.3 Wolverine Stratigraphic Sequence

The Wolverine stratigraphy is a sequence of deformed volcanic and sedimentary rocks for which various protoliths have been interpreted. The protoliths, which have been divided into four successive units, are described below from oldest to youngest and illustrated in Figure 2-3.4 with geology sections presented in Figures 2.3-5 and 2.3-6.

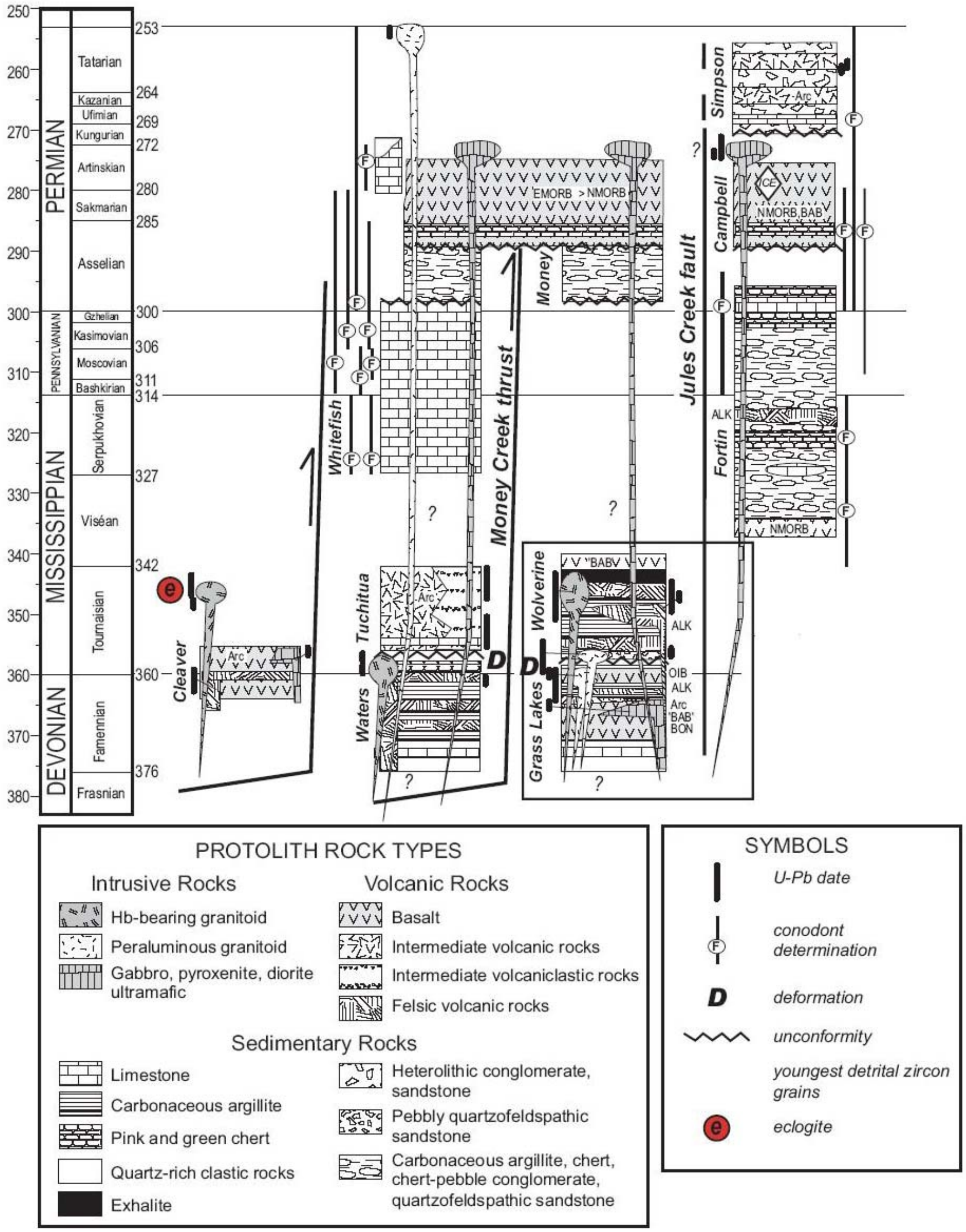


Figure 2.3-4 Wolverine Stratigraphy

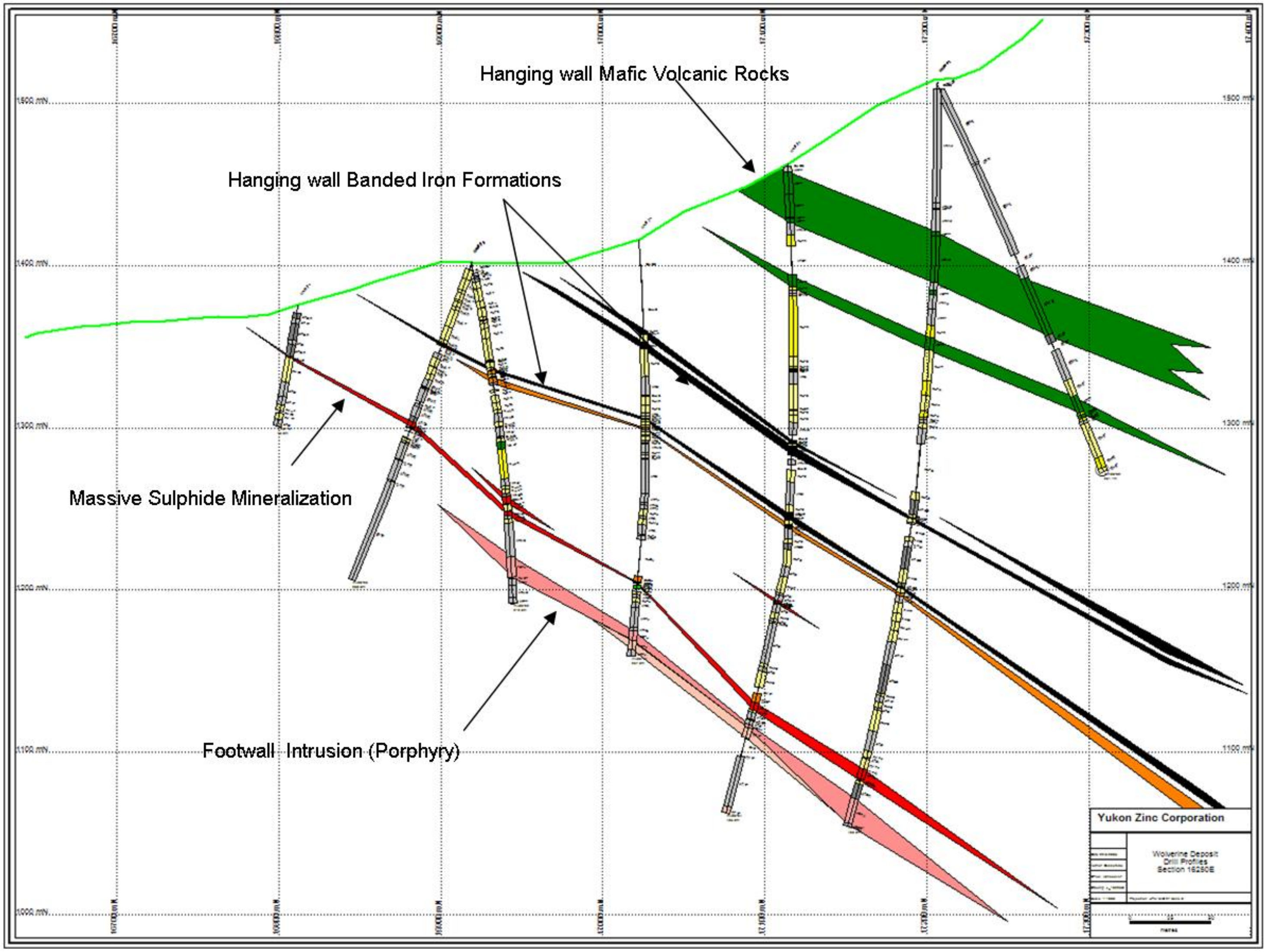


Figure 2.3-5 Wolverine Deposit Drill Profiles, Section 16250E

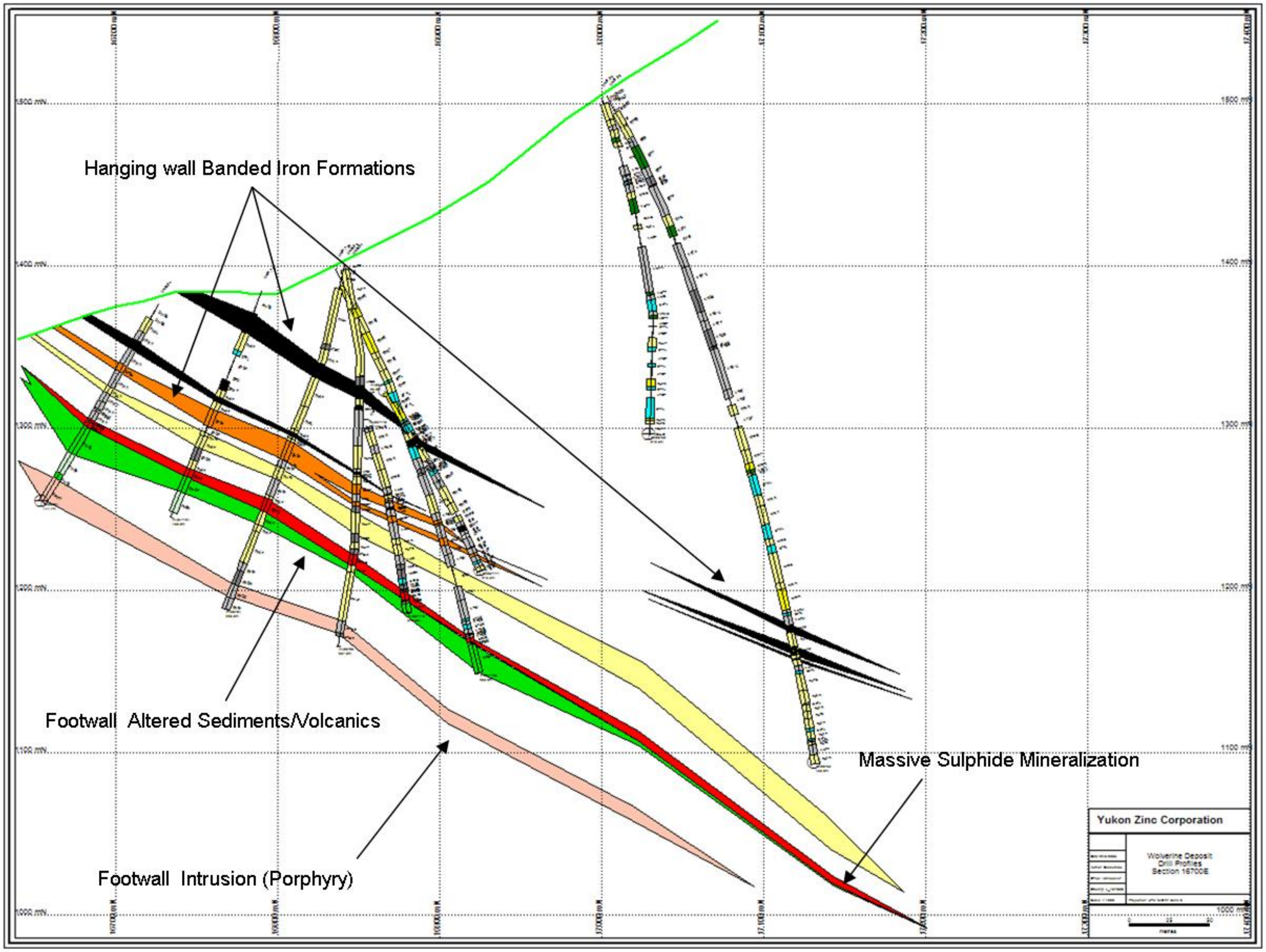


Figure 2.3-6 Wolverine Deposit Drill Profiles, Section 16700E

Footwall to Massive Sulphide Lens

One of the dominant units in the Wolverine stratigraphic column is the Footwall rocks that are composed of volcaniclastic, carbonaceous sedimentary and porphyritic intrusive rocks. This heterogeneous unit contains the following lithologies: (1) Green to grey quartz- and feldspar- crystal bearing rhyolite volcaniclastic rock with variable amounts of interbedded carbonaceous argillite that contains abundant flattened, fine- to coarse-grained fragments of rhyolite