AER/AGS Open File Report 2024-01

Summary of 2023 Field Activities: Leland Lakes and Andrew Lake Areas, Canadian Shield, Northeastern Alberta

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Abstract

This report provides an interim summary of field activities conducted in the summer of 2023 as part of a multidimensional study by the Alberta Geological Survey (AGS) to investigate mineral systems of the Canadian Shield in northeastern Alberta. In support of the Government of Alberta's initiative to increase publicly available geoscience information related to critical mineral potential, AGS crews visited nearly 400 stations and collected more than 500 samples for geochemical and petrographic analyses. Additional datasets generated from this fieldwork are described, and anticipated publications are outlined.

This work was completed under the Mineral Grant provided by the Government of Alberta on June 22, 2021.

1 Introduction

The exposed Precambrian basement rock of the Canadian Shield covers an area of approximately 9500 km^2 in northeastern Alberta. Although a number of metallic and nonmetallic mineral occurrences have been historically documented in the region, there has been little mineral exploration or geological mapping in the past several years. The last campaign of detailed geological mapping by the Alberta Geological Survey (AGS) concluded in the 1970s and little exploration for critical minerals or documentation of pegmatite types and distributions has taken place since. Recently, the rising global demand for minerals has renewed interest in the mineral potential of the Canadian Shield in Alberta.

In 2021, the Government of Alberta released *Renewing Alberta's Mineral Future: a Strategy to Re-Energize Alberta's Minerals Sector* (Alberta Ministry of Energy, 2021), a mineral strategy and action plan detailing six key actions to focus on to re-energize Alberta's mineral sector. The first key action is to enhance the public geoscience knowledge base for critical minerals in Alberta. As part of this initiative, the AGS launched a multidimensional study investigating mineral systems and the potential of the shield in northeastern Alberta. This involved an initial compilation, digitization, and reanalysis of historical rock samples, core, datasets, and reports, as well as the acquisition of new high-quality regional aeromagnetic and multispectral remote sensing data. A 33-day field mapping program in the Leland Lakes and Andrew Lake areas was conducted to follow up on leads from the abovementioned studies, ground-truth the findings of the remote sensing investigation, and collect new data examining rare-earth-element potential related to pegmatites and critical mineral exploration. During this field mapping program, crews visited nearly 400 stations, collecting more than 500 rock samples for geochemical and petrographic analyses, and took magnetic susceptibility, gamma-ray, and hyperspectral absorption measurements throughout the study areas.

The contents herein are an interim report that summarizes the field data and rock samples collected during the summer of 2023. Detailed reporting of geochemical results, with implications for understanding the mineral potential of the region is anticipated in 2024 after analytical results have been received and incorporated into updated geological maps.

2 Background

2.1 Regional Geology

The Canadian Shield of northeastern Alberta is an exposed surface expression of the Precambrian basement, which consists of variably metamorphosed granitoids, metasedimentary rocks, and orthogneisses. These basement rocks extend beneath Phanerozoic sedimentary rocks of the Western Canada Sedimentary Basin (WCSB), which is present throughout the rest of Alberta. The Canadian Shield in Alberta is broadly subdivided into the Paleoproterozoic Taltson magmatic zone (TMZ), and the late Paleoproterozoic to Mesoproterozoic Athabasca Group. See Figure 1 for a simplified geological map of the following major lithological subdivisions.

