Geochemical Soil Survey in an Archean Granite-Greenstone Terrane, International Falls Area, Koochiching County, Minnesota

Author:

Don Elsenheimer, Ph.D

Minnesota Department of Natural Resources

Lands and Minerals Division

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Minnesota Dept. of Natural Resources
Lands and Minerals Division
Central Office
500 Lafayette Road
St. Paul, Minnesota 55155-4049
Tel: (651) 296-4780

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Abstract

The Minnesota Department of Natural Resources has conducted a geochemical soil survey in the International Falls area, Koochiching County, Minnesota, an area of historic and active gold exploration. A total of 110 shallow A1 soil samples were collected within grids located on or near an accessible fault-bound granite-greenstone terrane that is part of the Archean Superior Province. These samples were shipped to ALS Chemex for independent analysis of 51 major and trace element concentrations.

The spatial distribution of metallic, major and trace elements within the project area do not appear to highlight "hotspot" areas of elevated concentrations. There is a possible linear trend in gold concentrations in the eastern portion of the project area that may be consistent with a dispersal trail generated by glacial transport. Variations in the distribution of certain elements do appear to be associated with both the type of underlying bedrock, and whether the sample was collected in an upland or lowland area.

1.0 Introduction

1.1. DNR Land Management

The Minnesota Department of Natural Resources (DNR) manages more than twelve million acres of state-owned and state-managed mineral rights within state boundaries. When these lands and rights are held in trust for Minnesota's public schools (both K-12 and secondary), the DNR has a fiduciary responsibility to generate income from the natural resources contained within them. The Minnesota State Legislature has also directed the DNR to engage in activities that support the diversification of the State's mining industry beyond taconite and other ferrous resources.

The DNR's Division of Lands and Minerals (LAM) is charged with supporting both of these missions by assessing the mineral potential of state-owned and state-managed lands and mineral rights. Areas of the State are selected where there has been historical mineral exploration, or where the geologic conditions are favorable for mineralization. The DNR gathers the historical maps and records, and collates and converts this information into digital formats (when necessary). New geological and geochemical data is sometimes collected, in areas that were previously underexplored, or in areas that are conducive to cost-effective methods of mineral exploration that were unavailable to private mineral exploration companies in the past. The combination of both old and new data, when posted on the Internet, may stimulate or renew interest in private mineral exploration on state lands. There is value in this work even in the absence of future mineral exploration and development, however, in that the determination of the mineral potential on these lands supports effective stewardship of public lands, especially when there are multiple (and sometimes competing) potential land uses.

1.2. Minnesota's Mineral Resources

Active mineral production and exploration activities in Northern Minnesota cover three distinct metallogenic provinces, with each province having a distinct Geologic Age, location, and targeted commodity. Mesabi Range iron ore and taconite deposits within the 1.8 Ga Biwabik Iron Formation have been mined for more than 120 years. East of the Mesabi Range, the 1.1 Ga Duluth Complex has several identified copper-nickel-precious metal deposits, some of which are in the advanced development and environmental permitting stages. The third metallogenic province covers that portion of the Archean Superior Province that lies north of the Mesabi Range and west of the Duluth Complex. As can be seen in Figure 1, the greenstone belts within Minnesota's portion of the Superior Province continue along strike across the Canadian Border, and into Northwest Ontario.

The discovery of Superior Province gold near Lake Vermilion in 1865 led to a mini-gold rush and the first mineral exploration efforts in Northern Minnesota. While these gold prospectors were unsuccessful, the influx of "gold rushers" did lead to the discovery of iron ore on the Vermilion Range. A total of eleven iron ore mines were eventually opened in the Vermilion District, with largest underground Soudan Mine closing in 1962 (Ojakangas and Matsch, 1982). In recent years, mineral exploration activity within Minnesota's Superior Province bedrock has returned to a focus on gold. The Archean Superior Province greenstone belts that host many of Canada's richest gold camps continue along strike across the U.S. border and into the northern portion of Minnesota. The potential for gold production in Minnesota's portions of the Wawa and Wabigoon Subprovinces is excellent, and the exploration models used for nearby gold deposits in Northwestern Ontario (e.g. Rainy River, Hammond Reef, Moss Lake/Shebandowan), could very well apply.

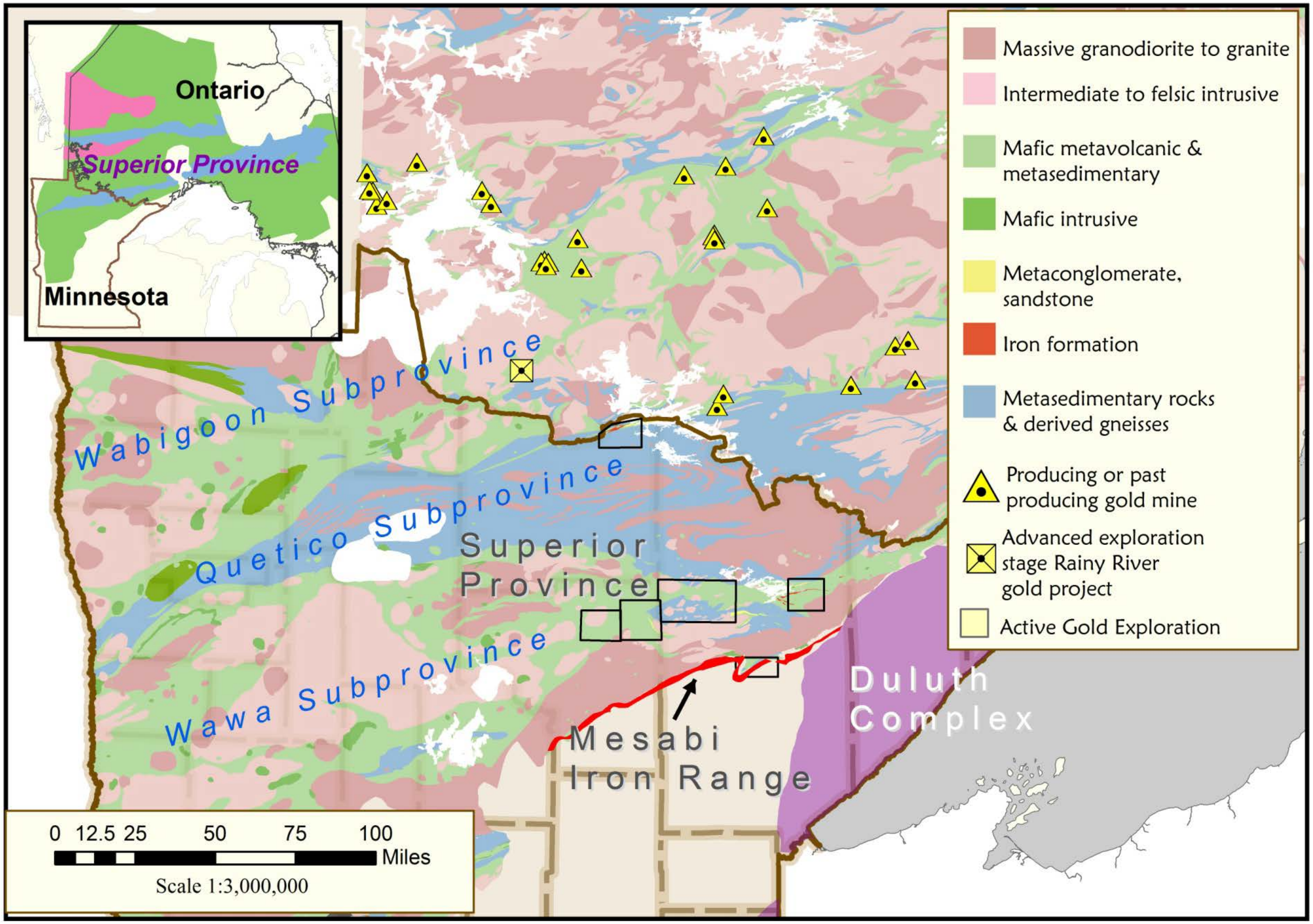

Figure 1: Generalized geology of Northern Minnesota and Northwestern Ontario, with identified areas of producing and past productng gold mines, and areas of active gold exploration in Minnesota. After MGS (2010), OGS (2003), and OGS MDI-2010

1.3 International Falls Gold Exploration Area

As of March 1, 2012, there were six areas with active gold exploration on State-leased land in Northern Minnesota (Figure 1). The northern-most area of historic and active gold exploration is along the Canadian Border, in that portion of Northern Koochiching County that lies east of International Falls, west of Voyageurs National Park and immediately south of Rainy Lake (Figure 2). The State of Minnesota has extensive land holdings and mineral rights in this accessible fault-bound granite-greenstone terrane that is part of the Archean Superior Province, and gold mineralization has been identified during historic mineral exploration efforts on these public lands. This part of Northern Minnesota was the site of a mini-gold rush in the 1890's, with gold discovered in the same Archean granite-greenstone belt that hosts numerous gold and base-metal deposits on the Canadian side of the International Border.

The DNR completed a pilot geochemical survey in the International Falls area in the mid-1980's (Sellner et al., 1985). Grids were established for geophysical and geochemical analyses, with gold and silver concentrations obtained from samples of both soil and vegetation. Anomalously high gold concentrations were identified in a number of shallow soil samples.

A number of private mineral exploration companies explored for gold in the International Falls Area in the decade following publication of this geochemical survey, on both public and private lands. This work included geophysical and geochemical surveys, and exploratory drilling programs. A total of 29 drill holes were completed in the Area of Interest, and while anomalously high gold assays were observed in a number of these wells, ore grades and intervals were not large enough to justify

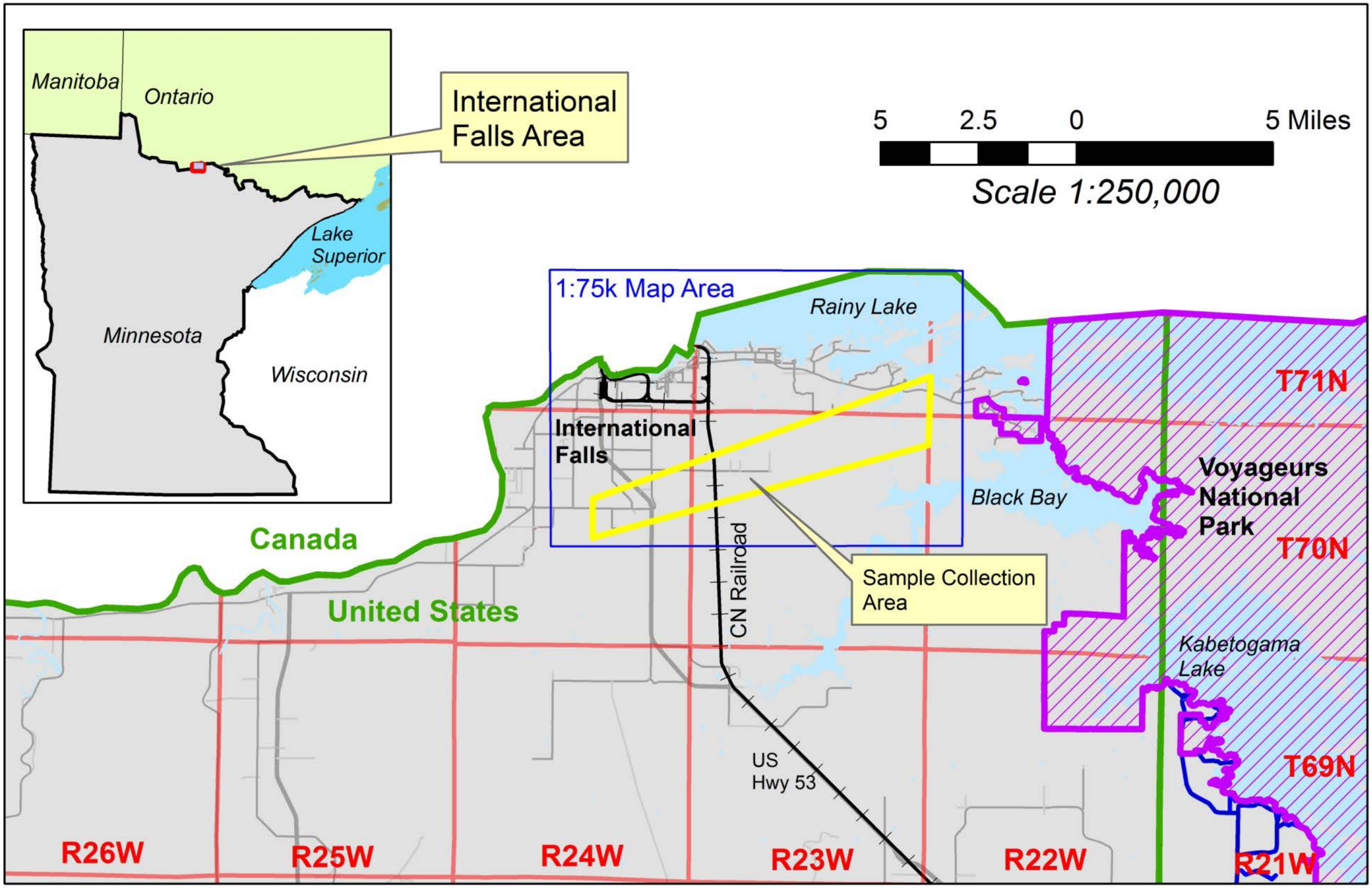

Figure 2: Project Location Map. The blue box outlines the area shown in Figure 2 and subsequent 1:75,000 scale maps. The smaller yellow polygon shows the area of sample collection.

program continuations, particularly after the significant drop in gold price in the early 1990's. All of the mineral leases on state-owned or state-administered mineral rights were terminated.

In 1997, the United States Geological Survey (USGS) reviewed the previously collected drill core assay results and geochemical data, collected new soil geochemical samples, and subsequently identified portions of the International Falls Area with "high potential" for both Lode Gold and Volcanogenic Massive Sulfide (i.e. Copper-Nickel) mineral deposits (Klein et al., 1997).

The Minnesota Department of Natural Resources recently initiated two projects to follow-up on the USGS identification of areas with high potential for lode gold deposits near International Falls. Frey (in preparation) selected drill cores from the International Falls Area were retrieved from the DNR Drill Core Library, relogged, and scanned with a hand-held X-Ray Fluorescence (XRF) analyzer instrument. Using these results as a guide, a total of 227 new geochemical assays were obtained from core samples from 13 drill holes in the Area. Besides low-grade gold mineralization, the chemical data and logging identified thin sphalerite-bearing intervals, abundant tourmaline, and pathfinder element associations with multiple types of gold mineralization.

This report documents the results of a new DNR geochemical soil survey in the International Falls Area. A total of 110 shallow soil samples were collected in the Fall of 2010 within grids located on State lands near major structural features and within areas of lode gold mineral potential. These samples were shipped to a third-party laboratory for independent analysis of major and trace element concentrations. The goal of this new geochemical survey was to confirm and supplement the results of Sellner et al. (1985), using sample grids in areas beyond their area of investigation.

2.0 Project Location, Land Tenure and Climate

Geochemical soil samples were collected within an area of historic and active gold exploration in Northern Koochiching County, Minnesota. This region is bounded, in general terms, by Rainy Lake and the U.S./Canadian border to the north, the city of International Falls to the west, and Voyageurs National Park to the east (Figure 2). The southern boundary of this area of potential gold mineralization is constrained more by diminished mineral potential as you travel farther away from the granite-greenstone terrane than by any cultural or political boundaries.

A 2010 aerial photograph of the International Falls area is shown in Figure 3. The sample collection area is located in the southeast corner of T71N, R23W, the northern half of T70N R23W, and the northeastern corner of T70N, R24W. This area is almost completely undeveloped, except for a small portion of the western edge. Access to the project area is provided by major highways that run west and north of the project area; access to the interior of the project area requires travel along unpaved snowmobile, hiking and cross-country ski trails.

Climate is typical of the northern U.S., with snow cover during the months of December to April. Climate does not usually interfere with exploration activities or diamond drilling, except during deep snow cover in the winter and during spring break up, generally during the month of April, when weight restrictions are placed on most highways and gravel roads.

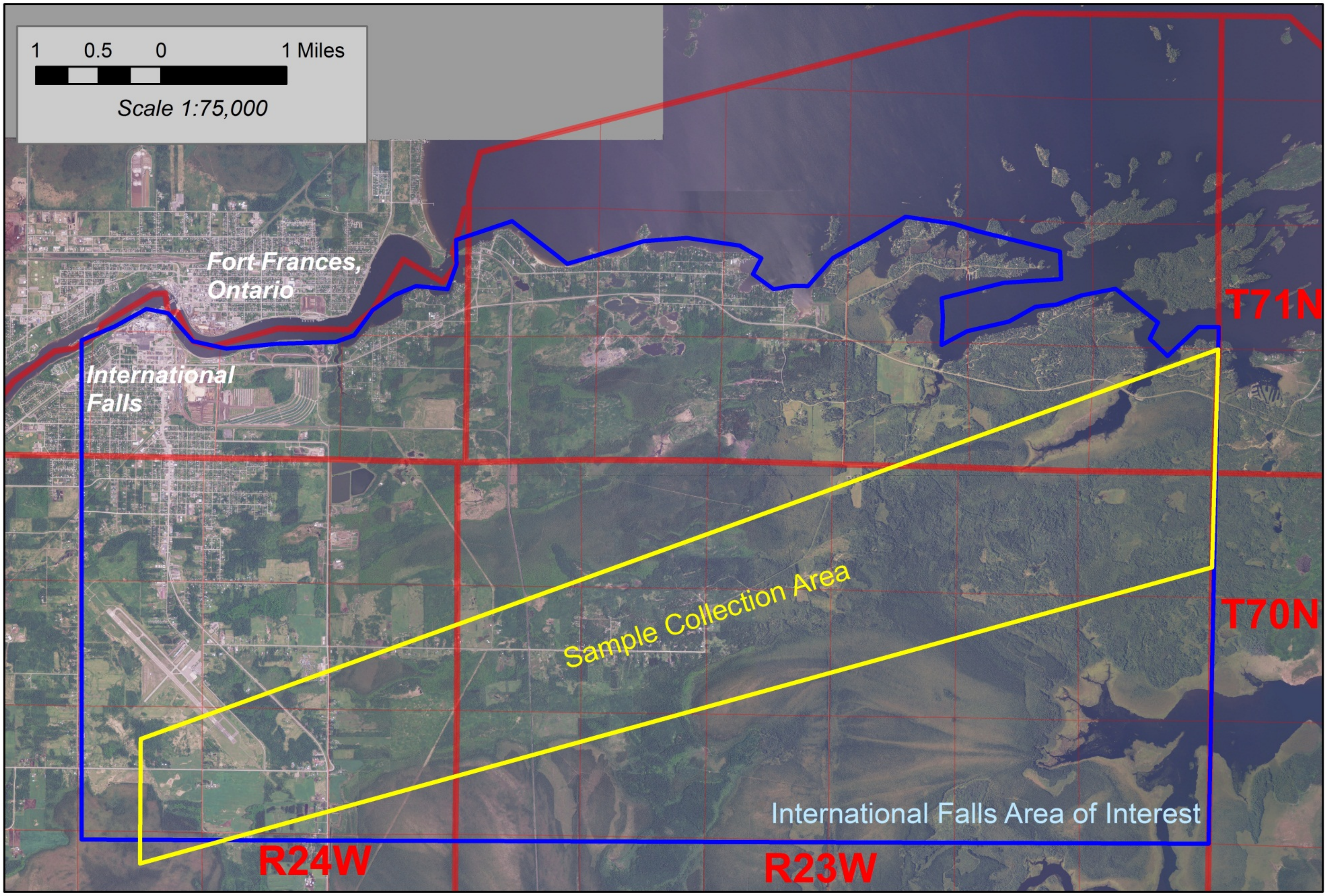

Figure 3: 2010 Aerial Photograph of the International Falls Area. Soil samples were collected in undeveloped areas to the south and east of International Falls.

As shown in Figure 4, the State of Minnesota has a dominant public land position within the International Falls Area. This real estate portfolio consists of lands and mineral rights that the State of Minnesota either owns or manages on behalf of entities such as the State's Permanent School Trust. The State of Minnesota can offer mineral leases to private companies that wish to explore for minerals on these lands. Leases are obtained on individual "mining units," with a mining unit consisting of all of the offered state-owned or managed mineral rights located with a one-square mile section of land. There are currently two mining units with active leases and one unit with a pending lease in the International Falls Area (Figure 4).

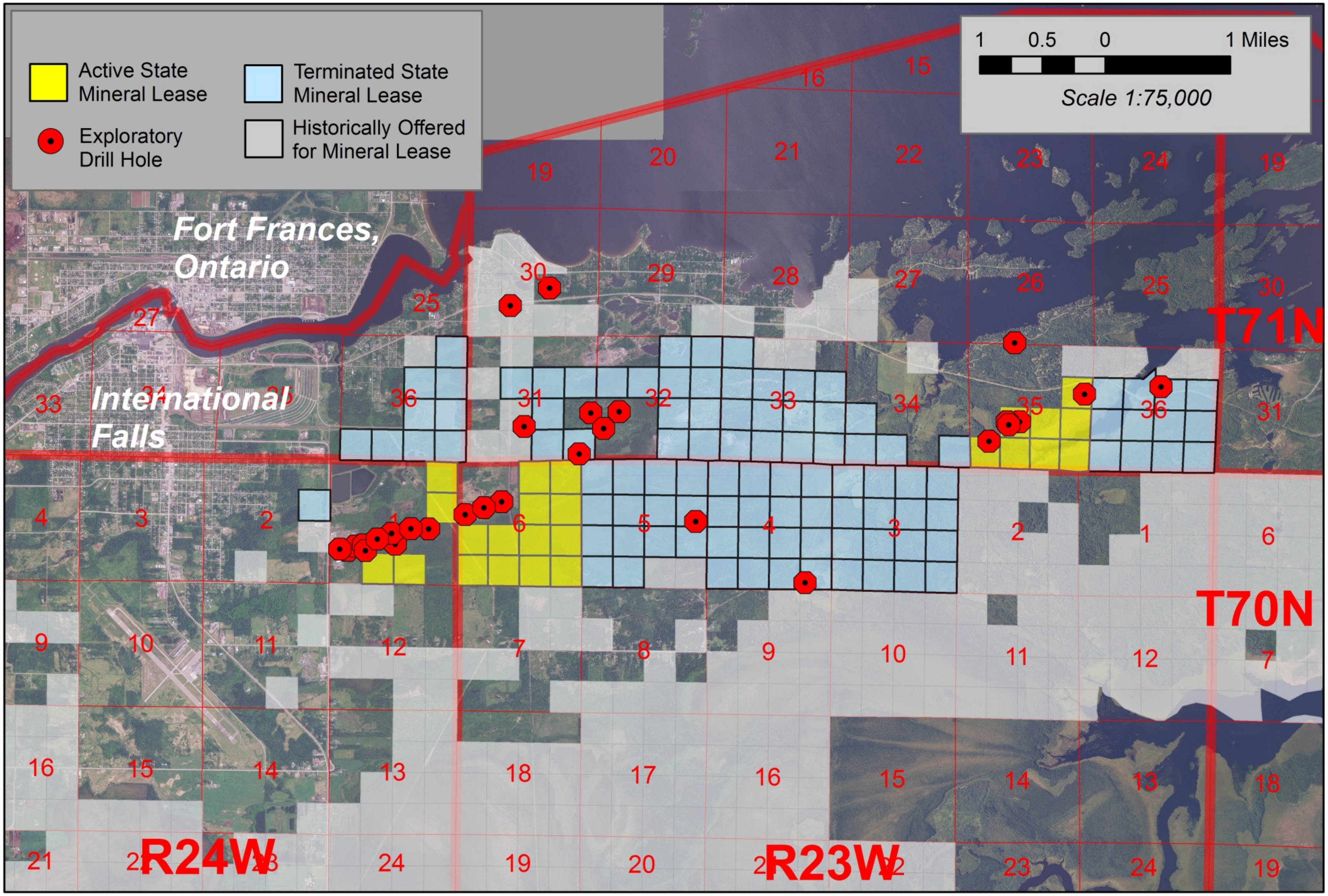

Figure 4: State Land Position, International Falls Area

3.0 Land Use, Access, and Infrastructure

3.1 Land Use and Cover

In 1999, the DNR produced an integrated GIS data set (Minnesota Land Use and Cover: 1990s Census of the Land) that provided an overview of land use and cover vegetation within the State (DNR, 1999). Eight generalized land uses were created: urban and rural development, cultivated land, hay/pasture/grassland, brushland, forested, water, bog/marsh/fen and mining. These designations were then applied based on existing maps and datasets.

Figure 5 displays the 1999 land use designations within the International Falls Area. The developed areas in the western part of the project area reflect the City of International Falls and commercial and residential development along US Highway 53. To the north, there is residential and recreational development along the south shore of Rainy Lake and Minnesota Trunk Hwy 11. Areas identified as "mining" correspond to sand and gravel deposits with aggregate mining operations.

Within both the areas of historical and active gold exploration and the sample collection area for this project, the primary undeveloped land cover is forest. Peat bogs and grasslands are also located within the sample collection area.

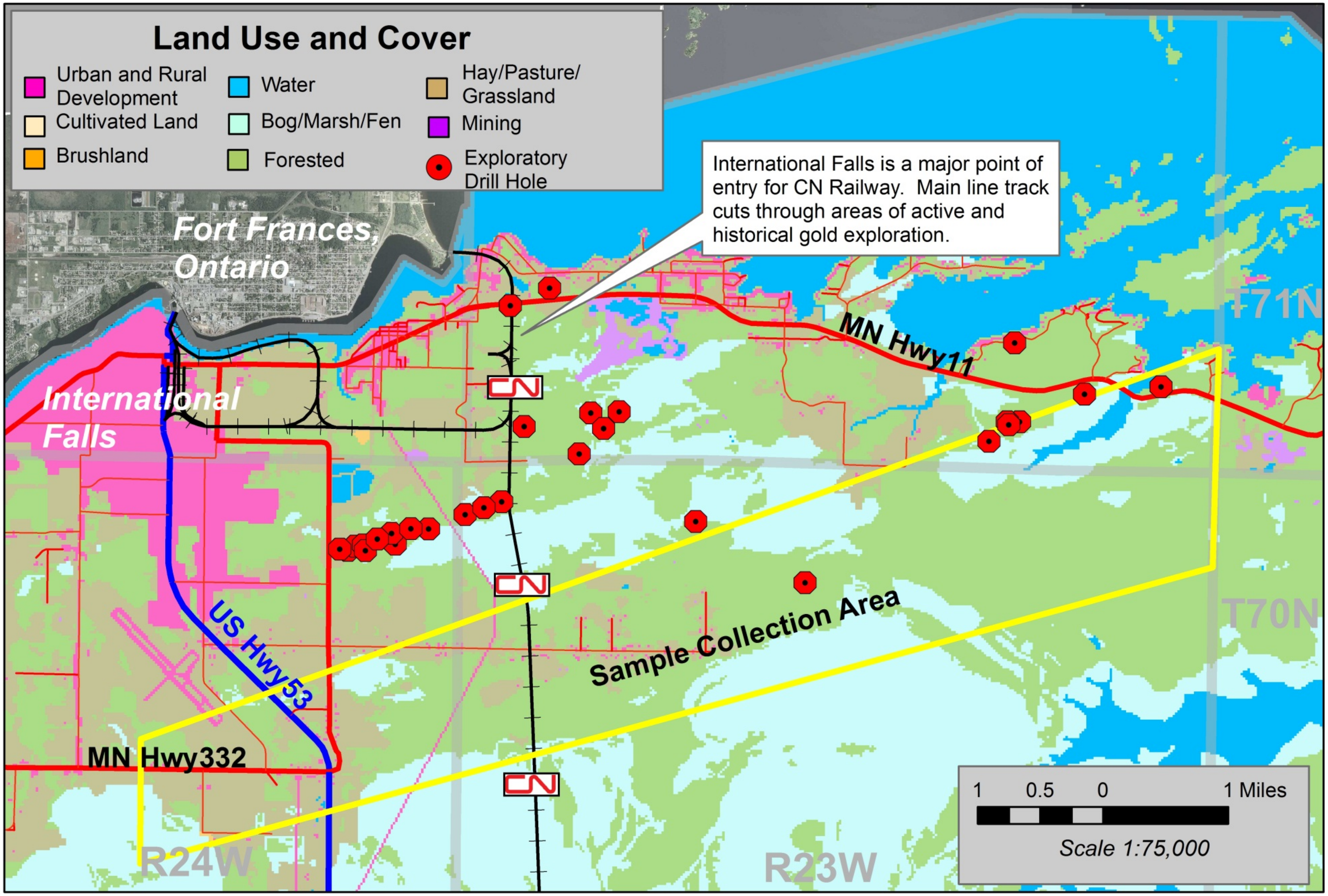

Figure 5: Land Use and Transportation, International Falls Area

3.2 Access, Transportation and Infrastructure

Figure 5 provides a general overview of the local transportation network and site accessibility within the project area. International Falls is located on the northern border of Minnesota and the international border shared with Canada. There is excellent road and rail access to the city, which is linked by toll-bridge to the city of Fort Frances, Ontario. International Falls is a major point of entry for

CN Railway, with track that connects the region to national rail networks in both Canada and the United States. As shown in Figure 5, CN Railway main line track actually cuts through both the project area and areas of historical and active gold exploration.

US Highway 53 is a major highway that links International Falls with the Mesabi Iron Range and the City of Duluth to the south (where it connects with US Interstate 35). Highway 53 terminates to the north at the international bridge crossing, which is connected to Ontario Highways 11 and 71, major roads that comprise the regional component of the Trans-Canada Highway. Minnesota Highway 11 is an two-lane paved road that generally parallels the international border; it is located on the northern edge of the project area, and connects the region to to the cities of Baudette and Warroad. It then continues west into North Dakota, where it connects with US Interstate 29.

International Falls is located 100 miles north of the city of Virginia and the Mesabi Iron Range, where iron mines have been in operation for over a century. The substantial local mining supply infrastructure developed for the taconite mines could readily be accessed by operations in International Falls, with less than two-hour travel times along Hwy 53. Water is abundant. Power is available in the project area, as is a local workforce drawn from the city of International Falls. Construction materials such as sand, gravel and crushed stone are available locally.

4.0 Physiography

4.1 Topography

The Project Area and entire Area of Interest lies within the Archean Superior Province, which is sometimes referred to as the Canadian Shield. This terrane is characterized by relatively flat topography, with crystalline bedrock overlain by glacially derived sediments.

The State of Minnesota has been systematically upgrading togographic information across the state, with complete LiDAR coverage and 3m Digital Elevation Models (DEM) statewide by the end of 2012. High-quality topographic images have been released as they become available. Figure 6 shows a topographic image of the International Falls Area of Interest, based on currently available LiDAR results (Minnesota Department of Natural Resources, 2012). Most of the Area of Interest has 3m LiDAR coverage, and the difference in resolution between these areas and those portions of the image that only have 10m DEM coverage is striking.

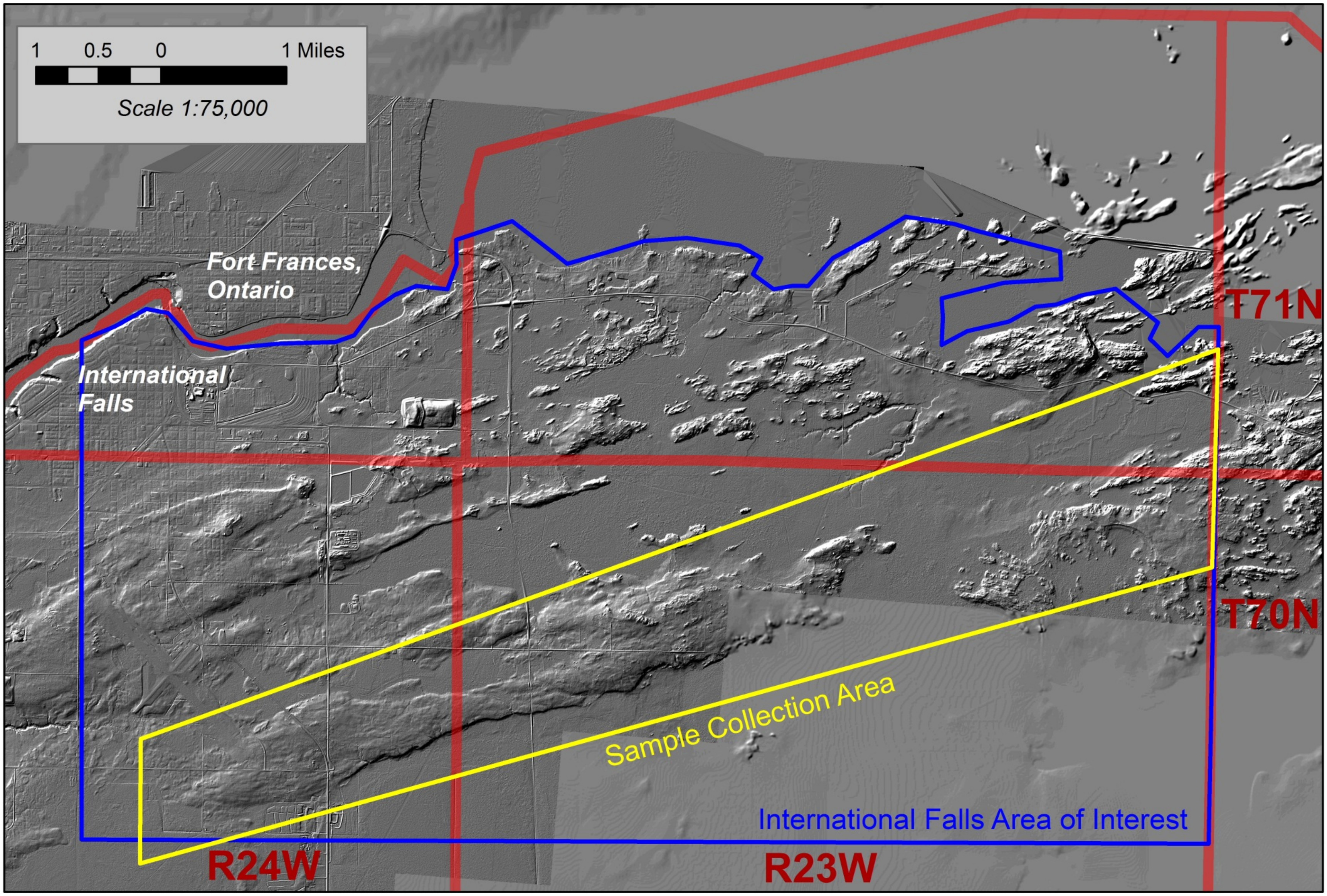

Figure 6:Topography of the International Falls Area of Interest, based on a 3m LiDAR Digital Elevation Model (DEM). Areas in the north and southeast display lower resolution 10m DEM data.

