

DGGS Earth MRI geologic mapping and geophysics program update

Evan Twelker, Abraham Emond, Rainer Newberry, Travis Naibert, Michelle Gavel, Wes Buchanan, David Szumigala, and Michael Barrera

Alaska Division of Geological & Geophysical Surveys

The Alaska Division of Geological & Geophysical Surveys is engaged in major data collection efforts in Interior and Southwest Alaska, funded through the U.S. Geological Survey's Earth Mapping Resources Initiative (Earth MRI) and the State of Alaska. The goal of these programs is to improve our understanding of the Nation's geologic framework and to identify areas that have potential for discovery of critical mineral resources. The program is regional in scope and focuses on geophysical surveys, geologic mapping, and geochemical sampling.

The 2023 Earth MRI geophysical program surveyed the northeastern portion of the Kuskokwim Mineral Belt using magnetic and radiometric sensors (fig. 1). The 2023 survey area includes the Cosna Dome (tin), Kaiyuh Hills (chromite), and Von Frank Mountain (gold) prospects, and the Ruby and Colorado Creek placer gold mining areas. The survey is divided into a mountainous portion, flown by contractor Geotech Ltd. using a helicopter platform, and a low-relief portion flown by contractor MPX Geophysics Ltd. using a fixed-wing aircraft. The survey line spacing was 400 m, and the mean ground clearance was 200 m for both survey blocks.

Alaska's gravity data coverage is sparse, particularly in areas of interest to metallic mineral exploration. The 2023 Earth MRI geophysical survey featured an experiment with "opportunistic" airborne gravimetry, made possible by a partnership with Lamont-Doherty Earth Observatory. The iMAR gravimeter installed on contractor MPX's aircraft weighs 10 kg and is capable of approximately 5 km resolution data collection—a major improvement over available data—with no modification to the aeromagnetic survey design.

Earth MRI and DGGS began an electromagnetic survey of the Seward Peninsula graphite belt, including the known resources at the Graphite Creek deposit and other prospective ground in the Kigluaik, Bendeleben, and Darby Mountains. Contractor SkyTEM completed part of the survey this fall.

DGGS geologists continued a multi-year effort to update and improve the geologic maps of the Yukon Tanana Upland in eastern Interior Alaska, as well as further investigating and understanding mineral occurrences in the region. DGGS's 500 person-day 2023 field season investigated an area of roughly 11,000 km² (4,250 mi²) including the Pogo Trend mineral deposits, the Chena Slate Belt, and the upper Salcha and Chena river drainages. This regional mapping program blends new fieldwork, geochronology, and geophysical interpretation with compilation of existing maps, industry data, and re-examination of archived USGS rock samples. Emphasis is on building a more detailed understanding of Cretaceous-Cenozoic plutonic rocks and fault systems. Geochemical sampling targeted both known and previously undocumented mineral occurrences, and we are employing litho-geochemistry and geochronology to understand suites of mineralizing and barren intrusive rocks.

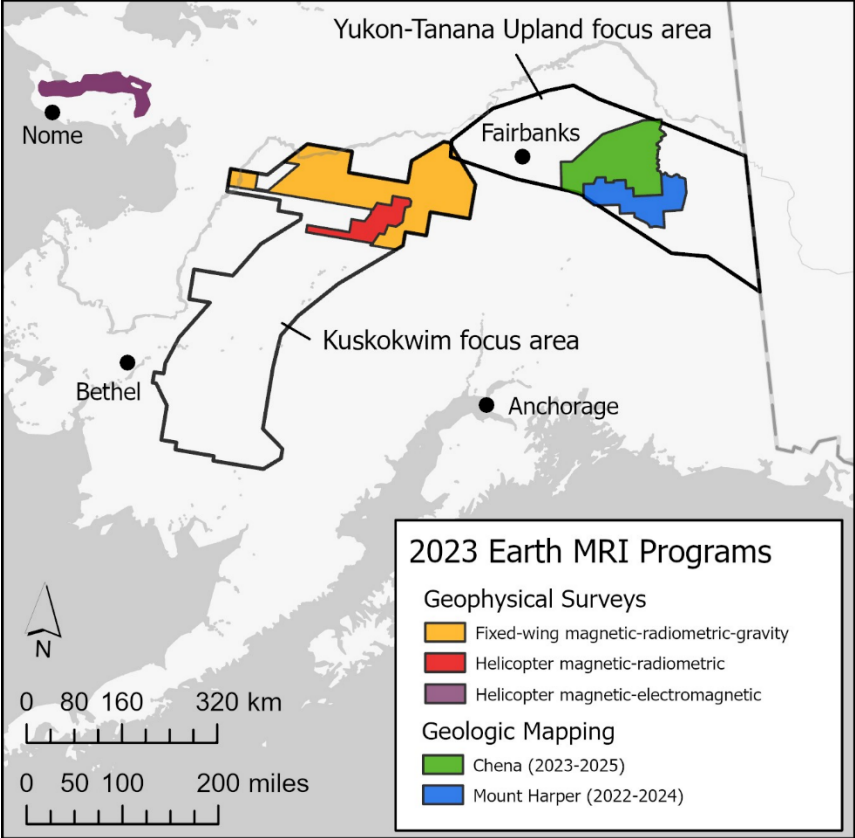


Figure 1. Location of DGGs Earth MRI geological and geophysical surveys during 2023.

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Largest DGGs programs since ...?

This is a Team Effort!

Geophysical Survey contractors:

MPX Geophysics Ltd.

Geotech Ltd.

SkyTEM

Land access to parts of the study area:

Doyon Ltd. & BLM

Industry cooperation: Northern Star, Tectonic Metals,

Resolution Minerals, Millrock Resources, SAM Alaska

USGS EarthMRI collaborators: Jamey Jones, Doug Kreiner, Ben Drenth, Jacob Murchek, George Case, Paul Bedrosian

2022-2023 Geologic Mapping Teams:

Alicja Wypych

Mike Barrera

Travis Naibert

Izzy Muller

Rainer Newberry

Rich Ketcham

Zoom Szumigala

Jenna Beigel

Michelle Gavel

David Harvey

Alec Wildland

Noel Blackwell

Wes Buchanan

Serena Fessenden

Evan Twelker

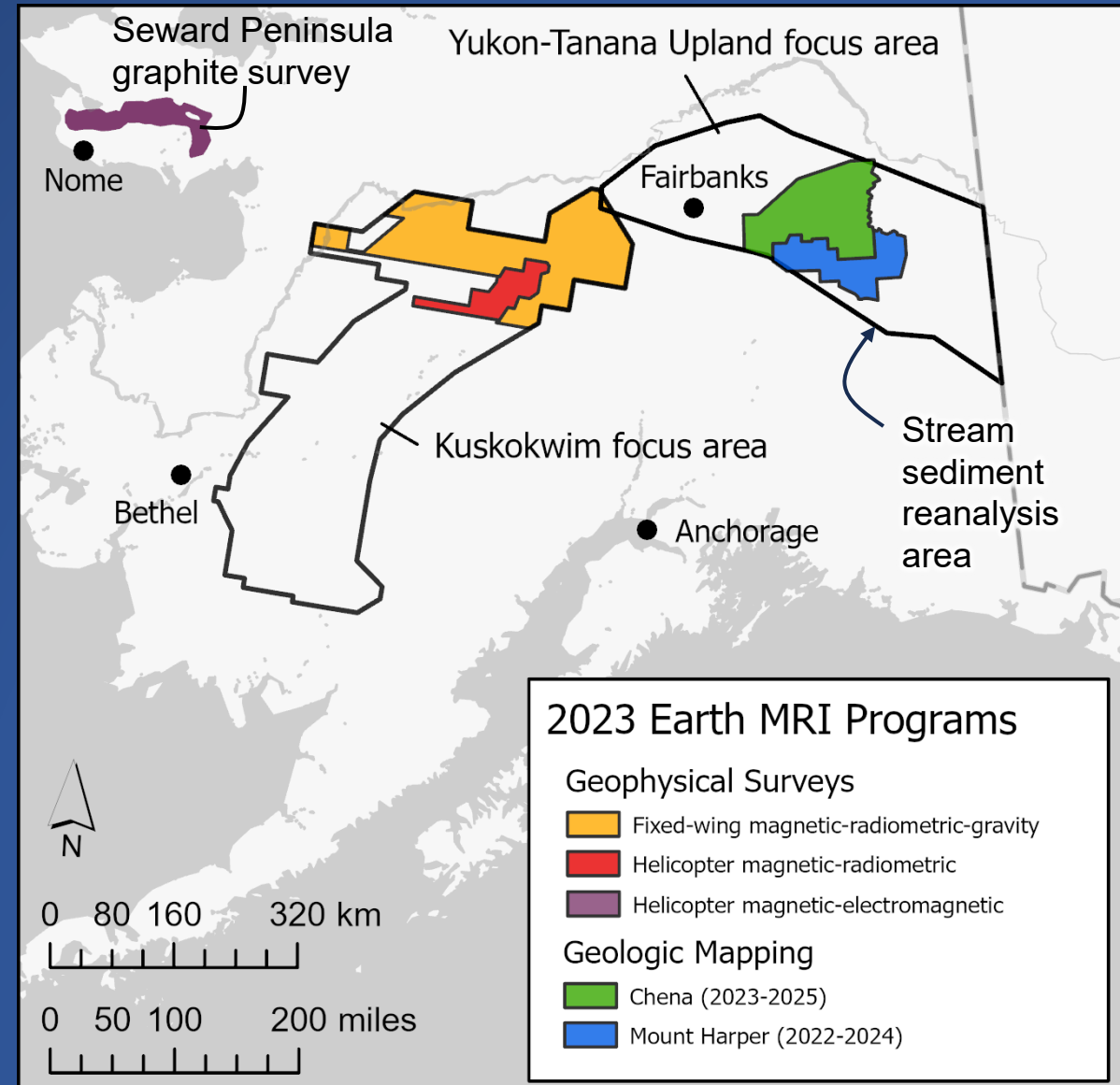
Keith Warren and Aurora Aviation Services

Funding for geophysical surveys and geologic mapping provided by U.S. Geological Survey Earth Mapping Resources Initiative (Earth MRI) cooperative agreements G19AC00263, G20AC00160, G21AC10326, G22AC00475, G23AC00408; G19AC00262, G20AC00156, G21AC00336, G22AC00288, G23AC00372; plus additional State of Alaska funds.

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Geological Survey. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Geological Survey.

What is Earth MRI?

