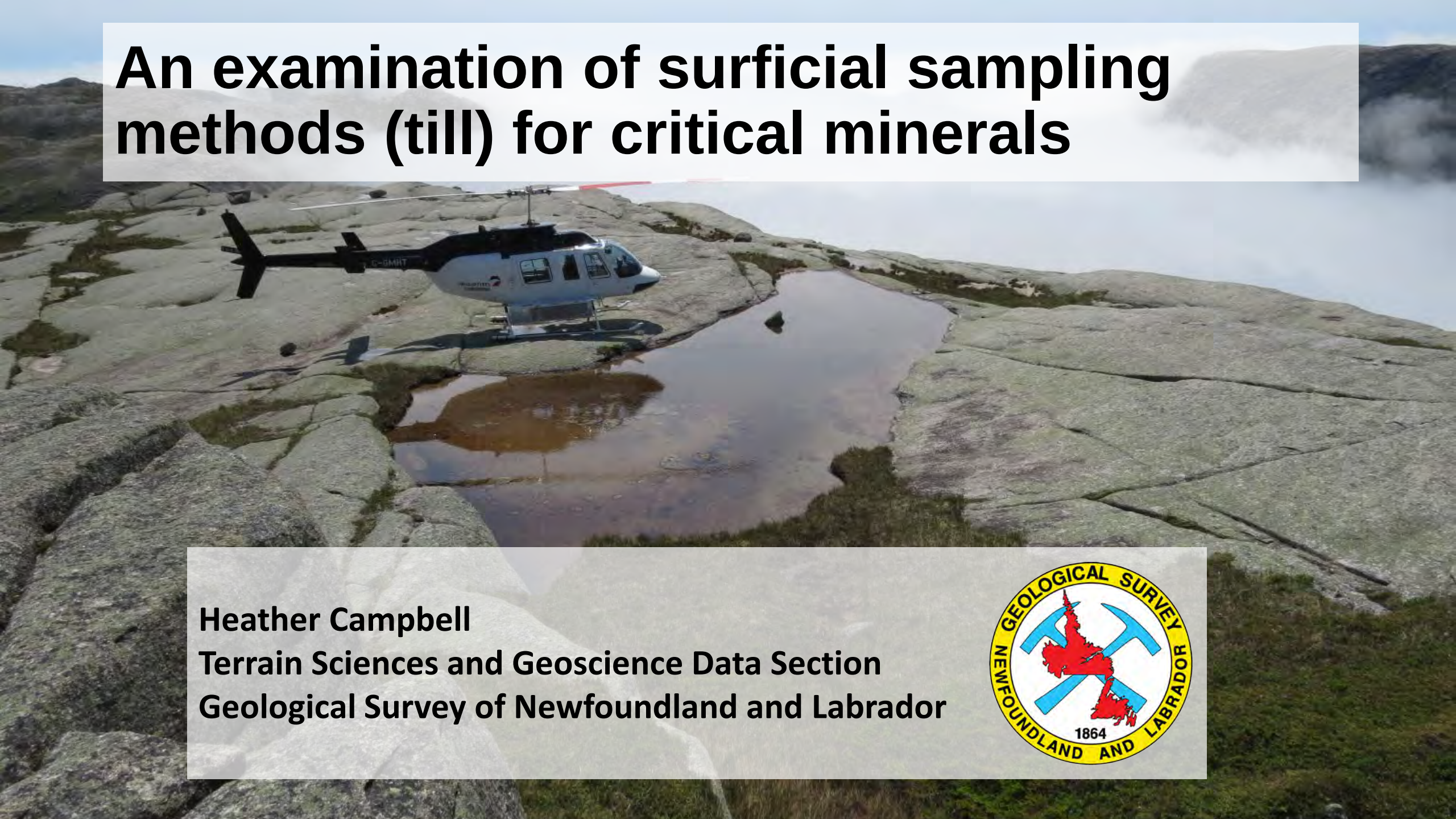
An examination of surficial sampling methods (till) for critical minerals



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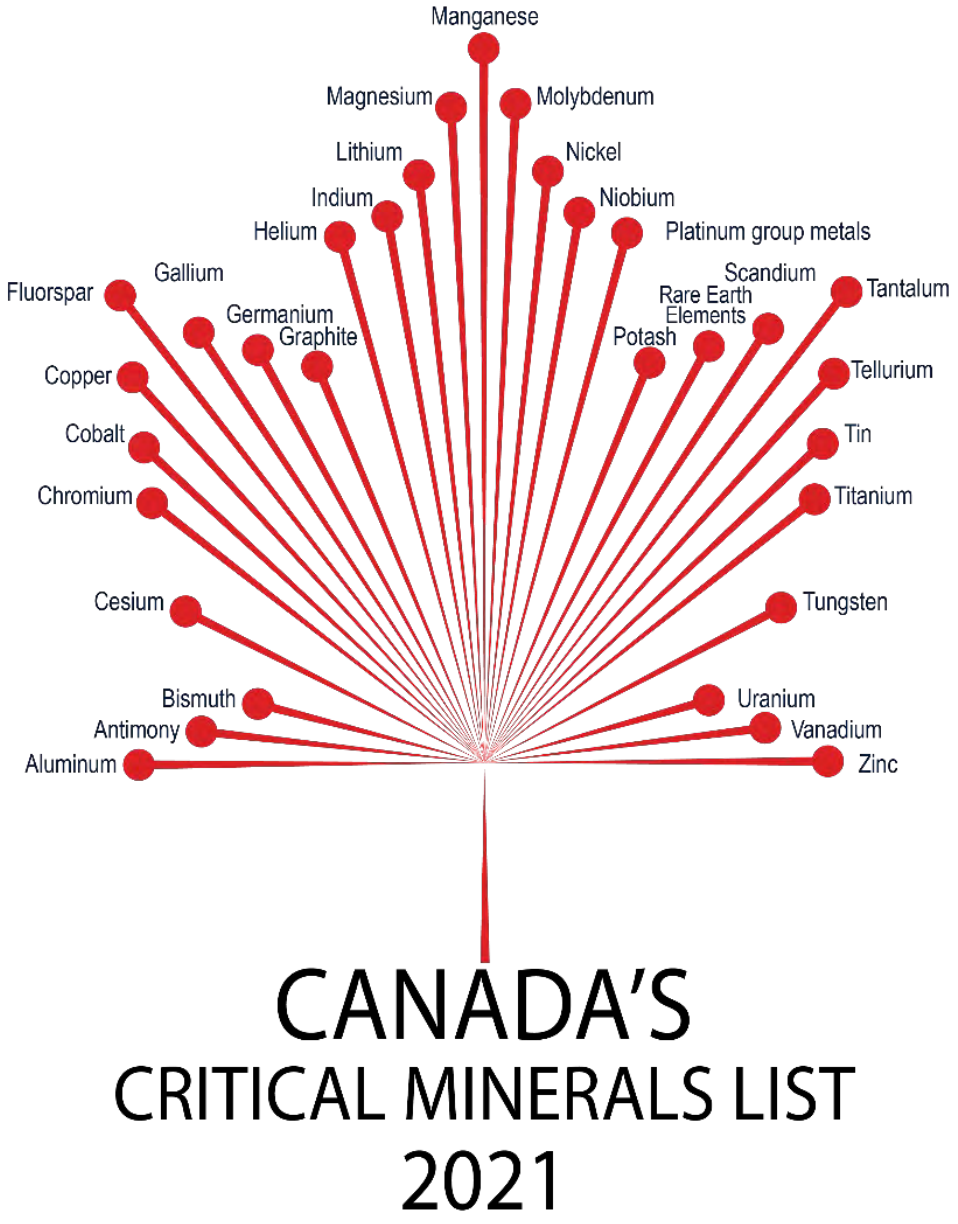


- **Represents a large variety of elements and minerals**
- **Some of these (copper, uranium, nickel) are already part of "traditional" exploration suites**
- **Others (e.g. cobalt, gallium, germanium, indium) are often associated with "traditional" base metals (e.g. (Co-Ni; (Ga, Ge, In)-Zn)**

Glacial erosion=natures processing, crushing and dispersal machine

The glacier as a crusher:

-Understanding how the mineral constituents erode mechanically and chemically in the field and in the lab (strength-MOH's hardness of minerals)
-Understanding how the minerals are retained in the field and lab (density)

