Geologic mapping in the Richardson-Uncle Sam area, interior Alaska

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During the 2017 field season, geologists from the Alaska Division of Geological & Geophysical Surveys (DGGS) conducted geologic mapping and sampling of part of the Richardson Mining District southeast of Fairbanks. The project area is about 30 miles west of the Pogo gold mine and covers gold exploration activity at the Montecristo and Uncle Sam properties. The goal of this work is to build an improved understanding of the area geology and controls on gold mineralization for purposes of exploration targeting and mineral resource assessment.

The 260-square-mile map area lies between the Salcha River and Shaw Creek and is bounded by the Trans-Alaska Pipeline access road to the southwest (figure 1). The area is characterized by forested, moderate-relief hills blanketed by vegetation, loess, and locally, sand dunes. Rock outcrop is less than one percent, consequently, the map interpretation relies heavily on the DGGS East Richardson airborne magnetic and electromagnetic survey (Burns and others, 2006) as well as rocks collected from pits dug into rocky colluvial deposits below the surficial loess or sand.

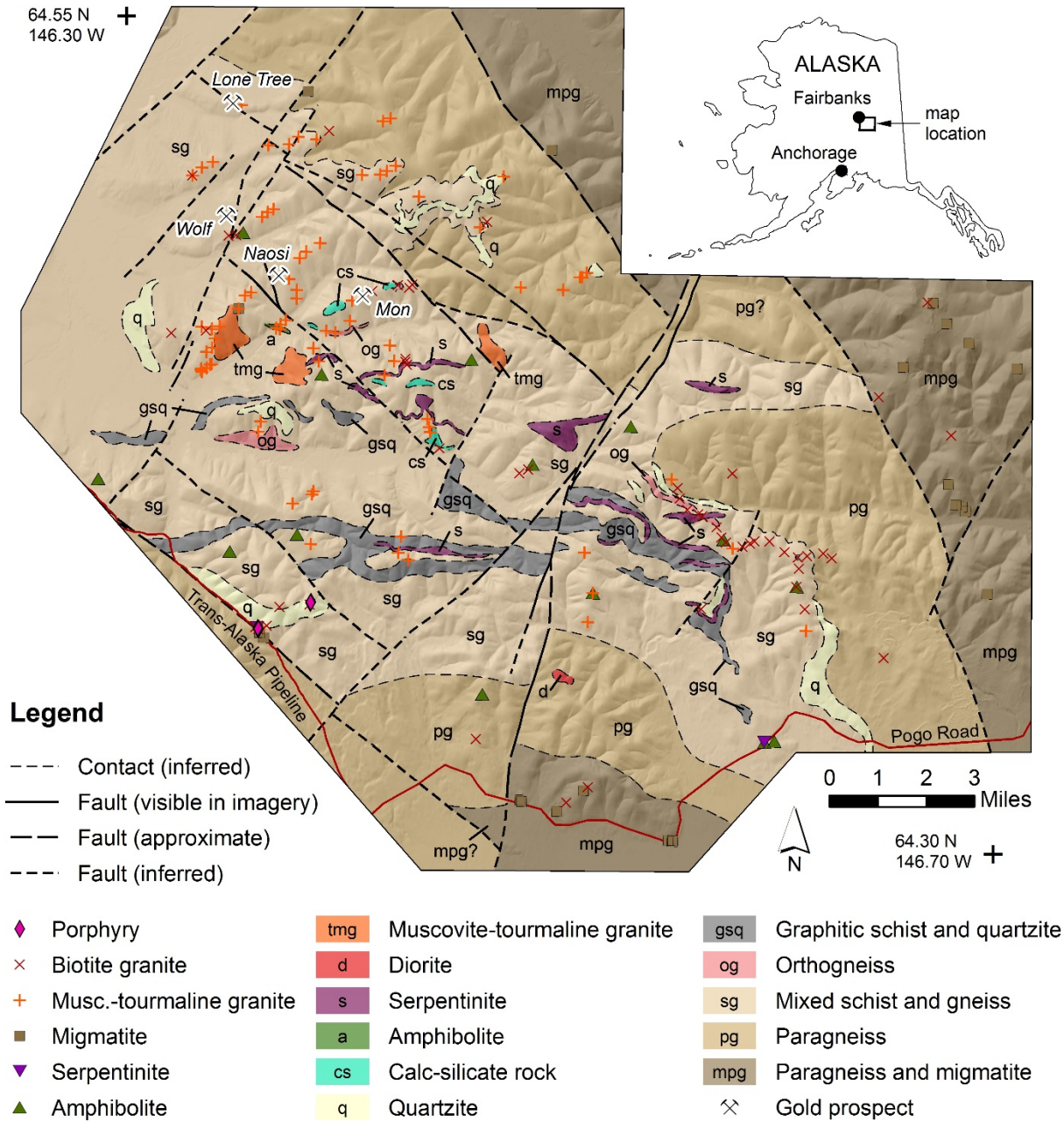
Metamorphic rocks form a map-scale upright synform plunging gently northwest (figure 1). Sillimanite-bearing paragneiss displaying migmatitic textures (unit mpg) forms the lowest structural level. The overlying unit is characterized by similar paragneiss but lacks migmatitic texture (unit pg). The structurally highest rock package (unit sg) is a mixed unit comprised of similar sillimanite-bearing paragneiss, biotite and muscovite schist, quartzite, calc-silicate rock, and graphitic schist and quartzite. This unit also contains small, discontinuous bodies of granitic orthogneiss, amphibolite, and serpentinite. These subsidiary units are mapped separately where possible.

The map area is intruded by abundant dikes and several small stocks of muscovite ± tourmaline ± garnet-bearing granite (unit tmg), as well as biotite granite. Whole-rock geochemical analyses indicate both are peraluminous granites of arc character (Twelker and others, 2017). They most closely resemble the early Cretaceous (105-114 Ma) peraluminous felsic dikes documented in the southeastern Richardson district (Graham and others, 2002). Altered hypabyssal quartz-feldspar porphyry dikes found south of the study area may correlate with ca. 90 Ma dikes of similar composition and texture at the Democrat prospect.

