DGGS Geological Investigations in Western Wrangellia

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Base and precious metal deposits geologically associated with Late Triassic mafic to ultramafic magmatism constitute a significant metallogenic province of the northern North American Cordillera. Deposits of signficance include the Wellgreen magmatic Ni-Cu-Co-PGE sulfide deposit in the Yukon Territory and bonanza-grade sediment-hosted Cu-Ag systems at Kennecott. In central Alaska, this magmatic event comprises the Nikolai Greenstone and cogenetic mafic and ultramafic intrusions of the Wrangellia terrane. Notable mineralization includes magmatic Ni-Cu-PGE mineralization at the Eureka Zone and Butte Creek prospects, and sediment-hosted Cu-Ag mineralization at the Caribou Dome deposit.

Through the State's Strategic and Critical Minerals Assessment Project and the United States Geological Survey's STATEMAP Program, the DGGS has pursued a multi-year effort to improve the geological knowledge base with an emphasis on the geologic setting of Ni-Cu-PGE mineralization. Newly released data include geophysical surveys (GPR 2014-1), geochemistry (RDF 2014-3; RDF 2014-5, RDF 2014-22), geochronology (RDF 2014-18, RDF 2015-10), and geologic mapping (PIR 2015-6). All reports are available free of charge from the DGGS website (dggs.alaska.gov).

Building on recent advances in the geochemical understanding of the Wrangellia volcanic stratigraphy, we have used geochemical classification and targeted fieldwork to refine the geologic maps of the area. Additionally, geochemical data and field relationships have enabled us to better establish the relationship of mineralized ultramafic intrusions to the broader Late Triassic magmatic episode.

Integrated geological and geophysical interpretation of newly generated data illuminate a number of previously unmapped faults, with significant implications for the structural framework of the region and the general distribution of lithologic units under cover. These structures reflect involvement in the Cretaceous accretion of Wrangellia and some of the effects of Tertiary to present dextral transpression, including the ongoing exhumation of the Eastern Alaska Range.

DGGS and the University of Alaska are completing a detailed study of the 30-km long, 3-km wide Alpha (Fish Lake) mafic-ultramafic complex in the Eureka Creek area of the Eastern Alaska Range. This sill-form complex consists of cyclically alternating dunite, wehrlite, and clinopyroxenite and has been variably interpreted as a layered mafic intrusion, a differentiated mafic-ultramafic complex, and as a multiphase complex of sills and possibly ultramafic volcanic rocks.

Geologic mapping shows that the igneous complex has four major peridotite sills, the longest of which can be traced out for over 2 km along strike. Centimeter scale clinopyroxenite layers are present within and along the edges of the peridotite sills. Multiple gabbroic dikes locally cut across these sills. Within a given sill, the forsterite component of olivine is most primitive along the edge and becomes increasingly evolved toward the center. Geologic mapping and modal compositional patterns observed in olivine forsterite content across the complex supports a hypothesis of repeated sill injections from an evolving or multiple magma source.

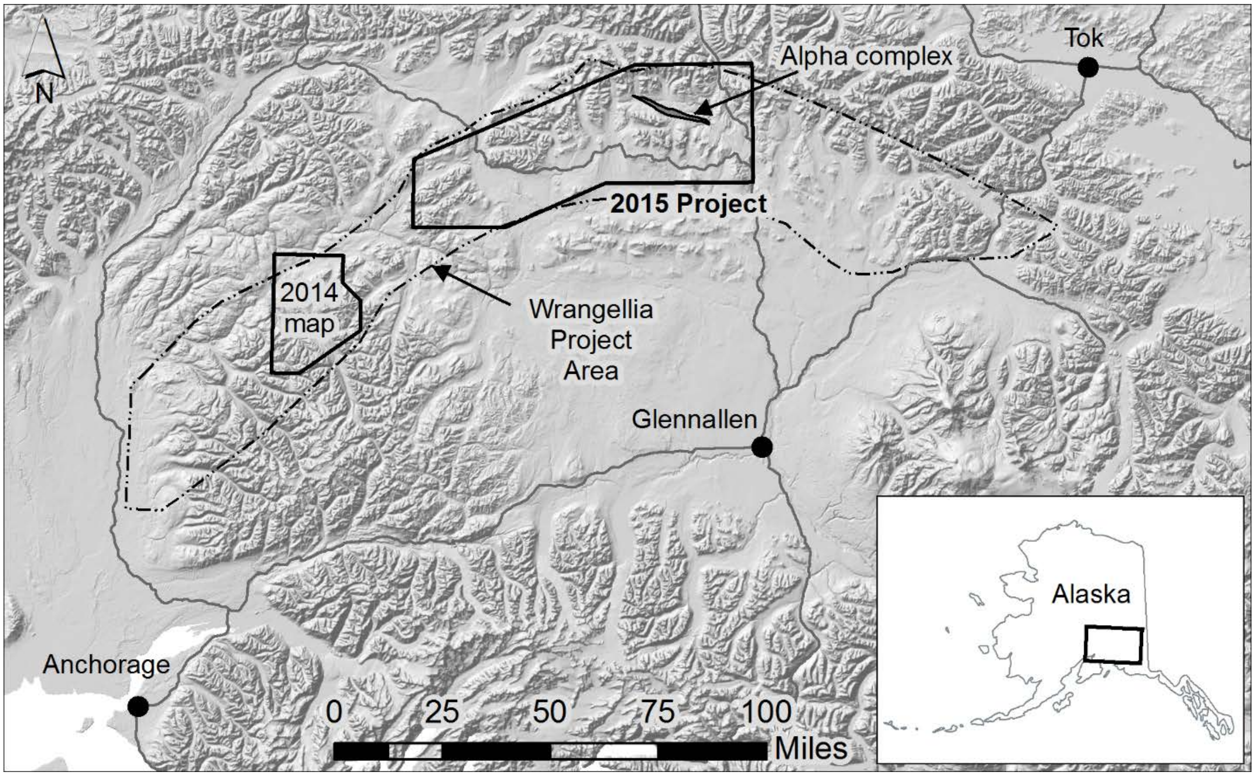

Figure 1. Project location map showing recent DGGS mapping in the Wrangellia terrane of south-central Alaska.

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Building a Geologic Framework for Successful Exploration

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- CIRI and Cook Inlet Region Working Group for 2014 land access
- Brenda Becker at the Glennallen BLM office
- Behind-the-scenes work by the DGGS staff

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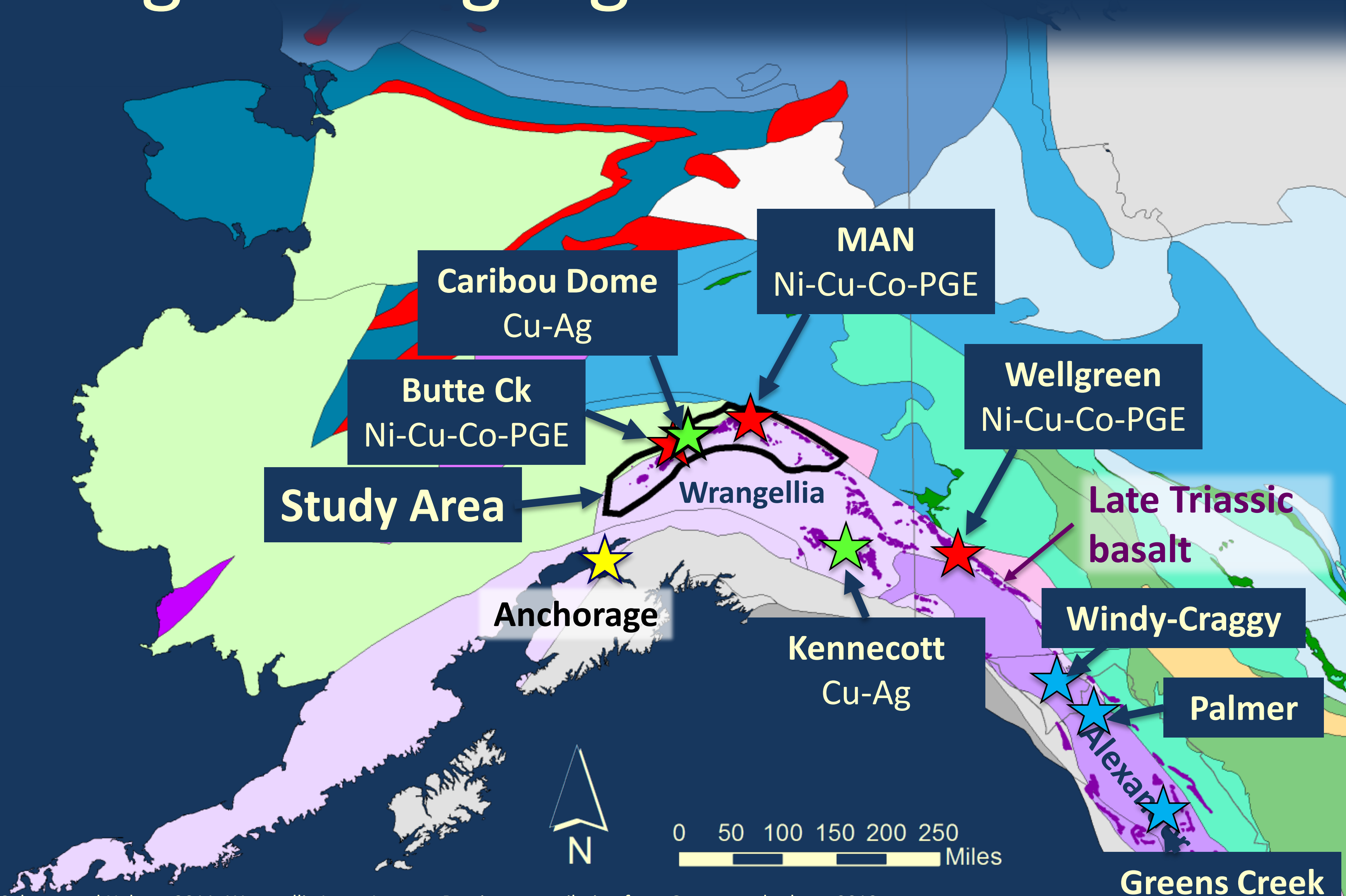
Please Note:

1. This area has complex mineral and surface estate ownership including State of Alaska, Federal Bureau of Land Management, Cook Inlet Region Inc. (CIRI) and associated village corporations, as well as other private land owners. The user of this data is responsible for all land status research and for obtaining appropriate access and operating permissions prior to completing any follow-up field work.
2. This is a presentation of preliminary results and an early draft of the geologic map. Neither the draft map nor the presentation have been reviewed for technical content or for conformity to the editorial standards of the DGGS

Metallogenic Context: Late Triassic Wrangellia Large Igneous Province



Terrane Map of Colpron and Nelson, 2011; Wrangellia Large Igneous Province compilation from Greene and others, 2010

What is the “Geological Framework”?

Wrong question:

- “What is the rock type at location X?”

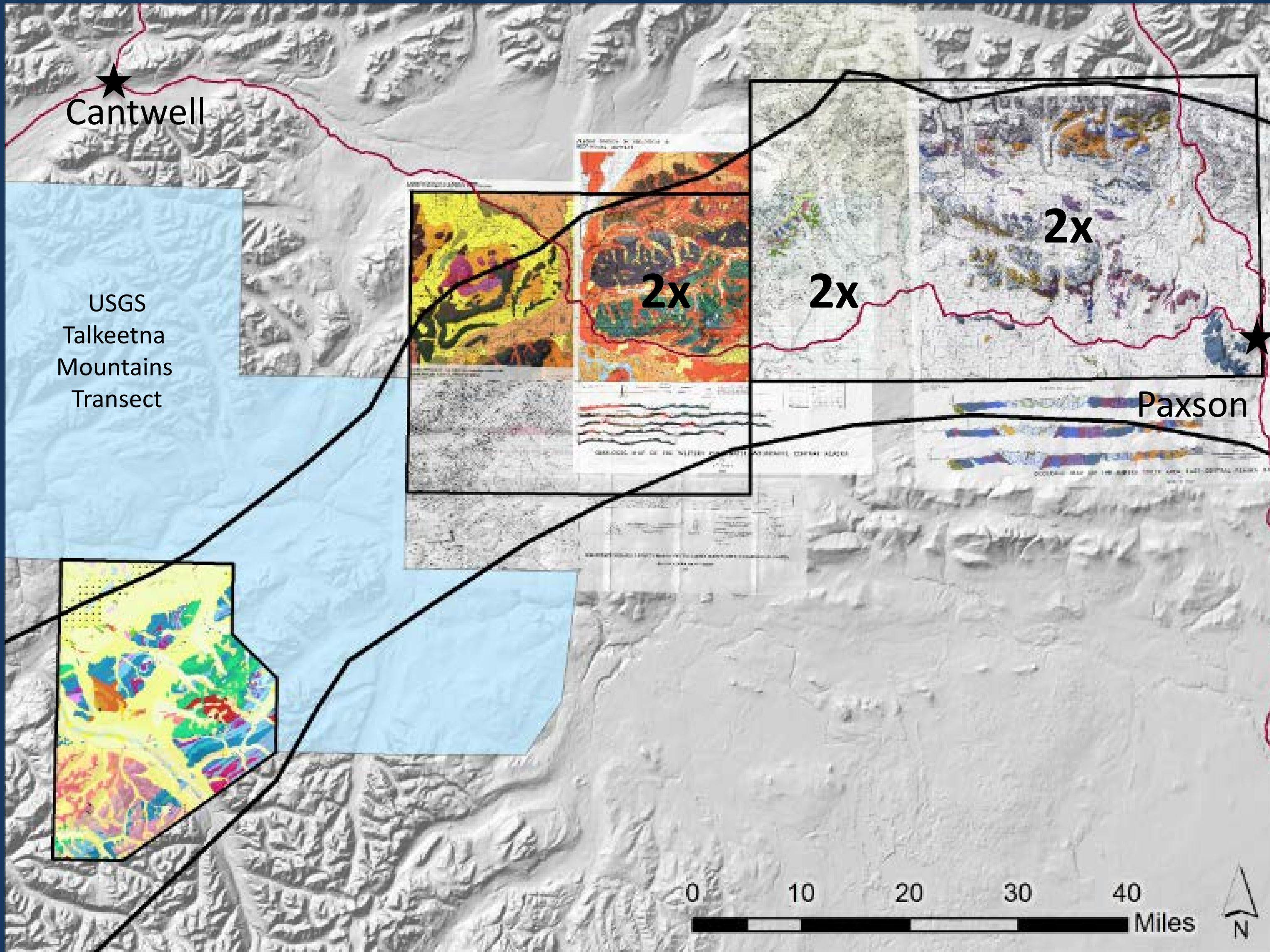
Right questions:

- **What** are the important geologic elements?
- **Where** do these geological elements occur?