4.2 Hydrology

International Falls lies north of the Laurentian Divide; the Area of Interest is completely within the Rainy River/Maniteau Watershed of the Rainy River Drainage Basin (MPCA, 2001). Small creeks and streams drain the area, flowing north into Rainy Lake. These discharge points are down gradient of the lakes and streams within Voyageurs National Park to the East; the outlet of Rainy Lake is the Rainy River, which flows westerly towards Lake of the Woods, the Winnipeg River and (eventually) Hudson Bay.

A majority of the land surface area east of International Falls meets National Wetland Inventory criteria as designated wetlands (Minnesota Department of Natural Resources, 1997), owing to the region's shallow relief and the poor drainage associated with glacial lake sediments and peat deposits. Figure 7 displays a wetland distribution pattern that mirrors what is found in Koochiching County as a whole, which has wetlands covering more than two-thirds of its land surface. The County's wetlands represent approximately 14% of the entire State of Minnesota's wetland inventory.

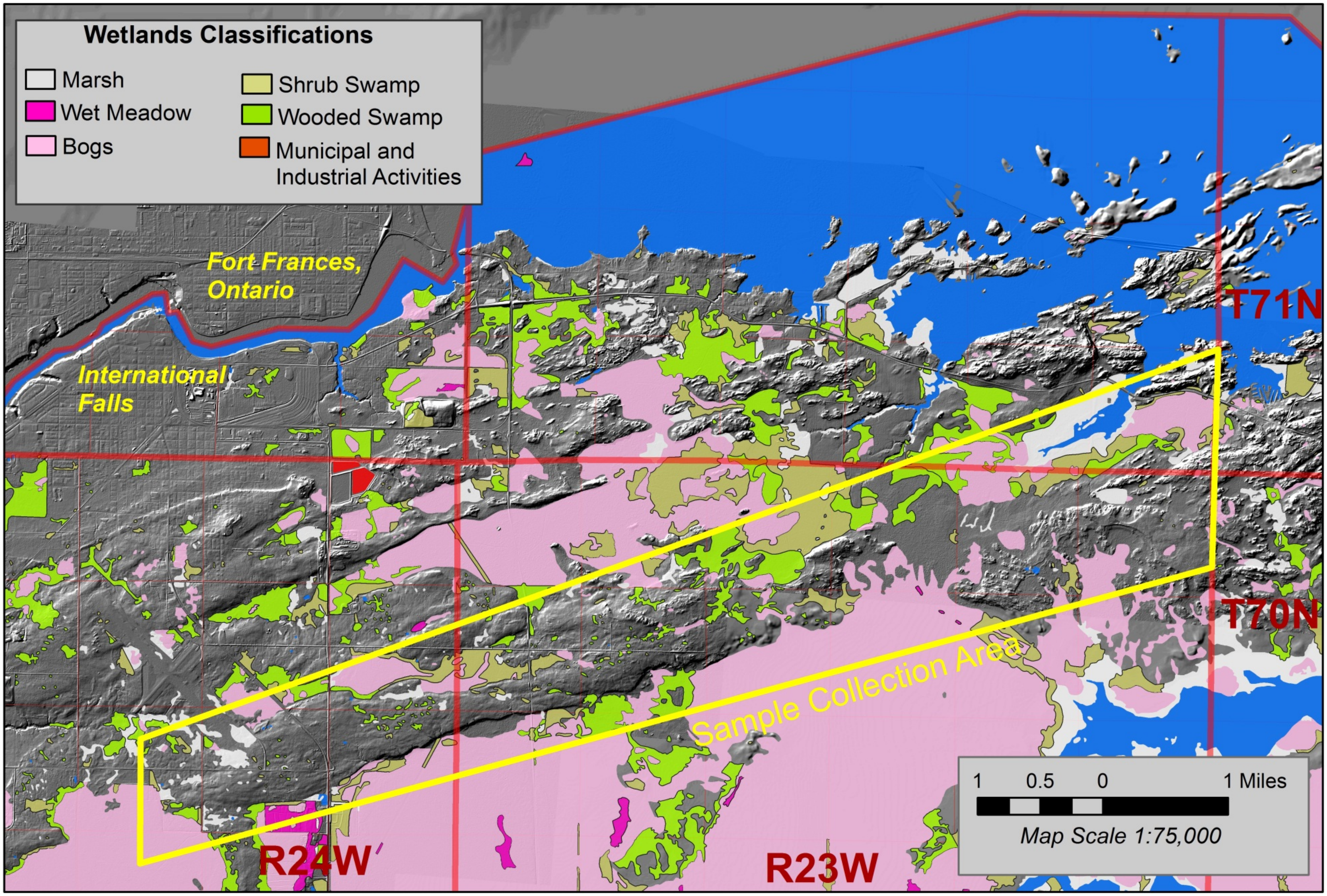

Figure 7: Wetland Areas, based on NWI wetlands inventory criteria.

4.3 Outcrops and Depth to Bedrock

Figure 8 shows the distribution of mapped outcrop locations in the Area of Interest, based on the limited data available. There is scant outcrop mapping over the majority of the International Falls Area of Interest.

Eng (1980) mapped the surficial geology of Koochiching County, which includes the entire International Falls Area of Interest. One of the identified units on his map was “Rock controlled landforms and outcrops.” As shown in Figure 8, these areas of outcrop and rock-controlled landforms generally correspond with upland areas, along topographic highs that extend along linear NE-SW trends.

Day et al. (1990) did not plot outcrop locations on their 1:250,000 scale geologic map of the International Falls 1°x2° quadrangle. They did, however, characterize outcrop distributions on a regional scale. They International Falls Area was described as having, “Generally extensive to moderate amounts of bedrock outcrop. Numerous outcrops on shores of lakes and major rivers; most hills are exposed bedrock or bedrock covered by thin, patchy glacial deposits.”

Hempstad et al. (2000) identified outcrop locations in the eastern portion of the Area of Interest as part of their geologic mapping of the Island View Quadrangle. Bedrock exposures are common along the southern shoreline and near-shore islands of Rainy Lake, and correspond well with Eng’s mapping of outcrops and “rock-controlled landforms” where the two map areas overlap.

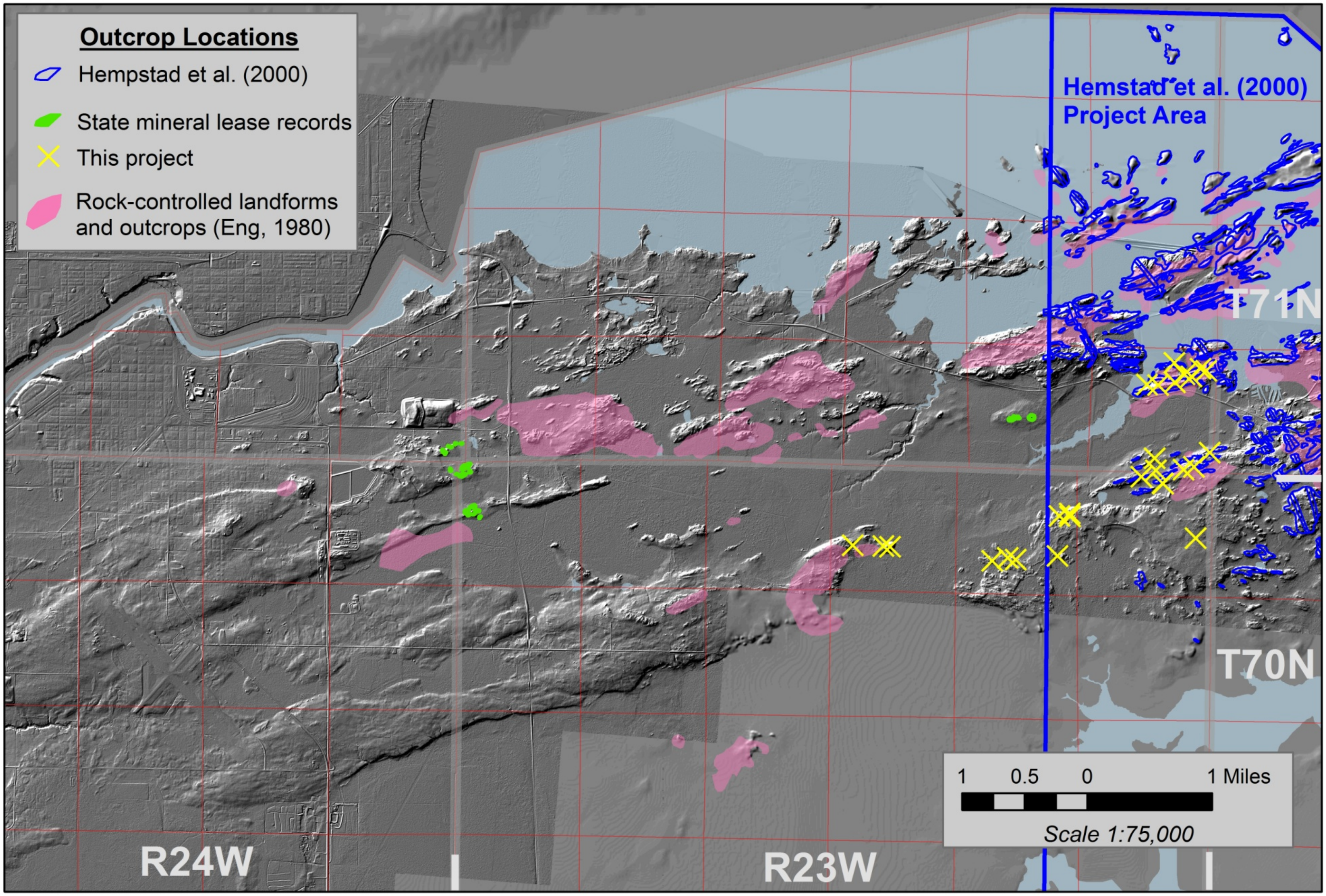

Figure 8: Outcrop distribution in the International Falls Area, based on limited data from Eng (1980), Hemstad et al., (2000), state lease records and observations in this report.

A review of maps and other archived documents associated with exploration activity on terminated state mineral leases within the Area of Interest identified a few isolated areas with identified outcrops. The Kerr-McGee Corporation (1988) identified outcrop locations in the eastern portion of the Area of Interest, in Sections 35 and 36 of T71N R23W (note that their mapped outcrops in Section 36 are not shown in Figure 8, as they overlap Hempstad et al. (2000)). The Normin Mining Company (1990) mapped outcrop locations in the western portion of the Area of Interest, in Section 1 of T70N R24W, Section 6 of T70N R23W, and Section 36 of T71N R24W.

Outcrop mapping within the sample collection area was not a primary goal of this project. That said, outcrops were noted and their positions established using GPS whenever they were encountered. Figure 8 marks the locations of these project-identified outcrops. Outcrops were observed in those portions of the sample collection area that were within Hempstad et al.'s (2000) mapped area. There were also five outcrop observations within that mapped area that were not identified by Hempstad et al. (2000), or included within Eng's (1980) mapped area of "outcrop or rock-controlled landforms." These outcrops were located south of Tilson Bay, along strike of mapped outcrop locations along the NE-SW trending upland areas. The six outcrop locations mapped outside of Hempstad et al.'s project area are consistent with these observations; outcrops are generally restricted to upland areas, along NE-SW trending ridges of exposed or shallow bedrock.

Surficial deposits are generally thickest in the western portion of the project area, and thinnest along the shore of Rainy Lake and along the northeast-southwest trending upland areas. The Minnesota Geological Survey (MGS) and Minnesota Department of Health's (MDH) County Well Index (CWI) has well log data for water supply wells and exploratory boreholes in the State of Minnesota. These well logs record depth to bedrock (when it is encountered). While the majority of these well records have unverified or approximate locations, most of these well logs can be tied to a specific homestead using air photographs. Figure 9 plots the verified and unverified locations of CWI wells within the International Falls Area of Interest, and assigns each data point a depth to bedrock based on associated well logs (MGS and MDH, 2011). These well depths are plotted against the MGS's most recent depth to bedrock model for the State of Minnesota (2010), which was compiled on a 1:500,000 scale and interpolated using cells that were 250m in both length and width. The MGS model was based on published bedrock outcrop locations and depth to bedrock data from exploratory boreholes and other CWI wells with verified locations.

There is fairly good agreement between the bedrock depths in wells with unverified locations and those wells and boreholes with verified locations. As seen in Figure 9, there is poorer agreement between the bedrock depths in wells with unverified locations and the corresponding modeled depth to bedrock (MGS 2010). This difference can be explained by the scale of the MGS compilation, and by its reliance only upon data from wells and boreholes with "verified" locations.

Relatively few water-supply wells have been completed in the lowland portions of the project area; these areas are covered with wetlands and peat bogs unsuitable for residential development. It is interesting to note the overburden thicknesses where wells or borings are completed in lowland areas in the northeastern portion of the project area. Klein et al. (1997) noted that it is not uncommon for glacial deposits greater than 100 feet in thickness to fill narrow valleys in between upland ridges with bedrock exposures.

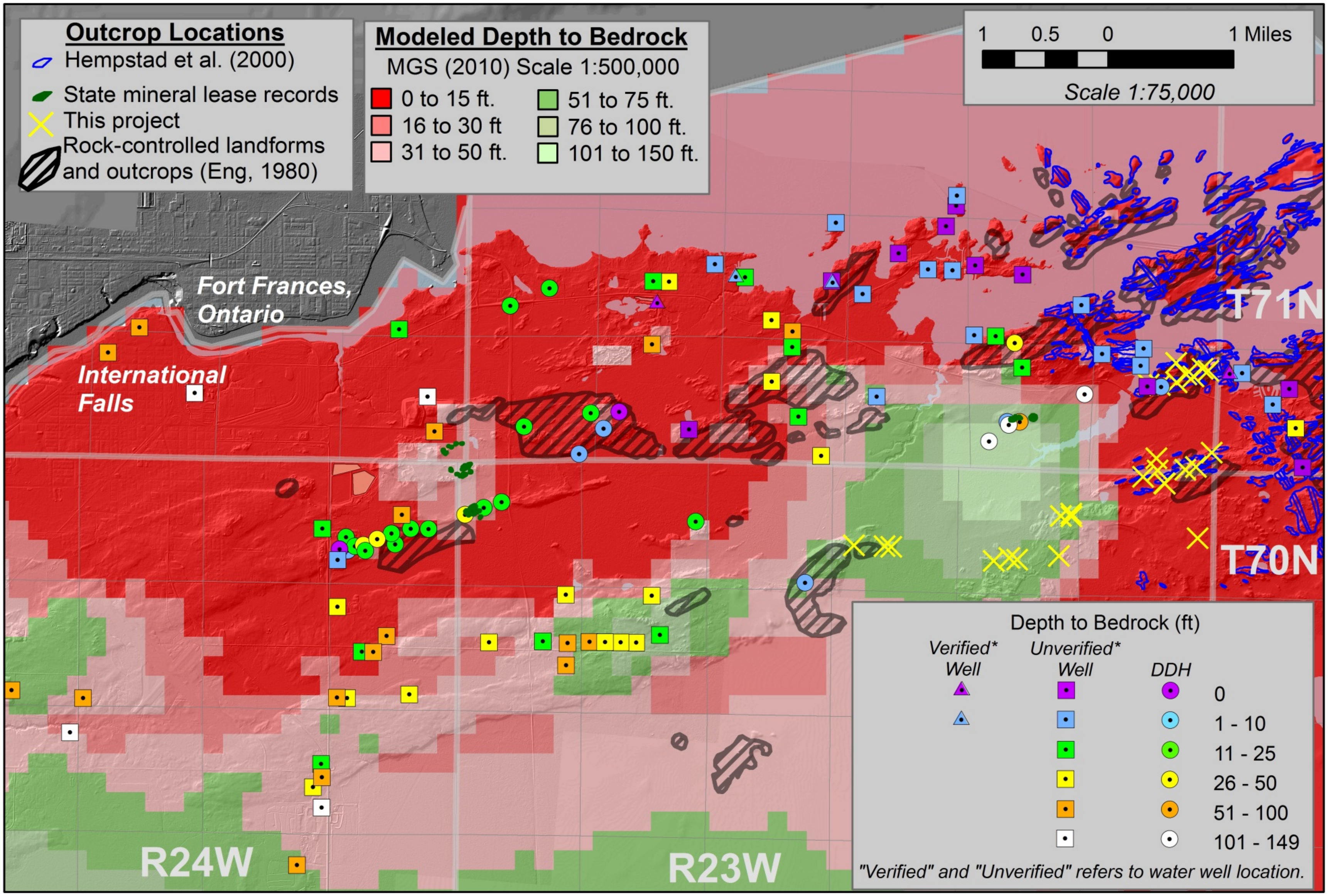

Figure 9: Depth to bedrock in exploratory bore holes and water wells, plotted against the MGS (2010) depth to bedrock model and mapped outcrop distribution

5.0 Surficial Geology

Unconsolidated sediment deposits within the International Falls Area consist of varying mixtures of till deposits, glaciofluvial and glaciolacustrine sediments, alluvium, and peat that lie unconformably over Archean bedrock and (in places) associated saprolite deposits. While the complex mixture of unconsolidated sediments in the International Falls area were deposited by several Pleistocene-era glacial advances, only the surficial deposits associated with the last glacial advance are exposed (Hobbs and Goebel, 1982).

The first major Quaternary-era glacial advance within the area from the northeast, by the late Wisconsinan-age Rainy Lobe. In the International Falls Area, all of the glacial till deposited by the Rainy Lobe was overlain and/or incorporated into deposits associated with the subsequent advance of the Koochiching (Des Moines) lobe (Martin et al., 1989) from the northwest. As seen within the inset map in Figure 10, this area was at the eastern edge of the Des Moines Lobe; thin layers of Rainy Lobe till cover the bedrock just east of the area mapped in Figure 10, and within Voyageurs National Park (Eng, 1980).

Eng (1980) mapped the surficial geology of Koochiching County on a 1:63,360 scale. In Figure 10, Eng's mapped surficial geologic units are overlain on a topographic DEM image of the area. The upland ridges and topographic highs in the area are predominately covered with thin layers of glacial till during the advance of the Koochiching lobe. When Glacial Lake Agassiz formed during the retreat of this glacial advance, these upland areas were islands, and the till deposits deposited in these areas were modified by wave action. Sand and gravel was deposited along this paleoshoreline, in layers thick enough in some places to be commercially mined for aggregate (See Figure 5, and the corresponding pits observable in the Figure 3 air photo).

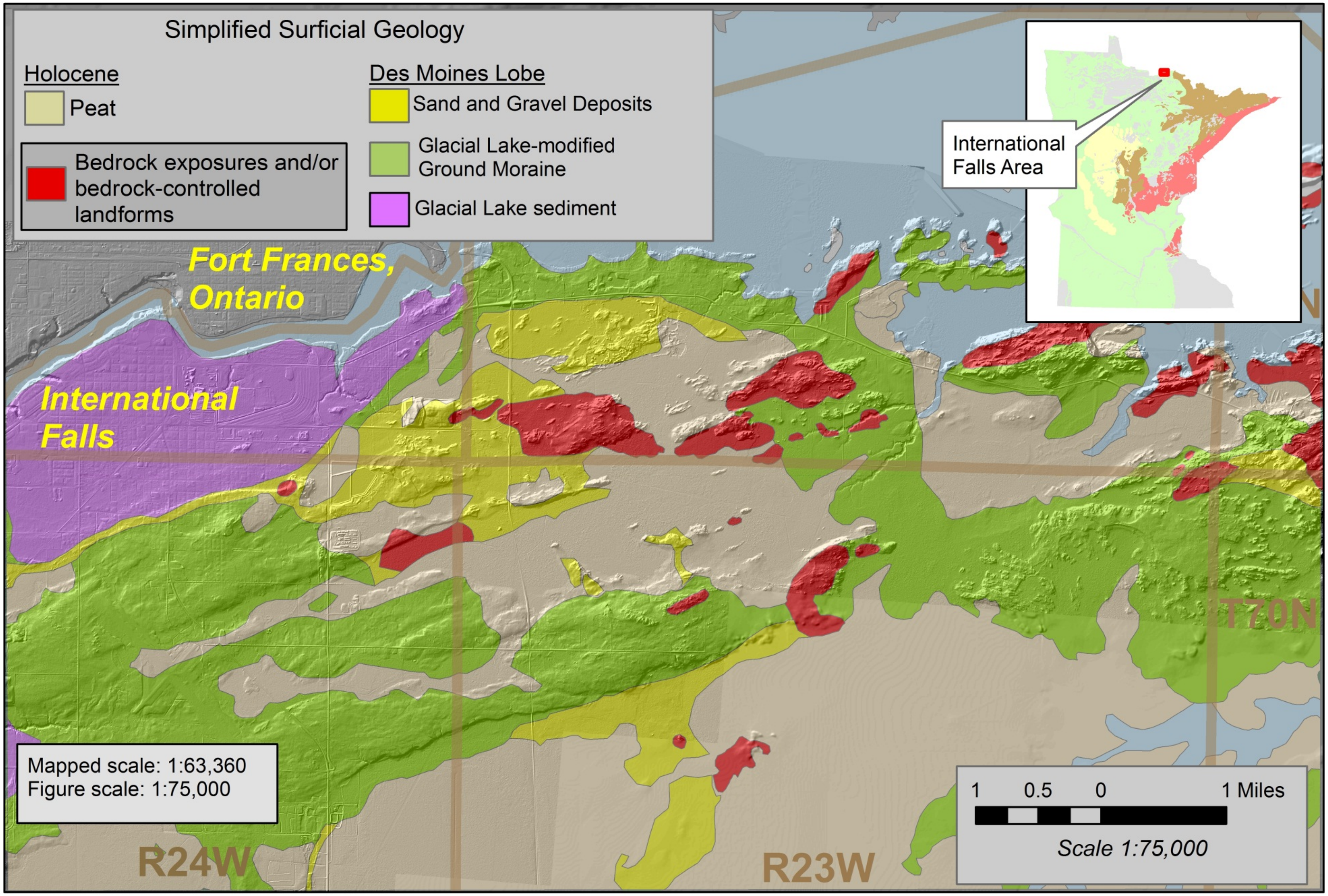

Figure 10:Simplified glacial geology map of the International Falls Area (georectified data mapped by Eng, 1980, scale 1:63,360)

The City of International Falls is built in a lowland area that overlies a thick layer of Glacial Lake Aggasiz lacustrine sediment. Lowland areas in much of the Area of Interest are covered with peat bogs, which formed in portions of the lake plain that lacked the topographic relief necessary to drain precipitation once the lake margins receded. It should be noted, however, that there are some lowland areas that have well-drained soils and well-developed soil profiles that are amenable to geochemical sampling programs.

6.0 Bedrock Geology

6.1. Regional Bedrock Geology

The northern one-third of the State of Minnesota is underlain by the Southern portion of the Archean Superior Province of the Canadian Shield. Within the Superior Province, alternating belts of granite-greenstone and metasedimentary terranes form northeasterly-trending subprovinces (Jirsa and Southwick, 2003). Three of these subprovinces extend across the international border into Northern Minnesota (Figure 11), with the Wabigoon and Wawa granite-greenstone terranes separated by the Quetico metasedimentary subprovince. These contacts are typically major east-west trending high-angle faults that have both vertical and dextral displacement (e.g. the Quetico and Rainy Lake-Seine River faults).

As shown in Figure 11, the Wabigoon and Wawa granite greenstone terranes host many active and past-producting gold mines along their extent within Ontario (OGS MDI, 2010). The continuity of geologic units across the international border and the proximity of known gold deposits in Northwestern Ontario and areas of active gold exploration in Northern Minnesota are shown in Figure 5. The International Falls area is the only area of active gold exploration within Minnesota located within the Wabigoon Subprovince. Given the number of Wabigoon Subprovince gold deposits on the Canadian side of the international border, the focus on Wawa subprovince prospects in Northern Minnesota should be viewed as having far more to do with shallower overburden depths and greater outcrop exposure than with overall mineral potential.

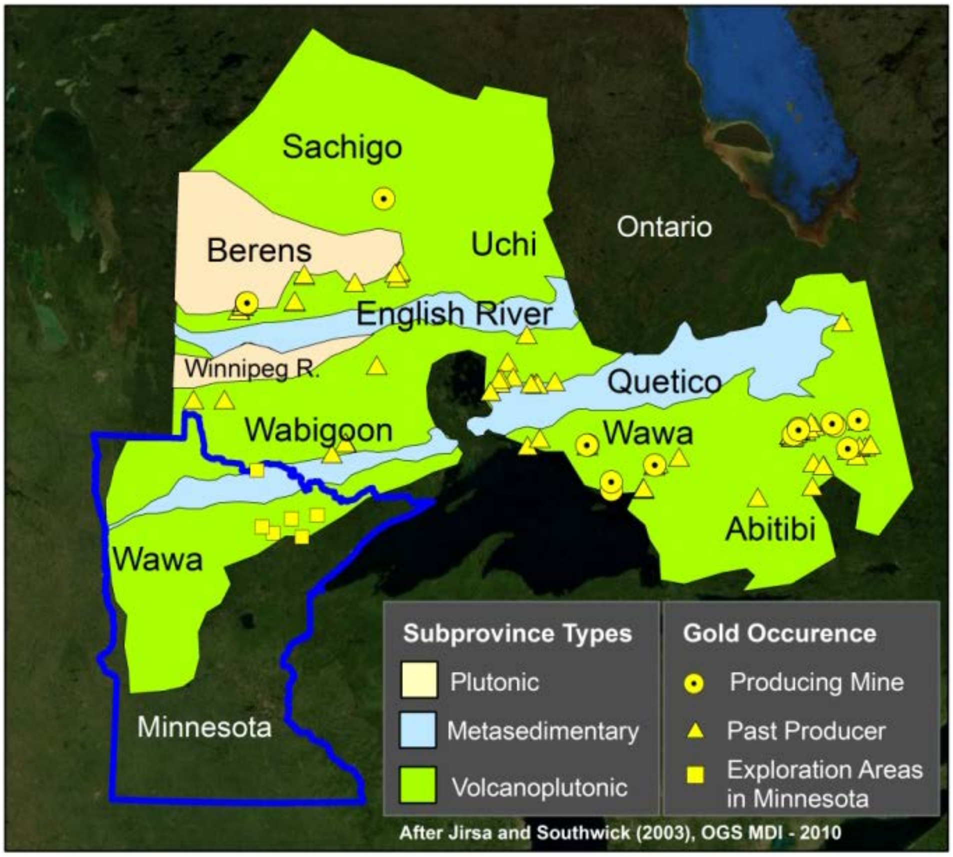

Figure 11: The Archean Superior Province in Ontario and Minnesota. The Wawa and Wabigoon Subprovinces that extend into Northern Minnesota host numerous producing and past-producing gold mines in Ontario.

6.2. Local Bedrock Geology

Several geologic maps have been published depicting the bedrock geology in and around the International Falls Area. The boundaries of these mapping projects, relative to the project area, are shown in Figure 12.

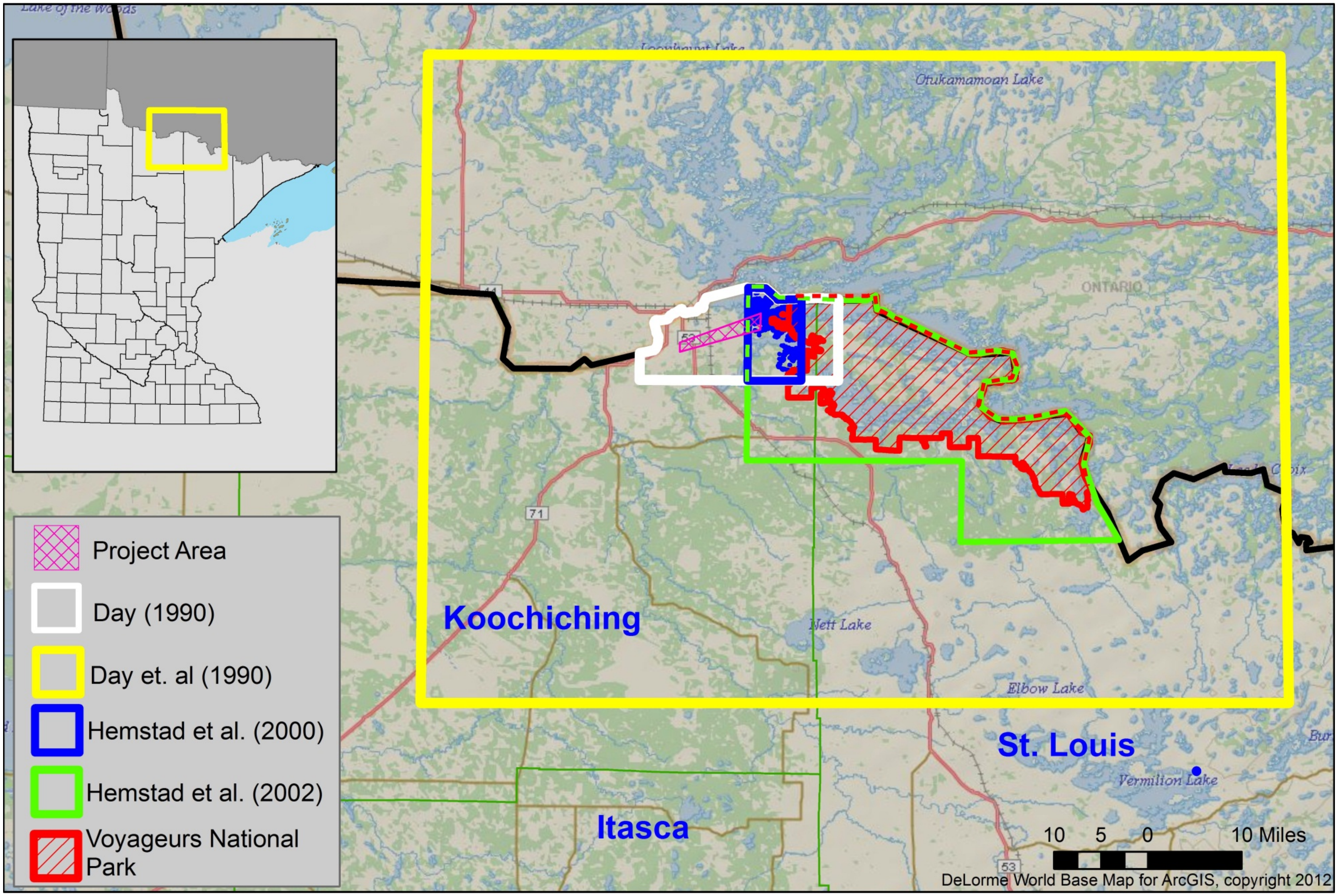

Figure 12: Geologic Mapping in the International Falls Area

Day et. al (1990) mapped both the U.S. and Canadian portions of the International Falls 1x2 quadrangle at a 1:250,000 scale. A portion of this quadrangle was mapped at a 1:50,000 scale by Day (1990), focusing on the area of historical gold exploration on the U.S. side of the international border south of Rainy Lake. The bedrock geology of the eastern portion of the project area was mapped at a 1:24,000 scale by Hemstad et al. (2000) as part of the Island View Quadrangle. Hempstad et al. (2002) published a geologic map of Voyageurs National Park at a scale of 1:50,000. The project area for this geochemical survey is located west of Voyageurs National Park, and mostly outside of Hempstad et al.'s (2002) mapping area.

Figure 13 is a simplified geologic map of the project area that uses the lithologic and structural features identified by the Minnesota Geological Survey (2011) in its latest 1:500,000 scale geologic map of Minnesota. The easternmost portion of the project area was mapped Hempstad et al. (2000) at a 1:24,000 scale, in far greater detail than is shown in Figure 13. The bedrock units selected by the MGS (2011) when mapping the entire state at a scale of 1:500,000 are generalizations, and lack the detail observable when the local geology is mapped at a smaller-scale. Figure 14 shows these differences by plotting the bedrock geology of the eastern portion of the project area at both scales (with the MGS map shown as in inset). Areas that Hempstad et al. identify as "schistose tectonite" and amphibolite schist are mapped by the MGS as a metavolcanic, while "schistose rhyolite" and "schistose conglomerate" are combined by the MGS into a "metaconglomerate" unit.

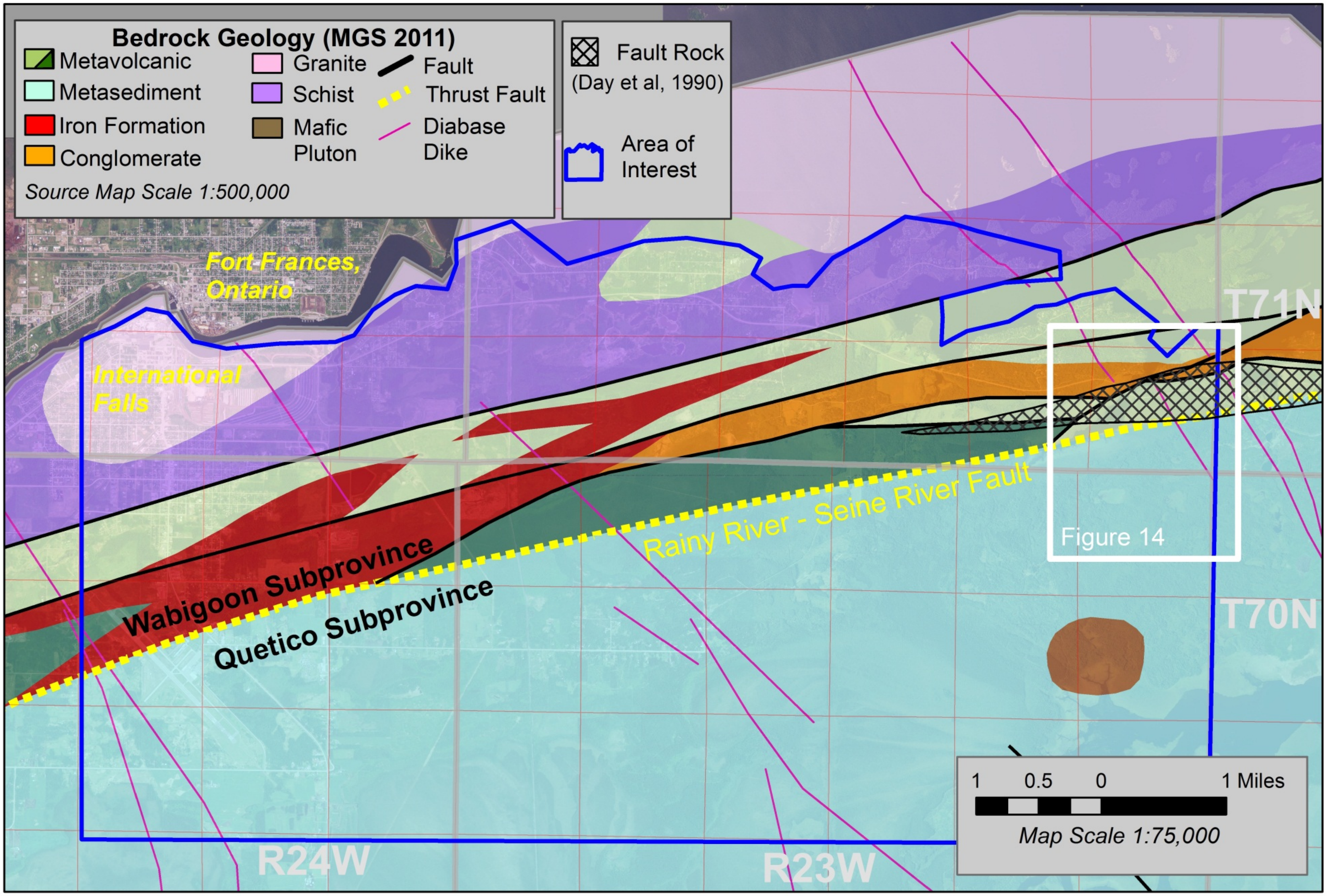

Figure 13: Simplified Bedrock Geology Map of the International Falls Area. White box shows the area of detailed geology in Figure 14.