Shallowly dipping, brittle–ductile-style shearing is evident in drill core, and these structures are an important host for gold mineralization at the Naosi and other prospects in the area. At map scale, fault-bounded and discontinuous bodies of serpentinite offer evidence of a broader, layer-parallel shear zone affecting the structurally uppermost mixed schist-gneiss unit. A similar broad shear zone cutting a similar mixed lithologic package hosts the low-angle veins at Pogo gold mine.

Two sets of high-angle faults cut the area; these are mappable as lineaments and offsets in airborne magnetic and electromagnetic survey data. Northwest-trending high-angle structures show apparent right-lateral offset of geologic markers, and faults of this orientation are mapped at both the Naosi and Lone Tree prospects. A similar structure localizes the porphyry dikes of the Democrat prospect south of the map area. Several northeast-trending structures cut the area, and these apparently cut the northwest-trending faults. The most prominent of these faults (at map center, figure 1) shows clear left-lateral offset of geological and geophysical markers, while a similarly oriented structure in the western map area connects the areas of the Lone Tree, Wolf, Naosi, and Democrat prospects.

Figure 1. Preliminary draft geologic map of the Richardson-Uncle Sam area, interior Alaska



References cited:

Burns, L.E., Fugro Airborne Surveys Corp., and Stevens Exploration Management Corp., 2006, Line, grid, and vector data and plot files for the airborne geophysical survey data of parts of the East Richardson, Liscum, and Black Mountain areas, interior Alaska: Alaska Division of Geological & Geophysical Surveys Geophysical Report 2006-5, 29 sheets, 1 DVD. http://doi.org/10.14509/14531

Graham, G.E., 2002, Geology and gold mineralization of the Richardson district, east-central Alaska: Fairbanks, Alaska, University of Alaska Fairbanks, M.S. thesis, 150 p.

Twelker, Evan, Wypych, Alicja, Sicard, K.R., Naibert, T.J., Werdon, M.B., Athey, J.E., Willingham, A.L., and Lockett, A.C., 2017, Major-oxide and trace-element geochemical data from rocks collected in the Richardson mining district, Big Delta Quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Raw Data File 2017-11, 4 p. http://doi.org/10.14509/29779

Speaker biography:

Evan Twelker is a mineral resources geologist with the Alaska Division of Geological & Geophysical surveys. He earned his BA in geology at Middlebury College and a MS in geology at the University of Alaska studying with Professor Rainer Newberry. At DGGS and as an exploration geologist in Alaska's minerals industry, Evan has worked throughout the state and gained direct experience in a wide variety of mineral deposit types and geologic settings, including the Ambler District, Seward Peninsula, Livengood, Greens Creek, Iliamna, the Talkeetna Mountains, and the Alaska Range. A life-long Alaskan, he thrives on unlocking the mysteries of the state's geology through geologic mapping and related research.

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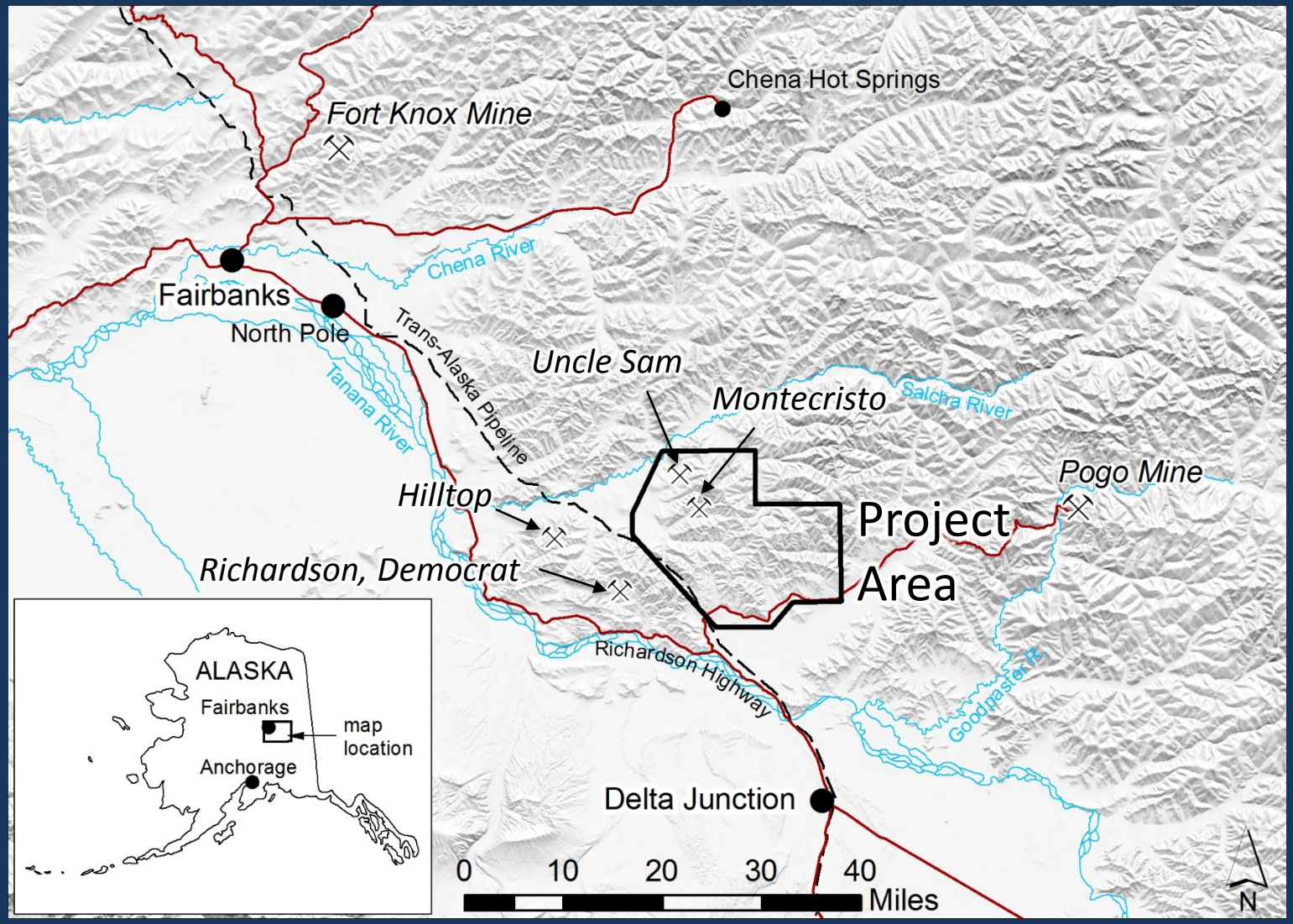
Alaska Miners Association
Annual Convention November 7, 2017

