GOLD MINERALIZATION IN THE VIRGINIA HORN GREENSTONE TERRAIN, ST. LOUIS COUNTY, MINNESOTA

Minnesota Department of Natural Resources
Division of Lands and Minerals
*Project Number 371

*Revised from project number 370 which was a different project.

Visible gold within quartz vein, Virginia Horn Greenstone Terrain. Sample taken from outcrop where gold was first discovered in the area. Field of view is 2mm wide.

Executive Summary

Mineralogical, geochemical and fluid inclusion data from archived drill core have been combined with a digital compilation of historic exploration data and new maps to reassess the gold mineralization potential of the Virginia Horn Greenstone Terrain, a thirty square mile exposure of Wawa subprovince rocks located in St. Louis County, Minnesota.

The Virginia Horn Greenstone Terrain (Virginia Horn) consists of a folded and faulted metamorphosed assemblage of Archean volcanic and sedimentary strata, intruded by a quartzofeldspathic porphyry (QFP) and overlain by a conglomerate sequence that was interpreted by Jirsa and Boerboom (2003) as a Timiskiming-type package. Metamorphic grade varies from prehnite-pumpellyite to middle greenschist facies. A notable feature of the Virginia Horn is bedrock exposures that cover approximately 10% of total surface area; this is relatively extensive when compared with other glaciated Archean terrains in Minnesota.

Visible gold within QFP outcrops were first identified in the 1930's. Gold is associated with quartz veining, carbonate-sericite alteration and major shear zones. Historic mineral leasing and gold exploration activity involved the completion of fifty-three diamond drill core borings, mostly within or near the highly-altered and sheared QFP. Assay results within portions of drill core were significant, but too inconsistent to be considered economic. There has been no drilling within the Virginia Horn since 1991, and all mineral leases held on state-owned or managed lands (which cover more than 50% of the terrain) have been allowed to expire.

Completion of subsequent geologic mapping and analog modeling (e.g. Jirsa 1998, Jirsa et al., 2005), combined with a resurgence of price-sensitive gold exploration activity prompted the Minnesota Department of Natural Resources (MnDNR) to reassess the potential for economic gold deposits within the Virginia Horn. A digital compilation was created of historic exploration activities and subsequent mineralogical and geochemical analyses were done on drill core housed in the MnDNR's drill core repository. This compilation includes the conversion of hard-copy sample location reports and laboratory reports into GIS-friendly maps, shape files and data tables. Drill core samples were reviewed to fill identified data gaps and better correlate drill core logs prepared by different companies, and new mineralogical, geochemical and fluid inclusion samples were collected to describe the gold mineralization.

Historic exploration efforts focused on a lode gold mineralization model for the QFP. The depth and density of drill cores completed using this model were not sufficient to rule out the possibility of economic lode gold deposits within the QFP. That said, reinterpretation of the Virginia Horn as a Timiskiming-type greenstone terrain would support new exploration efforts beyond the QFP, and into both the overlying basal conglomerate and associated country rock, particularly where major shearing and alteration is found.

Support for further evaluation within relatively unexplored portions of the Virginia Horn comes from a new visible gold occurrence, discovered during re-logging and examination of drill core DML-3 by Barry Frey, MnDNR. This bore hole intersected a major fault and was completed within a meta-argillite unit located approximately 8,000

feet from the QFP. The visible gold occurred in a quartz-calcite vein with local minor pyrite. The quartz vein, at 207.5 to 209 feet, had a broken ribbon texture parallel to the vein margins. The vein was oriented about 5 degrees to the core axis. Other quartz-calcite (and minor pyrite) veins were more numerous, but the internal texture was one of crackled quartz with infilling calcite.

Introduction and Terms of Reference

The purpose of this project is to assemble a package of digital historic and new data relevant to gold mineralization in the Virginia Horn greenstone terrain. Historical data within this package includes electronic scanned images of maps, drill core logs, chemistry reports and other data associated with mineral leases previously held within the Terrain, electronic data tables that combine geochemistry and assay results obtained from the different mineral leases, and GIS maps and data layers based on hard copy information provided within the mineral lease records. New data within this package include new logs of selected drill core from the area, a fluid inclusion microthermometry study, and supplemental geochemical analyses. This digital data package will be used to promote state mineral leases to new private-party mineral exploration in the area.

