MADRID-BOSTON PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT

Table of Contents

Table of Contents i
List of Figures ii
List of Tables ii

Glossary and Abbreviations iii

4. Geology 4-1
4.1 Introduction 4-1
4.2 Existing Environment and Baseline Information 4-1
4.2.1 Regional Setting 4-1
4.2.1.1 Bedrock Geology 4-1
4.2.1.2 Quaternary Geology 4-1
4.2.2 Local Setting 4-3
4.2.3 Data Sources 4-6
4.2.3.1 Topographic, Bathymetric and Air Photograph Data 4-6
4.2.3.2 Geophysical Data 4-6
4.2.3.3 Geological Mapping 4-8
4.2.3.4 Geochemical Sampling 4-8
4.2.3.5 Underground Sampling 4-8
4.2.3.6 Petrology, Mineralogical and Research Studies 4-8
4.2.3.7 Geotechnical and Hydrological Studies 4-9
4.2.4 Boston Area 4-9
4.2.4.1 Lithologies 4-11
4.2.4.2 Structural Geology 4-11
4.2.4.3 Mineralization 4-11
4.2.4.4 Surficial Deposits 4-11
4.2.5 Doris Area 4-14
4.2.5.1 Lithologies 4-14
4.2.5.2 Structural Geology 4-14
4.2.5.3 Mineralization 4-14
4.2.5.4 Surficial Deposits 4-18
4.2.6 Madrid Area 4-18
4.2.6.1 Lithologies 4-18
4.2.6.2 Structural Geology 4-20

4.2.6.3 Mineralization 4-20
4.2.6.4 Surficial Deposits 4-20
4.3 References 4-22

List of Figures

FIGURE **PAGE**

Figure 4.2-1. Regional Geology of the Slave Structural Province and Simplified Geology of the Hope Bay Volcanic Belt 4-2

Figure 4.2-2. Geology Map of the Hope Bay Volcanic Belt 4-4

Figure 4.2-3. Regional Structures for the Hope Bay Volcanic Belt 4-5

Figure 4.2-4. Detailed Geology Map of the Boston Area 4-10

Figure 4.2-5. Detail of Major Structures and Relationship to Boston Area Infrastructure 4-12

Figure 4.2-6. Schematic Cross-section of the West-East Section of the Boston Mineralization 4-13

Figure 4.2-7. Bedrock Geology of the Doris Deposit on the Western Shore of Doris Lake 4-15

Figure 4.2-8. Regional Faults in the Doris Area 4-16

Figure 4.2-9. Schematic West East Section of the Doris Deposit Showing the Folded Mineralization in the Doris Hinge 4-17

Figure 4.2-10. Bedrock Geology of the Madrid Deposit Area 4-19

Figure 4.2-11. Fault Architecture in the Madrid Area in relation to Existing and Proposed Infrastructure 4-21

List of Tables

TABLE **PAGE**

Table 4.2-1. Historical Geophysical Surveys of the Hope Bay Greenstone Belt 4-6

Table 4.2-2. Summary of Holes Drilled on the Hope Bay Project 4-9

Glossary and Abbreviations

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

DEFZ	Deformation Zone
DIAND	Department of Indian and Northern Affairs
HBVB	Hope Bay Volcanic Belt
ICP	Inductively-coupled plasma
IP	Induced polarization
Ma	Mega-annum (million years)
Ga	Giga-annum (billion years)
NRCan	Natural Resources Canada
The Project	Madrid-Boston Project

4. Geology

4.1 INTRODUCTION

In this section, a description of the geology of the Hope Bay Volcanic Belt is provided, outlining the regional geological setting and evolution of the bedrock geology and surficial Quaternary geology. This is followed by a more detailed review and description of each of the three deposits found within the belt. These include the Boston, Doris and Madrid deposits.

4.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

4.2.1 Regional Setting

4.2.1.1 Bedrock Geology

The Hope Bay Volcanic Belt (HBVB) is a greenstone belt that is located in the northeast portion of the Slave Structural Province and represents one of many Archean age belts that characterise the Slave Structural Province (Figure 4.2-1). Greenstone belts of the Slave province are subdivided into mafic volcanic-dominated, Yellowknife-type and felsic volcanic-dominated, Hackett River-type (Padgham 1985) and are intruded by felsic to intermediate plutons.

The HBVB is classified as a Yellowknife-type, typified by massive to pillowed tholeiitic flows interbedded with calc-alkaline felsic volcanic and volcaniclastic rocks, clastic sedimentary rocks, and rarely synvolcanic conglomerate and carbonates. Rifting and associated bimodal volcanism in the Slave province occurred between 2,715 Ma and 2,697 Ma (Davis and Bleeker 1999; Bleeker and Hall 2007) and was followed by widespread arc-like volcanism adjacent to and locally overlying the basement and volcanic cover at 2,687 Ma to 2,660 Ma (Henderson 1970; Bleeker and Hall 2007). This volcanic phase was followed at approximately 2,600 Ma by regional transtensional deformation resulting in north-south (N-S) trending folding, uplift and deposition of a series of fault bounded “Timiskaming-type” conglomerates and sandstones (Fyson and Helmsteadt 1988; Padgham 1996; Villeneuve and Relf 1998; Bleeker et al. 1999a, 1999b). The plutonic rocks that intrude the greenstone belts comprise 2.70 Ga to 2.64 Ga predeformation tonalite and diorite; 2.62 Ga to 2.59 Ga K-feldspar megacrystic granite, and post-deformation 2.60 Ga to 2.58 Ga two-mica granites (Villeneuve et al. 1997).

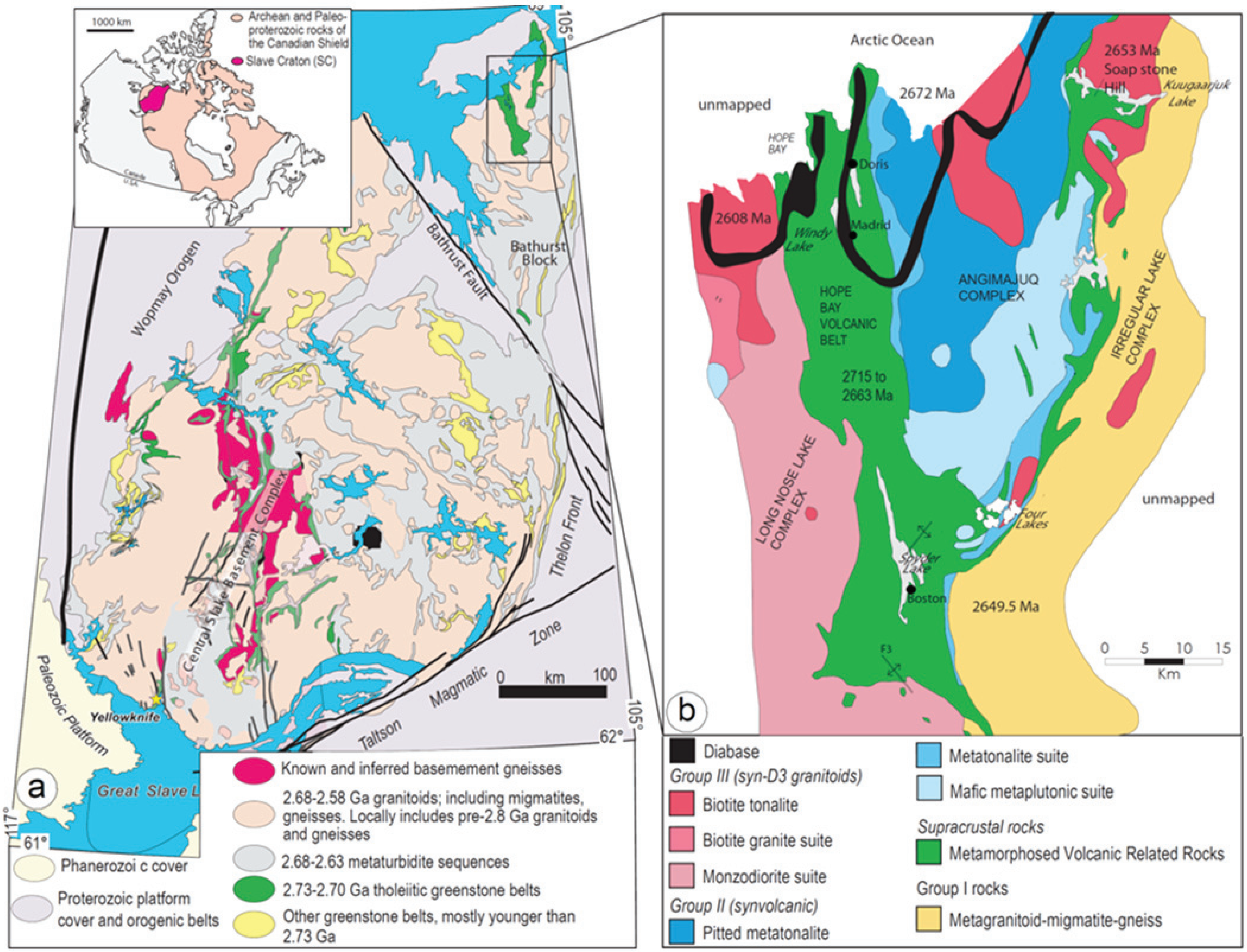
4.2.1.2 Quaternary Geology

Multiple Quaternary Ice Ages produced an extensive glaciated landscape that was covered by successive Laurentide ice sheets. The last Ice Sheet, which formed during the Late Wisconsin Glacial Episode, reached its climax approximately 25,000 to 21,000 years ago (Last Glacial Maximum) with ice flow directions towards the north-northwest and north. The Ice Sheet started receding about 8,800 years ago (Dyke and Prest 1986), melting back towards the southwest, leaving an extensive blanket of basal till. Immediately following the de-glaciation the entire Hope Bay region was submerged approximately 200 metres below present mean sea level (Dyke and Dredge 1989). Fine sediment, derived from meltwater (rock flour), was deposited onto the submerged Hope Bay shelf as marine clays and silts onto the basal tills. The greatest thicknesses accumulated in the deeper water zones, now represented by valleys.

Isostatic rebound after the de-glaciation, resulted in emergent landforms and reworking of the unconsolidated marine sediments and tills along the prograding shoreface (EBA 1996). Sediments were easily stripped off the uplands and redeposited in valleys, leaving relatively continuous north-northwest

Figure 4.2-1

Regional Geology of the Slave Structural Province and Simplified Geology of the Hope Bay Volcanic Belt



trending bedrock ridges and elongate lakes. The unconsolidated overburden, now up to 30 m in thickness, comprises locally and regionally derived tills and boulder tills with lacustrine and marine sediments and clay up to 15 m thick in the larger valleys.

4.2.2 Local Setting

The Hope Bay Project area covers most of the land underlain by the HBVB and includes the Boston, Doris and Madrid deposits (Figure 4.2-2). Gold mineralization is variable in terms of mineralization style and relationship to the host volcanic sequences (Sherlock et al. 2012). The Boston deposit is located near the south end of the belt and is associated with a flexure in the Hope Bay regional structure. The Doris deposit consists of a steeply dipping, four kilometre long quartz vein system in folded and metamorphosed pillow basalts and is situated on an inferred inflexion in the regional Hope Bay Break.