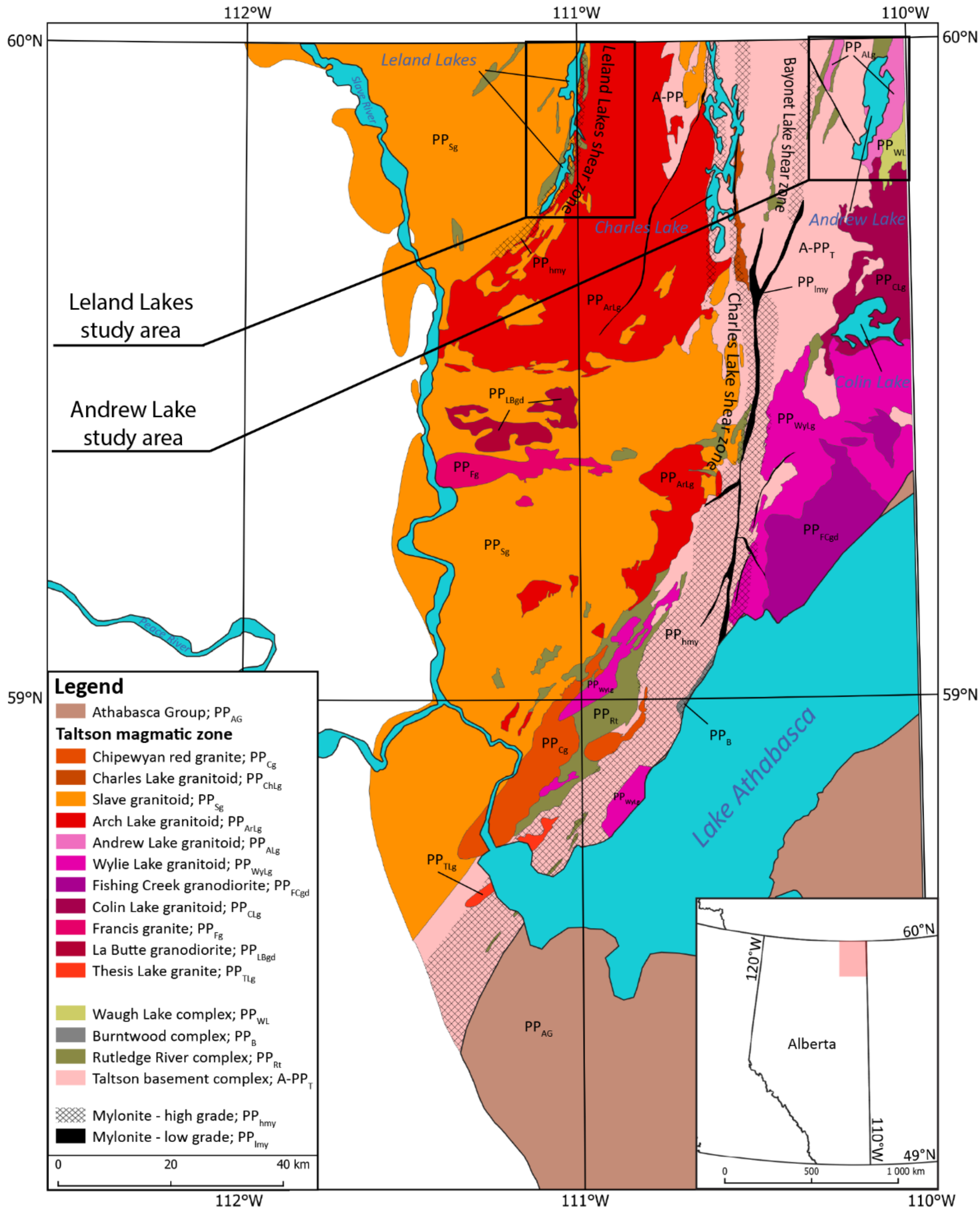

Figure 1. Simplified geological map of the Canadian Shield in northeastern Alberta, adapted from Godfrey (1986) and Prior et al. (2013). The inset map shows the location of the map area.

2.1.1 Taltson Magmatic Zone

The TMZ is the southern portion of the north- to northeast-trending Taltson–Thelon orogenic belt, which extends some 2500 km from the Queen Maud Gulf in Nunavut to central Alberta (Hoffman, 1988, 1989). The Taltson–Thelon orogenic belt was generated during a large Paleoproterozoic collisional event that sutured the Slave craton, Buffalo Head terrane, and the Churchill Province (Hoffman, 1989). There are three proposed tectonic explanations for the origin of this belt: (1) the belt was generated from subduction and collision at a convergent margin between the Slave craton, Buffalo Head terrane, and the Rae craton (Hoffman, 1988; Ross et al., 1991); (2) the belt was generated from intracratonic crustal thickening caused by a distant convergent plate margin (Thompson, 1989; Chacko et al., 2000); or (3) the TMZ and Thelon orogen are distinct tectonic entities entirely (Card et al., 2014), where the TMZ plutonism was generated at the western margin of the amalgamated Rae craton and Buffalo Head terrane during their collision with the Slave craton (Whalen et al., 2018; Davis et al., 2021; Berman et al., 2023).

The TMZ is exposed at surface for approximately 300 km, from the Great Slave Lake shear zone in the Northwest Territories to just south of Lake Athabasca in northeastern Alberta. The TMZ extends a further 300 km south, underneath Phanerozoic sediments of the WCSB, where it terminates at the Snowbird tectonic zone (Hoffman, 1988, 1989; Ross et al., 1991). Small enclaves of the TMZ outcrop south of the Athabasca Group within Alberta and are collectively known as the Marguerite River complex (Pană, 2010b). The TMZ separates the early Paleoproterozoic Buffalo Head terrane to the west and the Archean to Paleoproterozoic Churchill Province to the east (Ross et al., 1991). In Alberta, the TMZ is composed of 1.99 to 1.92 Ga granitoids that have intruded, reworked, and assimilated the Archean to Paleoproterozoic crust of the western margin of the Rae craton (Bostock et al., 1987; Ross et al., 1991; McNicoll et al., 1994, 2000). Collectively, the basement gneisses and metaplutonic rocks are known as the Taltson basement complex (TBC; McDonough et al., 1995). The TBC is exposed in northeastern Alberta as a curvilinear body of medium- to high-grade metamorphic rocks and is composed of a diverse suite of orthogneiss, paragneiss, and structurally complex sheared gneisses of undetermined origin. The TBC contains lithologies of Archean (3.2, 3.1, and 2.6 Ga) and Paleoproterozoic (2.4 to 2.1 Ga) age (Godfrey, 1986; Goff et al., 1986; McNicoll et al., 2000). There are seven major basement blocks that make up the TBC: Leland Lakes, Mercredi Lake, Dore Lake, Cornwall Lake, Potts Lake, Andrew Lake, and Berrigan Lake (McDonough et al., 1995; McNicoll et al., 2000).

Three major shear zones occur within the TMZ in northeastern Alberta: the Leland Lakes shear zone (LLSZ), the Charles Lake shear zone (CLSZ), and the Bayonet Lake shear zone (BLSZ), from west to east. Due to contemporaneous deformation and plutonism, the structural relationship between the various plutonic bodies and Taltson basement is complex.