The Virginia Horn Greenstone Terrain is in the U.S.A., where the Imperial System is used. Generally speaking, length is reported in feet and miles, volume in cubic feet, temperature in Fahrenheit, and element grades and concentrations in parts per million (ppm). Note that fluid inclusion results are reported using the Metric System.

Property Description and Location

The Virginia Horn greenstone terrain is located in St. Louis County, northern Minnesota. The approximately thirty-square mile area is located just southeast of the City of Virginia, northeast of the City of Eveleth, and west of the City of Gilbert, Minnesota. The terrain is named for its exposure within a horn-shaped bend in the generally east-trending overlying Biwabik Iron Formation, from which the Mesabi Iron Range derives its ore (Figure 1).

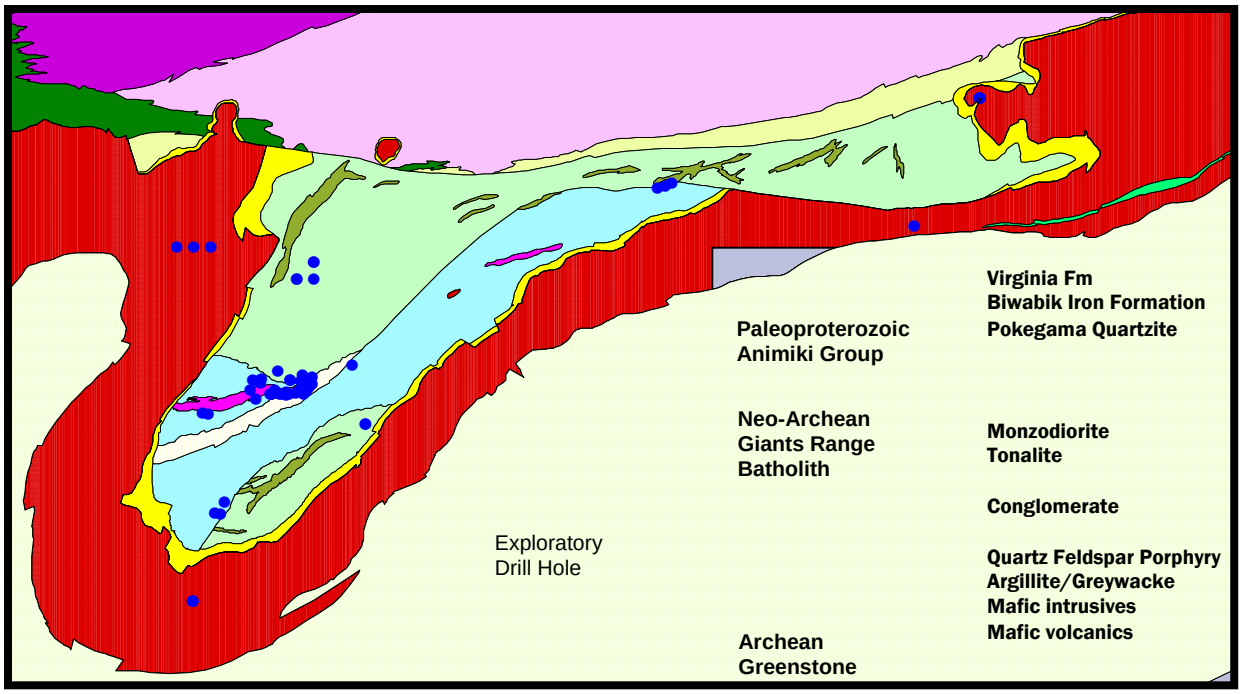

Figure 1: Geologic Map of the Virginia Horn Greenstone Terrain (modified from Jirsa and Boerboom, 2003)

Land Ownership

Land ownership within the Virginia Horn is a mixture of public and private interests, with mineral rights often detached from surface ownership. Surface and mineral rights held by the State of Minnesota are sufficient to have historically offered more than half of the greenstone terrain for mineral lease activity and exploration. Land ownership and mineral lease information for the Virginia Horn is compiled in Appendix A.