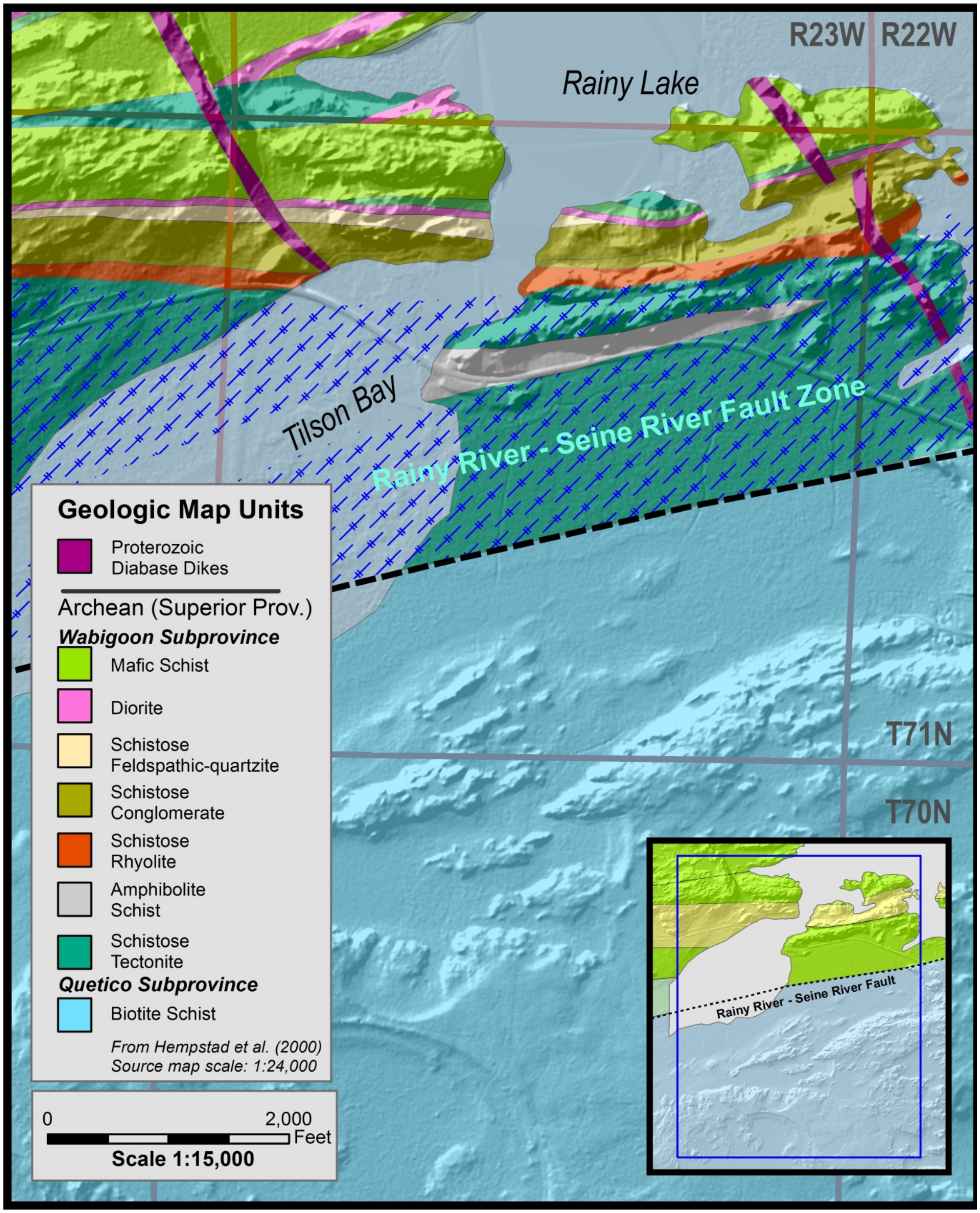

Figure 14: Detailed geologic map of the eastern portion of the project area (from Hemstad et al., 2000), Inset map shows the corresponding level of detail in the MGS 2011 statewide map.

The northern half of the project area is underlain by the Wabigoon Subprovince of the Archean Superior Province. The Wabigoon Subprovince is a granite-greenstone terrane that was metamorphosed to upper greenschist facies to lower amphibolite facies conditions. The southern half of the International Falls Area of Interest is associated with the Quetico Subprovince of the Archean Superior Province. The dominant bedrock in this portion of the project area is a biotite schist of metapelitic origin that experienced upper-amphibolite facies metamorphism (Klein et al., 1997). A brief description of the bedrock units within these two terranes follows.

6.2.1. Wabigoon Subprovince

The Wabigoon Subprovince is an Archean granite-greenstone terrane that is comprised of metamorphosed volcanic, plutonic, and metasedimentary rock units. Age dating of rocks within this terrane range from 2.725 to 2.685 Ga (Davis et al., 1989).

6.2.1.1. Metavolcanics

The volcanic rocks within this portion of the Wabigoon Subprovince are bimodal in composition. The areas mapped as “metavolcanic” in Figure 13 include both volcanic and volcaniclastic rocks of felsic to intermediate composition (dark green), and mafic metavolcanic rocks with minor volcaniclastic and hypabyssal intrusions (olive green) (MGS, 2011). Hempstad et al. (2000) notes that that these rocks are scale to fairly massive, dark-green-gray in color, and comprise of thin sequences of metabasaltic flows and interbedded tuffaceous sequences. There are relict vestiges of pillow rinds, and rare occurances of complete pillows.

6.2.1.2. Metaconglomerate

The unit mapped in Figure 13 as “conglomerate” includes individual subunits of metamorphosed conglomerate, lithic sandstone, greywacke, and mudstone that were too be small to be mapped individually on a 1:500,000 scale. Hempstad et al. (2000) mapped these metasedimentary units in finer detail the easternmost portion of the project area (Figure 14). What is shown as metaconglomerate in Figure 13 appears as three distinct units when mapped by Hempstad et al. at 1:24,000 scale; a schistose rhyolite, a schistose conglomerate, and a schistose feldspathic quartzite that together form the "Seine Group." The schistose rhyolite is described as a metamorphosed reddish-gray clast-rich felsic flow. The schistose conglomerate unit contains rounded pebbles, cobbles, and boulders of felsic plutonic rocks, mafic to felsic volcanic rocks, chert, biotite schist, and iron formation. This metaconglomerate was age dated by Davis et al. (1989) at 2.686 to 2.695 Ga. The schistose feldspathic quartzite is a metamorphosed sandstone with angular to subrounded quartz and feldspar grains within beds that are 5 centimeters to 1 meter thick. Cross-stratification is common.

6.2.1.3. Iron formation

The iron-formation that is interlayered with Wabigoon Subprovince metavolcanic and metaconglomerate rocks is generally oxide-facies (chert-magnetite), but there are areas within the project area where both silicate-facies and sulfide-facies iron formations occur (Klein et al., 1997). The iron-formation layers show evidence of a shared deformational history with the other supracrustal units.

6.2.1.4. Granite

The bedrock unit labeled simply as "granite" by the MGS (2011) is identified by Day et al. (1990) as a coarse-grained weakly-foliated hornblende monzonite that commonly forms intrusive complexes.

6.2.1.5. Schist

The MGS (2011) identifies the unit mapped as "Schist" in Figure 13 as "Schist of sedimentary protolith." Day et al. (1990) identified the same rock formation as "Metasedimentary rocks, undivided," and described it as, “Dominately dark-gray to brown, fine- to medium-grained metagraywacke and slate (biotite schist and pelite).”

6.2.2. Quetico Subprovince

Percival and Williams (1989) described Quetico subprovince as “monotonous metagraywacke, with derived migmatite and granite, in thrust and/or transcurrent fault contact with the adjacent Wabigoon and Wawa metavolcanic subprovinces.”

6.2.2.1. Metasediment

The main Quetico Subprovince bedrock unit that lies within the International Falls Area of Interest is identified in Figure 13 as a “Metasediment,” and as a biotite schist in Figure 14. Day et al. (1990) identified this rock formation as “Metasedimentary rocks, undivided.” Within the project area, this metasedimentary rock is a folded greywacke that has been metamorphosed to sillimanite-bearing biotite schist and intruded by small felsic bodies (Klein et al., 1997).

6.2.2.2. Mafic Pluton

The MGS (2011) maps a mafic pluton in the southeastern portion of the Area of Interest that it describes as a “Mafic plug-like intrusion; typically magnetic.” There are no outcrop exposures or drill core intercepts of this rock unit, and it was not mapped by Day et al. (1990). The MGS may have identified this bedrock unit based on the strong stock-shaped anomaly on an aeromagnetic map of the area (Chandler and Lively, 2007, See Figure 15).

6.2.3. Diabase dikes

Paleoproterozoic diabase dikes of the Kenora-Kabetogama dike swarm (Southwick and Day, 1983) cut across and are chilled against both Wabigoon and Quetico Subprovince rocks units. These dikes are generally orientated northwest-southeasterly, are gabbroic to dioritic in composition, and can reach up to 100 m in thickness (Hempstad et al., 2000). Wirth et al. (1995) obtained an age date of 2.076 Ga from a dike in this swarm.

6.3 Structural Geology

The simplified geologic map shown in Figure 13 is based on the bedrock units and structural boundaries identified by the MGS (2011) in its 1:500,000 scale statewide map. The Wabigoon and Quetico Subprovinces are distinct lithotectonic terranes that are separated by high angle faults that have both a vertical and dextral strike-slip component (Klein et al., 1997). Within the International Falls Area, this major structural divide is the Rainy Lake-Seine River Fault, which separates Wabigoon Suprovince rocks to the north from Quetico Subprovince rocks to the south.

The Wabigoon Subprovince rocks located along the northern edge of the Rainy River-Seine River Fault are cut by a series of faults that run sub-parallel to this major structural boundary. Hempstad et al. (2000) identify this mile-wide area of faults as the Rainy River-Seine River Fault Zone (Figure 14). This structurally complex zone is seen in Figure 15 as a strong linear aeromagnetic anomaly on the latest statewide aeromagnetic map (Chandler and Lively, 2007).

Figure 15 displays the locations of faults and fault rock within this fault zone as they were mapped by Day et al. (1990). This fault pattern is slightly different than what the MGS (2011) used in its 1:500,000 scale bedrock geology map of Minnesota. One example of this difference is shown in Figure 13, where the area of "fault rock" mapped by Day et al is plotted against the MGS's geologic map. The area of fault rock shown in Figure 15 is bounded by fault contacts that do not align with the faults mapped in Figure 13.

A precise placement of fault contacts within the fault zone immediately north of the Rainy River-Seine River Fault was not required for this geochemical survey. Day et al.'s (1990) bedrock geology map of the Rainy Lake area was plotted at a 1:50,000 scale, and was used by Klein et al. (1997) in their mineral potential maps of the International Falls Area. The MGS mapped fault locations often serve as lithologic contacts between different bedrock units in its geologic map. We have therefore used the MGS (2011) fault locations in this report only in those figures that display the associated bedrock geology; in all other figures, the structural geology of Day et al. (1990) is favored.

The area of "fault rock" mapped by Day et al. was also identified by Hempstad et al. (2000), who described the rocks within it as schistose tectonite, and extended the mapped area of intensely sheared and altered rock eastwards along the Rainy River-Seine River Fault Zone.

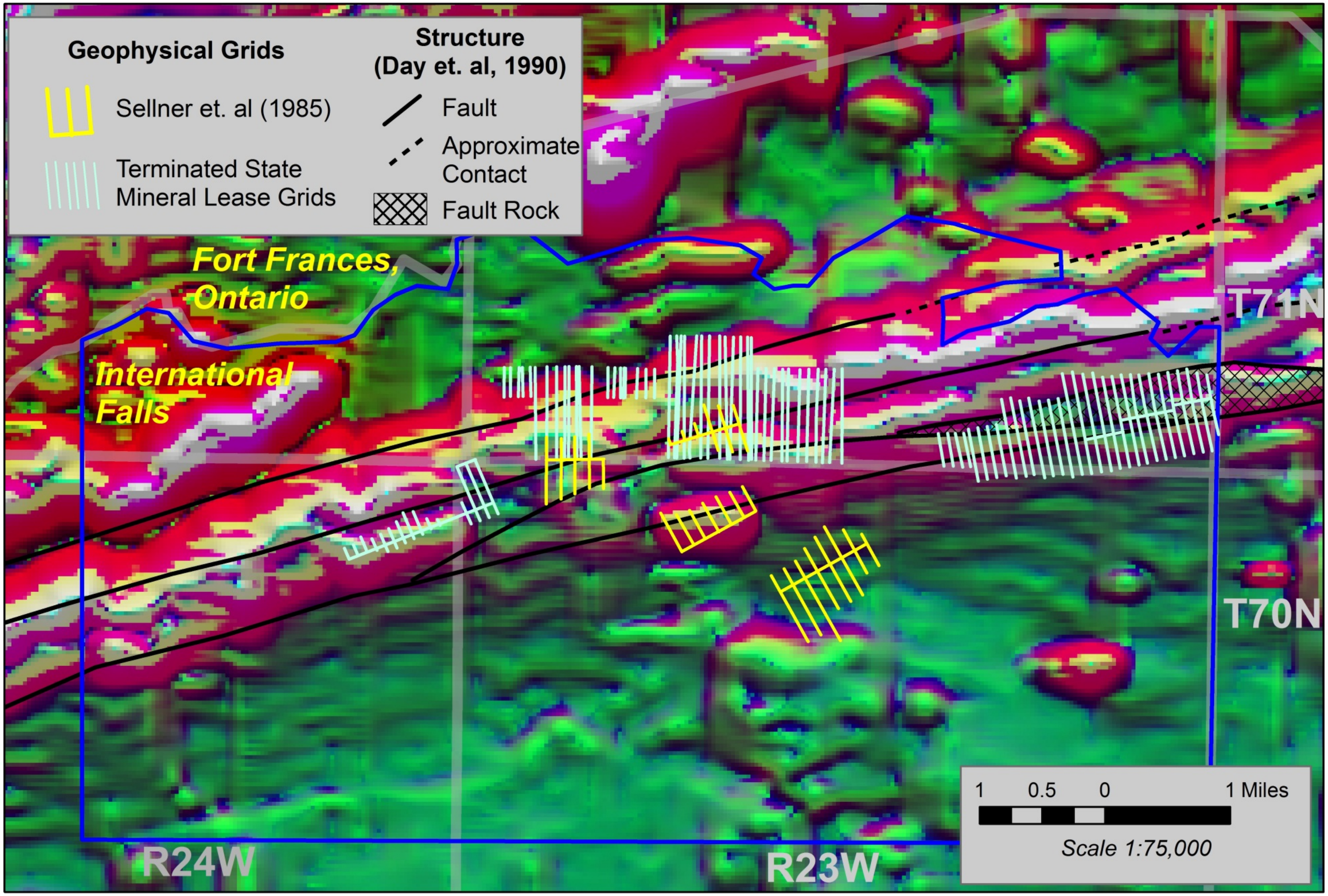

Figure 15: Historic geophysical grids in the International Falls Area, plotted against structural features (Day et al, 1990) and the revised aeromagnetic map of Minnesota (Chandler and Lively, 2007).

7.0 Mineral Exploration and Development

7.1 Historical Mineral Exploration

In 1893, gold was discovered in a 2m-wide quartz vein on Little American Island, located on Rainy Lake approximately ten miles east of International Falls and one-half mile west of Voyageurs National Park (Grout, 1937). The Island straddles the Rainy Lake-Seine River Fault, and has outcrop exposures and thin drift-covered bedrock exposures of a mylonitic schist (Day, 1990). Gold was typically found in quartz veins, and associated with pyrite, arsenopyrite and ankerite within a myolinitic schist host rock.

Several small excavations were completed on Little American and adjacent islands, including the Little America Mine, and in 1894 a stamp mill was constructed on the mainland. Gold production was insufficient to continue operations and extensive exploration within the area, although it did promote exploration efforts on the Canadian side of the international border, in what became known as "The Rainy District." This led to the discovery of exploitable gold deposits in the Mine Centre area of Northwestern Ontario, with more than a million dollar's worth of gold produced in the first few decades of the Twentieth Century (Grout, 1937).

There is no historic record of gold exploration in the International Falls area over the next ninety years. Record-high gold prices in the late 1980's and the discovery of the world-class Hemlo gold deposit in Ontario led to a relatively intense period of mineral exploration in correlative portions of the Superior Province in Northern Minnesota. Active exploration and drilling programs identified several gold prospects in six distinct areas of Northern Minnesota, including the International Falls Area. The sharp drop in gold prices in 1991 and the failure to identify gold deposits that were economically-feasible to mine led to a sharp drop off in mineral exploration. There has been very little gold exploration activity when measured in terms of numbers of drill holes since that time.

Mineral exploration companies that operate on State-leased lands are obligated to provide the State with copies of any maps, drill logs, or analytical results obtained during their tenancy. These hard-copy records are stored in an assessment file system that is available to the public. There is an on-going effort to digitize these hard copy records and make them available on-line. For example, in Figure 16, the distribution of geophysical grid lines run by mineral exploration companies on state-leased lands is plotted against the statewide aeromagnetic map (Chandler and Lively, 2007). Private mineral exploration companies focused primarily on the mile-wide fault zone within the Wabigoon Subprovince rocks in the International Falls Area, with grid lines running perpendicular or sub-perpendicular to the NE-SW trending faults and associated linear aeromagnetic anomaly.

7.1.1. Geophysical Surveys

Private mineral exploration companies completed geophysical surveys in the International Falls Area as part of their exploration programs on State mineral leases. These records are available on-line (http://minarchive.dnr.state.mn.us). The locations of these grid lines are shown in Figure 15, plotted against the state aeromagnetic map (Chandler and Lively, 2007). Figure 15 also displays the geophysical grid lines established by Sellner et al. (1985) during their combined geophysical and geochemical reconnaissance survey.

The USGS compiled geophysical data in the US portion of the International Falls 1° x 2° Quadrangle, producing both a magnetic map (Bracken and Godson, 1987) and a gravity map (Chandler and Horton, 1988) at a 1:250,000 scale. These maps were useful in the preparation of subsequent geologic maps of the area (e.g. Hempstad et al., 2002), particularly in areas with no outcrops and sparse drill hole or water well data.

7.1.2. Geochemical Surveys

The archived records submitted by mineral exploration companies operating on State-leased lands include limited information relative to their geochemical surveys of outcrop and soil samples (http://minarchive.dnr.state.mn.us). The Normin Mining Company conducted mineral exploration activities in the International Falls Area during the late 1980's on a land package that included both State and private mineral leases. One of the documents that they provided after terminating the State lease on Section 1 of T70N, R24W was a 1988 contour map of gold concentrations in soil (Figure 16). A total of 131 hand plotted data points are spaced at 100 foot intervals within a grid network on this map. Gold concentrations range from <1 ppb to 90 ppb. It is important to note that the archived records do not contain associated laboratory reports, or information concerning sampling methods or intervals (e.g. whether they sampled the A or B soil horizons).

7.1.3 Exploratory Drilling

Mineral exploration companies are obligated under state law to provide at least ¼ of any core recovered from exploratory borings. These drill cores are stored in a modern, climate-controlled facility that is open to the public.

Some of the analytical results for geochemical sampling and assays of drill core from the International Falls Area were compiled by Englebert and Hauck (1991) as part of a geochemical evaluation of Archean bedrock in Northern Minnesota. Some of the analytical results from drill holes in the International Falls Area were unavailable to these authors, either because they were completed after the report was published, or they weren't available at the time of publication.

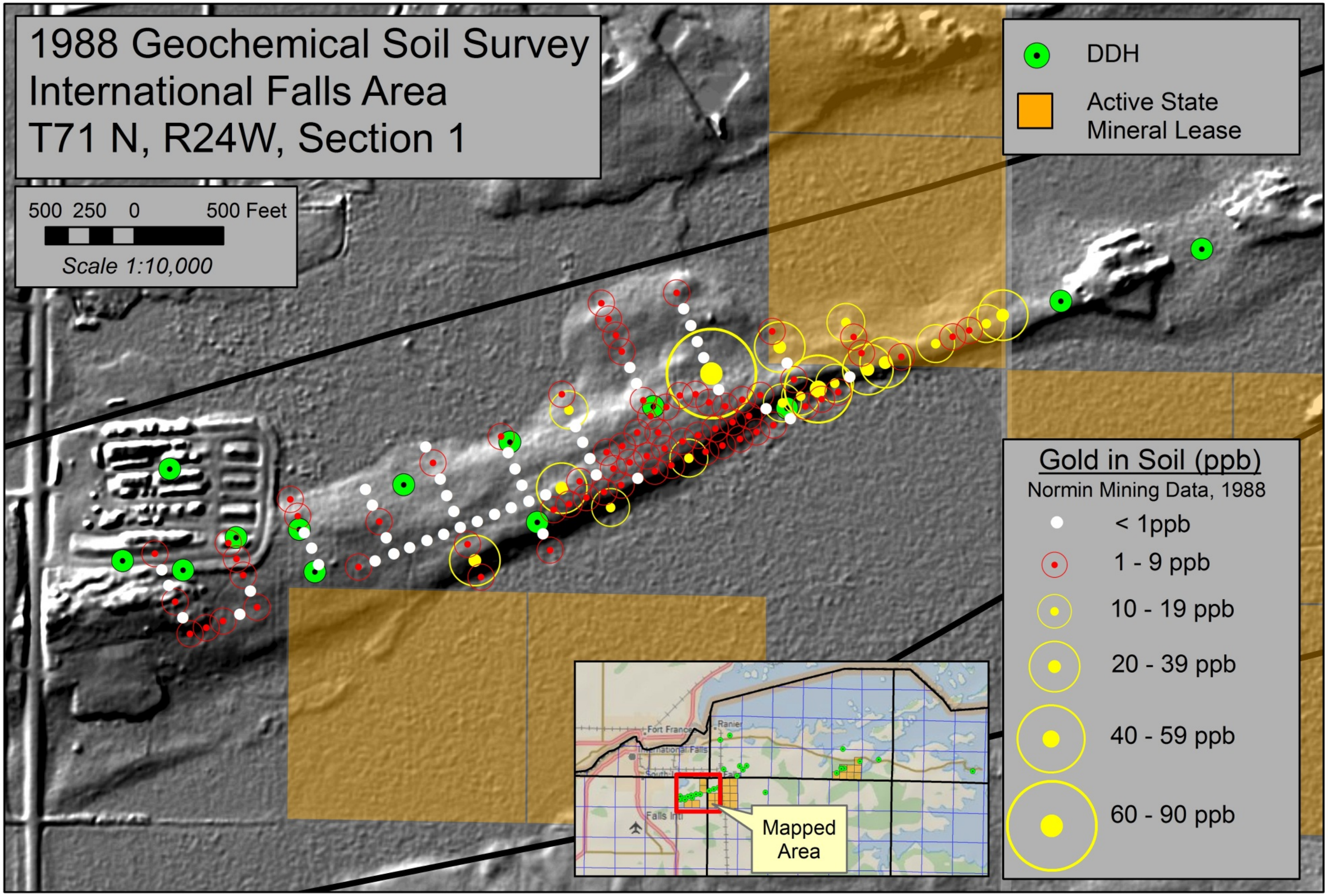

Figure 16: Gold concentrations (ppb) in International Falls soil samples, compiled by the Normin Mining Company (1988)

A review of the historic assays results from drill core in the International Falls Area identified several exploratory borings with high concentrations of gold over relatively long footage intervals. Selected assay results are summarized in Figure 17.

7.2 Active Mineral Exploration

There are currently three active mineral exploration leases on State lands within the International Falls Area (Figure 4).

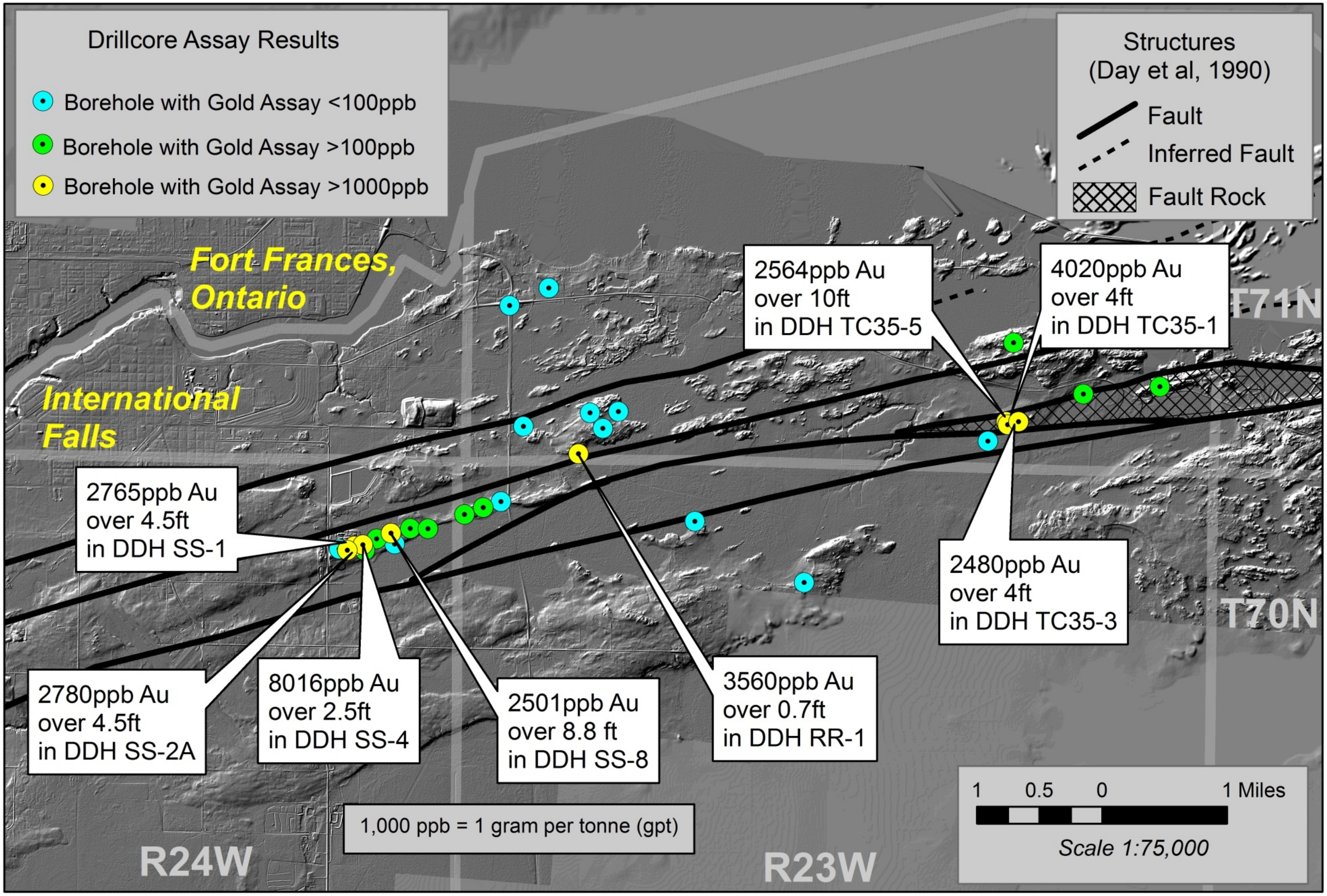

Figure 17: Selected gold assay results from historical drilling in the International Falls Area.

8.0 Deposit Types and Mineral Potential

Klein et al. (1997) used a three-step approach to identify ore deposit types and mineral potential in the International Falls Area. In the first step, mineralization models and ore deposit types in mining districts within comparable terranes were identified. As previously mentioned, the Archean granite-greenstone terrane and major structural fault systems extend upstrike into Northwestern Ontario. Comparable Wabigoon Subprovince bedrock units host world-class gold deposits and gold camps north of the International border, and extrapolations were made from the geologic settings and mineralization models associated with these ore bodies. As a second step, Klein et al. searched in the International Falls Area for those specific geological, geochemical, and/or geophysical features that characterize these comparable ore deposits. The genetic mineralization models of Ekstrand (1984) were used for this process.

The final step would involve estimating the number of undiscovered ore bodies within the Area of Interest. Klein et al. (1997) did not attempt this third step, citing the relatively small number of outcrops and exploratory drill holes in this region of drift-covered bedrock. Instead, they mapped areas with “High,” “Moderate” or “Low” potential for four types of mineral deposits in the International Falls Area: 1) lode gold, 2) Algoma-type iron formation, 3) volcanogenic massive sulfide deposits, and 4) chemical sediment-hosted gold deposits. The mineral potential for lode gold deposits is plotted against drill core locations and selected assay results in Figure 18. The high gold assays in these drill cores and their location proximal to the Rainy River-Seine River Fault were major factors in assigning this high mineral potentials. Note that their map of mineral potential for sedimentary-hosted gold deposits was roughly the same, except that areas of high lode gold potential are moderate, and moderate lode gold potential areas are considered low potential (Klein et al., 1997)

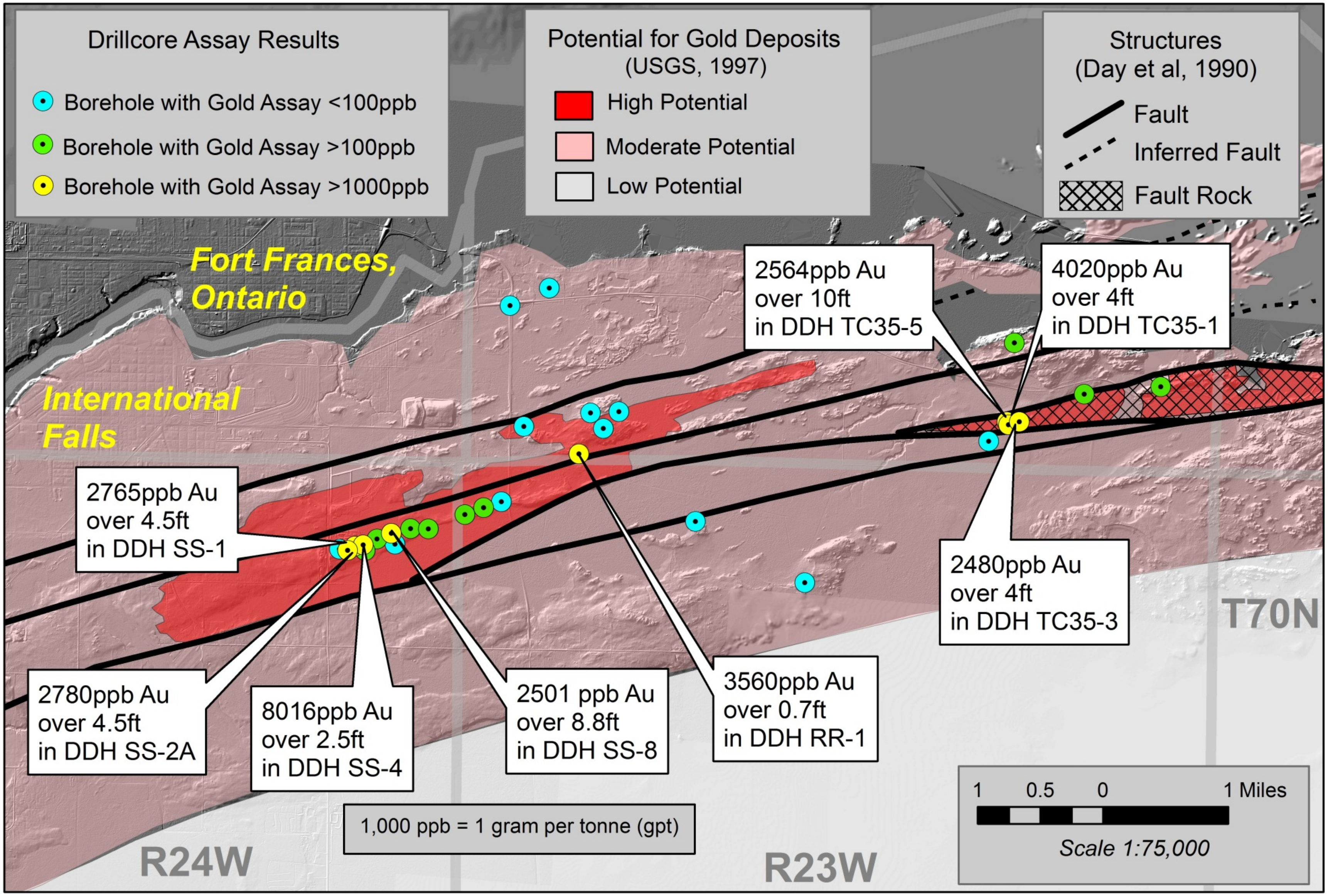

Figure 18: USGS classification of the potential for gold deposits, based in part on high assay results from historical drilling in the International Falls Area. See text for additional criteria descriptions.

9.0 Previous Geochemical Surveys

A number of regional and site specific geochemical soil surveys have been completed in and around the International Falls area.

In 1989, the DNR published the results of regional geochemical survey in the Effie Area, in Southern Koochiching and Northern Itasca Counties. (DNR Report 263, Martin et al., 1989). Twenty-three rotosonic holes were completed, with twenty of the twenty-holes reaching bedrock and/or saprolite. Glacial sediment and saprolite core samples were composited within stratigraphic units, and processed for gold grain counts and multi-element analysis of the heavy mineral concentrate and the -63 micron and clay-sized fractions. The use of rotosonic drilling methods allowed the DNR to delineate complex till stratigraphies, and evaluate the geochemistry and gold grain counts in till units proximal to saprolite or bedrock.

The DNR completed a pilot geochemical survey in the International Falls area in the mid-1980's (Sellner et al., 1985). Gold and silver concentrations were obtained from both A0 (humus) and A1 horizon soil samples obtained from existing geochemical grids. Gold concentrations in A1 soil samples collected by Sellner et al. (1985) are shown in Figure 19. Several locations with anomalously high gold concentrations were identified on either side of the Rainy River-Seine River Fault.