volcanic rock. This lithology can contain up to several volume percent of 1 to 5 mm diameter, subhedral to euhedral, K-feldspar crystals and 1 to 2% rounded greyish blue quartz “eyes”, although either, or both, may be absent. The relative abundances of feldspar crystals, quartz eyes, and volcanic rock fragments vary significantly in this lithology throughout the deposit. (2) Black to grey, aphanitic to fine-grained, carbonaceous tuffaceous argillite. This rock commonly contains several volume percent grey tuff as layers or clasts and may contain up to several volume percent rounded blue quartz eyes up to 1 mm in diameter. This footwall argillite is similar to the carbonaceous argillites in the hangingwall but is distinguished from it locally by a slightly coarser grain size, lighter colour, and presence of quartz eyes (Tucker et al., 1999). (3) Grey, weakly foliated, K-feldspar-phyric rhyolite porphyry. Contains 5 to 10% subhedral to euhedral, 5 mm to 1 cm diameter K-feldspar phenocrysts in a grey aphanitic siliceous groundmass. This unit only rarely contains quartz eyes (Tucker et al., 1999).

Massive Sulphide Lens

The massive sulphide lens typically lies immediately above and in some cases within the felsic volcaniclastic rocks; noting that there is a gradual transition from the upper felsic volcaniclastic rocks to the underlying carbonaceous argillite. A more detailed description of the mineralization can be found in Section 2.3.4.4 that follows. The appearance of carbonaceous argillite in the footwall marks the base of the sequence that hosts the sulphide mineralization. The potassium feldspar-phyric porphyries occur an average distance of 20 m below the lower limit of the massive sulphide horizon and are interpreted to be intrusions. The exact role of these intrusions with respect to the mineralizing event is unclear at the present time (Tucker et al., 1999).

he immediate host rock package to the massive sulphide mineralization ranges from 85 to 160 m in thickness and hosts up to four distinct exhalative lithologies – the upper two are most commonly magnetite-predominant exhalite, the middle is a carbonate-predominant exhalite and the lowermost is a massive sulphide lens. Their thickness ranges from less than 1 m up to 30m. The magnetite rich exhalative rocks are laterally extensive and are part of the stratigraphy on a regional scale. The exhalative units are separated by mixed sequences of interbedded argillite and rhyolite (Tucker et al., 1999).

Hanging wall to Massive Sulphide Lens

In the hanging wall above the massive sulphide mineralization, there is a sequence of intercalated argillite, felsic volcaniclastic and volcanic rocks, as well as magnetite-carbonate-pyrite exhalative units that are referred too as iron-formations. This sequence of rocks contains the following lithologies:

1. Grey, massive to flow-banded, aphanitic to very fine-grained, aphyric rhyolite. This rock is comprised of domains of aphanitic rhyolite with sub-millimetre to several

centimetre-wide micaceous partings oriented parallel to the dominant S1 foliation. The rhyolite domains commonly contain minute feldspar microlites.

2. Black, finely laminated, aphanitic, carbonaceous to strongly graphitic, argillite. This rock may contain several volume percent grey tuff layers or clasts. A strongly siliceous variant of this lithology contains abundant flattened and sheared veins of quartz and pyrite suggesting that the silicification may be an alteration phenomenon.

