CHAPTER 1: INTRODUCTION

1.1 Introduction
The Fenton Creek and Harmin zones are two polymetallic Zn-Cu/Cu-Zn massive sulphide deposits, which occur southeast of the Snow Lake volcanic hosted massive sulphide (VHMS) district, located in the province of Manitoba, Canada (Fig. 1.1). The two zones were discovered during the winter of 1998, following a multi-discipline exploration program of airborne (Spectrem)/ground geophysics and an extensive diamond drilling conducted by Hudson Bay Exploration And Development Company Limited (HBED) (Gilmore et al., 1999). The two zones are multi-lensed bodies, considered to be hosted within metamorphosed volcanics and/or sediments, which are overlain by approximately 30 meters of Palaeozoic limestone and dolomite and 20 meters of muskeg. Diamond drilling of the two zones has defined a combined geologic resource of 5,296,805 Mt @ 4.67% Zn, 1.5% Cu, 21.95g/t Ag and 0.17 g/t Au (Gilmore et al., 1999).

1.2 Location, Access and Physiography
The Fenton Creek zone is located 70 kilometres southeast of the townsite of Snow Lake, Manitoba and 25 kilometres east-southeast of Hargrave Lake at UTM coordinates 477170E, 6028080N (UTM Zone 14) (Fig. 1.2). The Harmin zone is located 3 kilometres east-southeast of Fenton Creek zone at UTM coordinates 479990E, 6029365N (UTM Zone 14).

Various forms of access are available into the property. During the winter and early spring months, freezing temperatures favour road access from the town of Snow Lake. Road access is via Provincial Highway #39 to Ponton, then 30 kilometres south along Provincial Highway #6, then 16 kilometres west down a winter bush road to the site. During summer and fall seasons access is generally restricted to air-supported travel due to wet ground conditions. Helicopter access can be made from Snow Lake located approximately 70 kilometres to the northwest of the properties (Gilmore et al., 1999) (Fig. 1.2).
Physiography in the vicinity of the Fenton and Harmin regions consists of relatively flat low-lying areas of muskeg. The region is drained by the small east flowing Fenton and Husyk Creeks. Vegetation consists of spruce and pine trees, small shrubs, buck brush, grasses and mosses (Fig. 1.3). Summer temperatures average 20°C while winter temperatures often hover around -20 to -40°C. Wild life includes deer, black bears and numerous small furry creatures.
Figure 1.2 - Location map of the Fenton and Harmin zones in relation to the major Zn/Cu deposits of the Flin Flon/Snow Lake VHMS District, Manitoba, Canada (created from data compiled by Natmap Shield Margin Project Working Group, 1998)
1.3 Exploration History

Regionally prospecting and mineral exploration within the Flin Flon and Snow Lake districts dates back to the beginning of the 20th century. The first discoveries made were lode gold deposits near Snow Lake, however, polymetallic VHMS style mineralisation was not found until 1915 with the discovery of the Mandy Mine, which was later put into production in 1917 (Richardson and Ostry, 1987). The largest deposit to be found to date is the Flin Flon deposit consisting of 62.92 million tonnes grading 2.2% Cu, 4.1% Zn and 2.2g/t gold and was found in 1915, but was not put into production until 1930 due to metallurgical problems (Galley et al., 1991).

The first VHMS deposit to be found in the Snow Lake district was the Chisel Lake deposit in 1960 and consisted of 7.29 million tonnes grading 0.5% Cu and 10.9% Zn (Galley et al., 1991). This discovery was followed by further finds from 1962-1985 including the Rod No.1, Stall Lake, Osborne Lake, Anderson Lake, Ghost Lake Cu-Zn-Au-Ag deposits (Galley et al., 1991) (See Table 1.1 for complete details).

The region in which the Harmin and Fenton zones are located has seen little exploration due to the extensive Palaeozoic dolomite that covers the Archean metavolcanics and metasediments. Exploration programs have relied heavily on electromagnetic/magnetic surveys to try and penetrate the cover rocks.
Table 1.1 - Historical tonnages, grades and production dates for VHMS deposits of the Snow Lake District (modified after Galley et al., 1991)

<table>
<thead>
<tr>
<th>DEPOSIT</th>
<th>PRODUCTION COMENCEMENT DATE</th>
<th>COMMODITIES</th>
<th>PRODUCTION [P] + RESERVES [R] (x 1000's tonnes)</th>
<th>AVERAGE GRADES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisel Lake</td>
<td>1960</td>
<td>Zn,Pb,Cu,Au,Ag</td>
<td>7,490 (P+R)</td>
<td>0.5% Cu, 10.9% Zn</td>
</tr>
<tr>
<td>Stall Lake</td>
<td>1964</td>
<td>Cu,Zn,Au,Ag</td>
<td>6,513 (P+R)</td>
<td>4.4% Cu, 0.5% Zn</td>
</tr>
<tr>
<td>Anderson Lake</td>
<td>1970</td>
<td>Cu,Zn,Au,Ag</td>
<td>3,354 (P+R)</td>
<td>3.4% Cu, 0.1% Zn</td>
</tr>
<tr>
<td>Spruce Point</td>
<td>1982</td>
<td>Cu,Zn,Au,Ag</td>
<td>1,763 (P+R)</td>
<td>2.7% Cu, 4.3% Zn</td>
</tr>
<tr>
<td>Rod No.2</td>
<td>1984</td>
<td>Cu,Zn,Au,Ag</td>
<td>688 (P+R)</td>
<td>7.2% Cu, 3.0% Zn</td>
</tr>
<tr>
<td>Chisel North</td>
<td>2001</td>
<td>Zn,Cu,Au,Ag</td>
<td>2,457 (R)</td>
<td>0.3% Cu, 9.7% Zn</td>
</tr>
<tr>
<td>Ghost Lake</td>
<td>1972</td>
<td>Zn,Pb,Cu,Au</td>
<td>646 (P+R)</td>
<td>1.3% Cu, 8.5% Zn</td>
</tr>
<tr>
<td>Osborne Lake</td>
<td>1968</td>
<td>Cu,Zn,Au,Ag</td>
<td>3,380 (P+R)</td>
<td>3.1% Cu, 1.5% Zn</td>
</tr>
<tr>
<td>Dickstone</td>
<td>1970</td>
<td>Cu,Zn,Au,Ag</td>
<td>1,083 (P+R)</td>
<td>2.4% Cu, 3.4% Zn</td>
</tr>
<tr>
<td>Rod No.1</td>
<td>1962</td>
<td>Cu,Zn</td>
<td>23 (P)</td>
<td>5.0% Cu, 4.5% Zn</td>
</tr>
<tr>
<td>Silvia Zone</td>
<td>1985</td>
<td>Cu,Zn</td>
<td>907 (P)</td>
<td>2.4% Cu, 0.8% Zn</td>
</tr>
</tbody>
</table>

In 1996 Hudson Bay Exploration and Development Company Limited (HBED) targeted the Hargrave Lake region as having potentially favourable metavolcanic and metasedimentary rocks under the Palaeozoic sedimentary cover rocks, which are known to host VHMS style Cu/Zn mineralisation in areas to the north. A 2500 square kilometre SPECTREM EM/MAG airborne geophysical survey was flown over the area, which located numerous EM conductors and magnetic anomalies (Gilmore et al., 1999).

In 1997 exploration Permit #155 was acquired by HBED to cover anomalies located with the geophysical survey. Following the acquisition of the exploration permit, ground EM and magnetic geophysical surveys were conducted to refine airborne anomalies and initial diamond drilling was completed on some grids (Gilmore et al., 1999).

In 1998 helicopter drilling on one of the EM targets discovered the Fenton Creek zone. Further helicopter supported drilling was completed in September and October of that year prior to the reduction of Permit #155 and the subsequent staking of the first claims over the Fenton Creek zone (Gilmore et al., 1999).

In 1999 winter road access and drilling located the Harmin zone 3 km to the northwest of the Fenton Creek zone. Continued effort in this area also discovered two other unnamed zones of mineralisation, located 1.4km east-southeast of the Harmin zone and 1 kilometre south along strike of the Harmin zone (Gilmore et al., 1999)
1.4 Previous and Current Work

Previous work completed on the Fenton Creek zones include airborne, ground and borehole geophysics, diamond hole drilling and interpretation, geochemical assaying, whole rock geochemical analysis (Gilmore et al., 1999). The type and amount of work type has been tabulated and is shown in Table 1.2.

In addition to the physical work one in house report compiled by Gilmore (1999) covers the geology, geophysics and geochemistry of the Fenton and Harmin zones. In October of 1998 Dr. J.F. Harris of Vancouver Petrographics Ltd. completed a petrographical report on 5 samples taken from the Fenton zone. In May of 2000 Mr. R.C Wells a (P.Geo, FGAC, Consulting Geologist) for Kamloops Geological Services completed a petrographic, lithogeochemical, and interpretive report using 31 polished thin sections, geological logs and geochemical analyses.

Table 1.2 - Summary of work completed on the Fenton Creek zones (Gilmore et al. 1999)

<table>
<thead>
<tr>
<th>WORK TYPE</th>
<th>DATE</th>
<th># OF HOLES/GRID</th>
<th>METERAGE/NO. SAMPLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground EM/MAG Survey</td>
<td>1997/98</td>
<td>Grid Har 30</td>
<td>24,499m</td>
</tr>
<tr>
<td>Diamond Drilling</td>
<td>1998/99/00</td>
<td>17</td>
<td>5,904.5m</td>
</tr>
<tr>
<td>Borehole Pulse Surveying</td>
<td>1998/99/00</td>
<td>17</td>
<td>5,904.5m</td>
</tr>
<tr>
<td>Wholerock Geochemical Samples</td>
<td>1998/99/00</td>
<td>17</td>
<td>313</td>
</tr>
<tr>
<td>Assay Samples</td>
<td>1998/99/00</td>
<td>17</td>
<td>716</td>
</tr>
</tbody>
</table>

1.5 Geological Resource

Drilling of the Fenton Creek and Harmin zones has defined an estimated geological resource as seen in the Table 1.3. The resource listed was calculated using the polygonal method, measured specific gravity for each intersection and did not include the effects of dilution or recovery analysis (Gilmore et al., 1999).
Table 1.3 - Preliminary ore resource estimates for the Fenton and Harmin Creek zones (from internal company report Gilmore K.H. et al. 1999)

<table>
<thead>
<tr>
<th>Zone Name</th>
<th>tonnes</th>
<th>Au (g/t)</th>
<th>Ag (g/t)</th>
<th>Cu (%)</th>
<th>Zn (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fenton Creek Zone</td>
<td>2,329,889</td>
<td>0.09</td>
<td>20.42</td>
<td>0.56</td>
<td>7.44</td>
</tr>
<tr>
<td>Harmin Zone</td>
<td>2,966,916</td>
<td>0.23</td>
<td>23.16</td>
<td>2.23</td>
<td>2.49</td>
</tr>
<tr>
<td>Total</td>
<td>5,296,805</td>
<td>0.17</td>
<td>21.95</td>
<td>1.5</td>
<td>4.67</td>
</tr>
</tbody>
</table>

1.6 Aim and Scope of this Study

The Fenton Creek and Harmin zones represent two new VHMS discoveries located south of the Snow Lake VHMS districts below substantial thicknesses of Palaeozoic cover rocks. The discovery of these zones may indicate a new mineral district or the southerly extension of the existing Snow Lake belt. Due to a lack of appropriate representative samples in the Harmin zone; this study will focus exclusively on the data and samples collected from the Zn-rich Fenton Creek zone.

The aim of this study is to use existing data which includes drill logs, geophysical surveys, contractors reports, assay and wholerock analyses, in conjunction with samples collected by the author, in order to:

1) Describe and characterize lithologies of footwall and hanging wall host rocks of the Fenton Creek zone.
2) Describe alteration mineralogy, distribution and lithogeochemistry of the Fenton Creek deposit.
3) Describe the ore petrography and metal zonation from the Fenton Creek zone.
4) Generate geological model for the region that may help relate these new zones to two existing deposits in the area.