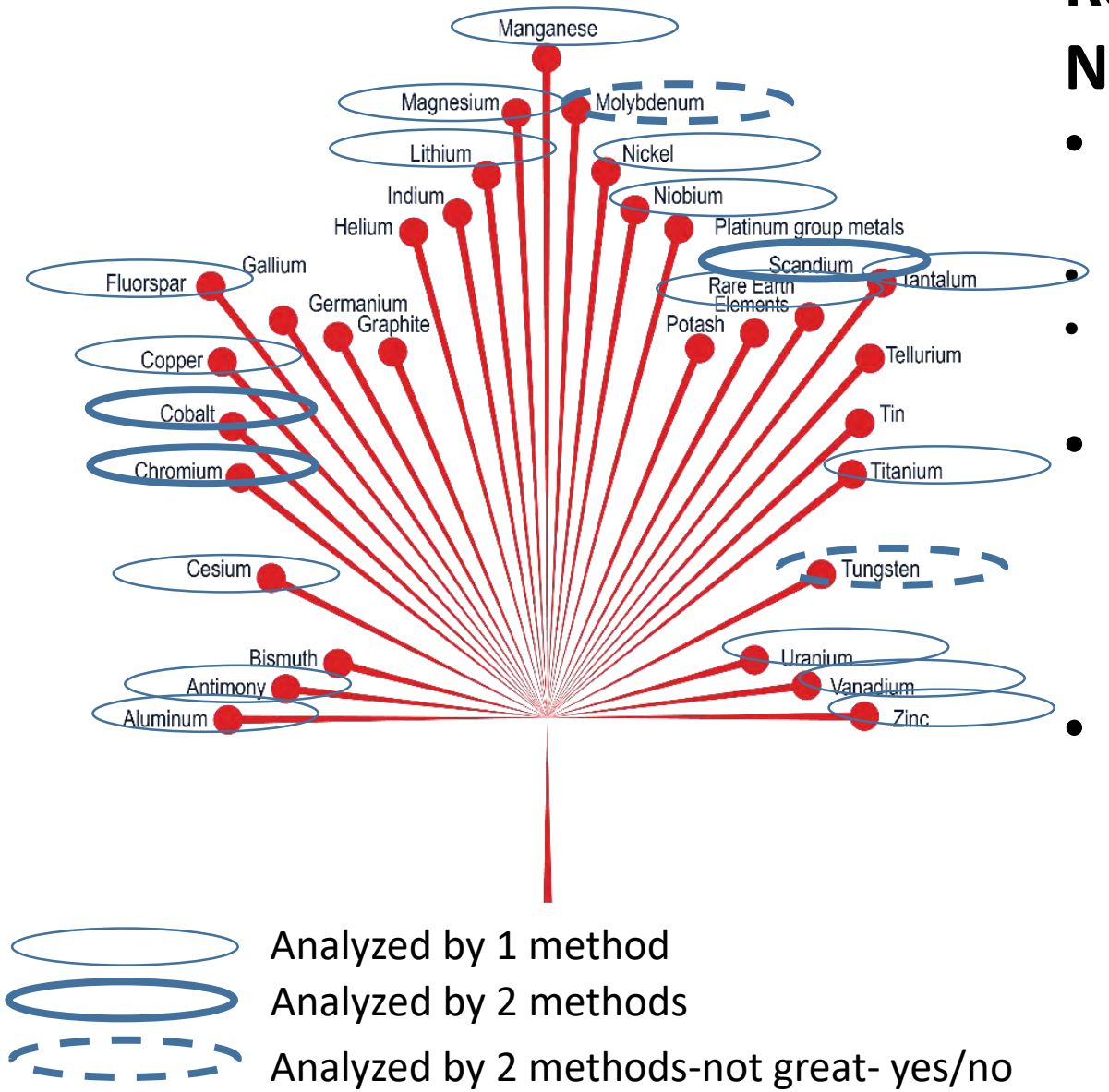
- **Will the glacier be able to erode the minerals easily?**
- **If the minerals are too easily eroded, will they be diluted by the abundance of other material?**
- **If there is water or post-glacial processes, are these minerals retained?**
- **Many minerals that are associated with critical elements are hard (> MOHS 5-e.g. coltan, spodumene) and do not break down easily**

Glacial erosion

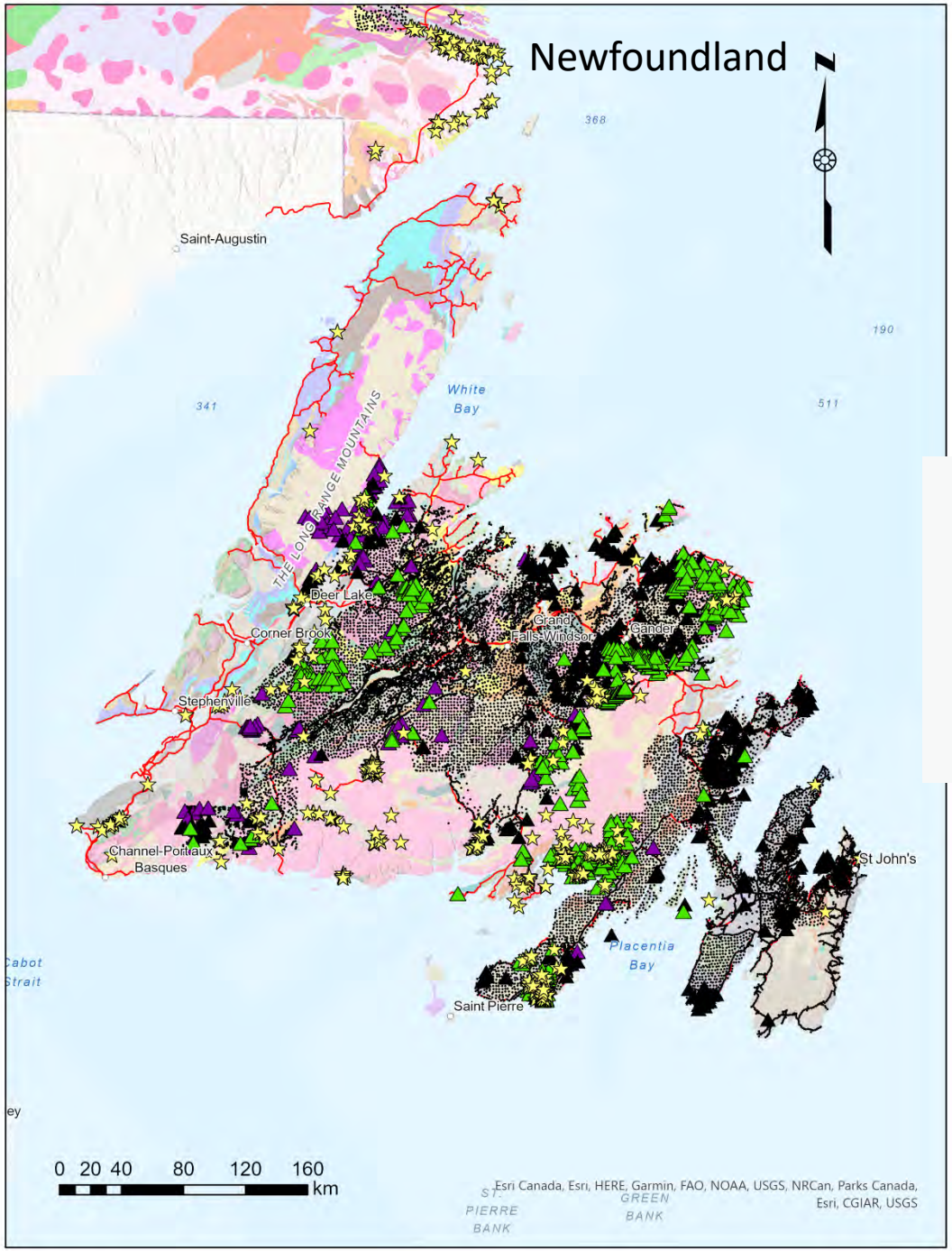
Subglacial entrainment, transport, thrusting and sliding

Subglacial abrading/milling into smaller particles

Regional Till analysis- Geological Survey of Newfoundland and Labrador



- **GSNL data-Coverage, catchment and characterization**
  - 4-Acid Digestion, ICP-OES Finish (“near complete”)
  - Instrumental Neutron Activation Analysis (INAA)-no digestion, (‘near complete”) Fluoride-Ion Selective Electrode (ISE)
- **Most of the elements shown are analyzed in the regional GSNL till geochemical datasets-some of them by two different methods!**
- **However, some important elements and elemental groups (e.g. PGE’s, molybdenum, tungsten, germanium, gallium) are not analyzed or not sufficiently illuminated in traditional surficial sampling methods**