2.1.2 Athabasca Group

The Athabasca Group is a late Paleoproterozoic to early Mesoproterozoic sedimentary succession in the Athabasca Basin, which extends into Saskatchewan. Approximately 10% of the Athabasca Basin is located within northeastern Alberta, where it makes up approximately 40% of the exposed Canadian Shield. In Alberta, the rocks of the Athabasca Group have a maximum thickness of approximately 810 m (Hobson and MacAulay, 1969) and are underlain by TMZ plutonic and TBC metamorphic rocks. Locally, the thickness of the Athabasca Group is variable due to capping carbonate sequences such as those belonging to the Carswell group as well as differing degrees of erosion across the stratigraphy (Ramaekers et al., 2007). The Athabasca Group is composed of four major unconformity-bounded fluvial sequences that filled the Athabasca Basin between 1760 and 1500 Ma (Ramaekers et al., 2007).

2.2 Local Geology

2.2.1 Leland Lakes Study Area

The Leland Lakes study area is located around the LLSZ, along the border between the Slave granitoid to the west and the Arch Lake granitoid to the east (Figure 1; Godfrey, 1986). There is a narrow exposure of the TBC called the Leland Lakes block, which separates the Slave granitoid from the Arch Lake granitoid at Leland Lakes (McDonough et al., 1995; McNicoll et al., 2000).

2.2.1.1 Slave Granitoid

The post-tectonic 1934 ±2 Ma Slave granitoid dominates the western half of the Leland Lakes study area (McDonough et al., 2000b). It is composed of weakly foliated S-type granite and contains numerous potential screens and rafts of assimilated Arch Lake granitoid and metasedimentary rocks (Godfrey and Langenberg, 1986; McDonough et al., 2000b). Similar to other areas in the TMZ, this granite displays a north- to northeast-trending foliation (Godfrey and Langenberg, 1986). The intrusion of this granitoid has truncated the western margin of the LLSZ (McDonough et al., 2000b).

2.2.1.2 Arch Lake Granitoid

The syntectonic 1938 ±3 Ma Arch Lake granitoid makes up the eastern half of the Leland Lakes study area (McDonough et al., 2000b). It is composed of homogeneous, strongly deformed, K-feldspar megacrystic granite to syenogranite gneiss with a penetrative foliation that varies in orientation with proximity to the LLSZ (Godfrey and Langenberg, 1986).

2.2.1.3 Leland Lakes Block

The Leland Lakes block is a small (~12.7 km^2) sliver of TBC gneisses exposed within the LLSZ, which separates the western Slave granitoid from the eastern Arch Lake granitoid (Godfrey, 1986; McDonough et al., 1995). It is the westernmost exposure of the TBC in Alberta and has an emplacement age of approximately 3.2 Ga (McNicoll et al., 2000). The basement complex and the surrounding Taltson plutons display multiple phases of mylonitic overprinting spatially related to the LLSZ though there is some debate on the strength and spatial extent of metamorphic overprint attributed to the LLSZ (Langenberg et al., 1994).

2.2.2 Andrew Lake Study Area

The Andrew Lake study area is located in the far northeastern corner of Alberta. The study area is dominated by north- to northeast-trending units of the TBC, the Rutledge River complex, the Waugh Lake complex, and the Taltson plutonic complex (Figure 1).

2.2.2.1 Taltson Basement Complex

The western half of the Andrew Lake study area is dominated by exposed granitoids of the TBC. These granitoids range from foliated to mylonitic felsic and intermediate orthogneisses. At a smaller scale, lenses of biotite schist, quartzite, and amphibolite are present, as is a widespread series of granitic pegmatite intrusions. In addition, there are numerous discrete intrusions of porphyritic granite and granodioritic dikes (Pană and Prior, 2010). The U-Pb zircon ages obtained from the basement gneisses range from ca. 2.56 to 2.14 Ga, including discrete layers dated at ca. 3.19 and 3.08 Ga, which indicate the TBC formed through Paleoproterozoic reworking of the western margin of the Rae craton (McNicoll et al., 2000).

2.2.2.2 Rutledge River Complex

The Rutledge River complex is sporadically exposed in the Andrew Lake study area. The Rutledge River complex is composed of amphibolite- to granulite-grade, variably migmatitic, pelitic, and quartzitic gneisses interpreted to have been generated in the Rutledge River basin between 2.13 and 2.09 Ga and subsequently metamorphosed and incorporated into the crust of the western Rae craton (Bostock and van Breemen, 1994; McDonough et al., 2000a, b).

2.2.2.3 Waugh Lake Complex

The Waugh Lake complex is found primarily east and southeast of Andrew Lake within the study area. It is a package of biotite-rich quartzitic schist, quartzite, and mafic schist overprinted by low-grade metamorphism and shearing in the Paleoproterozoic (Godfrey, 1963). There is some debate on the nomenclature and origin of the Waugh Lake complex (e.g., Godfrey, 1958; Ianelli et al., 1995; McDonough et al., 2000b; Pană and Prior, 2010). A study published by Pană (2010a) used Sm-Nd and U-Pb data to suggest that the Waugh Lake complex may have been derived directly from the surrounding TMZ crust.