- “Earth Mapping Resources Initiative”
- *USGS geologic framework mapping program focused on critical minerals*
- *Partnership with state geological surveys*
- *Three main components:*
 - *Geophysical surveys (mag-rad, EM, hyperspectral)*
 - *Geologic mapping*
 - *Geochemical mapping*
- *Mineral systems approach:*
 - *Broad footprints*
 - *Many critical minerals are produced as co-products in conventional mineral deposits*



Interior Alaska—not revealed easily

Poor bedrock exposure

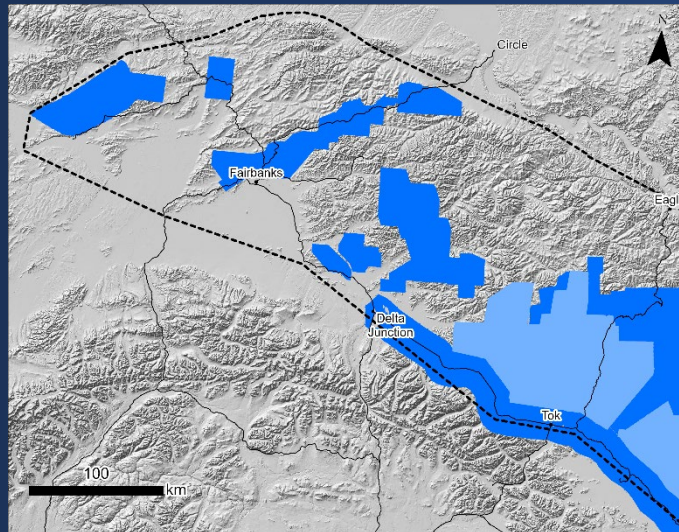
Complex intrusive and metamorphic geology



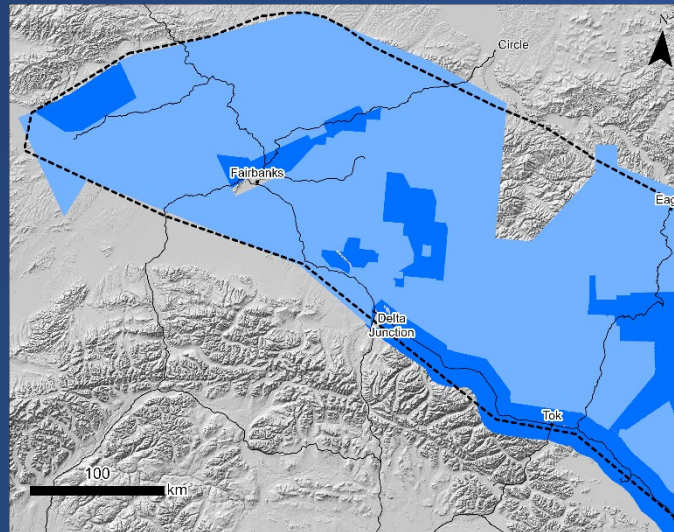
Yukon Tanana Upland Aeromagnetic Coverage

- Setting stage for new progress on geologic framework—both 2D and 3D
- Jacob Murchek (Michigan Tech PhD candidate) & Ben Drenth (USGS) working with the new data
- What lies beneath YTU's intrusion-related mineral districts?
 - Model depth-to-anomalies (intrusions?); hypothesized magmatic underplating, variations in crustal thickness; map major fault systems

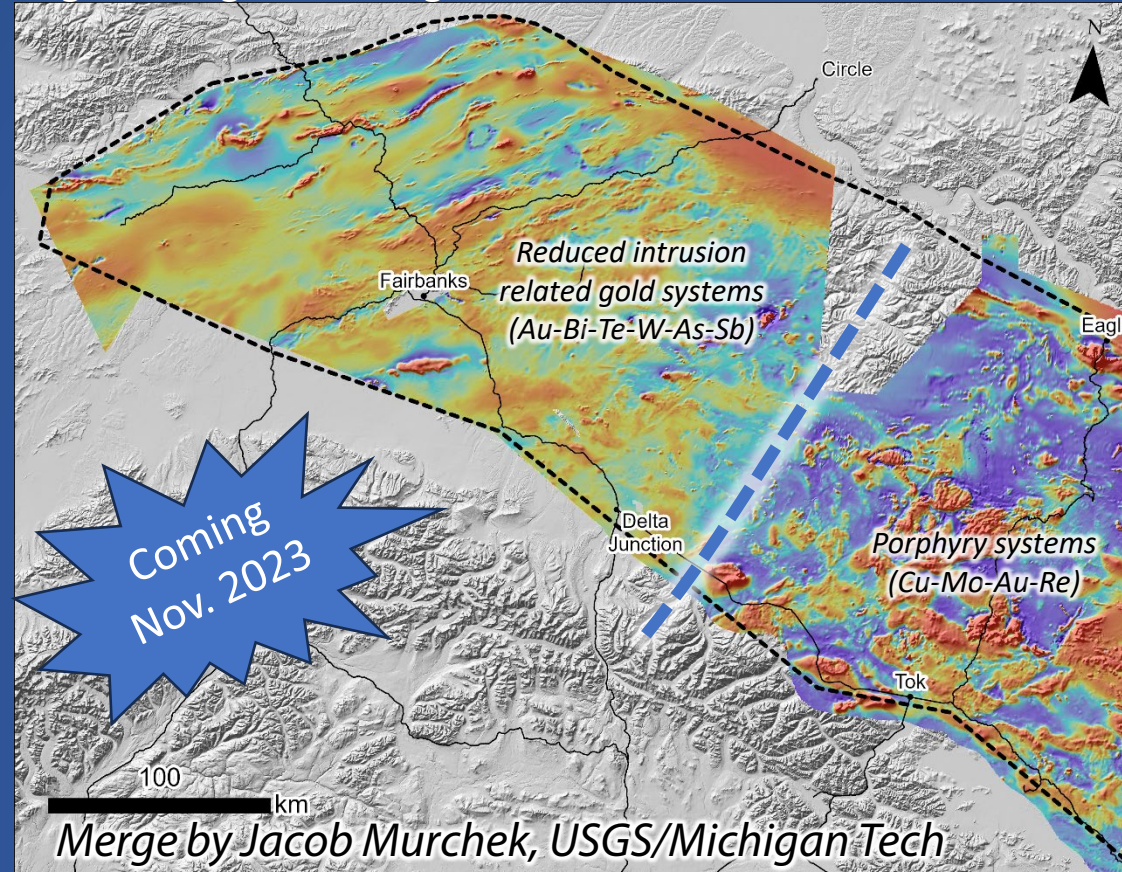
Pre-Earth MRI (2019)



With Earth MRI surveys 2019-2022



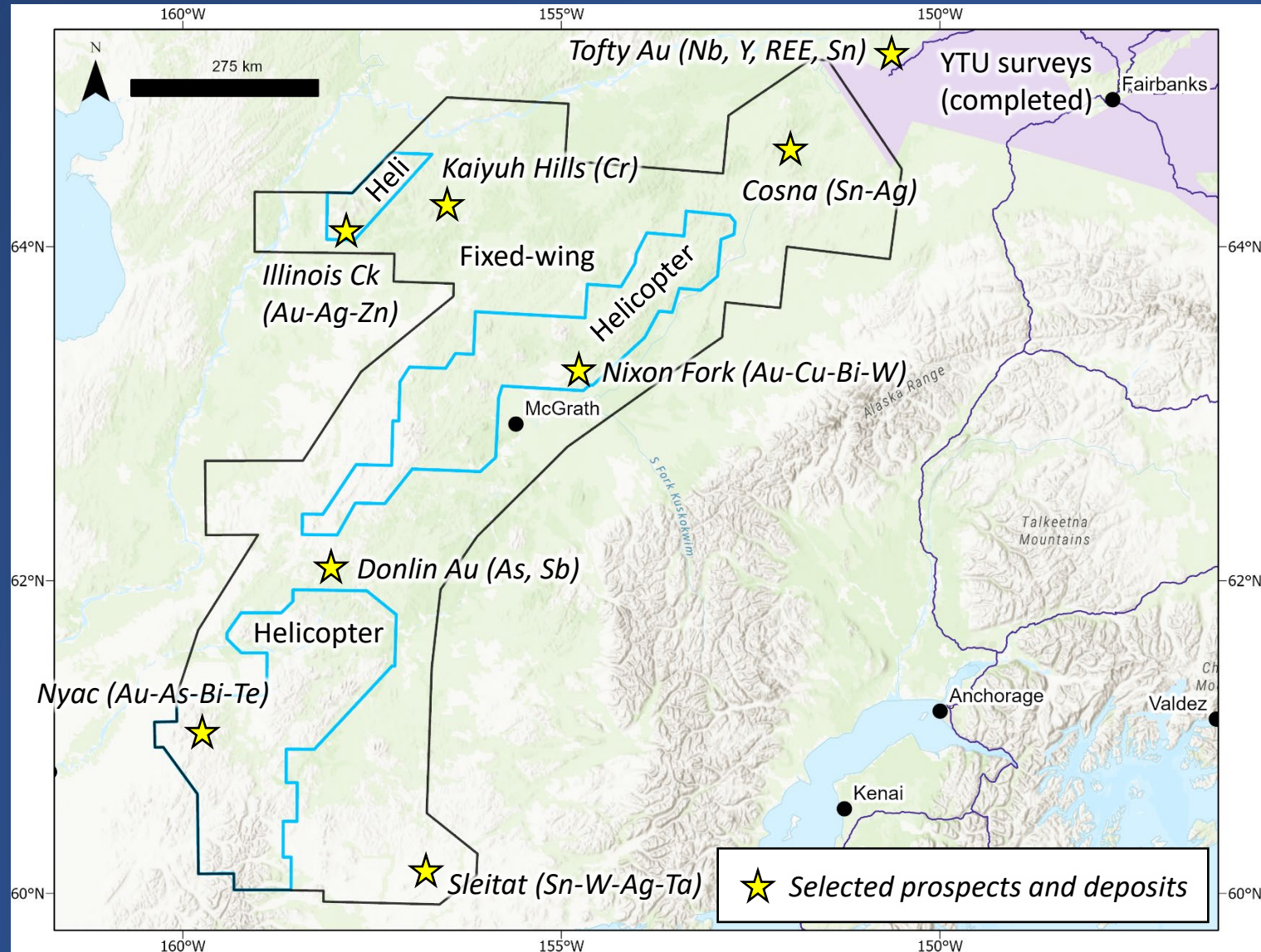
Digital magnetic merge--DRAFT



- TIER II magnetic data
- TIER III magnetic data

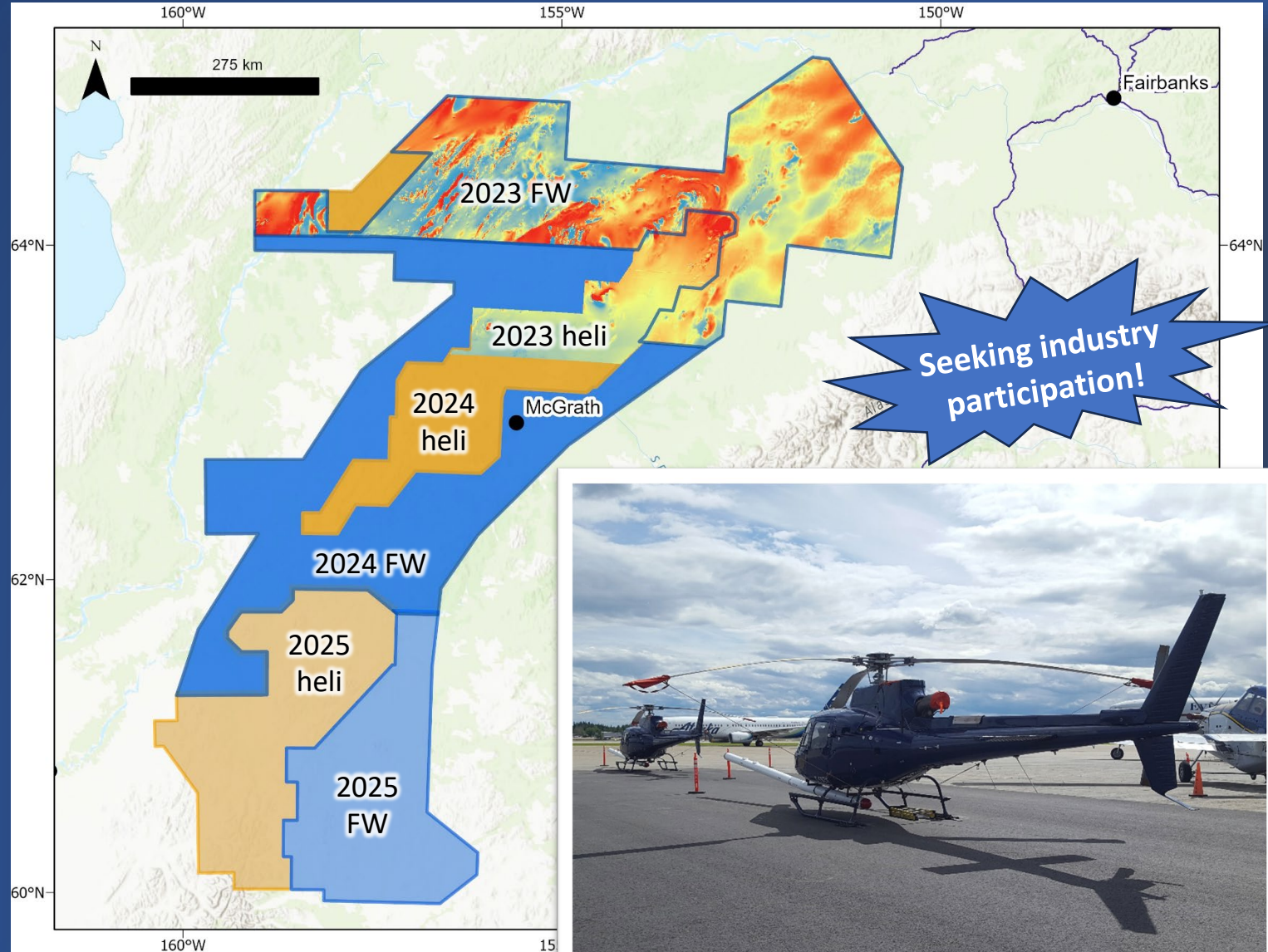
Kuskokwim magnetic-radiometric surveys

- *Intrusion-related mineral systems*
 - *Tin-tungsten*
 - *Porphyry Cu-Mo-Au*
 - *Gold (As-Sb)*
- *High industry interest, active exploration*
- *Data collection optimized:*
 - *Tier III mag-EM surveys will be overflowed*
 - *Mountainous terrain flown by helicopter*
- *Tier II magnetic data*