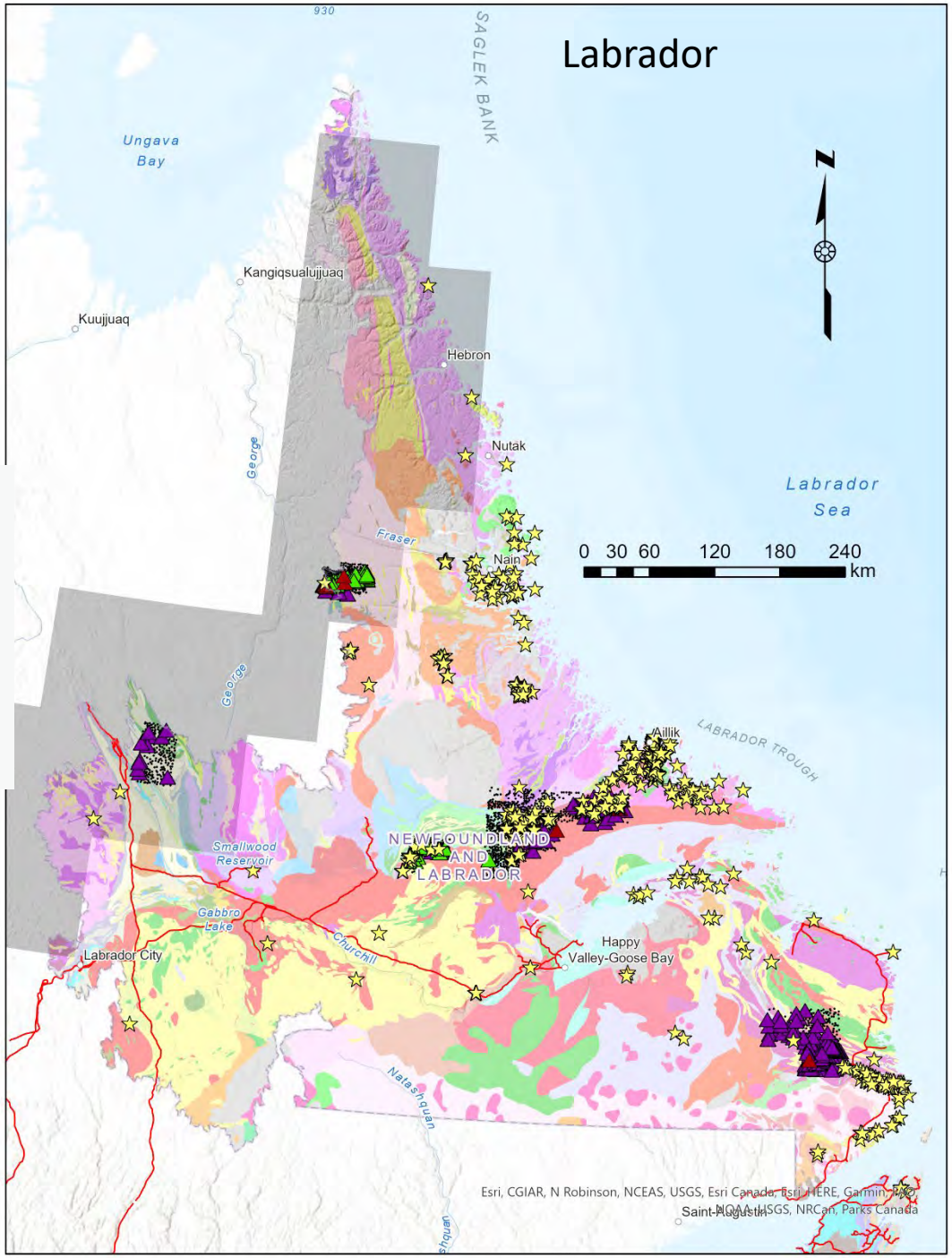


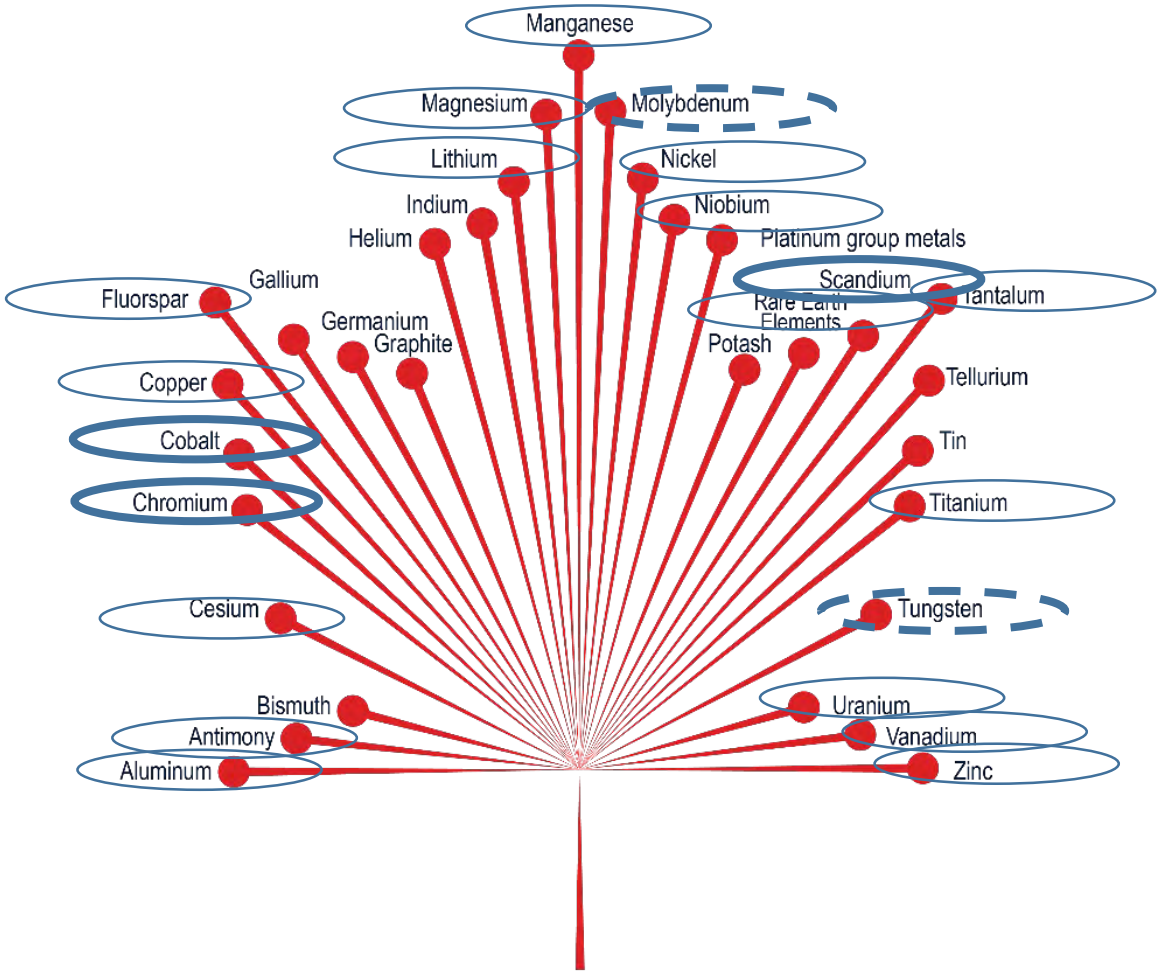
Be in tills > 4.3

Li in tills > 55 ppm

F in tills > 550 ppm

98th percentile





Analytical methods for other elements:

- (e.g. PGE's-Hashmi et al, 2021; 2022-NiS Fire Assay/modified Aqua Regia-ICP-AES/MS)
- Potash and Li brines- groundwater studies are important-(e.g. https://ags.aer.ca/publication/ofr-2009-20)
- Indium, germanium, molybdenum, tellurium, mercury, selenium ultratrace, detectable in soils using Aqua regia digestion, ICP-MS finish
- W, Sn -LiBo fusion- total digestion, ICP-MS finish

Alternative methods for field exploration:

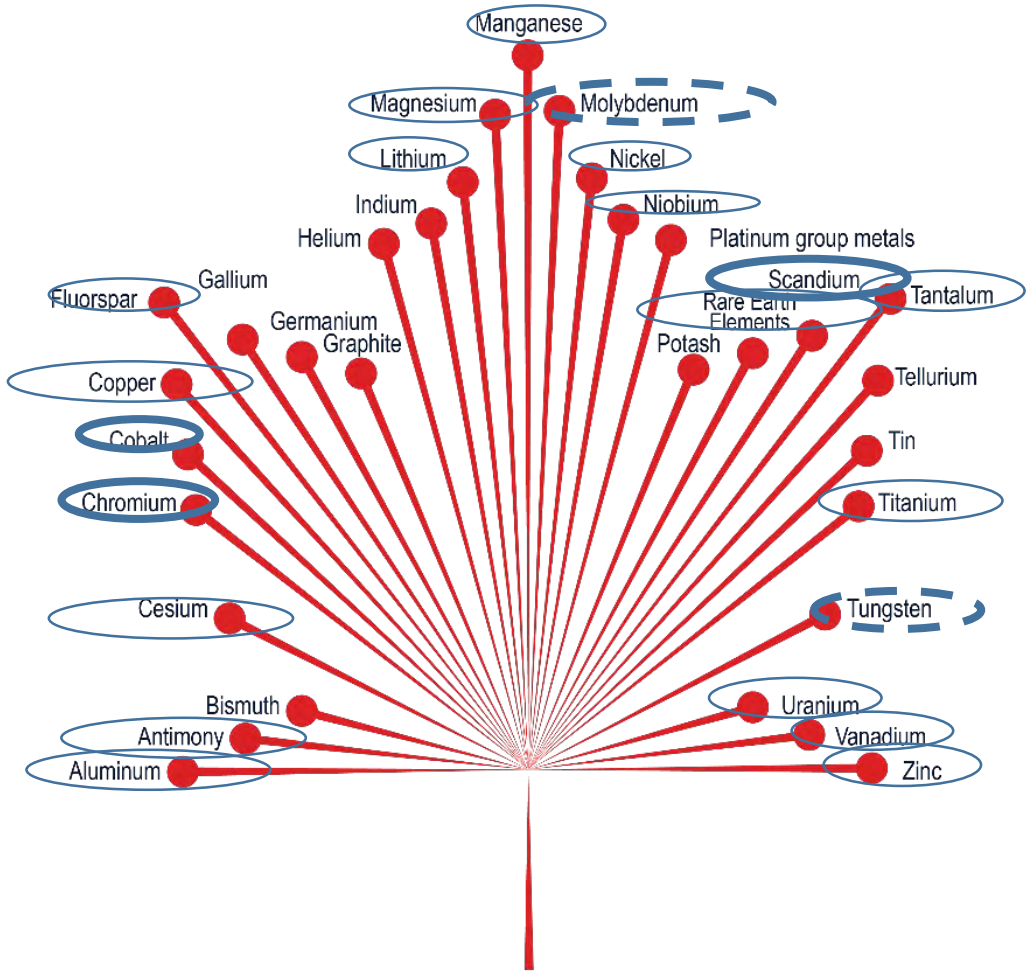
Hand-held LIB analyzer (Sci Aps)-(laser induced breakdown analyzer)