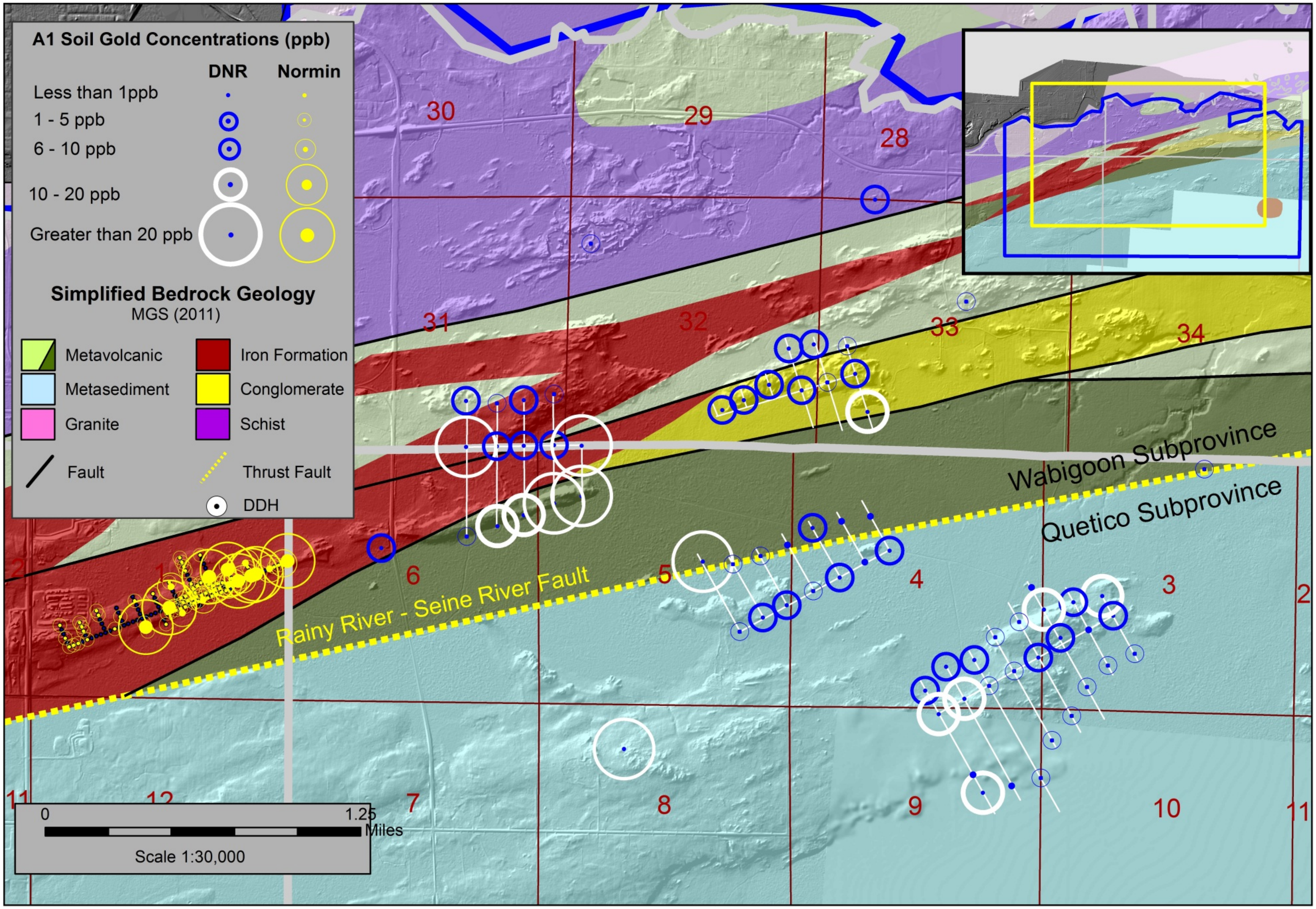

Figure 19: Historical A1 soil gold concentrations (Sellner et al., 1985), Normin (1988) plotted against bedrock geology. Inset map shows plotted area (gold box) relative to larger International Falls Area of Interest

As part of its evaluation of the mineral potential of the U.S. portion of the International Falls Quadrangle, the USGS (Klein et al., 1997) collected and geochemically analyzed almost 500 soil samples. They focused on B-horizon soils, and used an enzyme-based leach “to detect subtle patterns of hydromorphic trace element dispersion in areas where bedrock was covered by surficial deposits. They reported Ag-Co-As anomalies in soil samples along the Rainy River-Seine River fault, and suggested that these anomalies might indicate the presence of vein deposits in the underlying bedrock.

The USGS collected humus, soil and bedrock samples in Voyageurs National Park (Woodruff et al., 2002), located east of the project area. This work was part of a multi-disciplinary and multi-agency effort to establish background and baseline geochemistry within the park, with specific emphasis on determining terrestrial mercury sources and sinks. Different analytical techniques were used on the different types of samples; inductively coupled plasma-mass spectrometry (ICP-MS) was used for O-horizon samples, while A-horizon soils similar in depth and composition to those in this project were analyzed using inductively coupled plasma-atomic emission spectroscopy (ICP-AES). None of Woodruff et al.’s (2002) A-horizon soil samples had gold concentrations higher than the ICP-AES detection limit of 8ppm.

10.0 Project Methods

10.1 Project Design

Much of the International Falls Area is covered by thick layers of glacial sediments that were deposited over multiple periods of glacial activity. This makes the connection between soil samples and underlying bedrock more complex, relative to areas with relatively thin layers of drift where there is a greater chance that it incorporates material derived (at least in part) from local bedrock sources. In these areas of thin drift, the erosion of mineralized bedrock can mechanically produce dispersal trains with elevated concentrations of geochemical tracers in the till. In areas of thick drift with a more complex glacial history, it is harder to identify likely "up-ice" directions, and less likely that the soil layer incorporates material from underlying bedrock.

As seen in Figure 8, there are some bedrock exposures in portions the Area of Interest (most notably in the eastern one-third), and linear bedrock ridges that are overlain by thin layers of glacial sediment. These sediments, however, are identified by Eng (1980) as lake-modified Des Moines lobe ground moraine. Martin et al. (1989) showed that Des Moines Lobe tills (locally named the Koochiching Lobe by Meyer) contain materials transported long distances and are not useful for geochemical investigations. While these proximal glacial deposits may have incorporated material eroded from these bedrock outcrops, they could have easily been geochemically altered by subsequent lake water activity (e.g. wave action). Extensive peat deposits and wetlands further limit the scope of soil surveys in areas such as Koochiching County, where more than half of the land surface is designated wetland areas.

Geochemical surveys in areas with thick layers of glacial sediment and complex glacial histories can yield useful information when trace metals are concentrated using secondary means of dispersion. Groundwater flow is one dispersal method, with the upward vertical flow of groundwater connecting shallow soils with deeper, underlying bedrock (Levson, 2001). Over time, this groundwater transport can “imprint” overlying soils with the bedrock’s geochemical signature by producing hydromorphic soil profiles, particularly when there are elevated bedrock concentrations of trace elements that partition readily into the groundwater. Metals can be mobilized upwards from bedrock sources into unrelated sediments by gaseous transport (Mann et al., 1998). The root systems of local vegetation can also provide secondary dispersion pathways by direct uptake of trace elements, followed by decay and the incorporation of organic matter into the shallow soil (Dunn, 2001).

Previous regional geochemical surveys in the project area typically involved the collection and analysis of more than one type of soil horizon (Sellner et al, 1985; Klein et al., 1997, Woodruff et al., 2002). Differing opinions have been expressed on which soil horizon is more likely to contain geochemical markers associated with precious or base-metal mineralization. There is, in contrast, strong consensus that the likelyhood of identifying a geochemical anomaly associated with a mineral deposits increases as the density of sampling increases.

Gold mineralization within the Archean granite-greenstone terranes within the Superior Province is often linked to major fault systems. Identified gold occurrences and prospects in the International Falls Area are consistent with this style of mineralization; Little American Island is located directly on the fault contact, and the highest gold-bearing intervals of drill core come from holes advanced within a mile of the fault zone (Figure 17).

As part of its mission to determine the mineral potential of State-owned or State-administered lands, the Minnesota DNR had a compelling interest to focus its efforts in those portions of the project area where there are State-owned or State-administered mineral rights. At the same time, areas with active mineral exploration leases were avoided.

Potential sample locations were restricted to the non-wetland portions of land parcels that had State-owned or State-administered mineral rights and were within two miles of the Rainy Lake – Seine River Fault.

10.2 Sample Locations

Figure 20 shows sample locations relative to the State of Minnesota's land position. Sample grids were laid out in areas of accessible public lands that had state-owned mineral rights and surface ownership that was either State-owned or county tax forfeit. Samples were collected in areas that had previously been offered for State mineral exploration leases; approximately half of the samples were in areas with terminated State leases. The State of Minnesota conducted a Lease sale in April 2011; areas offered for lease included those within the sample grids.

Soil samples were collected in grids that were generally east of the grids established by Sellner et al., (1985). While there was a small amount of overlap, the sample location design emphasized extending the area of geochemical soil analyses beyond what had been previously examined.

The location of the sample grids relative to underlying bedrock geology is displayed in Figure 21. All sample locations were within two miles of the mapped location of the northeast-southwest trending Rainy River-Seine River fault that forms the border between the Wabigoon and Quetico Subprovinces. Generally speaking, there were three different bedrock units underneath the collected soil samples. Within the granite-greenstone terrane north of the Rainy River-Seine River Fault, ten samples were collected above a metasedimentary unit described by the MGS (2011) as "conglomerate, lithic sandstone, greywacke, (and) mudstone." Eleven additional samples were located within areas mapped by the MGS as "mafic metavolcanic rocks; minor volcaniclastic and hypabyssal intrusions".

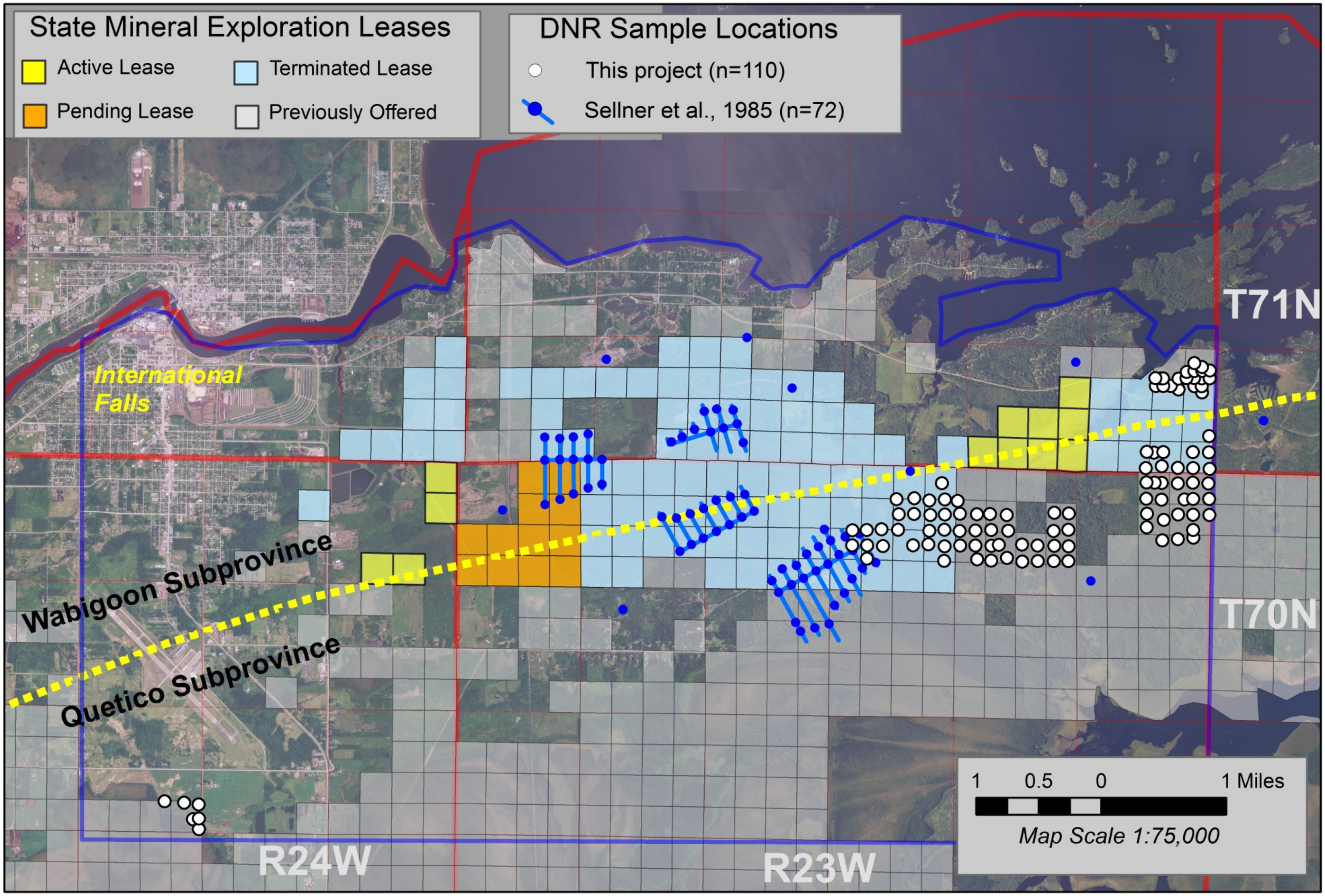

Figure 20: Geochemical soil sample locations (this project and Sellner et al., 1985) relative to State Land Position in the International Falls Area of Interest. Lease Status as of 1 March, 2012

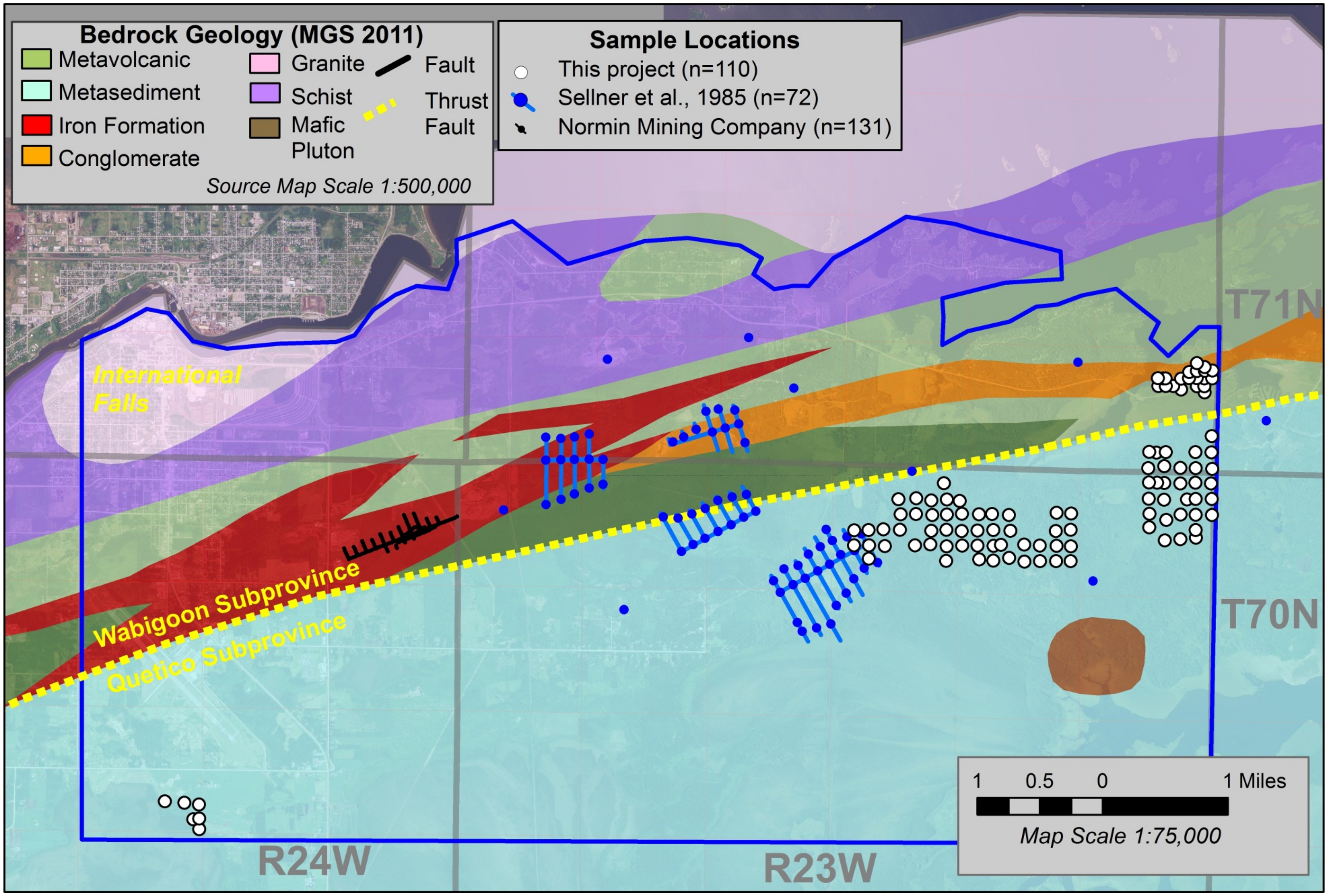

Figure 21: Soil sample locations plotted against a simplified bedrock geology map of the International Falls Area.

The remaining eighty-nine (89) samples were collected south of the fault, above Quetico subprovince "Biotite schist, paragneiss, and schist-rich migmatite."

Figure 22 shows the project sample locations relative to the mapped potential for lode gold deposits, based on the criteria established by the US Geological Survey (Klein et al., 997). The twenty-one Wabigoon Subprovince samples are within a mapped "fault rock" zone with high potential. Eighty-six of the eighty-nine Quetico Subprovince soil sample locations are in an area with "moderate" potential, with the remaining three lie just outside of this zone, and in areas that are considered to have low potential for lode gold deposits.

Sample locations grids planned in advance so as to avoid wetlands and areas of peat. Once in the field, minor adjustments were made in some of the sample locations when the targeted grid node point was located in areas of standing water or localized wetland areas. Figure 23 plots sample locations against the 3m LiDAR DEM and mapped "upland" and "lowland" areas. While, generally speaking, the majority of lowlands in the International Falls Area are wetlands and/or peat bogs, there were several samples collected in lowland areas that exhibited well-developed soil profiles and water table surfaces that were more than a few feet beneath ground surface. As shown in Figure 23, all of the twenty-one (21) Wabigoon Subprovince samples were in mapped upland areas. Thirty-six (36) of the eighty-nine (89) Quetico Subprovince samples were in lowlands, and fifty-three (53) in upland areas.

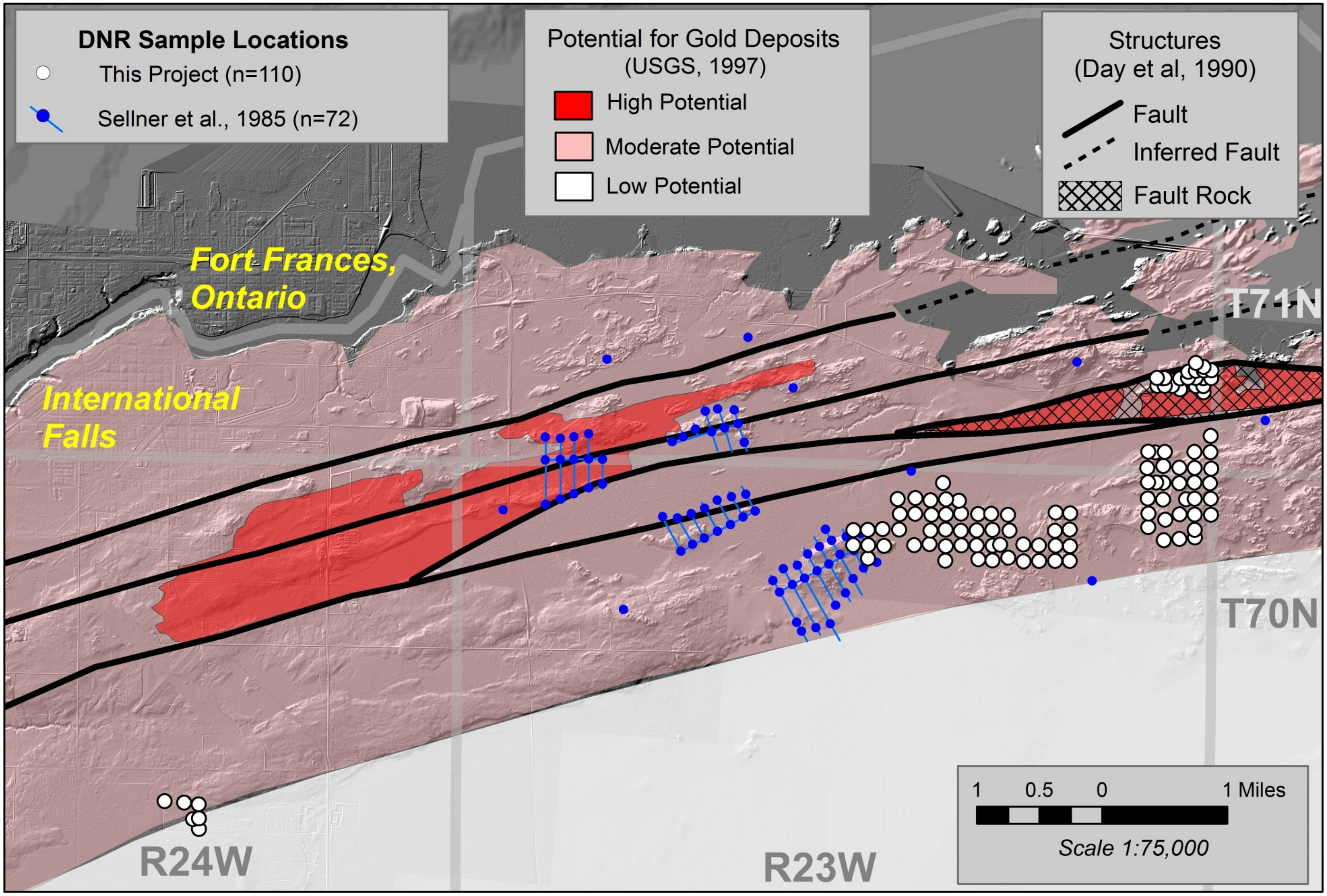

Figure 22: Sample locations, relative to previous A1 soil sample locations (Sellner et al., 1985) and USGS Lode Gold Mineral Potential.

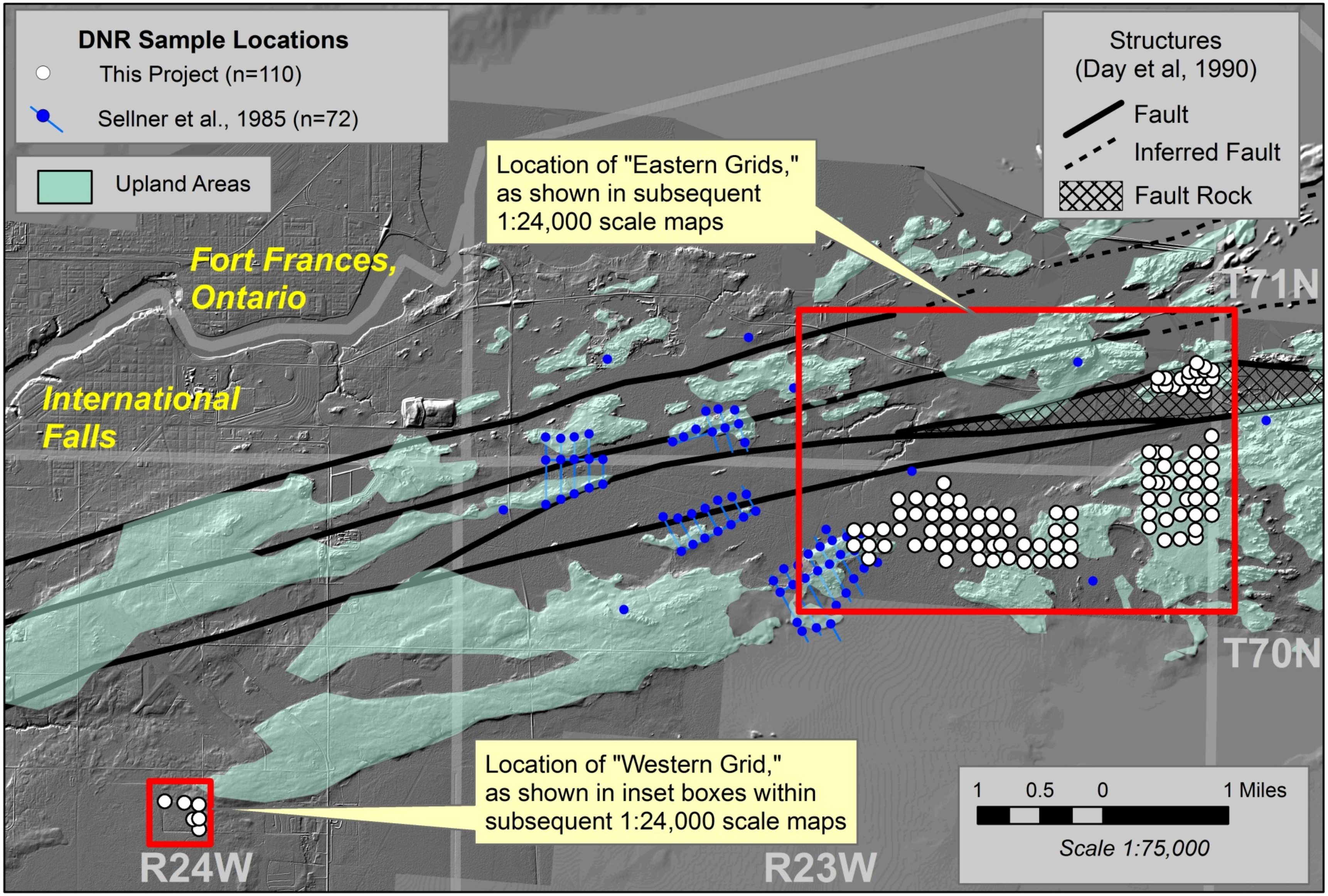

Figure 23 Sample locations, relative to upland areas. The red boxes outline the mapped areas in subsequent 1:24,000 scale maps.

The primary criteria for selecting sample locations (i.e. accessible public lands that are non-wetlands located within two miles of the Rainy River-Seine River fault zone) constrained the geographic distribution of the project's sample collection areas. Unusually high rainfall levels in the months preceding sample collection placed additional constraints on this distribution; public snowmobile and hiking trails that might normally be relatively dry in October were inaccessible for all-terrain vehicles, due to large stretches of deep standing water or thick mud. These limitations resulted in a significant spatial discontinuity for sample grids, with one of the grids located more than five miles southwest of the main sample collection areas.

The geographic relationship between this "Western Grid" and the other sample collection areas (i.e. the "Eastern Grids") is displayed in Figures 20 through 23. These maps are plotted on a scale (1:75,000) that makes it difficult to distinguish between individual data points, particularly in the northeastern portion of the project area, where the grid spacing was 100m, rather than 200m. We have therefore chosen to plot the majority of subsequent maps at a scale of 1:24,000, with an inset box that displays the results for Western Grid samples. Figure 23 has red outline boxes that identifies the areal extent of both this "Western Grid" inset box and the main "Eastern Grids" mapped area, as shown in Figure 24.

Figure 24 labels each sample location with its corresponding short-id number. Each sample location was identified as "IF2010-xxx," with "xxx" being a unique three-digit number. The "short id" for each location uses only the three-digit identifier (dropping the leading zero, as appropriate, to improve legibility).

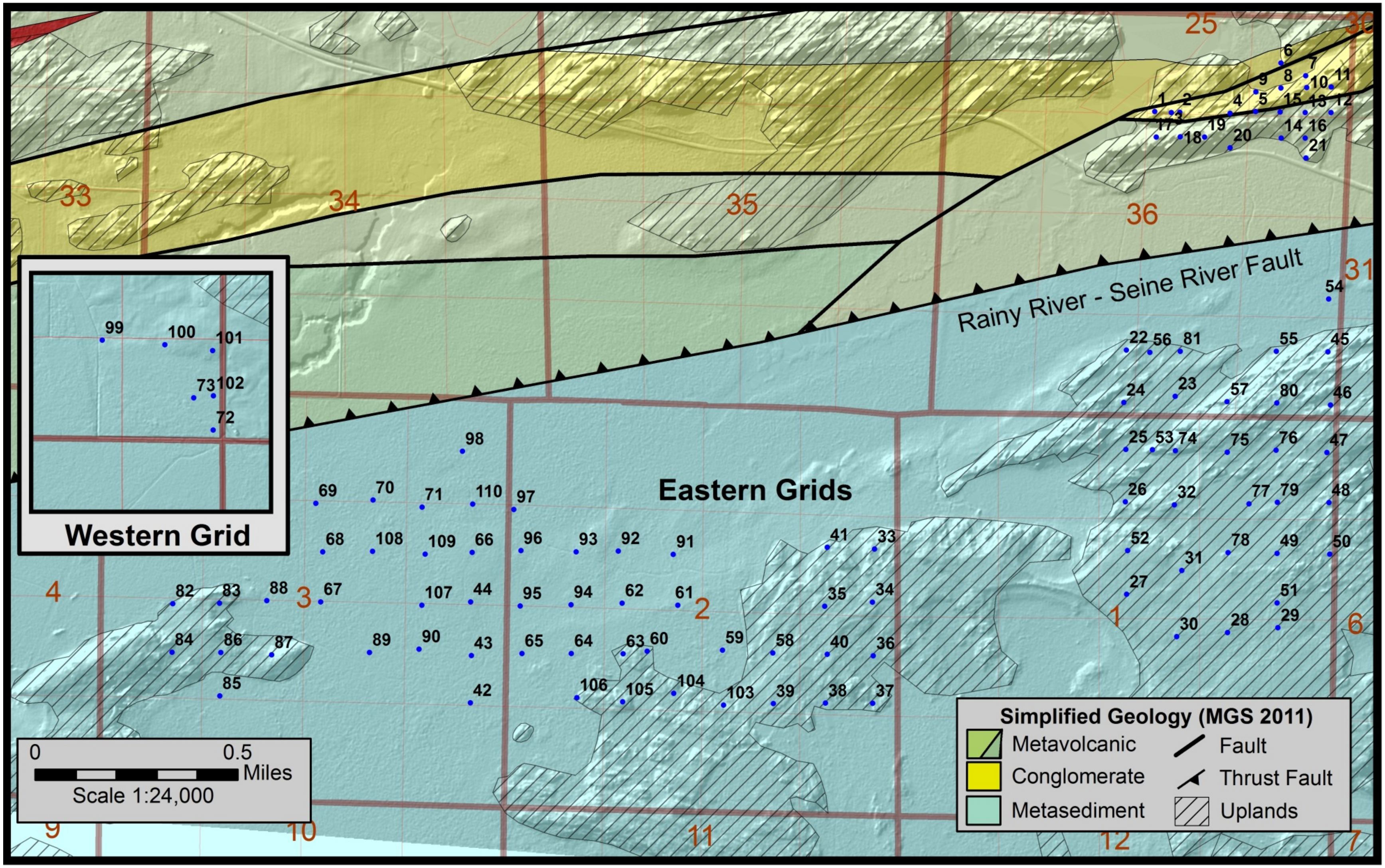

Figure 24: Numbered sample locations, relative to simplified geology (MGS 2011) and upland areas.

As discussed in Section 6, the easternmost portion of the project area was mapped by Hempstad et al. (2000) in far greater detail than is shown in Figure 24. Figure 25 displays sample locations within the area mapped by Hempstad et al. (2000). Samples were collected in soils that overlie four distinct bedrock units. Areas that Hempstad et al. (2000) identify as “schistose tectonite” and “amphibolite schist” are mapped by the MGS as a metavolcanic, while “schistose rhyolite” and “schistose conglomerate” are combined by the MGS into a metaconglomerate unit.

The possibility that the concentrations of certain major and trace elements in A1 soil samples are linked to underlying bedrock is examined in subsequent sections of this report. In reviewing this potential correlation, the Wabigoon Subprovince samples collected in the northeastern portion of the project area are classified based on the MGS’s simplified geologic classifications. While it would have been possible to look at variations based on Hempstad et al.’s (2000) more detailed mapped units, the resulting sample population sizes would have been too small to interpret with any degree of confidence. This can be seen in Figure 25; of the 11 samples classified as “metavolcanics,” only two are within the area mapped in greater detail as amphibolite schist, while the “metaconglomerate” group of ten samples would be equally divided between schistose rhyolite and schistose conglomerate.

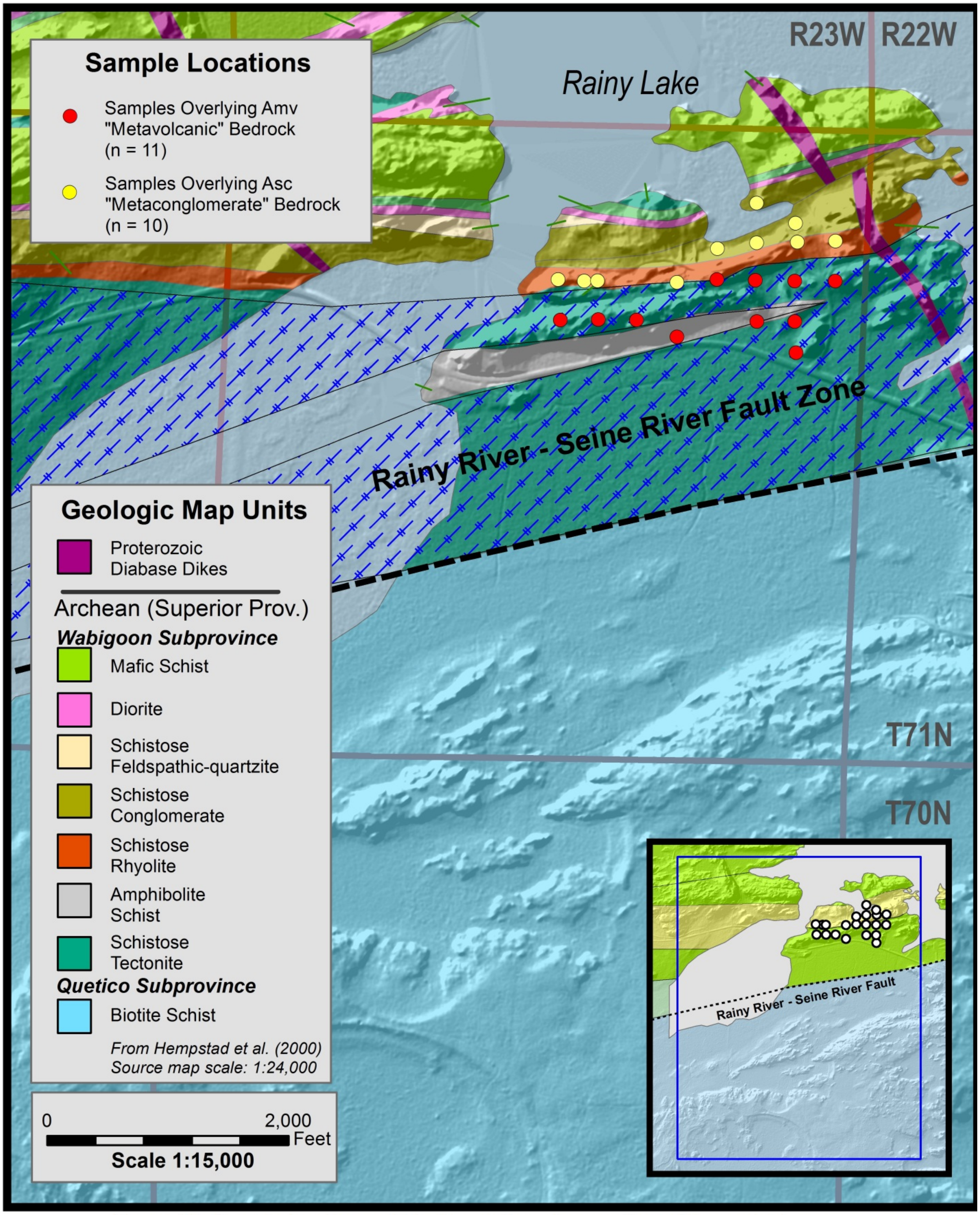

Figure 25: Sample locations within the northeastern portion of the project area, relative to the detailed geologic map of Hempstad et al. (2000).