2.2.2.4 Taltson Plutonic Complex

In the Andrew Lake study area, the Taltson plutonic complex is represented by the Colin Lake and Andrew Lake granitoids. At surface, the Andrew Lake granitoid is expressed as elongate northeast-trending bodies that outcrop northwest and northeast of Andrew Lake and display both mineralogical and deformational zonation towards the margins of the intrusions (Pană and Prior, 2010). The U-Pb zircon emplacement age of 1959 ±3 Ma has been obtained from the Andrew Lake granitoid (McDonough et al., 2000b). The Colin Lake granitoid is much more voluminous. It is found in the southeastern portion of the study area and extends farther south and east into Saskatchewan (Godfrey, 1986; Pană and Prior, 2010). The Colin Lake granitoid was emplaced during multiple phases and is dominated by megacrystic granodiorite at Colin Lake and equigranular diorite at Waugh Lake. The emplacement age of the Colin Lake granitoid has been established as 1971 ±4 Ma by U-Pb dating of zircons (McDonough and McNicoll, 1997).

2.3 Mineral Occurrences

2.3.1 Leland Lakes Study Area

The historical mineral showings in this study area are spatially related to the LLSZ; highlights are presented in Figure 2. These showings include anomalous copper, gold, uranium, and lead in surface rock samples. Aside from the granitoid-hosted anomalous uranium (revealed by assaying and scintillometer readings), the gold and base metal showings are hosted within gossans and quartz veins.

2.3.2 Andrew Lake Study Area

There is a wide variety of historical mineral showings in the Andrew Lake study area including anomalous uranium, molybdenum, silver, gold, tungsten, and rare-earth-element (REE) occurrences. Highlights are presented in Figure 3. Several structural features in the area are spatially correlated with elevated concentrations of critical minerals. The Bonny fault, characterized by shearing and brecciation, hosts several uranium showings with similar lithological and geochemical characteristics to the uraniferous zones in the Beaverlodge district of Saskatchewan (Godfrey, 1958; Pană et al., 2006). Elsewhere in the study area, uranium showings occur primarily in sheared and faulted pegmatites, typically hosted in granitoid gneisses and schists (e.g., Godfrey, 1958; Pană et al., 2006; Pană and Prior, 2010). The Rutledge River complex hosts a number of showings of sulphide-related nickel, silver, gold, and chromium within high-strain biotite-rich aluminosilicate bands and lenses (Godfrey, 1958; Pană and Prior, 2010). In addition, significant REE mineralization is documented in gossanous metasedimentary rocks and pegmatites in this complex (Smith and Griffith, 2007). The Waugh Lake complex hosts a significant number of mineral showings in association with a series of gossanous shear zones as well as abundant quartz-tourmaline veining exclusive to this complex. These showings include elevated tungsten, silver, gold, lead, and molybdenum values (Godfrey, 1958; Langenberg et al., 1993).