Al, B, Ba, Be, Ca, Cs, Fe, H, K, La, Li, Mg, Mn, Na, O, P, Rb, Si, Sr, and V

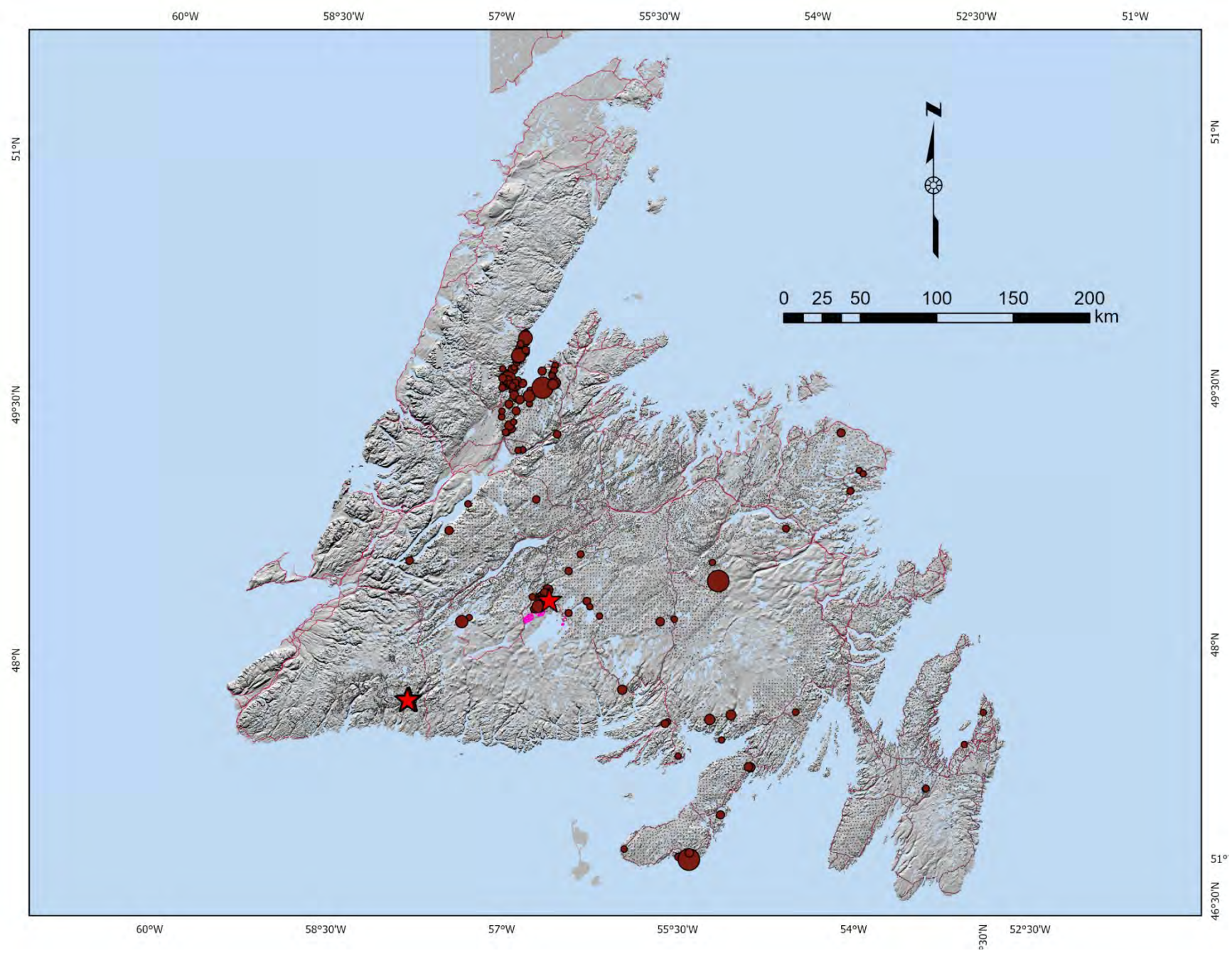
Hand-held XRF-

Low-atomic number elements Mg, Al, Si, P, S, K, Ca
Transition/pathfinder elements Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Rb, Zr, Nb, Mo, Te, Ag, Cd, Sn, Sb, Ba
Heavy metals Ta, W, Au, Hg, Tl, Pb, Bi, U

Michael A. Wise, Russell S. Harmon, Adam Curry, Morgan Jennings, Zach Grimac and Daria Khashchevskaya. “Handheld LIBS for Li Exploration: An Example from the Carolina Tin-Spodumene Belt, USA,” Minerals 2022, 12, 77.



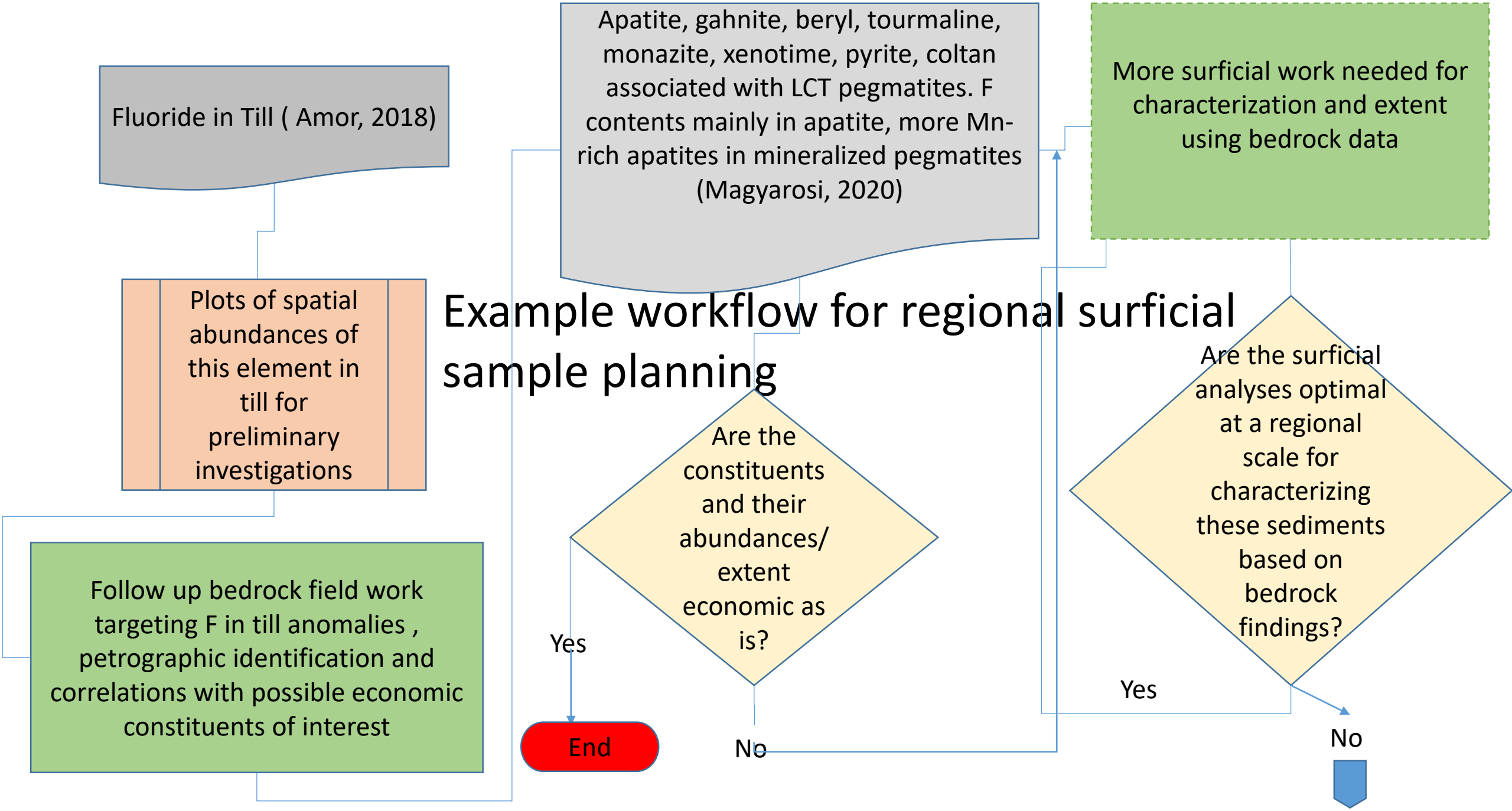
- **Till geochemistry is good is part of the picture**
- **Some of the minerals and elements occur in unusual/multiple associations Approach surficial sampling like a metallurgist in a mill-how are the minerals and elements eroded from their bedrock source units?**
- **Harder minerals- use mineral identification to trace minerals in till?**
- **Softer minerals- till geochemistry**



Example of surface (till) exploration workflow

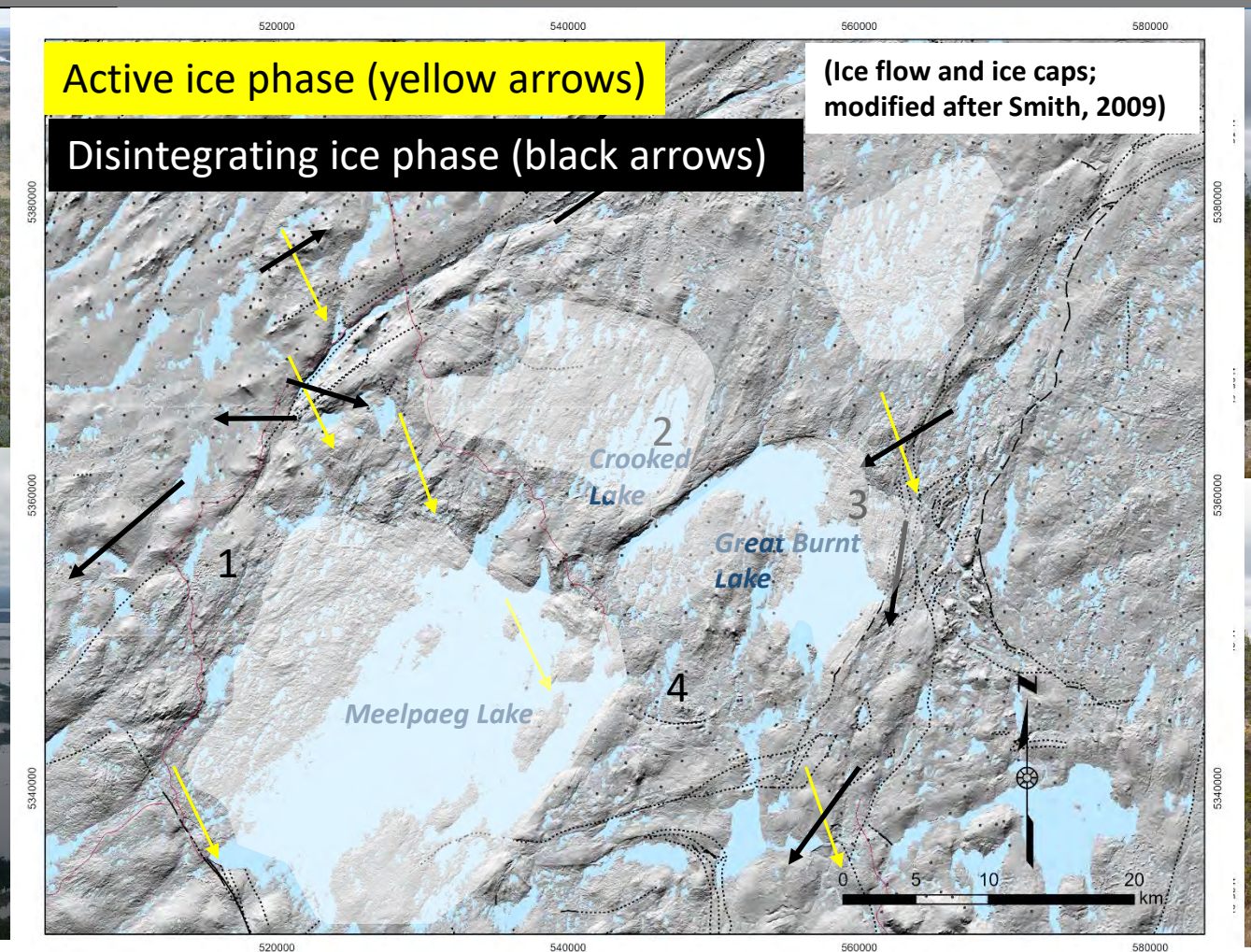
- F in tills leading to identification of pegmatites in central NL showing- Snowshoe Pond Lithium
- Fluoroapatites associated with pegmatites (Magyarosi, 2020)