The Madrid deposit, consists of three styles of veining and brecciation specific to the Matrim, Perrin, and Rand zones.

The Hope Bay belt, together with the Elu belt forms part of the Bathurst Block, a large area dominated by granitoids and gneissic migmatites that is isolated from the Slave province by Proterozoic platform cover of the Kilohibok Basin (Campbell and Cecile 1976; Figure 4.2-1). A granodiorite northeast of the Hope Bay belt gave a U-Pb zircon age of 2,672 +4/-1 Ma (Figure 4.2-1), suggesting a syn- to late-volcanic age of emplacement (Bevier and Gebert 1991). In contact with the southeastern belt (Figure 4.2-1) is a heterogeneous gneiss terrane that yielded a U-Pb zircon age of 2,649.5 +2.9/-2.5 Ma and a younger titanite age of 2,589 Ma, possibly representing a metamorphic age (Hebel 1999). To the northwest of the belt, plutonic rocks contain foliated mafic fragments at 2,608 ± 5 Ma. This places a lower limit on the age of deformation and metamorphism (Bevier and Gebert 1991), which is of lower greenschist facies within the belt and amphibolite facies near the belt margins. Structural geology of the belt is complex with three major ductile deformation events (D_1, D_2, and D_3) recognised (Sherlock et al. 2012). The earliest tectonic fabric, developed during D_1, is represented by an S_1 fabric that parallels the lithological layering, representing an early transposition fabric. This may contain isoclinal (F_1) folds with an S_1 axial planar fabric (Sherlock et al. 2012). S_1 is overprinted by an S_2 fabric with associated F_2 folds representing the D_2 deformation event. S_2 forms the dominant penetrative to spaced planar foliation in the belt, is generally oriented N-S, and commonly forms a composite $S_0/S_1/S_2$ transposition fabric (Sherlock et al. 2012). F_2 folds and associated mineral fold axis parallel stretching lineations, are steeply plunging. D_3 is recognised as a spaced, locally developed S_3 foliation associated with NE-SW trending domains that are axial planar to open F_3 upright folds.

As is typical of Archaen greenstone belts, a complex system of compressional structures are found within the Hope Bay Volcanic Belt (Figure 4.2-3). The structural architecture is dominated by a N-S trend, which parallels the greenstone belt and comprises a system of anastomosing Archean to Proterozoic structures. A series of mainly eastward directed thrusts are recognised as well as NE and SE structural trends.

Mineralization is associated with D_2 structures and specifically N-S, S_2 parallel shear zones. These host auriferous quartz carbonate shear veins associated with widespread ion-bearing carbonate alteration developed as an ankerite-ferroan dolomite-sericite-pyrite assemblage. Shear zones range in width from 1 to 10 m and may extend for several kilometres (Sherlock et al. 2012). Evidence of late reactivation of the N-S shear zones has also been observed displacing the NE-trending Proterozoic diabase dykes (Sherlock et al. 2012) that cut the Archean stratigraphy (Figure 4.2-1). This was followed by a system of Late NE or NW striking brittle faults with a subvertical dip and normal displacement (Sherlock et al. 2012).

Figure 4.2-2

Geology Map of the Hope Bay Volcanic Belt

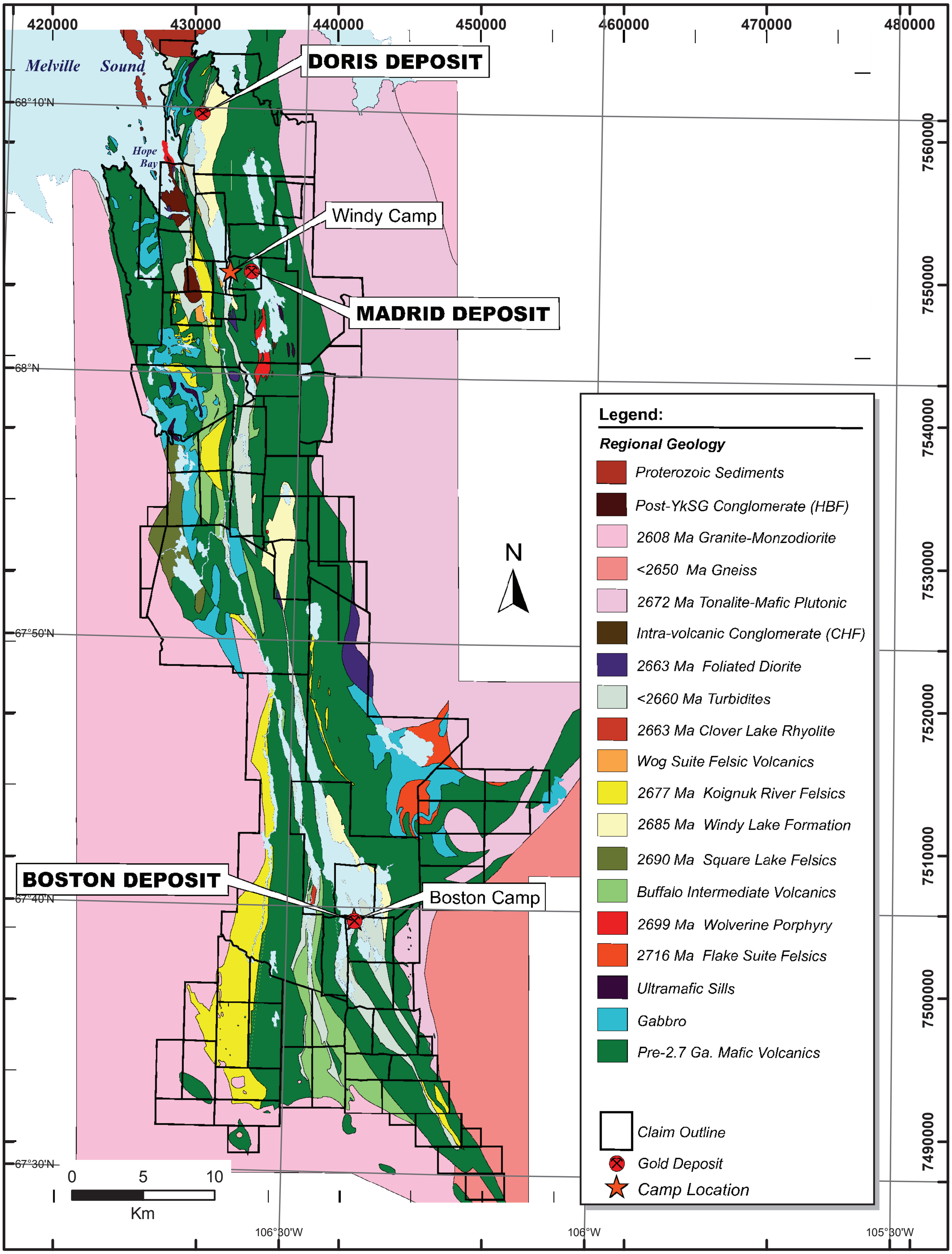
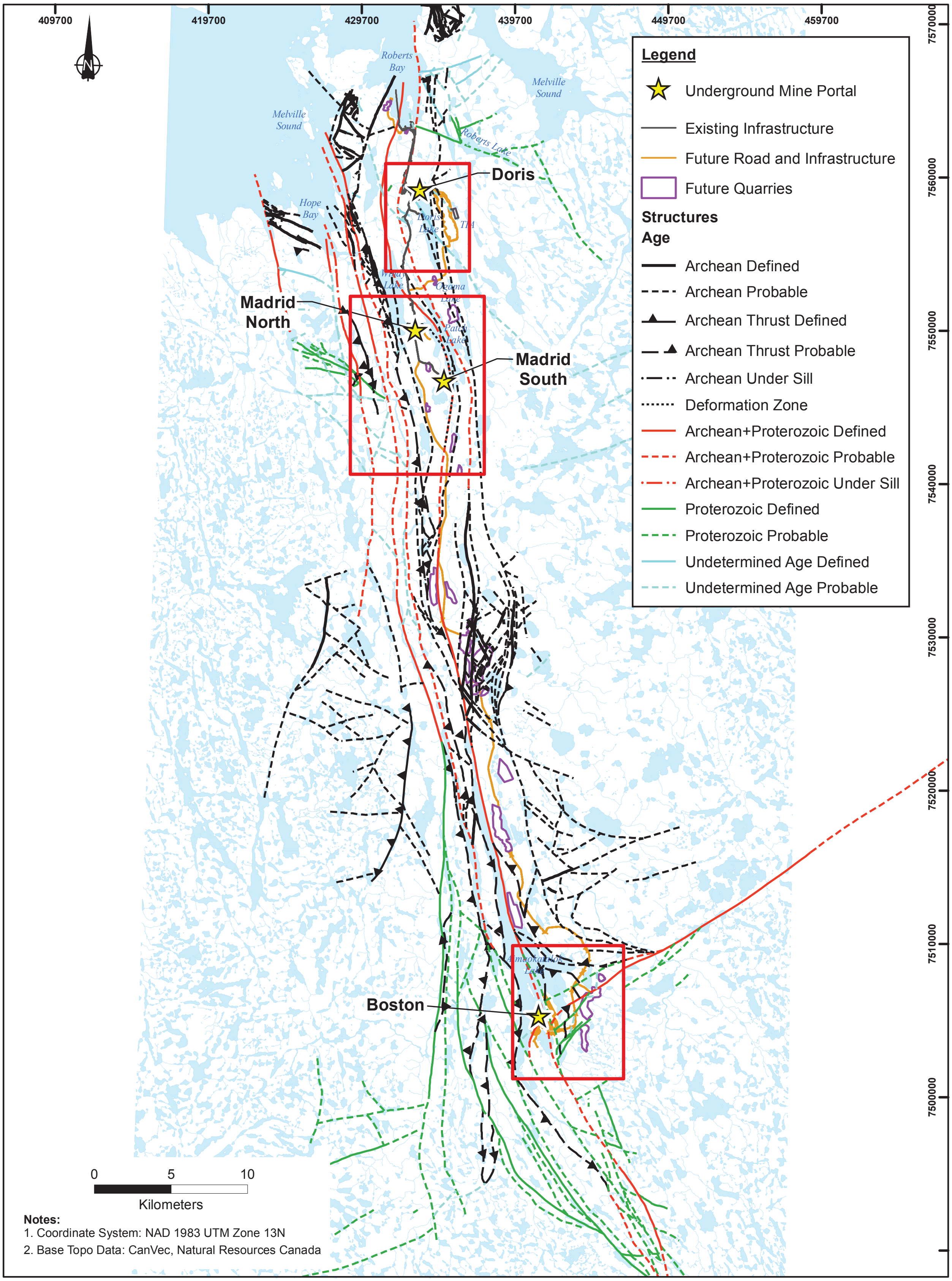


Figure 4.2-3

Regional Structures for the Hope Bay Volcanic Belt



Source: SRK, 2016.