3. Grey to black, magnetite-rich exhalite (iron formation). Contains 5-60% disseminated to massive layered magnetite with lesser carbonate and chlorite. The layering is interpreted as primary. Magnetite is interbedded with quartz and lesser micaceous minerals on a millimeter scale.

4. Grey to white carbonate exhalite. Contains up to 90% patchy to massive carbonate (calcite > ankerite > siderite) with lesser magnetite, chlorite and pyrite. Rarely exhibits fine laminations.

5. Finely laminated, very fine-grained polymetallic massive sulphides. The types and styles of mineralization are described in detail in the subsequent section.

One clearly identifiable lithology in the hanging wall is a felsic volcaniclastic rock unit known as ‘fragmental rhyolite’ contains the following facies variations:

1. Grey rhyolite with a distinctive fragmental texture. This texture is defined by wispy sub-millimeter dark green to black, anastamosing micaceous bands which separate centimetre-sized felsic aphanitic rock domains. Fragments are sub-angular to sub-rounded irregular shapes with jagged boundaries. A variant of this unit has a distinctive greenish hue and 1 to 2% disseminated magnetite which may be a weak chloritic alteration.

2. Grey to black, felsic volcanic rock with abundant (50-90% volume) siliceous lenses or clasts in a matrix of black carbonaceous argillite. The rock fragments are generally centimetre-sized, ovoid and flattened into the plane of foliation. This lithology is similar to the fragmental rhyolite described above, with the distinguishing criteria being a significantly greater sedimentary rock component. This felsic volcaniclastic unit occurs above the “mineralized sequence” and its base is generally marked by the presence of the uppermost magnetite-bearing iron formation. Its thickness throughout the deposit is fairly constant, averaging 80 m (Tucker et al., 1999).

At the top of the hanging wall stratigraphy is a unit composed of intercalated carbonaceous argillite and wacke with lesser mafic and felsic volcanic rocks. This unit contains the following lithologies:

1. Green, massively fine-grained basalt with biotite and minor epidote on partings. These rocks are interpreted to be flows where massive and homogeneous, although a volcaniclastic origin is preferred where layering is prominent, and where they are interbedded with carbonaceous sedimentary rocks.

2. Interbedded black aphanitic argillite and grey to black, slightly coarser-grained greywacke. Minor interbeds of felsic volcaniclastic rocks are present, and they are similar in appearance to the fragmental rhyolite volcanic rocks (Tucker et al., 1999).

This uppermost sequence probably represents the transition from the Wolverine stratigraphy to the overlying Campbell Range basalts. The upper limit to this unit is unknown, but its thickness is at least 200 m. The bottom of this unit is recognized by the last occurrence of green basaltic volcaniclastic rock (Tucker et al., 1999).

2.3.4.4 Mineralization

Massive sulphide mineralization associated with the Wolverine deposit most commonly occurs at or near the transition from interbedded, massive, aphyric rhyolite and carbonaceous argillite to coarser grained and commonly crystal- bearing rhyolite volcaniclastic rock. The immediate hanging wall to the massive sulphide is most commonly black, strongly graphitic argillite.

Morphology and Mineralogy

The sulphide mineralization at Wolverine can be classified on the basis of mineralogy and lens morphology as one of two types:

1. massive stratiform sulphide mineralization
2. massive replacement and stringer sulphide mineralization

Jambor (1996) noted that the bulk of the mineralization at Wolverine occurs as massive sulphide lenses composed of the sulphide minerals such as pyrite and sphalerite with lesser amounts of pyrrhotite, chalcopyrite, galena, tetrahedrite-tennantite and arsenopyrite. Other sulphide minerals identified through petrographic analysis include marcasite, native gold, and native silver. There are also lead sulfosalt zones that occur locally and contain minerals such as meneghinite, bournonite, boulangerite and miargyrite. Gangue minerals within the massive sulphide mineralization consist of quartz, calcite, dolomite-ankerite, and muscovite. These gangue minerals typically compose less than 5% of the mineralized zones and occur as very fine grains or irregular blebs interstitial to sulphides (Jambor, 1996).