Example workflow for regional surficial sample planning

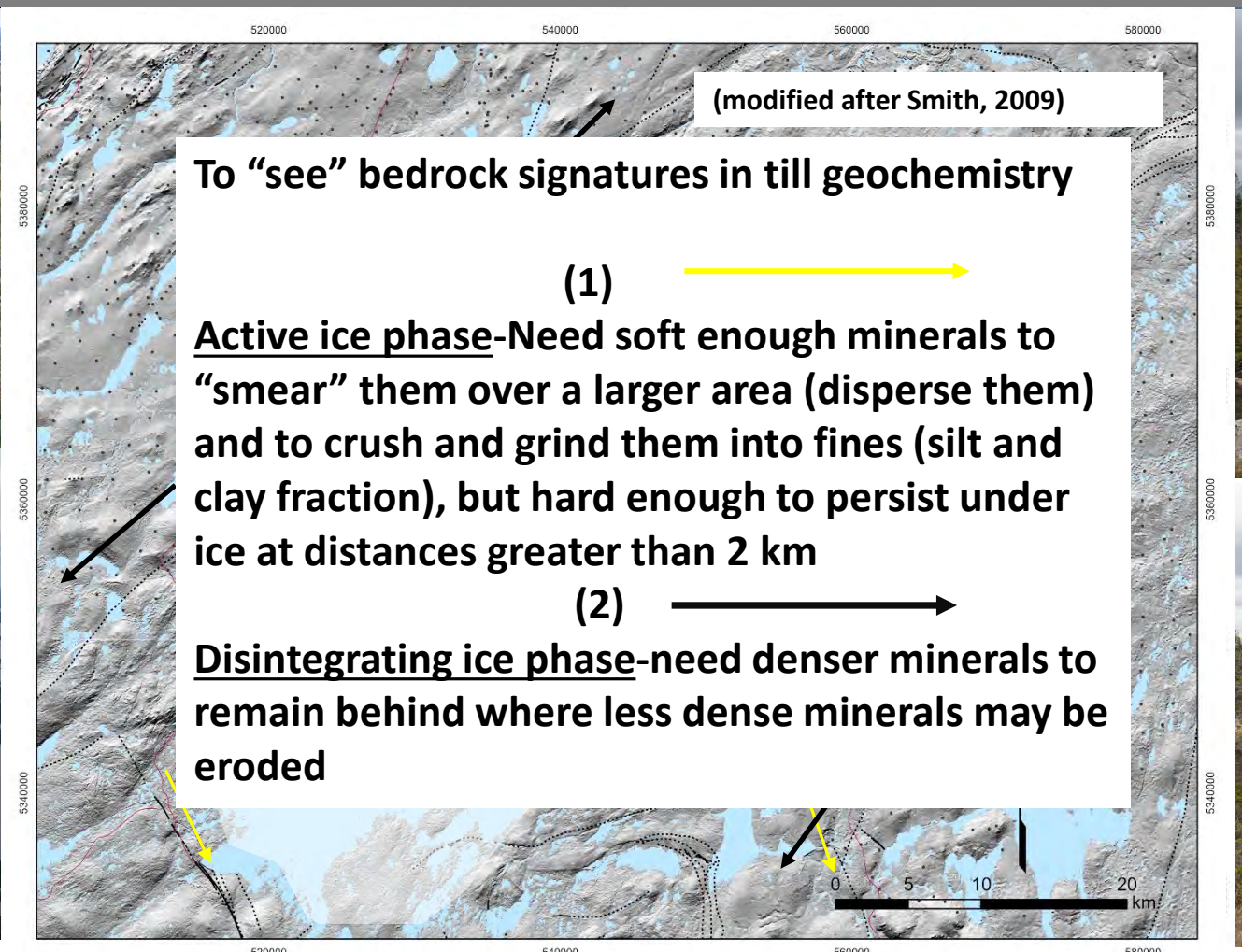


ICE FLOW CONSIDERATIONS……

Meelpaeg Lake -Burnt Lake till survey 2 x 2 (4 km²)



Meelpaeg Lake -Burnt Lake till survey
2 x 2 (4 km²)



(modified after Smith, 2009)

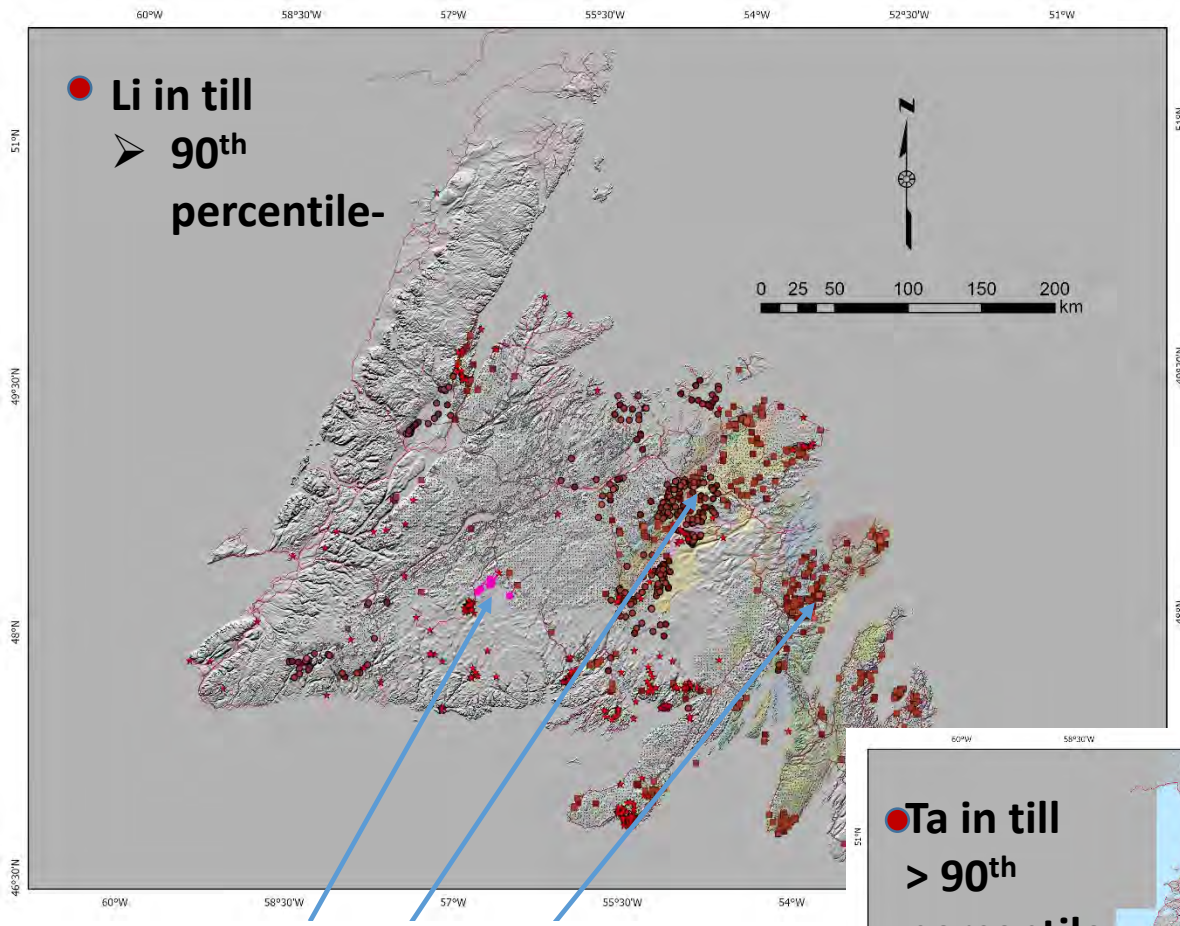
To "see" bedrock signatures in till geochemistry

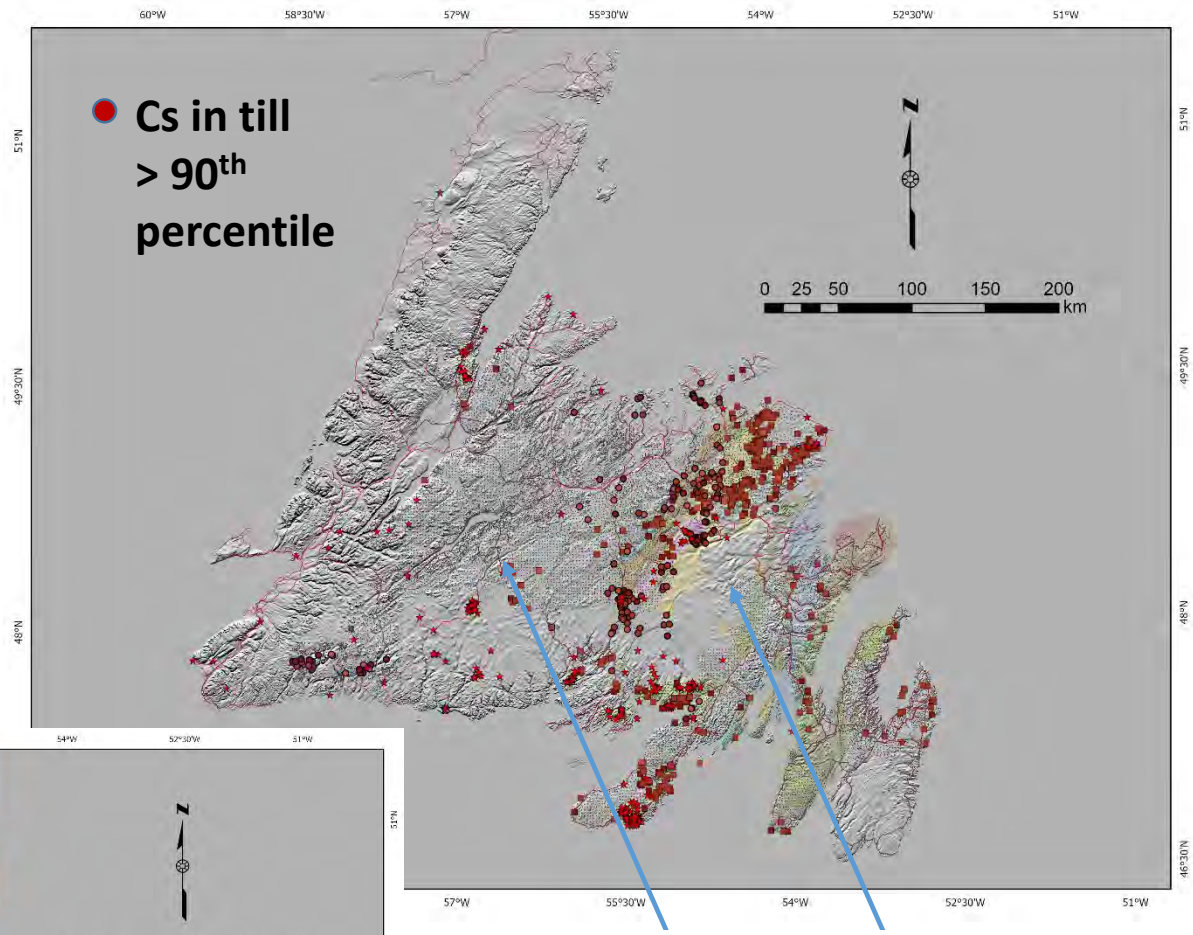
(1)