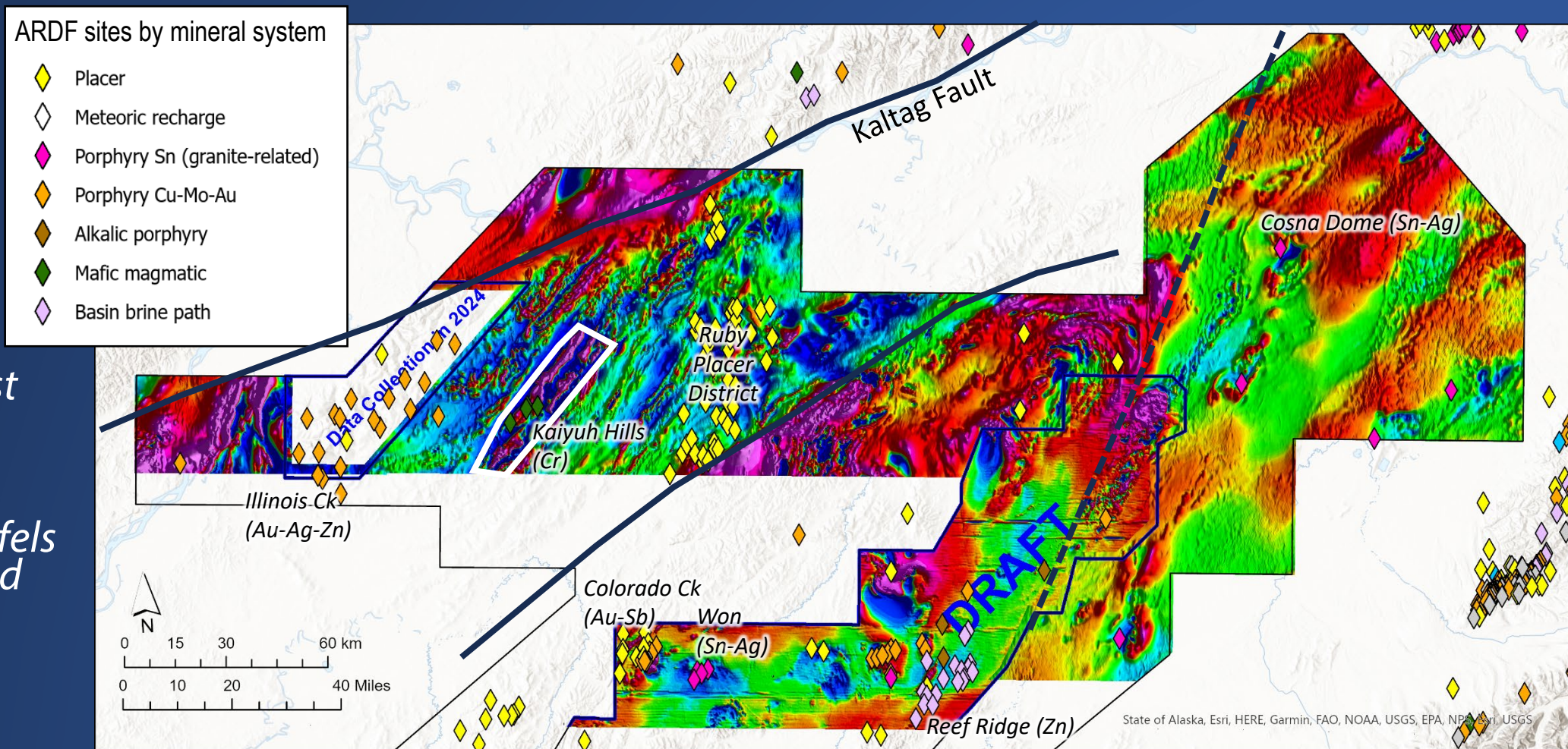


Kuskokwim magnetic-radiometric surveys

- 2023 Fixed-wing survey
 - 87,000 line-km
 - 29,000 sq km
- 2023 Helicopter
 - 25,000 line-km
 - 8,000 sq km
- Fixed-wing data to be released November 2023
- Helicopter magnetic-radiometric data to be released early 2024
- Three-year plan to finish Kuskokwim focus area



Preliminary Magnetic Survey Results

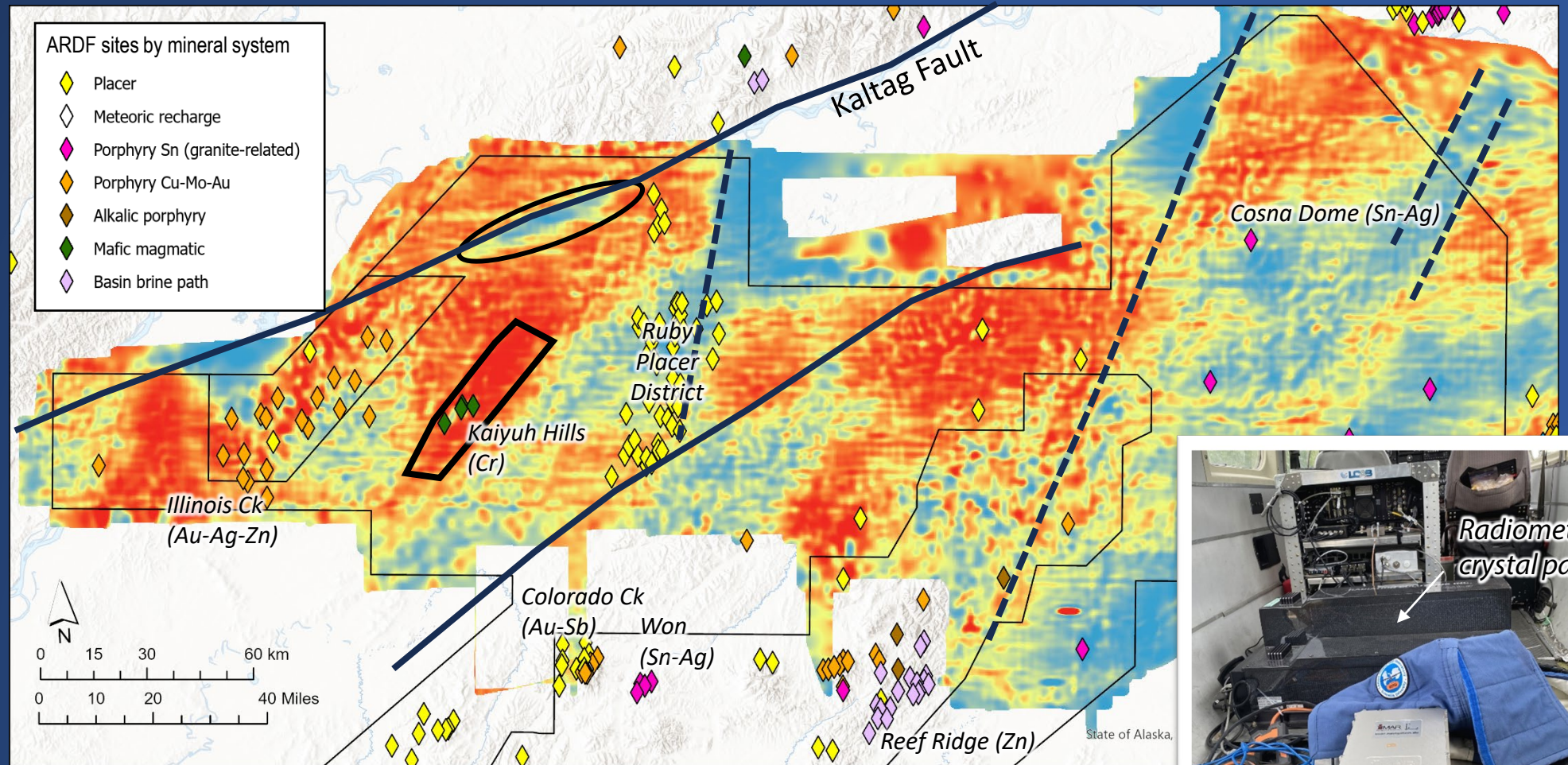


New data at first glance:

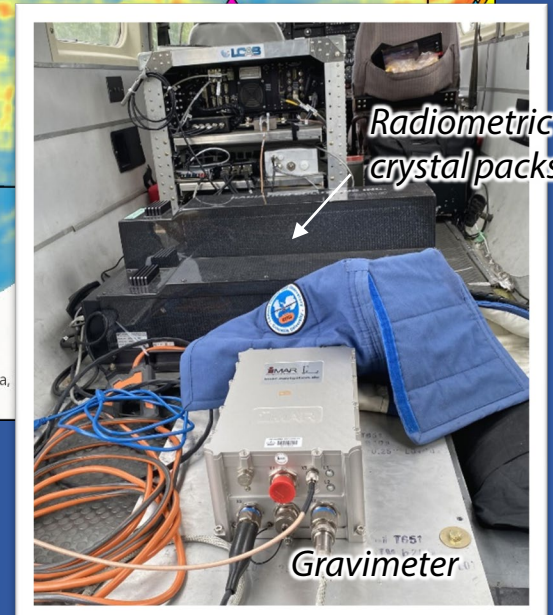
- Major faults
- Plutons, hornfels (magnetic and non-mag/ reverse-magnetized)
- Ultramafic complexes
- Both mapped and unmapped

Airborne gravity: testing new technology

- Alaska ground gravity dataset is very patchy
- Collaboration with Lamont Doherty Earth Observatory
- Survey contractor MPX
- Added airborne gravimeter to 2023 fixed-wing survey
- ~5 km resolution
- < \$2 added cost per line-km