→*For a given mineral deposit type*

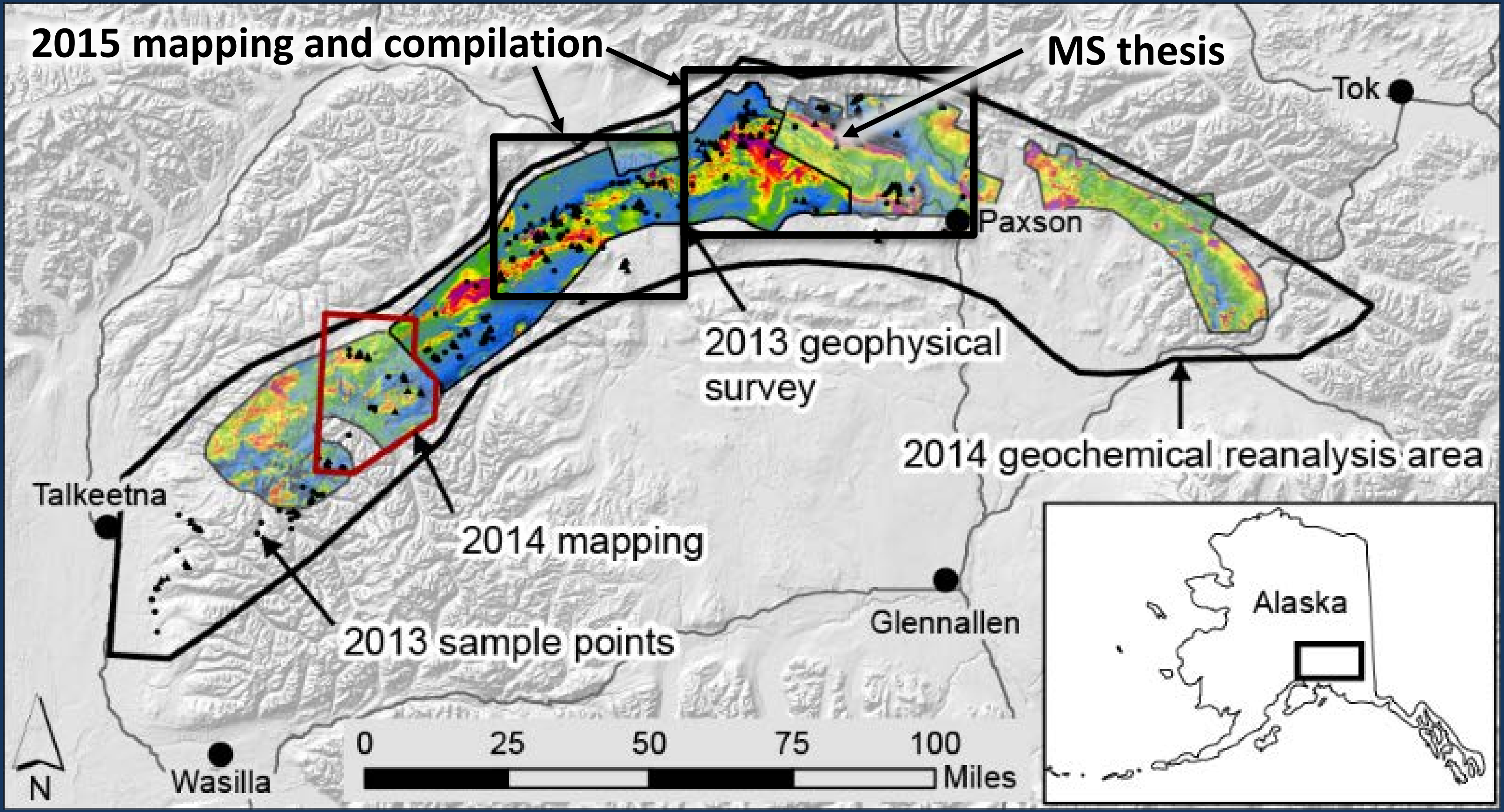
Different from traditional mapping:

- Targeted work at a variety of scales
- Incorporate new industry and academic data
- Use geophysics to project under cover
- More adaptable to different budget scenarios



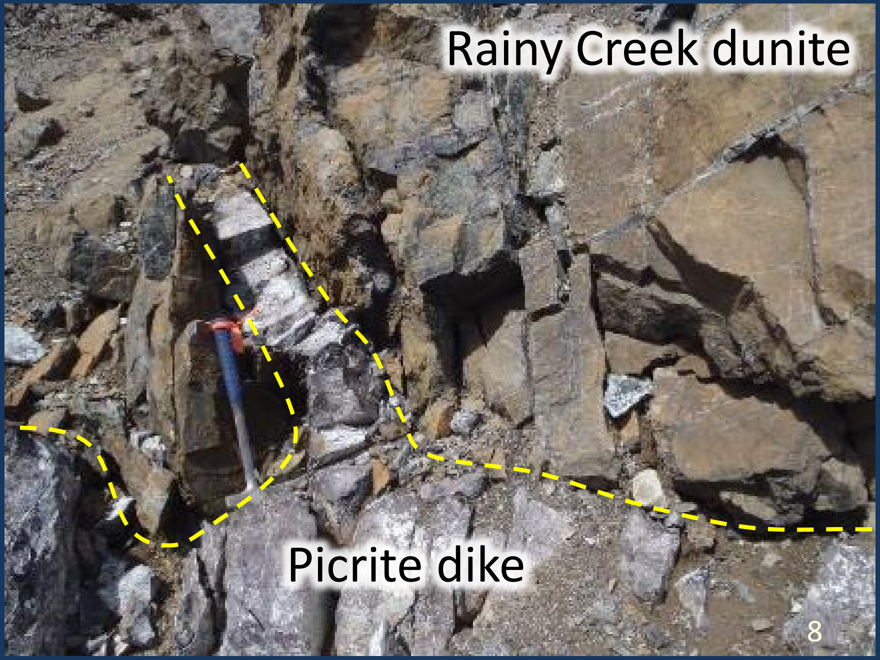
The area *is* covered by inch-to-mile geologic mapping (but there is a wide range of vintage, quality)

New data: visit dggs.alaska.gov



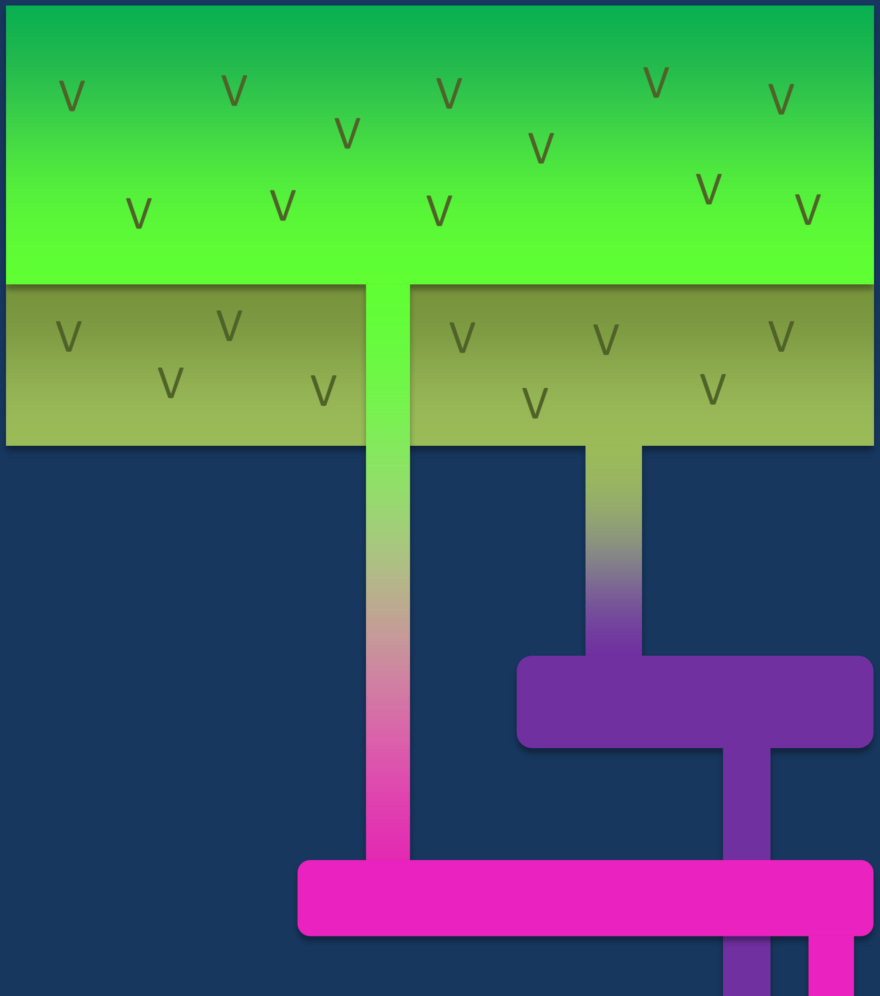
- New airborne magnetic and electromagnetic survey
- Geochemistry and geochronology raw data releases
- Targeted geologic mapping and research
- Compilation and interpretation

Elements of the Late Triassic
Magmatic Framework



The Wrangellia Large Igneous Province
A two-part magmatic event

Building on academic work by Andrew Greene (2008, 2009, 2010)



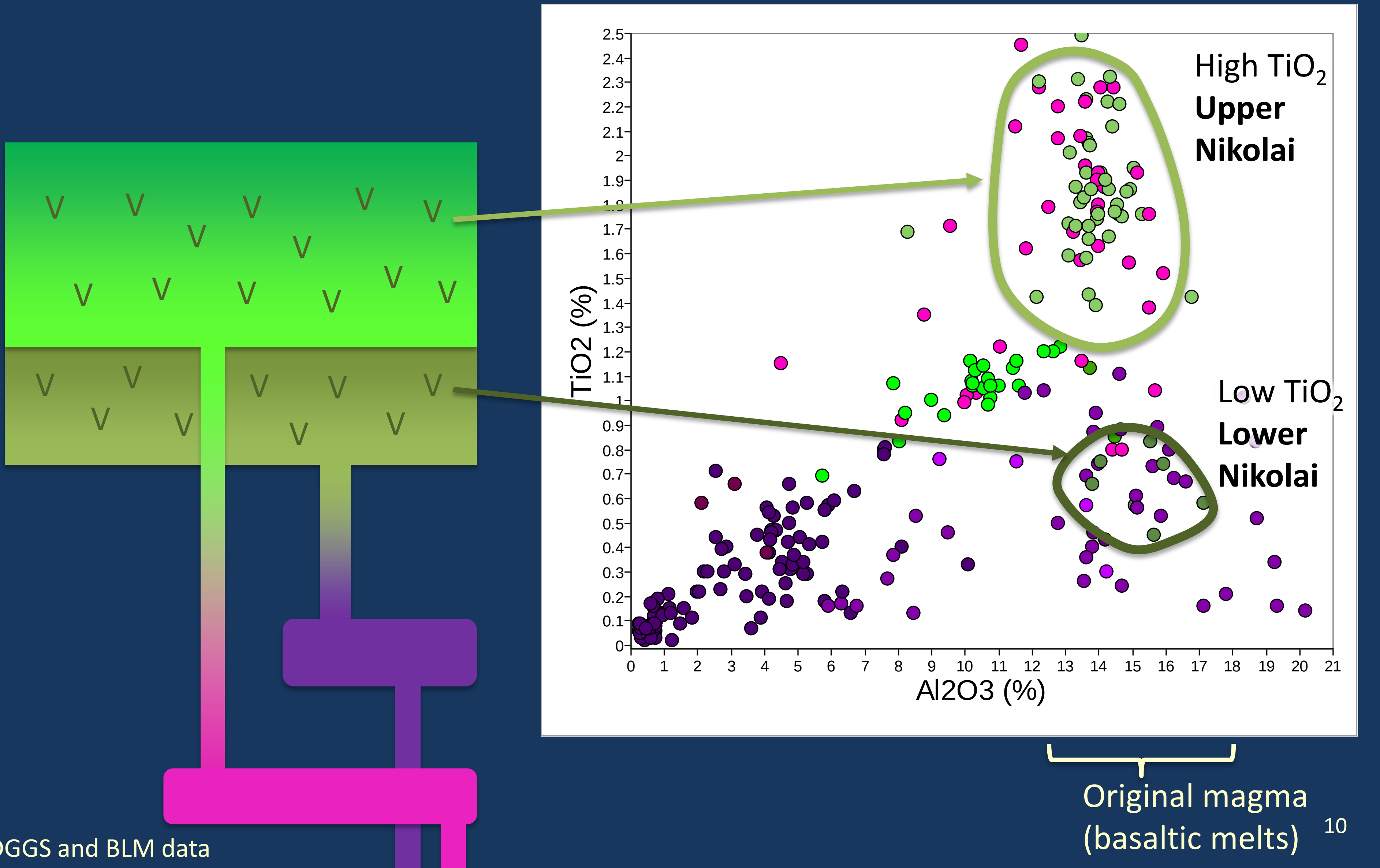
Upper, high TiO_2 Nikolai Greenstone:
- 'Normal' flood basalts
- → High magnetic susceptibility (~**10** $x10^{-3}$S

Lower, low TiO_2 Nikolai Greenstone:
- Arc lithosphere involved
- Low magnetic susceptibility (~**0.5** $x10^{-3}$SI)

Gabbro to ultramafic sills
→ feeding Lower Nikolai

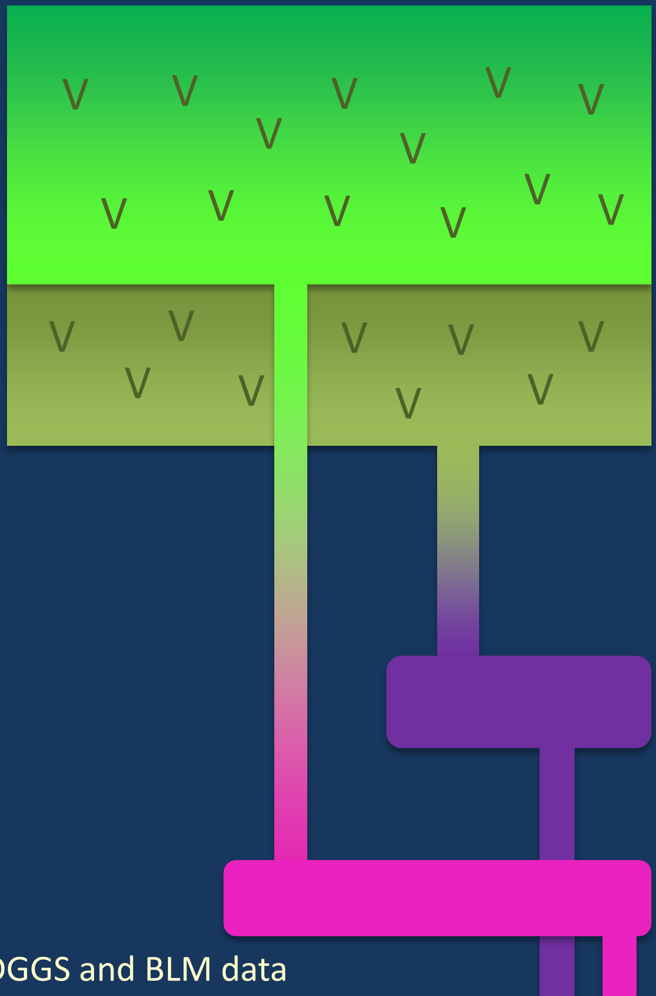
Gabbro to ultramafic sills
→ feeding Upper Nikolai

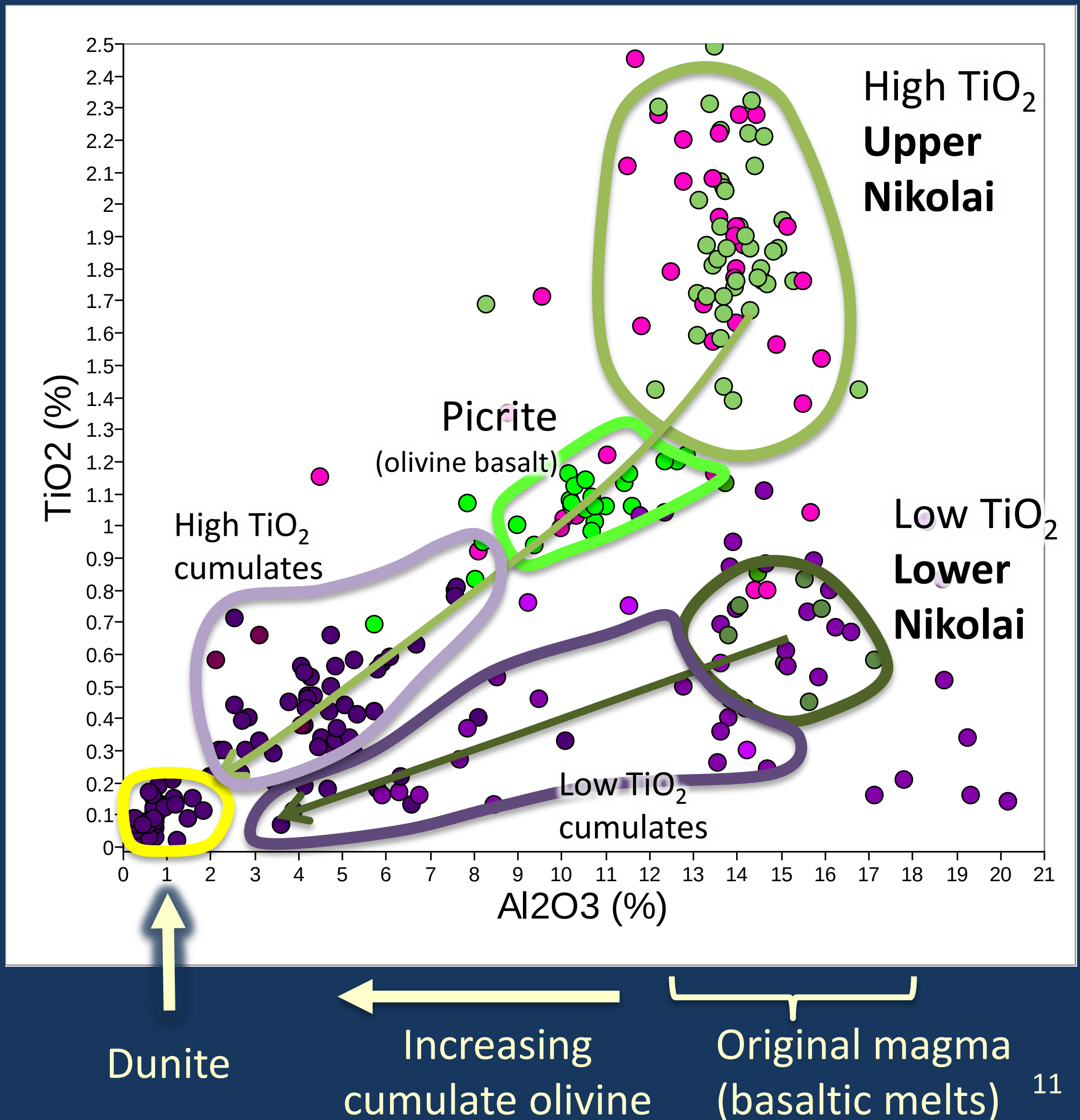
Magmatic framework: Two distinct mafic magmas