To satisfy these aims the author has completed the following:

1) Collected 106 representative samples from diamond drillholes Har010, Har018, Har021, Har043 and Har044.
2) Created an access database containing the samples used in this study.
3) Described and interpreted 45 polished thin sections some of which were used to characterise the geology of the sampled drillholes.
4) Reinterpreted existing geologic logs and sections using lithogeochemical results.
5) Compiled all available wholerock, and ICP-MS data for the Fenton Creek drillholes, generated various geochemical discrimination plots and created geological/geochemical downhole plot for ddh Har043.

6) Compiled HBED assay data for Fenton Creek and generated various grided/contour maps for Cu, Zn, Pb, Au, Ag & As.

7) Sampled, prepared and interpreted the results of carbon isotope analyses for 3 samples from the graphitic rocks collected along section 400N.
2.1 Introduction
The Flin Flon Belt is a 380km long east-west trending package of Paleoproterozoic volcanic arc rocks hosted within the 500km wide northeast-southwest trending Trans Hudson Orogen. Since the first discovery of copper and zinc in the region, the Flin Flon Belt has been the topic of much study. Recently there has been renewed interest in the region following the public release of the NATMAP Shield Margin Project GSC Open File D3884 and accompanying memoirs/reports. This multi-disciplined project has compiled, and where necessary re-interpreted, much of the geology of the Flin Flon and Snow Lake region. As a result of this study the Flin Flon Belt has been divided into the three following assemblages (1.) Glennie Complex (2.) Flin Flon Assemblage (3.) Snow Lake Assemblage, the latter being of most significance to this study. This chapter reviews the general tectonic setting, regional geology, alteration, metamorphism and metallogeny of the Snow Lake Assemblage located at the eastern end of the greater Flin Flon Belt with the aim of providing a regional framework into which the newly discovered Fenton Creek zones might fit.

2.2 Tectonic Setting
The Snow Lake area is located at the eastern end of the Flin Flon Belt, a 380km long east-west trending package of arc volcanics located in the juvenile Internal Reindeer Zone of the Trans Hudson Orogen (THO) (Hoffman, 1988). The THO is a 500km wide northeast-southwest trending zone of collision between the Superior and Slave cratons of central Canada (Fig. 2.1). The Orogen is comprised of four major lithotectonic zones (Hoffman, 1988; Galley et al., 1991; Lucas et al., 1999): (1) The Superior Boundary zone is a package of Proterozoic clastic-carbonate shelf sequences overlying the edge of an older Archaean craton of the Superior Province and intruded by mafic-ultra mafic intrusions thought to be related to the nickel deposits of the Thompson nickel Belt. (2) The Internal Zone (otherwise known as the 'Reindeer Zone') is a collection of Paleoproterozoic arc and oceanic volcanic rocks, plutons and younger molasse and turbiditic sedimentary rocks that contain numerous polymetallic
Figure 2.1 Tectonic Domains

The Trans-Hudson Orogen is a 500km wide Northeast-Southwest trending zone of collision between the Superior and Slave cratons of Central Canada.

Cu-Zn volcanic hosted massive sulphide (VHMS) deposits of the Flin Flon and Snow Lake assemblages. (3) An Andean-type Magmatic Arc known as the Wathaman-Chipewyan Batholith which is the result of northwest directed subduction of the Reindeer Zone. (4) Hinterland Zone, a package of Proterozoic clastic-carbonate shelf sequences referred to as the Wollaston and Hearne/Rae Province.

The earliest event recording the evolution of the THO is thought to be the deposition of clastic-carbonate shelf sequences along the boundaries of the Archean Superior and Hearne cratons pre-1.9 Ga. (Lewry and Sibbald, 1980; Bleeker and Macek, 1988a). This event was closely followed by deposition of clastic sedimentary sequences and
igneous intrusions, including the mafic-ultramafic intrusion related to the Thompson nickel deposits along the margin of the Superior Province and the formation of a foredeep (Hoffman, 1988).

The formation of the Internal juvenile Proterozoic crust (Reindeer Zone) followed the sedimentation along the cratonic boundaries, commencing approximately 1.9 Ga (Hoffman, 1988). During this event island-arc volcanism dominated, with the formation of the Lyn Lake Belt at 1.91 Ga (Baldwin et al., 1987), followed by the Flin Flon and La Ronge belts at 1.89 Ga (Van et al., 1987; Gordon et al., 1990) and concluding sometime between 1.88-1.77 Ga with the formation of the Rusty Lake Belt and subsequent deposition of volcaniclastic sediments within interarc basins (Galley et al., 1991).

During the next stage of development in the THO, the same subduction related to the formation of the juvenile volcanism continued northwest which resulted in the emplacement of Andean-type calc-alkaline granodiorite-granite intrusions of the Wathaman-Chipewyan batholith (Hoffman, 1988). During and following this intrusion phase the island arc assemblages were uplifted and deformed by isoclinal folds (F1) followed shortly after by erosion and continental molasses sedimentation infilling the inter-arc Kisseynew basin (Hoffman, 1988).

Following emplacement of the Wathaman-Chipewyan batholith the juvenile accreted terranes recorded south verging thrust-nappe deformation (F2), while the region then underwent a metamorphic event in which the P-T condition reached 750°C at 5.5 Kbars within the Kisseynew Belt (Gordon et al., 1987). The finals stages of development of the THO saw peak metamorphic conditions recorded at 1815 Ma coincident with the formation of NE-trending doubly plunging folds (F3). This event was followed by formation of NE-trending ductile fault systems and late brittle-ductile deformation along pre-existing fault zones post 1.77 Ga (Galley et al., 1991). The Proterozoic tectonic events (Table 2.1) within the Trans Hudson Orogen have been well summarized by Galley (1991).

2.3 Geologic Setting of the Snow Lake Arc Assemblage

Historically the Flin Flon Belt has been divided into two stratigraphic groups, namely the Amisk Group that consist of arc volcanics and the Missi Group that consist of continental sedimentary rocks (Bruce, 1915; Harrison, 1951). Recent reinterpretation and new work by researchers completing the EXTECH I and NATMAP Shield Margin programs have redefined much of the understanding of the Flin Flon Belt. Based on geological, temporal
Table 2.1 - Early Proterozoic tectonic events within the Trans-Hudson Orogen (modified after Galley et al., 1991)

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>ANDEAN MAGMATIC ARC</th>
<th>HINTERLAND</th>
<th>'HEARNE PROVINCE'</th>
<th>'WA THAMAN-CHIPPEWA YN'</th>
<th>'REINDEER ZONE'</th>
<th>FORELAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 1.9Ga</td>
<td>Shear deformation along margin of craton</td>
<td>Shelf sedimentation along margin of craton</td>
<td>Fold-thrust deformation of early Precambrian shelf margin with underlying Archean basement</td>
<td>NNE-verging nappes, infold with underlying Archean basement</td>
<td>NNW-verging nappes, infold with underlying Archean basement</td>
<td>NNE-verging nappes, infold with underlying Archean basement</td>
</tr>
<tr>
<td>1.9 to 1.88Ga</td>
<td>Shear deformation along margin of craton</td>
<td>Shelf sedimentation along margin of craton</td>
<td>Fold-thrust deformation of early Precambrian shelf margin with underlying Archean basement</td>
<td>NNE-verging nappes, infold with underlying Archean basement</td>
<td>NNW-verging nappes, infold with underlying Archean basement</td>
<td>NNE-verging nappes, infold with underlying Archean basement</td>
</tr>
<tr>
<td>1.88 to 1.77 Ga</td>
<td>Thickening and stabilization of cratonic margin, intrusion of Bulldon dyke swarm and related Fox River sill.</td>
<td>Thickening and stabilization of cratonic margin, intrusion of Bulldon dyke swarm and related Fox River sill.</td>
<td>Thickening and stabilization of cratonic margin, intrusion of Bulldon dyke swarm and related Fox River sill.</td>
<td>Thickening and stabilization of cratonic margin, intrusion of Bulldon dyke swarm and related Fox River sill.</td>
<td>Thickening and stabilization of cratonic margin, intrusion of Bulldon dyke swarm and related Fox River sill.</td>
<td>Thickening and stabilization of cratonic margin, intrusion of Bulldon dyke swarm and related Fox River sill.</td>
</tr>
</tbody>
</table>
and structural differences the volcanic arcs of the Flin Flon Belt can be divided into the three following assemblages, the Glennie Complex located east of town of Flin Flon, the Flin Flon Assemblage centred around Flin Flon and the Snow Lake Assemblage near the town of Snow Lake (Fig. 2.2). Due to the limited scope of this study, the geology of the Glennie Complex and the Flin Flon Assemblages will not be covered in any amount of detail. For information regarding these assemblages the author recommends (Bailes and Galley, 1999) who give good interpretations and detailed descriptions of the rock units in these assemblages.

Figure 2.2 Tectonic domains of the Trans-Hudson Orogen including the location of the Fenton/Harmin zones in relation to the Flin Flon and Snow Lake VHMS districts of the Flin Flon Belt (modified after Galley et. al, 1991)
The geology of the Snow Lake region is dominated by the Snow Lake Assemblage (formerly defined as the Amisk Group), subordinate amounts of Missi Group and Palaeozoic Internal Platform carbonates.

### 2.3.1 Snow Lake Assemblage

The Snow Lake Assemblage is a 20km wide, 6km thick, fault bounded, northeast dipping allochthonous volcanic arc that is host to numerous Cu-Zn and Zn-Cu VHMS deposits. Recently the Snow Lake Assemblage as defined by Bailes and Galley (1999), consists of 3 geochemically, and morphologically distinct groups: primitive arc, mature arc and arc rift rock sequences. It is believed that these groups represent progressive stages in arc development from primitive, to mature to incipient rifting (Fig. 2.3, 2.4a and 2.4b).

**Figure 2.3** - Schematic stratigraphic section showing the setting of the major base-metal rich sulphide deposits of the Snow Lake assemblage (modified after Bailes, 1999)
Figure 2.4a - Geology map of the Snow Lake Assemblage showing location of major base-metal sulphide deposits (created from data compiled by Natmap Shield Margin Project Working Group, 1998)
Chapter 2 - Regional Geology

LEGEND

**Major Mineral Deposits**
- Cu, Zn, Ag, Au
- Zn, Cu, Ag, Au

**Faults**

**Burntwood Group**
- Greywacke, mudstone, siltstone
- P - Parisian formation

**Intrusive Rocks**
- Gabbro, diorite, diabase
- Felsic Plutons
- Synvolcanic tonalite

**Mississ Group**
- Sandstone, siltstone, mudstone and derived gneiss

**Snow Lake Assemblage**
- Felsic volcanic rocks
- L - Lower mine felsic
- S - Stroud Lake felsic breccia
- Rhyolite
  - A - Anderson
  - G - Ghost/Photo
  - D - Daly
  - S - Sneath
  - K - Konzie
  - C - Choei
- Powderhouse dacite
- Mafic volcanoclastic
  - Th - Threelakehouse
  - C - Choei
  - Sn - Sneath Lake
- More Lake Fe-basalt
- Porphyritic basalt
  - Sn - Sneath Lake
  - T - Threehouse
- Bonite
- Aphyric basalt
  - W - Welch Lake
  - SN - Snow Lake
- Amphibolite

Figure 2.4b - Legend for geology map of Snow Lake Assemblage (created from data compiled by Natmap Shield Margin Project Working Group, 1998)

**Primitive Arc**

The primitive arc group is the lowest in the section and is characterised by a thick sequence (> 3km) of pillowed aphyric to sparsely porphyritic basalt, basaltic andesite, andesite flows (Welch Lake basalt) and an associated unnamed high Ca-bonite (Galley et al., 1991). Within these basalts are a series of aphyric to sparsely quartz phyric rhyolitic domes (Daly Lake, Sneath Lake, Konzie and Anderson Lake rhyolite), which are closely associated with the polymetallic massive sulphide deposits (Galley et al., 1991). The entire sequence is then intruded the Sneath Lake syn-volcanic tonalite intrusion. To date a total of 8 significant Cu-Zn and Zn-Cu deposits have been identified within the primitive arc group.