4.2.3 Data Sources

4.2.3.1 Topographic, Bathymetric and Air Photograph Data

Baseline geological investigations rely on high precision terrain data, which include:

- Air photographs (stereopair images): These include the flightlines from July 1996 at a scale of 1:15,000 covering the Hope Bay area.
- Orthophotographs: These are available from 2002, 2007, and 2010 in monochrome and colour.
- Satellite data (Photosat): Coverage of the area at 50 cm resolution from 2012.
- LIDAR: Coverage of specific sites within the Hope Bay is available from 2007.
- Topographic maps: Bathymetry maps are available. Bathymetric surveys were undertaken in 2006 of Roberts Bay, Doris Lake, Tail Lake, Patch Lake, Aimaokatalok Lake and Windy Lake. Additional bathymetric surveys were undertaken in 2010 of Aimaokatalok Lake and Stickleback Lake. Bathymetry was also obtained for Wolverine Lake.
- Contour data utilized is from 2007 orthophoto data, generated by Aero Geometrics with a contour interval accuracy of approximately 1.0 m for the Boston area and approximately 0.5 m for the Madrid and Doris areas. Additionally digital elevation models for the entire belt are with 1 m resolution were obtained from satellite data (Photosat) in 2012.

4.2.3.2 Geophysical Data

The Hope Bay volcanic belt has seen extensive geophysical coverage (Table 4.2-1). This includes full coverage by aeromagnetic, gravity, and conductivity/resistivity data. Radiometric and ground magnetic data cover approximately one quarter and one third of the belt, respectively. Induced polarization (IP)/resistivity and seismic surveys have been completed on several prospects. Newmont had collated the data from earlier programs, and in many cases, re-processed the airborne magnetic and ground magnetic data.

Table 4.2-1. Historical Geophysical Surveys of the Hope Bay Greenstone Belt

Year	Survey Type	Survey Details	Contractor	Location
1993	GMAG	552 line-km, 20 km², variable 25 m and 50 m line spacing, 2 m sensor height	Contractor not specified	Boston, Patch, Fickleduck
1993	AMAG, DIGHEM, VLF, ARAD	2,657 line-km, 263 km², 100 m line spacing, 40 m sensor height	Geoterrex	Boston, Mid-belt Corridor, QSP
1993	AMAG, DIGHEM, VLF	925 line-km, 168 km², variable 100 m and 200 m line spacing, 40 m sensor height	Geoterrex	QSP, Chicago, Barney
1994	GMAG, VLF	82 line-km, 4.0 km², 50 m line spacing, 2 m sensor height	Geoterrex	Kamik, South-West Patch
1994	AMAG, DIGHEM, VLF	3,328 line-km, 329 km², 100 m line spacing, 40 m sensor height	Geoterrex	Patch, Boston, North and Central Corridor
1995	GMAG, VLF	182 line-km, 8.8 km², 50 m line spacing, 2 m sensor height	Contractor not specified	Doris, Discovery, Boston
1995	AMAG, DIGHEM, VLF	4,700 line-km, 466 km², 100 m line spacing, 40 m sensor height	Geoterrex	Boston Region, North Doris
1995	AMAG, DIGHEM	477 line-km, 47 km², 100 m line spacing, 40 m sensor height	Geoterrex	Flake Lake
1996	GMAG, VLF	287 line-km, 15.7 km², 50 m line spacing, 2 m sensor height	Contractor not specified	North and South Patch, Wolverine

Year	Survey Type	Survey Details	Contractor	Location
1996	GMAG	1,235 line-km, 81 km², 50 m line spacing, 2m sensor height	Clearview Geophysics	Boston, Chicago, Daiwa, Discovery, Doris
1996	GMAG	157 line-km, 7.7 km², 50 m line spacing, 2 m sensor height	Contractor not specified	Kamik
1997	AMAG	880 line-km, 43.5 km², 50 m line spacing, 40 m sensor height	High Sense Geophysics	Madrid Corridor
1997	GMAG, VLF	19.6 line-km, 1.3 km², 100 m line spacing, 2 m sensor height	Contractor not specified	South Doris, North Patch
1997	GMAG	130 line-km, 10 km²,75 m line spacing, 2 m sensor height	Contractor not specified	North-West Boston
1997	Seismic Refraction	5.2 line-km, 7.5 m data spacing	Frontier Geoscience	Various locations in the Mid-belt
1997	Seismic Reflection	43 line-km, 7.5 m data spacing	Frontier Geoscience	Doris/Aimaokatalok Lake
1998	AMAG	3,776 line-km, 188 km², 50 m line spacing, 40 m sensor height	Geoterrex	Boston, Flake Lake, Gas Cache
1998	Seismic Refraction	2.5 line-km, 7.5 m data spacing	Frontier Geoscience	Boston Camp
2002	Seismic Refraction	11.6 line-km, 7.5 m data spacing	Frontier Geoscience	Nexus Area
2002	Seismic Reflection	56 line-km, 7.5 m data spacing	Frontier Geoscience	Windy/Patch Lake
2003	GMAG	30 line-km, 1.3 km², 50 m line spacing, 2 m sensor height	Aurora Geoscience	Inge
2003	Seismic Refraction	10.3 line-km, 7.5 m data spacing	Frontier Geoscience	Gas Cache
2005	Pole-Dipole IP	14.8 line-km, 100 m dipole spacing	Aurora Geoscience	Nexus, Naartok, Kink
2006	Pole-Dipole IP	31 line-km, 100 m dipole spacing	Aurora Geoscience	Havana, Patch, Peanut, Twin Peaks, Kink, Koig
2007	GMAG	3733 line-km, 91 km², 50 m line spacing, 2 m sensor height	Clearview Geophysics	Boston, Flying Squirrel, Windy Corridor
2008	Pole-Dipole IP (Titan-24)	12.5 line-km variable dipole spacing	Quantec Geoscience	Madrid/Boston
2008	Pole-Dipole IP (Conventional)	20 line-km, variable dipole spacing	Clearview Geophysics	Ak1, Ak3, Amarok
2009	Pole-Dipole IP	29 line-km, 100 m dipole spacing	Clearview Geophysics	Gas Cache, Kamik, Windy Lake, Kink
2009	Airborne assisted Ground Gravity	1,800 data points, 1,700 km², 1 km data spacing	Newmont Geophysics	Entire Hope Bay Belt
2011	Seismic Refraction	17 line-km, 7.5 m data spacing	Frontier Geoscience	Kink, Ogama, Main, Omayuk, Havana
2011	Pole-Dipole IP	5.5 line-km, 50 m dipole spacing	Aurora Geoscience	Omayuk, Peanut, QSP, North Tail
2011	Gradient IP	7 km²,100 m line spacing, 50 m dipole spacing	Aurora Geoscience	Omayuk, Peanut, QSP, Kink, North Tail
2011	AMAG/ARAD	2,865 line-km, 228 km², 100 m line spacing sensor height 40 m	Newmont Geophysics	6 blocks along the Belt margins
2015-2016	AMAG-TEM	12,123 line-km	SkyTEM Surveys Aps	Hope Bay Greenstone Belt
2016	AGG-HeliFALCON	12,676 line-km	CGG Canada Services	Hope Bay Greenstone Belt

Source: Varley, F. NI 43-101 Technical Report on the Hope Bay Project, March 2015

4.2.3.3 Geological Mapping

- A mapping campaign was completed by BHP at a scale of 1:10,000 over the Boston 18 and 19 claims and extended to cover the entire project holdings by the end of 1998. Further detailed mapping at a 1:100 scale was done for the Boston underground mine.
- Miramar undertook 1:5,000 scale geological mapping over the Project area.
- Newmont conducted numerous mapping campaigns from 2008:
  - 1:25,000 scale structural, stratigraphic, metamorphic and metallogenic mapping over the entire Project area;
  - 1:10,000 scale regional structural, metamorphic, and geological mapping of selected geological targets;
  - 1:5,000 scale structural and prospect mapping of selected geochemical and geophysical targets;
  - 1:2,000 scale structural and prospect mapping of selected prospects;
  - 1:1,000 scale prospect mapping; and
  - 1:50 scale detailed mapping.
- Surficial mapping on a regional scale, from air photographs in the Aimaokatalok Lake area was undertaken by J.M. Ryder and Associates for the University of British Columbia and BHP in 1992 (Ryder 1992).
- This was followed by more detailed surficial sediment and permafrost studies in 1996 by EBA Engineering Consultants of the Boston Gold Project.
- A surficial Quaternary geology map for the area is provided by Kerr and Knight (2001) Surficial Geology, Koignuk River. Geological Survey of Canada Map 1998A, scale 1:125,000.
- SRK undertook an Overburden Characterization in 2009 documenting specific geotechnical investigations of onshore and offshore overburden conditions (SRK 2009a).

4.2.3.4 Geochemical Sampling

- BHP collected approximately 24,000 samples of glacial till during the period 1991 to 1998. In 1994, a study of the variability of the soil geochemistry was undertaken.
- Miramar collected 15,300 rock and till samples in the Doris, North Madrid, and Daiwa areas from 2000 to 2008.
- In 2008, Newmont compiled the existing geochemical data. In addition to the compilation, Newmont collected 7,149 rock and tillite samples. Data collated included whole rock, inductively-coupled plasma (ICP) analyses, and gold assay data.

4.2.3.5 Underground Sampling

- BHP conducted an underground exploration and bulk sampling program on the Boston deposit between 1996 and 1997 for detailed analysis of grade, recovery, and metallurgical characteristics.

4.2.3.6 Petrology, Mineralogical and Research Studies

A number of studies have been completed on the Project, including the following theses:

- Clark D. B. 1996. *The Geology of the Boston Deposit, Hope Bay volcanic belt, Northwest Territories, Canada*. Unpubl. MSc Thesis, Queens University, Ontario, 94 p.

- Hebel, M.U. 1999. *U-Pb Geochronology and Lithogeochemistry of the Hope Bay greenstone belt, Slave Structural Province, Northwest Territories, Canada*. Unpubl. M.Sc. thesis, University of British Columbia, 96 p.
- Stemler, J. U. 2000. *A Fluid Inclusion and Stable Isotopic Examination of the Boston greenstone belt Hosted Archean Lode-Gold Deposit, Hope Bay volcanic belt, Nunavut, Canada*. Unpubl. MSc Thesis, University of Alberta, Edmonton, 212 p.
- Shannon, A.J. 2008. *Volcanic Framework and Geochemical Evolution of the Archean Hope Bay greenstone belt, Nunavut, Canada*. Unpubl. M.Sc. thesis, University of British Columbia, 211 p.

4.2.3.7 Geotechnical and Hydrological Studies

- SRK provided geotechnical and hydrological assessments for the Boston, Madrid and Doris pit designs and underground development in 2009 (SRK 2009b; SRK 2009c; SRK 2009d).
- SRK conducted a rock mass characterisation study of the Doris portal combing surface mapping and drill hole data (SRK 2010).
- SRK conducted a hydrogeological study of the system for the Doris project (SRK 2011a).
- SRK provided a geotechnical and hydrological assessment for the Doris central and Connector Underground Mines in 2011b (SRK 2011b).
- Since 1991, approximately 1,002,011 m has been drilled in 5,370 core and RC drill holes on the Project. Details of the various drilling programs are summarized in Table 4.2-2.