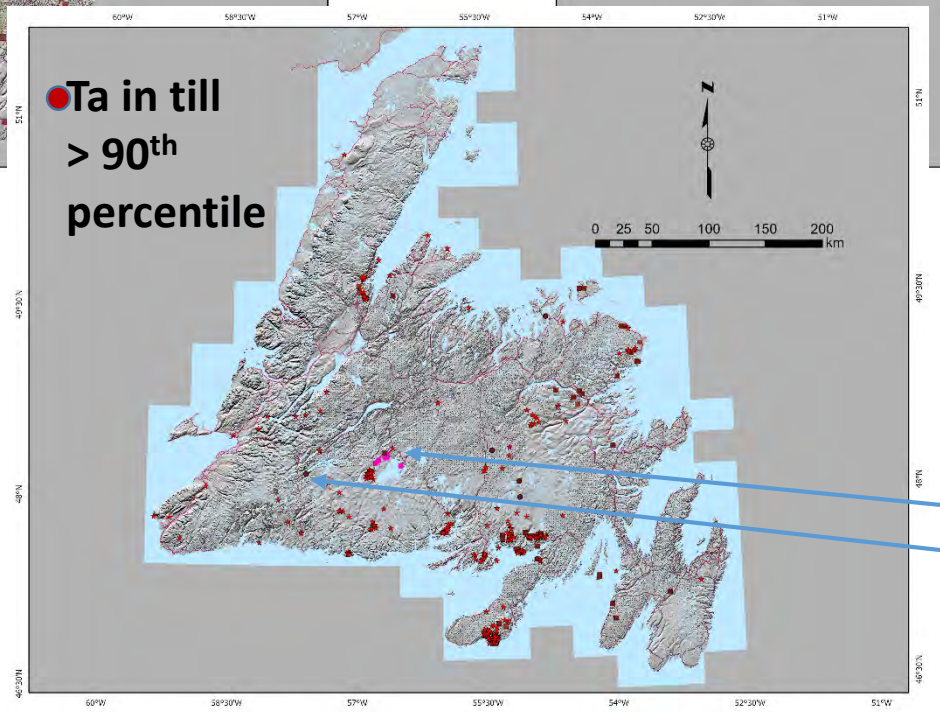
<u>Active ice phase</u>-Need soft enough minerals to "smear" them over a larger area (disperse them) and to crush and grind them into fines (silt and clay fraction), but hard enough to persist under ice at distances greater than 2 km

(2)

<u>Disintegrating ice phase</u>-need denser minerals to remain behind where less dense minerals may be eroded



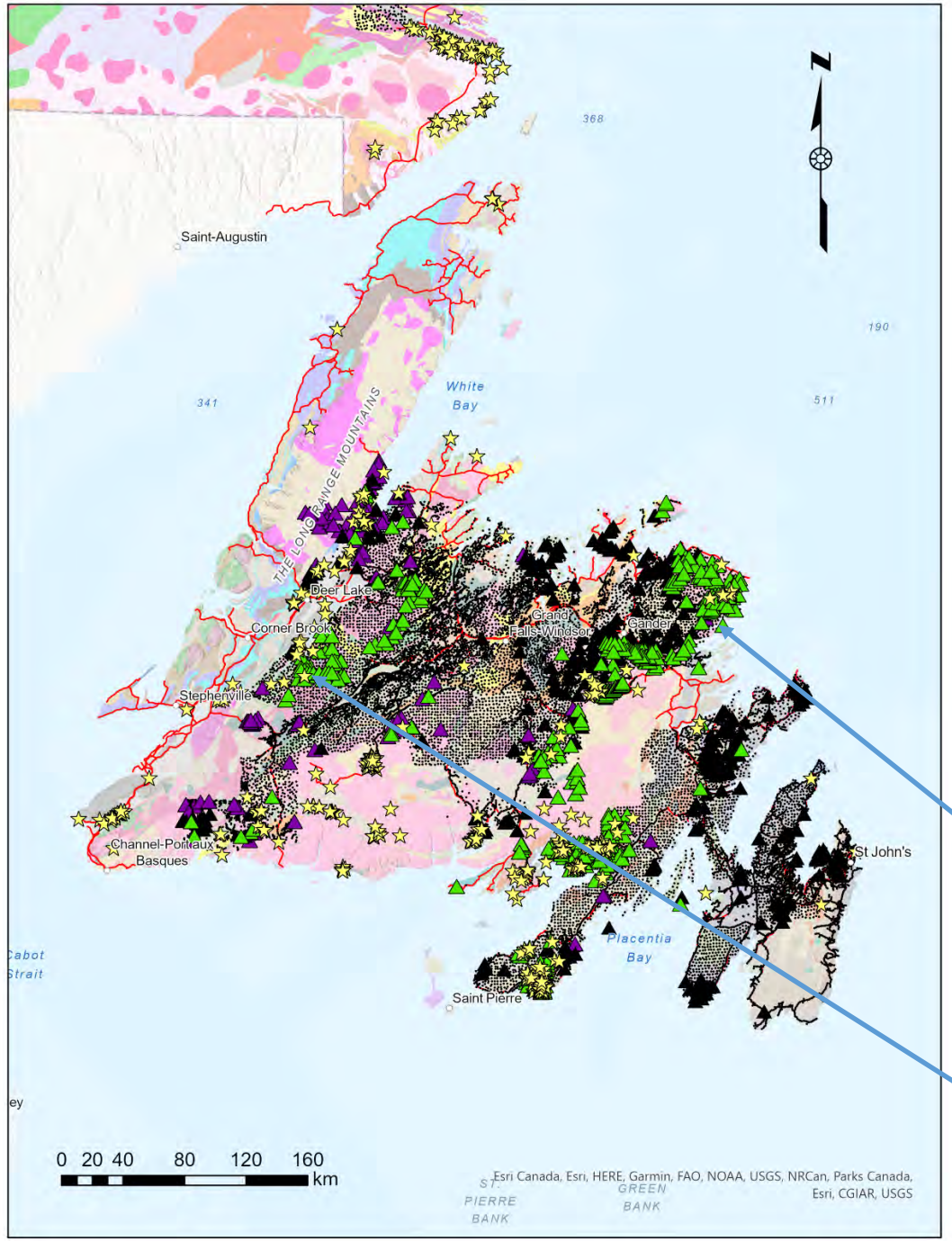


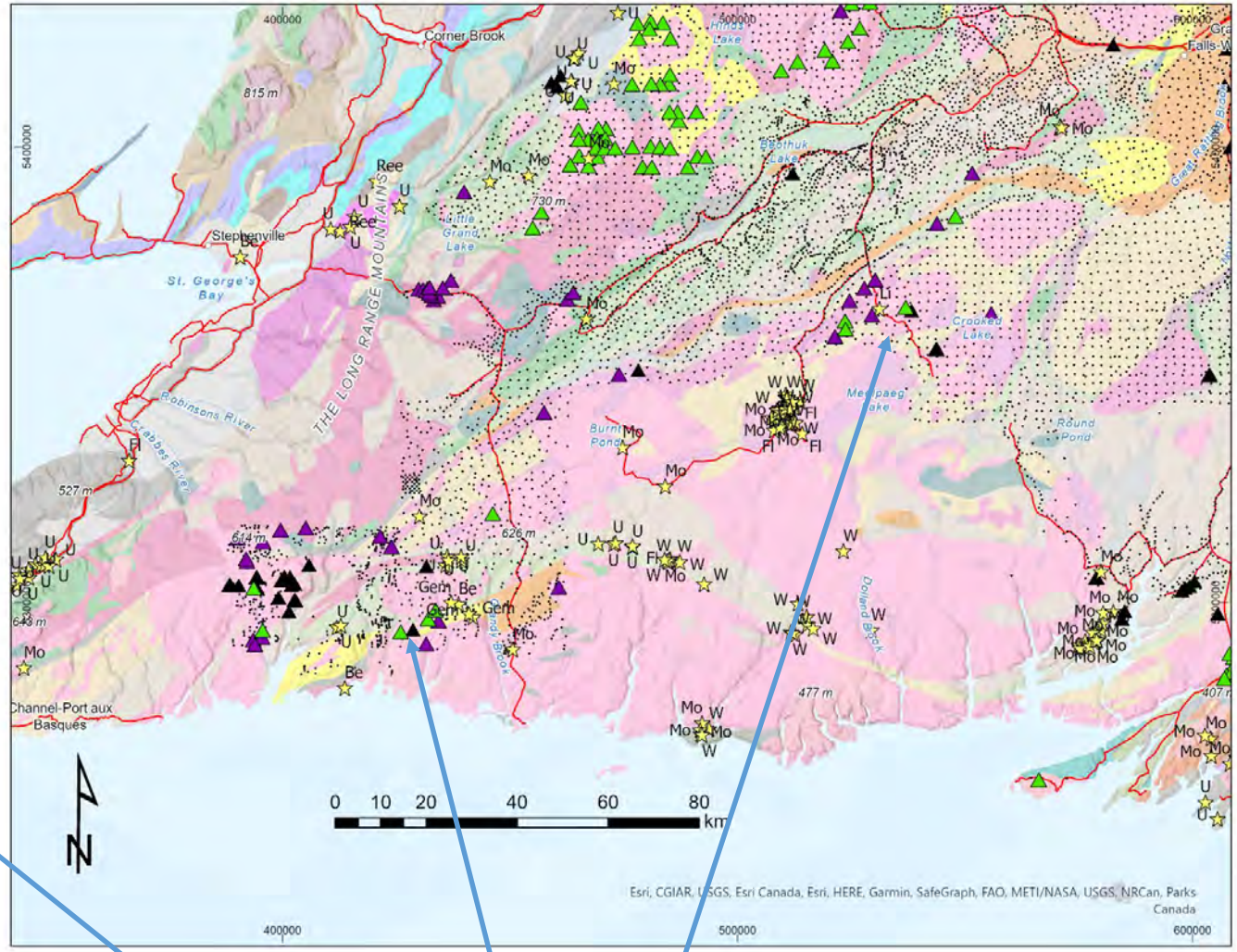


Distribution of Li (brown) in till limited but "close" to Li bearing pegmatites (pink). Li in till may also be indicative of underlying bedrock composition (see cluster east of Mount Peyton and along the isthmus-Avalon)

Distribution of Cs in till near showings and may also be indicative of underlying bedrock composition (see cluster east of Mount Peyton to north of Gander)

Distribution of Ta in till localized with one anomaly near showing and single anomalies throughout





Other elements may be helpful. F and Be are also associated with some regions of interest. Both these elements are part of the analytical suite at the GSNL

- Be in tills > 4.3
- Li in tills > 55 ppm
- F in tills > 550 ppm

GSNL future considerations for additional surficial sampling methods.....