The link between soil geochemistry and the topography of the sample collection site…whether the sample is in an “upland” or “lowland” area…is also explored in subsequent sections. Figure 26 shows sample grids relative to upland areas and outcrop locations, and identifies how each sample location was classified. All of the 21 Wabigoon Subprovince samples were collected in upland areas, whereas the Quetico Subprovince samples were subequally classified into lowlands and uplands locations.

Tables 1, 2, and 3 provide sample location UTM coordinates, and characterize each sample based on subprovince, whether it is located in an upland or lowland area, and the generalized lithology of the underlying bedrock.

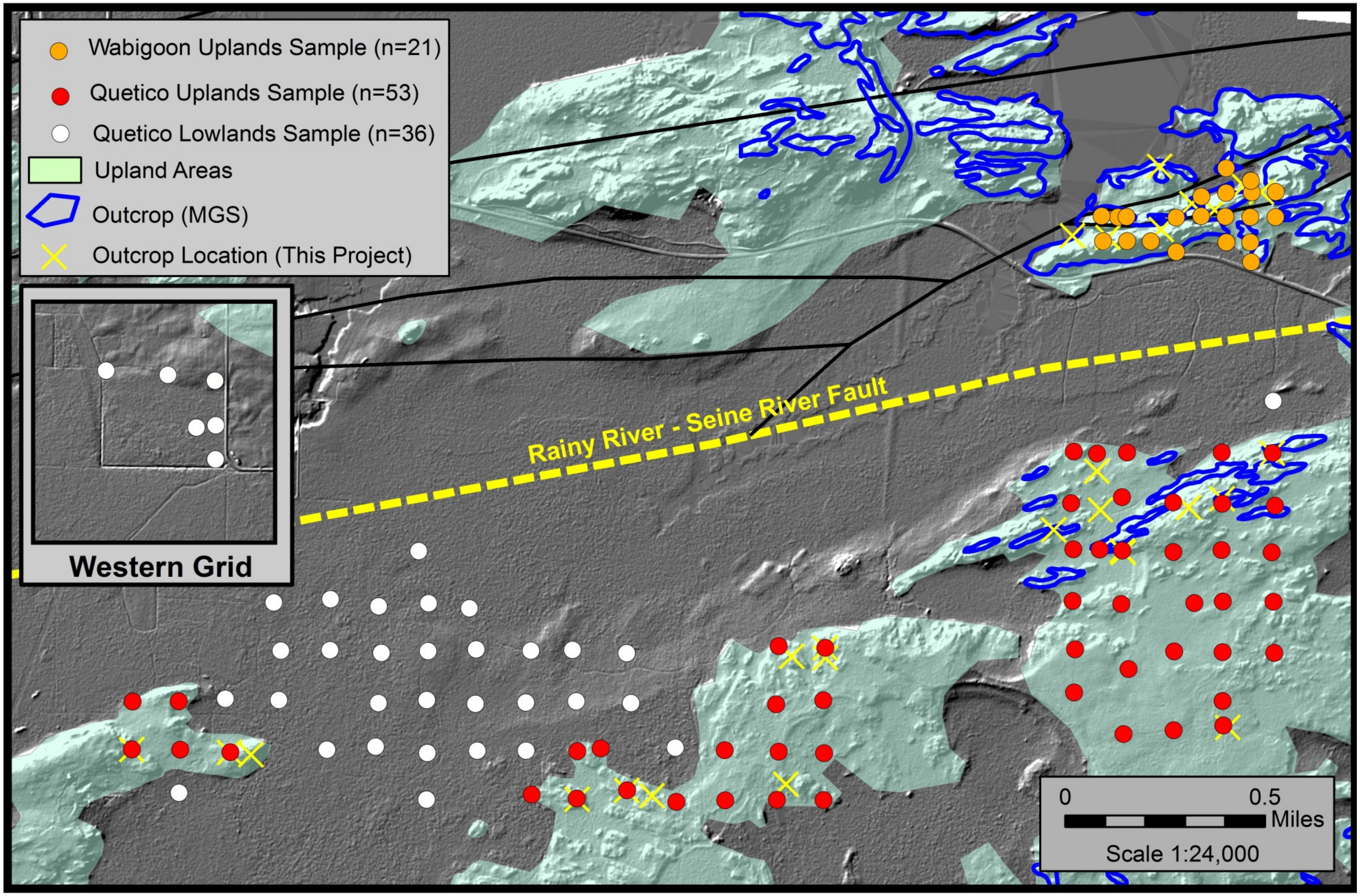

Figure 26: Distribution of sample locations between uplands and lowlands in the project area.

SampleID	UTME	UTMN	Subprovince	Topography	Map Unit	Bedrock Type
IF2010-001	483012	5383082	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-002	483112	5383079	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-003	483078	5383078	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-004	483312	5383075	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-005	483413	5383082	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-006	483513	5383275	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-007	483612	5383224	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-008	483513	5383175	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-009	483414	5383160	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-010	483616	5383177	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-011	483713	5383179	Wabigoon	Uplands	Asc	Metaconglomerate
IF2010-012	483712	5383078	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-013	483610	5383078	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-014	483514	5382976	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-015	483510	5383080	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-016	483610	5382976	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-017	483018	5382980	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-018	483114	5382981	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-019	483210	5382980	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-020	483312	5382937	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-021	483613	5382897	Wabigoon	Uplands	Amv	Metavolcanic
IF2010-022	482900	5382133	Quetico	Uplands	Aqs	Metasediment
IF2010-023	483094	5381949	Quetico	Uplands	Aqs	Metasediment
IF2010-024	482889	5381924	Quetico	Uplands	Aqs	Metasediment
IF2010-025	482898	5381737	Quetico	Uplands	Aqs	Metasediment
IF2010-026	482895	5381529	Quetico	Uplands	Aqs	Metasediment
IF2010-027	482901	5381160	Quetico	Uplands	Aqs	Metasediment
IF2010-028	483302	5381008	Quetico	Uplands	Aqs	Metasediment
IF2010-029	483501	5381027	Quetico	Uplands	Aqs	Metasediment
IF2010-030	483100	5380992	Quetico	Uplands	Aqs	Metasediment
IF2010-031	483120	5381255	Quetico	Uplands	Aqs	Metasediment
IF2010-032	483091	5381517	Quetico	Uplands	Aqs	Metasediment
IF2010-033	481899	5381340	Quetico	Uplands	Aqs	Metasediment
IF2010-034	481891	5381129	Quetico	Uplands	Aqs	Metasediment
IF2010-035	481701	5381112	Quetico	Uplands	Aqs	Metasediment
IF2010-036	481894	5380915	Quetico	Uplands	Aqs	Metasediment
IF2010-037	481892	5380726	Quetico	Uplands	Aqs	Metasediment
IF2010-038	481704	5380727	Quetico	Uplands	Aqs	Metasediment
IF2010-039	481496	5380725	Quetico	Uplands	Aqs	Metasediment
IF2010-040	481711	5380921	Quetico	Uplands	Aqs	Metasediment

Table 1: Sample location information, IF2010-001 through IF2010-040

SampleID	UTME	UTMN	Subprovince	Topography	Map Unit	Bedrock Type
IF2010-041	481711	5381347	Quetico	Uplands	Aqs	Metasediment
IF2010-042	480292	5380728	Quetico	Lowlands	Aqs	Metasediment
IF2010-043	480296	5380916	Quetico	Lowlands	Aqs	Metasediment
IF2010-044	480293	5381130	Quetico	Lowlands	Aqs	Metasediment
IF2010-045	483700	5382126	Quetico	Uplands	Aqs	Metasediment
IF2010-046	483710	5381914	Quetico	Uplands	Aqs	Metasediment
IF2010-047	483696	5381725	Quetico	Uplands	Aqs	Metasediment
IF2010-048	483704	5381526	Quetico	Uplands	Aqs	Metasediment
IF2010-049	483498	5381323	Quetico	Uplands	Aqs	Metasediment
IF2010-050	483707	5381320	Quetico	Uplands	Aqs	Metasediment
IF2010-051	483498	5381126	Quetico	Uplands	Aqs	Metasediment
IF2010-052	482905	5381334	Quetico	Uplands	Aqs	Metasediment
IF2010-053	483003	5381736	Quetico	Uplands	Aqs	Metasediment
IF2010-054	483703	5382336	Quetico	Lowlands	Aqs	Metasediment
IF2010-055	483495	5382128	Quetico	Uplands	Aqs	Metasediment
IF2010-056	482993	5382124	Quetico	Uplands	Aqs	Metasediment
IF2010-057	483300	5381927	Quetico	Uplands	Aqs	Metasediment
IF2010-058	481494	5380927	Quetico	Uplands	Aqs	Metasediment
IF2010-059	481294	5380938	Quetico	Lowlands	Aqs	Metasediment
IF2010-060	480995	5380934	Quetico	Uplands	Aqs	Metasediment
IF2010-061	481117	5381117	Quetico	Lowlands	Aqs	Metasediment
IF2010-062	480896	5381125	Quetico	Lowlands	Aqs	Metasediment
IF2010-063	480900	5380923	Quetico	Uplands	Aqs	Metasediment
IF2010-064	480694	5380925	Quetico	Lowlands	Aqs	Metasediment
IF2010-065	480497	5380925	Quetico	Lowlands	Aqs	Metasediment
IF2010-066	480299	5381327	Quetico	Lowlands	Aqs	Metasediment
IF2010-067	479698	5381130	Quetico	Lowlands	Aqs	Metasediment
IF2010-068	479706	5381329	Quetico	Lowlands	Aqs	Metasediment
IF2010-069	479678	5381523	Quetico	Lowlands	Aqs	Metasediment
IF2010-070	479906	5381536	Quetico	Lowlands	Aqs	Metasediment
IF2010-071	480100	5381508	Quetico	Lowlands	Aqs	Metasediment
IF2010-072	470693	5377275	Quetico	Lowlands	Aqs	Metasediment
IF2010-073	470616	5377403	Quetico	Lowlands	Aqs	Metasediment
IF2010-074	483095	5381732	Quetico	Uplands	Aqs	Metasediment
IF2010-075	483301	5381726	Quetico	Uplands	Aqs	Metasediment
IF2010-076	483494	5381734	Quetico	Uplands	Aqs	Metasediment
IF2010-077	483386	5381521	Quetico	Uplands	Aqs	Metasediment
IF2010-078	483304	5381326	Quetico	Uplands	Aqs	Metasediment
IF2010-079	483499	5381527	Quetico	Uplands	Aqs	Metasediment
IF2010-080	483497	5381922	Quetico	Uplands	Aqs	Metasediment

Table 2: Sample location information, IF2010-041 through IF2010-80

SampleID	UTME	UTMN	Subprovince	Topography	Map Unit	Bedrock Type
IF2010-081	483114	5382128	Quetico	Uplands	Aqs	Metasediment
IF2010-082	479109	5381123	Quetico	Uplands	Aqs	Metasediment
IF2010-083	479295	5381125	Quetico	Uplands	Aqs	Metasediment
IF2010-084	479106	5380930	Quetico	Uplands	Aqs	Metasediment
IF2010-085	479296	5380756	Quetico	Lowlands	Aqs	Metasediment
IF2010-086	479301	5380929	Quetico	Uplands	Aqs	Metasediment
IF2010-087	479503	5380919	Quetico	Uplands	Aqs	Metasediment
IF2010-088	479483	5381135	Quetico	Uplands	Aqs	Metasediment
IF2010-089	479892	5380929	Quetico	Lowlands	Aqs	Metasediment
IF2010-090	480088	5380942	Quetico	Lowlands	Aqs	Metasediment
IF2010-091	481099	5381319	Quetico	Lowlands	Aqs	Metasediment
IF2010-092	480881	5381332	Quetico	Lowlands	Aqs	Metasediment
IF2010-093	480713	5381329	Quetico	Lowlands	Aqs	Metasediment
IF2010-094	480693	5381119	Quetico	Lowlands	Aqs	Metasediment
IF2010-095	480490	5381114	Quetico	Lowlands	Aqs	Metasediment
IF2010-096	480493	5381334	Quetico	Lowlands	Aqs	Metasediment
IF2010-097	480465	5381499	Quetico	Lowlands	Aqs	Metasediment
IF2010-098	480261	5381730	Quetico	Lowlands	Aqs	Metasediment
IF2010-099	470253	5377633	Quetico	Lowlands	Aqs	Metasediment
IF2010-100	470501	5377615	Quetico	Lowlands	Aqs	Metasediment
IF2010-101	470691	5377592	Quetico	Lowlands	Aqs	Metasediment
IF2010-102	470694	5377412	Quetico	Lowlands	Aqs	Metasediment
IF2010-103	481298	5380719	Quetico	Uplands	Aqs	Metasediment
IF2010-104	481101	5380766	Quetico	Uplands	Aqs	Metasediment
IF2010-105	480898	5380732	Quetico	Uplands	Aqs	Metasediment
IF2010-106	480716	5380749	Quetico	Uplands	Aqs	Metasediment
IF2010-107	480099	5381117	Quetico	Lowlands	Aqs	Metasediment
IF2010-108	479904	5381331	Quetico	Lowlands	Aqs	Metasediment
IF2010-109	480112	5381320	Quetico	Lowlands	Aqs	Metasediment
IF2010-110	480301	5381520	Quetico	Lowlands	Aqs	Metasediment

Table 3: Sample location information, IF2010-081 to IF2010-110

10.3 Sample Collection, Processing, and Analysis

Soil sampling and associated field work were conducted in October 2010. Sample grids were accessed by foot, and the location of each sample point within these grids was identified by their GPS coordinates. Some proposed sample collection sites were abandoned due to inaccessibility, while others were shifted slightly in order to avoid standing water, wetlands, or poor soil profiles.

Soil samples were collected by scraping away organic debris and the organic-rich A0 layer (typically 1-2 inches thick). A small metal trowel was then used to excavate the underlying A1 soil layer, and collect the soil sample in a one-gallon plastic baggie. Each sample bag was labeled using a permanent marker. The field location and soil conditions were recorded in a dedicated field notebook.

Individual soil samples were submitted to the ALS-Chemex analytical laboratory in Winnamuca, Nevada for analysis, following standard chain-of-custody procedures. Each soil sample was dessicated in a drying oven with a maximum temperature of 60C then dry-sieved with a 180 micron brass sieve. Both the plus and minus fractions were retained.

A 0.25g fraction of each sieved sample was digested at low temperature using a mixture of nitric, hydrofluoric, perchloric and hydrochloric acids. The residue was topped with hydrochloric acid, then analyzed by ICP-AES. The results were reviewed for high concentrations of certain elements; sample dilutions were reanalyzed using ICP-MS as necessary. Results were corrected for spectral inter-element interferences (ALS-Chemex method ME-MS61).

A portion of each sample was separately analyzed by fire assay fusion and ICP-MS finish (ALS-Chemex method PGM-ICP23). This separate analysis was applied to obtain lower detection limits for gold, platinum and palladium than what would otherwise have been obtained by ICP-MS.

11.0 Results

ALS Chemex provided DNR with a laboratory report on January 20, 2011 that included the results from the 110 soil samples collected for this project. The DNR posted this report as part of an on-line monthly data release on February 1, 2011. The html link for this posting is:

http://www.dnr.state.mn.us/lands_minerals/mpes_projects/project385.html

The monthly data release included a zip file that contained the following files:

- PDF file of ALS Chemex laboratory report (project385_als_chemex_labreport.pdf, 98 kb)
- CSV file with analytical results, provided by ALS Chemex (WN11000670.csv file, 35 kb)
- A DNR-prepared spreadsheet that links results with the UTM coordinates of each sample location in a gis-compatible format (Feb2011_IntlFalls_A1data.xls, 81 kb)
- A GIS shapefile and metadata of each sample location with results (p385_soil.shp)

11.1 Distribution of Gold, Platinum, and Palladium

Given the project's location within an area of historic and active gold exploration, gold concentrations were of primary interest. One of the samples lacked sufficient material for the flame assay analysis of gold, platinum and palladium. Ninety-six of the remaining 109 samples had detectible gold concentrations (> 0.001 ppm) that ranged from 0.001 ppm to 0.019ppm (i.e. 19 parts per billion). Fewer soil samples contained detectible concentrations of platinum (3 of 109 with Pt concentrations greater than 0.005 ppm) or palladium (71 of 109 with detectible Pd concentrations that range from 0.001 to 0.010 ppm).

The distribution of gold concentrations within the project area is shown in Figure 27. An evaluation of the potential reasons for the distribution of gold and other elements and metals across the project area is presented in the following section.

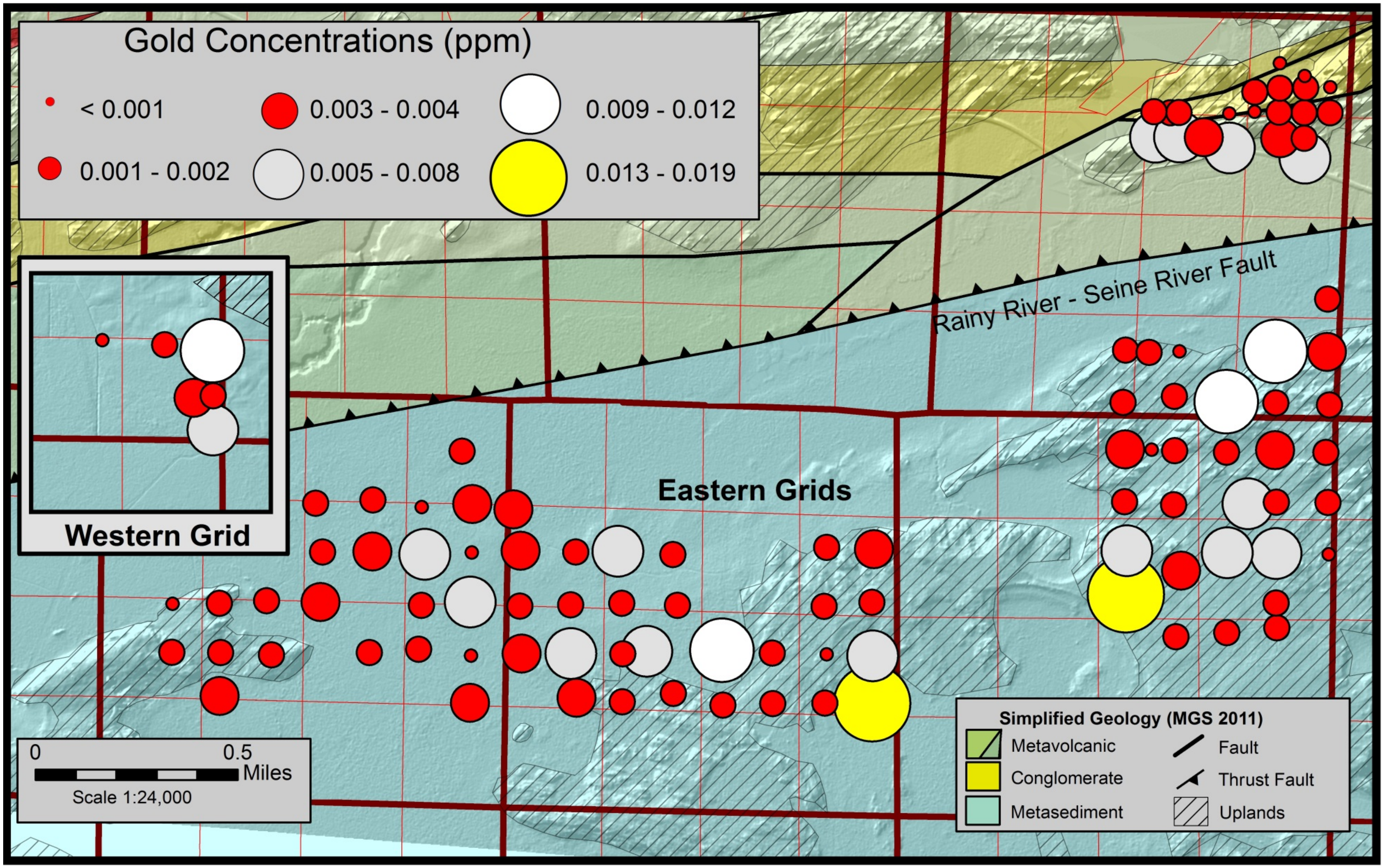

Figure 27: Distribution of Gold concentrations in A1 soil samples from the International Falls Area, MN.

11.2 Comparison of current and historical gold concentrations in A1 soil samples

Sampling for this project focused in areas outside of those investigated in the DNR's previous geochemical survey (Sellner et al., 1985). There was, however, a small amount of overlap, and the relative proximity of the two project's sample grids allows for comparative analysis.

Sellner et. al (1985) limited their pilot geochemical survey to gold and silver analyses. Figure 28 plots their measured gold concentrations against those obtained in the present study. The gold concentrations observed in our suite of 110 soil samples are generally comparable to previous results. Higher concentrations were observed in the pilot study, but they were not so much higher that they could not be explained by variations in source compositions. There were similar ranges of gold concentrations in the area of overlap.

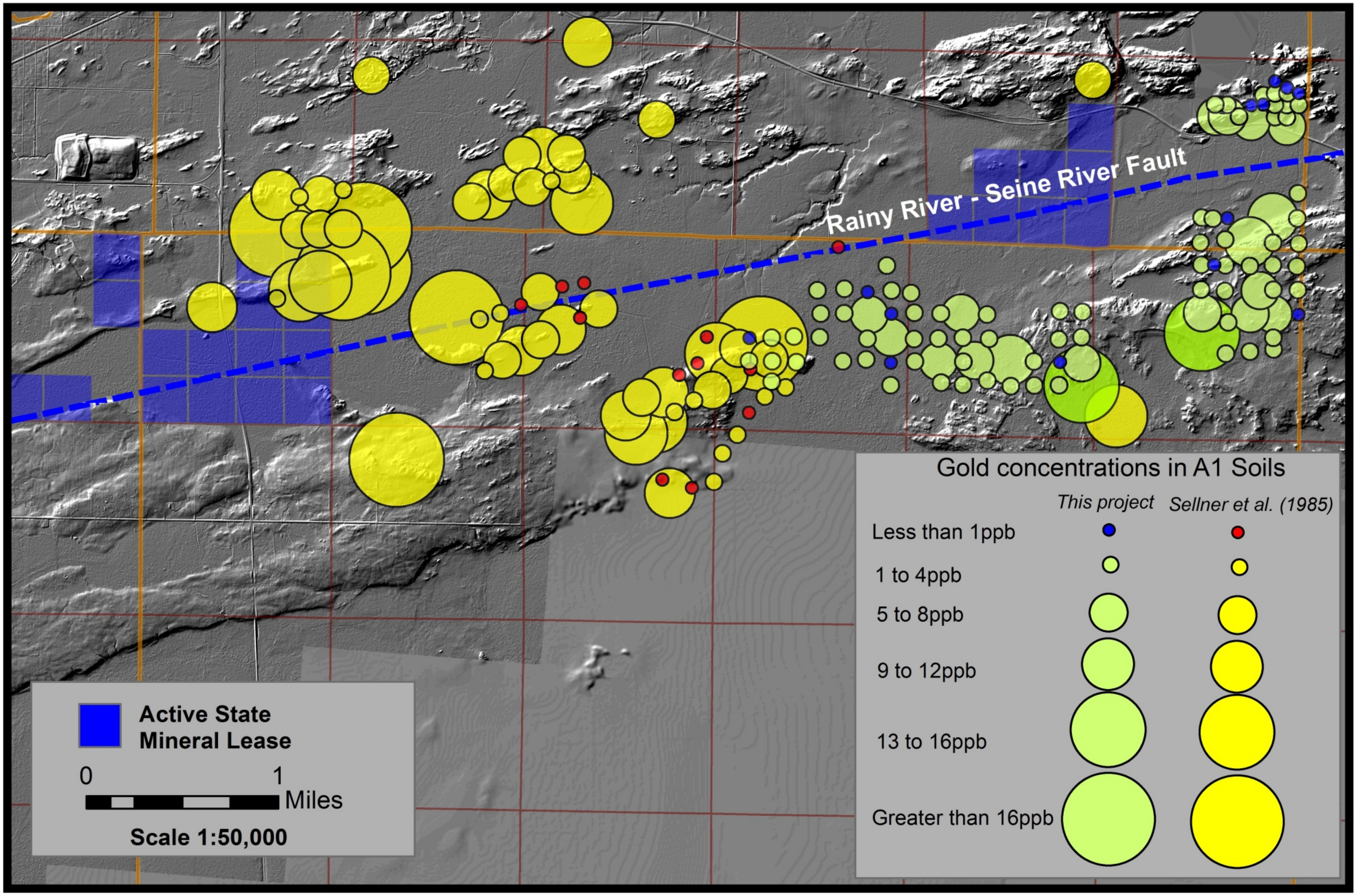

Figure 28: Comparison of gold concentrations in A1 Soils, as reported by Sellner et al. (1985) and this report.

12.0 Discussion

12.1 Interpretation of the distribution of precious metals, major and trace elements

Figure 27 plots the spatial distribution of soil gold concentrations against upland areas and a simplified bedrock map (MGS, 2011). The highest gold concentrations, and the greatest concentrations of values greater than 5ppb, are located in the upland portions of the eastern part of the project area, within the Quetico Subprovince. Gold concentration trends consistent with either a “hotspot” or dispersal train are not readily identifiable, although the distribution and level of gold concentrations in the eastern part of the project area could be associated with a northeast-southeasterly trend line.

All of the 110 soil samples had detectible concentrations of silver, ranging from 0.02 to 0.64ppm. Figure 29 displays the distribution of these silver concentrations within the project area. As with gold, there are no readily identifiable hotspots or linear trends. One observation that might be made is the relationship between silver concentrations and uplands; all of the highest silver concentrations were in upland areas, while all of the lowland samples had relatively low concentrations of less than 0.20ppm.

The observation that silver concentrations might vary based on topography, or that there might be links between soil geochemistry and underlying bedrock , prompted a review of possible links for other metals, major elements or trace elements. This review identified several analytes for which sample populations could be identified based on topography and/or underlying lithology.

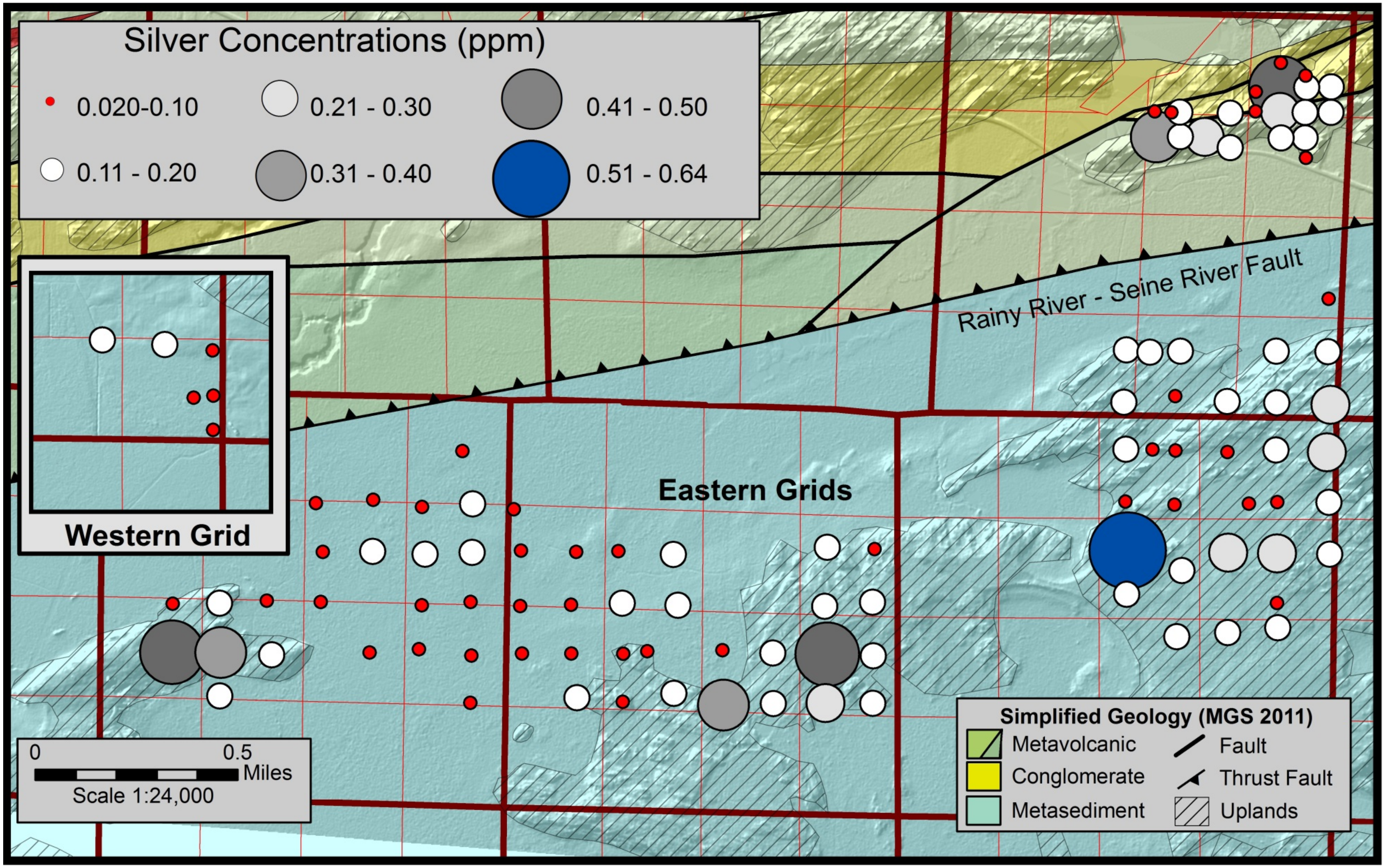

Figure 29: Distribution of Silver concentrations in A1 soil samples from the International Falls Area, MN.

In Figure 30, sulfur concentrations are plotted for the suite of 110 soil samples. While Figure 29 displays a link between higher silver concentrations and upland areas, here we see the opposite case; sulfur concentrations are higher in the Quetico lowland samples, and lower in the Quetico and Wabigoon upland samples. It should be noted that these sulfur concentrations, obtained by ICP-MS, are likely not as accurate or precise as LECO analyses. However, since all of the samples were analyzed using the same method there is internal consistency, and the relative differences in sulfur concentrations should still hold.

Variations in magnesium concentrations display a link that appears to be based more on underlying bedrock lithology than on upland location (Figure 31). All of the samples collected in the Quetico Subprovince display relatively lower Mg concentrations, whether they are from upland or lowland areas. But within the group of Wabigoon Subprovince upland samples there is a second observable trend; the magnesium concentrations in soils collected above the more northern metaconglomerate unit are much higher than the concentrations in soils collected in proximal locations overlying the metavolcanic unit. The eleven samples collected above this metavolcanic bedrock in fact display magnesium contents in line with the samples collected above Quetico metasedimentary bedrock.

Figure 32 displays the distribution of titanium concentrations in the project area. Higher titanium concentrations are observed in the upland areas, similar to the distribution pattern for silver. While the median titanium concentration for the Quetico upland samples (0.21 wt. %) is lower than the median Wabigoon uplands contentration (0.29 wt%), both are significantly higher than the median titanium concentration within the suite of thirty-six Quetico lowland samples (0.084 wt %)

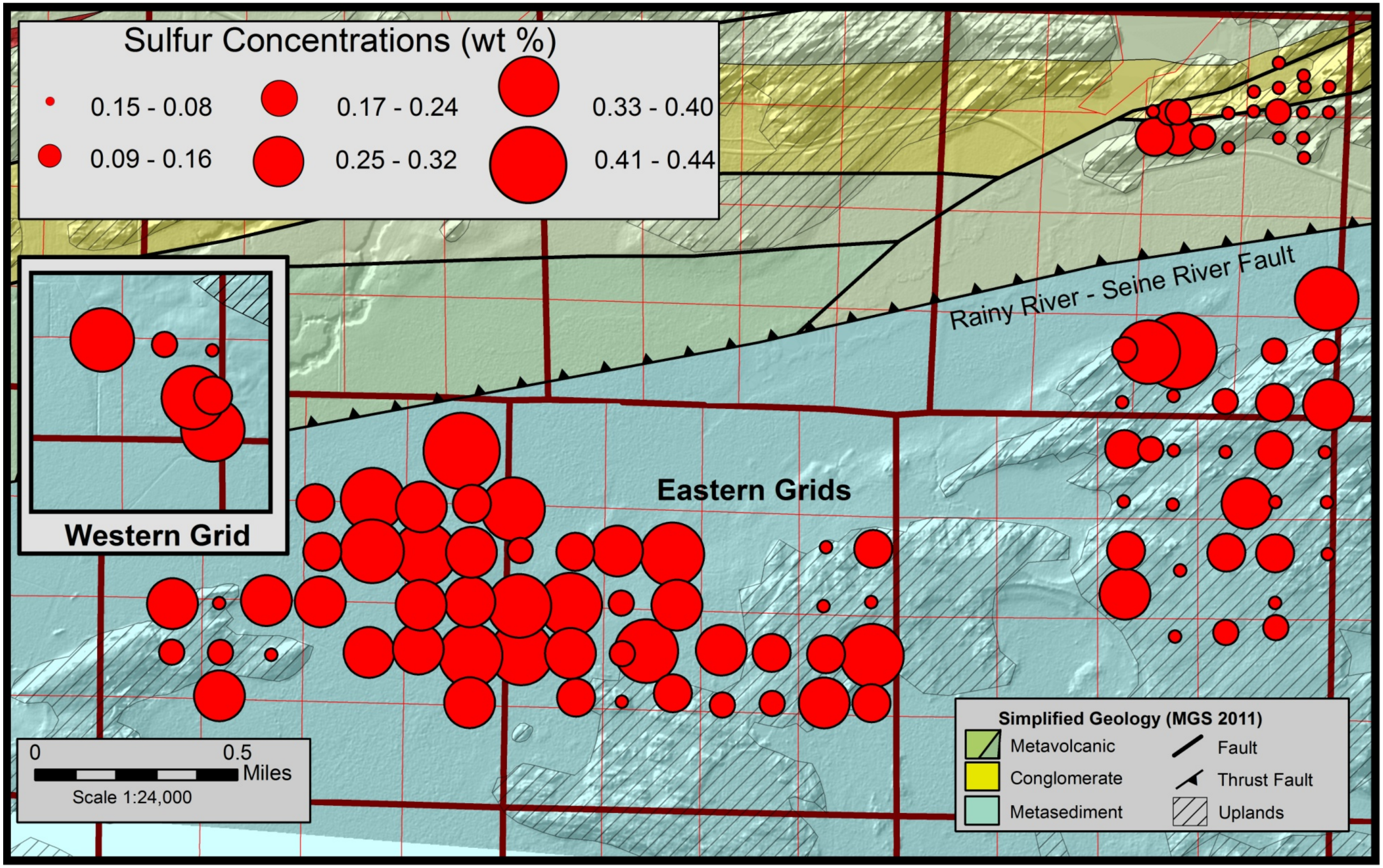

Figure 30: Distribution of Sulfur concentrations in A1 soil samples from the International Falls Area, MN.