DGGS and BLM data

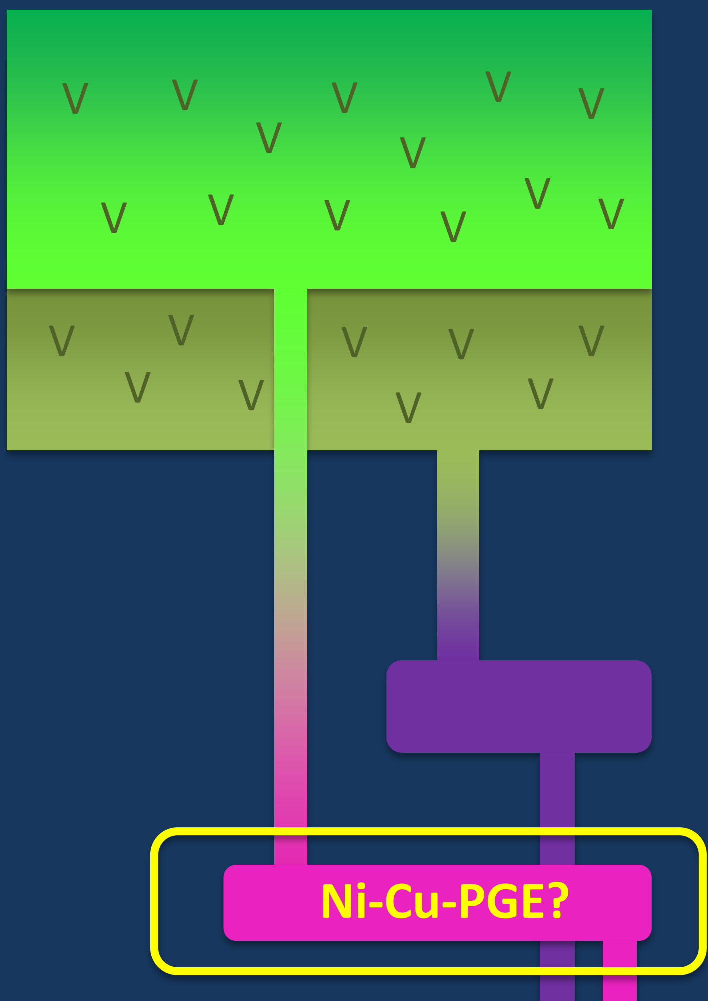
Magmatic framework: Two distinct mafic magmas