Apatite, gahnite, beryl, tourmaline, monazite, xenotime, pyrite, coltan associated with LCT pegmatites. F contents mainly in apatite, more Mn-rich in mineralized pegmatites (Magyarosi, 2020)

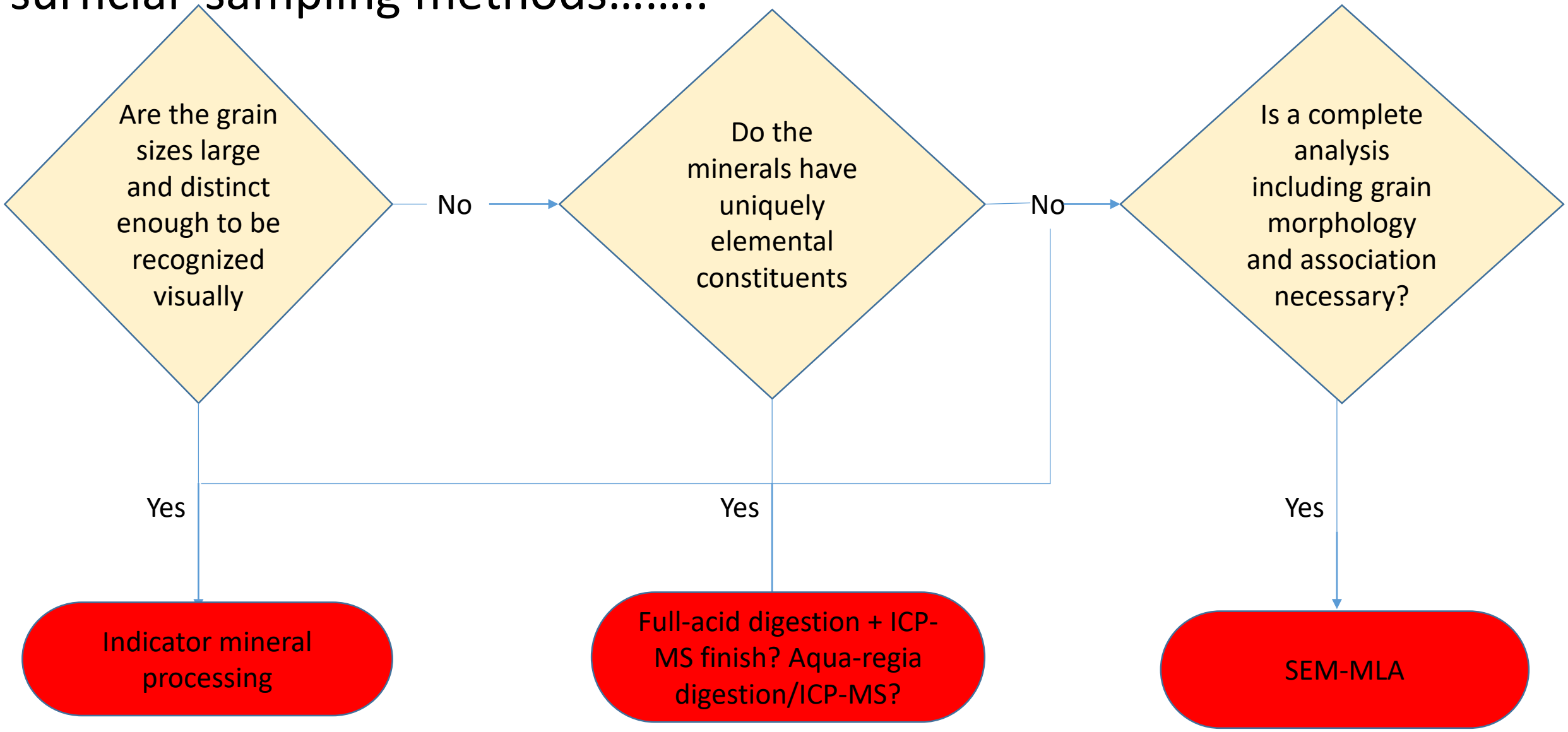
Are there other predefined analytical methods that are optimal in the same surficial environment (e.g. discontinuous ice-flow followed by ice-stagnation)

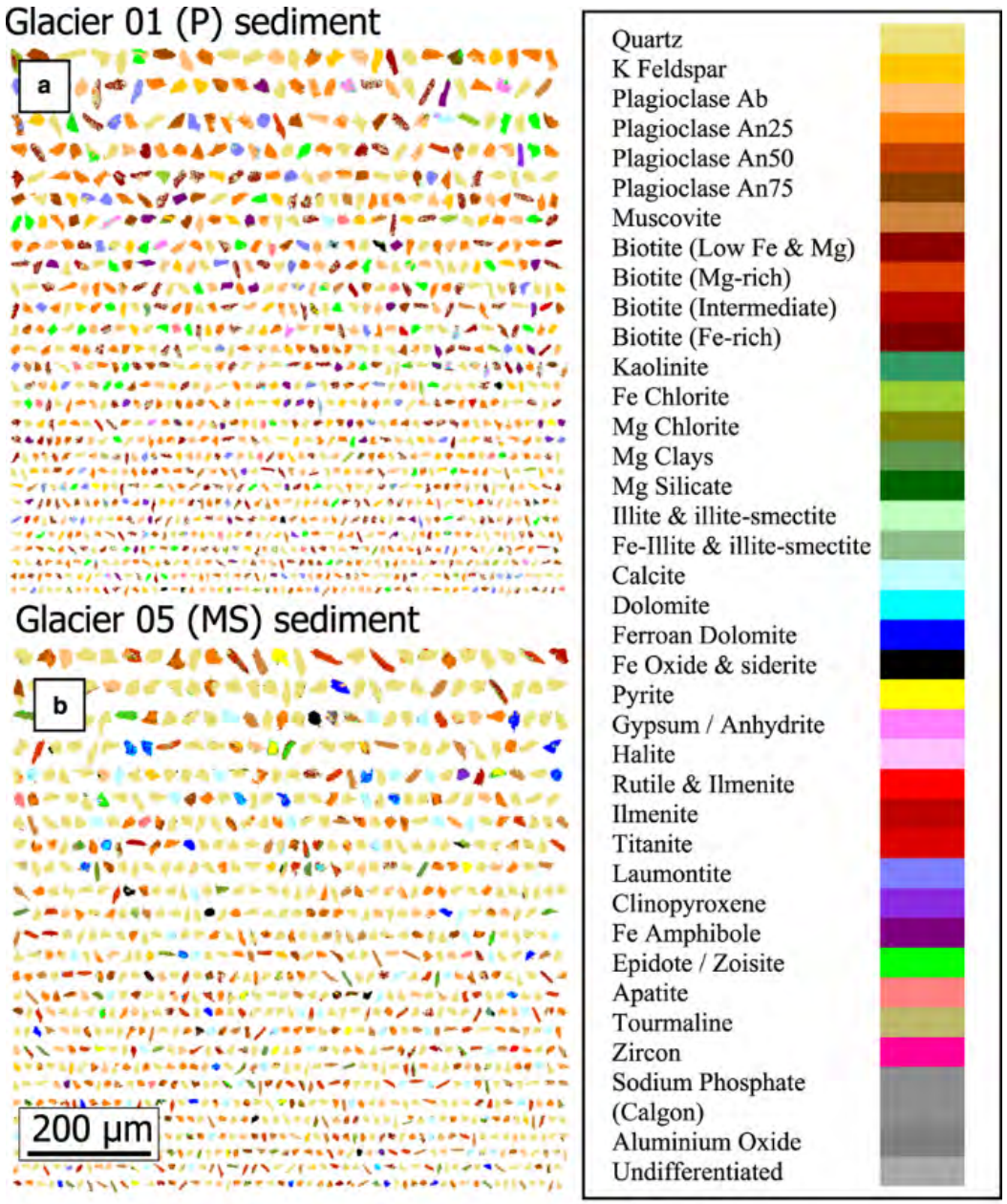
No

Investigation of the physical properties of these minerals (grain size, density, hardness, chemical durability) to determine their expected erosion and residence time in till