Acknowledgments:

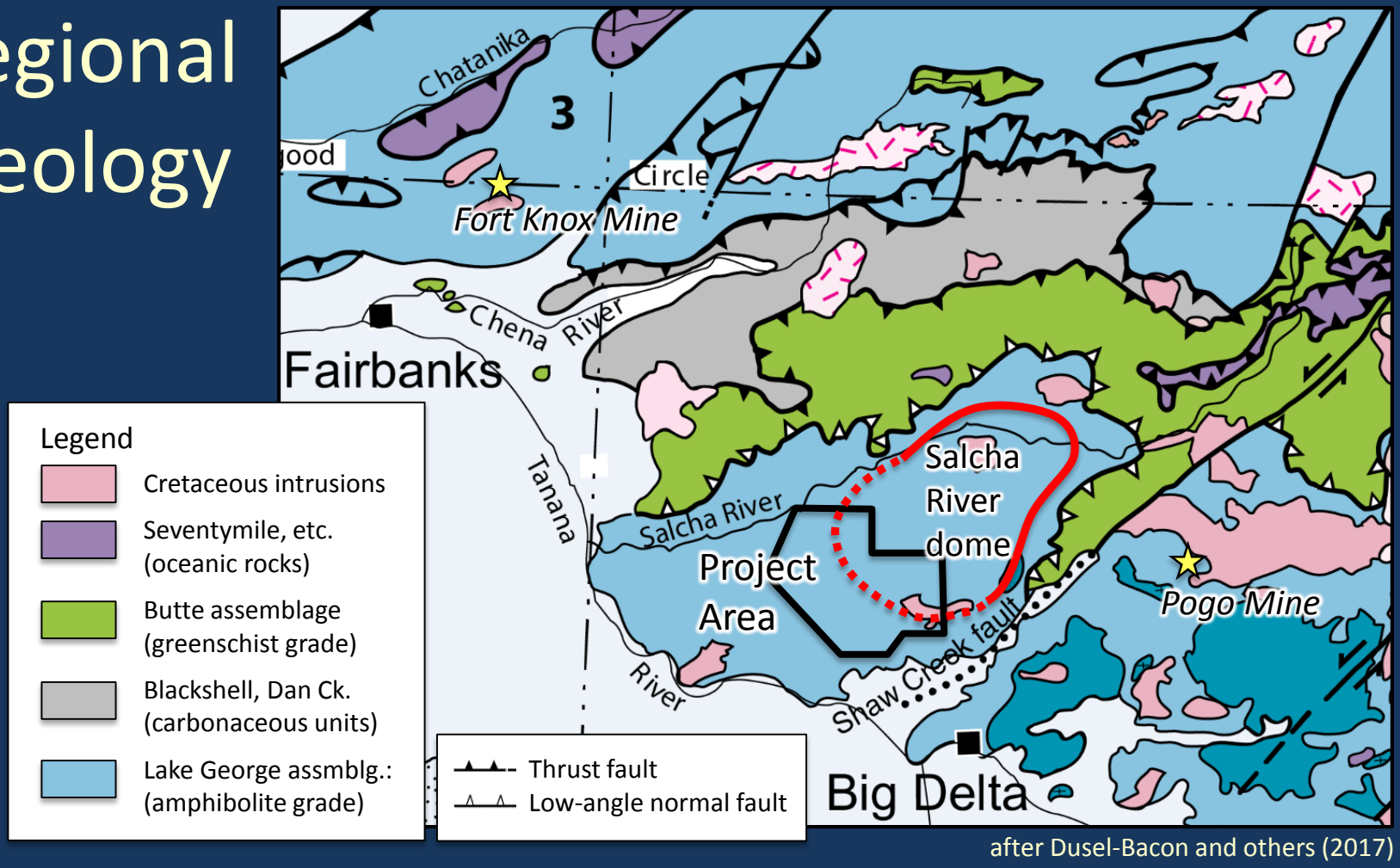
- Great American Minerals Exploration (GAME): Dennis McDowell and Pat Smith
- Bill Cronk and Northern Empire
- SMM Pogo Mine (road cuts and access)
- Alyeska Pipeline Service Co. (access, road cuts)
- Richard Lessard, Rainer Newberry, Dave Larimer (geological discussions)
- Soloy Helicopters and Ryan Skorecki
- Lazy Moose RV Park
- Barrett Salisbury (bear spraying)
- And others…

This project is funded by the State of Alaska Division of Geological & Geophysical Surveys

Project Location



Regional Geology



after Dusel-Bacon and others (2017)

Generalized Timeline:

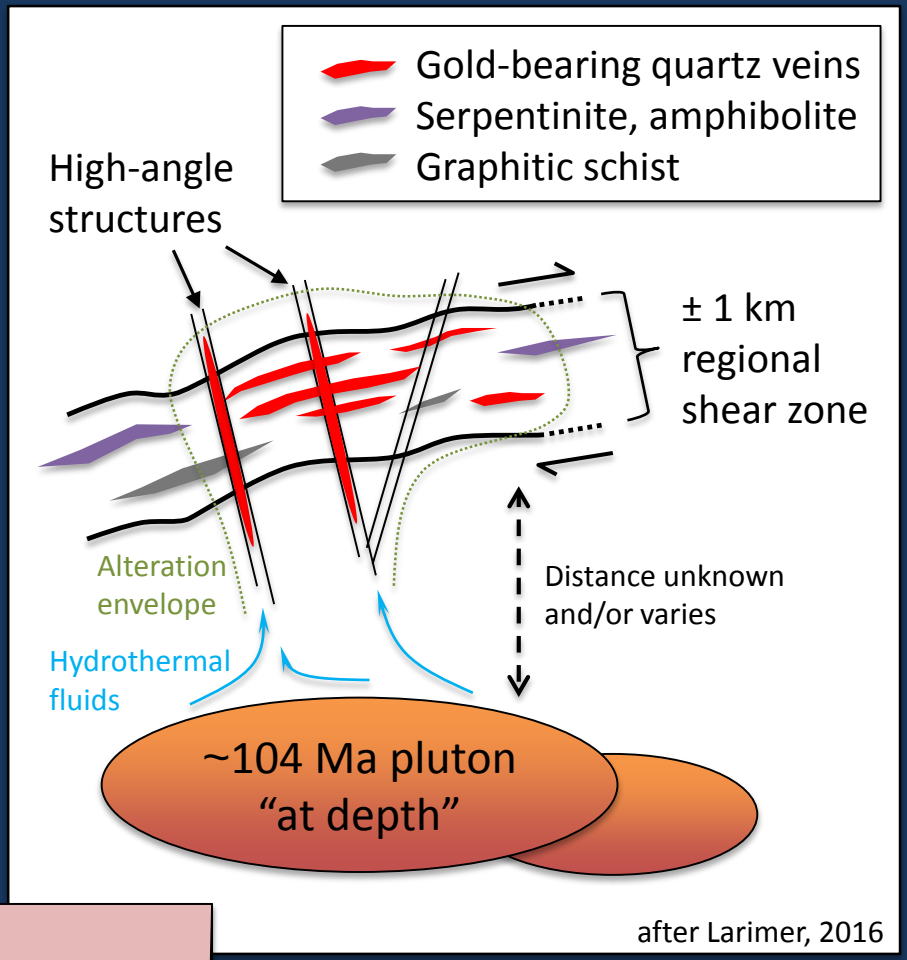
Devonian-Mississippian Protolith deposition	Jurassic Peak metamorphism	Early Cretaceous Extension, exhumation, metamorphic cooling	~ 105 Ma Magmatism Pogo	~ 90 Ma Magmatism Ft Knox	~ 55 Ma Extensional magmatism

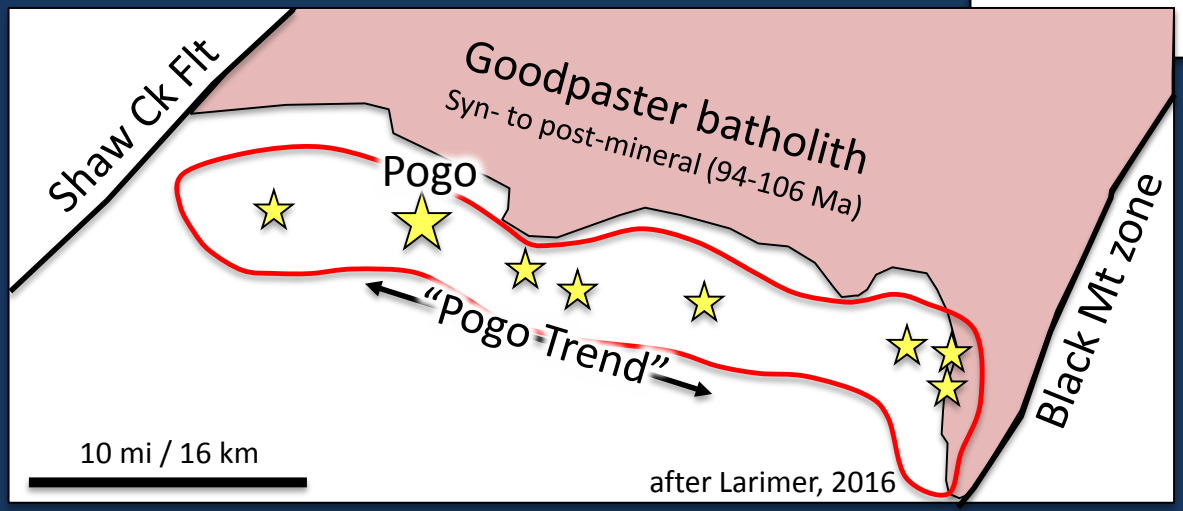
Mapping objectives:
Find/trace gold-related geologic features

- Low angle structures
  - Pogo Mine, LMS, Naosi
- High angle structures
  - Fairbanks District, Pogo N Zone
- Mineralized quartz-feldspar porphyry dikes
  - Richardson district: Democrat Lode, etc.
- Mineralized plutons
  - Fort Knox