**Mature Arc**

The mature arc group is characterised by a 2-3km thick variable suite of volcanic rocks (Galley et al., 1991; Bailes and Galley, 1999). The lowest portion of the group consists of thick-bedded felsic breccias (Stroud Lake felsic breccia 1892 +/- 3Ma (David et al., 1996). This is followed by sub-aqueously deposited felsic and heterolithic mafic breccia (Snell Lake and Edwards Lake). Overlying these units are mafic to felsic volcanic flows
(Moore Fe-basalts & Powderhouse dacites). On top of the Powderhouse dacite and forming the Chisel basin are the Photo, Ghost and Chisel rhyolitic domes that are also the footwall to the Chisel, Lost and Ghost Zn-Cu and the Photo Lake Cu-Zn VHMS deposits. The hanging wall to these deposits is comprised of mafic tuff, lapilli tuff, tuff breccia and related porphyritic basalt flows (Chisel basin mafic tuff & Threehouse basalt). Forming the upper most sequence to the mature arc group are the Threehouse mafic volcanioclastics and unnamed felsic breccia. To date a total of 4 significant Cu-Zn and Zn-Cu deposits have been identified within the mature arc group.

**Arc Rift**

The Arc rift group consists of a <1 km thickness of aphyric basalts of the Snow Creek formation. This formation is truncated by the Snow Lake fault, which is then overlain by the File Lake formation a volcanioclastic metagreywacke and mudstone turbidite unit that has been interpreted by Bailes (1980) to be part of a submarine dispersal system from eroded felsic volcanic detritus from the Flin Fion Belt volcanoes.

**Intrusive Complexes**

Two main subvolcanic intrusive complexes have been identified in the Snow Lake Assemblage (Figs. 2.3 & 2.4a). The Sneath Lake tonalite consists of a semi-conformable, broadly folded body, 1.5 km wide and over 14 km long (Galley et al., 1991). U/Pb zircon dating indicates that the Sneath Lake intrusion is 1886 ±17/-9 Ma (David et al., 1996), and is interpreted to be the associated heat source responsible for the formation of the massive sulphide deposits in the primitive arc setting (Walford and Franklin, 1982; Bailes, 1986).

The Richard Lake tonalite is a smaller intrusive complex measuring 1.7 km x 7.3 km and has been recorded cross cutting 3 km of mature arc stratigraphy including a series of hydrothermal alteration zones (Galley et al., 1991). U/Pb zircon dating indicates that the Richard Lake intrusion is 1889 ±8/-6 Ma (David et al., 1996), indicating that it is a synvolcanic intrusion, however, it’s relationship to the massive sulphide deposits in the mature arc setting is unclear.

**2.3.2 Missi Group**

The Missi Group is a sequence of metamorphosed lithic arenites, (Froese and Moore, 1980) conglomerates, cross-bedded fluvialite sandstones and minor volcanic rocks.
Missi volcanic rocks are not present near Snow Lake but form a substantial part of the Missi Group east of Wekusko Lake (Galley, 1991 #91). Gordon (1990) estimates the U-Pb zircon age to be 1832 +/-2 Ma, which is approximately 60 Ma younger than the volcanics of the Snow Lake Assemblage (Galley et al., 1991).

2.3.3 Palaeozoic Interior Platform

The rocks of the Interior Platform consist of a package of carbonates including limestone and dolomite that cover only the southern portions of the Flin Flon Belt including the Missi group and the Snow Lake Assemblage. The unit varies in thickness and outcrop from a couple of metres to >300m from north to south and is a significant barrier to exploration of the volcanic arc sequences of the Flin Flon belt.

2.4 Structure and Metamorphism

The Snow Lake Assemblage is characterised by fold-thrust style tectonics, which is thought to have occurred from 1.84 - 1.81 Ga (Connors, 1996; Kraus and Williams, 1999). To date four folding events have been recognized, over no less than 3 successive deformation periods spanning 30 Ma (Kraus and Williams, 1999).

The folding events, based on kinematic indicators include: F1 and F2 events - isoclinal folds and low-angle shear zones, F3 - NNE trending open to tight folds (eg. Threehouse synform) and F4 - local west-northwest and east-southeast trending folds. These events have been summarized in Table 2.2.

Metamorphism within the Snow Lake Assemblage was first characterised by Froese and Gasparini (1975), who divided Snow Lake region into four metamorphic zones based of metamorphic reactions in pelitic rocks: chlorite-biotite, chlorite-biotite-staurolite, biotite-staurolite-sillimanite and biotite-sillimanite-almandine. In general terms the metamorphic grade varies from lower greenschist facies in the south to upper (almandine) amphibolite grades in the north (Galley et al., 1991).

Recent work by Kraus and Williams (1999) has summarized the timing of the metamorphic events. Prograde metamorphism to chlorite grade is thought to have commenced between 1.840 – 1.830 Ma, during the F1 folding phase with temperatures reaching 400°C and pressures of 4 kbars (Bailes, 1985; Briggs and Foster, 1992; Kraus and Williams, 1999).

Thermal peak metamorphism in staurolite zone and lower is thought to have been coincident with second fold phase and reached peak temperatures of 550-650°C and pressures between 4-6 kbars (Froese and Moore, 1980; Kraus and Williams, 1999).
Table 2.2 - Summary of the tectono-metamorphic history of the Snow Lake Allochton (modified after Kraus and Williams, 1999)

<table>
<thead>
<tr>
<th>Deformation</th>
<th>Structures</th>
<th>Magmatic Events</th>
<th>Metamorphism</th>
<th>Age (Ga)</th>
<th>Tectonic setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 &amp; D2</td>
<td>Isoclinal folds and low-angle shear zones, S1 parallel to primary layering</td>
<td>Calc-alkaline granitoid suite; Missi volcanic suite</td>
<td>Prograde metamorphism: Chlorite grade, $T&lt;400^\circ$C, $P=4$ kbars</td>
<td>1.840 - 1.830</td>
<td>Overthrusting of Kisseynew Domain over Snow Lake Allocation during N-S convergence; crustal thickening: 12-15 km</td>
</tr>
<tr>
<td>D3 (Hudsonian orogeny)</td>
<td>Isoclinal curvilinear folds; regional S2; low-angle shear zones and reactivation of F1 shear zones</td>
<td>Calc-alkaline granitoid suite; Missi volcanic suite</td>
<td>Prograde metamorphism: Chlorite grade, $T&lt;400^\circ$C, $P=4$ kbars</td>
<td>1.840 - 1.830</td>
<td>Overthrusting of Kisseynew Domain over Snow Lake Allocation during N-S convergence; crustal thickening: 12-15 km</td>
</tr>
<tr>
<td>D4</td>
<td>NNE-trending open to tight folds (Threehouse synform); crenulations of S2</td>
<td>Calc-alkaline granitoid suite; Missi volcanic suite</td>
<td>Thermal peak in staurolite zone and lower: $T&lt;580^\circ$C, $P=4$-6 kbars</td>
<td>1.820 - 1.810</td>
<td>Continued N-S convergence; minor crustal thickening</td>
</tr>
<tr>
<td>D5</td>
<td>Local WNW-ESE trending folds; kink bands</td>
<td>Pegmatites in siliceous zones</td>
<td>Blocking temperatures of hornblende and biotite reached</td>
<td>1.800 - 1.765</td>
<td>Renewed N-S convergence; exhumation during orogen-parallel movements</td>
</tr>
</tbody>
</table>

Hydrothermal Activity:
- Cooling in staurolite zone; thermal peak in sillimanite zone and higher: $T=600-800^\circ$C, $P=5-6$ kbar
- E-W shortening; W-directed underthrusting of Superior plate
- Continued N-S convergence; minor crustal thickening
- Renewed N-S convergence; exhumation during orogen-parallel movements
- Ongoing exhumation

Mafic dykes and sills

Arc volcanism; synvolcanic intrusions (Sneath Lake tonalite, Herbert Lake and Squall Lake granitoids)
Thermal peak metamorphism in sillimanite zone and higher is thought to have occurred during the third fold phase and reached temperatures between 600-800°C and pressures between 5-6kbars (Kraus and Williams, 1999). For a summary see Table 2.2. As a result of the metamorphism and deformation in the Snow Lake Assemblage primary features, such as bedding, pillows, amygdales, etc., may or may not be recognizable (Galley et al., 1991). Furthermore, original textures in sulphide ores and hydrothermal alteration zones have for the most part been destroyed and/or replaced by coarser grained textures (Galley et al., 1991).

2.5 Alteration

Three different styles of alteration have been recognized in the Snow Lake Assemblage: (1.) Discordant (2.) Semi-conformable (3.) Intrusive related alteration. The discordant, semi-conformable and intrusive related alteration styles are thought to be a result of hydrothermal alteration related to volcanism and synvolcanic two-phase tonalite intrusions, which occurred during the formation of the volcanic arc sequences 1892-1896 Ma (Galley et al., 1991; Galley and Franklin, 1991; Galley, 1993; Kraus and Williams, 1999)

2.5.1 Discordant Alteration

The discordant alteration occurs as small discrete “pipe-like” zones immediately below VHMS deposits which may or may not join up with semi-conformable alteration as reported by the following investigators: Chisel Lake Zn-Cu deposit (Galley and Bailes, 1989; Bailes and Galley, 1989), the Anderson Lake Cu-Zn deposit (Walford and Franklin, 1982; Trembath, 1986), the Stall Cu—Zn deposit (Studer, 1922), the Rod Cu-Zn deposit (Coats et al., 1970) and the Linda Cu-Zn deposit (Zales, 1989). The alteration in these pipe-like zones is characterised by chloritized cores and sericitized peripheries, but also includes Fe-Mg metasomatism silicification/albitization, and minor epidotization and pyritization (Galley et al., 1991).

2.5.2 Semi-conformable Alteration

The semi-conformable alteration occurs as strata-parrallel, 300 to 700m wide by up to 12km long zones of alteration 0.5 to 3km below the base metal sulphide deposits (Bailes and Galley, 1989). This style of alteration has been divided into two main groups: (1.) zones of pervasive replacement by quartz and epidote and (2.) zones of chlorite and
amphibole replacement (Galley and Bailes, 1993). A third poorly understood type of local semi-conformable amphibole +/- sulphide alteration has been observed within immediate hangingwall to some of the VHMS deposits (Bailes and Galley, 1991). Another observation made regarding the semi-conformable alteration is that it appears to be restricted to individual formations and does not significantly effect overlying and underlying formations suggesting that hydrothermal fluid flow was conformable (Galley et al., 1991).

2.5.3 Intrusive Related Alteration
The alteration in the subvolcanic intrusions consists of zones of disseminated chalcopyrite-pyrrhotite; fracture controlled epidote-quartz-hematite, chlorite-biotite-magnetite and chlorite-aluminosilicate alteration. This style of alteration has been noted by Walford and Franklin (1982) and Bailes and Galley (1991) within the Sneath Lake Pluton as close as 200 m from the Anderson, Stall and Rod deposits.

2.6 Metallogeny
The Flin Flon belt is host to numerous VHMS deposits (Table 2.3). In total, the Flin Flon belt contains approximately 118.7 Mt of polymetallic base metal sulphide ore in 25 past and producing mines (Syme et al., 1999). The Snow Lake Assemblage located at the eastern end of the Flin Flon belt contains 7 past and producing mines totalling 20.6 Mt of polymetallic base metal sulphide ore (Syme et al., 1999). In the Snow Lake Assemblage polymetallic Zn-Cu base metal deposits have been observed at two stratigraphic levels Primitive Arc and Mature Arc, suggesting more than one mineralising event (Galley, 1999) (Fig. 2.3). This observation is supported by lead isotope research by Walford and Franklin (1982) on the Anderson-Stall-Rod Cu-Zn and Chisel-Ghost-Lost-North Chisel Zn-Cu deposits that indicate separate metal sources. In the Primitive Arc sequence the Anderson, Joannie, Linda, Pot, Stall, Rod, Raindrop deposits are associated with the Daly Lake and Anderson Lake rhyolite flows within the Welch Lake subaqueous aphyric basalts (Galley et al., 1991). In the Mature arc setting the Chisel, Ghost, Lost and Photos Lake deposits associated with the Chisel basin/Threehouse mafic tuff-lapilli tuff unit and associated Chisel and Ghost Lake rhyolite flows (Galley et al., 1991).