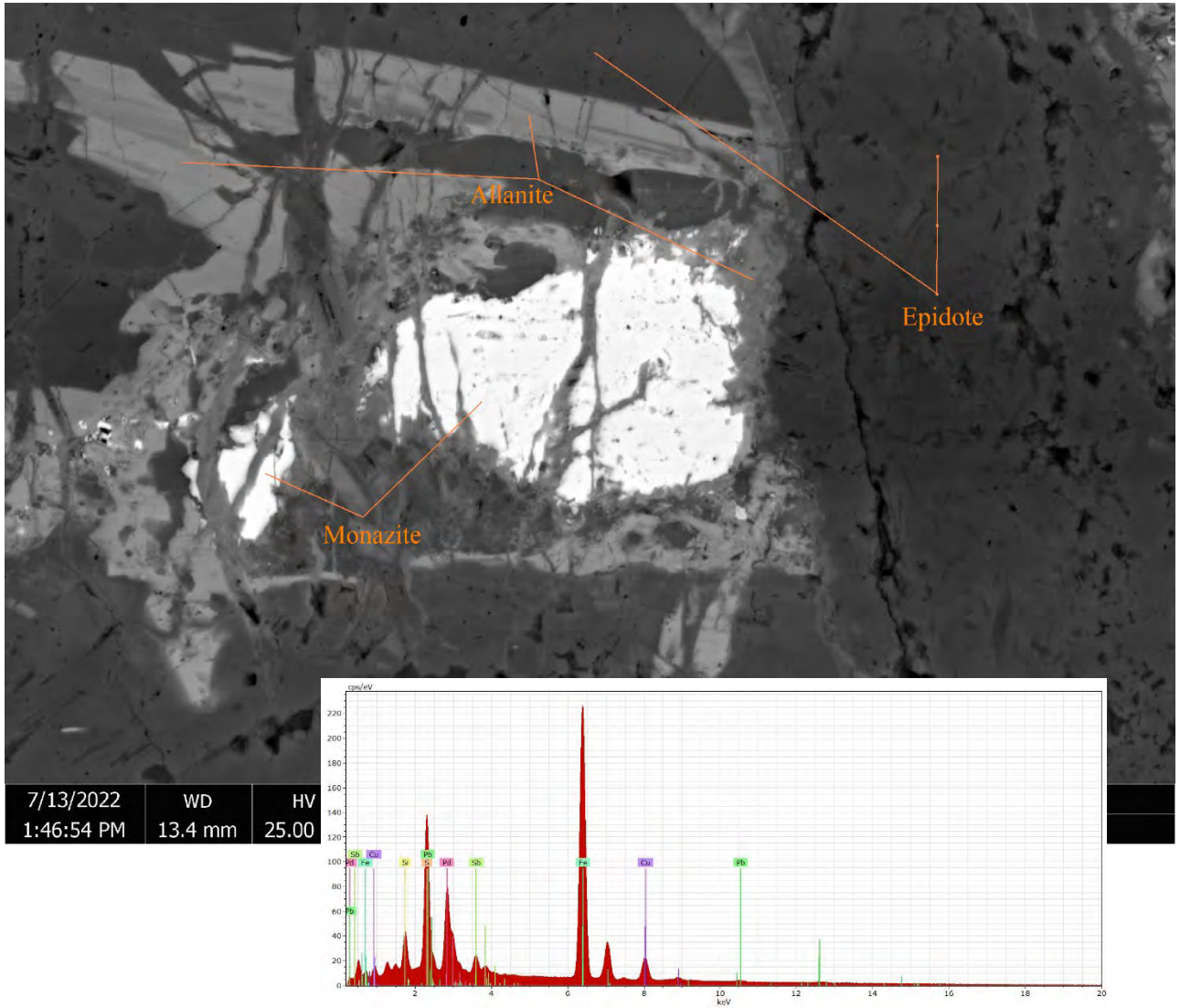
Grain size, hardness and chemical durability indicate a number of different options- including indicator mineral picking, geochemical analysis by different analytical methods, or SEM-MLA

GSNL future considerations for additional surficial sampling methods……..





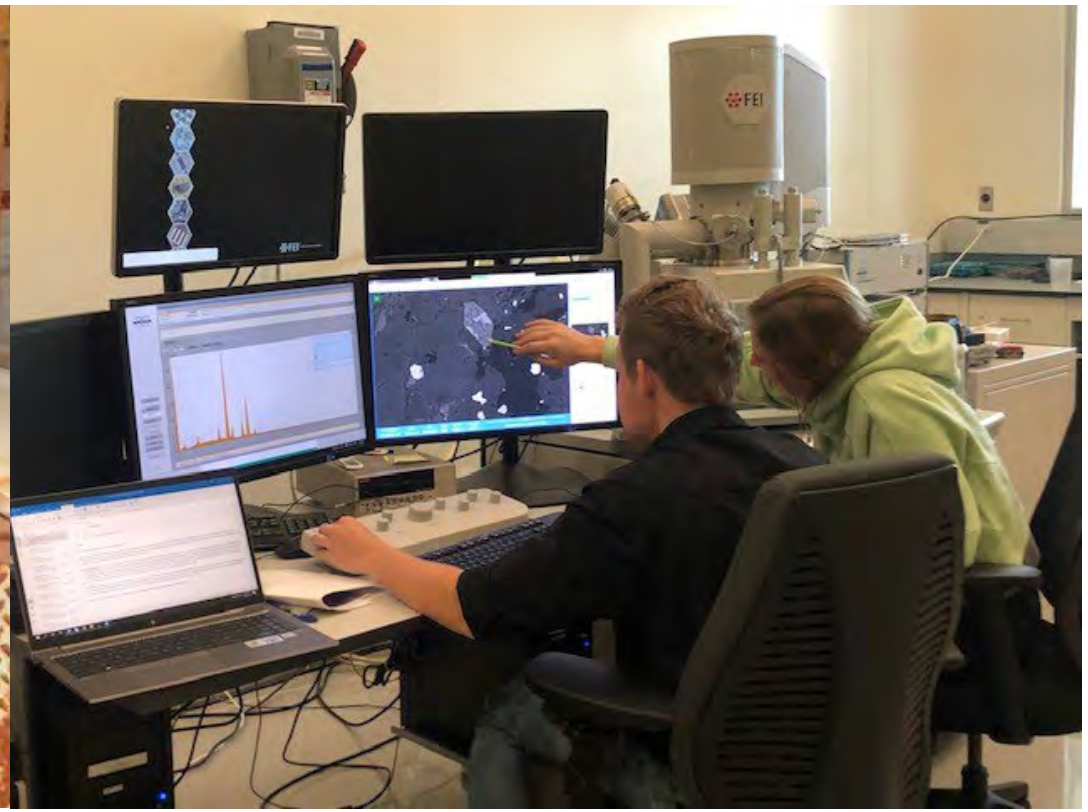
- **SEM-MLA**
- **Scanning Electron Microscopy-(SEM) Mineral Liberation Analysis (MLA)**



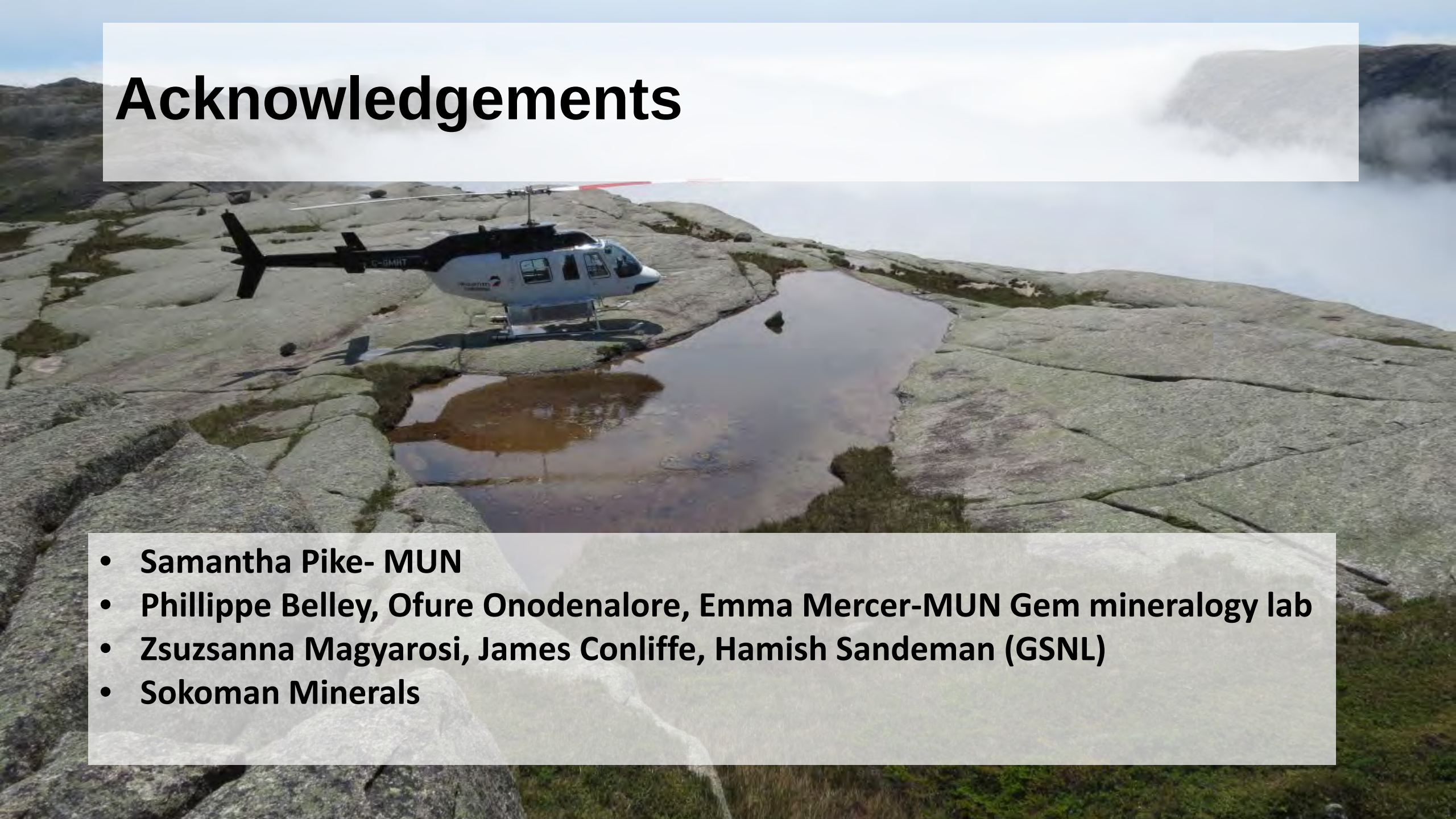
GSNL future considerations for additional surficial sampling methods……..

- **Looking at the rocks in mineralized regions**

- **Applying this knowledge to look for surficial sediments derived from bedrock**



Acknowledgements



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