Pogo geologic setting

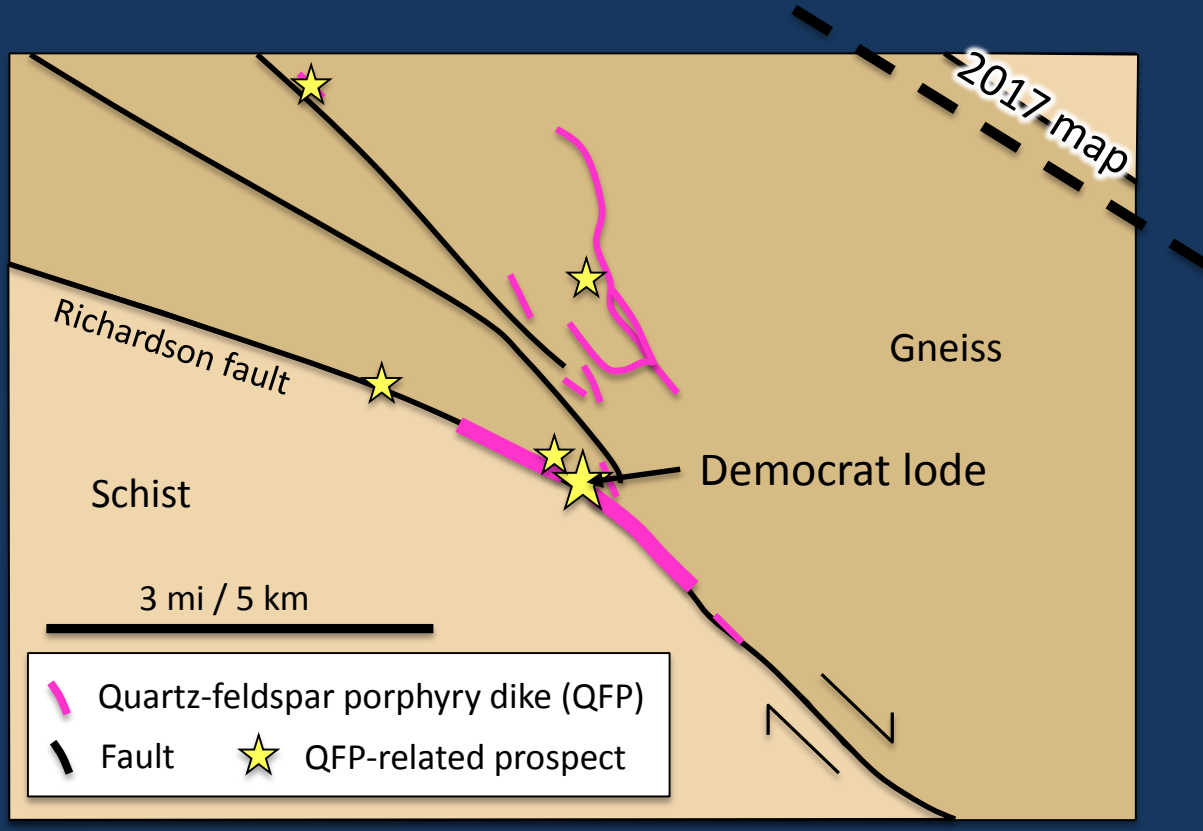
- Low angle veins (L1, etc.)
- Exploit regional (?) shear zone
- ‘Slippery’ lithologies:
  - serpentinite, graphitic schist
  - also: amphibolite, orthogneiss, paragneiss
- High angle veins (N zone)
- District-scale ‘Pogo Trend’
  - WNW structural control?