Table 4.2-2. Summary of Holes Drilled on the Hope Bay Project

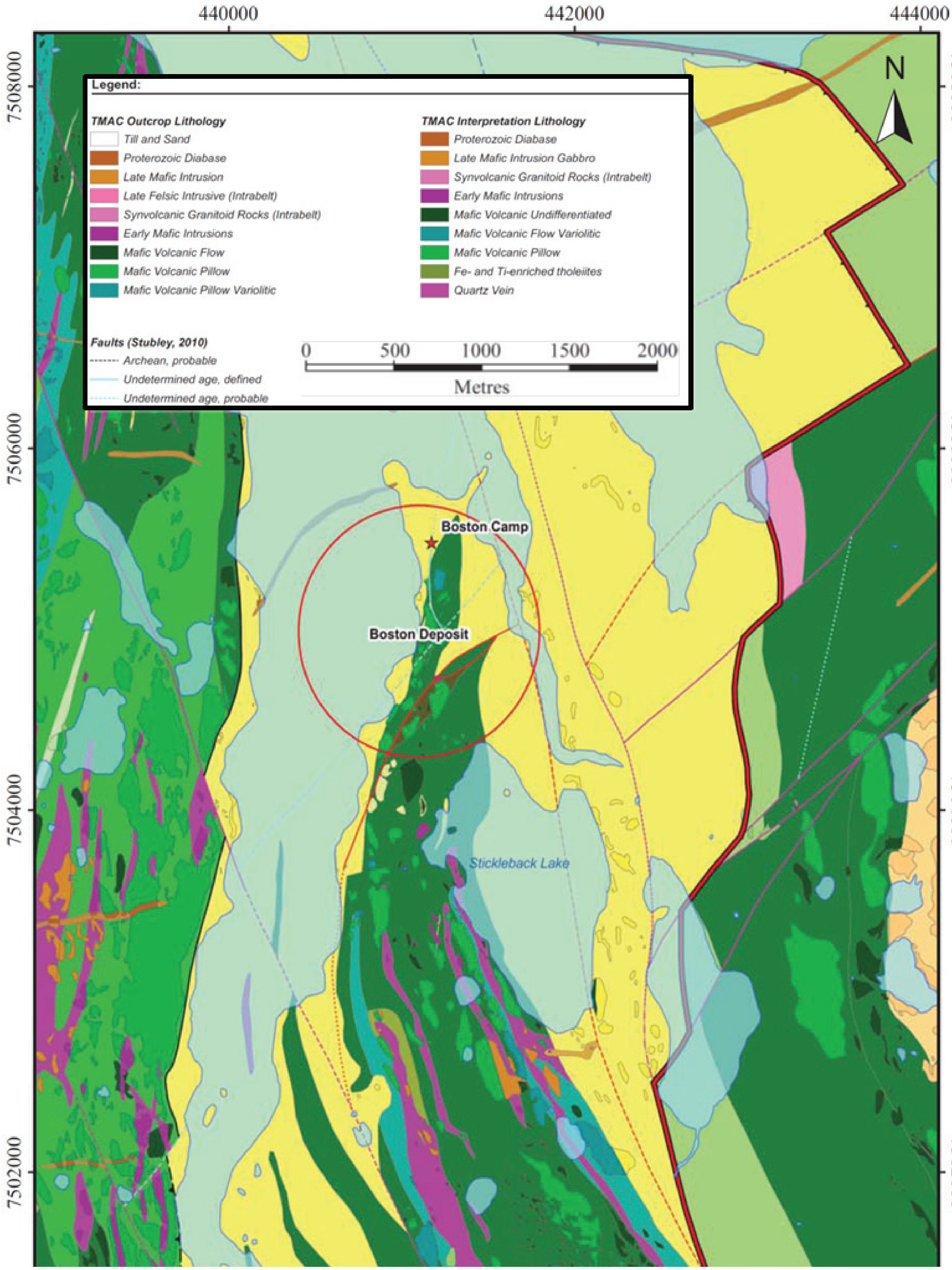
Company	Years	No. of Core Holes	Metres Drilled	No. of RC Holes	Metres Drilled
BHP	Pre 1999	933	195,269	328	6,111
Miramar/Cambiex JV	1999-2002	730	110,293	587	13,389
Hope Bay Maximus JV	2001-2009	58	9,536	-	-
Miramar	2003-2007	847	258,116	383	6,774
Newmont	2008-2012	873	212,617	108	15,081
TMAC	2013	63	29,622	-	-
TMAC	2014	152	67,530	-	-
TMAC	2015	120	33,153	-	-
TMAC	2016	95	27,231	-	-
TMAC	2017	69	16,825	24	464
Total		**3,940**	**960,192**	**1,430**	**41,819**

4.2.4 Boston Area

The Boston deposit is the larger of the known gold resources in the belt. Located in the south end of the greenstone belt, it is associated with an extensive iron carbonate alteration system with a strike length of over 9 km. The country rock geology comprises a bimodal assemblage of mafic pillowed basalts that have been subdivided texturally and geochemically (Figure 4.2-4). These are overlain by a sedimentary succession of greywacke to argillite. The transitional zone between the two successions, comprising reworked mafic-dominated epiclastic rocks is the main host to the Boston deposit (Sherlock et al. 2012).

Figure 4.2-4

Detailed Geology Map of the Boston Area



4.2.4.1 Lithologies

The mafic volcanic rocks recognized in the Boston area include the Boston suite and the East and West Spyder suites. These are characterised by pillow lavas that typically contain small, amygdaloidal, highly deformed pillow shapes that are unreliable way-up criteria and facing orientation is provided by pillow shelves. Interflow sediments are relatively common and comprise argillite with lesser chert. Variolitic and non-variolitic mafic volcanic rocks form consistent map units with non-variolitic units most abundant, underlying much of the map area. Although poorly exposed, a distinct variolitic phase is recognized in the Boston suite which can be correlated over several kilometres, containing large varioles, developed around pillow selvages and as coalesced varioles within pillows. Varioles may be highly elongate, defining a strong stretching lineation. The sedimentary succession, where exposed on the lakeshores ranges from quartzo-feldspathic wackes to a fine-grained argillite and are well-graded, providing facing directions.

4.2.4.2 Structural Geology

A large south–plunging, north-facing anticlinal fold dominates the geology of the Boston area. The core of the anticline is occupied by mafic volcanic rocks, that host the Boston deposit, and these are in turn overlain by sedimentary strata. The structure is defined by facing directions, recognized by graded bedding, bedding-cleavage relationships and from pillow shelves in the mafic volcanic rocks. The fold geometry is that of an elongate ellipsoid of mafic volcanic rocks surrounded by sedimentary rocks. The ellipsoidal shape is the result of either refolding or by development of a sheath fold (Stubley 2005).

The Fault architecture is shown in Figure 4.2-5. The fault system comprises a set of thrust faults that are offset by younger NE trending to ENE-trending faults. Newmont named four Faults, the Cambridge, Somerville, Brookline and Chelsea Faults within the proposed pit area, adjacent to the existing underground development (Figure 4.2-5). Drill core investigation by SRK (2008) showed that the faults typically contain a brecciated graphitic fault zone up to 1.5 m thick with a variable amount of soft gouge, between 2 and 15 cm. Fault damage zones were reported up to 7 m in thickness (SRK 2008).

4.2.4.3 Mineralization

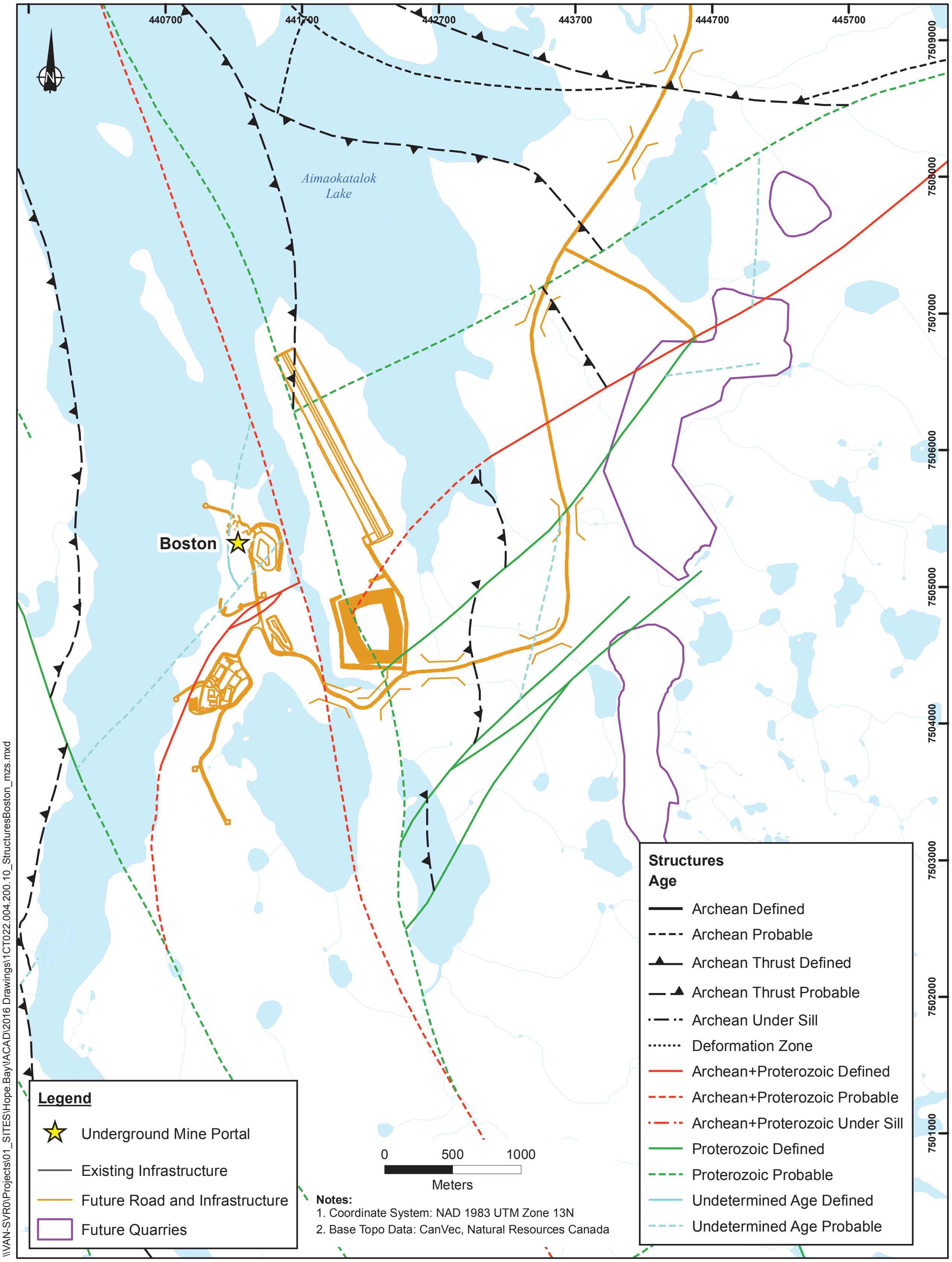
Gold mineralization is associated with a complex anastomosing high strain zone that has an orientation approximately axial planar to the main anticline, interpreted as a late D_2 structure (Sherlock et al. 2012). Auriferous veins are developed on the western side of the fold at the contact between the mafic and overlying sedimentary succession (Figure 4.2-6) and form a series of anastomosing fault fill veins on the western limb of the fold and at the contact with the overlying sedimentary rocks (Clarke 1996). Mineralization is associated with proximal ankerite, quartz and sericite, with a distal assemblage of chlorite and calcite (Sherlock and Sandeman 2004; Stemler et al. 2006).