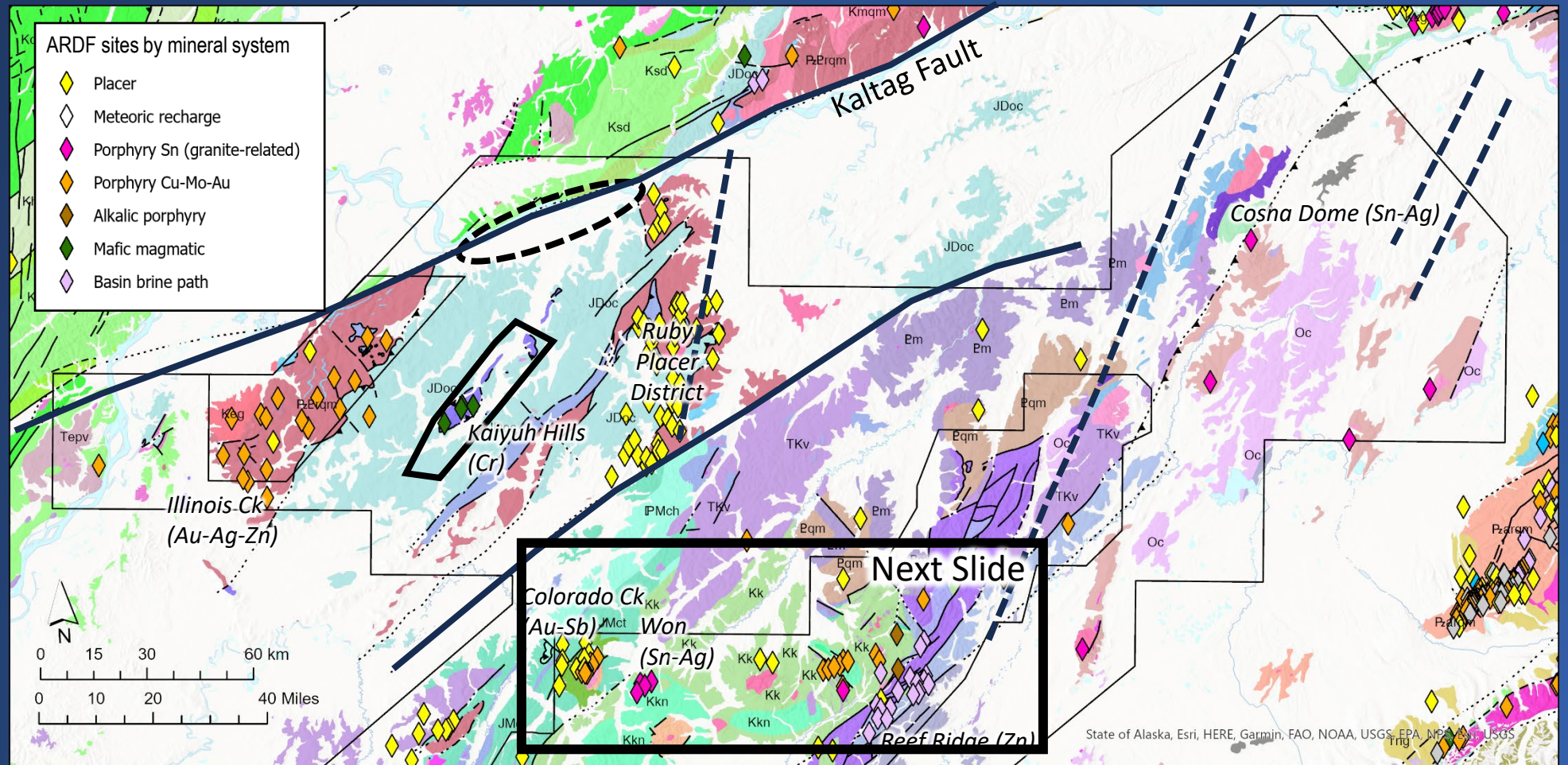


Preliminary Bouguer anomaly grid from 2023 survey
Courtesy Kirsty Tinto, LDEO



In comparison to mapped geology

- New faults to be mapped
- Cenozoic basin development and tectonics
- Plutons:
 - Variations magnetics
 - Concealed?
- 3D perspective

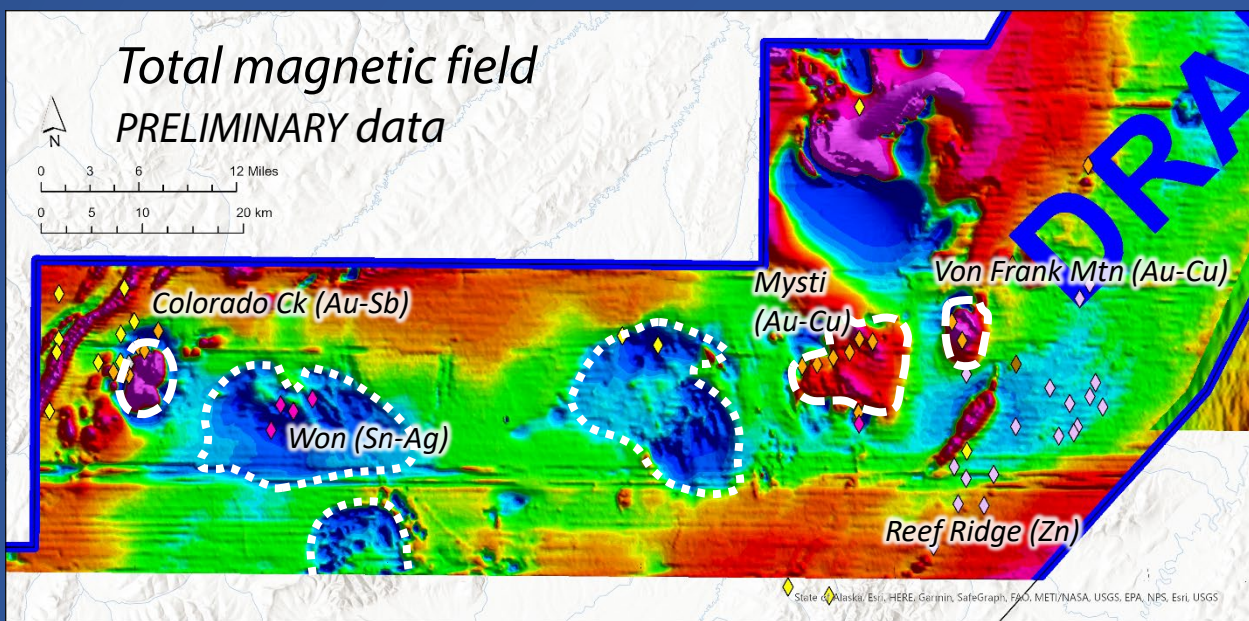
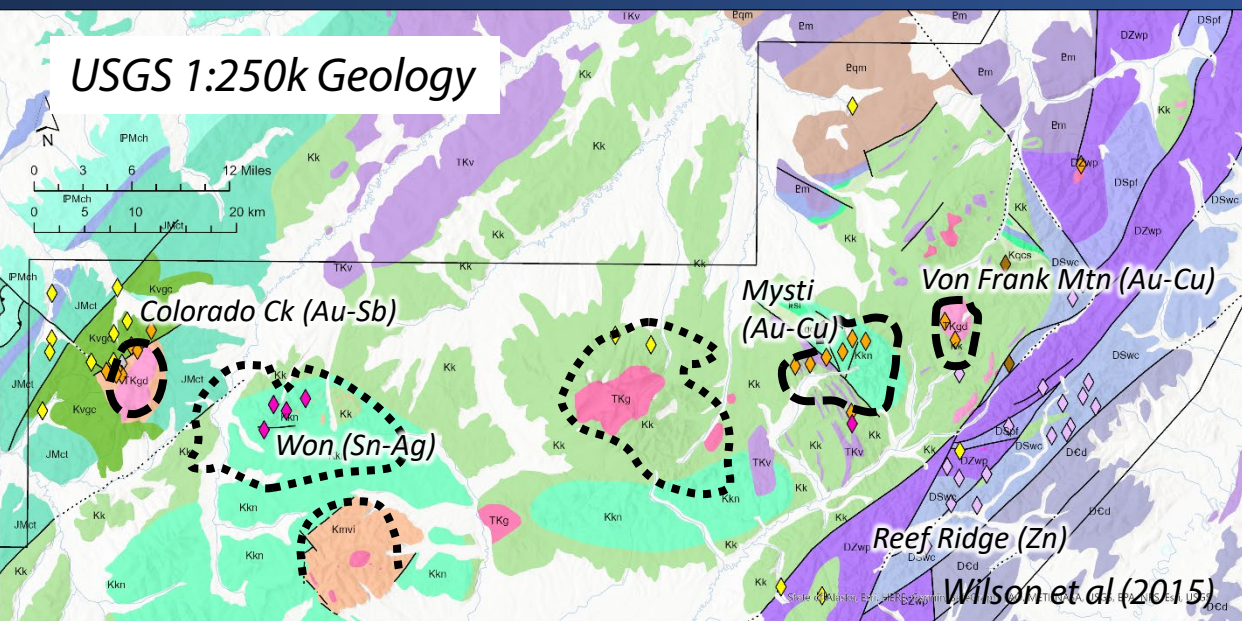
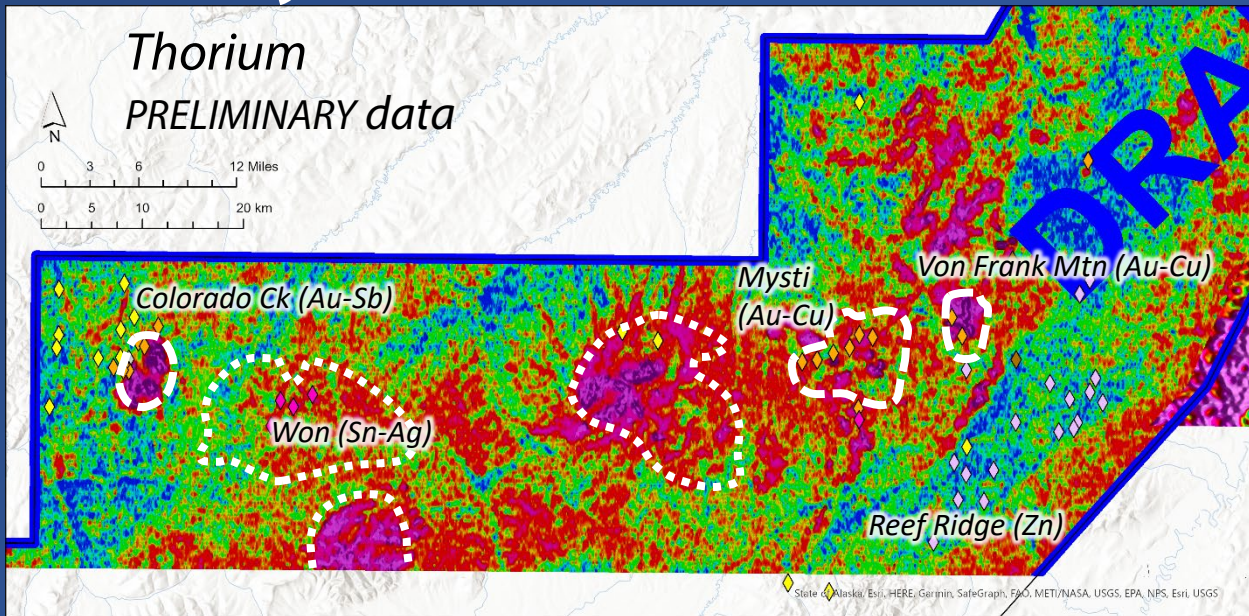


Close-up: Kuskokwim Preliminary Data

- Maps shallowly buried plutons
- Contrasting magnetic signatures:
 - Au-Cu: high mag
 - Sn-Ag: mag lows (or reversely magnetized)