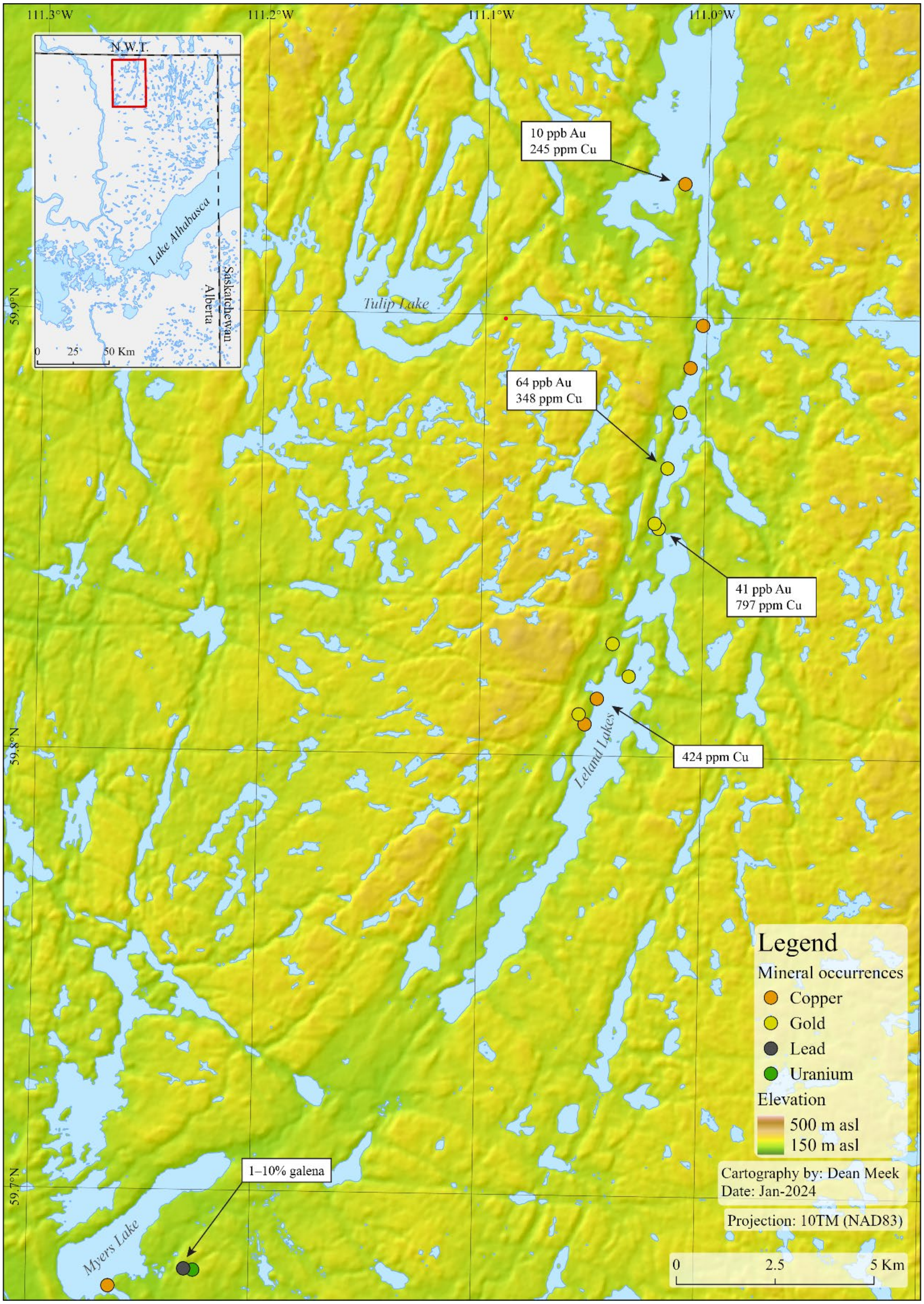

Figure 2. Leland Lakes study area with historical metallic mineral geochemical anomalies and showings (Lopez et al., 2020). Background digital elevation model from NASA JPL (2013).

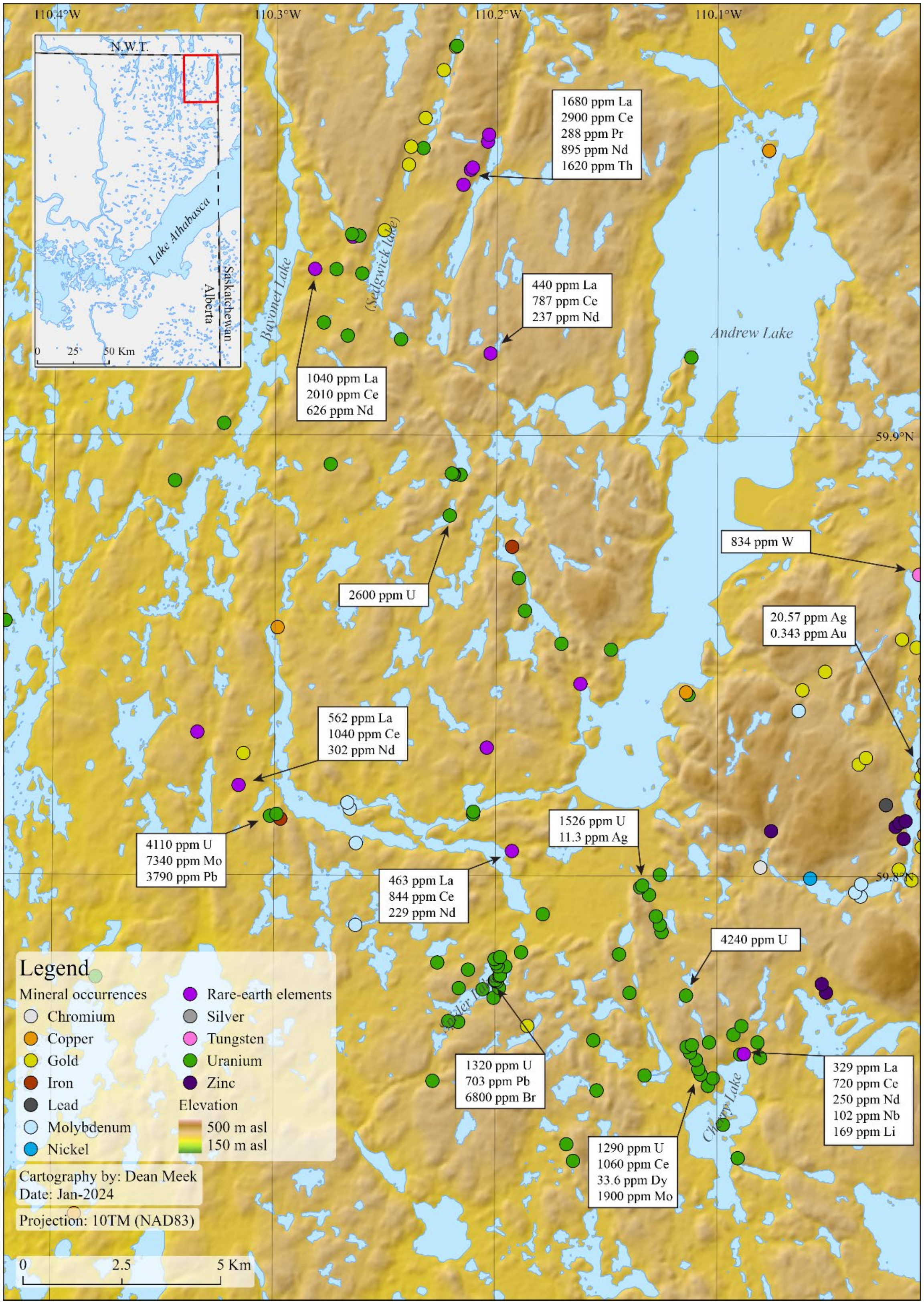

Figure 3. Andrew Lake study area with historical metallic mineral geochemical anomalies and showings (Lopez et al., 2020). Background digital elevation model from NASA JPL (2013). Place name in parentheses is unofficial.