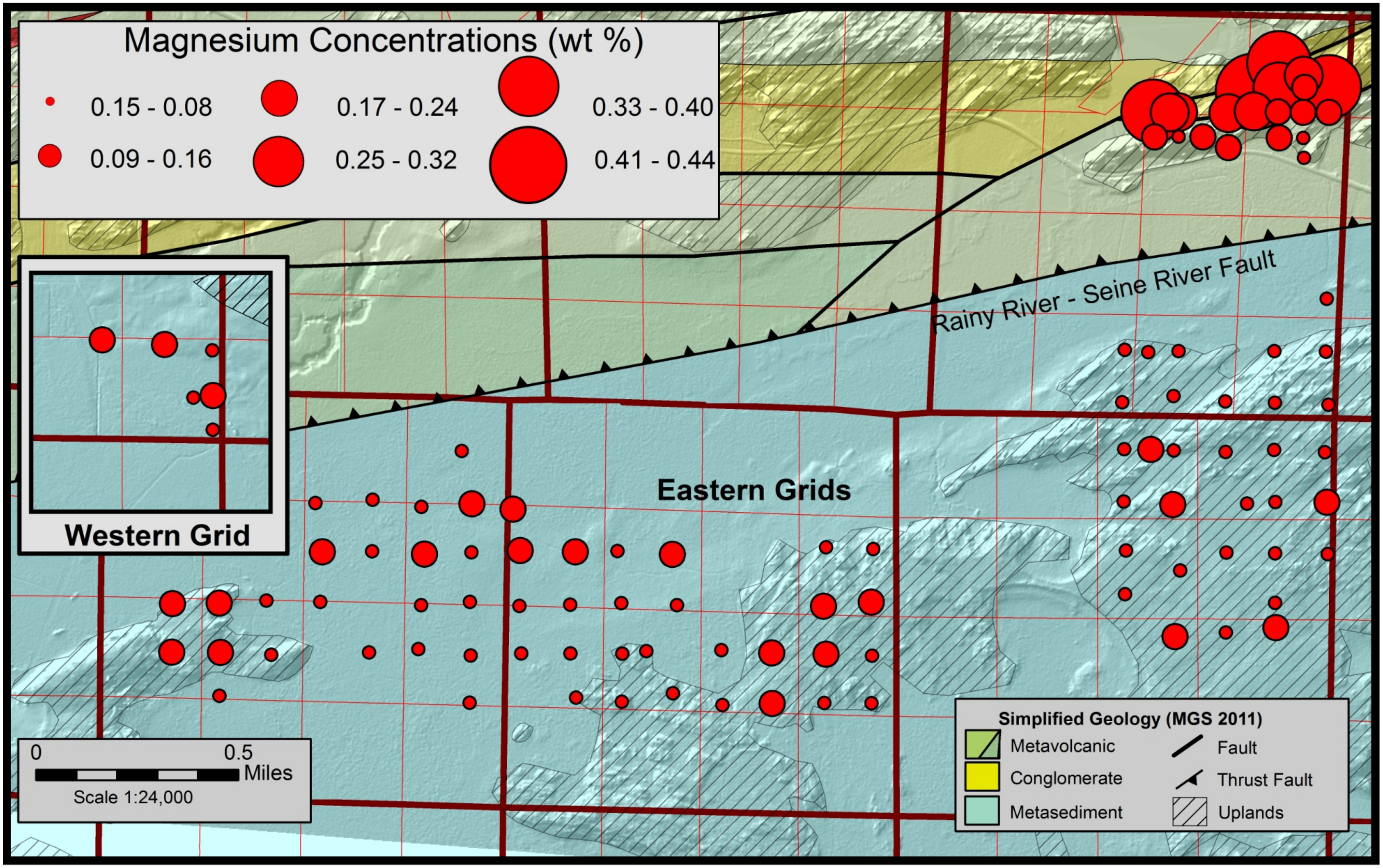

Figure 31: Distribution of Magnesiumr concentrations in A1 soil samples from the International Falls Area, MN.

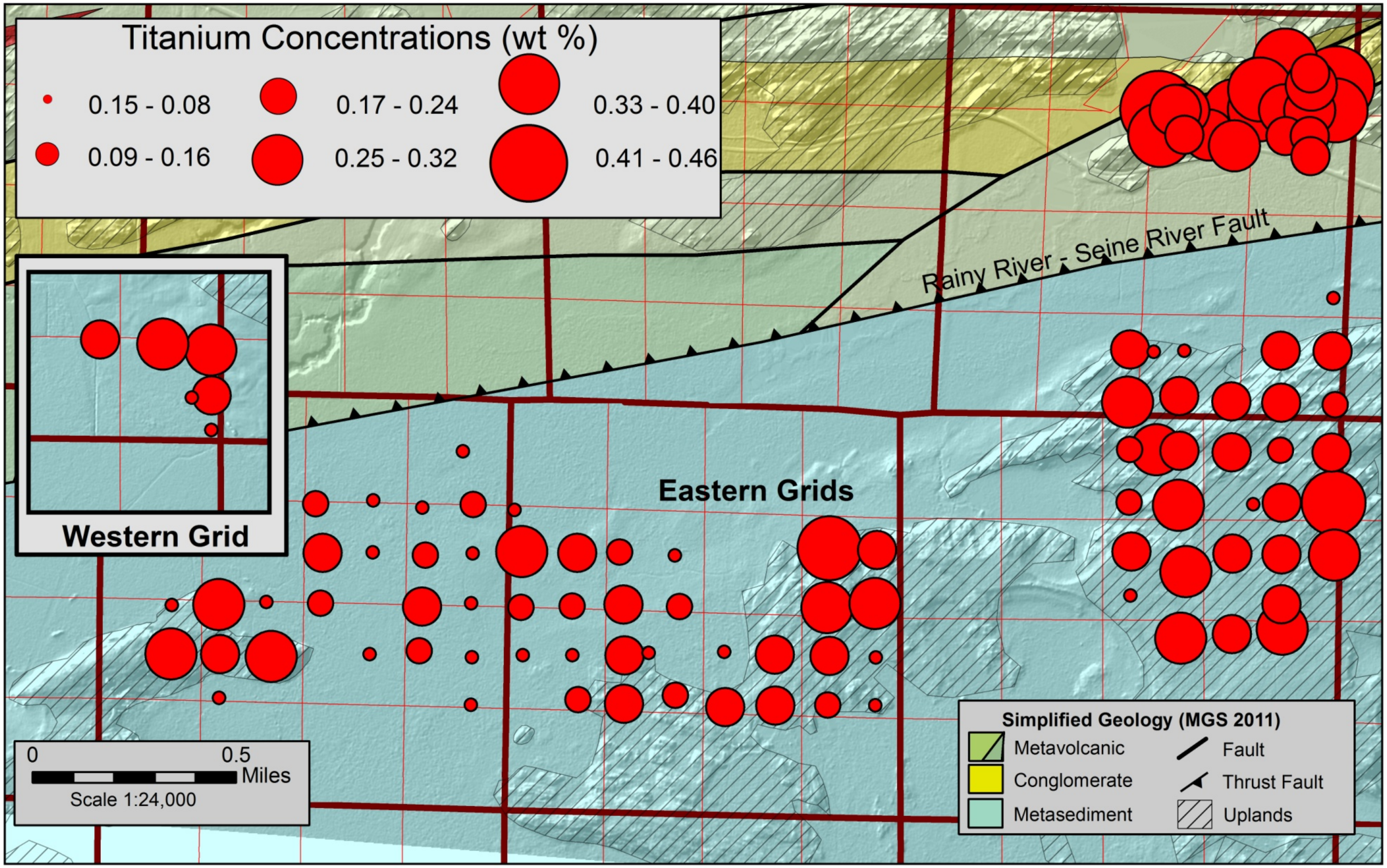

Figure 32: Distribution of titanium concentrations in A1 soil samples in the International Falls Area, MN.

Based on this cursory review of a handful of elements, there may be some links between soil geochemistry and both underlying lithology and topography (i.e. uplands vs. lowlands). The extent of these links for a wider range of elements is examined below.

12.2 Lithologic dependence on precious, major and trace element distribution

The suite of 110 soil samples was subdivided based on the underlying bedrock. Samples in the "Aqs" group overlie the Quetico Subprovince metasedimentary unit. Samples labeled "Asc" overlie Wabigoon Subprovince metaconglomerate, and those samples labeled "Amv" overlie Wabigoon Subprovince metavolcanics. For purposes of brevity and clarity, these three soil groupings may be identified by this underlying lithology. This does not, however, imply that the soils are in direct contact with or essentially derived from underlying bedrock.

Soils that overlie the Quetico Subprovince metasediments can be characterized (relative to the other two groups) as having higher sulfur concentrations, and lower aluminum, sodium, and titanium levels. The metaconglomerate group displays higher median concentrations of calcium, iron and magnesium relative to the other two, while the metavolcanic group is distinct in its higher median potassium concentration.

Element	Unit	All Samples (n=110)			Quetico Subprovince Metasediments Aqs (n=89)			Wabigoon Subprovince Metaconglomerate Asc (n=10)			Wabigoon Subprovince Metavolcanic Amv (n=11)		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Al	%	7.67	0.28	4.26	6.75	0.28	3.47	7.67	5.17	6.34	7.29	2.58	5.79
Ca	%	3.73	0.7	1.57	3.54	0.7	1.5	3.73	1.33	2.37	1.98	1.23	1.63
Fe	%	5.1	0.18	1.5	3.42	0.18	1.31	5.1	2.17	4.14	4.26	1.36	2.24
K	%	1.66	0.11	0.72	1.61	0.11	0.66	1.35	0.55	0.76	1.66	0.47	1.33
Mg	%	5.03	0.15	0.445	0.86	0.15	0.43	5.03	0.77	2.19	1.31	0.39	0.66
Na	%	3.13	0.04	0.77	1.99	0.04	0.5	3.13	1.34	1.63	2.21	0.35	1.58
S	%	0.44	0.01	0.1	0.44	0.02	0.13	0.07	0.01	0.04	0.15	0.01	0.04
Ti	%	0.455	0.015	0.187	0.343	0.015	0.163	0.455	0.207	0.351	0.367	0.184	0.266

Table 4: Maximum, minimum and median concentrations for major elements in A1 soil samples,

Table 5 displays maximum, minimum and median trace element concentrations for the same lithologic subgroups. Again, there are observable variations in certain trace elements that can be associated with underlying bedrock.

In Appendix 1, histogram distribution are provided for eighteen elements that display concentrations based on the three lithologic groups. Most of these plots display log normal distributions.

12.3 Topographic dependence on precious, major and trace element distribution

Grouping the suite of 110 soil samples based on their location within either upland or lowland areas is accomplished by combining the “metaconglomerate” and “metavolcanic” groups (since all of the samples in these groups were collected in uplands), and dividing the “metasediment” group into upland

and lowland subgroups. This creates three distinct sample groups: 1) Quetico Lowlands (n=35), 2) Quetico Uplands (n=53), and Wabigoon Uplands (n=21). While one might have combined the Quetico and Wabigoon Upland samples to restrict this review to a single variable, the fact that there are observable variations based on underlying lithology warrants this separation.

Table 6 provides the maximum, minimum and median major element concentrations for these three groups of soil samples. There are, again, associations that can be observed between certain major elements and topography. As previously discussed, sulfur concentrations are markedly higher in the Quetico Lowland samples (Figure 28), with the median sulfur concentration in the Quetico Upland samples much more similar to those in the Wabigoon Uplands. Aluminum concentrations display the opposite trend; higher in the upland samples, and lower in the Quetico lowlands.

Table 7 displays additional maximum, minimum and median values for selected trace elements, based on topography. Again, there are observable correlations in the data.

Element	Unit	All Samples (n=110)			Quetico Subprovince Metasediment Aqs (n=89)			Wabigoon Subprovince Metaconglomerate Asc (n=10)			Wabigoon Subprovince Metavolcanic Amv (n=11)		
		Max	Min	Median	Max	Min	Median	Max	Min	Median	Max	Min	Median
Ag	ppm	0.64	0.02	0.12	0.64	0.02	0.11	0.45	0.07	0.105	0.38	0.08	0.14
As	ppm	39.9	1.1	3	8.4	1.1	3	4.7	1.1	2.7	39.9	1.2	2.6
Ba	ppm	1030	60	380	610	60	300	740	330	545	1030	250	540
Be	ppm	1.55	0.09	0.885	1.55	0.09	0.81	1.4	0.89	1.07	1.27	0.56	0.97
Bi	ppm	0.38	0.05	0.17	0.38	0.05	0.18	0.26	0.08	0.115	0.32	0.09	0.14
Cd	ppm	1.84	0.06	0.39	1.84	0.09	0.44	0.45	0.09	0.245	1.44	0.06	0.22
Ce	ppm	166	2.99	28	166	2.99	24.7	93.7	33.2	56	76.3	15.95	31.2
Co	ppm	111.5	1.2	7.6	111.5	1.2	6.3	33.7	8	21.5	22.4	5.3	13.3
Cr	ppm	541	4	34.5	82	4	31	541	47	213	103	30	56
Cs	ppm	4.58	0.26	1.825	4.58	0.26	1.72	3.38	1.44	2.325	3.45	1.25	2.08
Cu	ppm	47.2	4.5	15.1	47.2	4.5	14.8	40	14.4	16.8	37.3	7.2	15
Ga	ppm	21	0.83	10.75	18.45	0.83	9.11	21	12.85	16.8	18.9	7.14	14.2
Ge	ppm	0.2	-0.05	-0.05	0.15	-0.05	-0.05	0.2	0.09	0.155	0.17	0.05	0.09
Hf	ppm	3.9	0.1	1.6	3.9	0.1	1.5	3	0.8	1.7	3.4	0.8	2.6
In	ppm	0.063	-0.005	0.026	0.05	-0.005	0.023	0.063	0.025	0.0435	0.053	0.022	0.035
La	ppm	72.9	1.5	13.25	72.9	1.5	12.1	38.2	15.4	24.75	34.7	7.1	14.8
Li	ppm	46.5	1.5	13.8	46.5	1.5	11.9	34.2	8.5	19	36	8.6	19.8
Mn	ppm	4640	31	580.5	4640	31	488	1580	405	917	3660	252	947
Mo	ppm	4.82	0.26	0.82	4.82	0.34	0.87	0.98	0.26	0.605	0.98	0.37	0.54
Nb	ppm	8.9	0.5	5.2	8.9	0.5	4.6	8.7	3.1	6.1	8.2	4	6.9
Ni	ppm	264	2.2	16.1	40.1	2.2	14.1	264	21.9	103.45	44.4	12.8	26.2
P	ppm	1760	220	805	1630	220	780	1750	640	1215	1760	250	830
Pb	ppm	53	8.5	22.5	53	8.5	24	51.4	10.8	18.7	45.8	14.2	18.5
Rb	ppm	137	6	50.6	137	6	48.7	73.7	39	50	132	25	58.5
Re	ppm	0.004	-0.002	-0.002	0.004	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Sb	ppm	0.84	0.16	0.425	0.79	0.21	0.44	0.63	0.16	0.31	0.84	0.2	0.35
Sc	ppm	16.9	0.5	5.75	9.3	0.5	5.1	16.9	7.9	13.15	11.8	6.9	9
Se	ppm	4	1	2	4	1	2	2	1	1	2	1	1
Sn	ppm	1.6	0.2	1	1.6	0.2	0.9	1.6	0.8	1.1	1.6	0.7	1.2
Sr	ppm	1290	35.9	155	393	35.9	127.5	1290	315	677	745	60.1	269
Ta	ppm	0.67	-0.05	0.385	0.67	-0.05	0.35	0.59	0.22	0.42	0.63	0.29	0.48
Te	ppm	0.09	-0.05	-0.05	0.09	-0.05	-0.05	0.05	-0.05	-0.05	0.07	-0.05	-0.05
Th	ppm	9.8	0.4	3.55	9.8	0.4	3.5	5.5	2.7	4.1	7.4	1.9	4.2
Tl	ppm	0.6	0.04	0.295	0.6	0.04	0.29	0.35	0.14	0.25	0.45	0.21	0.34
U	ppm	17.7	0.1	1.2	17.7	0.1	1.2	1.6	0.7	0.95	2.4	0.7	1.2
V	ppm	106	4	41.5	102	4	36	106	50	93	84	37	60
W	ppm	2	0.1	0.5	2	0.1	0.5	0.8	0.2	0.4	1.6	0.4	0.6
Y	ppm	27.8	0.9	7.3	27.8	0.9	6.8	13.9	8.7	10.85	16.7	6.1	8.9
Zn	ppm	252	10	65.5	206	10	58	197	36	119.5	252	21	70
Zr	ppm	139	3.7	57.4	139	3.7	54	107.5	30	59.7	118.5	31.6	84
Au	ppm	0.019	-0.001	0.002	0.019	-0.001	0.002	0.002	-0.001	0.001	0.008	-0.001	0.003
Pt	ppm	0.01	-0.005	-0.005	0.01	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005
Pd	ppm	0.004	-0.005	0.001	0.004	-0.005	0.001	0.001	-0.005	0.001	0.001	-0.001	-0.001

Table 5: Maximum, minimum and median concentrations for trace elements in A1 soil samples

Element	Al	Ca	Fe	K	Mg	Na	S	Ti
Unit	%	%	%	%	%	%	%	%
Quetico Lowlands (n =36)								
Max	5.06	3.54	2.11	1.35	0.86	1.35	0.44	0.269
Min	0.28	0.7	0.18	0.11	0.15	0.04	0.03	0.015
Average	2.07	1.86	0.94	0.50	0.44	0.34	0.19	0.10
Std dev	1.49	0.66	0.56	0.37	0.17	0.32	0.08	0.07
Median	1.76	1.905	0.85	0.38	0.425	0.27	0.20	0.084
Quetico Uplands (n=53)								
Max	6.75	3.46	3.42	1.61	0.75	1.99	0.37	0.34
Min	0.30	0.80	0.18	0.17	0.16	0.05	0.02	0.02
Average	4.01	1.51	1.59	0.79	0.42	0.96	0.10	0.19
Std dev	1.74	0.53	0.73	0.38	0.14	0.60	0.07	0.09
Median	4.37	1.44	1.58	0.77	0.43	1.01	0.08	0.21
Wabigoon Uplands (n=21)								
Max	7.67	3.73	5.10	1.66	5.03	3.13	0.15	0.46
Min	2.58	1.23	1.36	0.47	0.39	0.35	0.01	0.18
Average	5.88	2.03	3.05	1.03	1.56	1.61	0.05	0.31
Std dev	1.10	0.73	1.18	0.39	1.28	0.57	0.03	0.08
Median	5.90	1.83	2.85	1.01	1.00	1.61	0.04	0.29

Table 6: Maximum, minimum and median concentrations for major elements in A1 soil samples, based on whether it was collected in an upland or lowland area

Element	Ag	Au	Cr	Cu	Mn	Mo	Ni	Pb	Pt	Pd	W	Zn
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Quetico Lowlands (n =36)												
Max	0.14	0.010	50	32.3	2190	4.82	24.1	48.2	0.005	0.002	0.9	141
Min	0.02	<0.001	4	4.5	31	0.49	2.2	8.5	<0.005	<0.001	0.1	10
Median	0.08	0.003	18	12.1	392	0.92	9.85	19.4	0.005	0.001	0.3	47
Quetico Uplands (n=53)												
Max	0.64	0.019	82	47.2	4640	2.58	40.1	53	0.010	0.004	2	206
Min	0.03	<0.001	4	4.7	102	0.34	2.7	9.7	0.005	0.001	0.1	20
Median	0.14	0.002	36	15.7	603	0.85	17.2	26.1	0.008	0.001	0.5	74
Wabigoon Uplands (n=21)												
Max	0.45	0.008	541	40	3660	0.98	264	51.4	<0.005	0.001	1.6	252
Min	0.07	<0.001	30	7.2	252	0.26	12.8	10.8	<0.005	0.001	0.2	21
Median	0.13	0.001	75	16.5	942	0.55	37.4	18.5	<0.005	0.001	0.6	112

Table 7: Maximum, minimum and median concentrations for metallic elements in A1 soil samples, based on whether it was collected in an upland or lowland area

Trace element distributions based on whether a sample location was in an upland or lowland area are characterized in Table 8.

Element	As	Ba	Be	Bi	Cd	Ce	Co	Cs	Ga	Ge	Hf	In	La	Li	Nb
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Quetico Lowlands (n =36)															
Max	6.2	480	1.25	0.25	1.3	61.9	24.7	3.34	12.65	0.05	3.1	0.036	25.4	46.5	8.1
Min	1.5	60	0.1	0.05	0.14	3.16	1.2	0.27	0.83	0.05	0.1	0.007	1.5	1.5	0.5
Average	3.09	212	0.55	0.15	0.53	24.15	5.59	1.28	5.21	0.05	1.03	0.02	10.83	12.18	3.21
Std dev	0.92	119	0.33	0.05	0.23	16.31	4.31	0.89	3.60		0.78	0.01	6.98	11.22	2.26
Median	3	195	0.48	0.16	0.485	21.6	5.2	1.08	4.345	0.05	0.9	0.02	9.65	8.2	2.8
Quetico Uplands (n=53)															
Max	8.4	610	1.55	0.38	1.84	166	111.5	4.58	18.45	0.15	3.9	0.05	72.9	40.8	8.9
Min	1.1	70	0.09	0.05	0.09	2.99	1.8	0.26	0.84	0.05	0.1	0.007	1.5	1.5	0.5
Average	3.3	384	0.87	0.20	0.44	37.63	12.3	2.18	10.48	0.08	1.8	0.028	17.0	15.1	5.3
Std dev	1.4	135	0.31	0.07	0.31	35.86	16.0	1.06	4.66	0.03	0.9	0.009	14.0	8.4	2.3
Median	3.0	420	0.91	0.2	0.38	26.6	8	2.03	11.25	0.075	1.9	0.027	12.8	13.9	5.7
Wabigoon Uplands (n=21)															
Max	39.9	1030	1.4	0.32	1.44	93.7	33.7	3.45	21	0.2	3.4	0.063	38.2	36	8.7
Min	1.1	250	0.56	0.08	0.06	15.95	5.3	1.25	7.14	0.05	0.8	0.022	7.1	8.5	3.1
Average	4.6	544	1.00	0.15	0.33	48.50	16.7	2.36	15.03	0.12	2.1	0.039	21.4	20.7	6.2
Std dev	8.2	167	0.19	0.07	0.32	22.22	8.2	0.69	3.16	0.05	0.8	0.011	9.4	7.9	1.5
Median	2.6	540	0.99	0.13	0.24	44.1	15.3	2.22	14.45	0.11	2	0.039	18.9	19.5	6.3

Table 8: Maximum, minimum and median concentrations for trace elements in A1 soil samples, based on whether they were collected in an upland or lowland area

12.4 Combined lithologic and topographic dependence on elemental distribution

A third way of examining the geochemical variation within the 110 samples is to combine the associations based on underlying bedrock lithology and topography. This approach classifies the samples into four groups. The Quetico Subprovince metasediment samples are categorized based on upland/lowland designations, while the Wabigoon Subprovince upland samples are distinguished based on underlying bedrock lithology. The resulting subgroups are classified as “Quetico Uplands,” “Quetico Lowlands,” “Wabigoon Metaconglomerate,” and “Wabigoon Metavolcanic.”

Tables 9 through 12 display the variations in maximum, minimum, and median concentrations for twenty-five selected metals, major elements and trace elements for these four subgroups.

Data plots may also be used to identify trends in geochemical variations based on these groups. Figures 33 through 37 display high-low-median plots for select metals and elements, based on the four subgroups. In addition, the same data is plotted for the two main subgroups (i.e. Quetico metasediments and Wabigoon Uplands).

Aluminum (wt %) *High Al in WU, Low Al in QL*	Higher Aluminum in Wabigoon Uplands (median 70% higher than metased, 35% higher than Quetico Uplands). Low Aluminum in Quetico Lowlands (median 1.76% vs. 4.37% in uplands)						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	6.75	0.28	3.47	Wabigoon Uplands (21)	7.67	2.58	5.9
Quetico Lowlands (36)	5.06	0.28	1.76	Metaconglomerate (10)	7.67	5.17	6.34
Quetico Uplands (53)	6.75	0.3	4.37	Metavolcanic (11)	7.29	2.58	5.79
Calcium (wt %)	No significant high/low trends observed.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	3.54	0.7	1.50	Wabigoon Uplands (21)	3.73	1.23	1.83
Quetico Lowlands (36)	3.54	0.7	1.91	Metaconglomerate (10)	3.73	1.33	2.37
Quetico Uplands (53)	3.46	0.8	1.44	Metavolcanic (11)	1.98	1.23	1.63
Iron (wt %) *High Fe in Asc, Low Fe in QL*	Higher Wabigoon median due to High Fe in metaconglomerate. Quetico Upland median 1/2 as big as Wabigoon Uplands, but twice as big as Quetico. Lowlands						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	3.42	0.18	1.31	Wabigoon Uplands (21)	5.10	1.36	2.85
Quetico Lowlands (36)	2.11	0.18	0.85	Metaconglomerate (10)	5.10	2.17	4.14
Quetico Uplands (53)	3.42	0.18	1.58	Metavolcanic (11)	4.26	1.36	2.24
Potassium (wt %) *High K in Amv, Low K in QL*	Higher potassium values in Wabigoon Uplands, driven by high values in metavolcanic Amv. Quetico lolands median K value is 1/2 of the Quetico upland's, and 1/4 the Amv value.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	1.66	0.11	0.72	Wabigoon Uplands (21)	1.66	0.47	1.01
Quetico Lowlands (36)	1.35	0.11	0.38	Metaconglomerate (10)	1.35	0.55	0.76
Quetico Uplands (53)	1.61	0.17	0.77	Metavolcanic (11)	1.66	0.47	1.33
Magnesium (wt %) *High Mg in Asc*	High Mg values in metaconglomerate, with Amv magnesium values comparable to both Quetico highlands and lowlands.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	0.86	0.15	0.43	Wabigoon Uplands (21)	5.03	0.39	1.00
Quetico Lowlands (36)	0.86	0.15	0.43	Metaconglomerate (10)	5.03	0.77	2.19
Quetico Uplands (53)	0.75	0.16	0.43	Metavolcanic (11)	1.31	0.39	0.66
Sodium (wt %) *Low Na in QL*	Higher Na content in Wabigoon Uplands; 3x higher than median metasediment value. Quetico median value driven by low value in Lowlands (with QU value intermediate)						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	1.99	0.04	0.50	Wabigoon Uplands (21)	3.13	0.35	1.61
Quetico Lowlands (36)	1.35	0.04	0.27	Metaconglomerate (10)	3.13	1.34	1.63
Quetico Uplands (53)	1.99	0.05	1.01	Metavolcanic (11)	2.21	0.35	1.58
Sulfur (wt %) *High S in Quetico Lowlands*	Sulfur values are much higher in the Quetico metasediments, but Quetico lowland median value is more than twice higher than Uplands.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	0.44	0.02	0.13	Wabigoon Uplands (21)	0.15	0.01	0.04
Quetico Lowlands (36)	0.44	0.03	0.20	Metaconglomerate (10)	0.07	0.01	0.035
Quetico Uplands (53)	0.37	0.02	0.08	Metavolcanic (11)	0.15	0.01	0.04
Titanium (wt %) *Higher Ti in Uplands*	Higher Ti in Wabigoon samples, but the dominant trend is higher median values in the Uplands (.21 and .29%) compared against low Ti in Quetico Lowlands (.084%)						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	0.343	0.015	0.163	Wabigoon Uplands (21)	0.460	0.180	0.290
Quetico Lowlands (36)	0.269	0.015	0.084	Metaconglomerate (10)	0.455	0.207	0.351
Quetico Uplands (53)	0.343	0.015	0.210	Metavolcanic (11)	0.367	0.184	0.266

Table 9: Comparison of maximum-minimum-median major elements concentrations. Samples are grouped based on underlying bedrock type and topographic position (uplands vs. lowlands).

Silver (ppm)

Higher Ag in Uplands

The Uplands have median silver values that are comparable, and signficantly higher than the Quetico lowland value. QL also has a much lower "Max" value than the upland samples.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	0.64	0.02	0.11	Wabigoon Uplands (21)	0.45	0.07	0.13
Quetico Lowlands (36)	0.14	0.02	0.08	Metaconglomerate (10)	0.45	0.07	0.11
Quetico Uplands (53)	0.64	0.03	0.14	Metavolcanic (11)	0.38	0.08	0.14

Gold (ppm)

There is little systematic variation in median gold values, based either on lithology or upland/lowlands.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	0.019	<0.001	0.002	Wabigoon Uplands (21)	0.008	<0.001	0.001
Quetico Lowlands (36)	0.010	<0.001	0.002	Metaconglomerate (10)	0.002	<0.001	0.001
Quetico Uplands (53)	0.019	<0.001	0.002	Metavolcanic (11)	0.008	<0.001	0.003

Chromium (ppm)

High Cr in Asc, Low Cr in QL

Wabigoon Upland median Cr values more than twice greater than Quetico samples. Asc median value 4x higher than Amv, while Quetico lowland value is half the Quetico upland value.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	82	4	31	Wabigoon Uplands (21)	541	30	75
Quetico Lowlands (36)	50	4	18	Metaconglomerate (10)	541	47	213
Quetico Uplands (53)	82	4	36	Metavolcanic (11)	103	30	56

Copper (ppm)

No significant variation between median copper values for the different subgroupings.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	47.2	4.5	14.8	Wabigoon Uplands (21)	40	7.2	16.5
Quetico Lowlands (36)	32.3	4.5	12.1	Metaconglomerate (10)	40	14.4	16.8
Quetico Uplands (53)	47.2	4.7	15.7	Metavolcanic (11)	37.3	7.2	15

Manganese (ppm)

Low Mn in QL, higher in WU

Wabigoon samples have median manganese values that are twice as high as Quetico values. Little difference between Wabigoon Asc and Amv; Quetico lowland values lower than uplands.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	4640	31	488	Wabigoon Uplands (21)	3660	252	942
Quetico Lowlands (36)	2190	31	392	Metaconglomerate (10)	1580	405	917
Quetico Uplands (53)	4640	102	603	Metavolcanic (11)	3660	252	947

Molybdenum (ppm)

Higher Mo in Quetico

Quetico molybdenum median values are higher than Wabigoon median values. Little difference between Quetico lowlands and highlands, or between Wabigoon Asc and Amv.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	4.82	0.34	0.87	Wabigoon Uplands (21)	0.98	0.26	0.55
Quetico Lowlands (36)	4.82	0.49	0.92	Metaconglomerate (10)	0.98	0.26	0.61
Quetico Uplands (53)	2.58	0.34	0.85	Metavolcanic (11)	0.98	0.37	0.54

Table 10: Comparison of maximum-minimum-median concentrations for selected metallic elements. Samples are grouped based on underlying bedrock type and topographic position (uplands vs. lowlands).

Nickel (ppm)

Wabigoon Uplands median value 2.5x higher than Quetico Metasediments, due to high value in metaconglomerate (Asc median 4x higher than Amv median)

	Max	Min	Median		Max	Min	Median
Metasediment (89)	40.1	2.2	14.1	Wabigoon Uplands (21)	264	12.8	37.4
Quetico Lowlands (36)	24.1	2.2	9.9	Metaconglomerate (10)	264	21.9	103.5
Quetico Uplands (53)	40.1	2.7	17.2	Metavolcanic (11)	44.4	12.8	26.2

Lead (ppm)

Quetico metasediments median lead value 30% higher than Wabigoon Uplands. Highest median value in Quetico Uplands, but no significant variation within sample populations.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	53	8.5	24.0	Wabigoon Uplands (21)	51.4	10.8	18.5
Quetico Lowlands (36)	48.2	8.5	19.4	Metaconglomerate (10)	51.4	10.8	18.7
Quetico Uplands (53)	53	9.7	26.1	Metavolcanic (11)	45.8	14.2	18.5

Platinum (ppm)

Only 3 of 110 samples had detectible concentrations of Pt (detection limit 0.005 ppm). All three were in Quetico; two in Uplands, one in lowlands.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	0.010	<0.005	<0.005	Wabigoon Uplands (21)	<0.005	<0.005	<0.005
Quetico Lowlands (36)	0.005	<0.005	<0.005	Metaconglomerate (10)	<0.005	<0.005	<0.005
Quetico Uplands (53)	0.010	<0.005	<0.005	Metavolcanic (11)	<0.005	<0.005	<0.005

Palladium (ppm)

Highest concentrations were in Quetico sediments, but all Pd concentrations were relatively low, with no significant trends or variation observed.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	0.010	<0.001	0.001	Wabigoon Uplands (21)	0.001	<0.001	0.001
Quetico Lowlands (36)	0.002	<0.001	0.001	Metaconglomerate (10)	0.001	<0.001	0.001
Quetico Uplands (53)	0.004	<0.001	<0.001	Metavolcanic (11)	0.001	<0.001	<0.001

Tungstun (ppm)

No significant trends or variation in tungstun concentrations observed.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	2	0.1	0.5	Wabigoon Uplands (21)	1.6	0.2	0.6
Quetico Lowlands (36)	0.9	0.1	0.3	Metaconglomerate (10)	0.8	0.2	0.4
Quetico Uplands (53)	2	0.1	0.5	Metavolcanic (11)	1.6	0.4	0.6

Zinc (ppm)

Wabigoon Uplands median value 2x higher than Quetico metasediments. Highest values in Amv, but highest median values in Asc.