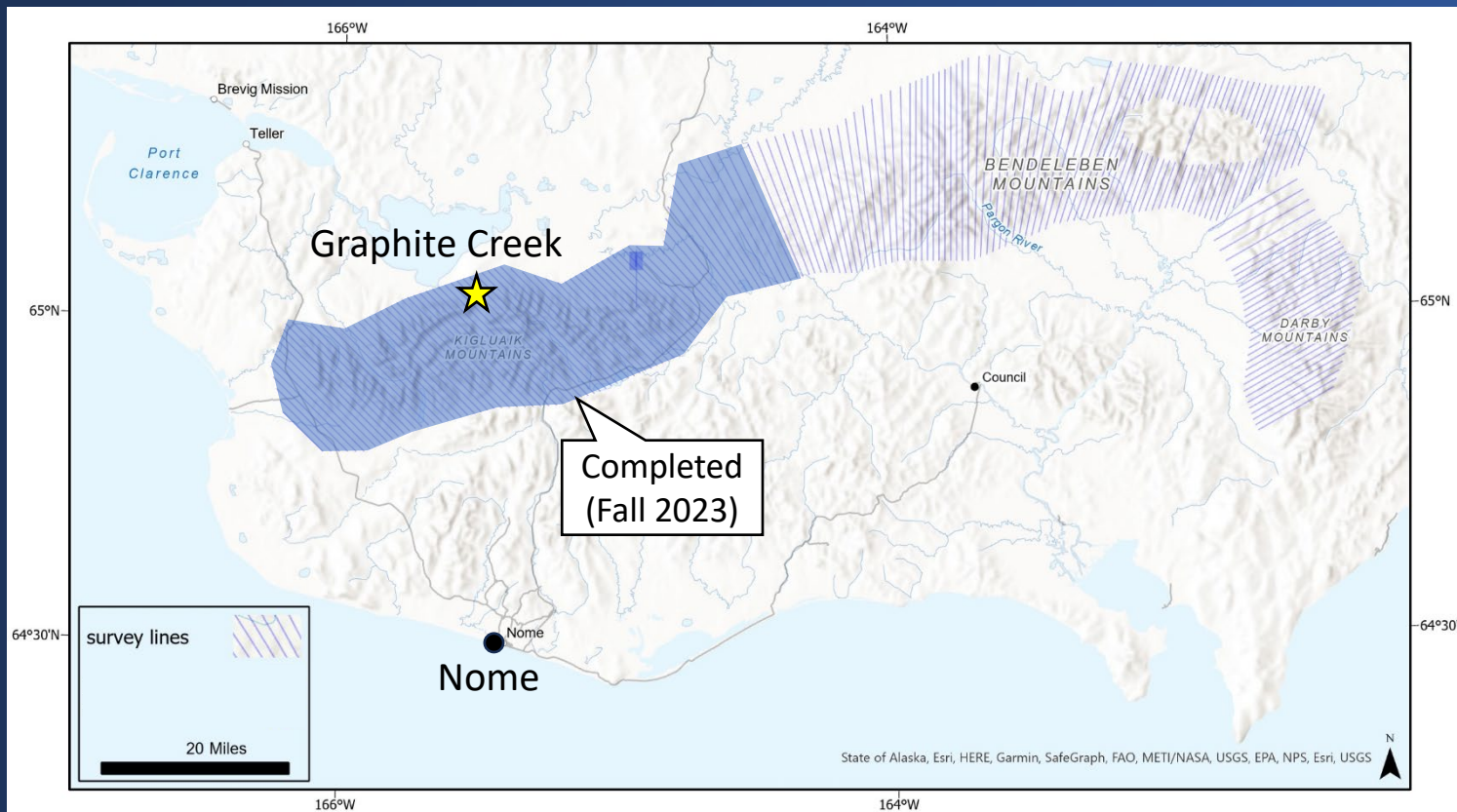
ARDF sites by mineral system

- ◆ Placer
- ◇ Meteoric recharge
- ◆ Porphyry Sn (granite-related)
- ◆ Porphyry Cu-Mo-Au
- ◆ Alkalic porphyry
- ◆ Mafic magmatic
- ◆ Basin brine path



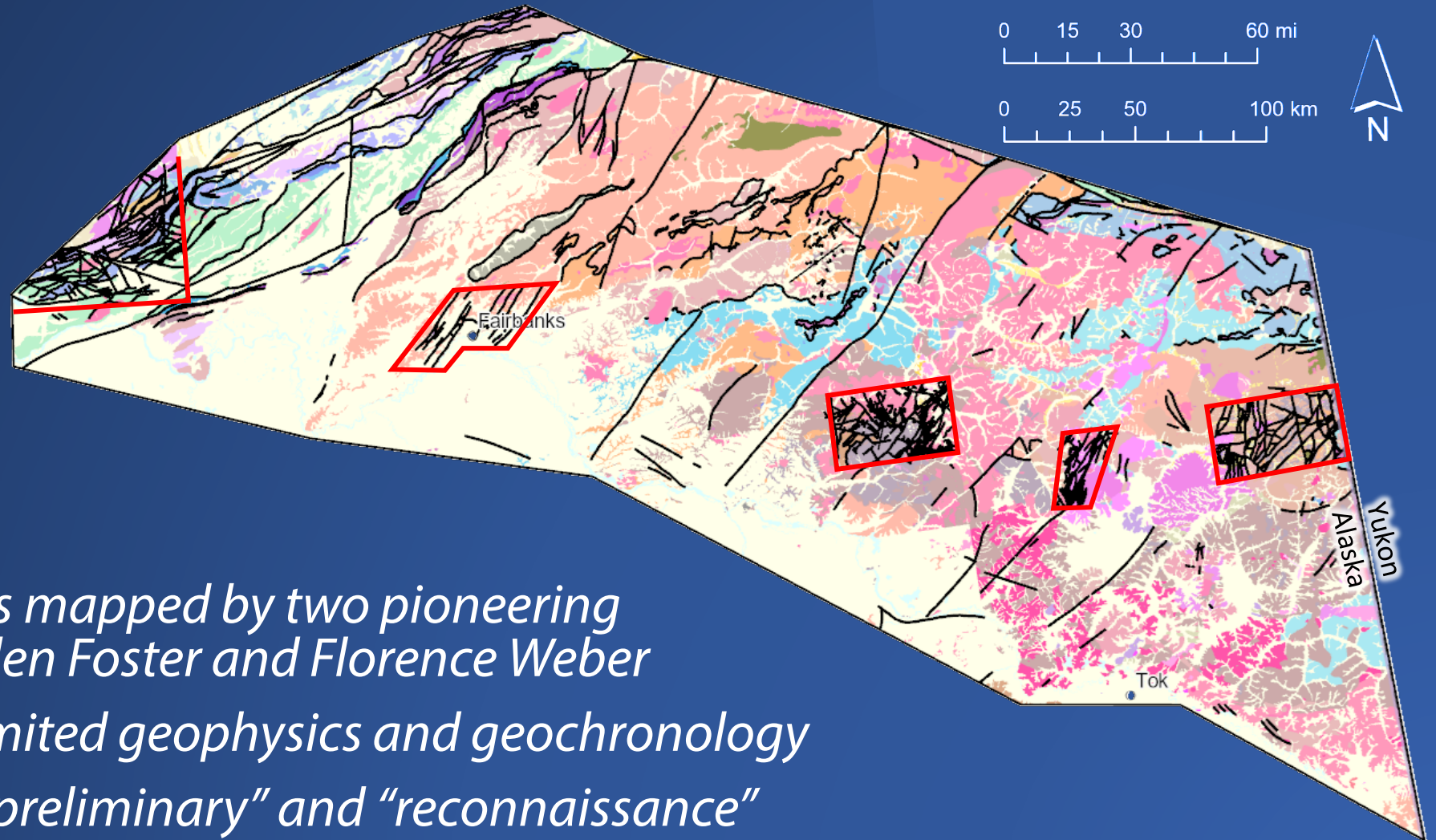
Seward Peninsula Graphite

- Largest large-flake graphite deposit in U.S.
- Alaska's most advanced critical mineral project
- U.S. DoD recently invested \$37.5 million towards Graphite Creek deposit feasibility study



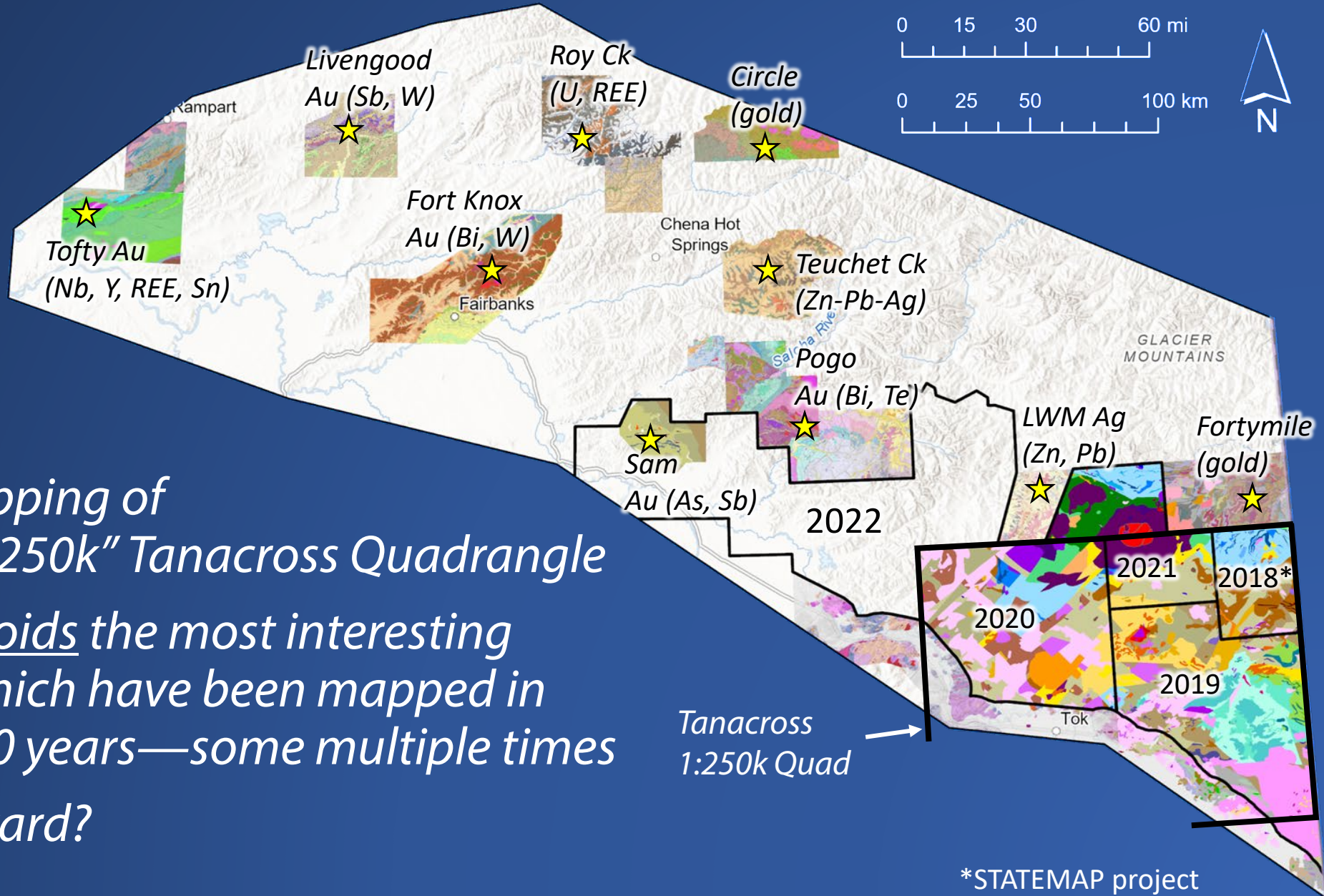
- Time-domain (SkyTEM) electromagnetic survey of prospective geology
- ~40% of 4,400 line-km complete
- Data release projected Fall 2024

Yukon Tanana Upland Geologic Mapping



- Much of the YTU was mapped by two pioneering USGS geologists, Helen Foster and Florence Weber
- 1960s-1970s; very limited geophysics and geochronology
- Maps published as “preliminary” and “reconnaissance”
- Key metallogenic elements—magmatism and structure—are not mapped in sufficient detail