3 Field Activities

3.1 Indigenous Engagement

The AGS respectfully acknowledges that the 2023 field activities took place in Treaty 8 territory on the traditional territory of Smith's Landing First Nation, the Tthebatthı Dënésųłıné, and the Lower Athabasca territory of the Otipemisiwak Métis, formerly known as the Métis Nation of Alberta Region 1.

Throughout the planning and execution of this field program, the AGS worked to create and maintain open engagement channels through email and phone communications with Smith's Landing First Nation. At Leland Lakes, the field crew met with the Chief of Smith's Landing First Nation and two community members. Together, they shared their knowledge of the region, listened to concerns, reviewed plans and maps, discussed geological information, and demonstrated various pieces of equipment. The AGS respected the boundary of the Tsu K'adhe Túe Reserve No. 196F reserve, which is located on the south end of Leland Lakes, and did not collect any samples there.

As the next stage of the program begins, the AGS is committed to sharing the findings, and building and enhancing the relationships with Indigenous communities in the Leland Lakes and Andrew Lake areas.

3.2 Access to AGS Field Camps

Access to the remote northeastern corner of Alberta was facilitated via float planes, based out of Fort McMurray. A Cessna 206 was used for moving staff in and out of the field and delivering supplies. A Cessna Caravan was used for larger staff moves, mobilizing and demobilizing camp, and providing groceries. Periodic flight support was provided by a Cessna 180.

3.3 Leland Lakes Field Camp

The AGS crews were in the Leland Lakes area for 13 days from June 21 to July 3, 2023 (Figure 4). The field camp was then moved to Andrew Lake on July 3. A camp on the east side of Leland Lakes consisted of a prospector's tent and five personal tents. Access to traverse lines was primarily via boat, with additional traverse lines at Myers Lake supported by chartered flights on a Cessna 180.

Field data were collected with GPS-enabled tablets. Location (from the internal GPS), lithological, mineralogical, alteration, metamorphism, structural, and sample details were recorded in OPENGIS.ch's QField program. Samples were mainly collected using rock hammers, although some stations required the use of a channel saw to extract enough material from glacially polished surfaces for geochemical analysis. A total of 199 samples were collected from 166 stations in the Leland Lakes area.

In addition to geological information, measurements of magnetic susceptibility, radioactive isotopes, and hyperspectral absorption were taken at selected Leland Lakes localities. Magnetic susceptibility was measured at 42 localities with a magnetic susceptibility meter (ZH Instruments' SM 30). Measurements of background radiation, reported in counts per second, were taken with a handheld gamma-ray spectrometer (Radiation Solutions Inc.'s RS-230 BGO Super-SPEC) throughout the study area, and radionuclide identification assays were performed at six localities. Hyperspectral absorption measurements were captured at 192 localities with a near-infrared spectrometer (Malvern Panalytical Ltd.'s ASD TerraSpec® Halo mineral identifier), covering the full absorption spectrum from 350 to 2500 nm.