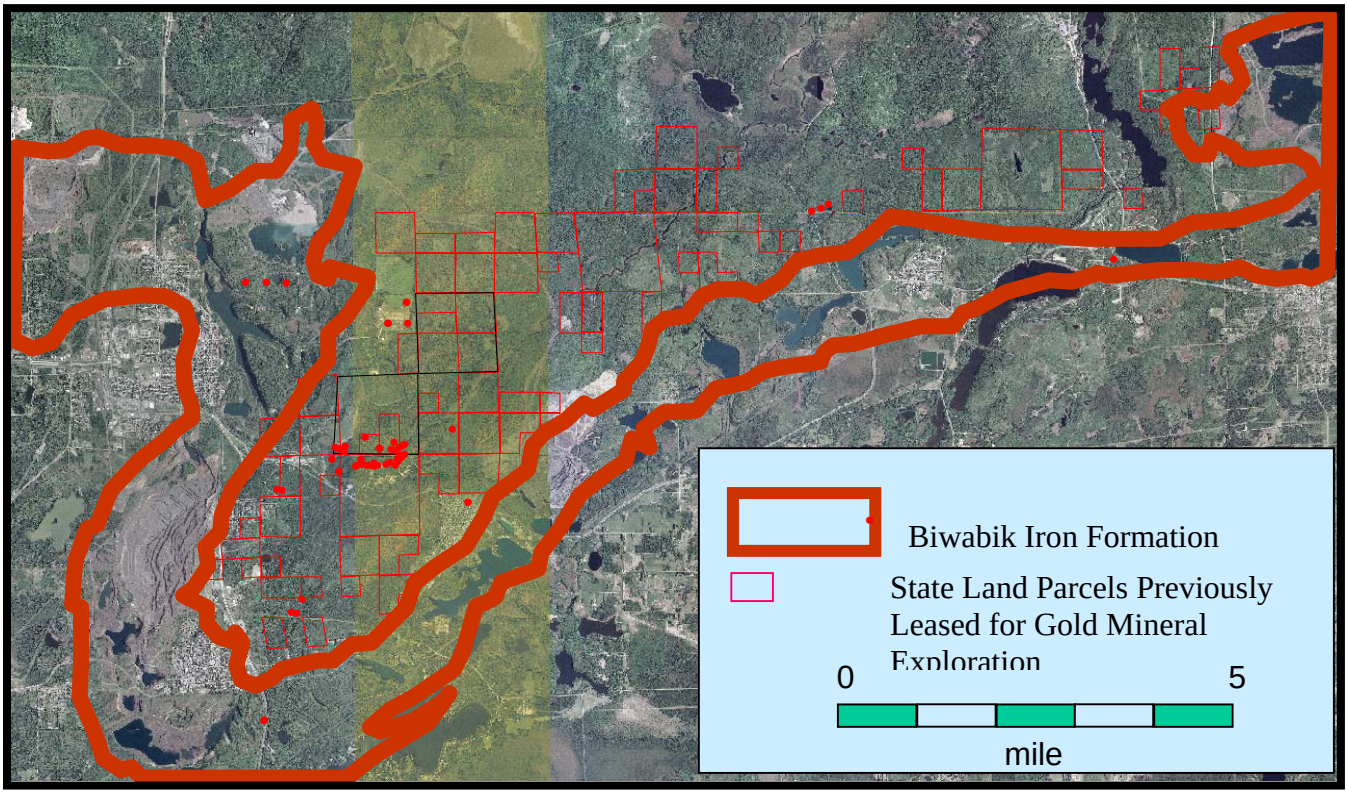

Figure 2: Aerial Photograph of the Virginia Horn area, showing extent of state lands previously leased for mineral exploration

Accessibility, Climate, Local Resources, Infrastructure and Physiography

A network of primary, secondary and tertiary roads provides access to most of the Virginia Horn greenstone terrain. The local infrastructure related to mining is excellent, with several operating open-pit taconite mines adjacent to this area (see Figure 2), and rail system connections to the Twin Ports of Duluth, Minnesota and Superior, Wisconsin. The northern Minnesota climate is midcontinental, with local high temperatures averaging 9.8 degrees F in December and and 75.4 degrees F in July. Precipitation averages between 24 and 27 inches, with about half of the precipitation arriving during the summer months.