Geologic (Re?)-mapping

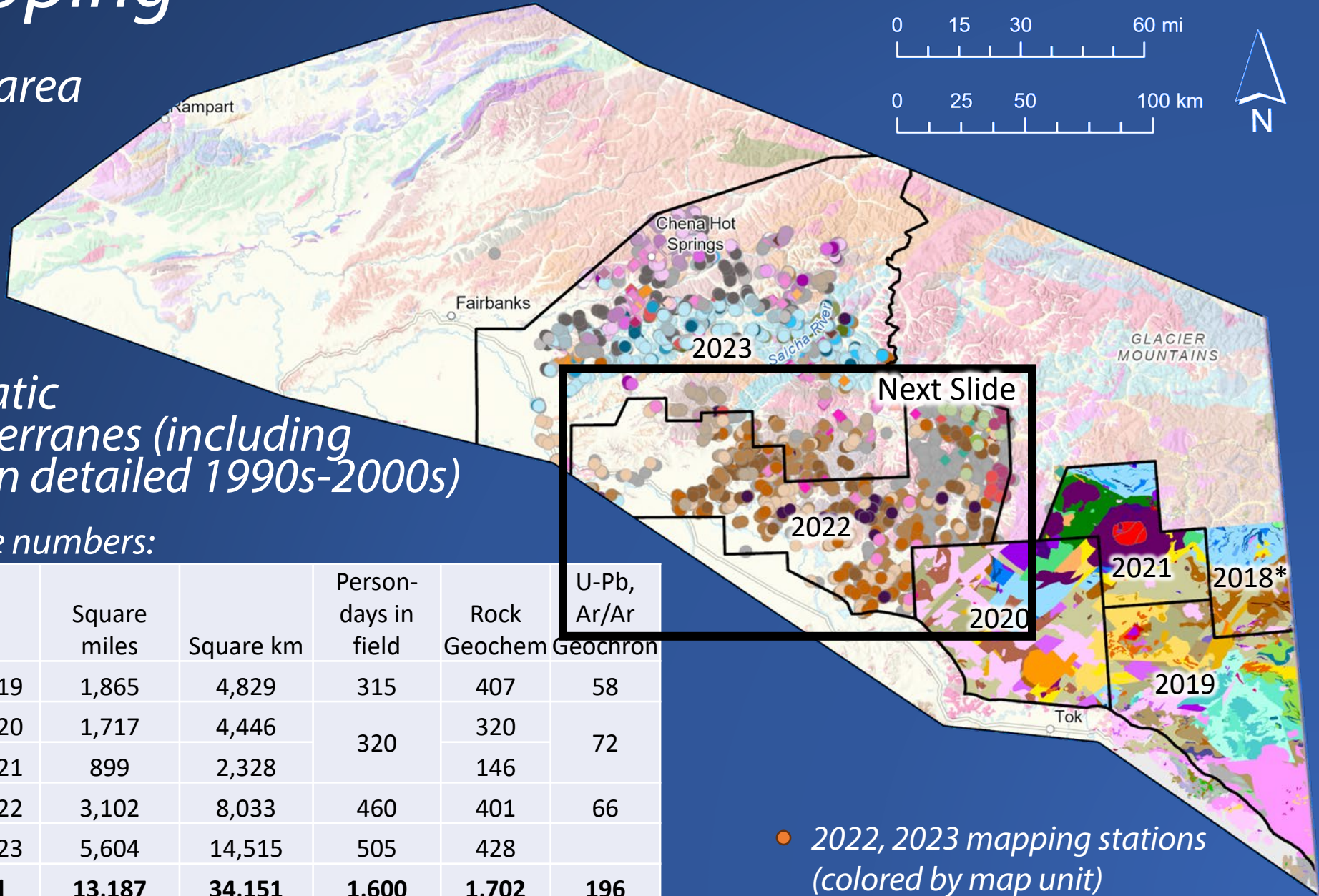


- 2018-2021: Re-mapping of “reconnaissance 1:250k” Tanacross Quadrangle
- 2022: Map area avoids the most interesting mining districts, which have been mapped in detail in the past 20 years—some multiple times
- How to move forward?

*STATEMAP project

Geologic Mapping

- 2023: Very large map area
- Mix compilation and new mapping
- Resolve conflicts between existing maps
- Data to refine & map modern units: magmatic suites, metamorphic terranes (including in the areas mapped in detailed 1990s-2000s)
- Benefitting from archived USGS samples 1960s-1980s



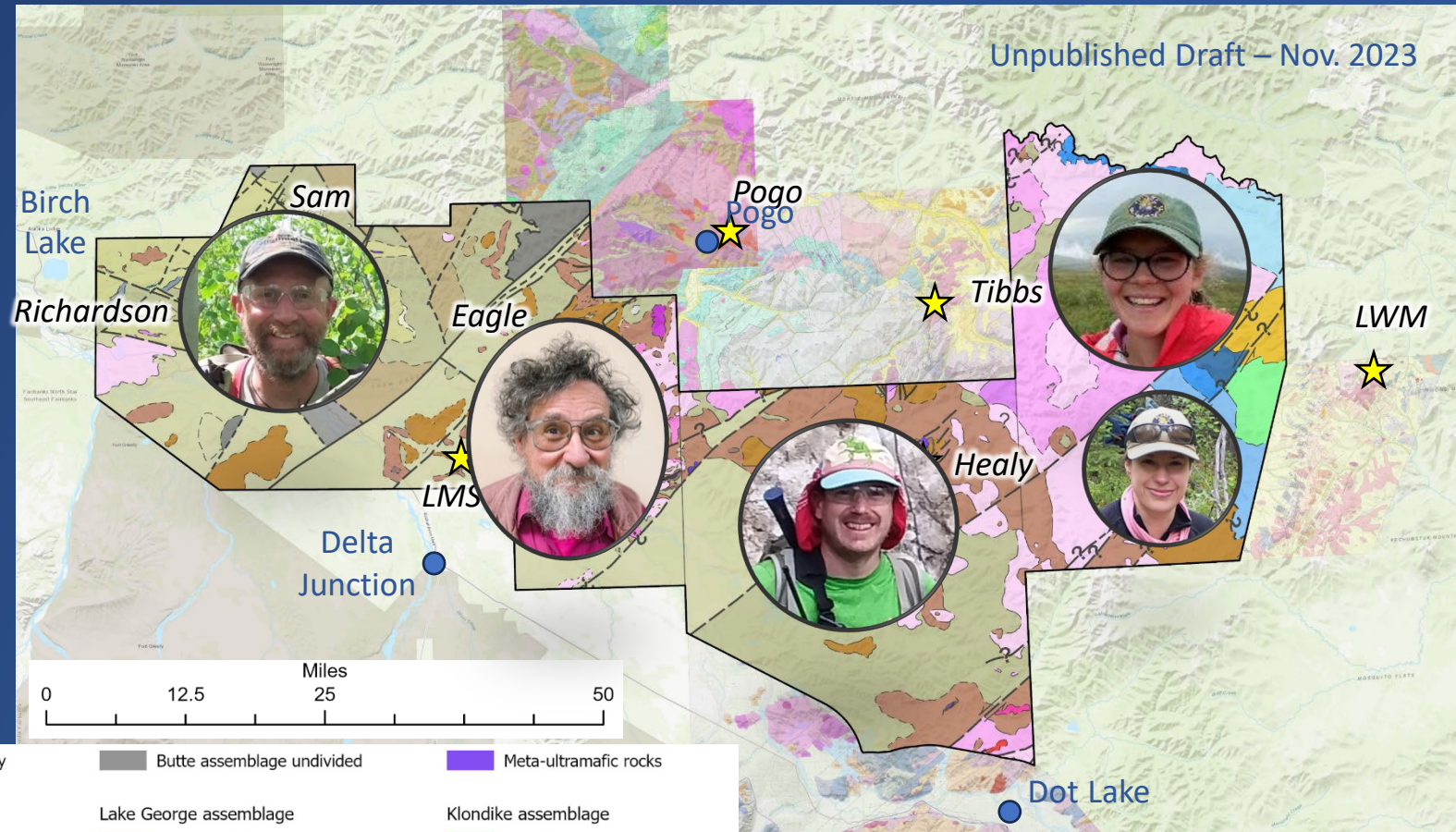
By the numbers:

	Square miles	Square km	Person-days in field	Rock Geochem	Geochron
FFY2019	1,865	4,829	315	407	58
FFY2020	1,717	4,446	320	320	72
FFY2021	899	2,328		146	
FFY2022	3,102	8,033	460	401	66
FFY2023	5,604	14,515	505	428	
Total	13,187	34,151	1,600	1,702	196

• 2022, 2023 mapping stations (colored by map unit)

Mt. Harper – Richardson mapping update

- EarthMRI now 3-year projects
 - ~75% mapped first year
 - ~25% second year,
 - Publish during third year
- 2022 Mt Harper-Richardson map is due Spring 2025
- Large area divided among staff
- 3-4 map sheets with unified map unit descriptions/booklet

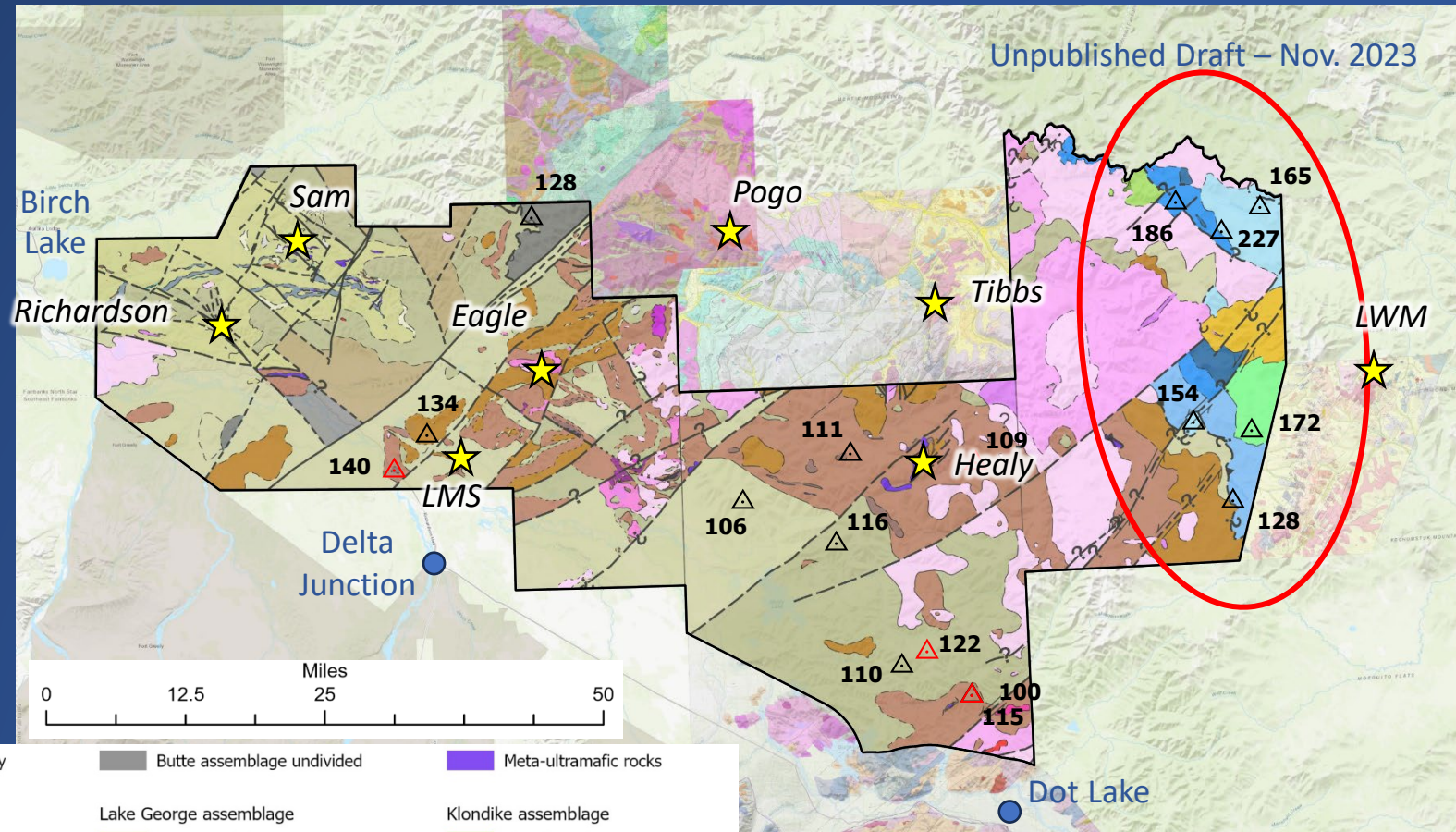


■ Felsic porphyry	■ Butte assemblage undivided	■ Meta-ultramafic rocks
Late Cretaceous		
■ Volcanics	Lake George assemblage	Klondike assemblage
■ Granodiorite	■ LG undivided	■ Klondike schist
■ Porphyritic granite	■ LG metasediments	■ Klondike metamafics
■ Monzonite	■ LG paragneiss	
Cretaceous	■ LG quartzite	■ Nasina assemblage undivided
■ Granite	■ LG marble	Fortymile River assemblage
■ Granodiorite	■ LG graphitic schist	■ Fortymile River metasediments
■ Quartz diorite	■ LG calc-silicate schist	■ Fortymile River paragneiss
■ Two-mica granite	■ LG orthogneiss	■ Fortymile River orthogneiss
■ Gabbro	■ Divide Mtn. augen gneiss	■ Fortymile River amphibolite
■ Tonalite	■ LG amphibolite	■ Unassigned
■ Quartz porphyry	■ LG sillimanite gneiss	