The overall distribution of the stratiform mineralization is illustrated in Figure 2.3-7 which contours the surface projection of the true thickness of massive sulphide mineralization; noting that the pre-2004/2005 isopach map is presented in conjunction with the new isopach map recently created to account for the 2004/2005 definition drilling. There are two areas where the accumulation of massive sulphide is known to be thickest and these areas are separated by a Zone of non-stratiform replacement and stringer mineralization that occurs at the same stratigraphic horizon and is known as the Saddle Zone. The thickness of the sulphide lenses in the Wolverine deposit ranges from less than one meter near the fringes of the deposit to over 16 meters in the core of the Lynx Zone. In some areas of the deposit, there are possibly multiple sulphide lenses that are separated by 4 to 8 meters of either barren or weakly mineralized argillite or rhyolite. These multiple lenses may represent distinct exhalative horizons (Tucker et al., 1999) or may be a result of structural repetition due to folding or faulting; noting that low angle thrusts recently identified in the underground workings of the Advanced Exploration program lend support for possible fault repetitions; however, additional examination is needed to be conclusive. True widths of the sulphide mineralization that have been contoured and presented in Figure 2.3-7 represent a combination of massive stratiform mineralization; which includes multiple lenses, massive replacement type mineralization, and stringer type mineralization where well developed (Tucker et al., 1999).