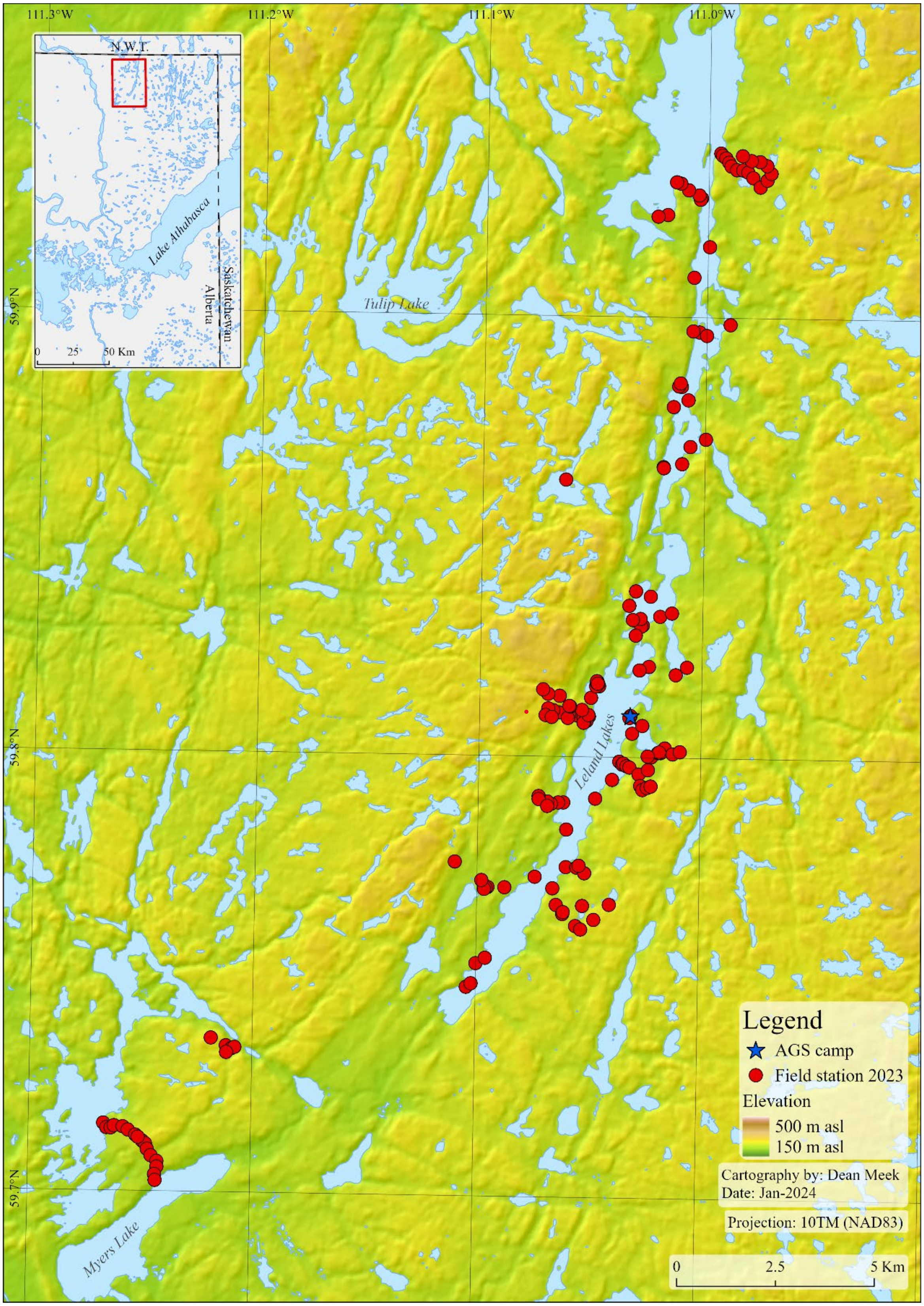

Figure 4. Leland Lakes study area with all of the 2023 field stations indicated. Background digital elevation model from NASA JPL (2013).

3.4 Andrew Lake Field Camp

The AGS crews were in the Andrew Lake area from July 3 until the camp was demobilized on July 23. The field camp, located on a sandy shore of Andrew Lake, included a prospector's tent and five personal tents (Figure 5). Access to traverse lines was primarily via boat, with additional traverse lines at Bayonet Lake, Cherry Lake, Potts Lake (location not included in extent of Figure 5), Sedgwick lake[1], and Spider Lake supported by chartered flights on a Cessna 180.

A total of 228 stations were studied in the Andrew Lake area and the field methods followed those used at the Leland Lakes area. At these stations, 328 samples were collected.

Magnetic susceptibility measurements were captured at 56 localities, and background gamma-ray and radionuclide assay measurements were captured at 85 localities. Hyperspectral absorption measurements were captured at 436 localities.

4 Postfield Analyses

4.1 Current Status

Analyses of samples and data collected from the 2023 field season is underway at the AGS Mineral Core Research Facility (MCRF) in Edmonton. More than 500 samples were submitted to Activation Laboratories Ltd. (Actlabs) in Ancaster, Ontario, for whole-rock geochemical analysis. Three different analytical packages were selected: (1) the 4Lithoresearch whole-rock analysis and trace element package, using lithium borate fusion and inductively coupled plasma–mass spectrometry (ICP-MS) and –optical emission spectroscopy (ICP-OES) to analyze for major oxides and trace elements, (2) the 4B1 package for the analysis of base metals, using a four-acid digestion with ICP-OES, and (3) the Ultratrace 7 package for the analysis of lithium, using a sodium peroxide fusion with ICP-MS. Together these packages will provide concentrations for a total of 60 reported major oxides and trace elements from the samples collected in the Leland Lakes and Andrew Lake areas.

A subset of samples (>150) submitted for whole-rock geochemical analysis were also selected for thin section petrography. Thin section billets were sent to Spectrum Geosciences Ltd. (Calgary, Alberta) and AGAT Laboratories Ltd. (Calgary, Alberta) to create standard sized (e.g., 25 by 45 mm), polished, 30 µm thick, thin sections. Petrographic descriptions are used to refine lithologies and the associated map units. A small subset of the thin sections was prepared as oriented thin sections for structural analysis.

4.2 Deliverables

4.2.1 Field Data Digital Dataset

A series of geology-related datasets generated from this fieldwork are in the publication process. These are anticipated to include field observations as a series of shapefiles (e.g., locations, geological observations, structural measurements), tabular whole-rock lithogeochemical results, and petrographic descriptions.

4.2.2 Mineralization Potential Open File Report

A report is in preparation that summarizes the mineral potential in the Leland Lakes and Andrew Lake areas. This report will include detailed petrographic descriptions of all geological units, revised 1:20 000 scale geological maps, and an evaluation and analysis of the new whole-rock geochemical data, including discrimination plots. An important component of this publication is a series of suggestions for follow-up work.

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[1] Unofficial place name.