Mt. Harper – Richardson mapping update

Mount Harper area

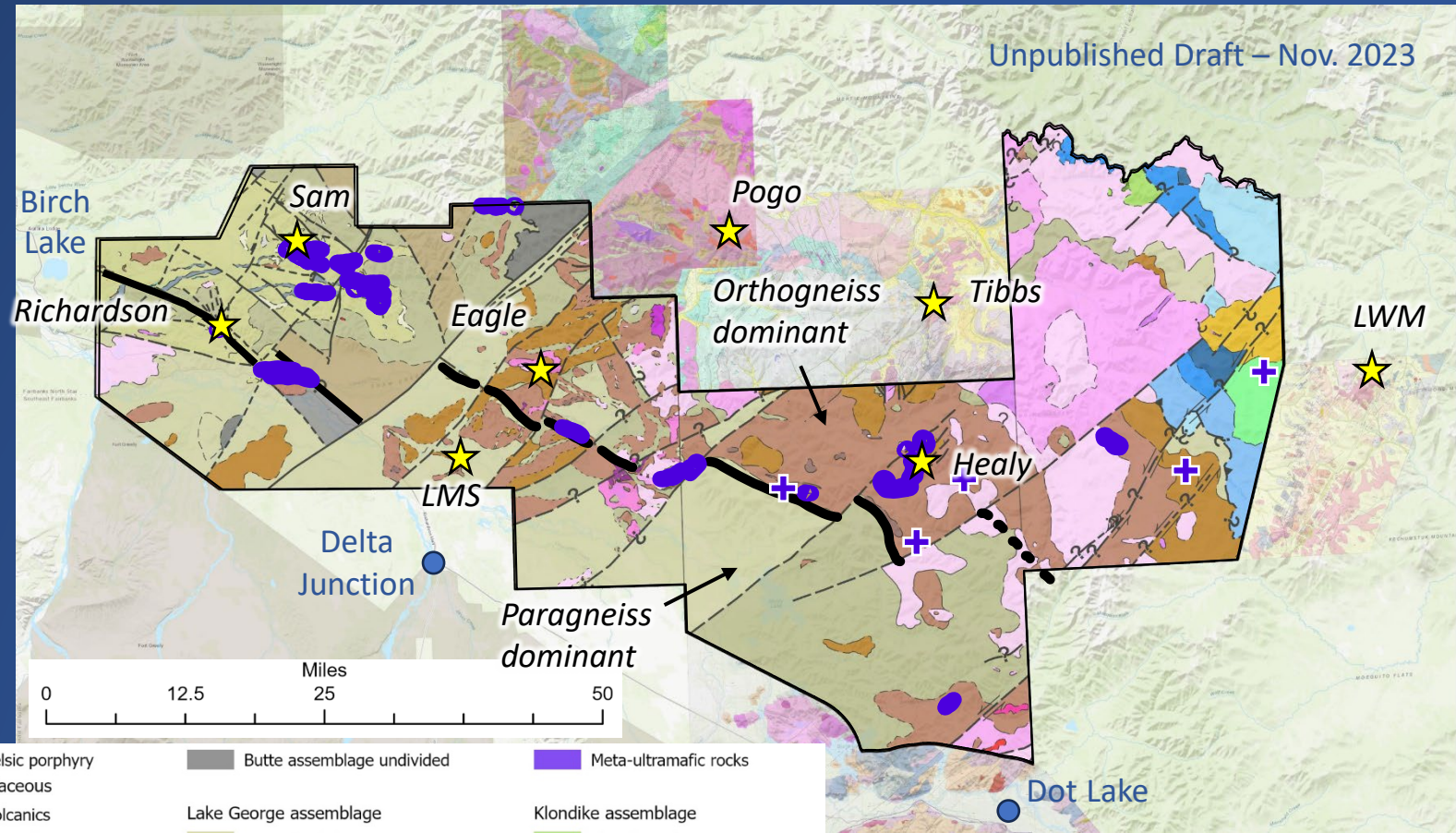
- Yukon Tanana terrane rocks (Fortymile River, Nasina, Klondike assemblages) on east side of Mt Harper batholith
- Preliminary Ar/Ar cooling ages (unpublished)
 - Jurassic-Triassic in YTT (red oval)
 - Cretaceous in LG assemblage



■ Felsic porphyry	■ Butte assemblage undivided	■ Meta-ultramafic rocks
Late Cretaceous		
■ Volcanics	Lake George assemblage	Klondike assemblage
■ Granodiorite	■ LG undivided	■ Klondike schist
■ Porphyritic granite	■ LG metasediments	■ Klondike metamafics
■ Monzonite	■ LG paragneiss	
Cretaceous	■ LG quartzite	■ Nasina assemblage undivided
■ Granite	■ LG marble	Fortymile River assemblage
■ Granodiorite	■ LG graphitic schist	■ Fortymile River metasediments
■ Quartz diorite	■ LG calc-silicate schist	■ Fortymile River paragneiss
■ Two-mica granite	■ LG orthogneiss	■ Fortymile River orthogneiss
■ Gabbro	■ Divide Mtn. augen gneiss	■ Fortymile River amphibolite
■ Tonalite	■ LG amphibolite	■ Unassigned
■ Quartz porphyry	■ LG sillimanite gneiss	

Mt. Harper – Richardson mapping update

- NW-striking fault divides the Lake George assemblage
 - Mixed augen gneiss, orthogneiss, amphibolite, and metasediments to the NE
 - Mostly metasedimentary rocks to the SW
 - Slivers of ultramafic rocks to the NE and along the fault



■ Felsic porphyry	■ Butte assemblage undivided	■ Meta-ultramafic rocks
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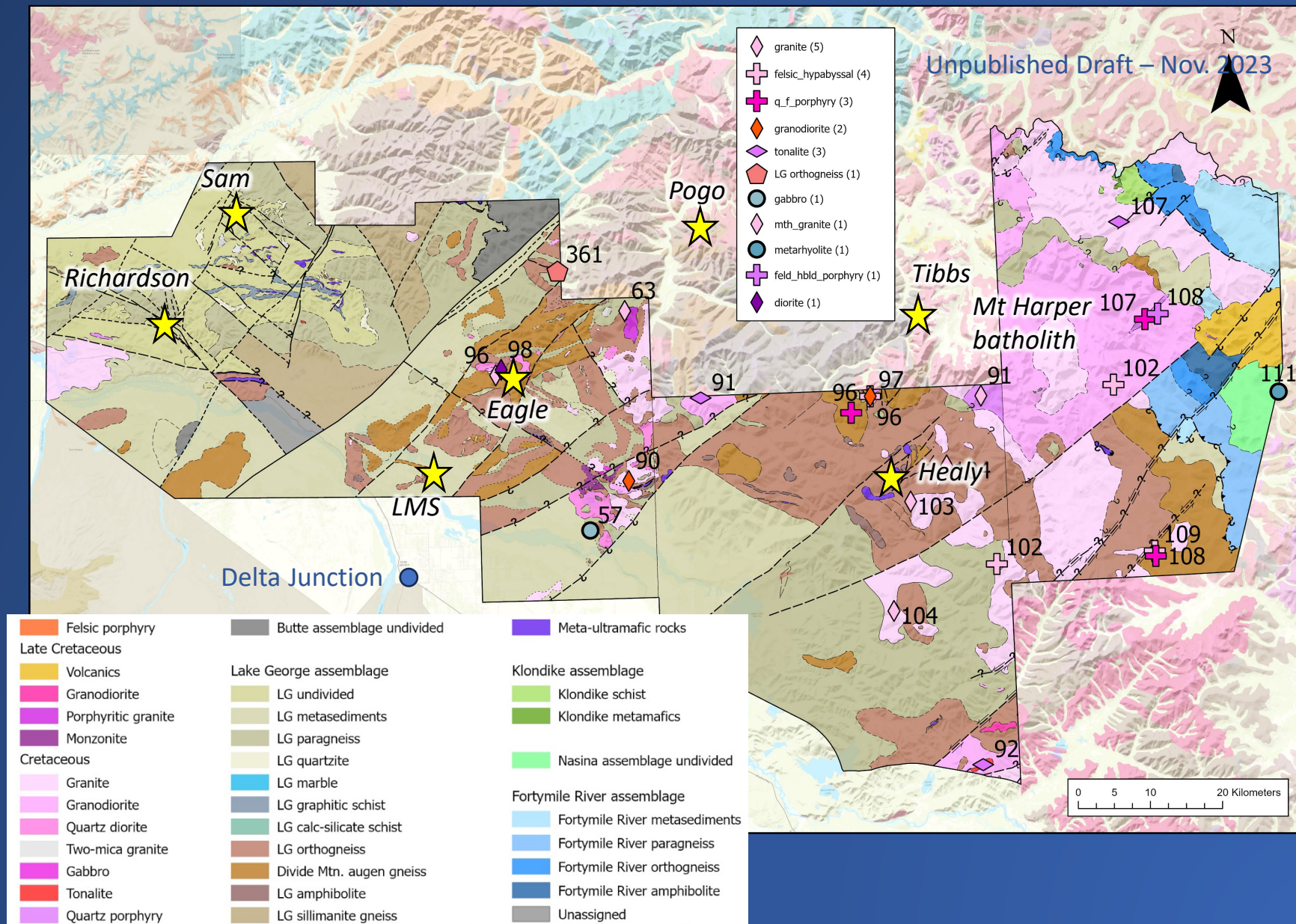
Mt. Harper – Richardson mapping update

Preliminary U-Pb zircon results

- LA-ICP-MS Zircon U/Pb ages
 - Analyzed in spring 2023
 - Arizona LaserChron
 - GeoSep Services