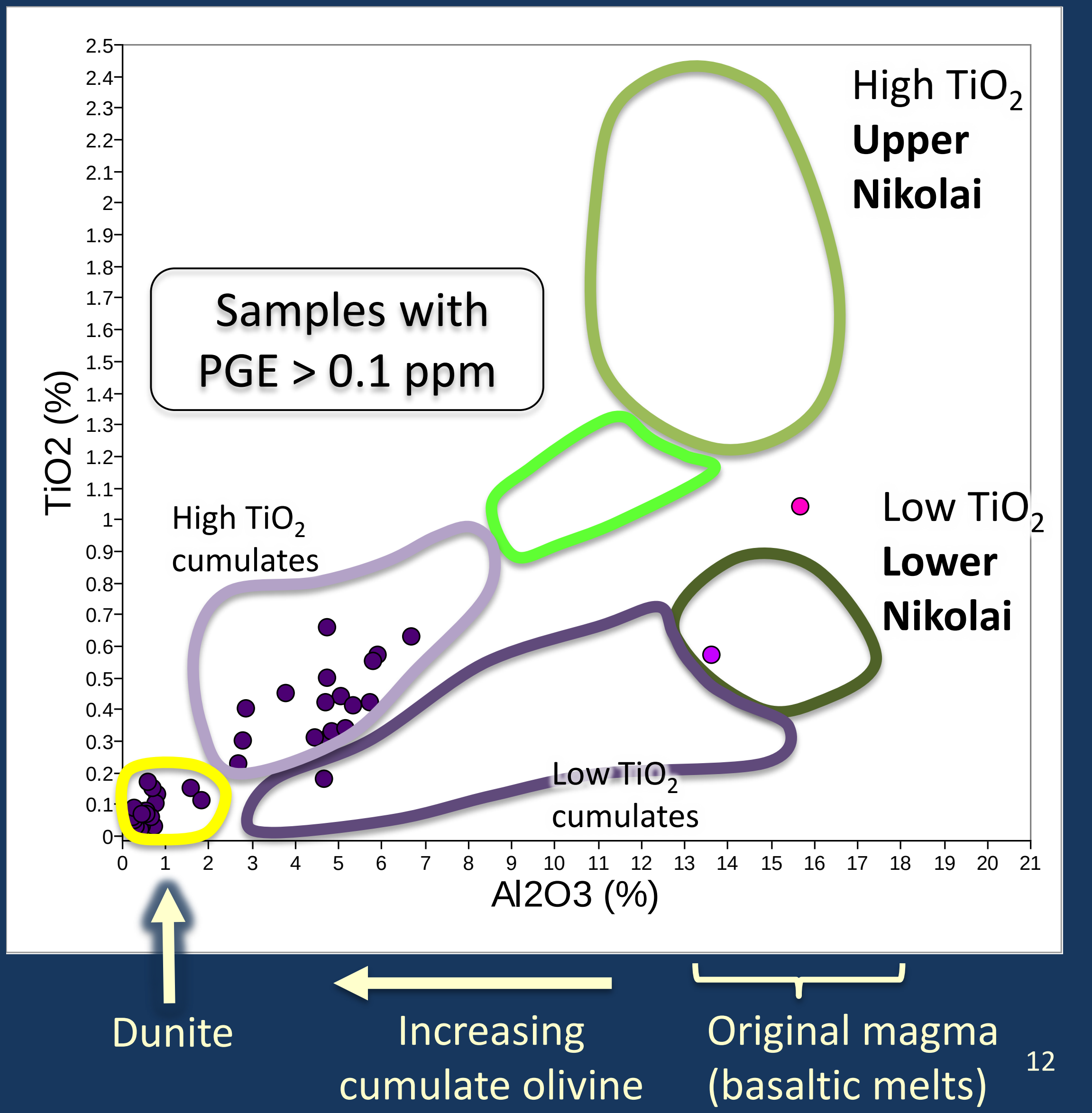




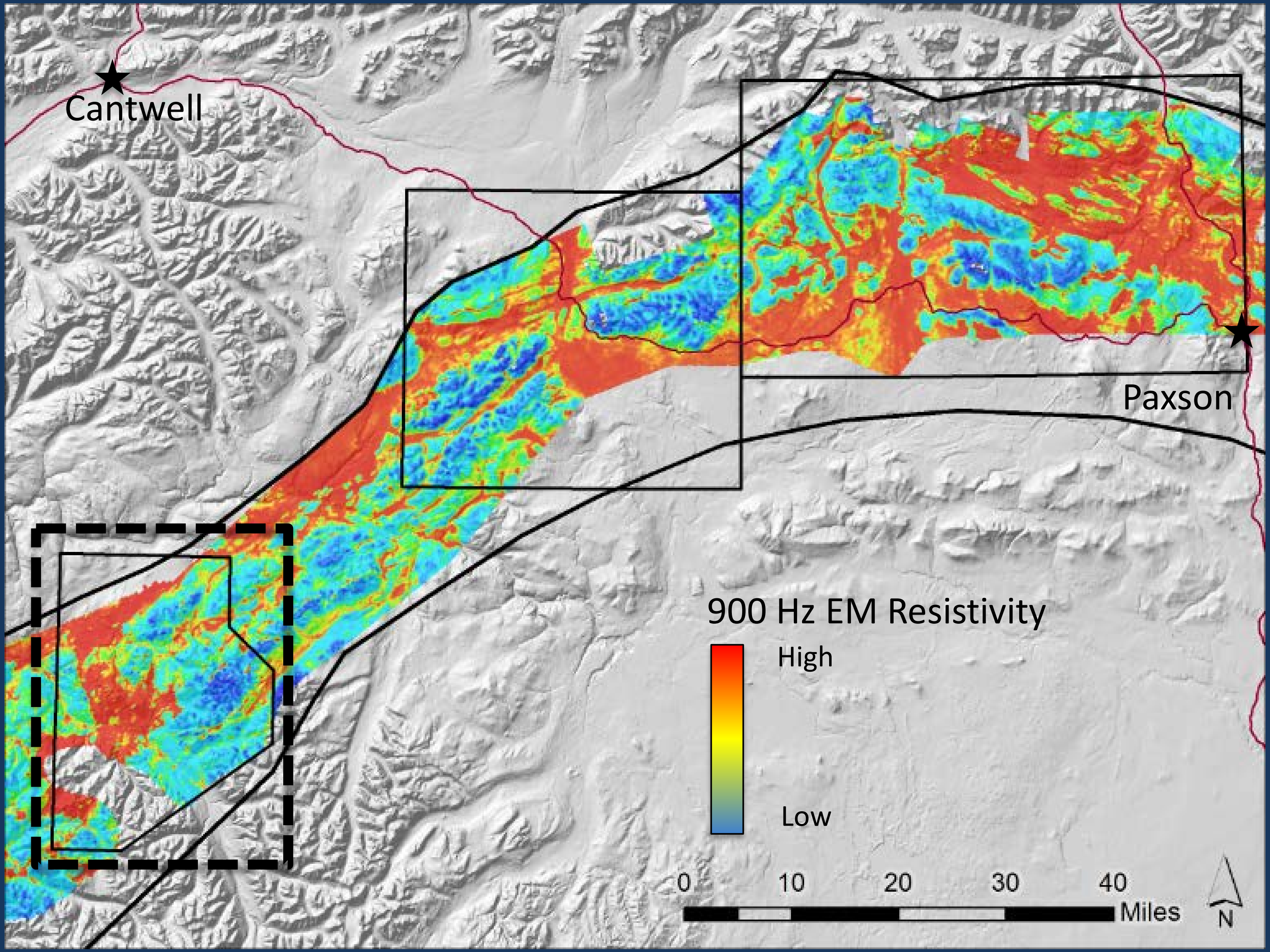
DGGS and BLM data

Magmatic framework:
Implications for magmatic sulfide exploration



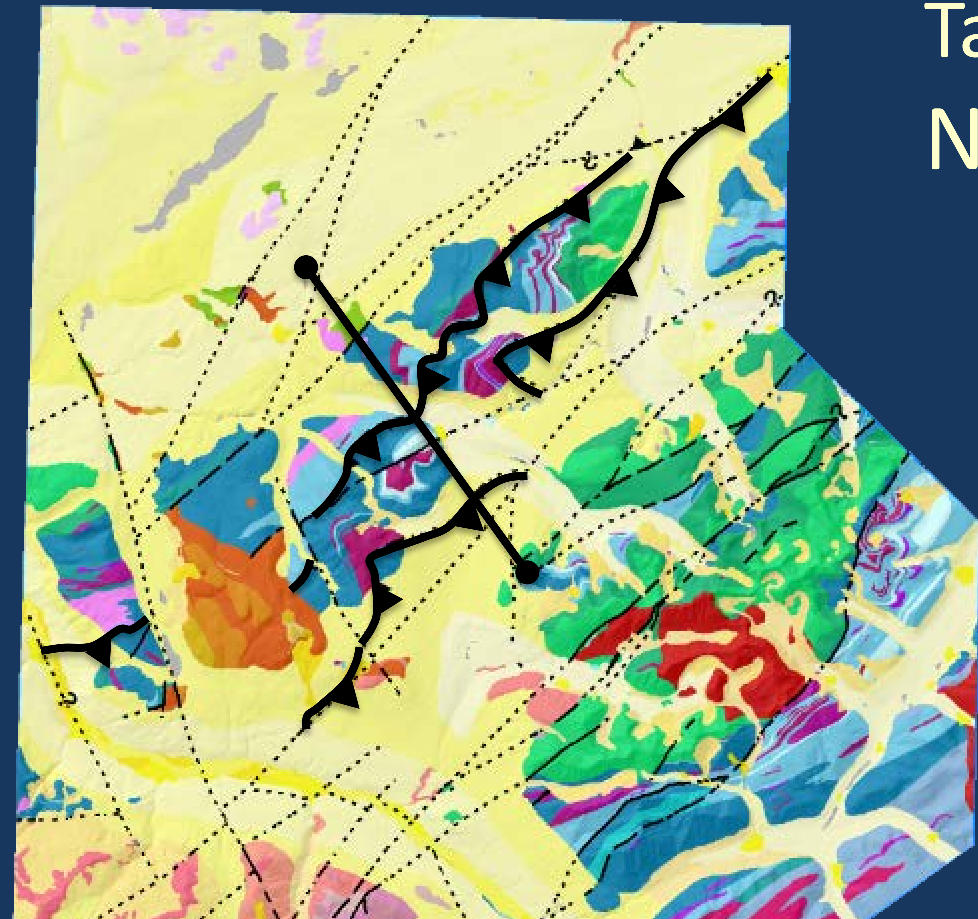


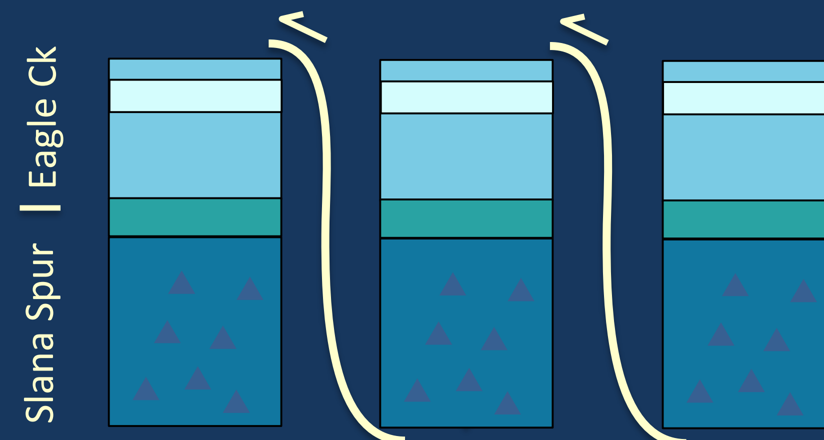
Structural Architecture

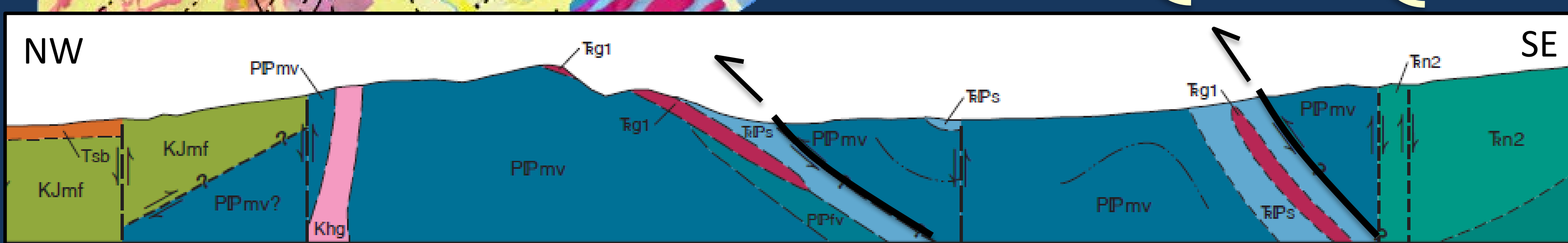


Talkeetna Mountains: NW-directed thrusts

- Paleozoic section is too thick
  - > 5 km as mapped
- Stratigraphic repetition



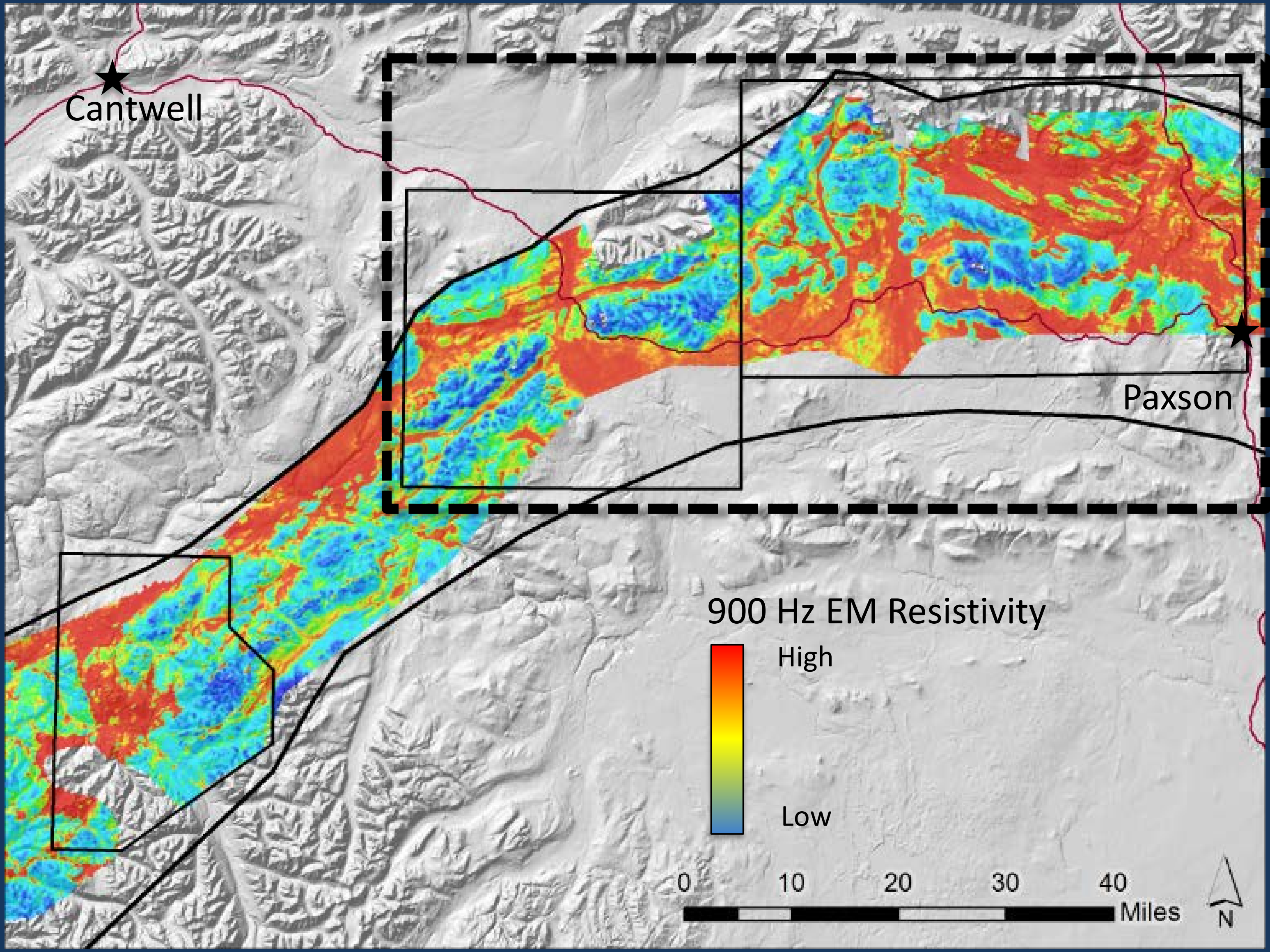




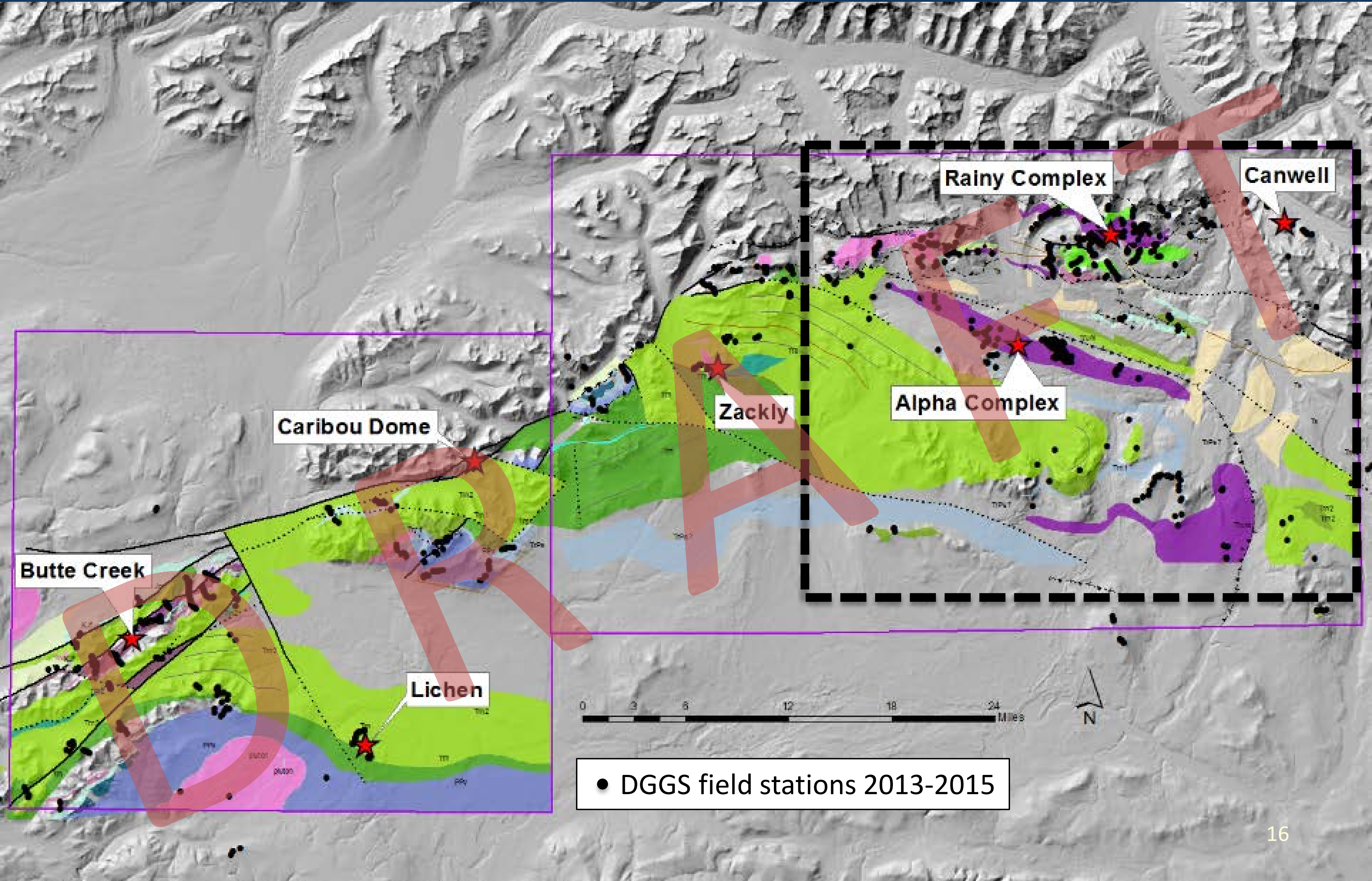
Preliminary map released!

Online at dggs.alaska.gov

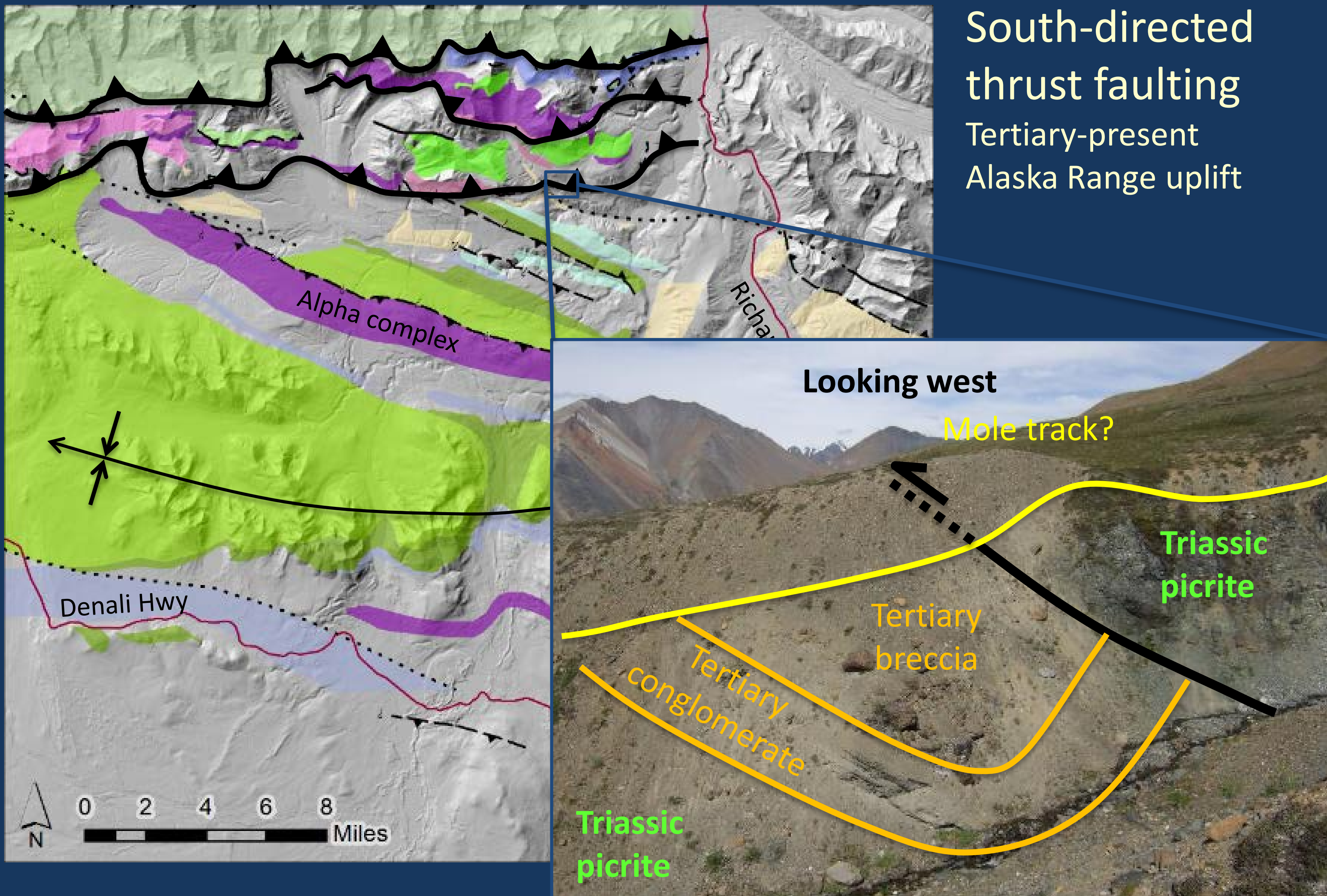
Structural Architecture



A new mineral district map *(in progress….)*
New mapping, compilation, and geophysical interp