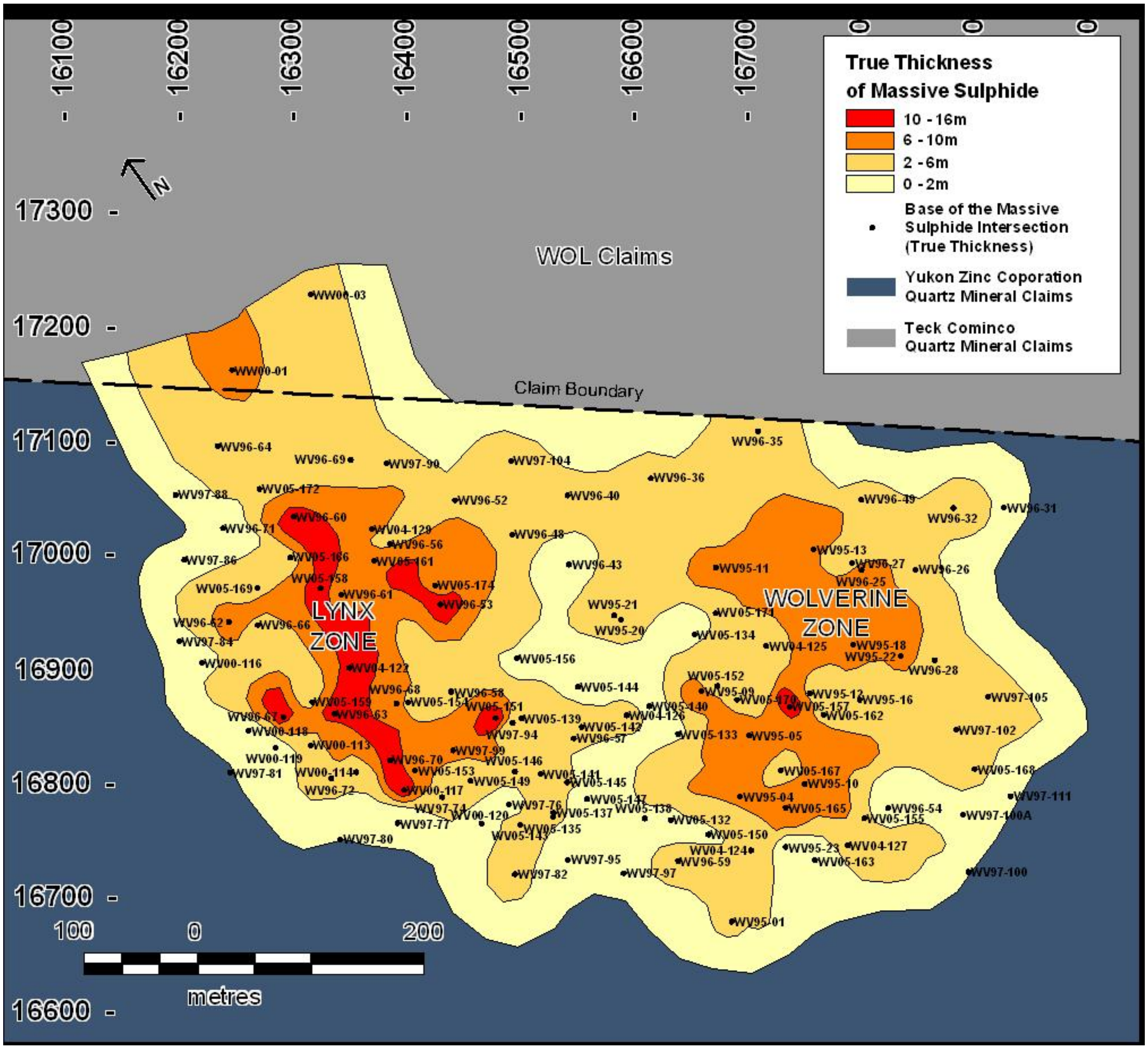


Figure 2.3-7 Isopach Contour Plot of Massive Sulphide Thicknesses

The replacement mineralization tends to occurs dominantly in the Saddle Zone, as well as within the immediate footwall to both the Wolverine and Lynx Zones where there is strong chlorite and/or carbonate alteration in both the hanging wall and footwall rocks. The stringer-style mineralization is dominantly associated with the replacement mineralization in the Saddle Zone and in the immediate footwall to the thickest stratiform and semi-massive replacement sulphide mineralization in the Wolverine Zone (Tucker et al., 1999).

Tucker et al. (1999) also noted that the replacement zones are areas where sulphide minerals have replaced the porosity and permeability of the host rocks. This replacement results in fine grained, massive sulphide mineralization that ranges in thickness from several centimeters to approximately one metre. In most instances, sphalerite is the most common replacement sulphide mineral, and occurs either as massive beds or as irregular blebs and disseminations with lesser pyrite. Semi-massive pyrite and sphalerite replacement mineralization hosted by chlorite and carbonate altered rhyolite and/or argillite in the Saddle Zone can reach up to 13 m in thickness. There is also known to occur semi-massive pyrite and sphalerite mineralization in the footwall to the stratiform massive sulphide in the Wolverine Zone that ranges from 6 to 8 meters in thickness. Locally, chalcopyrite forms small massive replacement zones in the immediate footwall to the massive stratiform sulphide mineralization; noting that chalcopyrite replacement zones have well defined upper and lower boundaries and are on the order of 30 cm thick with 60 to 80% chalcopyrite and minor pyrrhotite, and are associated with intense and pervasive chlorite alteration.

Well developed stringer zones are present locally and are confined to relatively small specific areas which are interpreted to relate to upflow of hydrothermal fluids and associated with silicification of the host rock. Where well developed, stringer zones consist of 5-10%, 3-5 mm wide, randomly oriented veins containing quartz, pyrite, and sphalerite, with an alteration halo of silicified rock. Weakly developed stringer zones occur over a much wider area and have sparse quartz-sulphide veins which are typically 5 m to 1 cm wide with no associated alteration halo. Well developed stringer Zones in the Wolverine Zone range in thickness from 1 to 4 meters, while sparse, smaller quartz chalcopyrite stringer veins can extend as many as 10 m down into the chlorite altered footwall.