Area topography is relatively flat and glacial drift thickness is generally less than twenty feet. Rock outcrop exposures cover approximately 10% of total surface area. Glacial till deposits within the Virginia Horn are associated with the Rainy Lobe of the Laurentian Ice Sheet. Recent surface geology mapping identifies little or no till deposited on top of topographically high (and abrasion resistant) areas.

Drainage within the Virginia Horn is part of the St. Louis River Watershed. Under the ecologic classification system, the Virginia Horn is located within the Nashwauk Uplands Subprovince of the Northern Superior Uplands Section of the Laurentian Mixed Forest Province. This region consisted of forest communities dominated by white pine, red pine, balsam fir, white spruce, and aspen-birch. Forestry and mining are the most important land uses presently.

Soils are formed in sandy to fine-loamy glacial till and outwash sand. Soils on the Nashwauk Moraine have a loamy cap with dense basal till below at depths of 20 to 40 inches. They are classified as boralfs (cold, well-drained soils developed under forest vegetation).

History

Given its location within the Mesabi Iron Range, the potential for ferrous resources within the Virginia Horn area were extensively explored in the late 1800's. Non-ferrous mineralization within the Virginia Horn was first described in the 1930's, with visible gold discovered in a an outcrop exposed during construction of a railroad line to support iron mining in the adjacent Biwabik Iron Formation.

Geologic Setting

The Virginia Horn is an Archean greenstone terrain associated with the Wawa subprovince of the Superior Province (Figure 1). Age is inferred based on similarity with age-dated rocks within the proximal Vermilion Greenstone Belt. The Proterozoic Biwabik Iron Formation (from which the Mesabi Iron Range extracts its ore) and overlying Virginia Formation are truncated to the east by the intrusive Duluth Complex and North Shore Volcanic Group rocks associated with the 1.1 Ga Midcontinent Rift. The Virginia Horn is bordered to the north by intrusive rocks of the Archean Giants Range Batholith.

The Virginia Horn greenstone terrain consists of a folded and faulted metamorphosed assemblage of volcanic and sedimentary strata, intruded by a quartzofeldspathic porphyry (QFP) and overlain by a conglomerate sequence that was interpreted by Jirsa and Boerboom (2003) as a Timiskiming-type package. Metamorphic grade varies from prehnite-pumpellyite to middle greenschist facies.

No geochronologic data exists for rocks within the Virginia Horn terrain. Volcanic rocks within the proximal Ely Greenstone Terrain, which is lithologically, geochemically and stratigraphically similar to the Virginia Horn, have been zircon aged-dated at 2,720 Ma for(Peterson et al., 2001).

Stratigraphy

Archean-aged rocks within the Virginia Horn consist (predominately) of two limbs of a composite volcanic package that lie on either side of an east-trending unit of greywacke/slate (Figure 2). These volcanic limbs have calc-alkaline basal units underlying more tholeiitic flows, and stratigraphic faces (e.g. classic pillow structures) orientated towards a east-trending fold axis within the slate. Quartzo-feldspathic dikes were emplaced into and metamorphosed with the volcanic and sedimentary rocks from zeolite to lower greenschist facies. The Midway Sequence is a package of conglomerate, sandstone and trachyandesite flows that unconformably overly the older "Mud Lake"units.

Structural Geology

The Midway Sequence was deposited after F1 folding but prior to D2 deformation and associated metamorphism (Jirsa and Boerboom, 2003). The F1 event produced the upright folds within the volcanic and greywacke assemblages but no metamorphic fabric. All of these units were subjected by brittle D3 deformation, during which much of the faulting that truncates this Archean terrain took place.

Gold mineralization is associated with moderate to intense carbonate and sericite alteration of host rock. While the quartz-feldspar porphyry unit is the most heavily altered, many alteration zones are fault-related, and found outside of the QFP (Figure 3).