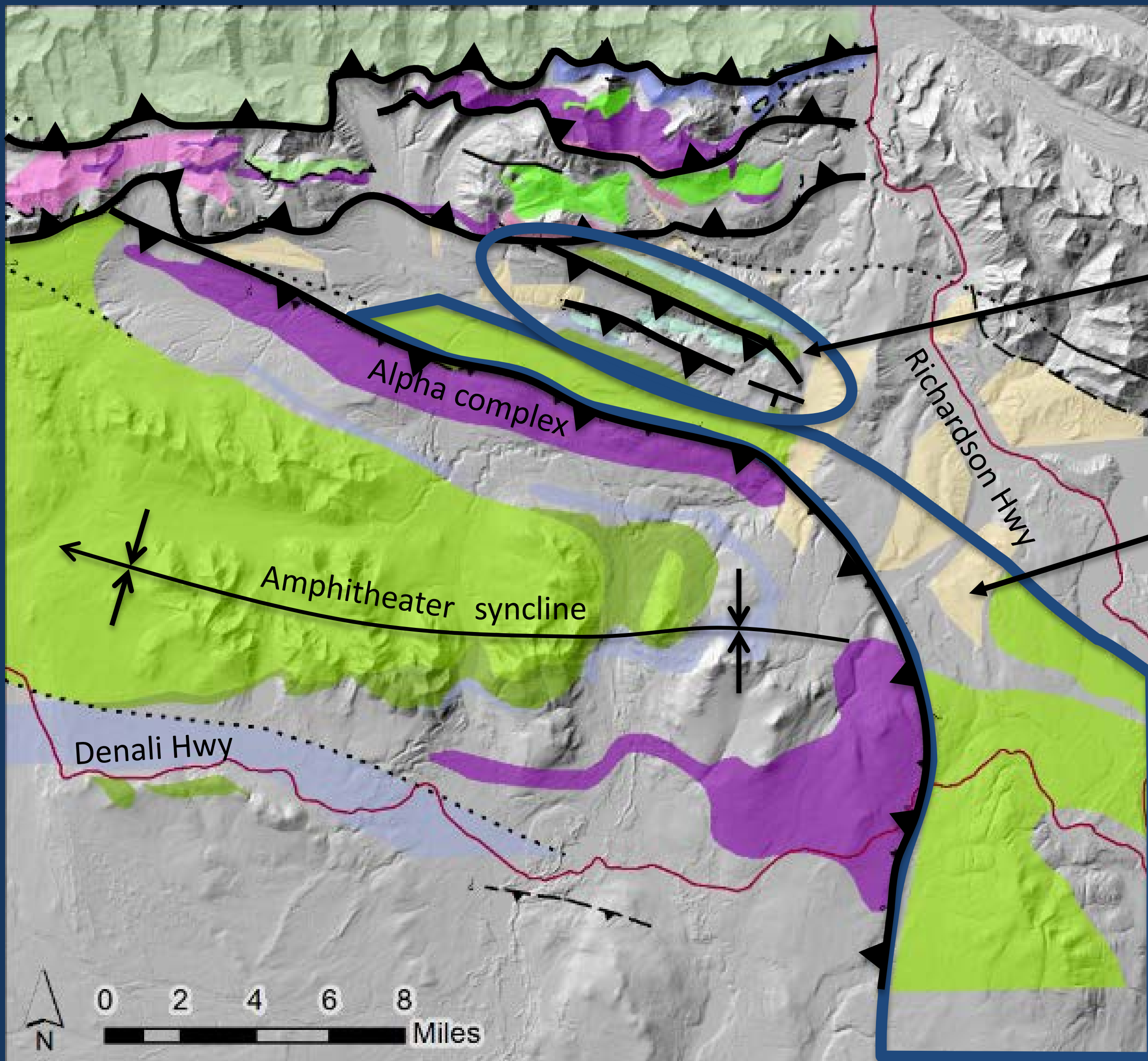
Amphitheater Mtns Structure



South-directed thrust faulting

Tertiary-present Alaska Range uplift

Amphitheater Mtns Structure

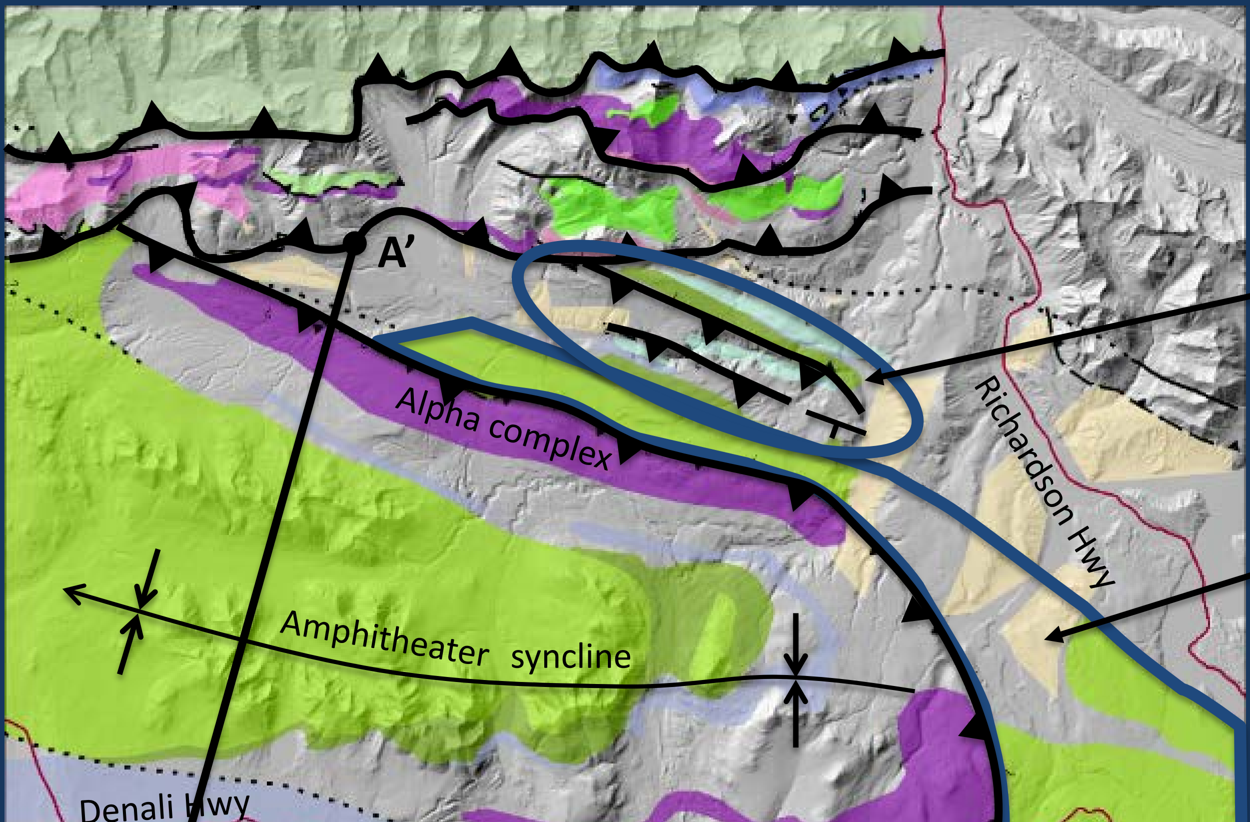


NW-striking faults cut by thrusts

Stratigraphic repetitions, faults, 40-60° dips to S

Map pattern: Nikolai *underlies* ultramafic sills

Amphitheater Mtns Structure



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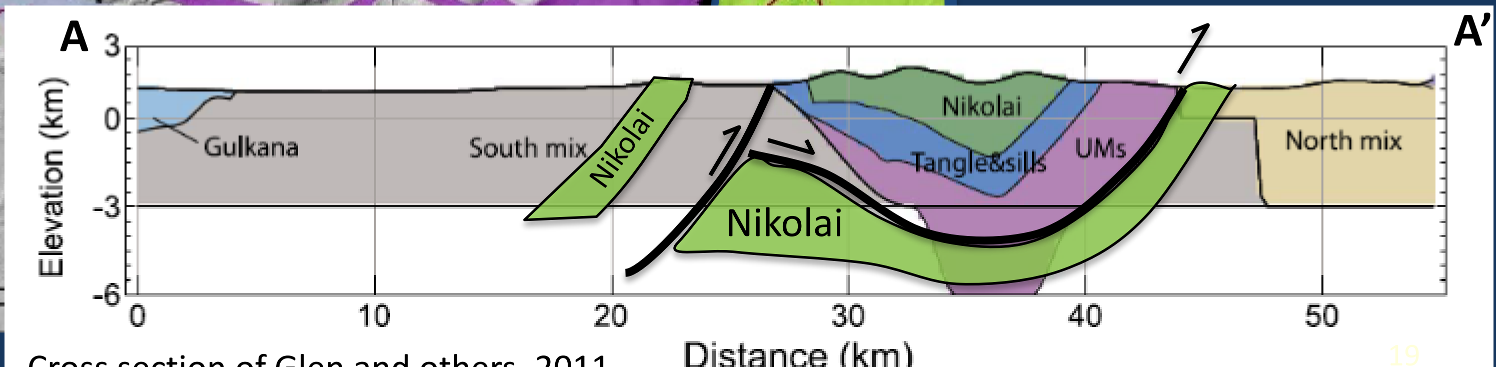
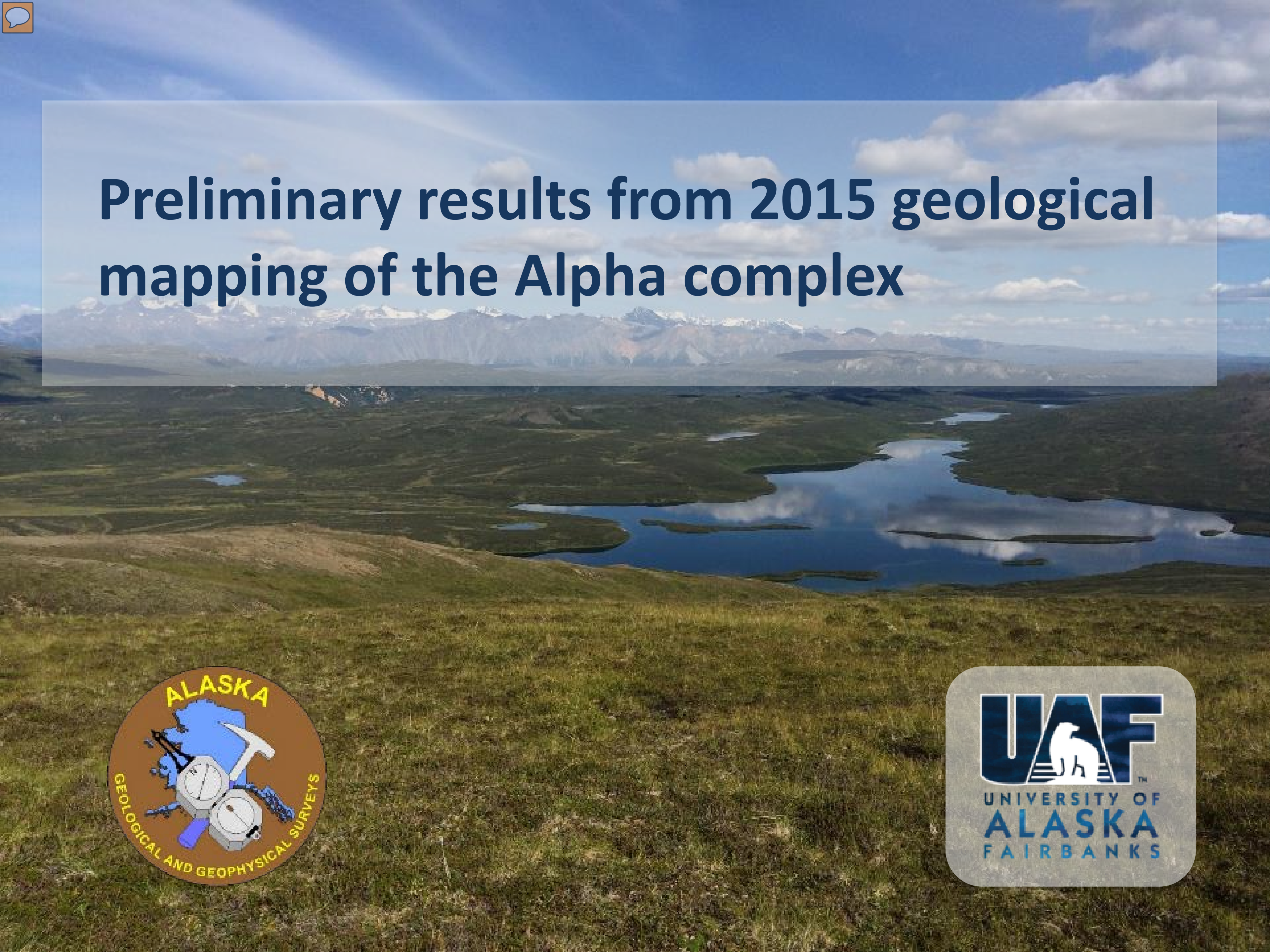


Cross section of Glen and others, 2011

Conclusions

- Early, north-directed thrust faulting may affect Wrangellia more than previously thought
- The Ni-Cu-PGE mineralized samples appear to be related to the high TiO_2 suite, although some large ultramafic bodies appear to be of the low-TiO_2 suite
- High-MgO basalts are picrites; they are also tied to the later, high TiO_2 magmatic suite
- Representing the different magmatic suites on maps (in progress) will be an aid to exploration

Preliminary results from 2015 geological mapping of the Alpha complex



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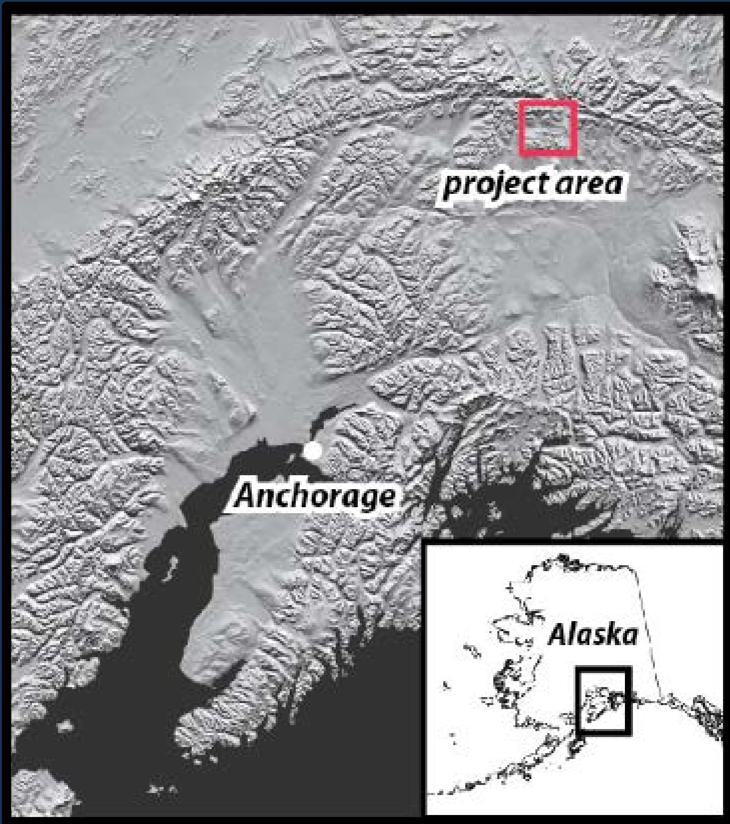
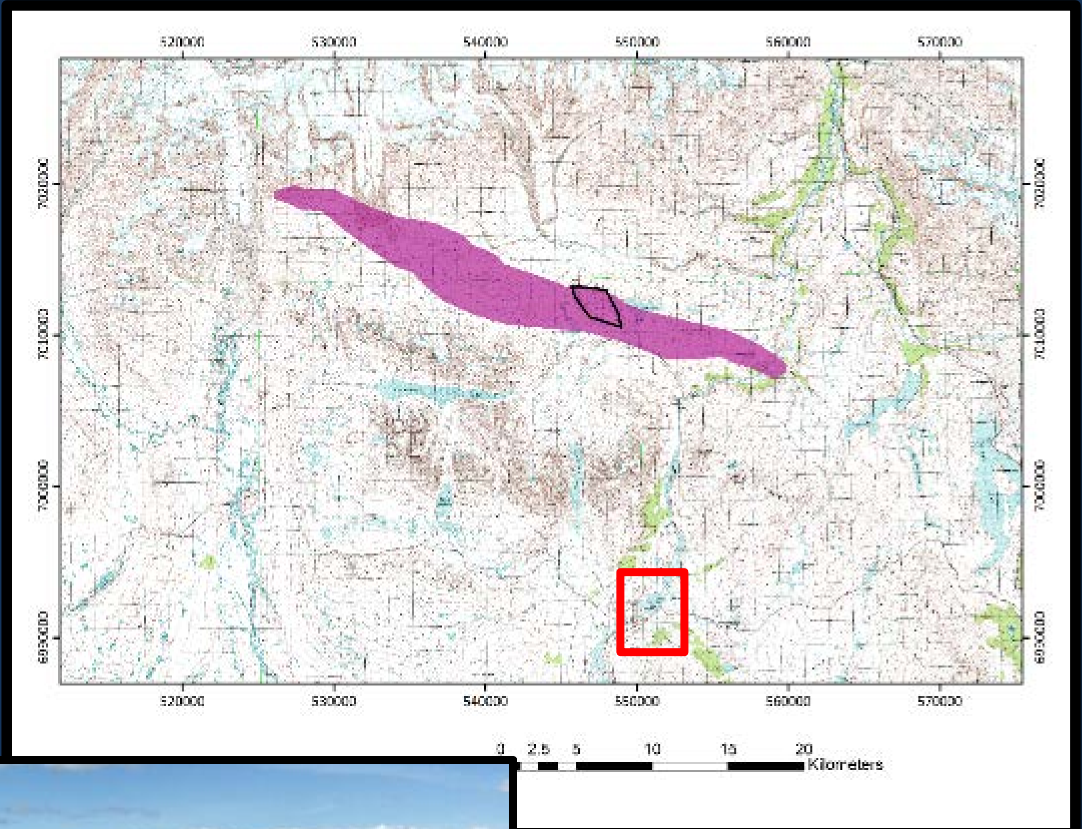
Location: Eastern Alaska Range

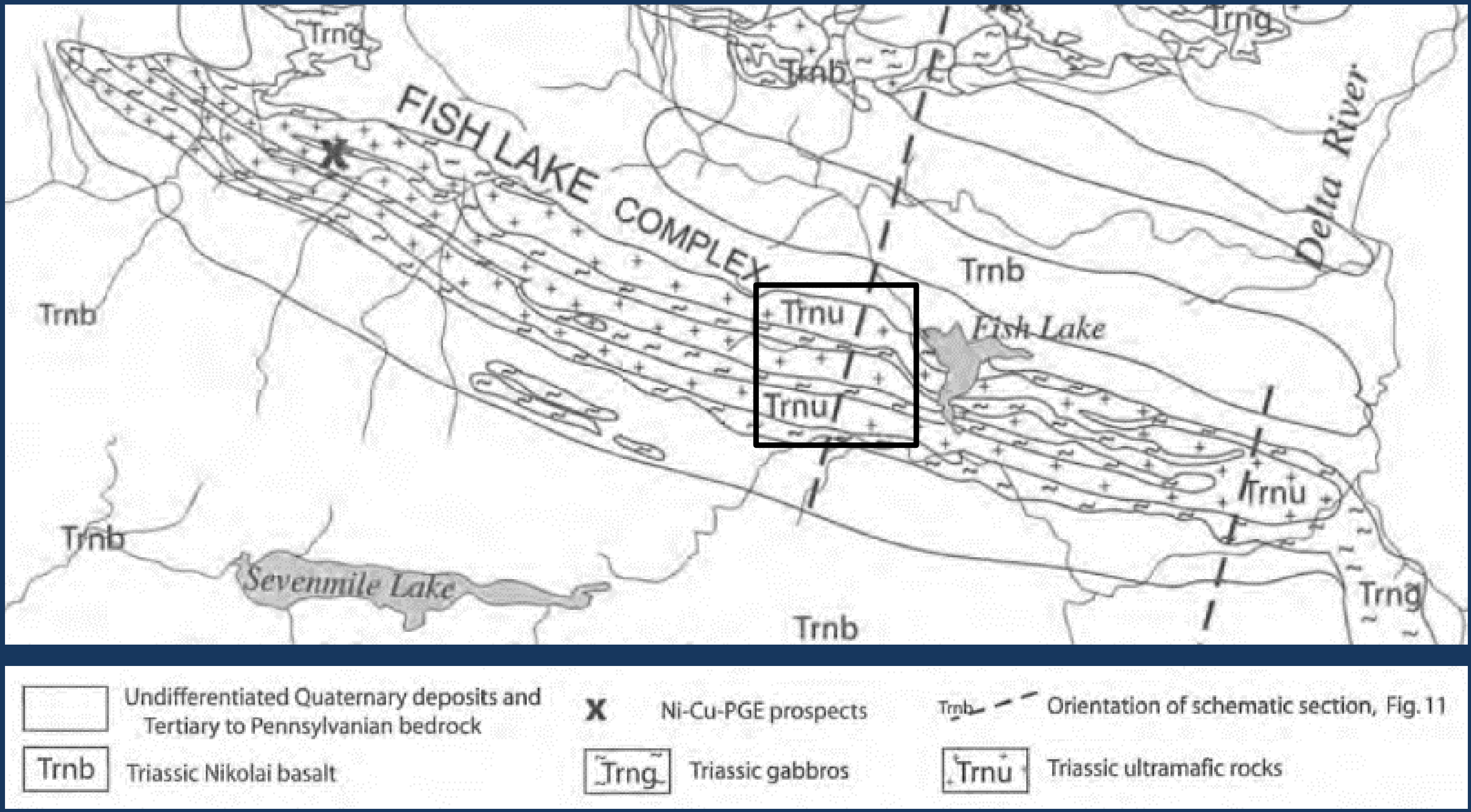




Objectives

Conduct detailed sampling across the field area, focusing on contact relationships between the ultramafics, in order to gain clearer insight into the petrological subdivisions of the complex