	Max	Min	Median		Max	Min	Median
Metasediment (89)	206	10	58	Wabigoon Uplands (21)	252	21	112
Quetico Lowlands (36)	141	10	47	Metaconglomerate (10)	197	36	120
Quetico Uplands (53)	206	20	74	Metavolcanic (11)	252	21	70

Table 11: Comparison of maximum-minimum-median concentrations for selected metallic elements. Samples are grouped based on underlying bedrock type and topographic position (uplands vs. lowlands).

Arsenic (ppm)							
	No signicant high/low trends observed.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	8.4	1.1	3.0	Wabigoon Uplands (21)	39.9	1.1	2.6
Quetico Lowlands (36)	6.2	1.5	3.0	Metaconglomerate (10)	4.7	1.1	2.7
Quetico Uplands (53)	8.4	1.1	3	Metavolcanic (11)	39.9	1.2	2.6
Barium (ppm)	Upland samples have higher barium concentrations, relative to the Quetico Lowlands. Quetico Uplands have a median value that is more than twice that of the Quetico Lowlands.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	610	60	300	Wabigoon Uplands (21)	1030	250	540
Quetico Lowlands (36)	480	60	195	Metaconglomerate (10)	740	330	545
Quetico Uplands (53)	610	70	420	Metavolcanic (11)	1030	250	540
Beryllium (ppm)	Upland samples have higher beryllium concentrations, relative to the Quetico Lowlands. Quetico Uplands have a median value that is almost twice that of the Quetico Lowlands.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	1.55	0.09	0.81	Wabigoon Uplands (21)	1.40	0.56	0.99
Quetico Lowlands (36)	1.25	0.10	0.48	Metaconglomerate (10)	1.40	0.89	1.07
Quetico Uplands (53)	1.55	0.09	0.91	Metavolcanic (11)	1.27	0.56	0.97
Cadmium (ppm)	Median cadmium values are almost twice as high in Quetico metasediments than in Wabigoon Uplands. Quetico Uplands values track closer to Quetico Lowlands than with Wabigoon Uplands.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	1.84	0.09	0.44	Wabigoon Uplands (21)	1.44	0.06	0.24
Quetico Lowlands (36)	1.30	0.14	0.49	Metaconglomerate (10)	0.45	0.09	0.25
Quetico Uplands (53)	1.84	0.09	0.38	Metavolcanic (11)	1.44	0.06	0.22
Cobalt (ppm)	While highest cobalt value came from Quetico Uplands, the Quetico metasediments have much lower median values. Wabigoon Asc median is higher than Amv.						
	Max	Min	Median		Max	Min	Median
Metasediment (89)	111.5	1.2	6.3	Wabigoon Uplands (21)	33.7	5.3	15.3
Quetico Lowlands (36)	24.7	1.2	5.2	Metaconglomerate (10)	33.7	8	21.5
Quetico Uplands (53)	111.5	1.8	8	Metavolcanic (11)	22.4	5.3	13.3

Table 12: Comparison of maximum-minimum-median concentrations for selected trace elements. Samples are grouped based on underlying bedrock type and topgraphic position (uplands vs. lowlands).

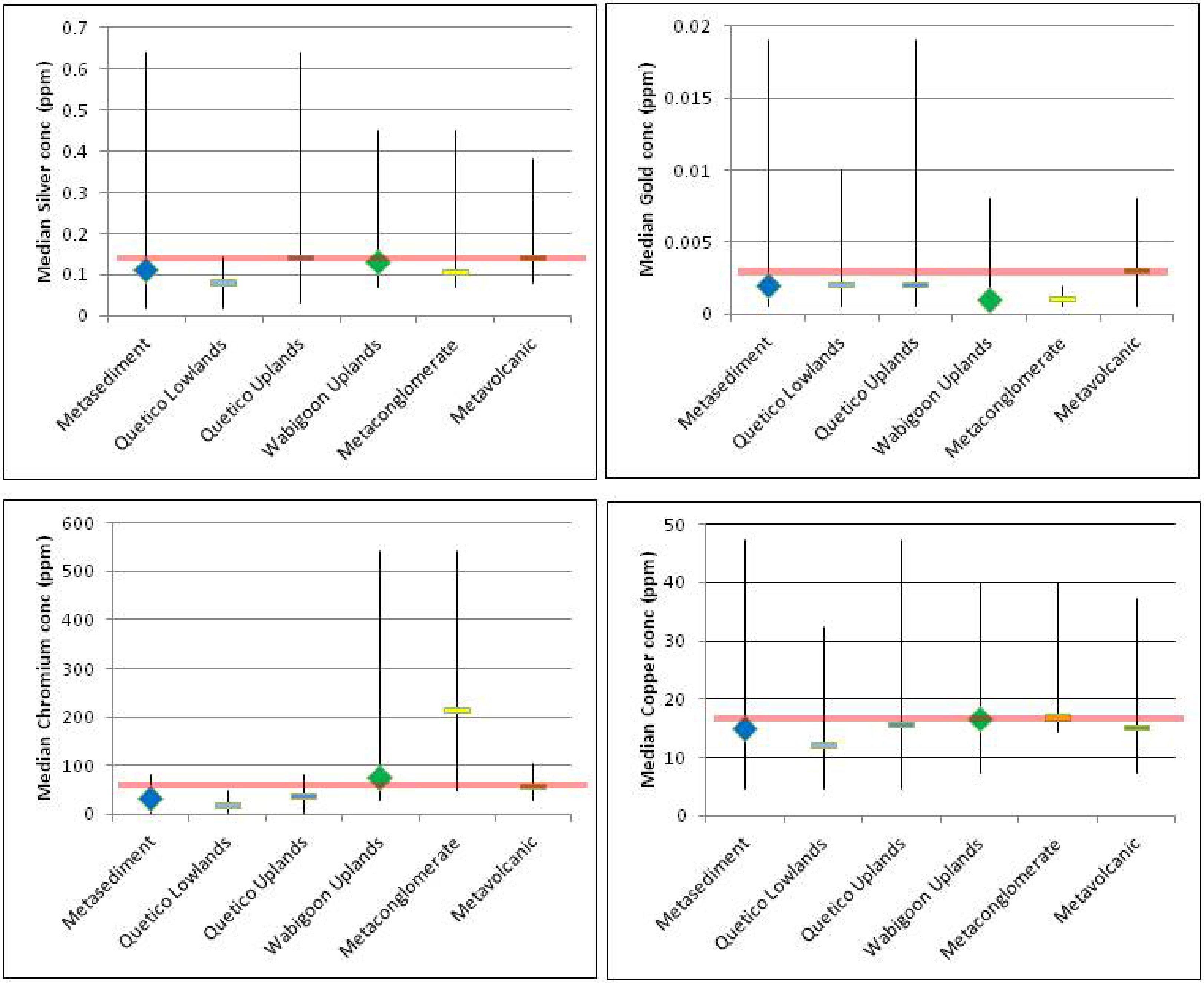

Figure 33: High-Low-Median Concentration Plots for Silver, Gold, Chromium and Copper. Red lines represent median values of the entire sample suite.

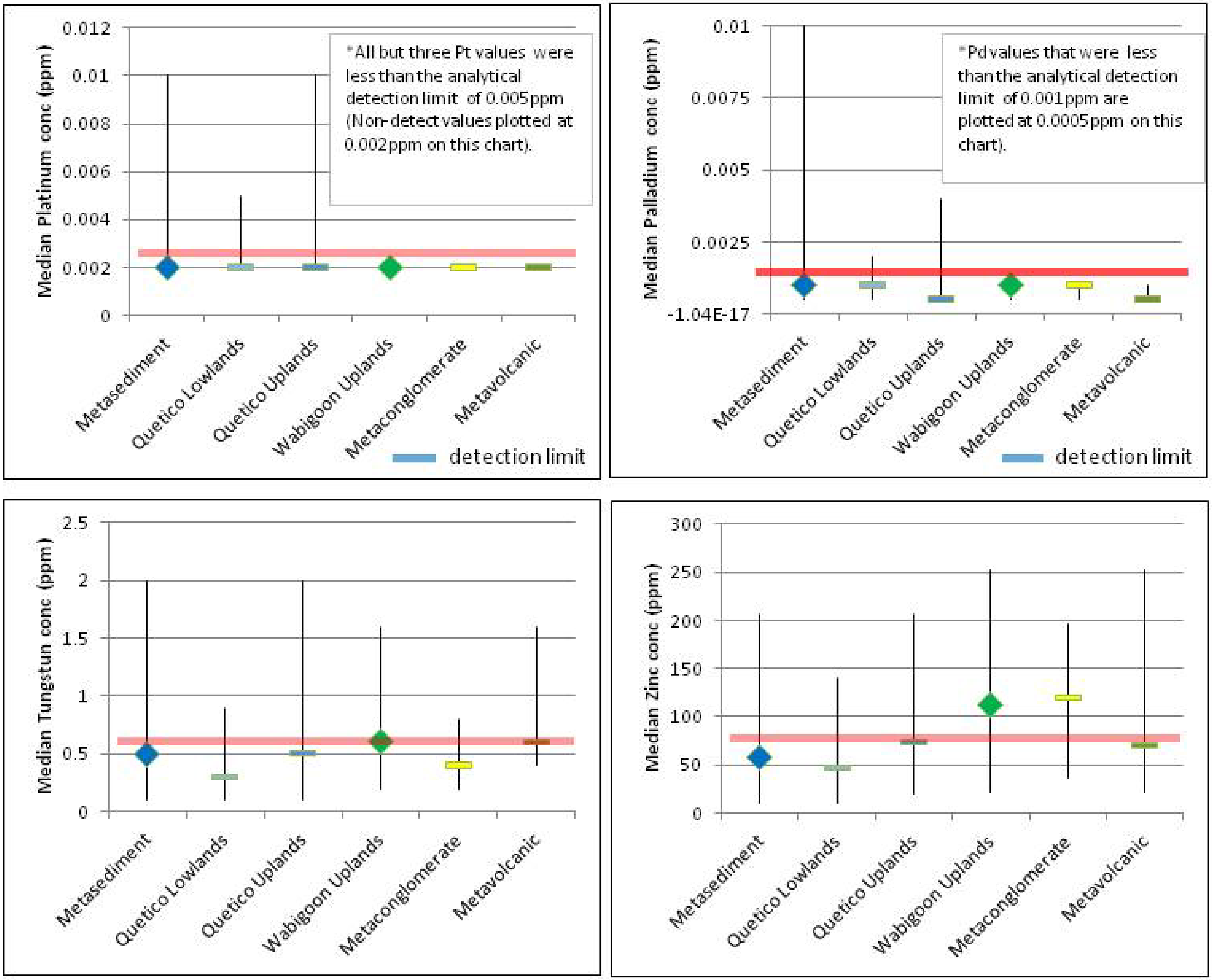

Figure 34: High-Low-Median Concentration Plots for Platinum, Palladium, Tungstun and Zinc. Red lines represent median values of the entire sample suite.

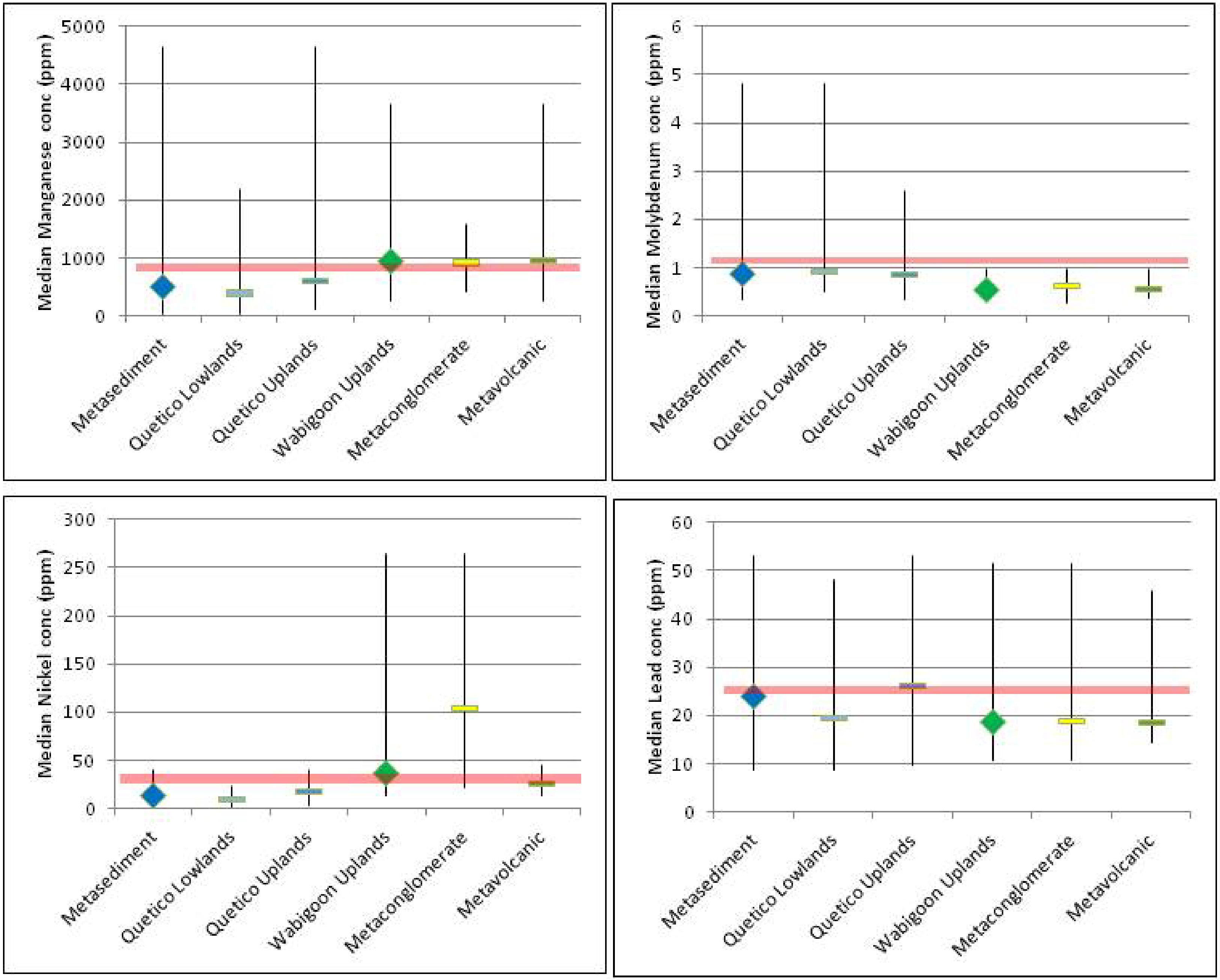

Figure 35: High-Low-Median Concentration Plots for Manganese, Molybdenum, Nickel and Lead. Red lines represent median values of the entire sample suite.

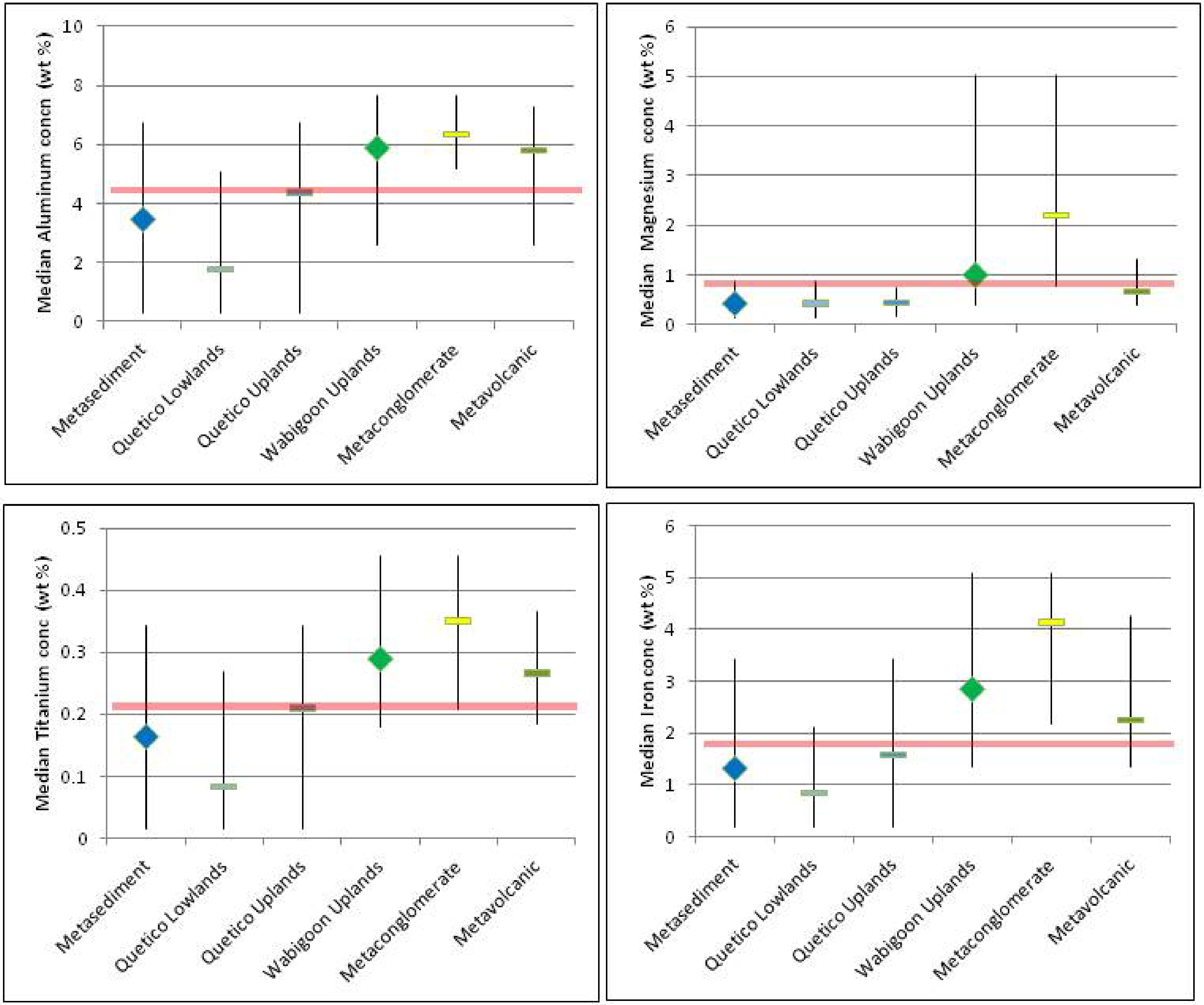

Figure 36: High-Low-Median Concentration Plots for Aluminum, Magnesium, Titanium, and Iron. Red lines represent median values of the entire sample suite.

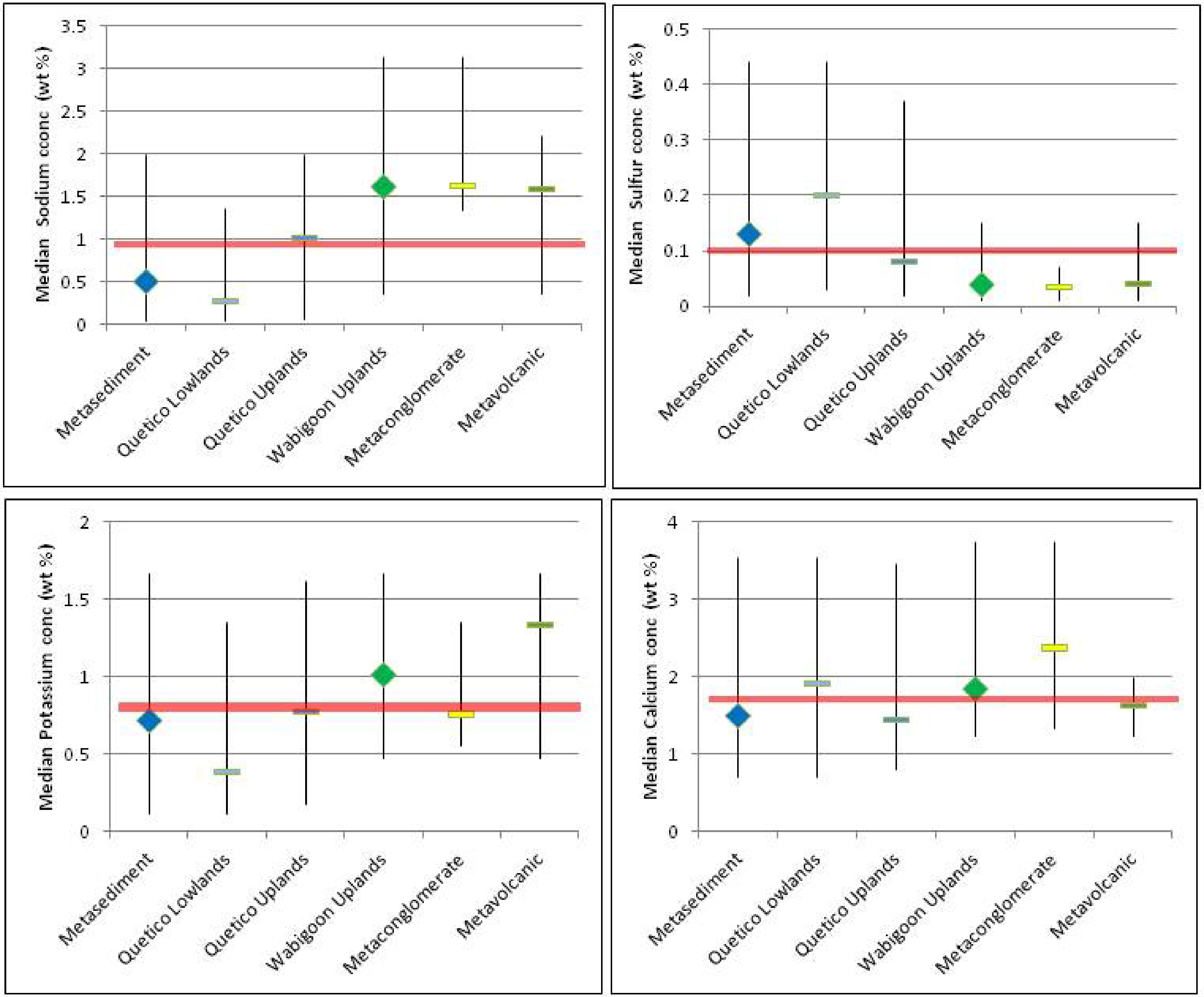

Figure 37: High-Low-Median Concentration Plots for Sodium, Sulfur, Potassium and Calcium. Red lines represent median values of the entire sample suite.

The data tabulated and plotted on the previous tables and graphs can be summarized and visualized using the modified Venn diagram in Figure 38. Within this diagram, the four main subgroupings (Quetico Lowlands, Quetico Uplands, Wabigoon Metaconglomerate and Wabigoon Metavolcanic) are each assigned a individual field. Different intersections of these four fields can then be used to demonstrate common traits. For example, the intersection of the Quetico Lowlands and Quetico Uplands fields creates a smaller field that reflects the geochemistry of all 89 Quetico Metasediment samples. Similarly, the intersection of the metaconglomerate and metavolcanic fields describes the Wabigoon Uplands. Finally, When this Wabigoon Uplands field intersects the Quetico Uplands field, the intersection forms an “Uplands” field that reflects the geochemical characteristics shared by all of the upland samples.

Designation of any selected element as having higher or lower concentrations in any given group is based on the data displayed within Tables 5 through 8. As indicated in Figure 38, there are several geochemical markers for samples collected within the Quetico lowlands and samples collected in the Wabigoon Subprovince over metaconglomerate bedrock. In contrast, higher potassium concentrations are the sole distinguisher for Wabigoon subprovince metavolcanics amongst the reviewed analytes, while the Quetico Uplands lack any distinguishing geochemical marker. They do, however, share characteristics with both the Quetico Lowlands (i.e. higher cadmium and molybdenum, lower cobalt) and, separately, the Wabigoon Uplands (i.e. higher titanium, silver, barium, beryllium, and zirconium).

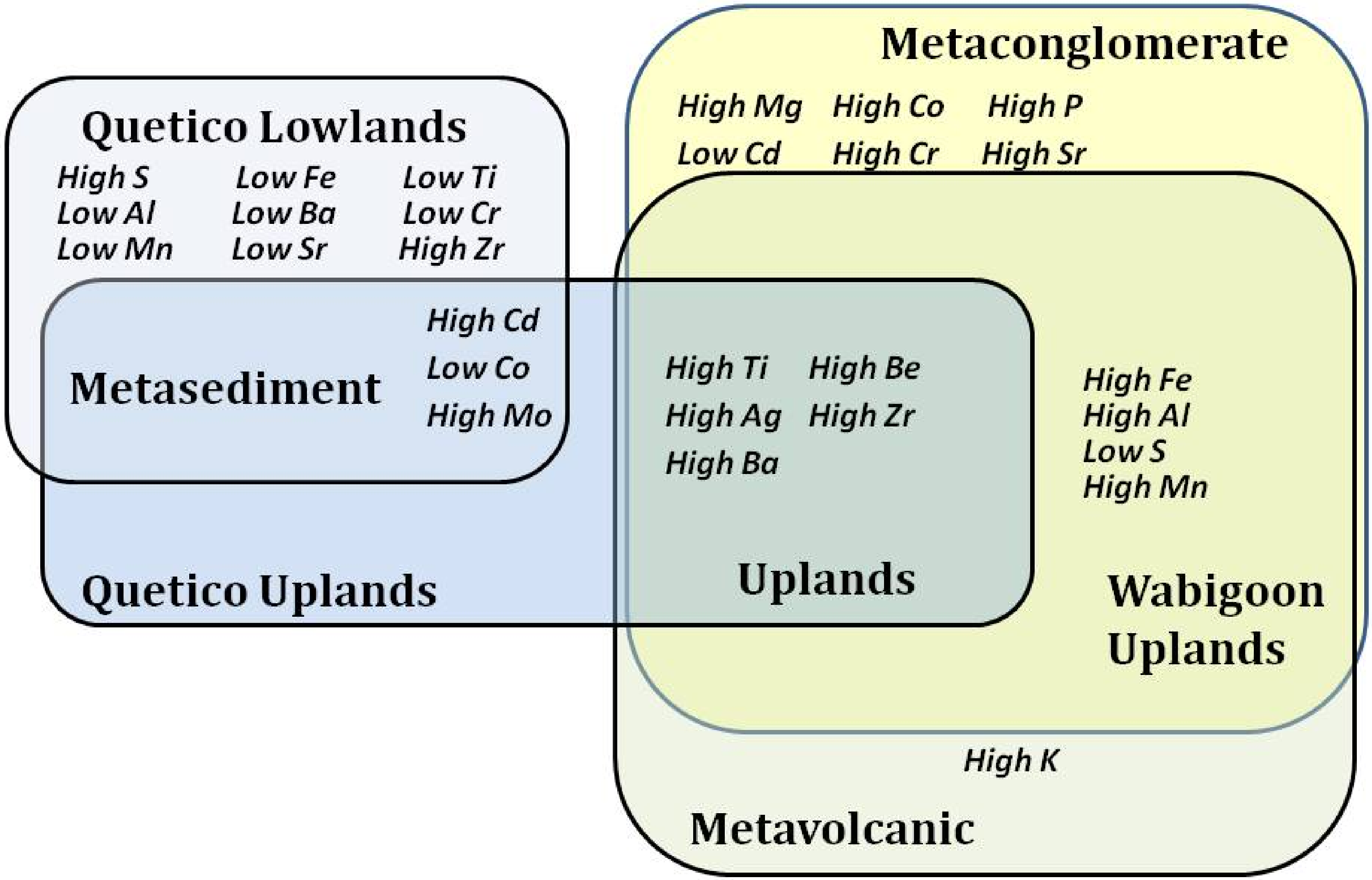

Figure 38: Venn diagram that displays geochemical variations based on the underlying bedrock type and topographic position (uplands vs. lowlands).

12.5. Links Between Soil and Underlying Bedrock

The geochemical results presented above indicate that there are distinct geochemical differences within the suite of shallow soil samples that may be linked to the underlying bedrock. For example, soils collected above a Wabigoon Subprovince metaconglomerate (Asc) have elevated concentrations of magnesium (Mg), chromium (Cr) and nickel (Ni) relative to the other two groups. Iron, titanium and (to a lesser extent) barium are elevated in soils collected above both the Wabigoon Subprovince metaconglomerate (Asc) and metavolcanics (Amv), relative to the soils collected above the Quetico Subprovince. These associations suggest that there is a link between shallow soils and underlying bedrock in the project area.

An alternative hypothesis could be formed that links systematic variations in soil geochemistry to geography, rather than underlying geology. The soil samples collected above the Asc and Amv Wabigoon Subprovince bedrock units were all located in the far northeast portion of the project area. The elevated concentrations of certain elements could, therefore, be explained by differences in distal sources of glacially transported material, and be totally unrelated to the underlying bedrock. The pattern and type of geochemical variation, however, supports a bedrock link. Elevated soil concentrations of magnesium, iron, chromium and titanium would be expected when soils are either derived from or in hydromorphic communication with mafic rock units, such as the Wabigoon Subprovince metavolcanic, and the Wabigoon Subprovince metaconglomerate unit that is described by Day et al (1990) and Hempstad et al. (2000) as having predominately mafic igneous clasts.

For at least one analyte, variations in soil concentrations may have been produced as the result of the absence of a direct link with underlying bedrock. Sulfur concentrations were markedly higher in Quetico lowland samples (Figure 30), in comparison with both Quetico upland and Wabigoon upland soils. Through microbial activity, sulfur within iron sulfides can be liberated and converted into sulfate

(SO_4-) which is soluble in water. Infiltration and groundwater flow can therefore mobilize sulfur, and leach sulfate from well-drained soils (Schippers, 2004). In contrast, poorly-drained soils with low hydraulic conductivities hinder the transport of sulfate, and can actually concentrate “perched” sulfur over time above the impermeable layer.

The shallow water table surface and predominance of peat bogs and other types of wetlands in the Quetico lowland areas (Figure 7) are evidence of poor drainage and soils with low permeability. That sulfur concentrations are lower in better-drained upland areas that overlie Quetico Subprovince metasediments suggests that the variation in soil sulfur content has more to do with surficial topography than bedrock lithology. Some of the sulfur leached from Quetico Upland areas could have even been transferred to the lowland wetlands, and reduced concurrently with organic matter oxidation. This bacterially mediated process would drop the Upland-sourced sulfur out of solution as either elemental sulfur, organic sulfur, or a metal sulfide (Kim Lapakko, personal communication).

Establishing a geochemical link between shallow soil samples and underlying bedrock is important, since it supports the interpretation of geochemical anomalies as being linked to proximal mineralized bedrock sources. The link between soils and underlying bedrock can be established by either primary methods (i.e. bedrock erosion and incorporation into local overlying soils), or secondary methods (i.e. creation of hydromorphic soils through vertical groundwater transport).

It is relatively easy to imagine a primary connection for proximal soils collected in the Wabigoon Subprovince, since they were all collected in upland areas with proximal bedrock exposures. Many of the samples were, in fact, collected directly above shallow bedrock, and it is difficult to evaluate potential variations based on depth to bedrock. In the Quetico Subprovince samples, however, there is variation in bedrock depths; samples collected in the eastern and southern portions of the grids were mostly in uplands, and within areas where there are bedrock exposures. Samples collected in the central portion of the project area, were from lowland areas without outcrop exposures.

12.7. Potential Geochemical Anomalies

Martin et. al (1989) identified potential geochemical anomalies in glacial till samples collected in the Effie Area of Northern Minnesota (south of the project area) by considering the median value for any given analyte to reflect background conditions, following the ideas of Hawkes and Web (1962). They then considered any result that was three times the associated median value as “threshold” concentration that could be considered anomalously high.

We have followed Martin et. al’s methodology, and determined the median values for each of the elements analyzed for in this geochemical survey. Concentrations greater than three times these median values were identified, and considered potentially anomalous. There were many potential geochemical anomalies identified using this method. However, a review of these results determined that most of these potential anomalies were better explained by differences in underlying bedrock, and by the disproportionate number of samples collected in the Quetico Subprovince. With only 21 of the 110 samples collected in the Wabigoon Subprovince, the median values for the entire sample suite were based overwhelmingly on the geochemistry of the Quetico soil samples. As a result, the concentrations of elements that were found in higher concentrations in the Wabigoon Subprovince were often identified as anomalies based on low median values for the entire sample suite.

The geochemical data were then screened a second time, and potential anomalies were identified based on median values within each subgroup, rather than within the entire group. This method greatly reduced the number of potential anomalies; only 1 of the 42 “anomalies” identified within the metaconglomerate suite was higher than three times the median values for that subgroup, while 4 of the 9 initial “anomalies” within the metavolcanic group met this second threshold test.

Figure 39 shows the distribution of anomalous metal concentrations based on this second method. Most of the anomalous values were located within the Quetico Subprovince, but the overall number of anomalies was low. With the possible exception of anomalously high gold values in the eastern portion of the project area, the anomalies are relatively isolated, and do not appear to be associated with potential dispersal trains. There is more of an association between anomalously high values and topography, as shown in Figure 39. There are only a few anomalously high values within the lowland areas, where the soils are generally clay-rich and glacial till deposits were later reworked by lakeshore-related processes.

The fact that a soil sample might have anomalously high concentrations of a particular metal or element relative to either the entire sample suite or its subgroup does not mean that it is reflective of a mineralized bedrock source. If the background concentrations were low, three times a low value could still be low, relative to results from mineralized soils. The measured concentrations of metals and pathfinder elements within the sample suite are, in fact, low, and the measured variations more easily explained by statistical variations than discrete mineralized sources. The one exception to this observation, however, is gold. Gold concentrations in A1 soil samples that are greater than 5ppb are worth further consideration. There are a series of elevated gold concentrations in the eastern portion of the project area; possible follow-up investigations of these gold values are explored in the recommendations.