Sulphide textures

Stratiform sulphide lenses are generally uniformly fine grained and homogeneous, although a delicate bedding is commonly preserved. Pyrite is the principal sulphide mineral throughout the deposit and typically occurs as massive very fine anhedral grains, but also commonly occurs as coarser well formed crystals (termed “buckshot” pyrite) set in a fine matrix of pyrite or sphalerite. Framboidal pyrite is present within the massive sulphide lenses, but is rare. Abundant fine grained sphalerite forms delicate, wispy sub millimeter to centimeter scale layers and is largely responsible for the bedded appearance of the massive sulphide mineralization. Sphalerite also commonly occurs as very fine grains interstitial to massive pyrite (Jambor, 1996).

The minerals galena, tetrahedrite-tennantite, and arsenopyrite are common, though difficult to distinguish from one another, and typically occur together as fine aggregates of anhedral grains within the sphalerite rich layers. Tetrahedrite-tennantite can also occur as very fine grains interstitial to and forming a matrix for pyrite, though this is only rarely observed in drill core due to the fine grained nature of the mineralization. Chalcopyrite is rare within the stratiform sulphide lenses, occurring almost exclusively as remobilized medium grained masses on the edges of large blebs of quartz or calcite gangue (Jambor, 1996).

Locally in the Lynx Zone are breccia textures that occur on both upper margin of the massive sulphide lens and within the massive sulphide lens. Breccia facies include:

1. a matrix supported breccia with 20-30%, rounded 3-5 mm diameter clasts of fine-grained pyrite within a matrix of similarly fine grained pyrite
2. a clast-supported, jigsaw breccia with very little matrix and angular clasts of pyrite and sphalerite from 1 cm to several cm in diameter

These breccias are interpreted as primary features associated with the precipitation of sulphides on the seafloor (Tucker et al., 1999)

2.3.4.5 Hydrothermal Alteration

Tucker et al. (1999) noted that there are four main styles of hydrothermal alteration associated with the VMS sulphide system that formed the Wolverine deposit that occurs principally in the footwall rocks adjacent to the massive sulphide mineralization. The presence of the hydrothermal alteration beneath the massive sulphide mineralization signifies where the both structurally controlled and primary permeability and porosity of the footwall rock has been exploited by hydrothermal fluid passage. The alteration types in order of decreasing abundance are:

1. sericitization
2. chloritization
3. silicification
4. carbonatization

Sericitization is typically evident as constrained to the footwall rocks that underlie the massive sulphide mineralization and is typically moderate to strongly pervasive in intensity. Sericite altered sedimentary and volcaniclastic rocks are always intensely foliated and extremely friable, as well as fissile. The hydrothermal alteration appears to be stratabound and typically found peripheral to chlorization; however, it is important to note that sericitization is the most widely distributed alteration facies reaching a thickness of approximately 50 m locally. Tucker et al. (1999) noted that sericite alteration is locally observed in hangingwall rocks, especially on the eastern fringe of the deposit.

Chloritization is commonly quartz or feldspar crystals set in a dark green chlorite matrix that is dominantly in felsic volcaniclastic rocks with and without intercalated argillite. Tucker et al. (1999) has noted that chloritization is best developed in the Wolverine Zone and is much less widespread than sericite alteration; however, spatially, chlorite alteration is very closely associated with sulphide mineralization. Within the chlorite alteration, massive replacement type mineralization is much more common than stringer-style mineralization. In most localities where chlorite alteration is present, there is a gradual transition in alteration types from chlorite-dominant to sericite-dominant further from the massive sulphide (and presumably heat and fluid flow).

Silicification is characterized by the presence of quartz–sulphide (pyrite > sphalerite >> chalcopyrite) veins (more related to silica precipitation) and associated intense, pervasive silicification of the rocks immediately beneath the massive sulphide. Carbonate alteration is characterized by the formation of a carbonate assemblage that consists of varying degrees of white calcite, orange-brown ankerite, and brown siderite, in the fine to coarse grained felsic volcaniclastic lithology which in most places is the immediate footwall to the massive sulphide. The distribution of this alteration type is erratic and poorly understood (Tucker et al., 1999