4.2.4.4 Surficial Deposits

The Boston area has a low to moderate relief, of no more than 50 m. Surficial deposits that overly the bedrock, comprise: glacial tills, marine sediments, glaciofluvial deposits, lacustrine deposits and alluvial deposits (EBA 1996). Till is widespread, but mostly confined to elevations above 80 m elevation, where it is exposed on the flanks of bedrock outcrops as relatively thin, approximately 1 m thick infill and depressions in the bedrock, with a maximum thickness of 7 m recorded (EBA 1996). Till typically has a sand matrix with variable amounts of silt, gravel, cobbles and boulders. Till is overlain by marine deposits, approximately 5 m thick, which typically consist of silt and clay with traces of sand and shells present. In the southwestern portion of the area, marine deposits form two well defined terraces.

Figure 4.2-5

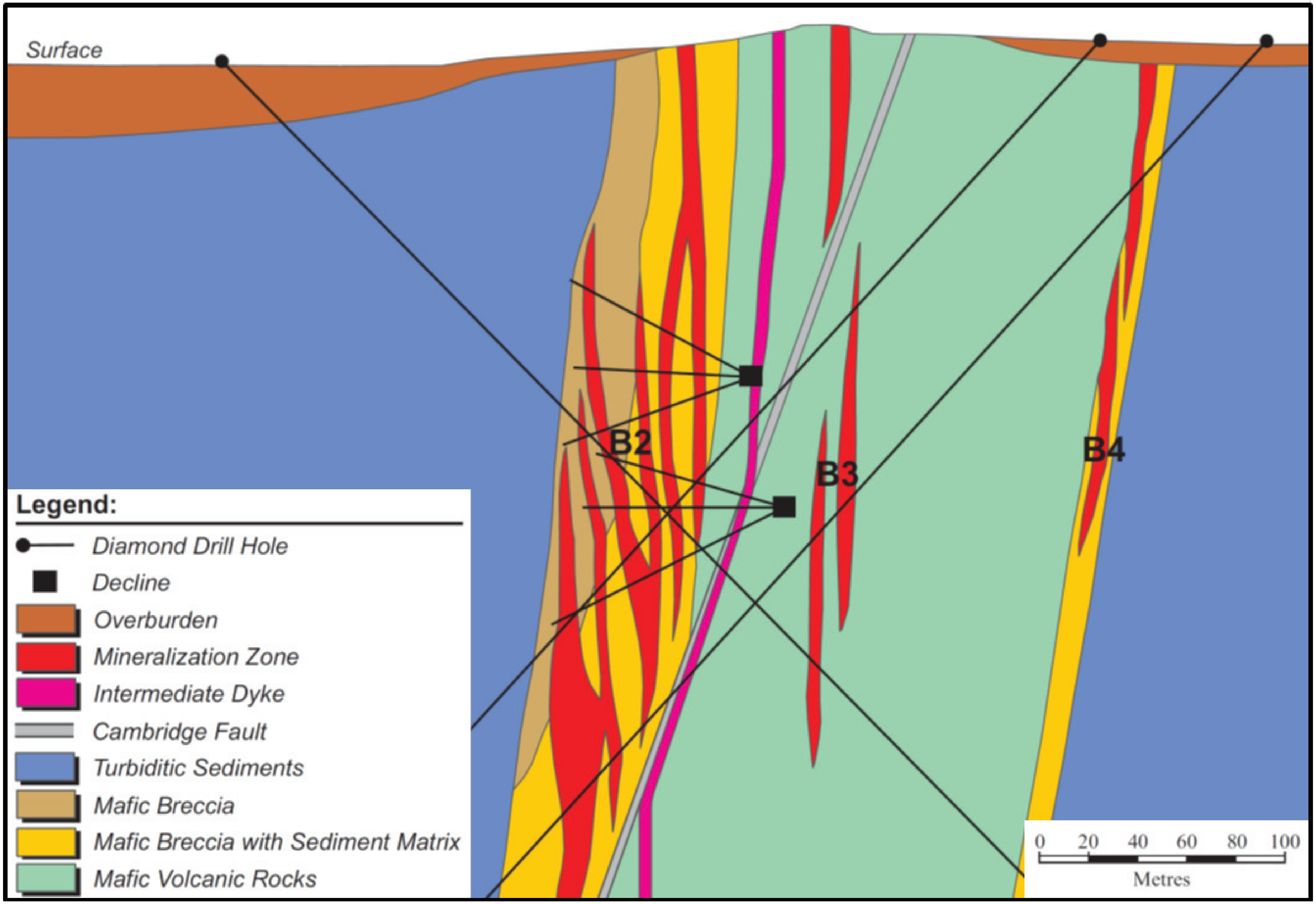
Detail of Major Structures and Relationship to Boston Area Infrastructure



Source: SRK, 2016.

Figure 4.2-6

Schematic Cross-section of the West-East Section of the Boston Mineralization



Marine deposits are overlain by glaciofluvial deposits developed as eskers and isolated patches of sand and gravel (EBA 1996). Sediment comprises mainly coarse sand with gravel, boulder and cobble lags. Eskers are typically 3 m high and between 10 and 12 m in width. Lacustrine deposits were exposed as lakes shrank and underlie plains and gentle slopes adjacent to lakes. Deposits typically comprise silt and sand with a few lenses of organic detritus. Two ages are recognised, a more recent (Holocene) and a Holocene-Pliocene age. Alluvial deposits are found within floodplains and low river terraces and consist of sand and gravel that may contain lenses of organic material (EBA 1996).

4.2.5 Doris Area

The Doris deposit is situated at the northern Hope Bay greenstone belt (Figure 4.2-7). Mineralization occurs within a steeply dipping, over 3 km-long quartz vein system in folded and metamorphosed pillow basalts. At the north end, the veins are folded forming a high-grade anticlinal hinge zone lying close to surface (the Doris Hinge; Figure 4.2-8). The anticlinal fold axis extends south through Doris Lake, marking the transition between east-facing strata on the east shore of Doris Lake and west-facing strata on the west shore of Doris Lake

4.2.5.1 Lithologies

Several distinct suites of mafic volcanic rocks are recognized in the Doris area and are broadly divisible into Mg and Fe tholeiites. Although this is based on the existing lithogeochemical database, the chemically distinct units a field and visual descriptor for each unit has been developed. The Fe tholeiites can contain elevated TiO_2 values and all rock units can be further subdivided based on the presence or absence of varioles, amygdales and magnetism (Carpenter et al. 2003).

4.2.5.2 Structural Geology

The dominant structure in the area is a tight to isoclinal antiform structure (Figure 4.2-7). The fold axis strikes approximately north-south and is doubly plunging. The antiform plunges shallowly to the north around the Doris deposit, and shallowly to the south at the south end of Doris Lake. The antiform axial plane is slightly inclined with an east vergence. The antiform is mapped based on younging directions from gas cavities in the pillowed Mg tholeiitic basalts.

Late brittle faults typically are less than one metre in width and be traced for over one kilometre (Figure 4.2-8). In several cases, stratigraphic offsets up to 5 m are recognized across these structures with a consistent apparent sinistral displacement. These structures offset the mineralization and three distinct faults are mapped and inferred in drill core; the Lakeshore Fault, the Glacier Fault and the Valley Fault. Interpreted displacements for all of these faults include left-lateral and north-side down movement. These faults do not cross-cut or offset the Franklin diabase. Faults are typically marked by rubble zones associated with sericitic alteration, slickensides, brecciation and clay gouge. Graphitic alteration, common at Madrid and Boston, has not been observed at Doris (SRK 2008).

4.2.5.3 Mineralization

Gold mineralization at Doris is hosted in a conformable succession of mafic volcanic and gabbroic rocks that are folded into a tight, shallowly north-plunging antiform. Mineralization is associated with continuous quartz veins with sericite and tourmaline-rich septa with Fe dolomite, sericite, paragonite, and pyrite alteration. Three significant, north-trending vein systems are known: West Valley Wall, Central, and Lakeshore veins (Figure 4.2-9). The Hinge zone occurs where the Central and Lakeshore veins merge. The overall geometry of the vein systems closely mimics the regional antiformal fold geometry in basaltic and gabbroic rocks. Textural relationships and vein geometries are consistent with vein precipitation along bedding-parallel fault zones during folding, developing a saddle-reef geometry during D_2 strain (Hodgson 1989; Carpenter et al. 2003).