2.7 Summary
The Flin Flon belt is a 380 km long east-west trending package of arc volcanics and related sediments located in the juvenile Internal Reindeer Zone of the Trans Hudson
Table 2.3 - Grades, tonnages and characteristics of selected polymetallic VHMS deposits of the Flin Flon belt (modified after Galley et al., 1991)

<table>
<thead>
<tr>
<th>Table 2.3 - VHMS Deposits of the Flin Flon Belt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLIN FILON ASSEMBLAGE</strong></td>
</tr>
<tr>
<td>Deposit Name</td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td>Flin Fion</td>
</tr>
<tr>
<td>Triple 7 (Under Development)</td>
</tr>
<tr>
<td>Trout Lake</td>
</tr>
<tr>
<td>Callinan</td>
</tr>
<tr>
<td>Schist</td>
</tr>
</tbody>
</table>

<p>| <strong>SNOW LAKE ASSEMBLAGE</strong> |</p>
<table>
<thead>
<tr>
<th>Deposit Name</th>
<th>Host Rock</th>
<th>Deposition style</th>
<th>Commodity</th>
<th>Tonage/Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chisel Lake</td>
<td>Rhyolite/Mafic volcaniclastic</td>
<td>massive/stringer sulphides</td>
<td>Zn,Cu,Pb</td>
<td>7.5 Mt @ 0.5% Cu, 10.9% Zn</td>
</tr>
<tr>
<td>Chisel Lake (North)</td>
<td>Rhyolite/Mafic volcaniclastic</td>
<td>massive/stringer sulphides</td>
<td>Zn,Cu,Pb</td>
<td>2.4 Mt @ 0.3% Cu, 9% Zn</td>
</tr>
<tr>
<td>Stall Lake</td>
<td>Rhyolite</td>
<td>massive/stringer sulphides</td>
<td>Cu,Zn</td>
<td>6.5 Mt @ 4.4% Cu, 9% Zn</td>
</tr>
<tr>
<td>Anderson Lake</td>
<td>Rhyolite</td>
<td>massive/stringer sulphides</td>
<td>Cu,Zn</td>
<td>3.3 Mt @ 3.4% Cu, 0.1% Zn</td>
</tr>
<tr>
<td>Osborne Lake</td>
<td>Rhyolite</td>
<td>massive/stringer sulphides</td>
<td>Cu,Zn,Ag,Au</td>
<td>3.3 Mt @ 3.1% Cu, 1.5% Zn</td>
</tr>
</tbody>
</table>
Orogen, a 500km wide Northeast-Southwest trending zone of collision between the Superior and Slave cratons of Central Canada (Hoffman, 1988). The Flin Flon belt has been divided into the following domains/assemblages: (1.) Glennie Complex (2.) Flin Flon Assemblage (3.) Snow Lake Assemblage (Bailes and Galley, 1999). The Snow Lake Assemblage is located at the eastern end of the belt and is the nearest exposed and studied locality hosting economic massive sulphide mineralisation to the Fenton Creek zone.

The Snow Lake Assemblage is a 20km wide x 6km thick fault bounded northeast dipping allochthonous volcanic arc which has been subjected to a complex history of fold-thrust style tectonics, deformation and metamorphism ranging from lower greenschist facies in the south to upper amphibolite facies in the north (Galley et al., 1991).

The Fenton Creek zone is a newly discovered polymetallic Zn-Cu massive sulphide deposit located approximately 40km southeast of the exposed portions of the Snow Lake Assemblage under significant overburden. Recent study has divided the Snow Lake Assemblage into 3 geochemically and morphologically distinct groups including the Primitive, Mature and Rift Arc settings that describe the evolution of the arc through time (Bailes and Galley, 1999). To date only the Primitive and Mature Arc lithologies have been found to host polymetallic massive sulphide mineral deposits.

This review of the regional geology provides the necessary background and framework required to effectively investigate, characterise and hopefully classify the local geology, geochemistry and metallogeny of the newly discovered blind Fenton Creek zone.
CHAPTER 3: LOCAL GEOLOGY

3.1 Introduction

The local geology of the Fenton Creek region is largely unknown due to excessive overburden and Ordovician dolomite. The nearest well exposed and studied geology is in the Snow Lake Assemblage located some 50km to the north and is known to host numerous base metal deposits associated with metamorphosed rhyolitic flows, domes and volcanoclastics. Recent geological and magnetic mapping by the Geological Survey of Canada suggest that the geology in the Fenton Creek locality is comprised of metagreywacke from Burntwood Group which is not known to host any base metal sulphide deposits. Determination and characterisation of the geologic setting and the geology hosting the Fenton Creek zone is of great importance to firstly understand the deposit and secondly to aid in the future exploration for similar targets in the region. The main objective of this chapter is to describe and correlate the lithologies comprising the hanging wall and footwall of the Fenton Creek zone along section 400N; with an aim to standardize the geologic names used to describe the lithologies and then apply these names to the lithologies logged along section 300N & 500N thereby standardizing the geology across 3 sections. The secondary objective of this chapter is to comment on the metamorphic grade and structural geology of the Fenton Creek zone.

3.2 Methods

Interpretation of the local geology is based on regional mapping and interpretation by Geological Survey of Canada (Open File D3884), diamond drill hole logs completed by staff of Hudson Bay Exploration and Development Company Limited and representative core samples collected by the author. A total of 107 samples were collected from section 400N through the centre of the Fenton Creek Zone (Fig. 3.1). These samples were cut on a diamond saw, photographed, stained using sodium cobaltinitrite for K-feldspar, described and where possible classified using geochemistry. From the 107 specimens, 45 representative samples were made into polished thin
Figure 3.1 Plan section of drillhole traces on the Fenton Creek zone (modified after Gilmore et. al. 1999).

Figure 3.1 - Plan Section of Fenton Creek zone

- Collar location
- Collar location (Drillholes sampled for study)
- Section used in study
sections for detailed examination. The results of the examinations of hand samples and thin sections were then used by the author, in conjunction with geologic logs, to characterise the geology of the Fenton Creek zone. Complete list of samples used in this study is given in Appendix A.

3.3 Local Geology

The local geology around the Fenton Creek Zone is largely unknown due to thick amounts of overburden and Ordovician dolomite. Airborne magnetic survey's flown and interpreted by the GSC indicate that the Fenton Creek zone is hosted in rocks of the Burntwood Group metasediments located on the eastern flanks of a 20km long north-south trending plutonic intrusion of calc-alkaline composition (Fig. 3.2). No documented studies have been completed on the Burntwood Group within the Fenton Creek region due to lack of exposure and the fact that significant mineral occurrences have not been found in this unit. However, there has been some study of the Burntwood Group metagreywackes northeast of Flin Flon within the Kisseynew-Duval Lake region. From this work Jungwirth et al. (2000) determined the Burntwood Group contains massive thicknesses of alternating layers of psammitic and pelitic horizons, which they have divided into three subdivisions 1.) porphyroblastic metagreywacke 2.) porphyroblast-free metagreywacke 3.) migmatite. Petrographical studies indicate that the dominant minerals within all three subdivisions include plagioclase, quartz, biotite +/- muscovite, whilst staurolite, garnet and sillimanite are primarily found in the porphyroblastic metagreywacke (Jungwirth et al., 2000). This suite of lithologies are very similar to the rocks logged in the Fenton Creek zone, with the notable absence of post kinematic granitic intrusions and the lack of any mineralisation.

The geology of the Fenton Creek region as based on diamond drilling consists of a west dipping sequence of inferred metavolcanics and metasediments which have been crosscut by a series of post kinematic granitic sills and pegmatites. Original logging of diamond drill core by numerous company geologists subdivided the geology on the Fenton Creek Zone into many units including meta-greywacke, meta-siltstone, quartzite, calc-silicate, meta-argillite, etc. This style of logging using genetic names based on grain size, colour and tentative mineral identification proved moderately effective to delimit gross units but, failed to identify subtle changes in the rocks due to complications caused by the high metamorphic grade as well as the variation caused by numerous
people performing the geologic logging (Wells, 2000). These factors made correlation of the units from hole to hole very difficult.

In an aim to more thoroughly identify the lithologies and correlate them from hole to hole, selected samples from section 400N were collected and re-interpreted using geochemistry (Chapter 5) and non-genetic metamorphic rock names based on mineralogy. The result of this exercise has subdivided the geology of section 400N of
the Fenton Creek Zone into 10 mineralogically and/or geochemically distinct units. The units are (1.) Ordovician dolomite/sandstone/regolith (2.) garnet-sillimanite schist (3.) clinopyroxene-scapolite-carbonate schist (4.) quartz-biotite-sillimanite schist (5.) garnetiferous-graphititic metasediment (6.) clinopyroxene-biotite/amphibole-plagioclase schist (7.) amphibolite (8) ore lenses (9) quartz-muscovite-sillimanite schist (10.) granitic intrusion and pegmatite. These same divisions were then applied to section 300N and 500N so that correlations between sections could be made (Fig. 3.3, 3.4 & 3.5).

3.3.1 Dolomite, sandstone and regolith

The youngest rocks within the region are the Ordovician dolomites of the Red River and Stony Mountain Formations. The Fenton Creek Zones are located along the boundary between the two formations (Fig. 3.6). The Red River formation is dominated by buff to brown, fine to medium-crystalline fossiliferous dolomite which is generally massive, except for the top of the sequence where it grades into argillaceous dolostone with minor breccia (Fort Garry Member & Herald Formation) (Viljoen et al., 2000). The Stoney Mountain Formation is another package of dolomites immediately overlying the Red River Formation. It is very similar to the Red River formation, however it is characterised by a lack of fossils and commonly displays nodular bedding instead of the more mottled appearance of the Red River Formation (Viljoen et al., 2000). Both formations range in thickness from <55m (Red River Formation) to <35m (Stoney Mountain Formation).

The dolomites collected from section 400N of the Fenton Creek Zone consist of massive to weakly vuggy, buff to light brown, mottled fossiliferous (crinoid) dolomites (Fig. 3.7) which range in apparent thickness from 29m to +37m (Fig. 3.4). The upper contact to the unit is an eroded unconformable contact that is overlain by approximately 20m of muskeg. The lower contact is a sharp unconformity with a light brown to grey, variably consolidated-unconsolidated sandstone and regolith.