Previous Work

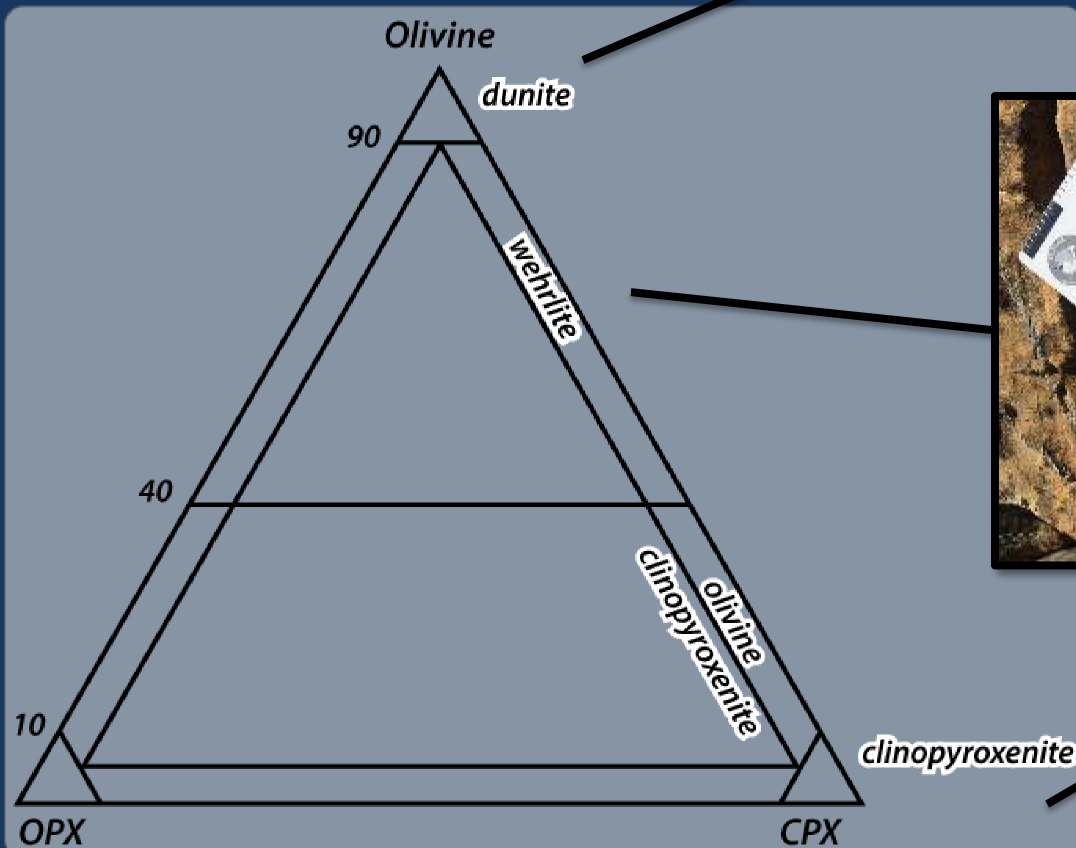


Schmidt and Rogers, 2007

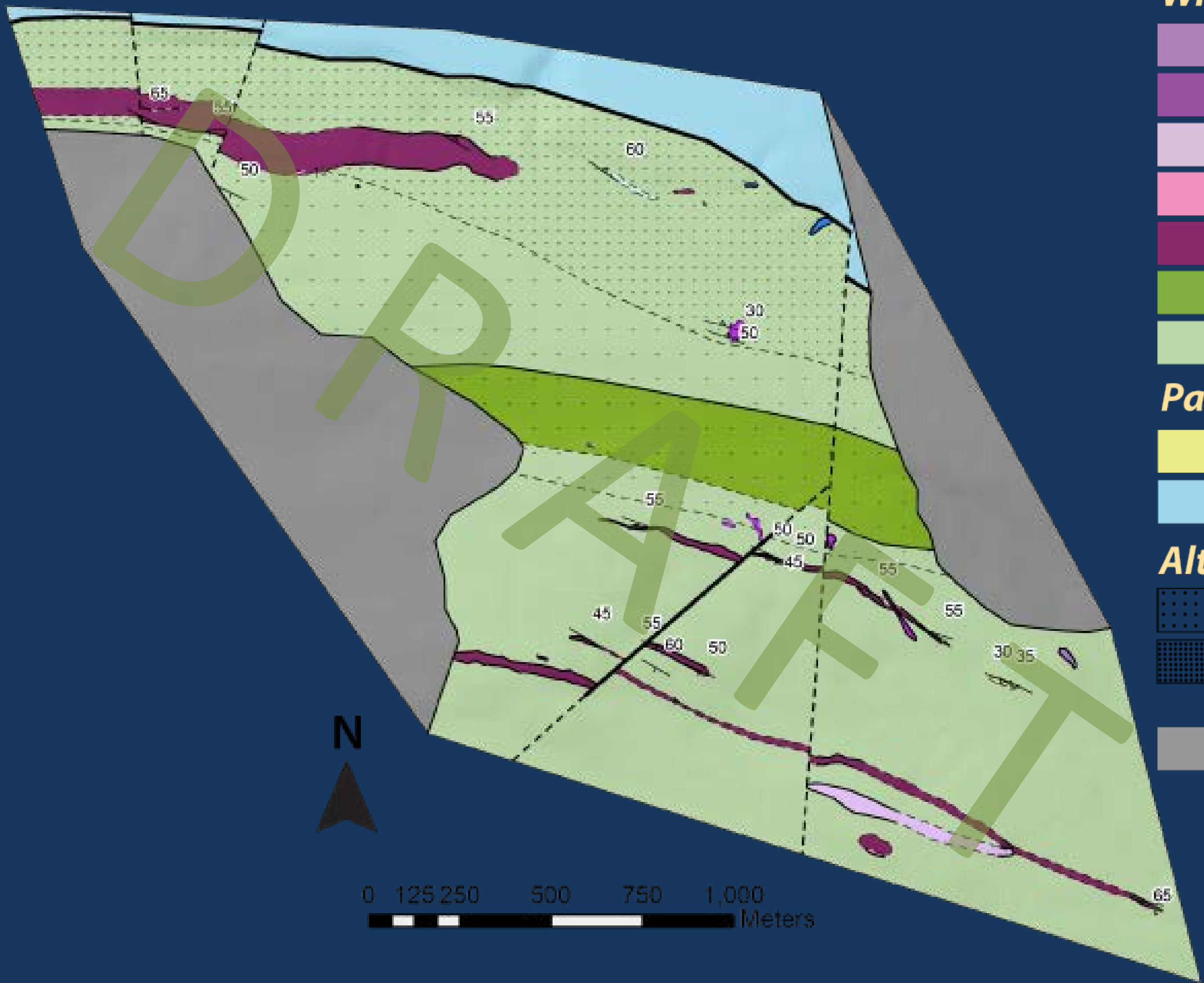
Alpha (formerly Fish Lake) complex

- Triassic age, sill form body
- Intrusion was likely a feeder system to overlying **Nikolai Basalt**

Ultramafic lithologies



Bedrock Geology 1:5,000



Volcanics

- dacite porphyry
- felsic metavolcanics

Wrangellia Terrane

- high-TiO_2 gabbro
- low-TiO_2 gabbro
- troctolite
- clinopyroxenite
- wehrlite
- feldspathic dunite
- dunite