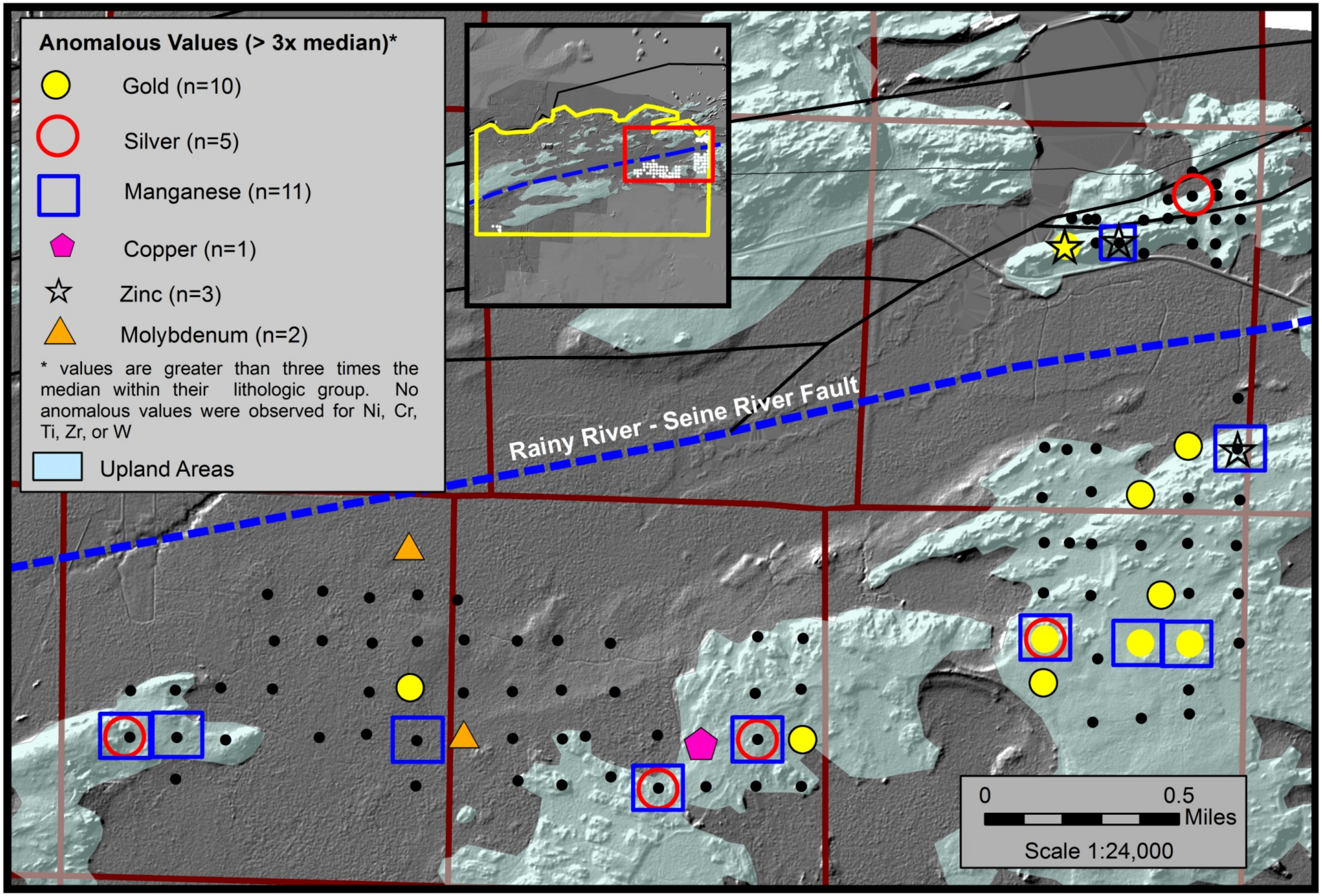

Figure 39: Anomalous metals concentrations in A1 Soils, International Falls Area.

13.0 Recommendations for Additional Work

This geochemical soil survey was conducted in a granite greenstone terrane that has experienced both historic and active gold mineral exploration programs. Gold concentrations in the eastern portion of the project area display a spatial distribution and concentration levels potentially reflective of a linear trend, or potential dispersal train for glacial transport from the northeast to the southwest (Figure 40), which is the general flow direction of the Rainy Lobe.

There are a number of exposed outcrops within the easternmost portion of the project area. The collection of gold grain counts in till samples has been a useful exploration tool across Minnesota and, more generally, the Canadian Shield. Till samples collected in the eastern portion of the project area, along the possible linear trend with elevated gold concentrations, could be analyzed for gold grain counts. The number of gold grains and their morphology could prove useful in determining whether there is a dispersal trail along this linear trend, and whether a potential bedrock gold source was relatively close or distant.

The locations of the anomalously-high gold values are consistent with a potential dispersal train that originates on or near the Rainy River-Seine River Fault and extends approximately 1.5 miles in a southwesterly direction (Figure 40). The potential source area is located in the eastern one-half of Section 36, T70N R23W, and is Permanent School Trust land that was offered in the April 2011 Metallic Minerals Lease Sale.

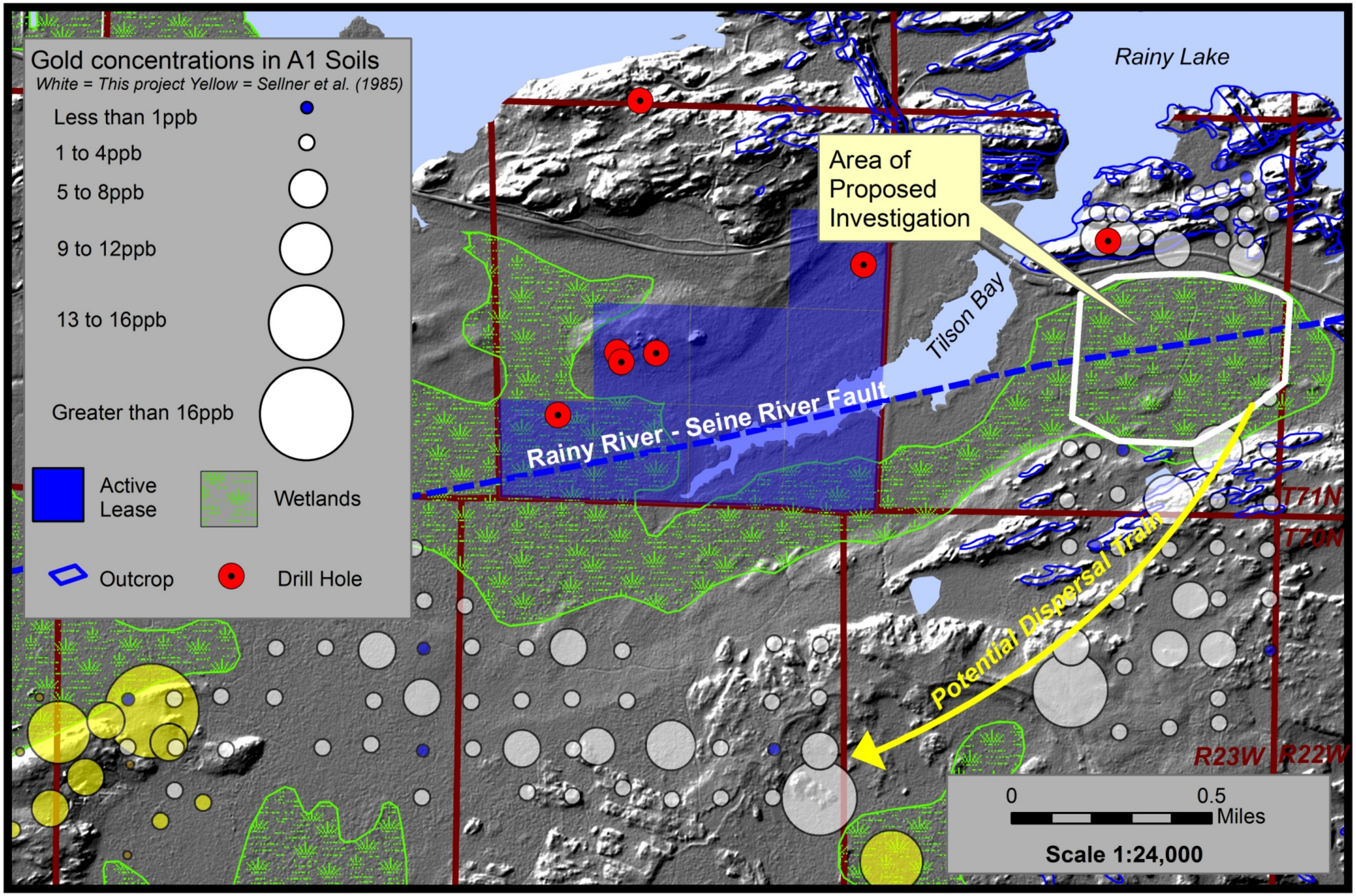

Figure 40: Area of proposed additional investigation in the eastern portion of the project area.

The potential source area is located outside of the soil sample grids established for this project, and was not included within the 1985 DNR pilot geochemical survey. As shown in Figures 40, this area is topographically low, and covered with wetland vegetation and peat bogs, making it unsuitable for either an A1 layer geochemical soil survey or a gold-in-till survey. Figure 41 is a photograph taken in this potential source area that shows peatland vegetation and scattered trees, including black spruce. While these trees are not uniformly distributed across this lowland area, it may be possible to determine whether the anomalous gold concentrations extend back to this potential source area by conducting a geochemical survey of black spruce limbs or other vegetation. Sample collection for this type of vegetation survey would be best conducted during the winter months, when frozen ground conditions would allow access to sample locations that are otherwise inaccessible by foot.

Figure 41: Photograph of proposed Area of Additional Investigation

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15.0 Revision History

July 3, 2012: Original open-file report published and made available on-line.

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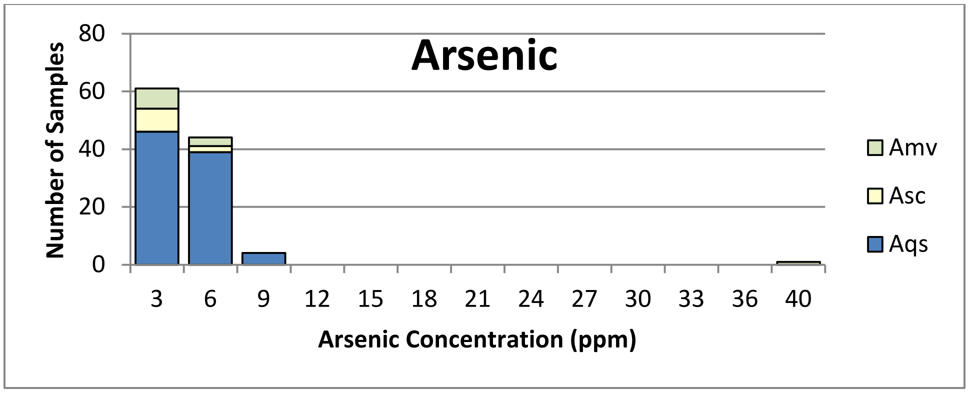
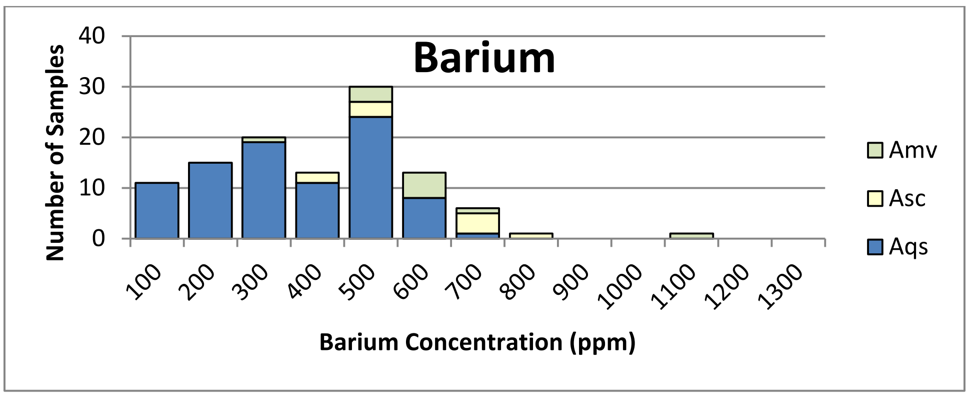
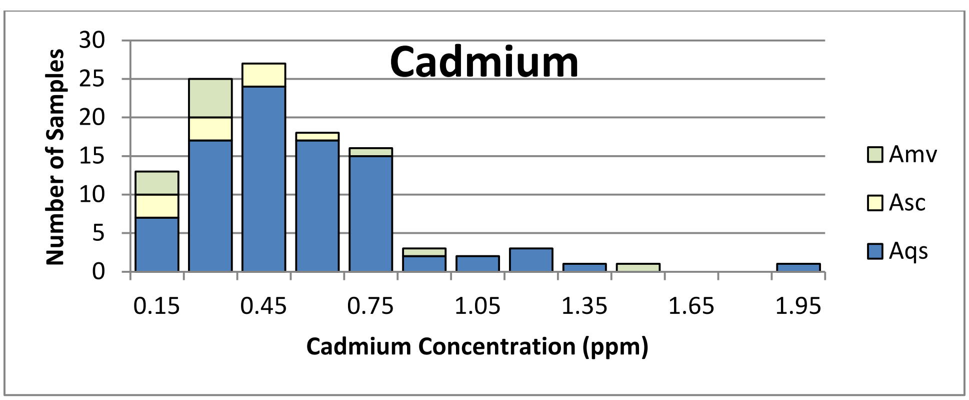
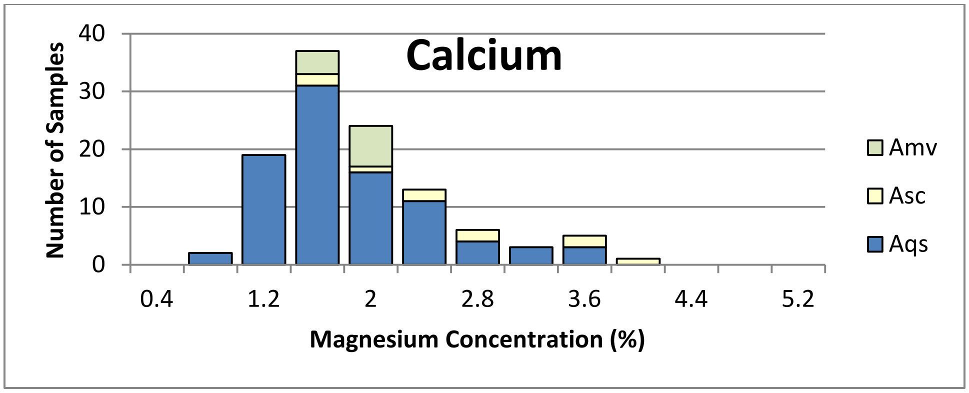
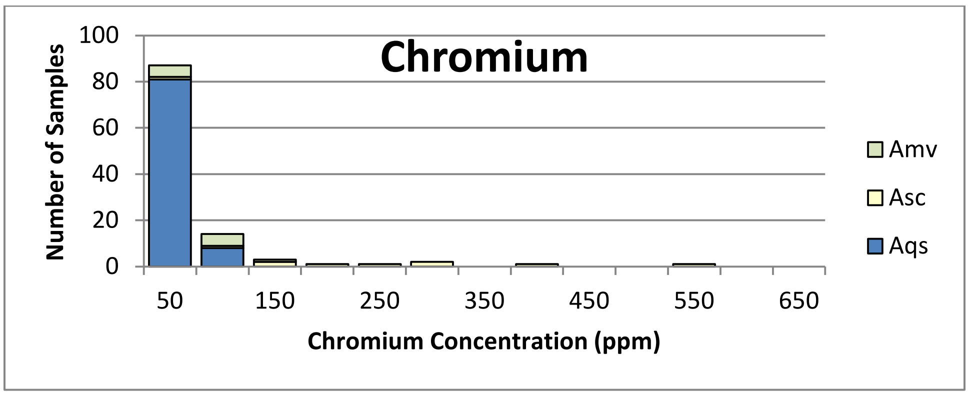
Appendix 1: Histogram distribution plots for selected elements

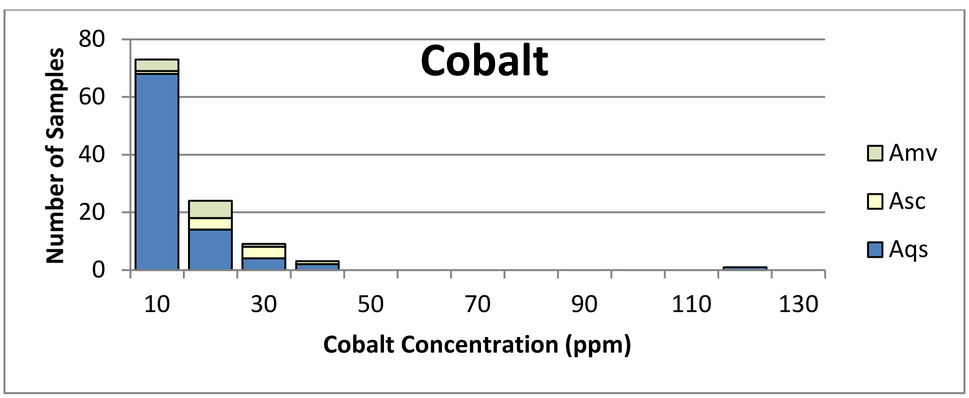

Arsenic
Number of Samples
0
20
40
60
80
3
6
9
12
15
18
21
24
27
30
33
36
40
Arsenic Concentration (ppm)
Amv
Asc
Aqs

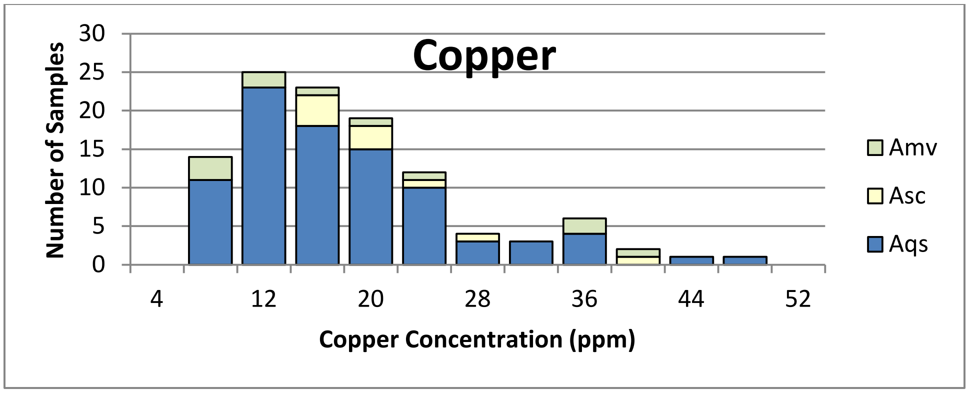

Barium
Number of Samples
0
10
20
30
40
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Barium Concentration (ppm)
Amv
Asc
Aqs

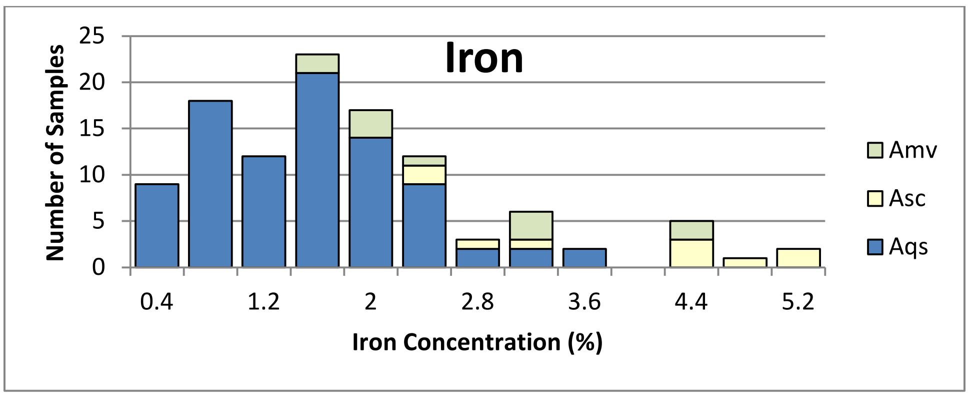

Cadmium
Number of Samples
0
5
10
15
20
25
30
0.15
0.45
0.75
1.05
1.35
1.65
1.95
Cadmium Concentration (ppm)
Amv
Asc
Aqs

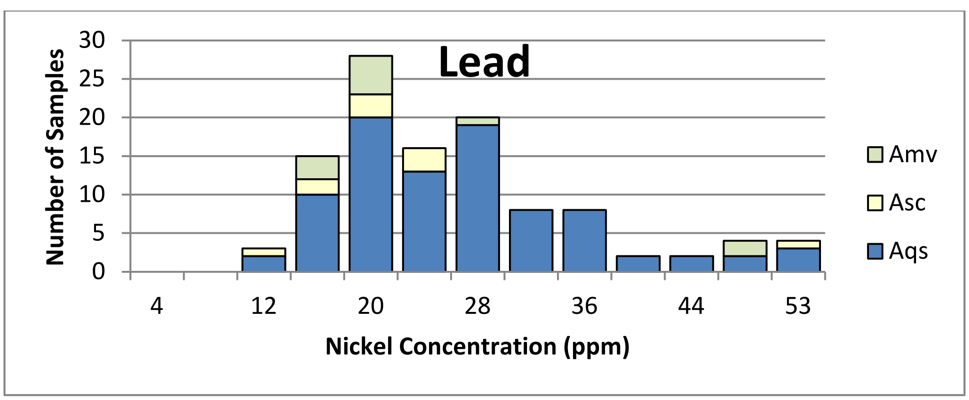

Calcium
Number of Samples
40
30
20
10
0
0.4
1.2
2
2.8
3.6
4.4
5.2
Magnesium Concentration (%)
Amv
Asc
Aqs

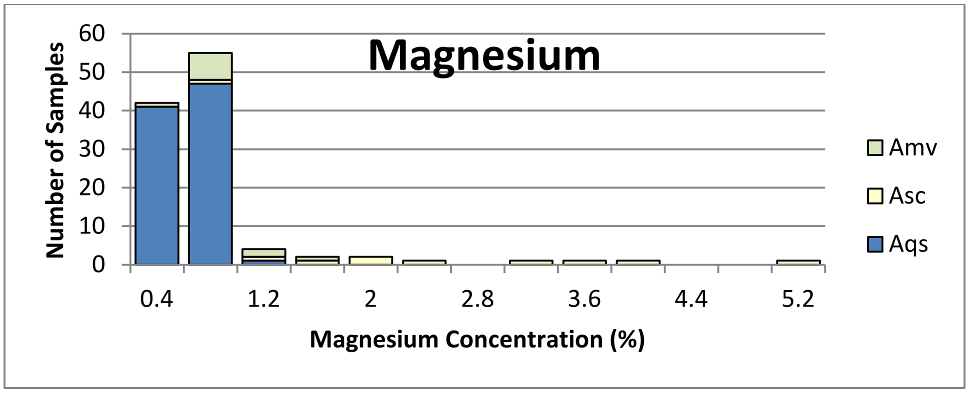

Chromium
Number of Samples
100
80
60
40
20
0
50
150
250
350
450
550
650
Chromium Concentration (ppm)
Amv
Asc
Aqs

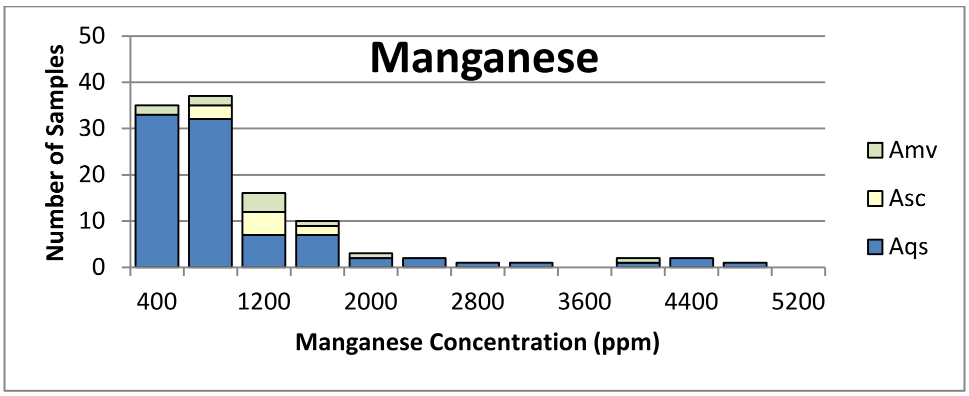

Cobalt
Number of Samples
80
60
40
20
0
10
30
50
70
90
110
130
Cobalt Concentration (ppm)
Amv
Asc
Aqs

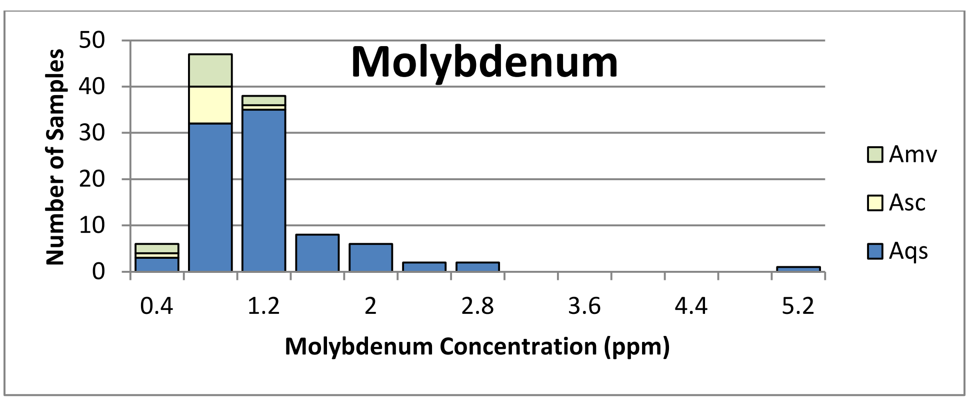

Copper
Number of Samples
30
25
20
15
10
5
0
4
12
20
28
36
44
52
Copper Concentration (ppm)
Amv
Asc
Aqs

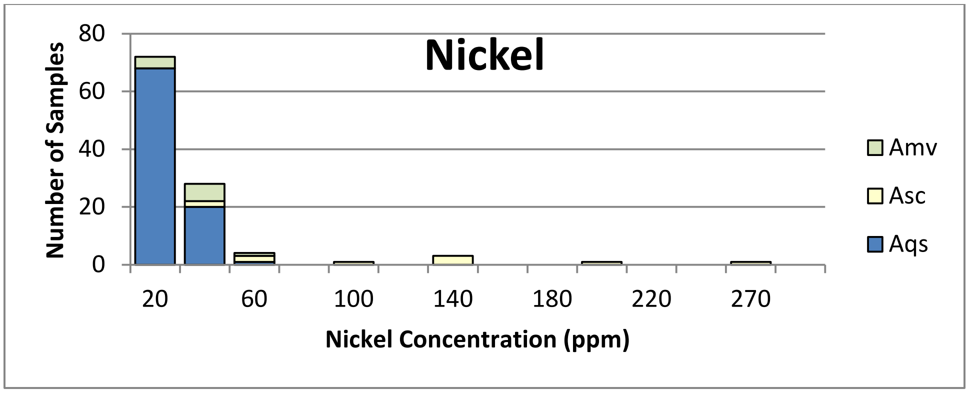

Iron
Number of Samples
25
20
15
10
5
0
0.4
1.2
2
2.8
3.6
4.4
5.2
Iron Concentration (%)
Amv
Asc
Aqs

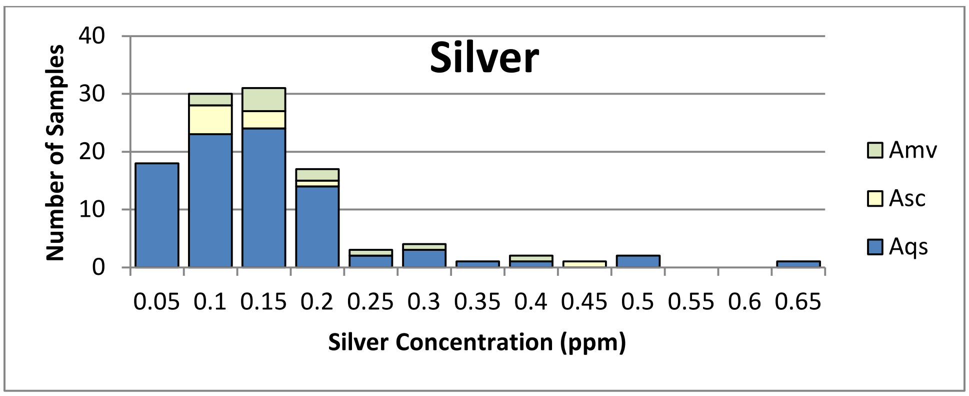

Lead
Number of Samples
30
25
20
15
10
5
0
4
12
20
28
36
44
53
Nickel Concentration (ppm)
Amv
Asc
Aqs

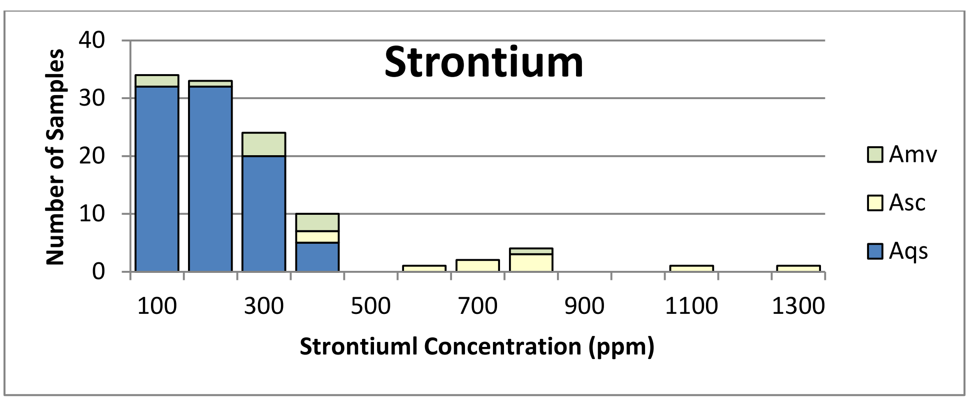

Magnesium
Number of Samples
60
50
40
30
20
10
0
0.4
1.2
2
2.8
3.6
4.4
5.2
Magnesium Concentration (%)
Amv
Asc
Aqs

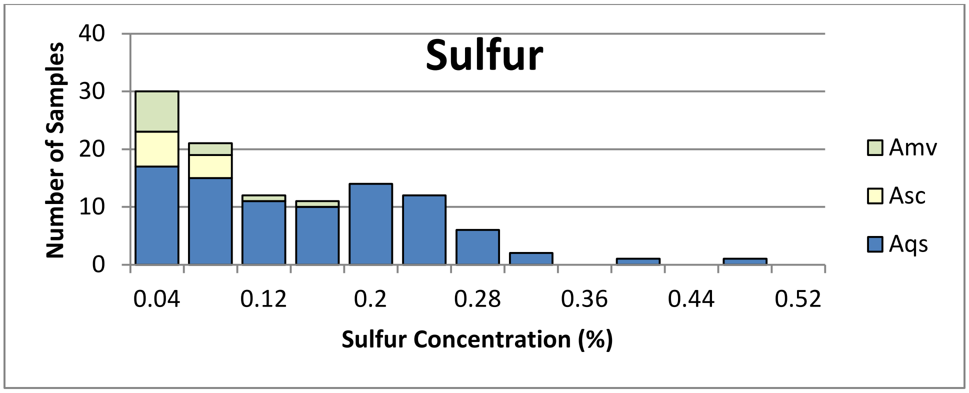

Manganese
Number of Samples
50
40
30
20
10
0
400
1200
2000
2800
3600
4400
5200
Manganese Concentration (ppm)
Amv
Asc
Aqs

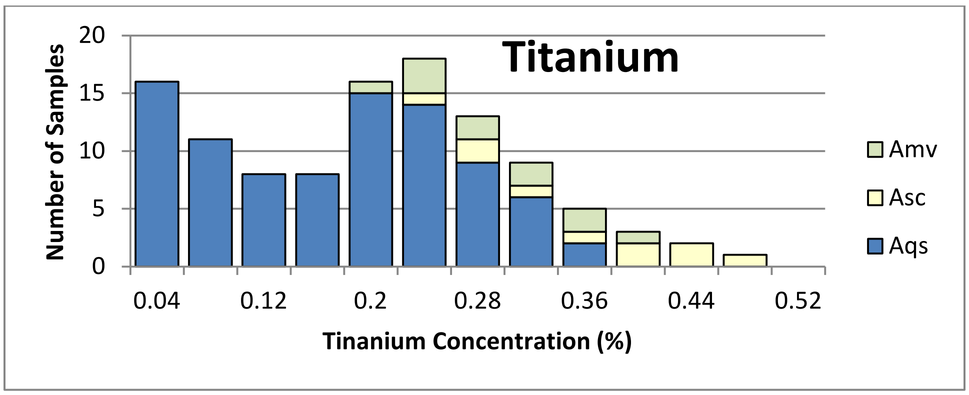

Molybdenum
Number of Samples
50
40
30
20
10
0
0.4
1.2
2
2.8
3.6
4.4
5.2
Molybdenum Concentration (ppm)
Amv
Asc
Aqs

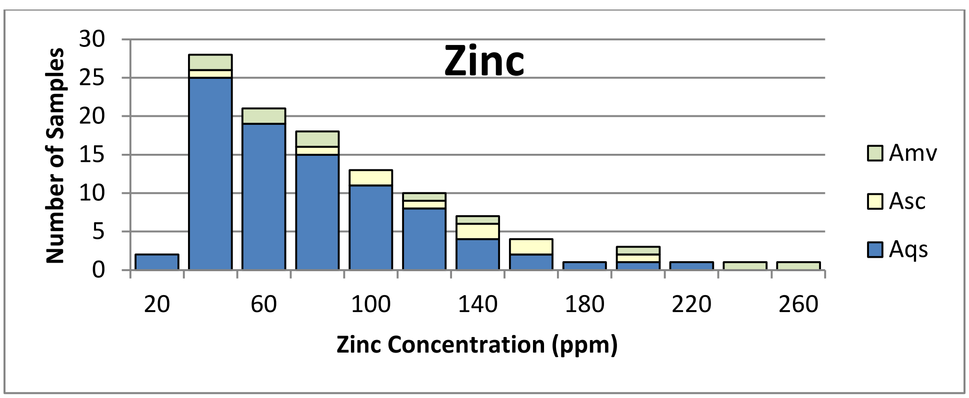

Nickel
Number of Samples
0
20
40
60
80
20
60
100
140
180
220
270
Nickel Concentration (ppm)
Amv
Asc
Aqs


Silver
Number of Samples
0
10
20
30
40
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
Silver Concentration (ppm)
Amv
Asc
Aqs


Strontium
Number of Samples
0
10
20
30
40
100
300
500
700
900
1100
1300
Strontiuml Concentration (ppm)
Amv
Asc
Aqs


Sulfur
Number of Samples
40
30
20
10
0
0.04
0.12
0.2
0.28
0.36
0.44
0.52
Sulfur Concentration (%)
Amv
Asc
Aqs


Titanium
Number of Samples
20
15
10
5
0
0.04
0.12
0.2
0.28
0.36
0.44
0.52
Tinanium Concentration (%)
Amv
Asc
Aqs


Zinc
Number of Samples
30
25
20
15
10
5
0
20
60
100
140
180
220
260
Zinc Concentration (ppm)
Amv
Asc
Aqs