The sandstone unit varies in thickness from 0 to 5m and consist of buff to grey, variably consolidated weathered sandstone that is occasionally intercalated with minor buff clay seams. The lower contact of this unit is most often gradational with the underlying regolith and is often lost during drilling due to its friable condition. The regolith ranges in thickness from 5 to 20m and is comprised of highly weathered/altered metasediments and intrusive. The lower contact of this unit is also gradational into the coherent units below. The
Figure 3.3 Reconstruction of cross-section 300N using company geological logs and lithogeochemical control interpreted by the author (Chapter 5) (modified after data from HBED diamond drill logs and lithogeochemical data; internal company report Gilmore et al. 1999)
Chapter 3 - Local Geology

- Garnet-sillimanite schist
- Elinopyroxene-scapolite carbonate schist
- Quartz-biotite-sillimanite schist
- Garnet-graphite metasediment
- Biotite-amphibole-plagioclase schist
- Amphibole-clinopyroxene-plagioclase schist
- Ore lense
- Quartz-muscovite-sillimanite schist

Interpreted Geology

- Muskeg
- Dolomite
- Sandstone/regolith
- Granitic pegmatite
- Granitic intrusion
- Garnet-sillimanite schist
- Clinopyroxene-scapolite carbonate schist
- Quartz-biotite-sillimanite schist
- Garnet-graphite metasediment
- Garnet-amphibole-plagioclase schist
- Amphibole-clinopyroxene-plagioclase schist
- Ore lense
- Quartz-muscovite-sillimanite schist

Figure 3.4 Reconstruction of x-section 400N using company geological logs and lithogeochemical control interpreted by the author (Chapter 5) (modified after data from HBED diamond drill logs and lithogeochemical data; internal company report Gilmore et al. 1999)
Chapter 3 - Local Geology

Garnet-sillimanite schist
Cl inopyroxene-scapolite
carbonate schist
Quartz-biotite-sillimanite schist
Garnet-graphite metasediment
Biotite-amphibole-plagioclase schist
& Amphibole-clinoptyroxene
-plagioclase schist
Ore lens
Quartzite

Interpreted Geology
- Muskeg
- Dolomite
- Sandstone/regolith
- Granitic pegmatite
- Granitic intrusion
- Fault
- Gneiss
- Alteration zone
- Garnetiferous metagreywacke
- Metasiltstone
- Metagreywacke
- Amphibolite/diorite/gabbro
- Biotite rich metagreywacke
- Ore lens
- Quartzite

Figure 3.5 Reconstruction of x-section 500N using company geological logs and lithogeochemical control interpreted by the author (Chapter 5) (modified after data from HBED diamond drill logs and lithogeochemical data; internal company report Gilmore et al. 1999)
Study Localities
- Harmin Zone Cu-Zn massive sulphide
- Fenton Creek Zone Zn-Cu massive sulphide
- Road
- Lake

Major Mineral Deposits
- Cu, Zn, Ag, Au
- Zn, Cu, Ag, Au

Phanerozoic Rocks
- Red River Formation (Herald and Yeoman formations) (<55m)
- Stonewall Formation (<25 m)
- Stony Mountain Formation (<35 m)

Supracrustal Rocks
- INTRUSIVE ROCKS
- INTRUSIVE ROCKS, GNEISSES, AND TECTONITES
- LATE INTRUSIVE ROCKS
- UNKNOWN - NO OUTCROP
- SEDIMENTARY, VOLCANIC AND HYPABYSSAL INTRUSIVE ROCKS
- VOLCANIC, INTRUSIVE AND SEDIMENTARY ROCKS

Figure 3.6 Local geology of Fenton Creek zone showing the extent of the Phanerozoic dolomitic cover rocks (modified after data from Natmap Shield Margin Project Working Group, 1998)
Figure 3.7 - Fossiliferous dolomite cover rock

A) Vuggy and mottled fossiliferous dolomite inferred from regional geology map to have come from the Ordovician Stoney Mountain formation. Sample 75666H from drillhole Har044 (35m)
B) Close-up view of sample 75666H showing crinoid stems and small pin sized solution vugs
C) Similar to sample 75667H a less vuggy mottled sample of fossiliferous dolomite. Sample 75667H drillhole Har018 (39m).
D) Close-up view of sample 75667H showing a large crinoid stem (2.5mm dia.) with groove segments well preserved in a matrix of unidentifiable sedimentary and fossil detritus.
Figure 3.8 - Clinopyroxene-scapolite-carbonate schist

A) Photograph showing the lower contact of the clinopyroxene-scapolite-quartz-carbonate schist with sheared and clay altered quartz(Qtz)-biotite(Biot)-sillimanite(sill) schist. Drillhole Har044 (131.81m).
B) Clinopyroxene(Cpx)-scapolite(Scap)-carbonate(Carb) schist showing strong banding and segregation of the clinopyroxene from quartz and carbonate. Sample H25874 drillhole Har044 (81.30m).
C) Clinopyroxene-scapolite-carbonate schist stained for K-feldspar (Kfs) (yellow). Sample H25875 drillhole Har044 (92.70m).
D) Similar to sample H25852 with less quartz & carbonate but increased scapolite giving the sample a pale green color from sample H25875 drillhole Har044 (92.70m).
E) Sample H25875 stained for K-feldspar(Kfs) (note segregation of quartz(Qtz)-carbonate(Carb) from k-feldspar rich bands Sample H25875 drillhole Har044 (92.70m).
thickness of dolomite in conjunction with sandstone and muskeg make this package of rocks a formidable barrier to conventional exploration methods.

### 3.3.2 Garnet-sillimanite schist

The garnetiferous-sillimanite schist forms the upper most stratigraphic unit intersected on the Fenton Creek property it occurs below the overburden and Ordovician dolomite/sandstone. Company geologists logged this unit as a garnetiferous metagreywacke and “anatexis metagreywacke”. Separation and distinction of this unit from other metagreywackes in the stratigraphy has been based on mineralogical and geochemical discrimination (Chapter 5). Major intersections of this unit occurring in diamond drill holes Har031 and Har041 along section 500N suggest that it is >120 m thick and dips 40-45° W (Fig. 3.5). Unfortunately no samples of this unit were available for detailed study, however, the unit as described in diamond drill logs consists of a poor to well foliated metagreywacke-anatexis with 12-17% garnet porphyroblasts, minor amounts of graphite and trace sillimanite occurring parallel to the foliation. The logged descriptions also mention numerous pegmatite and granitic intrusions as well as quartz sweats and a fair amount of partial melting indicating anatexis.

### 3.3.3 Clinopyroxene-scapolite-carbonate schist

The clinopyroxene-scapolite-carbonate schist occurs immediately below the garnet-sillimanite schist. Identification of the clinopyroxene-scapolite-carbonate schist was made using logged mineralogy and geochemistry (Chapter 5). Company geologists logged this unit as a calc-silicate altered quartzite to metasiltstone. Major intersections of this facies occurring in diamond drill holes Har031, Har041 and Har044 suggest that it has an apparent thickness of 40-60m and dips 40-45° W (Fig. 3.4 & 3.5). Clinopyroxene-scapolite-carbonate schist dominates the unit, though minor amounts garnet-graphite metapelite and calc-silicate altered siltstone/metagreywacke (from the geologic logs) have also been noted. From the diamond drill logs the upper and lower contacts for this unit are often truncated by intrusions or faults, as is the case in diamond drill hole Har044 where the lower contact is relatively sharp (Fig. 3.8A).

In hand specimen this rock is composed of a grey to light green, medium grained schist with alternating bands of quartz, carbonate, k-feldspar and clinopyroxene (diopside??) (Figs. 3.8B and 3.8D). Bands vary in thickness from 0.25 to 1cm and may represent bedding ($S_0$), which are thought regionally to be parallel to $S_1$, foliation. Most samples
are strongly foliated and are marked by the occasional quartz augen as shown in (Fig. 3.8 B&D).

In thin section this rock is composed of a granoblastic mosaic of 15-25% clinopyroxene (diopside), 10-20% scapolite, 10-20% K-feldspar, 5-10% quartz, 5-10% amphibole, 5-10% carbonate occurring as alternating domains of K-feldspar, clinopyroxene and quartz-scapolite-carbonate rich bands (Fig. 3.9). Accessory minerals include, 3-5% sphene occurring as sub-rounded to subangular blebs and crystals and 1-2% pyrrhotite and trace chalcopyrite.

The mineralogy of this unit, including the clinopyroxene, amphibole and sphene association, together with the granoblastic textures of this unit are consistent with an upper amphibolite to granulite facies metamorphosed rock of probable basic igneous origin. The occurrence of scapolite may indicate the presence of a CO$_2$ and Cl-rich solution; however further detailed research is required to confirm such a claim. Unfortunately, much if not all of the minerals have been recrystallised into coarser grains and in that process destroyed the original textures of this rock unit.

### 3.3.4 Quartz-biotite-sillimanite schist

The quartz-biotite-sillimanite schist occurs as a +300m thick stratiform unit predominantly in the hanging wall to the mineralised lenses and is intersected in all diamond drill holes except Har010 and Har016 of the sections studied (Fig. 3.4). Though this unit dominantly occurs in the hanging wall of the deposit, other occurrences have been noted in the footwall of the deposit. Previous logging by HBED geologists have identified this unit as a variably altered metagreywacke. As with the previously described clinopyroxene-scapolite-carbonate skarn; geochemistry and mineralogy was employed to help discriminate the quartz-biotite-sillimanite schist from other HBED logged metagreywackes (Chapter 5). The unit is dominated by quartz-biotite-sillimanite schist with minor interbedded garnet-graphite metapelite and amphibole-biotite schist. The contacts for this unit are almost always sharp with the granitic intrusions and often gradational with other units in the stratigraphy (Fig. 3.10A).

In hand specimen this rock is often light to dark grey, fine to medium grained, with a mottled, coarse pseudo-clastic texture that is parallel to the foliation. These pseudo-clasts range in size and degree of roundness but are generally 1-2 cm in diameter. At hand specimen scale this rock is characterised by quartz augens and wispy sillimanite.
Chapter 3 - Local Geology

A) Granoblastic mosaic of fine grained quartz (Qtz) and K-feldspar (Kfs) with coarser grained scapolite (Scap). Sample H25852 (1.25x magnification, crossed Nichols).

B) Granoblastic mosaic of fine grained carbonate (Carb) with coarser grained scapolite (Scap). Sample H25852 (5x magnification, crossed Nichols).

C) Granoblastic mosaic of quartz (Qtz) and scapolite (Scap) and twinned subhedral clinopyroxene (Cpx) grain. Sample H25852 (5x magnification, crossed Nichols).

D) Intergrowth of colorless clinopyroxene (Cpx) and green amphibole (Amp) with 100 μm subhedral sphene crystals. Sample H25852 (5x magnification, plane polarized light).

E) High relief clinopyroxene and brown sphene crystals in granoblastic mosaic of quartz, scapolite and carbonate. Sample H25852 (5x magnification, plane polarized light).

F) Disseminated sulphides of intergrown pyrrhotite (Po) and chalcopyrite (Cpy). Sample H25852 (20x magnification, reflected light).

Figure 3.9 Clinopyroxene-scapolite-carbonate schist

A) Granoblastic mosaic of fine grained quartz (Qtz) and K-feldspar (Kfs) with coarser grained scapolite (Scap). Sample H25852 (1.25x magnification, crossed Nichols).

B) Granoblastic mosaic of fine grained carbonate (Carb) with coarser grained scapolite (Scap). Sample H25852 (5x magnification, crossed Nichols).

C) Granoblastic mosaic of quartz (Qtz) and scapolite (Scap) and twinned subhedral clinopyroxene (Cpx) grain. Sample H25852 (5x magnification, crossed Nichols).

D) Intergrowth of colorless clinopyroxene (Cpx) and green amphibole (Amp) with 100 μm subhedral sphene crystals. Sample H25852 (5x magnification, plane polarized light).

E) High relief clinopyroxene and brown sphene crystals in granoblastic mosaic of quartz, scapolite and carbonate. Sample H25852 (5x magnification, plane polarized light).

F) Disseminated sulphides of intergrown pyrrhotite (Po) and chalcopyrite (Cpy). Sample H25852 (20x magnification, reflected light).
Figure 3.10 Various examples quartz-biotite-sillimanite schist

A) Sharp conformable contact of the quartz(Qtz)-biotite(Biot)-sillimanite(Sill) schist with quartz(Qtz)-feldspar(Fs)-carbonate(Carb) psammite. Sample H25881 drillhole Har044 (194.70m).

B) Typical quartz(Qtz)-biotite(Biot)-sillimanite(Sill) schist showing mottled pseudo clastic textures. Sample H25853 drillhole Har043 (132.50m).

C) Quartz(Qtz)-biotite(Biot)-sillimanite(Sill) schist showing the distribution of K-feldspar(Kfs) (stained yellow). Sample H25853.

D) Late stage quartz vein through mottled moderately foliated quartz(Qtz)-biotite(Biot)-sillimanite(Sill) schist. Sample G35271 drillhole Har018 (85.80m).

E) K-feldspar staining of sample G35271 including the late stage quartz vein showing halo effects of potassium rich fluid associated with the vein.

F) Biotite rich example of the quartz(Qtz)-biotite(Biot)-sillimanite(Sill) schist showing strong foliation with development of quartz augen and minor sillimanite. Sample F70402 drillhole Har021 (137.40m).