Paleozoic Wrangellia

- schist
- Paleozoic undivided

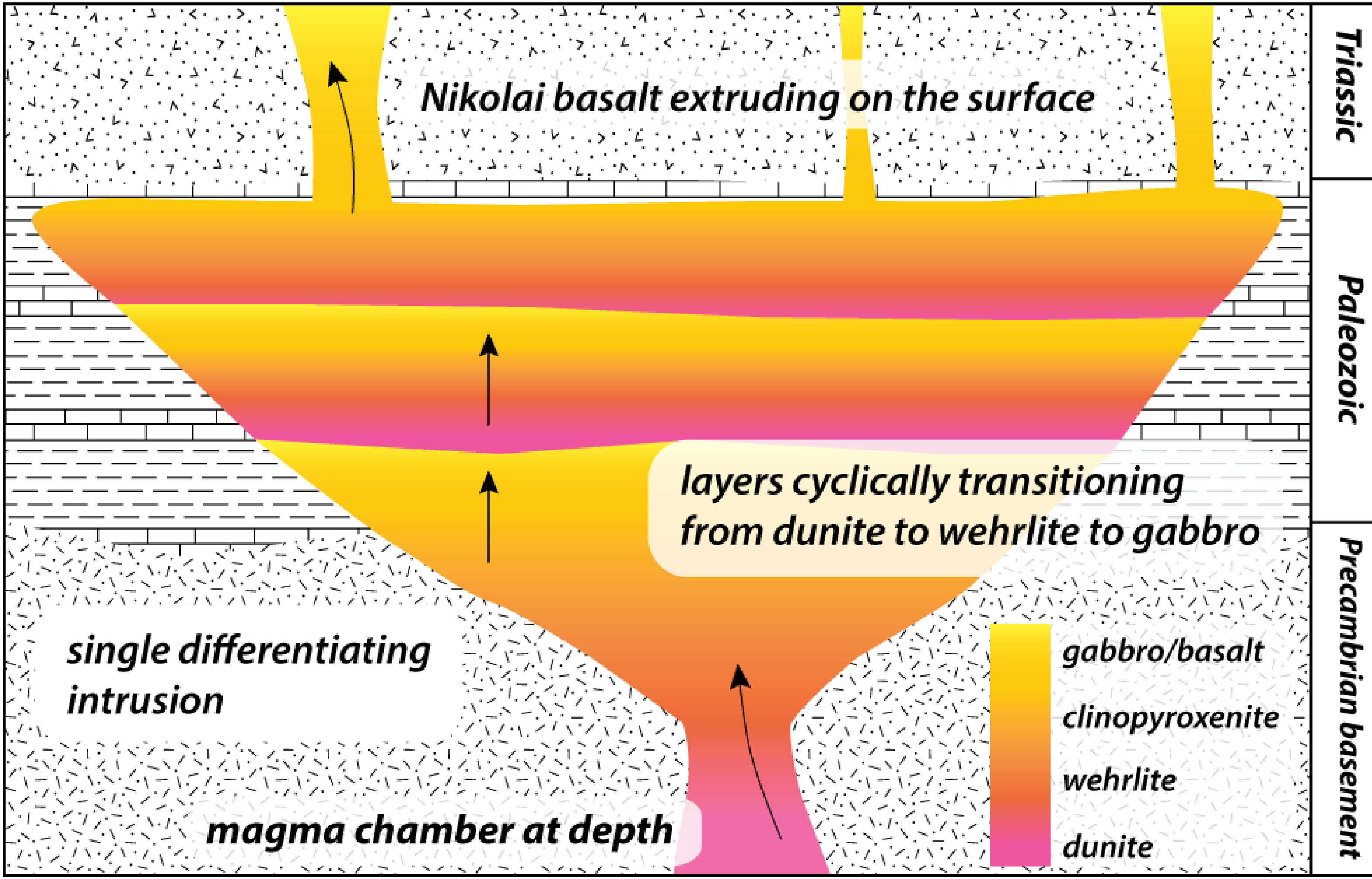
Alteration

- variably serpentinized dunite
- serpentinite

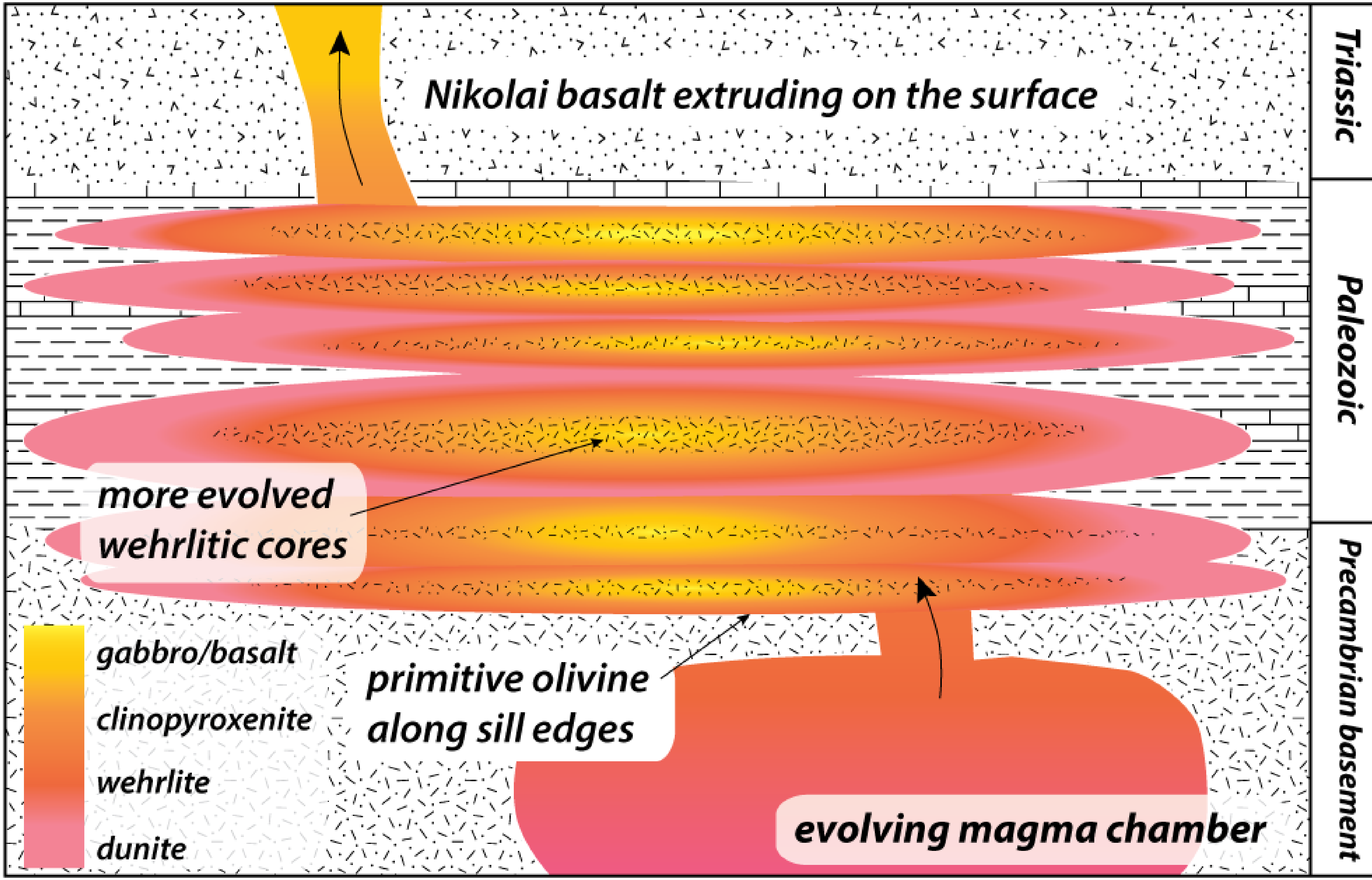
- unmapped area

Potential Models

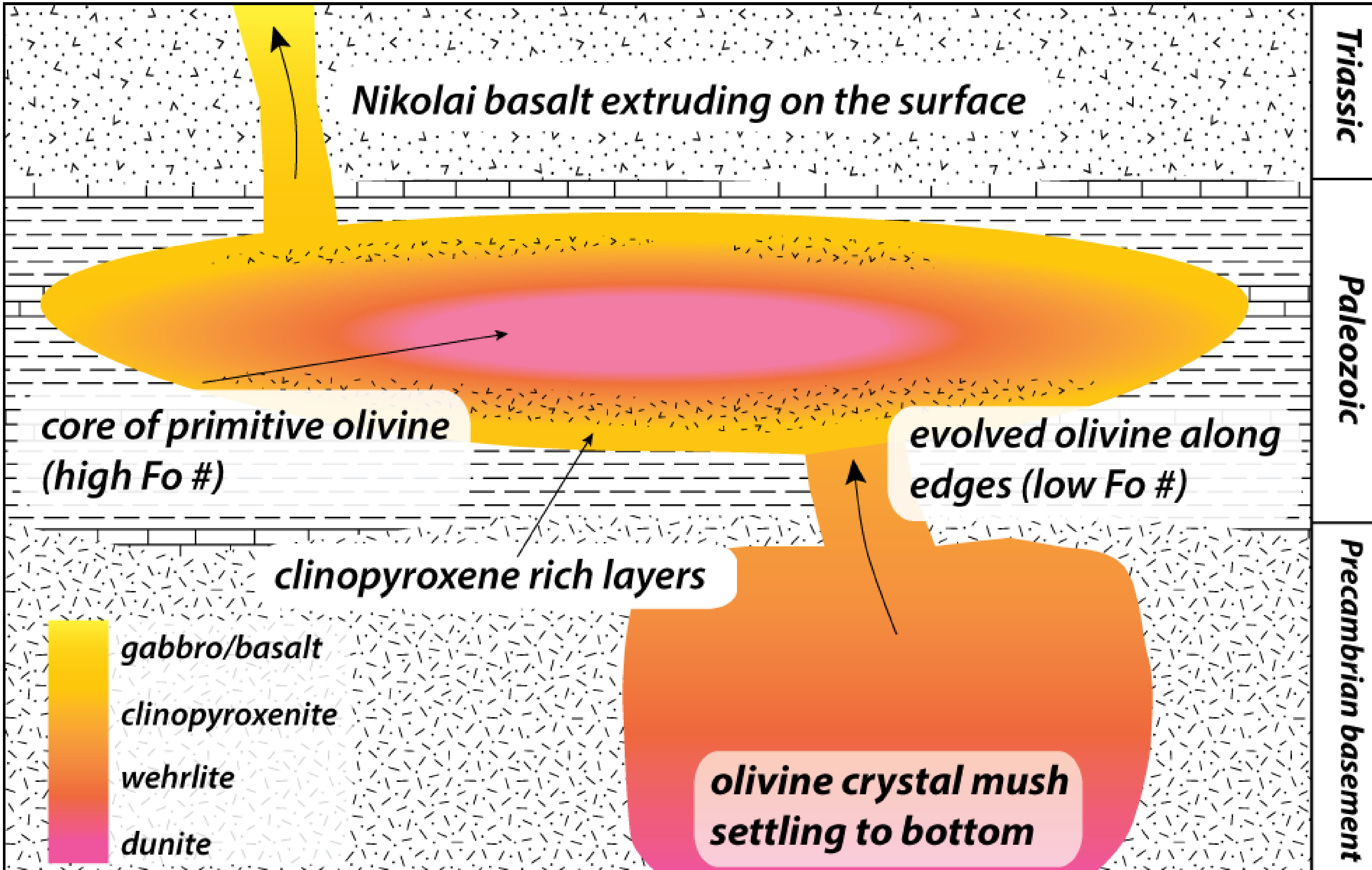
Hypothesis #1: Differentiating magma chamber



Hypothesis #2: Multi-sill system



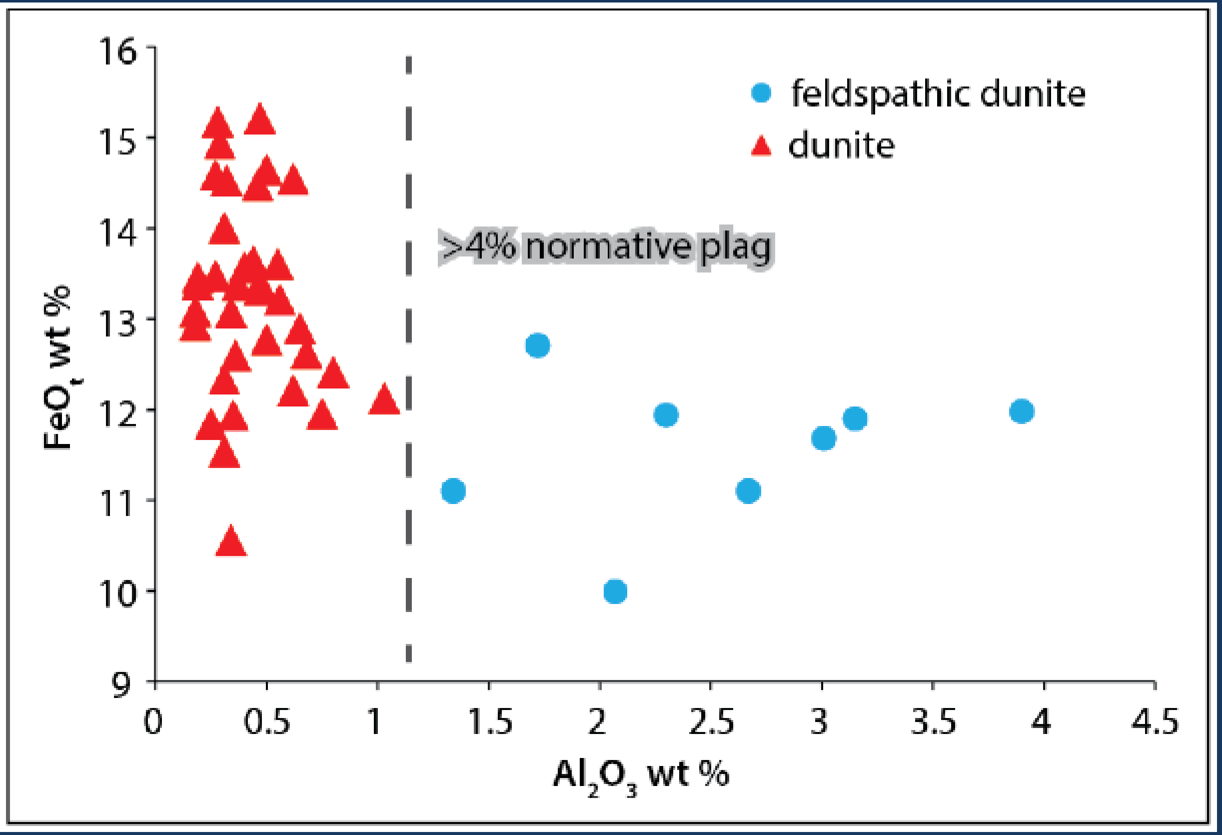
Hypothesis #3: Single sill system



Ultramafics: Dunite

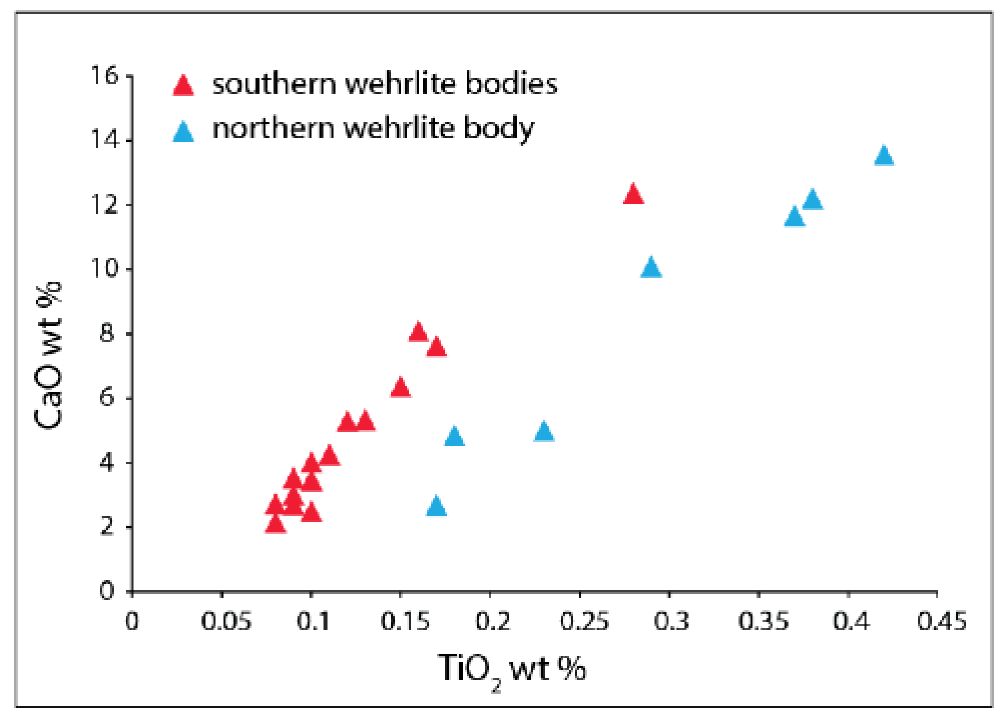
Two different dunite compositions identified:

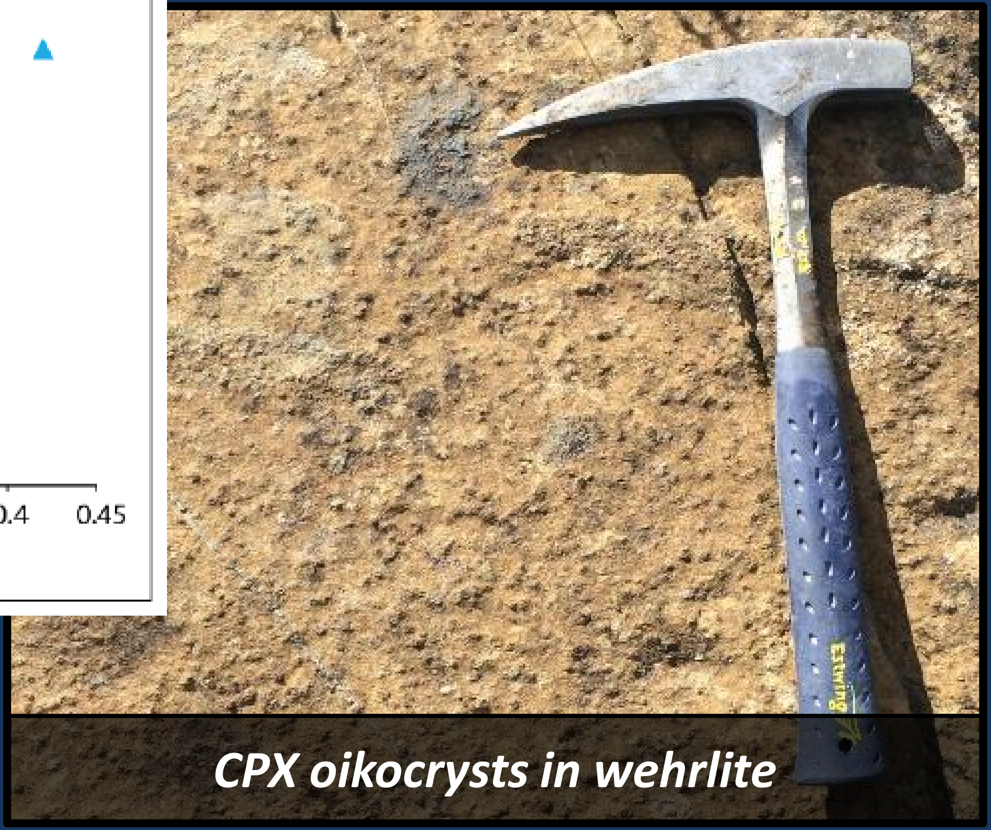
- Normal low Al_2O_3 dunite
- Central 250 m wide band of feldspathic dunite



Ultramafics: Wehrlite

Northern wehrlite layer (base of alpha) crystallized from a **more evolved, TiO_2–rich** magma than the wehrlites to the south (top of alpha)