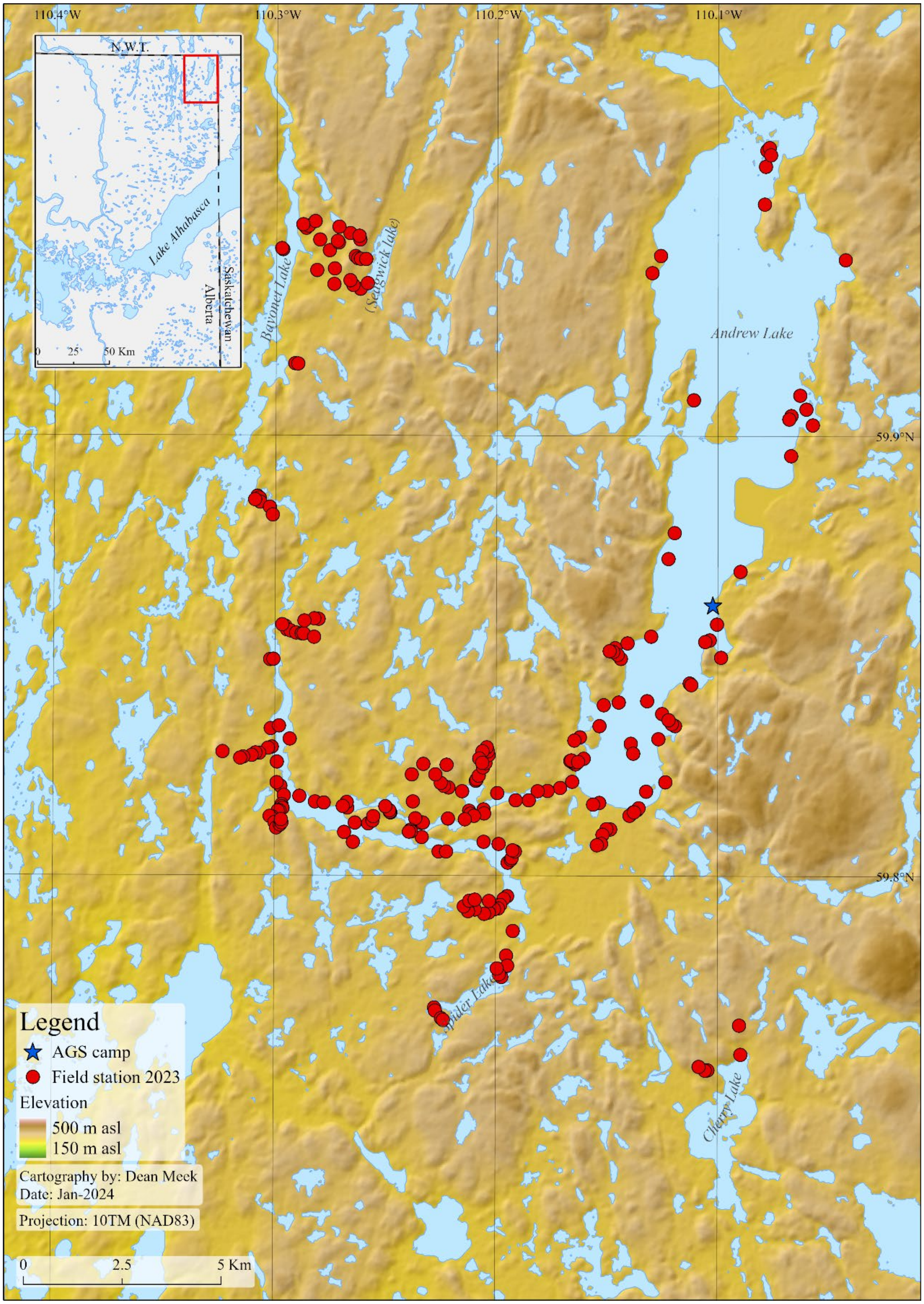

Figure 5. Andrew Lake study area with all of the 2023 field stations indicated. Background digital elevation model from NASA JPL (2013). Place name in parentheses is unofficial.

4.2.3 Halo Spectral Library Digital Dataset

A digital dataset of hyperspectral absorption features measured from outcrop is being prepared. The dataset includes the hyperspectral signature from 350 to 2500 nm measured at hundreds of locations. The spectral results will be classified based on the associated field lithologies.

4.2.4 Andrew Lake Remote Sensing Special Report

A second special report outlining spectral features in the Andrew Lake area is in preparation by B. Rivard, and will be similar to AER/AGS Special Report 116 published for the Leland Lakes area (Rivard, 2023). This report will detail the generation of indices for the potential detection of anomalies using multispectral data from WorldView-3 satellite imagery. These indices may also aid in refining map unit boundaries and the identification of lithologies not currently mapped (e.g., pegmatites).

5 Summary

This report provides an interim summary of field activities conducted in the summer of 2023 as part of a multidimensional study by the Alberta Geological Survey to investigate mineral systems of the Canadian Shield in northeastern Alberta. In support of the Government of Alberta initiative to increase publicly available geoscience information related to critical mineral potential, Alberta Geological Survey crews visited nearly 400 stations and collected more than 500 samples for geochemical and petrographic analyses. New magnetic susceptibility, gamma-ray, and hyperspectral absorption measurements were collected to complement recently released regional aeromagnetic and multispectral remote sensing datasets. Anticipated publications resulting from the 2023 field program include digital datasets, reports, and updated geological maps for the study areas.

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