G) Sillimanite rich example of the quartz(Qtz)-biotite(Biot)-sillimanite(Sill) schist showing wispy sillimanite and biotite aligned parallel to the foliation. Sample H25889 drillhole Har044 (418.23m).
clots parallel to a moderately well developed foliation at 20-30° to core axis. Discernable mineralogy consists of quartz, plagioclase, K-feldspar (by staining), biotite and sillimanite (Fig. 3.10B-E).

In thin section this rock generally is seen to be comprised of a granoblastic mosaic of 40-50% irregularly shaped 0.3-1.5mm quartz grains, 10-30% brown 0.3-0.5mm elongate biotite lathes, 5-15% 0.3-1.5mm weakly altered plagioclase, 10-20% 1-5mm slender elongate sillimanite crystals which are most often aligned with foliation, and 1-3% <0.5mm irregularly shaped muscovite/sericite crystals. Accessory minerals include, 1-3% K-feldspar and trace cordierite (Fig. 3.11).

The mineralogy of this unit, including the quartz, biotite, plagioclase and sillimanite, suggest that this unit is likely of probable acid igneous origin. As with most units from the Fenton Creek zone the metamorphic grade has destroyed many of the primary textures. The quartz-biotite-sillimanite schists do however, display a mottled texture that is also seen in the quartz-muscovite-sillimanite schist but absent from the other units in the Fenton Creek stratigraphy. This texture may indicate a coarser volcaniclastic rock or may simply reflect compositional differences in the original rock.

3.3.5 Garnetiferous-graphitic metasediment

The garnetiferous-graphitic metasediment occurs as semi-continuous, 1-5m horizons within and around the massive sulphide lenses and as a large 10-25m thick continuous horizon dipping 40-45° W and located high in the hanging wall to the mineral lenses (Fig. 3.4). The unit as defined in the hanging wall consists of 1-5m horizons of garnet-graphite metapelite interbedded with a 15-20m thick quartz-carbonate-feldspathic psammite.

In hand specimen the garnet-graphite metapelite is fine to medium grained, dark brown to black metamorphic rock. The matrix of the metapelite is comprised of fine-grained biotite and small <1mm long acicular graphite crystals that appear to grossly wrap around porphyroblasts. The porphyroblasts consist 0.25 to 1cm subhedral pink garnets that appear dispersed throughout the sample with other almost undiscernible, unidentified porphyroblasts (Fig. 3.12A-C). Further photographs of the mineralised garnetiferous graphitic metapelite are shown in Figure 6.3.

In thin section the metapelite is consists of a variable granoblastic mosaic of 30-40%, subhedral, 0.2-0.75mm quartz grains; 20-30%, 0.3-1mm, fresh plagioclase; 10-20%,
Figure 3.11 - Biotite-sillimanite schists

A) Granoblastic mosaic of quartz (Qtz) with 500mm elongate brown biotite along foliation. Sample G35271 (5x magnification, plane polarized light).

B) Granoblastic mosaic of quartz (Qtz) with 500mm elongate brown biotite (Biot) along foliation from sample G35271 (5x magnification, crossed nicols).

C) Large sillimanite (Sill)-biotite (Biot) knot >1mm consisting of needle-like sillimanite and brown biotite parallel to the foliation from sample F70402 (2.5x magnification, plane polarized light).

D) Granoblastic mosaic of quartz (Qtz) and minor feldspar (Fs) with sillimanite (Sill) porphyroblast and biotite (Biot) parallel to the foliation. Sample F70402 (1.25x magnification, crossed nicols).

E) Deformed mosaic of sutured quartz (Qtz) with undulose extinction and weakly altered plagioclase (Plag) with sillimanite (Sill) porphyroblast. Sample H25889 (1.25x magnification, crossed nicols).

F) Mosaic of sutured quartz with altered feldspar and minor anhedral muscovite/sericite grain. Sample H25889 (5x magnification, crossed nicols).
Figure 3.12 - Metasediments - Graphite-garnet metapelite & clinopyroxene-quartz-carbonate psammite

A) Typical garnet(Gt)-graphite(Graph) metapelite showing size and distribution of garnet porphyroblasts. From drillhole Har043 (106.82m).

B) Massive metapelite with pink garnet porphyroblasts and graphite crystals. Sample H25851 drillhole Har043 (103.2m).

C) Close-up view of sample H25851 showing the garnet porphyroblasts and acicular graphite crystals.

D) Clinopyroxene(Cpx)-quartz(Qtz)-carbonate(Carb) psammite showing gradational bedding fining upward. Sample H25852 drillhole Har043 (118.2m).

E) Close-up view of sample H25852 showing narrow 0.25cm thick K-feldspar rich bands drillhole Har043 (118.2m).

F) Transitional biotite(Biot)-garnet(Gt) psammite/metapelite displaying mottled domains of K-feldspar(Kfs) and biotite(Biot) with a few garnet(Gt) porphyroblasts and no graphite(Graph). Sample H25882 drillhole Har044 (199.3m).

G) Close-up view of sample H25882 showing the K-feldspar(Kfs) rich bands (stained yellow).
brown, 0.3-0.5mm elongate biotite lathes which often wrap around the garnet porphyroblasts; 5-10% 0.5-1mm slender elongate graphite crystals which also wrap around garnet porphyroblasts, and 3-5%, 1-10mm, corroded, subhedral garnets which often display pressure shadowed margins. Accessory minerals include K-feldspar, anthophyllite, and cordierite occurring in porphyroblasts after garnet, chloritoid also occurring as porphyroblasts after cordierite and minor clinopyroxene around the margins of the garnets (Fig. 3.13 A-F).

The quartz-carbonate-feldspathic psammite is a fine to medium grained metamorphic rock with alternating laminations of quartz/feldspar and carbonate, which at times looking similar to banded clinopyroxene-scapolite-carbonate schist. The mineralogy of this unit consists of 30-45% quartz, 30-45% feldspar and 2-5% clinopyroxene/amphibole. Accessory minerals include minor K-feldspar occurring as thin bands of white quartz/feldspar and 1-3%, disseminated pyrrhotite (Fig. 3.12D & 3.12E). Sample H25852 collected from Har043 displays textures that can arguably be called graded bedding (Fig. 3.12D).

The metapelite and psammite are often interbedded and have gradational contacts. An example of this can be seen in sample H25882 (Fig. 3.12F) where the specimen has garnet and biotite mineralogy characteristic of the metapelite as well as quartz bands similar to the psammite.

The mineralogy of quartz, plagioclase, biotite and garnet in the garnetiferous-graphitic metapelite is consistent with argillaceous sediment that has been subjected to metamorphic conditions ranging from upper amphibolite to granulite facies. This argillaceous sediment may indicate a period of quiescence that is important for the preservation of associated mineralisation. The graphite within the metapelite units has been found to be of biogenic origin (Chapter 5) adding more evidence that suggests that the metapelite unit represents a seafloor position.

### 3.3.6 Biotite-clinopyroxene-plagioclase schist, Amphibolite and Amphibole-plagioclase schist

The mineralogy of this group covers a broad spectrum of compositions ranging from biotite-clinopyroxene-plagioclase schist to amphibole-plagioclase schist that suggests a basic igneous origin. Original logging identified these units as amphibolites, diorites and/or biotite-rich metagreywacke. An attempt to correlate these mapped units individually
Figure 3.13 Garnet-graphite metapelite

A) A 1500μm subhedral corroded garnet (Gt) porphyroblast showing two modes of biotite (Biot). Mode 1 biotite and graphite occurs parallel to the foliation and wraps around the garnet porphyroblast. Mode 2 biotite occurs as randomly oriented grains within pressure shadow of the garnet, likely formed during retrograde metamorphism. Sample H25851 (1.5x magnification, plane polarized light).

B) Cluster of garnet (Gt), which has almost been completely consumed and replaced by cordierite (Cord) and plagioclase (Plag). Sample H25851 (1.5x magnification, plane polarized light).

C) Biotite (Biot) and graphite (Graph) wrapping around the of a cordierite (Cord) porphyroblast after garnet (Gt) within a mosaic of granoblastic quartz (Qtz) and plagioclase (Plag). Sample H25851 (1.5x magnification, crossed nicols).

D) Cordierite (Cord) porphyroblasts infilled with inclusions of graphite in a granoblastic mosaic of quartz (Qtz) and K-feldspar. Sample 75507H drillhole Har010 (119.6m) (1.25x magnification, crossed nicols).

E) Cluster of graphite (Graph) with characteristic fibrous texture in quartz-biotite mosaic. Sample 75507H drillhole Har010 (119.6m) (5x magnification, plane polarized light).

F) Large anthophyllite (Anth) crystal and chloritoid (Chl) after cordierite (Cord) porphyroblast in a granoblastic mosaic of quartz (Qtz), biotite (Biot), K-feldspar (Kfs) with disseminations of graphite (Graph) and pyrrhotite (Po) from sample 75507H drillhole Har010 (119.6m) (1.5x magnification, plane polarized light).
failed due to their complex distribution and/or the lack of geologic control and understanding. However, through this process it was realized that the various units often occurred together in close proximity to one another. Re-interpretation of the geologic logs in conjunction with the lithogeochemical controls suggests that the units of this group occur as deformed intercalated, semi-continuous to continuous stratiform horizons of variable thickness throughout the stratigraphy of the study region (Chapter 5). Spatially this group appears to form the immediate hanging wall to the main ore zones and decrease in frequency into the hanging wall. The thickest intersections occur in drillholes along section 400N where the unit appears 20-30m thick (Figs. 3.3, 3.4 & 3.5).

*Biotite-clinopyroxene-plagioclase schist*

In hand specimen samples of biotite-clinopyroxene-plagioclase schist appear medium grained, massive to weakly foliated dark brown to black metamorphic rocks. The rock is a fine to medium grained mosaic of biotite and plagioclase, with minor amounts of K-feldspar along late veins/fractures (Fig. 3.14). In thin section the biotite-plagioclase schist is comprised of a granoblastic mosaic of 50-60% subhedral, plagioclase grains, 10-30%, brown, elongate biotite lathes which are aligned along a weak to moderate foliation and 5-10%, pale green clinopyroxene, 3-5% quartz and 2-4%, anhedral to subhedral sphene. Accessory minerals include, trace K-feldspar, 1-2% pyrrhotite and trace amounts of chalcopyrite and sphalerite (Fig. 3.15).

*Amphibolite*

In hand specimen samples of amphibolite appear medium to coarse grained, massive to weakly foliated, dark green to black metamorphic rocks. The rock contains medium grained mosaics of amphibole and plagioclase (Figs. 3.16 A & B). Diamond drill logs suggest that the contacts for this rock type vary from sharp (contacts with intrusives/pegmatites) to gradational contacts with other lithologies in the stratigraphy (Fig. 3.16 D).

In thin section the amphibolite is a granoblastic mosaic of 60-70%, subhedral, brown amphibole and 15-25%, subhedral, plagioclase grains. Accessory minerals include, 1-2% quartz, 1-2% pyrrhotite and trace amounts clinopyroxene and K-feldspar (Figs. 3.17 A-C).
Figure 3.14 Examples of biotite-clinopyroxene-plagioclase schist

A) Massive to weakly foliated fine to medium grained biotite(Biot)-plagioclase(Plag) schist. Note the disseminated pyrrhotite(Po). Sample F70405 drillhole Har021 (215.8m).
B) Sample F70405 stained for K-feldspar(Kfs). Note that the K-feldspar occurs as fine grains throughout the sample except for a 1 cm wide band in the lower end of the sample. Drillhole Har021 (215.8m).
C) Moderately foliated to banded biotite(Biot)-plagioclase(Plag) schist with minor pyrrhotite(Po) aligned along and within segregated bands of biotite rich domains. Sample G35272 drillhole Har018 (116.0m).
D) Sample G35272 stained for K-feldspar(Kfs). Note that the K-feldspar is occurring in the fractures/veins.
E) Well foliated biotite(Biot)-clinopyroxene(Cpx)-plagioclase(Plag) schist with visible brown anhedral grains of characteristic sphene +/- pyrrhotite(Po) and chalcopyrite(Cpy). Sample H25862 drillhole Har043 (319.70m).
F) Sample H25862 stained for K-feldspar(Kfs). While mineral is plagioclase(Plag).
E) Well foliated/bedded biotite(Biot)-clinopyroxene(Cpx)-plagioclase(Plag) schist sampled in the vicinity of the ore lense. Note darker colored biotite domain defining the bedding horizon and the pyrrhotite(Po) and chalcopyrite(Cpy) along the foliation/bedding. Sample H25866 drillhole Har043 (396.40m).
F) Sample H25866 showing the high percentage of K-feldspar(Kfs) (from staining).
Figure 3.15 Biotite-clinopyroxene-plagioclase schist

A) Typical weakly foliated biotite(Biot)-plagioclase(Plag) schist, showing distribution of biotite. Sample F70405 drillhole Har021 (215.8m) (2.5x magnification, plane polarized light).