Figure 4.2-7

Bedrock Geology of the Doris Deposit on the Western Shore of Doris Lake

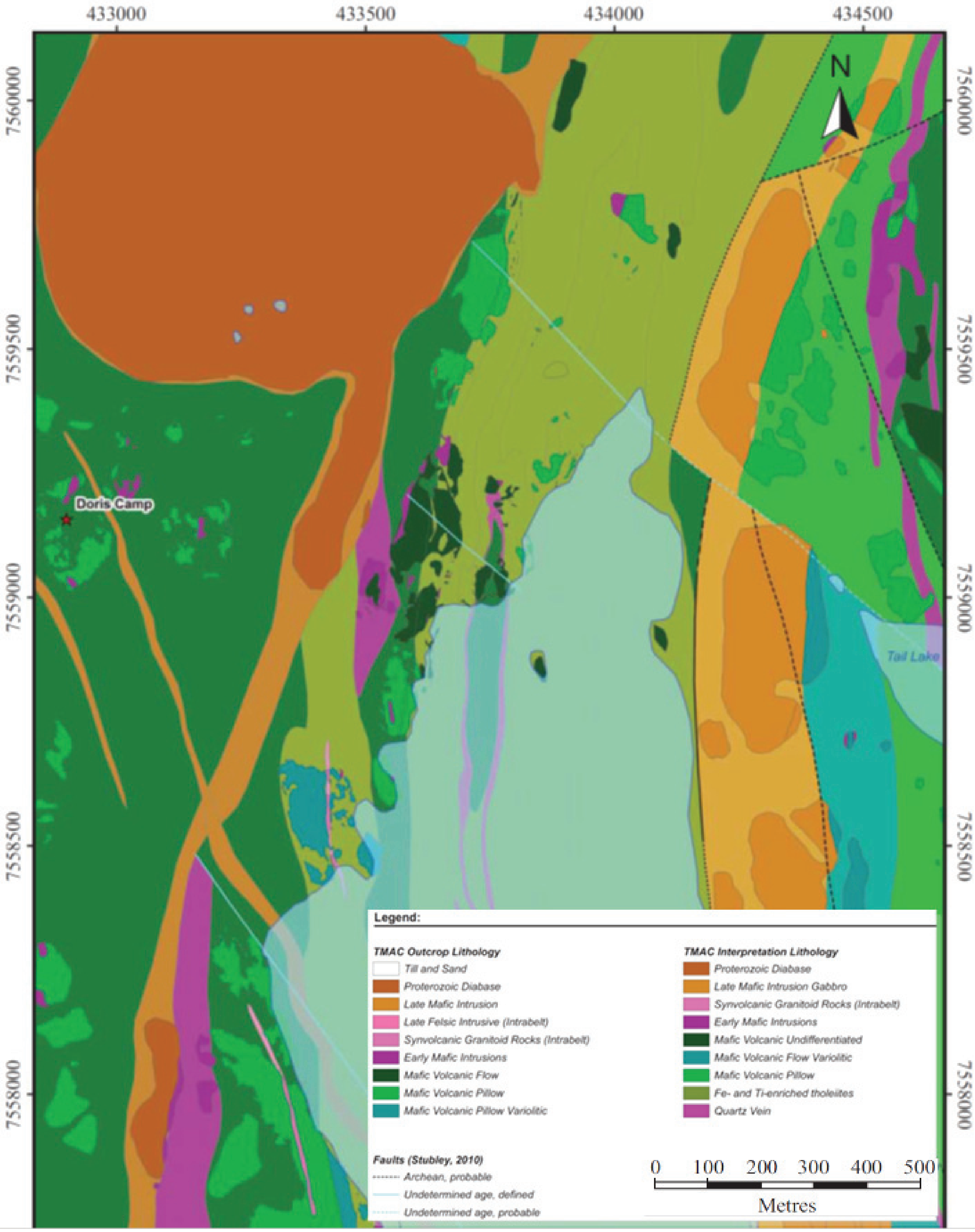
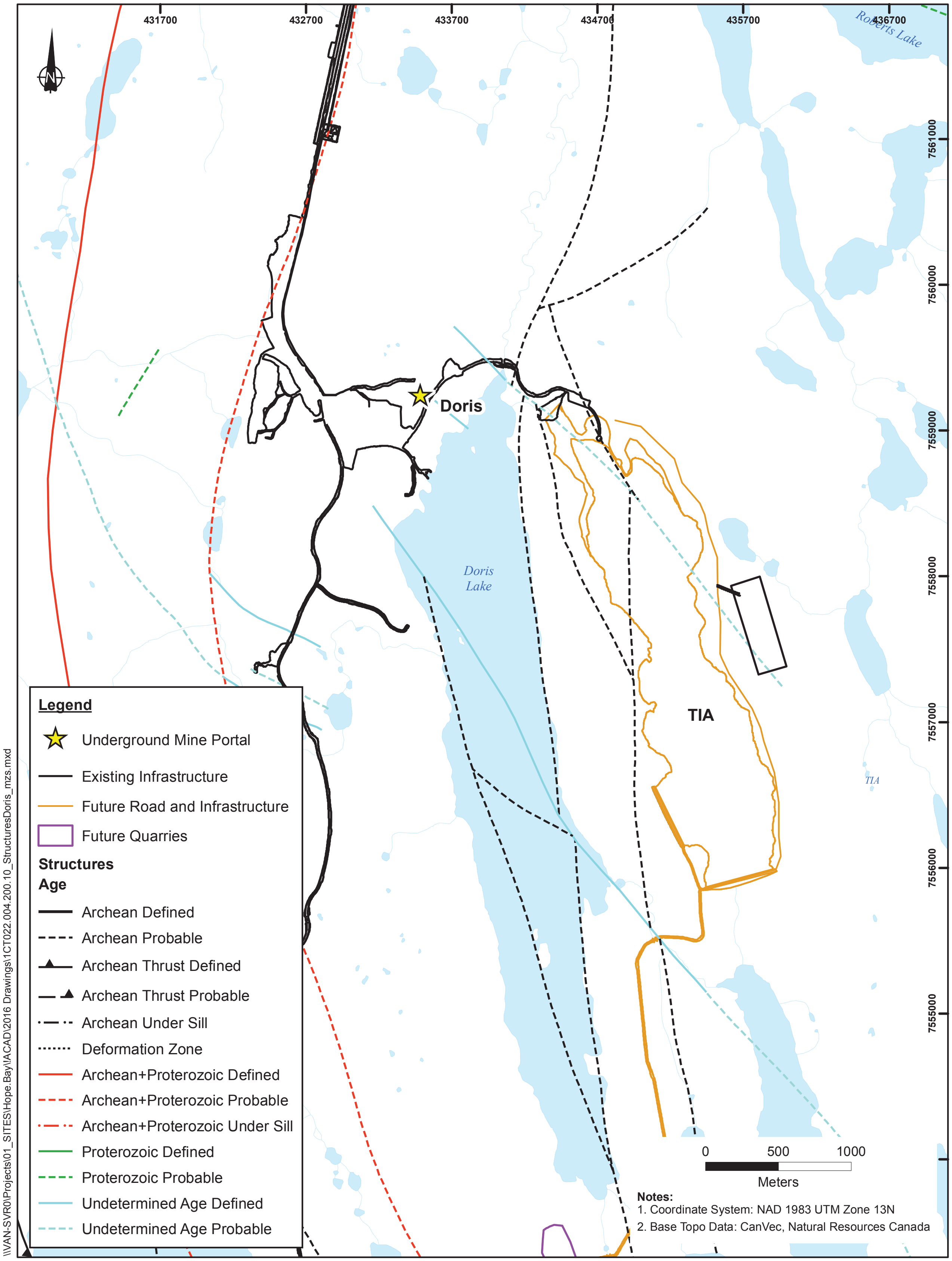


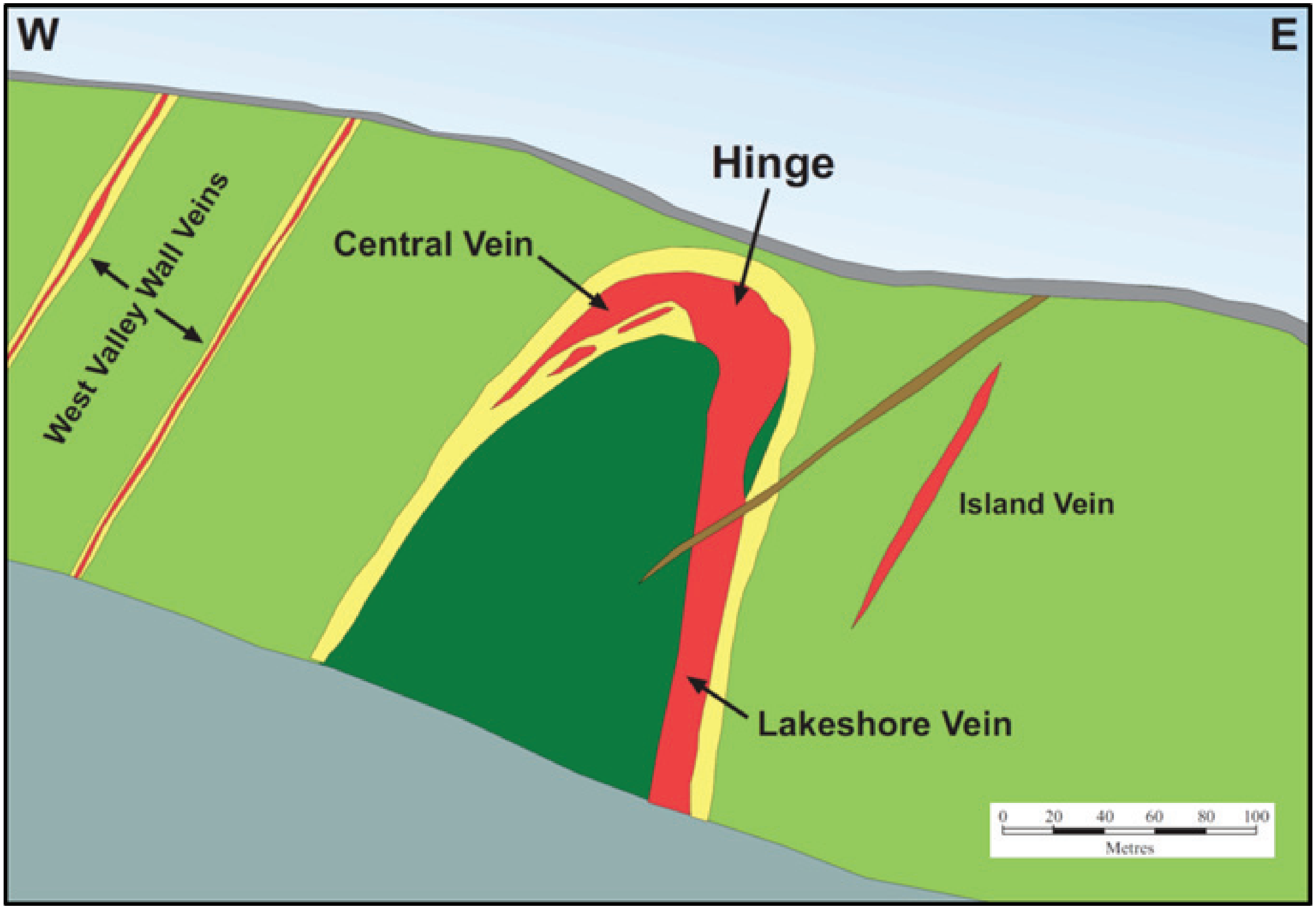
Figure 4.2-8
Regional Faults in the Doris Area



Source: SRK, 2016.

Figure 4.2-9

Schematic West East Section of the Doris Deposit Showing the Folded Mineralization in the Doris Hinge



4.2.5.4 Surficial Deposits

Surficial deposits at in the Doris area consist mainly of marine clay, silts and some sand (Kerr and Knight 2001; Thurber Engineering 2008) with thickness up to 20 m reported from between Roberts Bay and Tail Lake. Surficial geology is consistent with the Hope Bay region, although no Quaternary Late Wisconsin, glacial deposits were found exposed in the area (Thurber 2003). These are considered either buried by post-glacial marine deposits or have been reworked during the marine regression. Marine sediments comprise clay, silt, sand and gravel, with relatively common marine shells. Three subdivisions are recognised: marine veneer sediments (M1), marine blanket sediments (M2) and Littoral deposits (M3). M1 sediments are no more than 2.5 m thick and comprise clay to sand matrix with pebble, cobbles and boulders that fill depressions within the bedrock. M2 deposits comprise clay, silt and sand up to 20 m in thickness, generally with a coarsening upward sequence (Kerr and Knight 2001). These deposits are overlain by M3 littoral deposits that comprise sand, gravel, cobbles ad boulders deposited in emergent spit and beach deposits during the marine regression. These are typically less than 2 m thick and overlie either bedrock or the finer grained marine blanket (Thurber 2003).