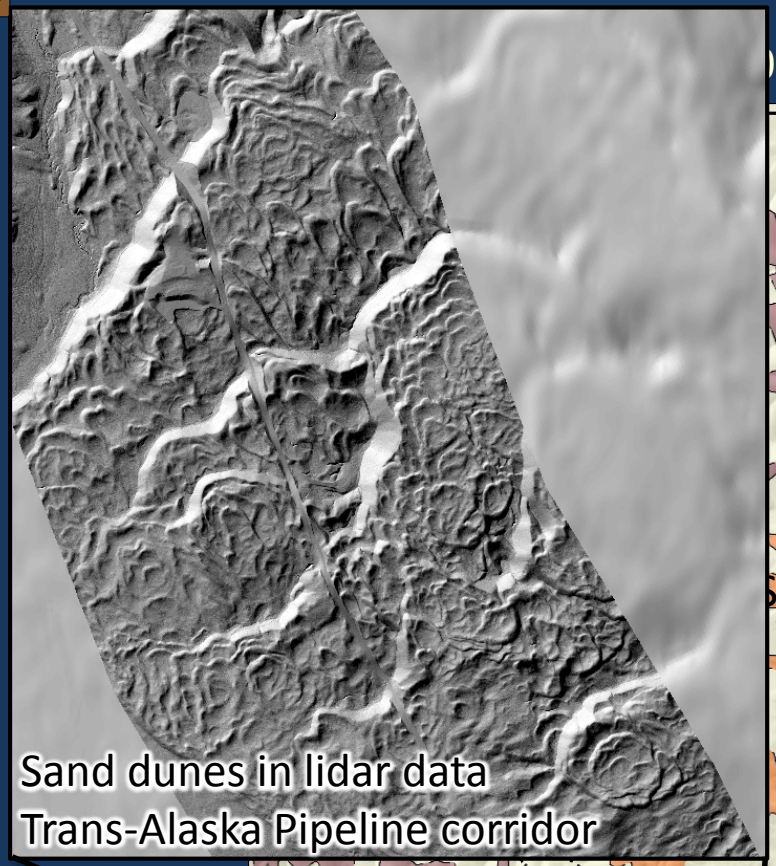


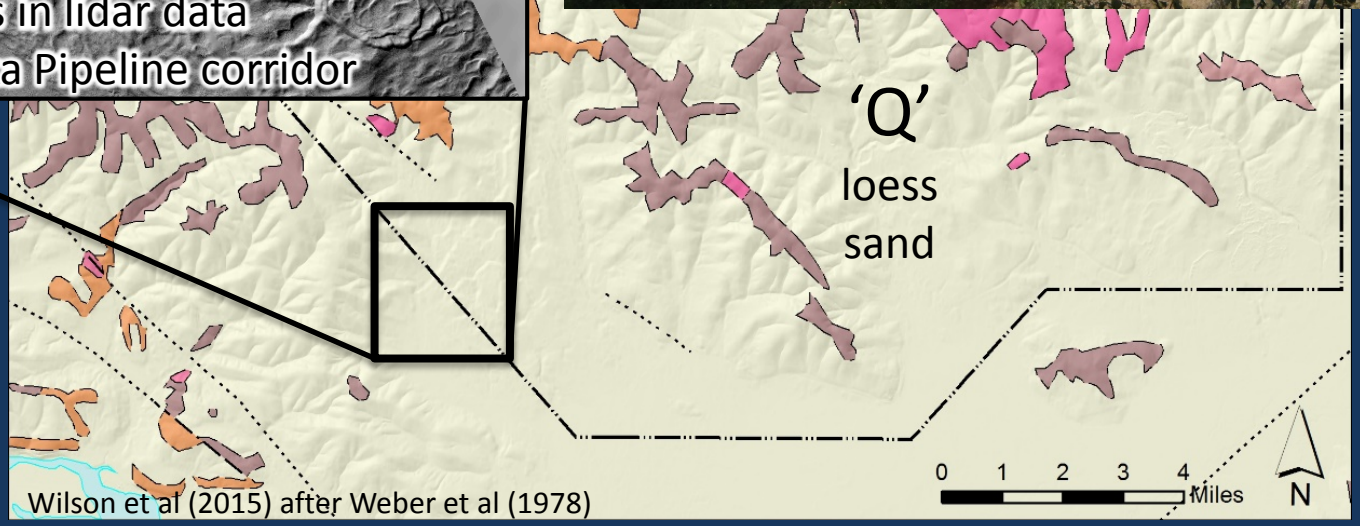
Democrat Lode geologic setting

- Syn-mineral (± 90 Ma) quartz-feldspar porphyry dikes host gold at many of the prospects in Richardson district
- Structural control along NW-trending apparent right-lateral fault
- 'Distal' style gold mineralization
- Relatively shallow emplacement, lower T?



Adapted from Singh and others (2017)





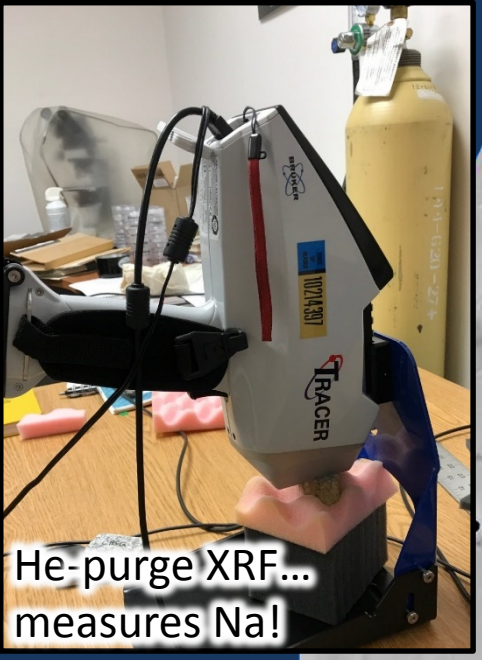
Wilson et al (2015) after Weber et al (1978)