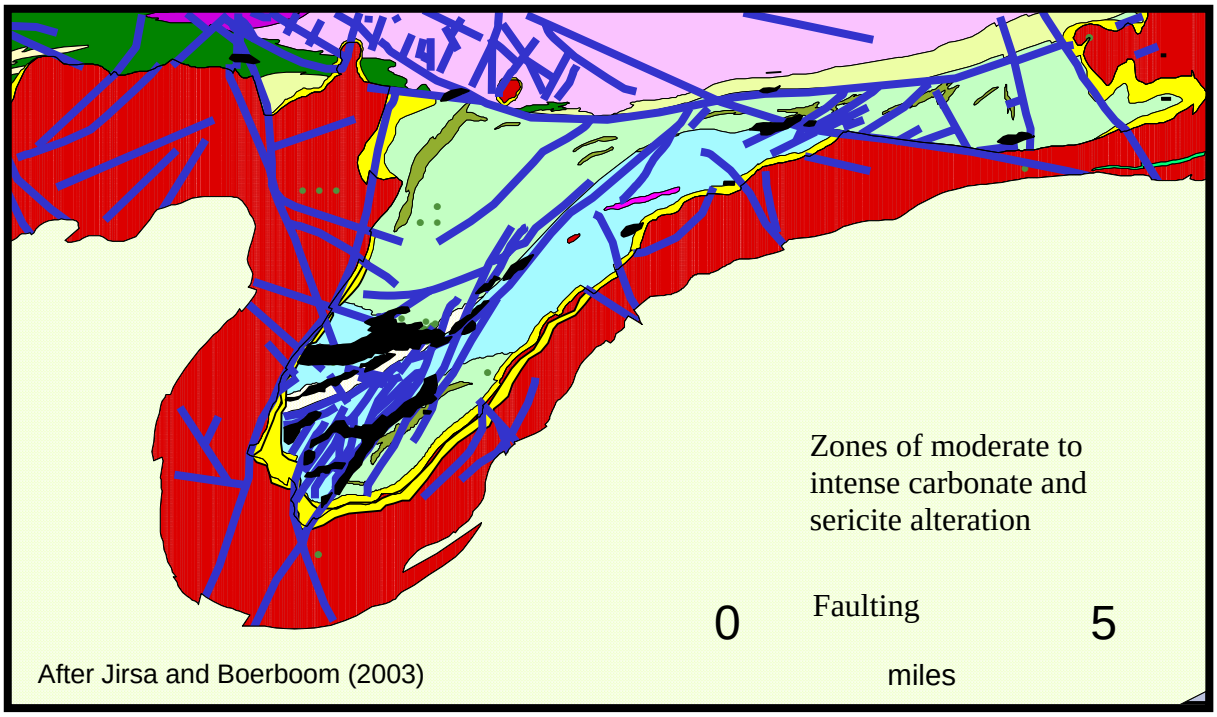

Figure 3: Distribution of fault and alteration zones (modified from Jirsa and Boerboom (2003)

Surface Geology

Glacial till deposits within the Virginia Horn are associated with the Rainy Lobe of the Laurentian Ice Sheet. Recent surface geology mapping (Jennings and Reynolds, 2005) identifies relatively little or no till deposited on top of the topographically high and abrasion resistant metavolcanic units. Till may be present, however, in topographic lows on the irregular surface of the metavolcanics. On the metagraywacke/slate units, deposits of Rainy lobe till and ice-contact sediments are found.

Gold Mineralization

Deposit Types

Subeconomic gold occurrences within the Virginia Horn have historically been associated with a quartzofeldspathic porphyry (QFP unit), based upon data in the terminated sate lease exploration files. Mineralization occurs in secondary quartz-chlorite-sericite veins; while these veins cross-cut all Virginia Horn units they are the most numerous and complex within the porphyry. Given this association, exploration for lode gold deposits have been based on both shear-zone-hosted gold and porphyry vein-type gold.

The depth and density of drill cores completed using this model were not sufficient to rule out the possibility of economic lode gold deposits within the QFP. High grade gold deposits in other portions of the Superior Province have been discovered in subvertical ore shoots less than 50 feet wide.

In addition, reinterpretation of the Virginia Horn as a Timiskiming-type greenstone terrain would support new exploration efforts beyond the QFP, and into both the overlying basal conglomerate and associated country rock, particularly where major shearing and alteration is found. Jirsa and Boerboom (2003) recommended additional lode gold exploration: 1) at depth within the QFP, and 2) along major structural features outside of the QFP (e.g. the Fayal and Pike River Faults).

Mineral Associations

Visible gold is associated with quartz veining, carbonate-sericite alteration and shear zones. Gold concentrations correlate with high arsenic concentrations, and arsenopyrite. Arsenopyrite is observed in the most heavily altered/sericitzed samples (Frey and Hudak, 2007).