4.2.6 Madrid Area

The Madrid deposit area is located in the north-central part of the belt, south of the Doris deposit (Figure 4.2-2). It includes the Wolverine-Madrid corridor which is defined as the belt of rocks extending from the southern end of Wolverine Lake to the northwest end of Patch Lake (Sherlock et al. 2002). The Madrid deposit area comprises the Naartok East, Naartok West, Rand, Suluk, Wolverine and Patch 14 deposits, while the Madrid trend includes the Spur, Suluk T3, South Suluk, and Patch 7 prospects.

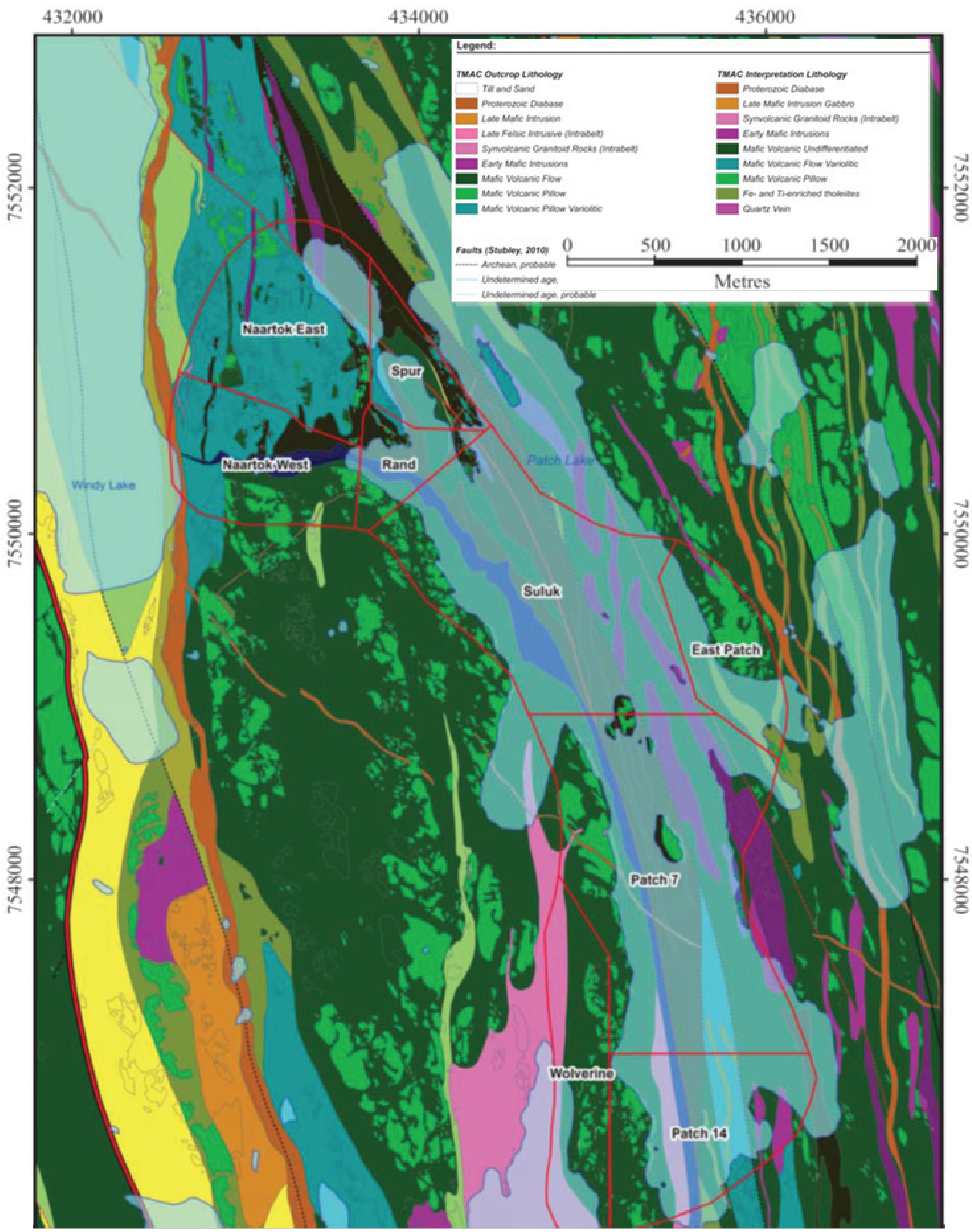
4.2.6.1 Lithologies

The rocks within the Madrid corridor consist primarily of north-south striking mafic volcanic rocks (Figure 4.2-10). These include a sequence of iron-titanium tholeiitic basalts, magnesium-tholeiitic basalts, komatiitic basaltics, synvolcanic to late gabbroic and ultramafic rocks (RPA 2015). Several intervals of felsic rocks are present in the immediate Wolverine area. These include felsic fragmental rocks and massive quartz-feldspar-phyric bodies. The fragmental rocks are distinguished by their clastic nature with numerous chloritic fragments, and coarse grained feldspar and quartz phenocrysts. Massive quartz-feldspar-phyric bodies are considered to represent small sub-volcanic intrusions or flows with the main felsic intrusive phase centred under Wolverine Lake.

Rocks of the northern Madrid area, Naartok West to Suluk, are classified based on textural and lithogeochemical similarities. The general stratigraphy of the area is composed of three major volcanic packages: Wolverine Group (C-type rocks), Patch Group (A-type rocks), and a C-type tholeiite (PGP) (Watts, Griffis and McQuat Limited 2006). The Naartok stratigraphy consists of a package of intercalated C-type and A-type basalts with interflow sediment, dipping to the north at Naartok West, and moderately westerly dipping in Naartok East. At Rand, stratigraphy consists of a steep northerly dipping package of C-type and A-type variolitic basalts and volcanics. Stratigraphy continues south to Suluk as south-southeast trending, steeply dipping, and west younging volcanic and interflow sediment packages (Watts, Griffis and McQuat Limited 2006).

Figure 4.2-10

Bedrock Geology of the Madrid Deposit Area



4.2.6.2 Structural Geology

Ductile strain is largely represented in the Madrid area by the main strain corridor of the Deformation Zone (DEFZ) and its associated splays, as well as within local zones of moderate to high strain (outside of the DEFZ). Intensity of the ductile strain increases towards the DEFZ where mafic volcanic rocks begin to exhibit pervasive intense foliation and locally show mylonitic textures. Splays off of the DEFZ preferentially develop along volcanic-sediment horizons, possibly related to the large competency contrast between massive flows and argillite-volcaniclastic layers. It is clear in both section and plan views that the DEFZ is not a single planar structure, but a complicated anastomosing feature with several splays and local pinch-and-swell textures.

A number of brittle faults occur in the Madrid area (Figure 4.2-11). Brittle and brittle/ductile structures are being recognised as drilling density increases in the Madrid area. Apparent discontinuities in alteration, mineralization and lithological units generally define a set of NW trending steep structures in the Naartok area and a structure partially defining the footwall contact of the Naartok East mineralised horizon. Graphitic faults with fault gouge are reported as well as healed quartz-carbonate breccias (SRK 2008).

4.2.6.3 Mineralization

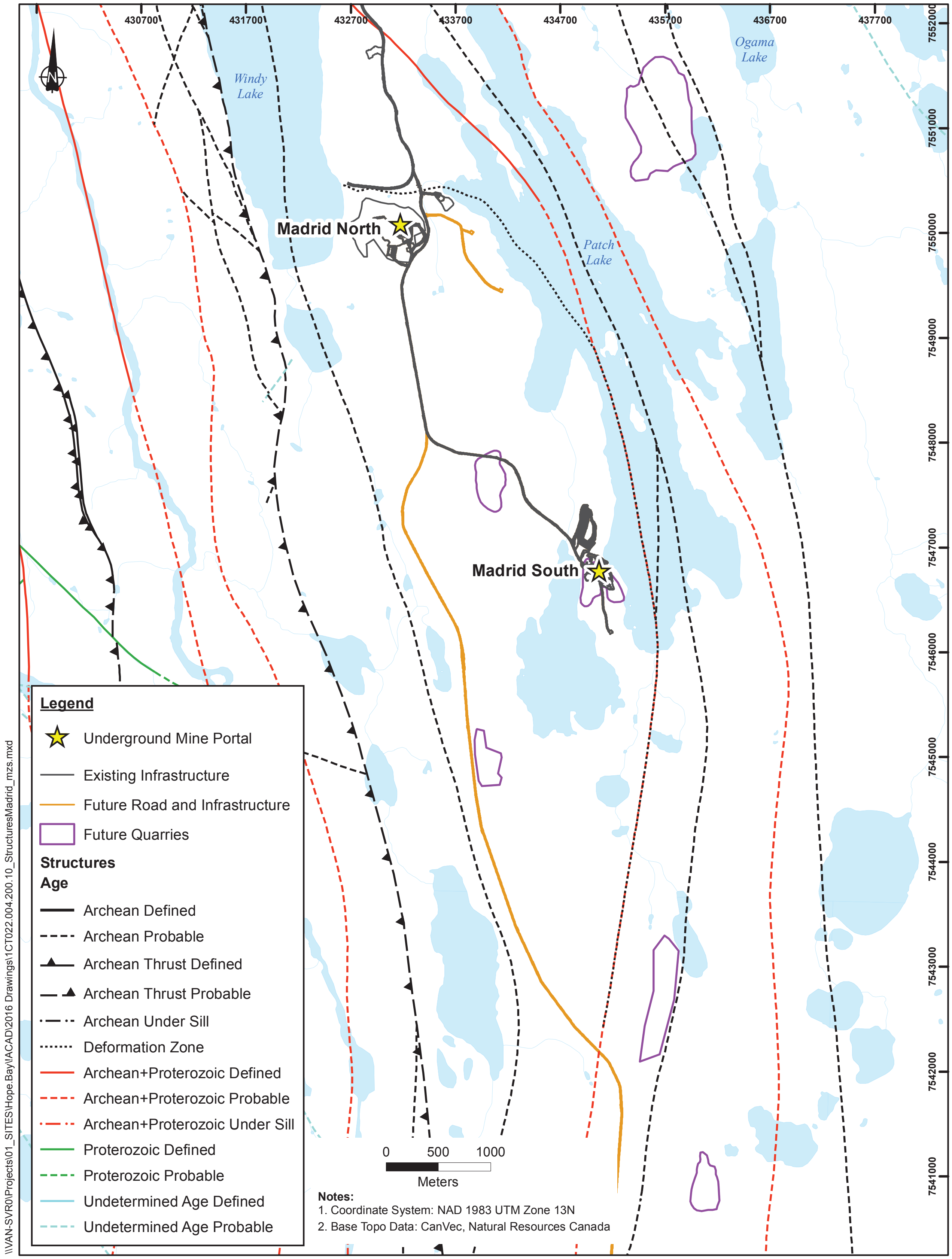
Gold mineralization is most commonly associated with high Fe-Ti tholeiites and is structurally controlled by the DEFZ and localized within the hanging wall of the zone. The DEFZ trends north-south from its southern extent at the Nexus area (south of Patch Lake) through to the northern portion of Patch Lake, where the DEFZ sharply changes orientation to an east-west trend across to Windy Lake. The style of mineralization, which is different to that of the Boston or Doris deposits, is characterised by replacement of favourable stratigraphic units (Madsen et al. 2007) and typically include Fe-rich tholeiitic basalts. Mineralization is associated with an early alteration assemblage of sericite and carbonate (magnesite and ankerite) with a stockwork of quartz-carbonate veinlets. Gold is associated with secondary albite and paragonite with lesser ankerite and quartz-ankerite stockwork veinlets. Higher gold tenor is associated with fine grained pyrite, intense albite flooding and hematite discolouration (Sherlock et al. 2012).