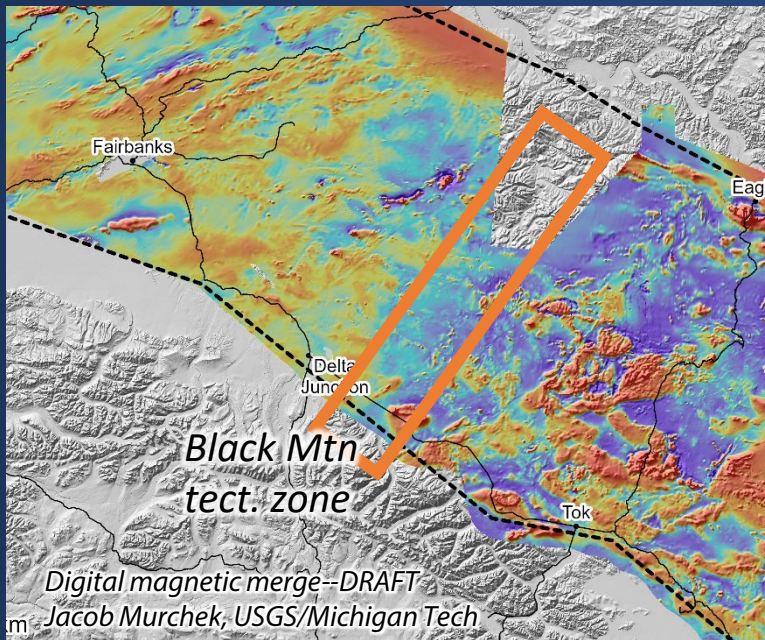
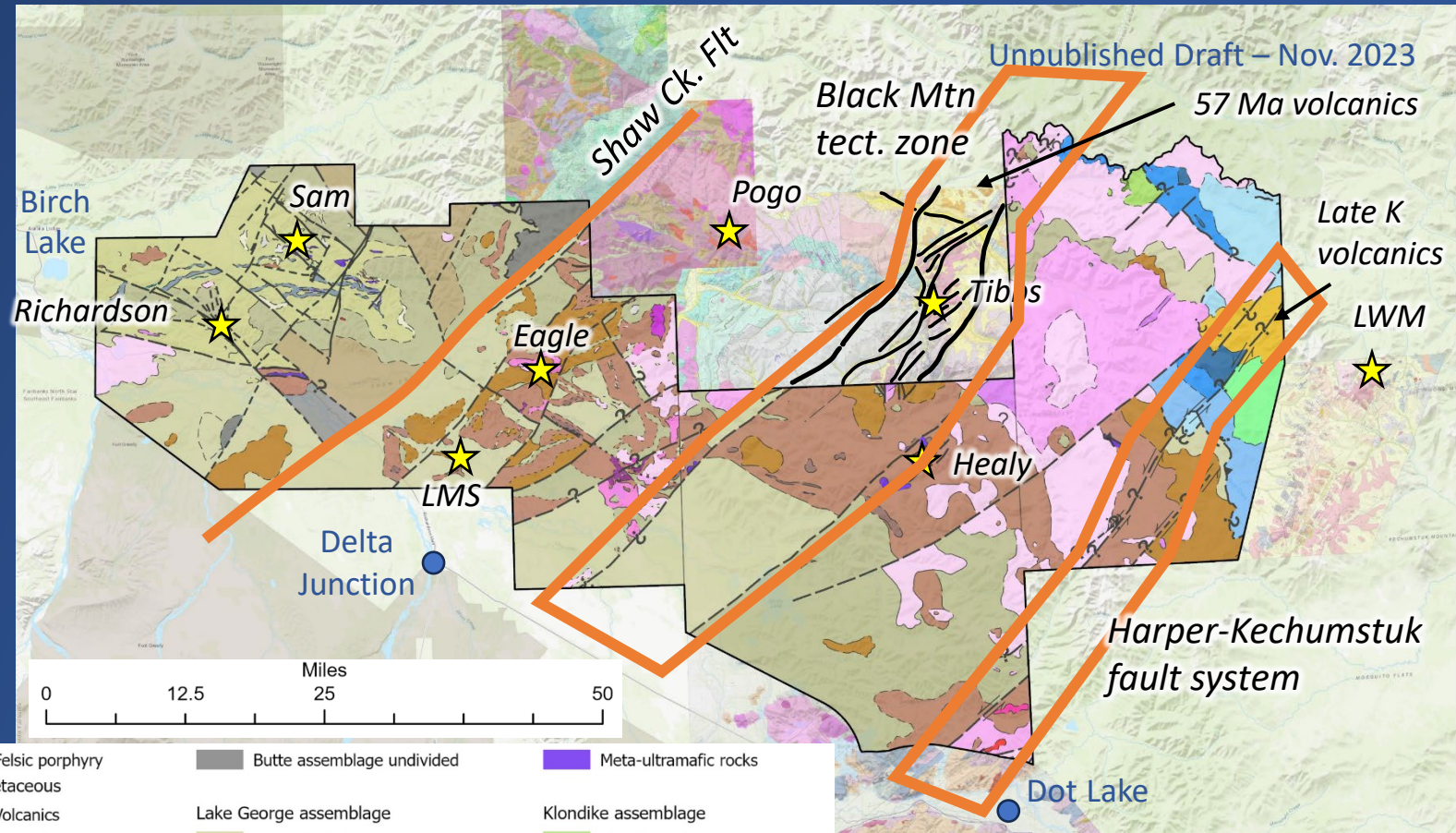
Plutonic rocks fall into several suites:

- Mt Harper area: 102-109 Ma
 - Arc; tonalite-granite
- Southwestern belt: 90-98 Ma
 - Arc; wider compositional range
- Widely scattered 57-73 Ma
 - Within-plate; Sn-granites; 2-mica granites

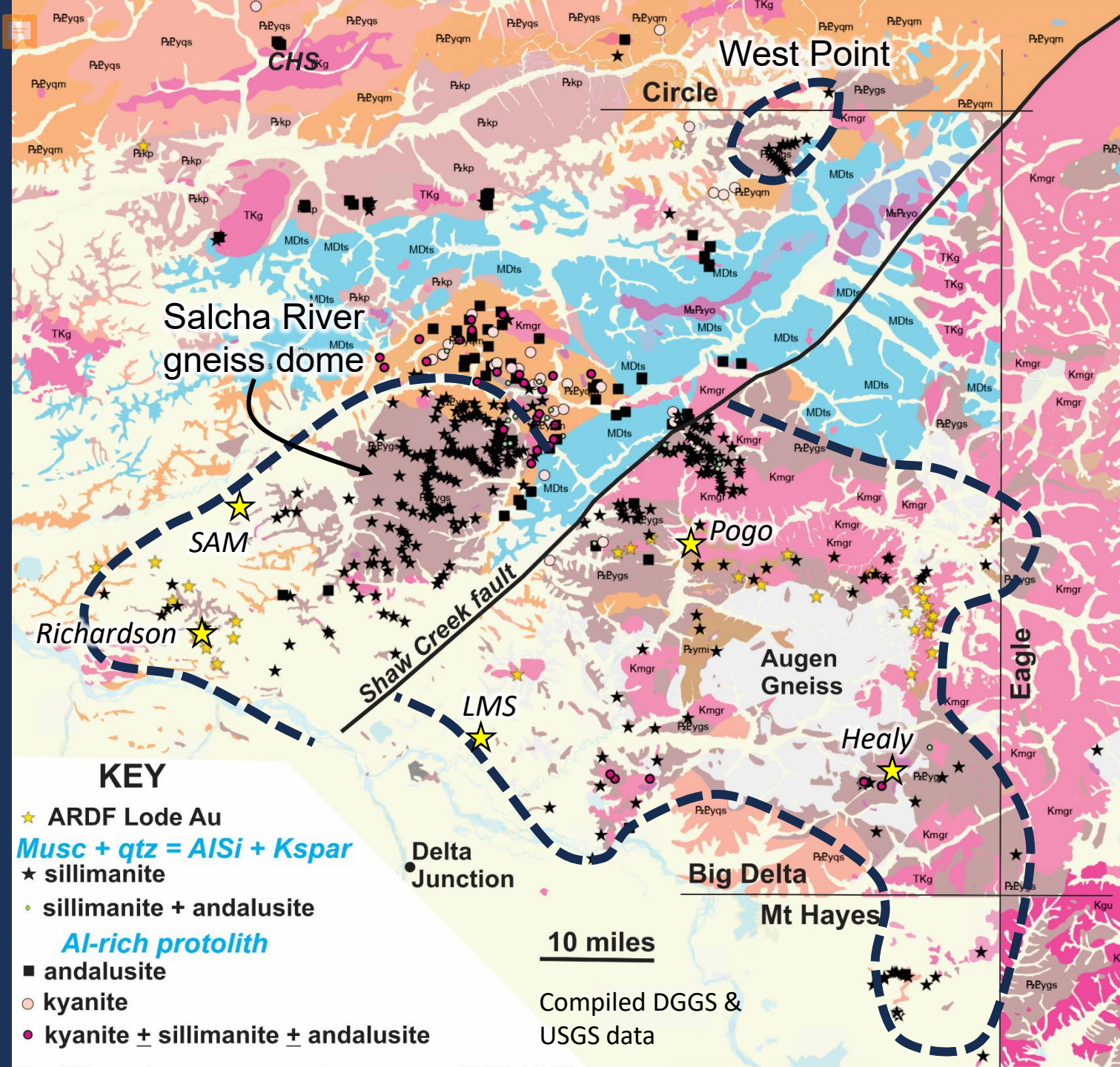


Mt. Harper – Richardson mapping update

- Black Mountain Tectonic Zone is a major geophysical boundary
- Mapped by Day et al (2007) as en-echelon strike-slip and normal faults
- The BMTZ and Harper-Kechumstuk fault system localize younger volcanic rocks
- Apatite fission track study (Izzy Muller PhD candidate at University of Texas)



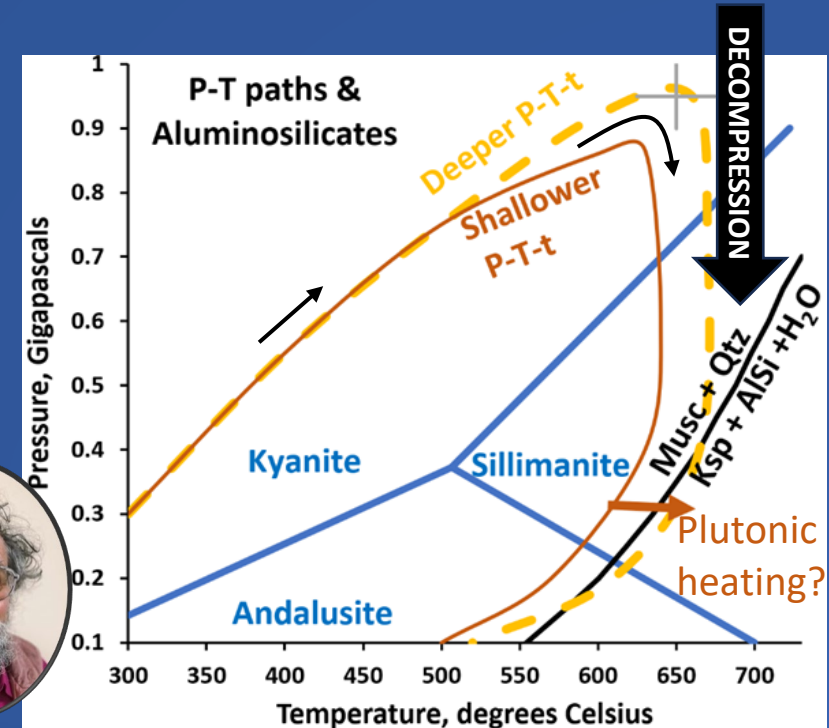
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Quartz porphyry		



Aluminosilicate minerals

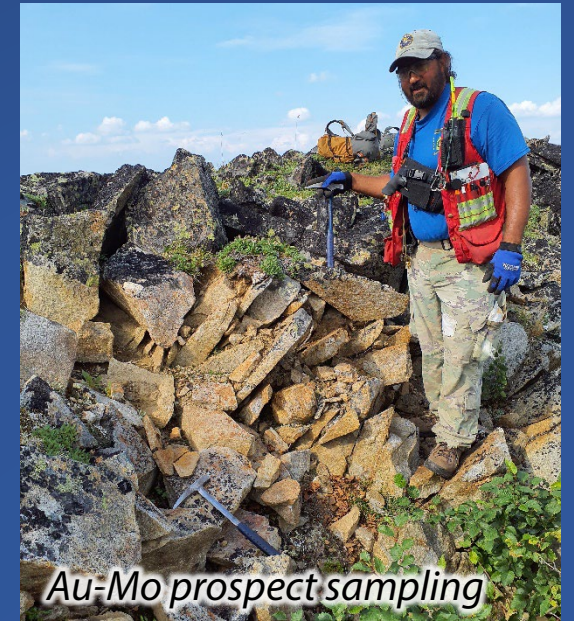
Map patterns determined by:

- Rock composition, and
- P-T history
- Isolated areas high-Al rocks
- Broad area of musc. → sillimanite
- Timing: ~117 Ma? Predates gold, but there is a spatial relationship?



Visit our website and booth dgggs.alaska.gov

- *Recently released data:*
 - *N. Kuskokwim fixed-wing mag-rad*
 - *2022 Mt. Harper-Richardson geochemistry*
 - *2022 Mt. Harper-Richardson field station data*
 - *Tanacross-Taylor Mtn U-Pb zircon ages*
 - *Moran project U-Pb zircon ages*
- *Coming soon:*
 - *N. Kuskokwim gravity (early 2024)*
 - *N. Kuskokwim helicopter mag-rad (early 2024)*
 - *2023 Chena-Pogo-Harper field station data*
 - *2023 Chena-Pogo-Harper geochemistry*
 - *2022 Mt Harper-Richardson U-Pb, Ar/Ar ages*
 - *Tanacross-Taylor Mtn. Ar/Ar ages (pending)*
- *Earth MRI geochemistry online (2 options)*
 - *Via DGGGS Exploration Geochem Web App*
 - <https://mrdata.usgs.gov/earthmri/geochemistry/>



Au-Mo prospect sampling



Mt. Harper tungsten skarn prospect

Join Us!

- *Soon-to-be recruiting: Mapping Geologists background in economic geology, hard-rock geology*
- *Watch Workplace Alaska for announcement*
- *Industry partners for upcoming magnetic-radiometric surveys in the Kuskokwim Mineral belt*

Contact Us:

evan.twelker@alaska.gov

abraham.emond@alaska.gov