Prior to 2006, high gold concentrations were considered to be restricted to the QFP, which supported a lode gold mineralization model. However, a new visible gold occurrence has been discovered during re-logging and examination of drill core from bore hole DML-3, completed within a meta-argillite unit located approximately 8,000 feet from the QFP. The visible gold occurred in a quartz-calcite vein with local minor pyrite. The quartz vein, at 207.5 to 209 feet, had a broken ribbon texture parallel to the vein margins. The vein was oriented about 5 degrees to the core axis. Other quartz-calcite (and minor pyrite) veins were more numerous, but the internal texture was one of crackled quartz with infilling calcite. Prior orientation of the vein during this stage of deformation may have created the different styles. The new visible gold occurrence is located within a major shear zone (Fayal Fault) with highly altered rock. Relatively late faulting, shearing, and rock alteration occurs throughout the Virginia Horn greenstone terrain.

Gold Exploration History

Visible gold was first identified within the Virginia Horn greenstone terrain during the 1930's (Grout, 1937). Exploration for economic concentrations of gold has historically been associated with state mineral lease activity in the late 1980's and early 1990's. Exploration activity included geological mapping, geochemical sampling of soil, loam, and surface rock exposures, and geophysical investigations. The results of this exploration activity were apparently used by those companies that held mineral leases to target areas for diamond drill core sampling.

The MnDNR drill core repository holds a portion of all drill core samples obtained through state mineral leases. Three mineral lease files associated with these drill core samples contain 168 separate documents, including 26 geophysical maps and reports, 28 maps of local geology and geochemistry, 46 drill core logs, and 39 geochemistry reports. A total of 361 gold assay results are provided within these records (see Appendix A and B). Drill core and associated logs, drill

hole locations and geochemical and geophysical results are a public resource (Appendix B). Various parties have, over the years, reviewed this material, and obtained new geochemical and mineralogical information. These data have been used to evaluate competing models of mineralization and better understand the underlying geology of the area.

A digital compilation of historic geologic and geochemical data is provided in Appendix B.

Historic Drilling

Mineral leasing and gold exploration activity involved the completion of fifty-three diamond drill core borings, mostly within or near the highly-altered and sheared QFP. Assay results within portions of drill core were significant, but too inconsistent to be considered economic. There has been no drilling within the Virginia Horn since 1991, and all mineral leases held on state-owned or managed lands (which cover more than 50% of the terrain) have been allowed to expire.

New Data

Completion of geologic mapping and analog modeling subsequent to the last round of private exploration, combined with a resurgence of price-sensitive gold exploration activity prompted the MnDNR to reassess the potential for economic gold deposits within the Virginia Horn. A digital compilation was created of historic mineral lease records. This compilation includes the conversion of hard-copy sample location reports and laboratory reports into GIS-friendly maps, shape files and data tables. Mineralogical and geochemical analyses were completed on drill core housed in the MnDNR's drill core repository. Drill core samples were reviewed to fill identified data gaps and better correlate drill core logs prepared by different companies, and new mineralogical, geochemical and fluid inclusion samples were collected to better constrain the conditions and timing of gold mineralization. This work included the following: 6 drill logs, 49 sample descriptions, 675 geochemistry samples, 24 fluid inclusion samples, 314 microprobe analyses from 38 samples, and 216 ArcView shape files. Frey and Hudak (2007) provide additional information regarding this new data.

Fluid Inclusions

A fluid inclusion micro-thermometry study of quartz veins within Virginia Horn greenstone terrain rocks was completed under contract by Dr. Andrew Conly, Lakehead University, in order to characterize ore-forming fluids, identify potential areas of exploration outside of the historic area of interest, and evaluate mineralization models for the terrain by comparing results with those obtained in gold deposits elsewhere within the Superior Province.

Samples were submitted blind; no information on ore grades and paragenesis were available at the time of fluid inclusion analysis. Twenty-one of the twenty-five samples submitted to the Lakehead University Mineralogy and Experimental Laboratory (LUMINEX) for micro-thermometric analysis had fluid inclusions from which homogenization temperatures (Th), freezing temperatures (Tf) and salinity data could be obtained.