4.2.6.4 Surficial Deposits

The surficial geology for the Madrid area is consistent with the surficial geology for northern Hope Bay and the Doris area in particular (Kerr and Knight 2001). Surficial geology maps indicate the absence of glacial deposits in the area, these are considered either buried by post-glacial marine deposits or have been reworked during the marine regression. Marine sediments comprise clay, silt, sand and gravel, with relatively common marine shells. Three subdivisions are recognised: marine veneer sediments (M1), marine blanket sediments (M2) and Littoral deposits (M3). M1 sediments are no more than 2.5 m thick and comprise clay to sand matrix with pebble, cobbles and boulders that fill depressions between bedrock outcrops, and as a lag on washed bedrock and till surfaces. M2 dominates the area and comprises clay, silt and sand up to 20 m in thickness, commonly as a coarsening upward sequence. These deposits are overlain by M3 littoral deposits that comprise sand, gravel, cobbles and boulders deposited in emergent spit and beach settings during the marine regression (Kerr and Knight 2001).

Figure 4.2-11

Fault Architecture in the Madrid Area in relation to Existing and Proposed Infrastructure



Source: SRK, 2016.

4.3 REFERENCES

Bevier, M.L. and Gebert, J.S. 1991. U-Pb Geochronology of the Hope Bay-Elu Inlet area, Bathurst Block, northeastern Slave Structural province, Northwest Territories. *Canadian Journal of Earth Science* 28: 1925-1930.

Bleeker, W., and Hall, B. 2007. The Slave Craton: Geology and Metallogenic Evolution. *Geological Association of Canada, Mineral Deposits Division Special Publication* 5: 849-879.

Bleeker, W., Ketchum, J.W.F., Jackson, V.A., and Villeneuve, M.E. 1999a. The Central Slave Basement Complex Part I: Its Structural Topology and Autochtonous Cover. *Canadian Journal of Earth Sciences* 36: 1083-1109.

Bleeker, W., Ketchum, J.W.F., Jackson, V.A., and Villeneuve, M.E. 1999b. The Central Slave Basement Complex Part II: Age and Tectonic Significance of High-strain Zones along the Basement Cover Contact. *Canadian Journal of Earth Sciences* 36: 1111-1130.

Campbell, F.H.A., and Cecile, M.P. 1976. Geology of the Kilohigok basin, Goulburn Group, Bathust Inlet, District of Mackenzie, N.W.T. *Geological Survey of Canada Paper* 76-1A: 369-377.

Carpenter, R.L., Sherlock, R.L., Quang, C., Kleespies, P., McLeod, R. 2003. *Geology of the Doris North gold deposits, northern Hope Bay volcanic belt, Slave Structural Province, Nunavut*. Geological Survey of Canada, Current Research 2003-C6.

Clark, D.B. 1996. *The geology of the Boston deposit, Hope Bay volcanic belt, Northwest Territories, Canada*. Unpublished MSc thesis, Queens University.

Davis, W.J., and Bleeker, W. 1999. Timing of Plutonism, Deformation and Metamorphism in the Yellowknife Domain, Slave Province, Canada. *Canadian Journal of Earth Sciences* 36: 1169-1187.

Dyke, A.S., and Dredge, L.A. 1989. *Quaternary Geology of the Northwestern Canadian Shield*. In *Quaternary Geology of Canada and Greenland*. Ed. R.J.Fulton. Ottawa: Geological Survey of Canada.

Dyke, A.S., and Prest, V.K. 1986. *Late Wisconsin and Holocene retreat of the Laurentide Ice Sheet*. Geological Survey of Canada, Map 1702A

EBA. 1996. *Report on the Boston Gold Project. Surficial geology and Permafrost features*. Prepared for Rescan Environmental Services Ltd. Vancouver, BC.

Fyson, W.K., and Helmstaedt. H. 1988. Structural Patterns and Tectonic Evolution in the Archean Slave Province. *Canadian Journal of Earth Sciences* 25: 301-315.

Hebel, M.U. 1999. *U-Pb geochronology and lithogeochemistry of the Hope Bay greenstone belt. Slave Structural Province, Northwest Territories, Canada*. Unpublished MSc thesis, University of British Columbia.

Henderson, J.B. 1970. Stratigraphy of the Yellowknife Supergroup, Yellowknife Bay-Prosperous Lake area, District of Mackenzie. *Geological Survey of Canada Paper* 70-26: 12.

Hodgson, C.J. 1989. The structure of shear-related, vein-type gold deposits: A review. *Ore Geology Reviews* 4: 231-235.

Kerr, D.E., and Knight, R.D. 2001. *Surficial geology, Koignuk River*. Geological Survey of Canada map 1998A, scale 1:125,000.

Madsen, J.K., Sherlock, R., and Linday, D. 2007. *The geology, geochemistry and mineralization of the Naartok gold deposit: Hope Bay belt, Nunuvat Territory [abstract].* Geological Association of Canada Abstract, 52.

Padgham, W.A. 1985. Observations and speculations on supracrustal successions in the Slave Structural Province. *Geological Association of Canada Special paper* 28: 133-151.

Padgham, W.A. 1996. Slave conglomerate dating: Northern Affairs Program Northwest Territories: Department of Indian and Northern Affairs (DIAND), *Economic Geology Series paper*, 1996-12: 85.

Roscoe Postle Associates Inc. 2015. Technical Report on the Hope Bay Project, Nunavut, Canada. Project #2325, Toronto.Ryder, J.M. and Associates. 1992. *Syder Lake Area (Hope Bay Greenstone Belt) Terrain Analysis and Surficuial geology*. Prepared for W.K. Fletcher, Geological Sciences, University of British Columbia and BHP Utah Mines Ltd.

Shannon, A. 2008. *Volcanic framework and geochemical evolution of the Archean Hope Bay greenstone belt, Nunavut, Canada.* MSc thesis, University of British Columbia.

Sherlock, R.L. and Sandeman, H.A. 2004. *Volcanic stratigraphy and structural geology of the Boston area, Hope Bay volcanic belt, Nunavut*; Geological Survey of Canada, Current Research 2004-C2, 11.

Sherlock, R.L., Carpenter, R.L., Bardoux, M., Flood, E., and Kleespies, P. 2002. V*olcanic relationships and gold mineralization in the Wolverine-Madrid corridor, Hope Bay volcanic belt, Nunavut*; Geological Survey of Canada, Current Research 2002-C9, 11.

Sherlock, R.L., Shannon, A., Hebel, M., Lindsay, D., Madsen, J., Sandeman, H., Hrabi, B., Mortensen, J.K., Tosdal, R., Friedman, R. 2012. Volcanic Stratigraphy, Geochronology, and Gold Deposits of the Archean Hope Bay Greenstone Belt, Nunavut, Canada. *Economic Geology* 107: 991-1042.

SRK Consulting (Canada) Inc. 2008. *Hope Bay Structural Geology Memo*. Prepared for SRK and Newmont Mining Corporation. Project No.: 2CH009.000. June 2008.SRK Consulting (Canada) Inc. 2009a. *Hope Bay Gold Project Overburden Characterization Report*. Prepared for Hope Bay Mining Limited. Project No.: 1CH008.002. June 2009.

SRK Consulting (Canada) Inc. 2009b. *Geotechnical and Hydrological Assessment for the Boston Open Pit, Nunavut, Canada.* Prepared for Hope Bay Mining Limited. Project No. 2CH009.000. June 2009.

SRK Consulting (Canada) Inc. 2009c. *Geotechnical and Hydrological Assessment for the Madrid Open Pit and Underground, Nunavut, Canada.* Prepared for Hope Bay Mining Limited. Project No. 2CH009.000. June 2009.

SRK Consulting (Canada) Inc. 2009d. *Geotechnical and Hydrological Assessment for the Doris North Open Pit and Doris Central Underground, Nunavut, Canada.* Prepared for Hope Bay Mining Limited. Project No. 2CH009.000. June 2009.

SRK Consulting (Canada) Inc. 2010. *Doris North Portal Investigation*. Prepared for Hope Bay Mining Limited. Project No. 2CH009.001. September 2010.

SRK Consulting (Canada) Inc. 2011a. *Water Quality Model*. Prepared for Hope Bay Mining Limited. Project No. 2CH008.047. November 2011.

SRK Consulting (Canada) Inc. 2011b. *Stage 2 Geotechnical and Hydrogeological Assessment for Doris Central and Connector*. Prepared for Hope Bay Mining Limited. Project No. 2CH008.054, November 2011.

Stemler, J.U. 2000. *A fluid inclusion and stable isotopic examination of the Boston greenstone belt hosted Archean lode gold deposit, Hope Bay volcanic belt, Nunavut,* Canada. MSc thesis, University of Alberta.

Stemler, J.U., Richards, J.P. and Muehlenbachs, K. 2006. A fluid inclusion and stable isotope investigation of the Boston lode-gold deposit, Hope Bay volcanic belt, Nunavut. *Exploration and Mining Geology* 15: 101-121.

Stubley, M. 2005. *Kilometer scale sheath folds in the Slave Craton.* Yellowknife Geoscience Forum, Program with Abstracts.

Thurber Engineering Ltd. 2003. *Hope Bay Doris North Project, Nunavut, Surficial Geologic Mapping, October 1, 2003.*

Thurber Engineering Ltd. 2008. *Hope Bay Doris North Project, Nunavut, Surficial Geologic Mapping.* 17-713-35, Vancouver, 6.

Varley, F., VP Operations, TMAC Resources Inc. 2015. Mine plan updated from Roscoe Postle Associates Inc. NI 43-101 Technical Report on the Hope Bay Project, Nunavut, Canada, March 2015.

Villeneuve, M.F., and Relf, C. 1998. Tectonic setting of 2.6 Ga carbonatites in the Slave province, northwest Canada. *Journal of Petrology* 39: 1975-1985.

Villeneuve, M.F., Henderson, J.R., Hrabi, R.B., Jackson, V.A., and Relf, C. 1997. *2.70-2.58 Ga plutonism and volcanism in the Slave province, District of Mackenzie, Northwest Territories.* Geological Survey of Canada Current Research 1997, report 10, 37-60.

Watts, Griffis and McQuat Limited. 2006. *A technical review of the Hope Bay Gold Project, west Kitikmeot Nunavut Territory, Canada.* Prepared for Miramar Mining Corporation: Toronto, ON.