B) Previous plate showing granoblastic mosaic of plagioclase(Plag) and minor quartz(Qtz) (2.5x magnification, crossed nicks).

C) Characteristic anhedral brown sphene and high relief clinopyroxene. Sample H25862 drillhole Har043 (319.7m) (1.25x magnification, plane polarized light).

D) Previous plate under crossed nicks showing large subhedral plagioclase(Plag), clinopyroxene(Cpx) and carbonate(Carb) (1.25x magnification, crossed nicks).

E) Intergrown green clinopyroxene(Cpx) and biotite(Biot). Sample G35272 Har018 (116.0m) (10x magnification, plane polarized light).

F) Intergrown green clinopyroxene(Cpx) and biotite(Biot) including a pyrrhotite(Po) grain with a sphene overgrowth. Sample G35272 drillhole Har018 (116.0m) (6.25x magnification, plane polarized light).
Amphibole-plagioclase schist

In hand specimen the amphibole-clinopyroxene-plagioclase schist is a medium to coarse grained, moderately foliated, dark brown to dark green metamorphic rock. The rock is almost entirely coarse-grained amphibole and plagioclase +/- quartz which appear segregated in some samples into felsic and mafic domains (Fig. 3.16 E-F). Pyrrhotite is the dominant sulphide and occurs along fractures, veins and as disseminations.

In thin section the amphibole-plagioclase schist contains a granoblastic mosaic of 60-70%, pale brown amphibole and 20-30%, plagioclase. Accessory minerals include trace quartz and muscovite and 1-2% pyrrhotite with minor sphalerite and chalcopyrite (Figs. 3.17 D-F)
Figure 3.16 Amphibolite and Amphibole-plagioclase schist

A) Sample originally logged as an amphibolite/metagabbro. Note large amphibole (Amph) porphyroblasts intergrown with plagioclase (Plag). Also pyrrhotite (Po) along small veins oblique to the foliation. Sample H25859 drillhole Har043 (249.30m).

B) Sample originally logged as a metadiorite. Composed almost entirely of hornblende (Hbl) and plagioclase (Plag), re-interpreted as an amphibolite. Sample F70408 drillhole Har021 (307.40m).

C) Close-up photograph of the narrow pyrrhotite (Po) vein from previous plate Sample F70408.

D) Lower contact of amphibolite with granitic pegmatite. Drillhole Har043 (255.58m).

E) Medium to fine grained amphibole-plagioclase schist. Sample H25890 drillhole Har044 (450.20m).

F) Medium grained amphibole-plagioclase schist showing distinct domains of plagioclase (Plag) and amphibole (Amph) & biotite (Biot). Sample H25864 drillhole Har043 (355.50m).
Figure 3.17 Amphibolite and amphibole-plagioclase schist

A) Granoblastic mosaic of amphibole (Amph) and plagioclase (Plag). Sample F70408 drillhole Har021 (307.4m) (2.5x magnification, cross nicols).
B) Brown amphibole (Amph) showing the distinctive 120° cleavage angles. Sample F70408 (5x magnification, plane polarized light).
C) Pyrrhotite vein from sample F70408. Note the change in the color of the amphibole from brown to colorless in a narrow alteration envelope (2.5x magnification, plane polarized light).
D) Amphibole (Amph) and plagioclase (Plag) + biotite (Biot). Sample H25864 drillhole Har043 (355.3m) (1.5x magnification, cross nicols).
E) Previous plate under plane polarized light showing brown and colorless amphibole (Amph) intergrown with biotite (Biot) (1.5x magnification, plane polarized light).
F) Anhedral pyrrhotite (Po) grain with small blebs of intergrown sphalerite (Sph) and chalcopyrite (Cpy). Sample H25864 (5x magnification, reflected light).
3.3.7 Quartz-sillimanite-muscovite schist

The quartz-sillimanite-muscovite schist occurs as a west dipping 40 to 80m thick stratiform unit found dominantly in the footwall wall to the Fenton mineralised lenses (Fig. 3.3). Previous logging by HBED geologists have identified this unit as a variably altered quartzite and siltstone. In addition to marked differences in the mineralogy this unit was also discriminated by geochemistry from the biotite-sillimanite schist. The unit is dominated by quartz-sillimanite-muscovite schist with minor horizons of siliceous meta-sediment and intercalated with garnet-graphite metapelite and biotite-plagioclase/amphibole-plagioclase schist.

In hand specimen this rock is often buff to light grey, fine-grained, with a mottled to banded texture parallel to a strong foliation/bedding similar to the textures seen in the quartz-sillimanite-muscovite schist (Fig. 3.18 A-B & 3.18F). Banded samples have compositional bands that have separated into domains of quartz-feldspar and sillimanite-muscovite. Mottled samples contain muscovite/sillimanite knots and quartz/plagioclase +/- K-feldspar domains (from staining) (Fig. 3.18 C-E).

In thin section this rock consists of a granoblastic mosaic of 30-50%, 0.1-0.5mm, variably-strained quartz grains, 10-20%, 0.1-0.5mm plagioclase, 5-15%, 0.3-2mm elongate muscovite lathes and 5-15%, 1-3mm, slender, elongate sillimanite crystals which occur in clusters (knots) and/or are aligned along the foliation. Accessory minerals include 3-5% K-feldspar, elongate biotite/phlogopite, trace cordierite, and variable amounts of disseminated pyrrhotite, chalcopyrite, and sphalerite (Fig. 3.19 A-F).
Figure 3.18 Quartz-muscovite-sillimanite schist

A) Foliated quartz(Qtz)-muscovite(Musc)-sillimanite(Sill) schist with minor disseminated pyrrhotite(Po). Sample H25865 drillhole Har043 (390.60m).

B) Sample H25865 stained for K-feldspar.

C) Mottled quartz(Qtz)-muscovite(Musc)-sillimanite(Sill) schist with minor pyrrhotite(Po) blebs occurring parallel to moderately developed foliation. Sample G35276 drillhole Har018 (235.0m).

D) Sample H25865 stained for K-feldspar(Kfs). Minor amounts of K-feldspar in mottled domains, which are surrounded by wispy sillimanite(Sill) parallel to foliation.

E) Quartz(Qtz)-muscovite(Musc)-sillimanite(Sill) schist showing large 0.5-1 cm elongated sillimanite clots parallel to the foliation. Minor pyrrhotite(Po) also occurs parallel to the foliation. Sample 75521 drillhole Har018 (221.7m).

F) Quartz-muscovite-sillimanite schist originally logged as a metaquartzite showing what appears to be original bedding features. Drillhole Har043 390m.
Figure 3.19 Quartz-muscovite-sillimanite schist

A) Granoblastic quartz(Qtz)-K-feldspar(Kfs) mosaic with elongate muscovite grains aligned parallel to the foliation. Sample 75521H drillhole Har021 (221.7m)(2.5x magnification, crossed nicols).

B) Elongate sillimanite(Sill) grains wrapping around muscovite(Musc) porphyroblast parallel to the foliation. Sample 75521H drillhole Har021 (221.7m)(5x magnification, plane polarized light).

C) Granoblastic quartz(Qtz) and K-feldspar(Kfs) mosaic overprinted by fine grained muscovite(Musc). Sample 75531H drillhole Har043 (388.84m)(2.5x magnification, crossed nicols).

D) Granoblastic mosaic of quartz(Qtz) with strained annealed grains boundaries and characteristic undulose extinction. Sample 75511H drillhole Har0301 (5x magnification, crossed nichols).

E) Strained quartz(Qtz)-K-feldspar(Kfs) mosaic showing annealed grain boundaries. muscovite(Musc) occurs parallel to foliation whilst K-feldspar(Kfs) is partially altered to muscovite(Musc)/sericite. Sample 75535H drillhole Har043 (416.00m)(2.5x magnification, crossed nichols).

F) Example of an anhedral pyrrhotite(Po) grain intergrown with minor galena(Gal) and pyrite(Py). Sample 75521H drillhole Har018 (221.7m)(20x magnification, reflected light).
3.3.8 Granitic Intrusions and Pegmatites

The granitic intrusions occur as 5-45m thick dykes and/or sills that crosscut all of the stratigraphy except for the Phanerozoic dolomite on the Fenton Creek property. Logging by HBED personnel identified these units primarily as granites, granodiorite, granite pegmatite and aplite. At least three granitic bodies can be traced laterally and connected from hole to hole along section, however, only one main granitic body can be traced from section to section (Fig. 3.3 and 3.4). Granitic pegmatite as logged often occurs in close proximity to granitic intrusions. In general all granitic intrusions show sharp contacts with the surrounding stratigraphy and appear unaltered with little evidence of deformation. Microprobes analysis of monazites from two of the granitic intrusions by R. Berry of the University of Tasmania indicate that there are a small range of ages of intrusions in the stratigraphy of the Fenton Creek zone. Dating of sample 75501H returned an age of 1764 +/- 5Ma, while sample H25858 returned a younger age of 1742 +/- 6Ma (Complete microprobe results are located in Appendix B). Both samples are from small granitic dyke like intrusions located in the hanging wall amphibole-plagioclase schist and quartz-biotite-sillimanite schist. According to the regional tectono-metamorphic history of the Snow Lake Allochton (modified after Kraus and Williams, 1999) these ages would confirm that the intrusions are post kinematic and would have intruded after the D₄ event during the formation of brittle structures and ongoing exhumation (Table 2.2).

In hand specimen the granitic intrusions vary from light grey to orange, medium to coarse grained, non-foliated plutonic rocks. Samples collected for this study range in composition but generally consist of equal amounts of quartz, plagioclase and K-feldspar with minor amounts biotite and muscovite (Fig. 3.20).

In thin section samples of the granitic intrusion consist of an equigranular mosaic of 20-40%, anhedral quartz grains ranging from 1-2mm, 20-40%, anhedral plagioclase grains ranging from 0.5-2mm with good albite twinning, 20-40%, anhedral microcline ranging from 0.5-2mm and 3-5%, brown, 0.3-2mm subhedral biotite grains with no preferred alignment. Accessory minerals include, trace Fe-oxides and pyrrhotite (Fig. 3.21).

In hand specimen the granitic pegmatite range in colour from white to orange and have an uneven-granular coarse grained texture. Like the granitic intrusions the pegmatite often have sharp contacts with other rock-types in the stratigraphy and can often be seen cross-cutting everything including the granitic intrusions. The pegmatites are
Figure 3.20 Various textures and compositions of post kinematic intrusions

A) Medium grained granodiorite with a composition of quartz>plagioclase>K-feldspar>biotite. Sample G35277 drillhole Har018 (254.2m).

B) Sample G35277 from the previous plate showing the amount and distribution of K-feldspar.

C) Medium-coarse grained, massive granodiorite with a composition of quartz>plagioclase>K-feldspar>biotite. Sample 75501H drillhole Har010 (84.5m).

D) Sample 75501H from the previous plate showing the amount and distribution of K-feldspar.

E) Medium grained, massive potassium-rich granite with darker domains of hornblende and/or Fe-Ti oxides. Sample 75505H drillhole Har010 (106.2m).

F) Sample 75505H from the previous plate showing the amount and distribution of K-feldspar.