Preliminary results indicate that mineralizated samples display bimodal distributions of Th (100 to 350 degrees C) that are similar to the range displayed in the Williams Mine, Hemlo Gold District. This bimodal distribution suggests two distinct fluid regimes: a higher-temperature magmatic event possibly related to emplacement of the QFP, and a contemporaneous lower-temperature event of possible meteoric or metamorphic origin (Conly, 2007 open file data).

Fluid inclusion data and reports are provided in Appendix C.

Geochemistry

Selected drill core samples held in the MnDNR repository were submitted for geochemical analysis of a wide array of elements. The purpose of this effort was to evaluate previously proposed associations of gold with other elements (e.g. Arsenic) and identify potential new associations, particularly in rocks and drill-core samples that had limited geochemical information available. All chemical analyses were completed by contract laboratory ALS Chemex.

New geochemistry data for the Virginia Horn is compiled in Appendix D.

Gold grain counts and pathfinder elements in till

In the Spring of 2007, MnDNR staff collected 29 till samples and one duplicate sample from the Virginia Horn greenstone terrain. These samples will be analyzed for gold grain counts and pathfinder element concentrations in Summer, 2007. The purpose of this project is to identify potentially anomalous gold and pathfinder element concentrations within till that can be linked to proximal bedrock.

Sampling Approach and Methodology

Till samples were obtained from land that the State of Minnesota either owns outright or holds mineral rights to, and included sites both within and beyond the area of sub-economic gold mineralization constrained by previous drilling and exploration studies.

The factors used select potential till sample locations included land ownership, accessibility, and bedrock, surficial, structural and economic geology. Preference was given to: parcels with undisputed State of Minnesota surface ownership, or (secondarily) current county tax forfeit status; locations that overlie metasedimentary greywacke/slate, metavolcanic, and quartz-feldspar porphyry units; sample locations identified as Rainy lobe till; sample locations on or near major structural features (e.g. faults, shears); samples at or immediately down-ice of a location with historic gold shows; and, sample locations less than 0.5 miles from nearest access point.

Samples were collected using the methods described by Dahl (2005) for glacial till prospecting in the Vermillion District.

Environmental Considerations

The policy of the State of Minnesota is to encourage environmentally and socially responsible mineral exploration and development on its leased lands. The terms of each mineral lease as well as the governing statutes guide mineral exploration in the state. Provisions for non-ferrous mineral leasing of state-owned lands are provided in Minnesota Statutes sec. 93:25.

Reliance Upon Independent Testing and Analysis

It is policy of the MnDNR Lands and Mineral Division to rely upon independent, third-party contractors for test results and chemical analyses performed on samples collected or obtained from areas of prospective mineral lease activity. All new data reported in this document were obtained from the following contractors: ALS Chemex for geochemical analysis, Dr. Andrew Conly, Lakehead University for fluid inclusion analysis, and Overburden Drilling Management (ODM) for gold grain counts and pathfinder element surveys in till samples.

Historic geophysical and geochemical data compiled from expired mineral lease records were obtained by the lessees themselves within the individual lease periods.

References

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Appendices

Appendix A – Mineral Lease Information

terminated lease v horn.xls	Mineral lease information for all terminated leases within the Virginia Horn (e.g. Company, Location, Lease start and termination dates).

Appendix B – Previous Geologic and Geochemical Data

lease file inventory.xls	Description of documents preserved within historic Virginia Horn mineral leases.
Virginia Horn Collar Data.xls	Collar information for Virginia Horn DDH.
Historic Rock and Chanel Sample Geochem.xls	Geochemistry data for surface rock samples collected by mineral lease holders and other third-party researchers.
VH Past Data.xls	Previously obtained Geochemistry data from Virginia Horn DDH.

Appendix C – Fluid Inclusion Data

Mins-FI-Report#2-May-17-2007.pdf	Fluid Inclusion Report by Dr. Andrew Conly
fluid inclusion data.xls	Fluid inclusion data table, with added information about sample locations, depths, and Au content.
fluid inclusion plots.xls	Fluid inclusion histogram plot data and charts
fi geochem cross ref.xls	Cross references fluid inclusion samples with available geochemistry data

Appendix D – New Geochemistry Data

VhchemSamples.xls	Sample location and depths for 140 geochem samples.
VH.xls	P368 Geochemistry and Mineralogy Data (2007)