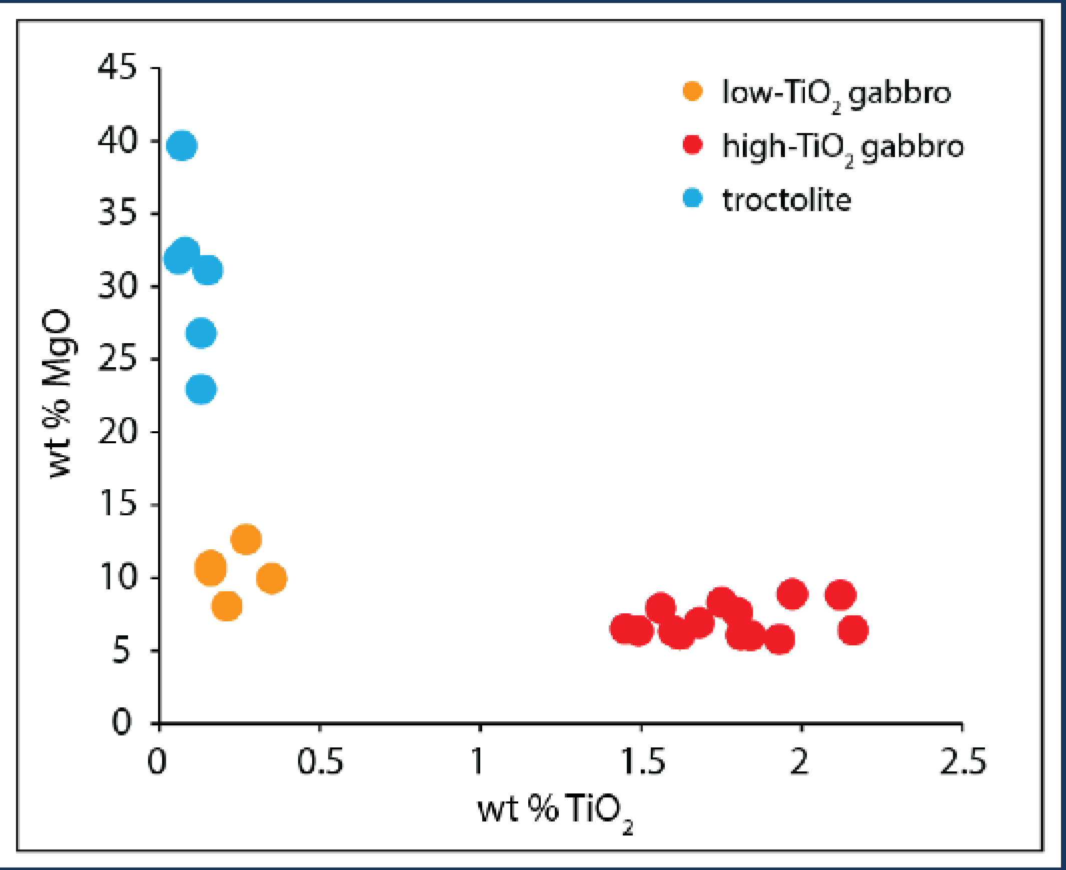




CPX oikocrysts in wehrlite

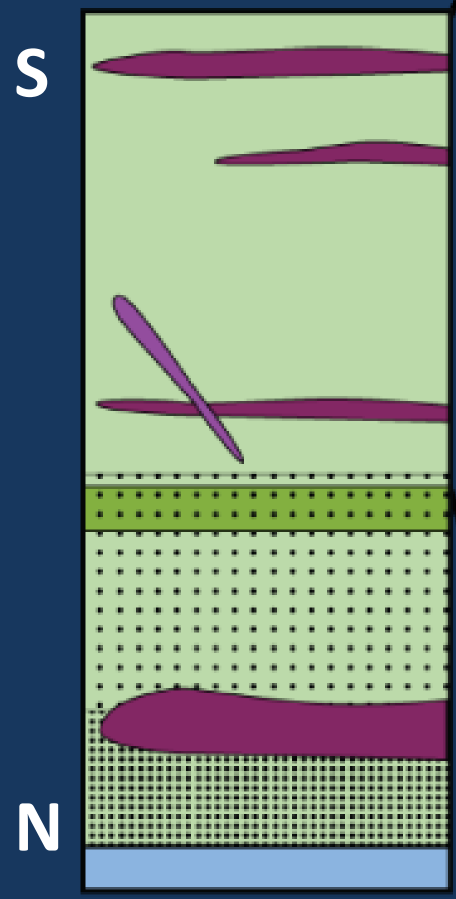
Mafic dikes

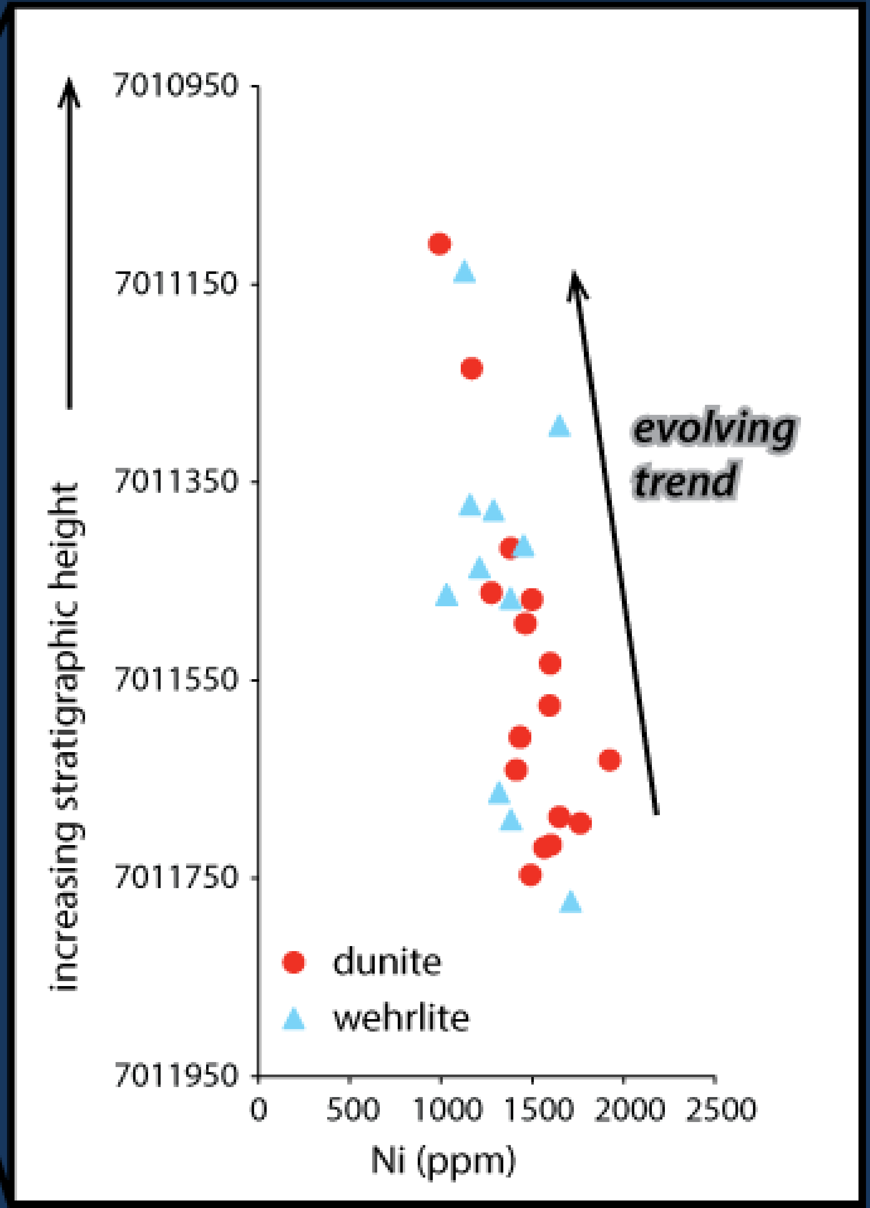
- Three different compositions of mafic dikes can be distinguished geochemically
- Gabbros may correspond to the upper and lower Nikolai basalts



Ultramafics: top of stratigraphy

Evolving toward the top of the Alpha



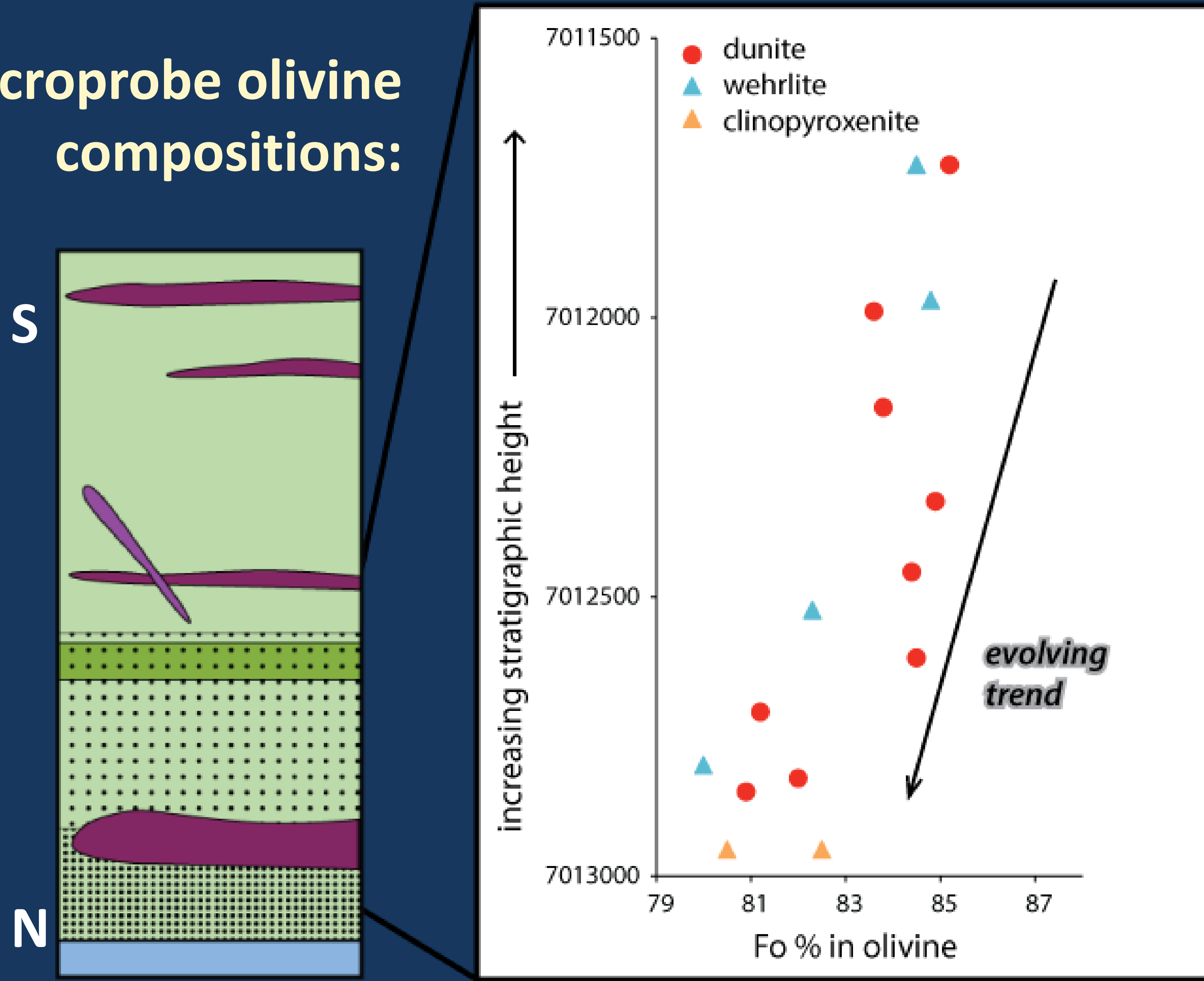


Southern wehrlite layers may have crystallized as magma cyclically became saturated in Ca and Al and formed clinopyroxene

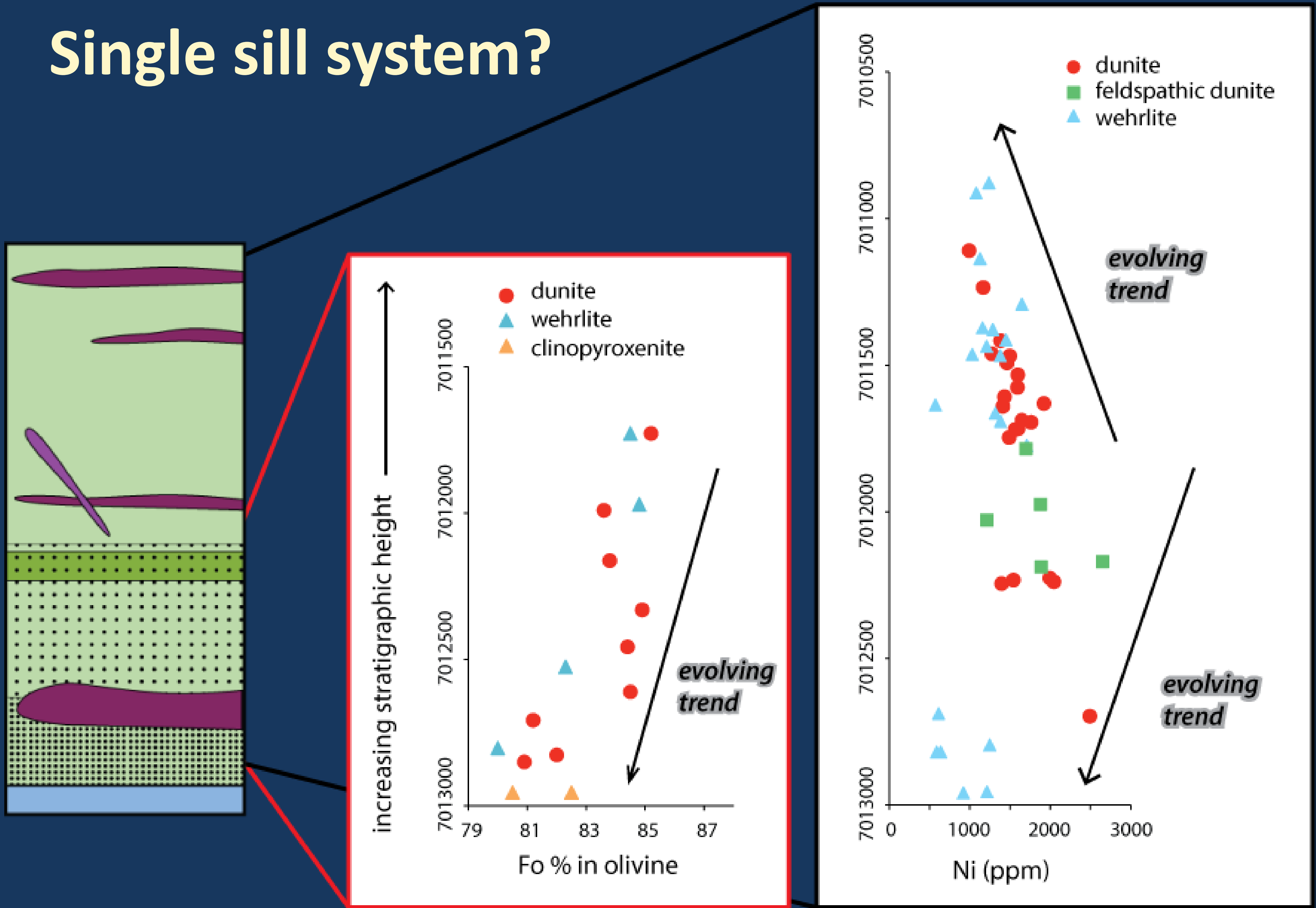
Southern wehrlite layers may have crystallized as magma cyclically became saturated in Ca and Al and formed clinopyroxene

Ultramafics: base of stratigraphy

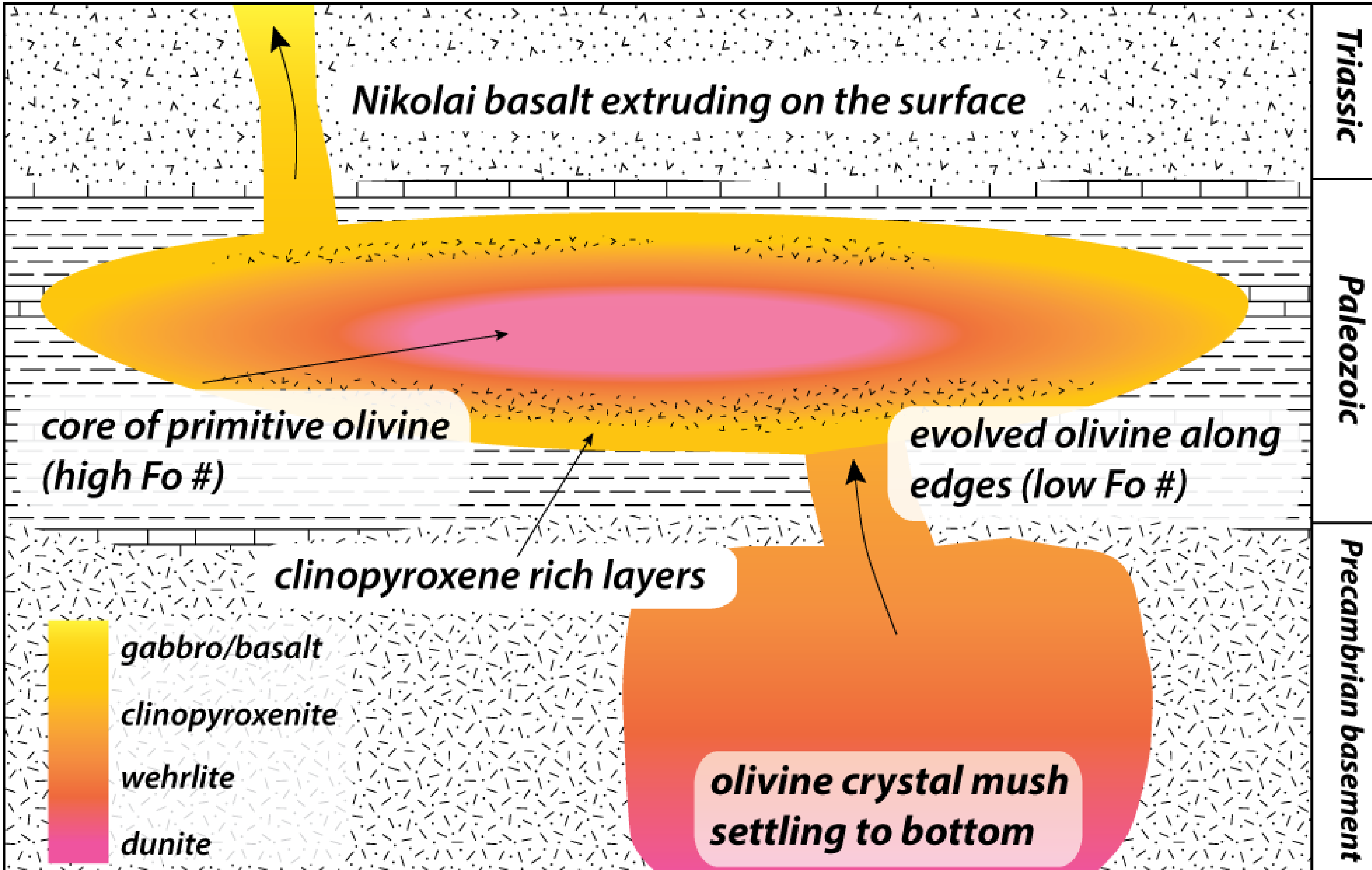
Microprobe olivine compositions:



Single sill system?



Potential model: single sill system



What We Know

- The base of the complex has the most evolved composition

- The central section has the most primitive compositions in both olivine and whole rock analyses
    - Presence of feldspar could be explained by the open magmatic system model

- Gabbroic dikes are crosscutting ultramafic layers
    - Gabbros did not form from fractional crystallization of the ultramafic magma

Upcoming Work

- Transmitted and reflected light petrographic analysis of new samples

- Detailed microprobe analysis of olivine and clinopyroxene across ultramafic layers
  - This will allow for better understanding of the relationship between dunite and wehrlite layers

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