G) Typical sharp contact between granitic intrusion and amphibole-plagioclase schist. Note coarsening of pyrrhotite(Po) near contact and some local partial melting of schist. Sample 75525H drillhole Har021 (310.7m).

H) Sample 75525H from the previous plate showing the amount and distribution of K-feldspar.
Figure 3.21 Post kinematic intrusions

A) Equigranular quartz (Qtz), K-feldspar (Kfs) and plagioclase (Plag) with minor muscovite (Musc). Sample H25858 drillhole Har043 (227.1 m)(2.5x magnification, crossed nichols).

B) Mosaic of quartz (Qtz), K-feldspar (Kfs) 'microcline' with characteristic tartan twinning, dark brown biotite (Biot), and minor muscovite (Musc) and myrmekitic intergrowth of quartz (Qtz) and plagioclase (Plag). Sample H25858 drillhole Har043 (227.1 m)(2.5x magnification, crossed nichols).

C) Equigranular quartz (Qtz), biotite (Biot) and K-feldspar (Kfs) 'microcline'. Sample 75501H drillhole Har010 (84.6 m)(2.5x magnification, crossed nichols).

D) Previous plate sample 75501H under plane polarized light showing the brown biotite (Biot) and the dusty sericite alteration of the k-feldspar (Kfs) (2.5x magnification, plane polarized light).

E) Contact zone between biotite (Biot)-plagioclase (Plag) rich schist and granitic intrusion. Note distribution of pyrrhotite (Po) dominant in the schist with minor amounts in the intrusion. Sample 75525H drillhole Har021 (310.7 m) (1.25x magnification, plane polarized light).

F) Previous plate as seen under crossed-nichols showing the equigranular mosaic of quartz (Qtz) and plagioclase (Plag) in the intrusion versus sutured grain boundaries in the schist (1.25x magnification, crossed nichols).
Figure 3.22 Pegmatites

A) Potassium-rich granite pegmatite consisting of K-feldspar (Kfs), quartz (Qtz), plagioclase (Plag) and amphibole (Amph). Sample H25873 drillhole Har044 (69.4m).

B) Previous plate, sample H25873 stained for K-feldspar.

C) Contact between biotite-plagioclase schist and very coarse grained granite pegmatite. Note sharp 0.25mm wide chill margin. Sample 75608H drillhole Har018 (69.0m).

D) Previous plate showing distribution of K-feldspar in the pegmatite and the host schist.

E) Narrow granite pegmatite dyke with a thin potassic-rich chill margin. Sample 75529H drillhole Har021 (374.0m).

F) Previous plate showing distribution of K-feldspar along the margin of the granite pegmatite dyke.

G) Coarse grained granite pegmatite showing the interlocking texture between quartz (Qtz), K-feldspar (Kfs) and biotite (Biot). Sample 75517H drillhole Har018 (196.3m).

H) Previous plate showing distribution of K-feldspar in the granite pegmatite.
generally 60-70% K-feldspar (from staining), 10-20% quartz and plagioclase and minor amounts of hornblende, biotite and Fe-Ti oxides (Fig 3.22).

3.4 Structure

The structural geology around the Fenton Creek zone is largely unknown due to Phanerozoic dolomitic cover that obscures the underlying geology. A single north-south striking fault structure of unknown displacement has been recognized from magnetic interpretation (Fig. 3.3). This structure is inferred to be located 1.1km east of the Fenton Creek zone and 1.9km west of the Harmin Creek zone (Fig. 3.2) This structure has a north-south strike similar to some of the major faults recognized in the Snow Lake Assemblage near the Chisel, North Chisel and the Ghost Lake deposits and is also proximal to a large intrusive body.

Limited interpretation of the structural geology of the Fenton Creek zone is possible from diamond drillcore due to the short amount of time spent by the author logging and the lack of information from the unoriented core. A strong foliation is recognizable in most samples collected from section 400N of Fenton Creek zone with the exception of the granitic intrusive rocks. This foliation is fairly variable ranges from 45° to 57° to the core axis along diamond drill holes from section 400N (Fig. 3.23A).

As mentioned previously much of the primary textural features including bedding are difficult to positively identify do to the high degree of metamorphism which has overprinted finer features with coarse-grained metamorphic minerals. Some inferred bedding features are locally preserved (Figs. 3.24B).

Regionally, rocks of the Snow Lake Assemblage have been subjected to at least four folding events (Kraus and Williams, 1999). The folding events, based on kinematic indicators include: F1 and F2 events - isoclinal folds and low-angle shear zones, F3 – NNE trending open to tight folds and F4 – local west-northwest and east-southeast trending folds (Kraus and Williams, 1999). There is little observable evidence of folding in the diamond drillcore studied from section 400N with the exception of a small open to close fold as in (Fig. 3.23C) which suggests larger scale folds are highly probable. The lack of evidence is probably due to the scale of observation.

Regional faulting in the Snow Lake Assemblage is thought to consist of early stage high angle faults associated with synvolcanic rifting and later stage low angle faults associated with isoclinal folding (Kraus and Williams, 1999). Faults logged along section 400N and
Figure 3.23 Various structural and textural features

A) Strongly foliated quartz-muscovite-sillimanite schist from sample 75521 in the footwall of drillhole Har018 (221.7m). Note elongation of sillimanite (Sill) knots/clusters parallel to the foliation.

B) Comparative sample of inferred bedding as evident by the gradational changes in composition and clast size. Diamond drillhole Har010-91.3m.

C) Open asymmetric fold within quartz-biotite-sillimanite schist. Drillhole Har044 (325m).

D) Gouge filled fault from drillhole Har044 (157.5m). Region around the fault gouge appears to be silicified.
500N appear to be concentrated in the upper hanging wall, grossly parallel to the dip of the stratigraphy (Figs. 3.4 & 3.5). Drill logs indicate that these faults often occur in 1-7 m zones with associated quartz-carbonate +/- pyrite and are sometimes in-filled with fault gouge (Fig. 3.23D).

### 3.5 Metamorphism

Metamorphic grade of the Snow Lake Assemblage in general varies from lower greenschist facies in the south to upper (almandine) amphibolite grades in the north (Galley et al., 1991). Investigations into the mineral assemblages of the metabasic and pelitic rocks indicate that the Fenton Creek zone has been subjected to upper amphibolite facies metamorphism, which agrees in part with previous work by Wells (2000) who suggests the metamorphism ranges from upper amphibolite to granulite. Unlike the findings of Wells (2000), no orthopyroxene, a key mineral indicating granulite metamorphism, was observed in any of the thin sections examined. Other evidence suggesting that the metamorphic grade is upper amphibolite and not granulite is the significant abundance of prograde muscovite in the footwall rocks that would likely have been destroyed if the rocks were to have reached granulite facies. A summary of the two studies is shown in Table 3.1

Regionally prograde metamorphism to chlorite grade within the Snow Lake Assemblage has been estimated to have been achieved between 1840-1830Ma, followed by a thermal peak in the staurolite zone between 1820-1810Ma and thermal peak in the sillimanite zone and higher approximately 1810-1805Ma (Kraus and Williams, 1999). No dates of metamorphism have been established for the Fenton Creek zone. Dating of monazites from the biotite schists was attempted; however, no suitable monazites were located in the samples submitted for analysis within the time frame of this study.

No formal investigation into the temperatures and/or pressures has been conducted on the Fenton Creek zone. The mineral assemblages in the basic and pelitic rocks suggest that the metamorphism occurred under moderate to high pressures (approximately of 3000 bars as indicate by the coexistence of garnet and cordierite) with temperatures in the range 550° to <750°C as evident by the co-existence of quartz and muscovite (Fig. 3.24)
Table 3.1 Summary of indicated metamorphic grade from mineral assemblages in the basic igneous, pelitic, and felsic rocks from the Fenton Creek zone. Based on the mineral assemblages observed in this study the rocks of the Fenton Creek zone have experienced upper amphibolite metamorphism.

<table>
<thead>
<tr>
<th>Study</th>
<th>Probable Precursor</th>
<th>Logged Rock Name</th>
<th>Mineral Assemblage</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Study</td>
<td>Basic Igneous</td>
<td>Gar-sill schist</td>
<td>Gar + Sill + Plag</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cpx-scap-carb schist</td>
<td>Cpx + Plag + carb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biot-cpx-plag schist</td>
<td>Biot + Cpx + Plag +/- Qtz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Amph-plag schist</td>
<td>Amph + Plag</td>
</tr>
<tr>
<td></td>
<td>Pelite</td>
<td>Metapelite</td>
<td>Qtz + Plag + Biot + Garn +/- Cord, Sill, Kfs</td>
</tr>
<tr>
<td></td>
<td>Felsic</td>
<td>Qtz-musc-sill schist</td>
<td>Qtz + musc</td>
</tr>
<tr>
<td>Wells, 2000</td>
<td>Basic Igneous</td>
<td>Amphibolite</td>
<td>Plag + brown Hbl + Qtz</td>
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<td></td>
<td>Pyroxene granulite/meta-</td>
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<tr>
<td></td>
<td></td>
<td>gabro</td>
<td>Cpx + Opx +/- Gar</td>
</tr>
<tr>
<td></td>
<td>Pelite</td>
<td>Metapelite</td>
<td>Qtz + Sill and/or Cord + Mica</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+/- Gar +/- Kfs</td>
</tr>
</tbody>
</table>

Gar=garnet      Sill =sillimanite   Plag=plagioclase  Cpx=clinopyroxene
Biot=biotite    Amph=amphibole      Qtz=quartz       Opx=orthopyroxene
Musc=muscovite  Cord=cordierite    Carb=carb        Kfs=K-feldspar

Figure 3.24 Generalized showing suspected range of pressure and temperature for the Fenton Creek zone plotted on the fields of the various metamorphic facies (modified after Yardley, 1989).
3.6 Summary

The Fenton Creek zone is a newly discovered Zn-Cu massive sulphide deposit overlaid by approximately 20m of muskeg and 30m of Ordovician dolomite/sandstone/regolith. Initial logging of the diamond drillholes by numerous geologists failed to accurately identify and characterise the lithologies hosting the deposit.

Utilizing 107 representative hand samples collected from diamond drillholes along section 400N, company geologic logs and lithogeochemistry, the geology of the Fenton Creek zone has been separated into 10 units. The footwall is characterised by quartz-muscovite-sillimanite schist: +/- garnetiferous-graphitic metasediment and minor biotite-clinopyroxene-plagioclase and amphibole-plagioclase schist. The ore lenses are dominated and characterised by garnetiferous-graphitic metasediments with minor amounts of mineralisation occurring in the footwall. The immediate hanging-wall is characterised by probable basic igneous rocks consisting of biotite-clinopyroxene-plagioclase and amphibole-plagioclase schist. Quartz-biotite-sillimanite schist, followed by non-mineralised garnetiferous-graphitic metasediment, clinopyroxene-scapolite-carbonate schist, and a unit of garnet-sillimanite schist, defines the greater hanging wall. Crosscutting all the logged units are non-foliated, undeformed fresh granitic dykes and/or sills that have been dated at 1764 +/- 5Ma and 1742 +/- 6Ma. The dates indicate that the granitic intrusions are post kinematic and that deformation and peak metamorphism in the surrounding rocks occurred prior their emplacement.

Estimates of the metamorphic grade from mineral assemblages observed in the pelitic and metabasic rocks suggest that the Fenton Creek zone has been subjected to upper amphibolite facies metamorphism. Moderate to high pressures of 3000 bars, as indicate by the coexistence of garnet and cordierite; with temperatures in the range 550° to <725°C are expected at these grades of metamorphism.

Regionally the Fenton Creek zone is located 1.1 km west of a major north-south fault of unknown displacement. This fault does have a similar strike to some of the major faults recognized in the Snow Lake Assemblage near the Chisel, North Chisel and the Ghost Lake deposits. Limited structural information in the diamond drill logs suggest that there is faulting parallel to the stratigraphy in both the hanging wall and in the ore zone itself. This faulting may represent thrusting, which is common regionally and may have implications for stratigraphy repetition, however additional structural information and interpretation are needed to properly investigate this possibility.