260 square mile map area: roughly 1 outcrop per 3 square miles

Make your own outcrop!*

*subcrop at best

2017 field project



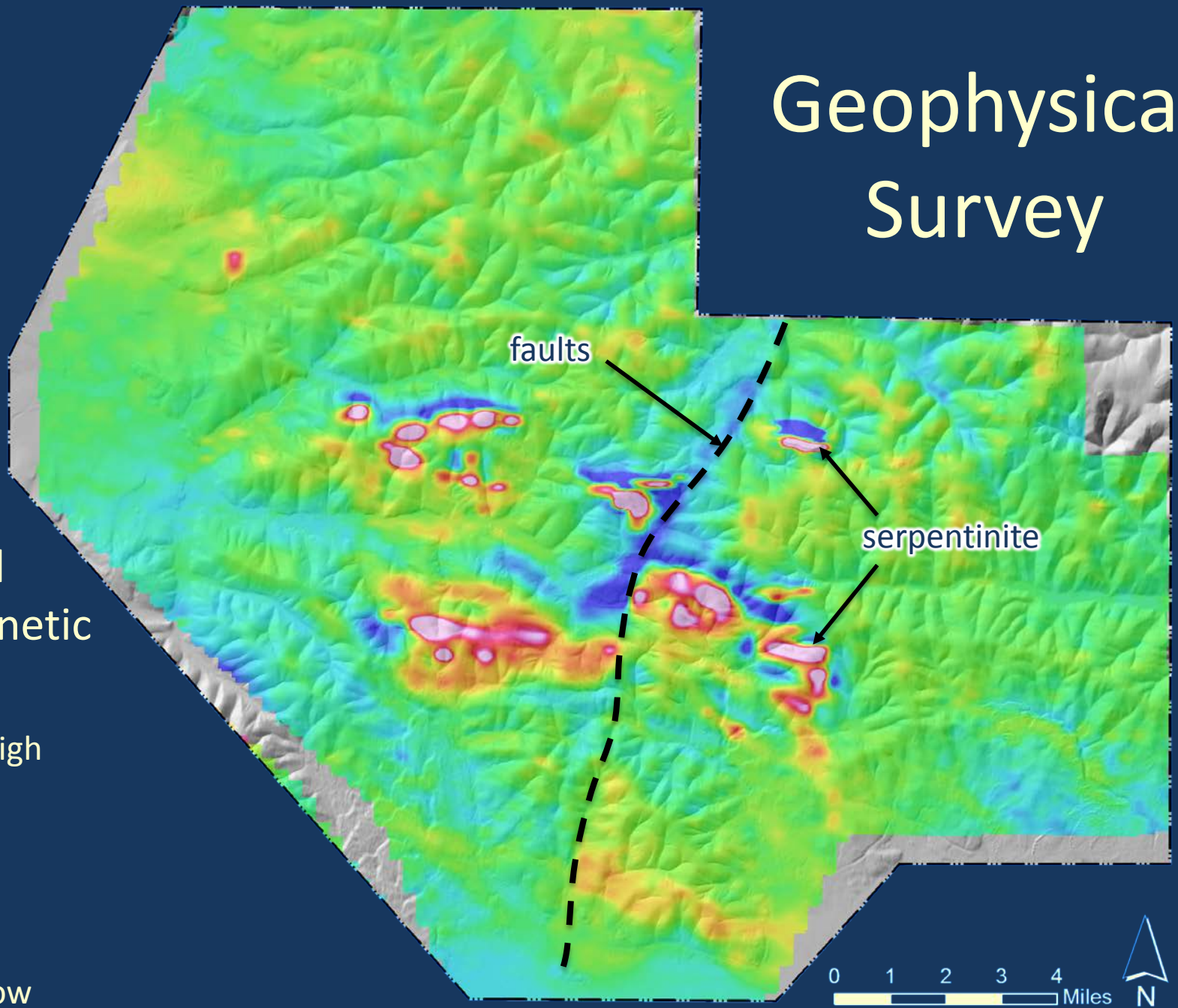
- Field stations
- XRF Data

~700 field stations
225 XRF analyses

Boots, hammers/shovels, and
high-tech!

0 1 2 3 4 Miles 10 N

Geophysical Survey



East Richardson geophysical survey (Burns and others, 2006)

Draft bedrock geologic map

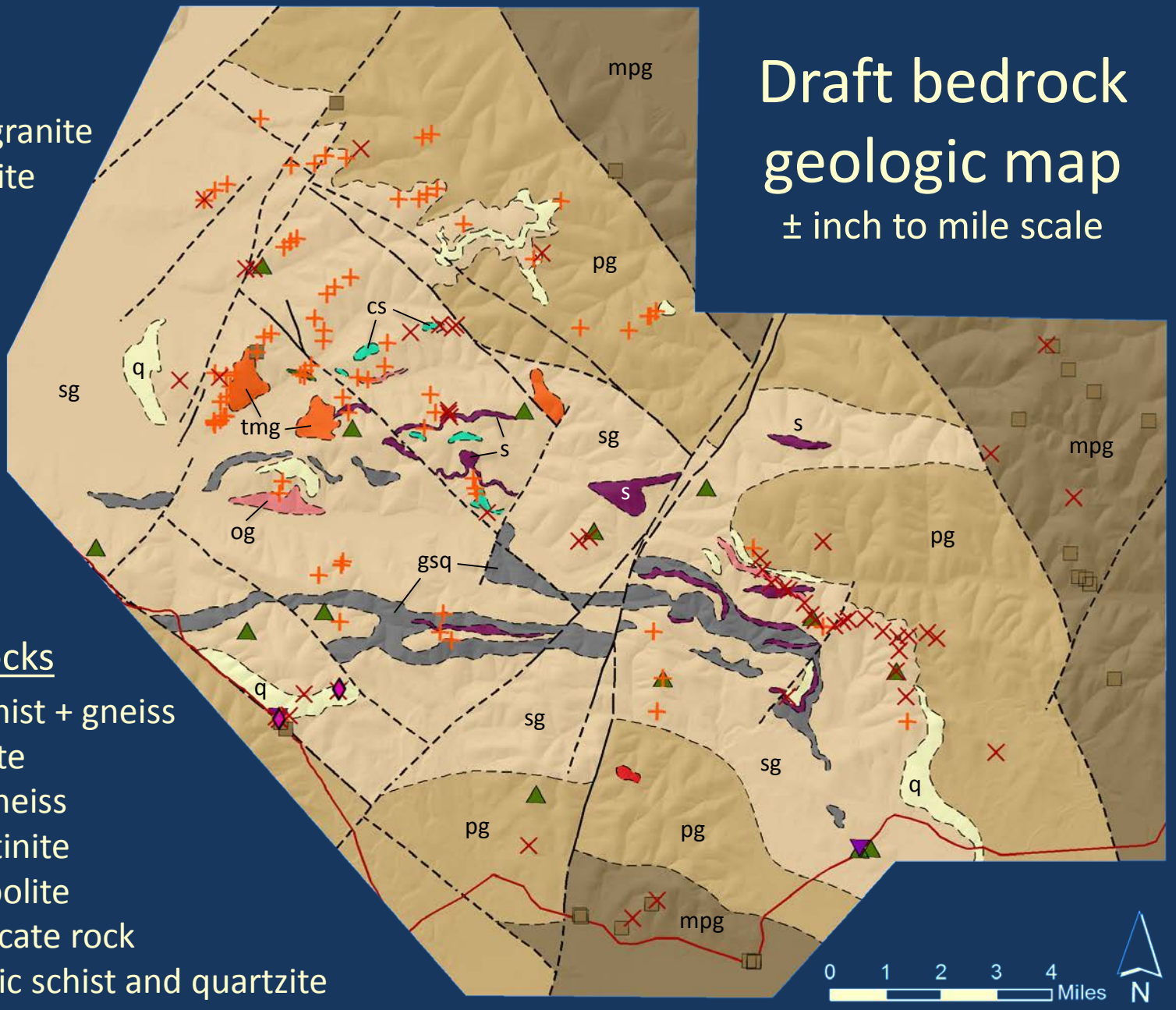
± inch to mile scale

Intrusive rocks

- Porphyry
- Musc-tour granite
- Biotite granite
- Diorite

Metamorphic rocks

- sg — Mixed schist + gneiss
- q — Quartzite
- og — Orthogneiss
- s — Serpentinite
- a — Amphibolite
- cs — Calc-silicate rock
- gsq — Graphitic schist and quartzite
- pg — Paragneiss
- mpg — Paragneiss and migmatite



Structure:

Generalized map-scale synform

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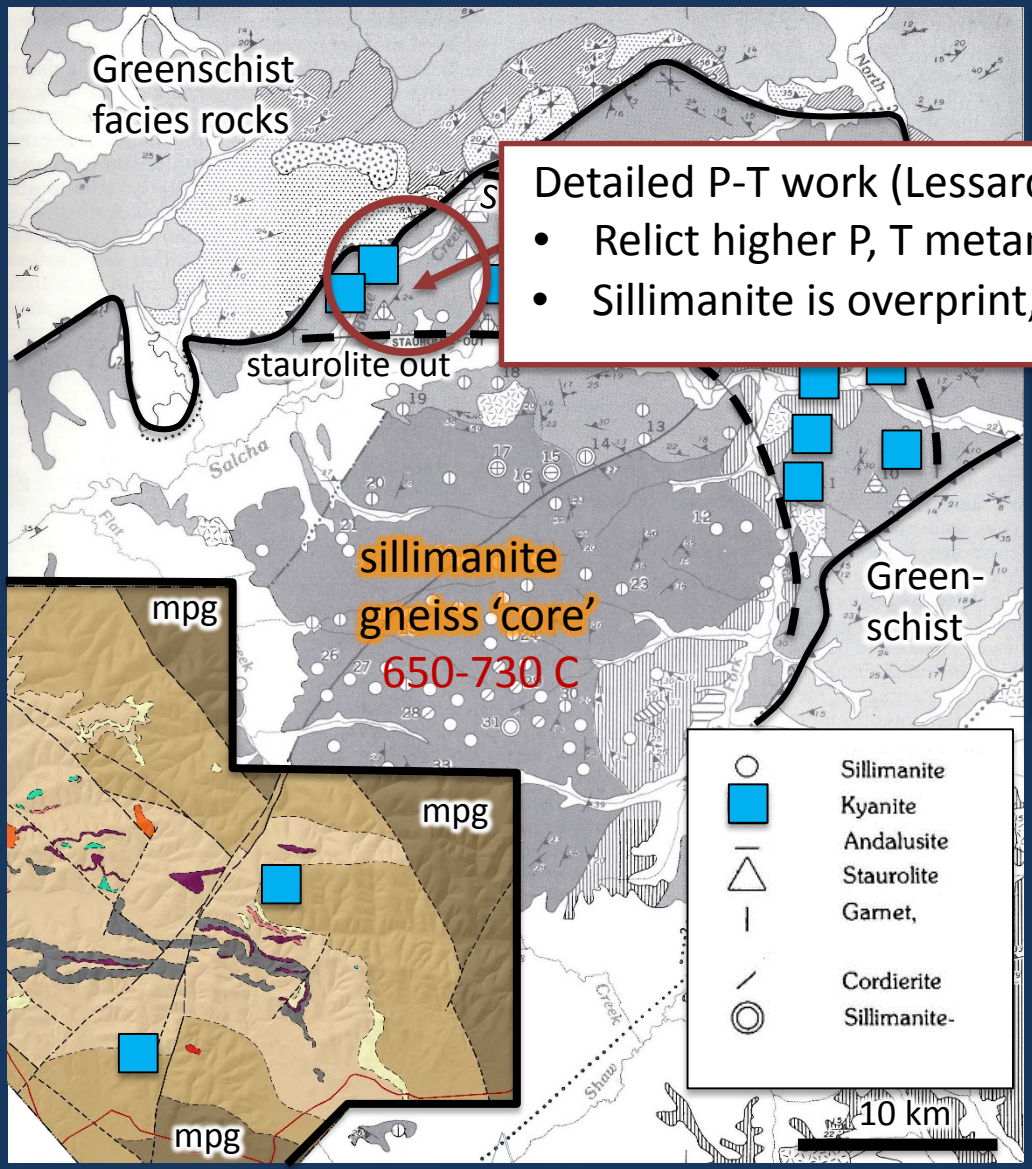
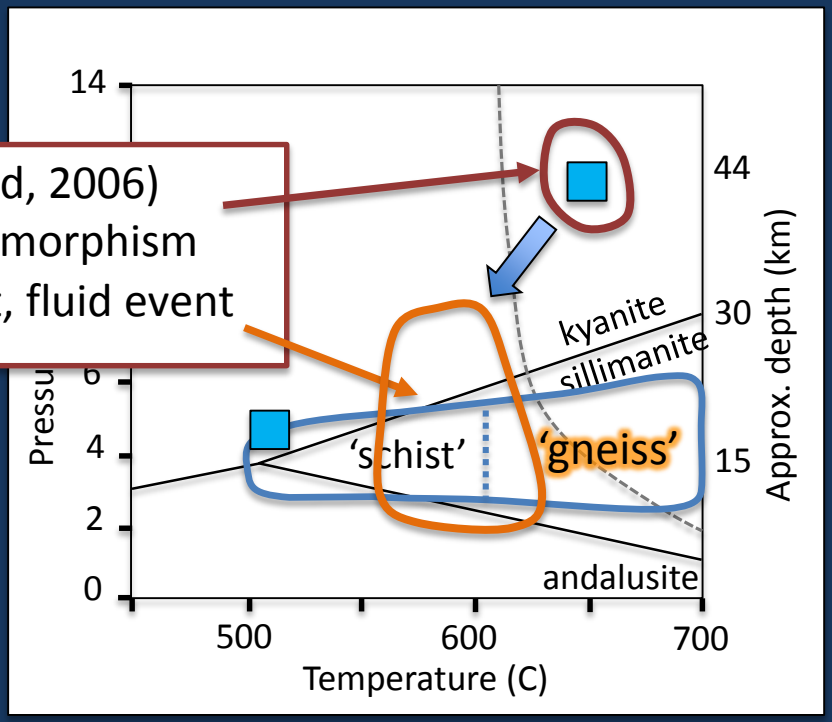
Salcha River gneiss dome

Dusel-Bacon and Foster, 1983:



Detailed P-T work (Lessard, 2006)

- Relict higher P, T metamorphism
- Sillimanite is overprint, fluid event

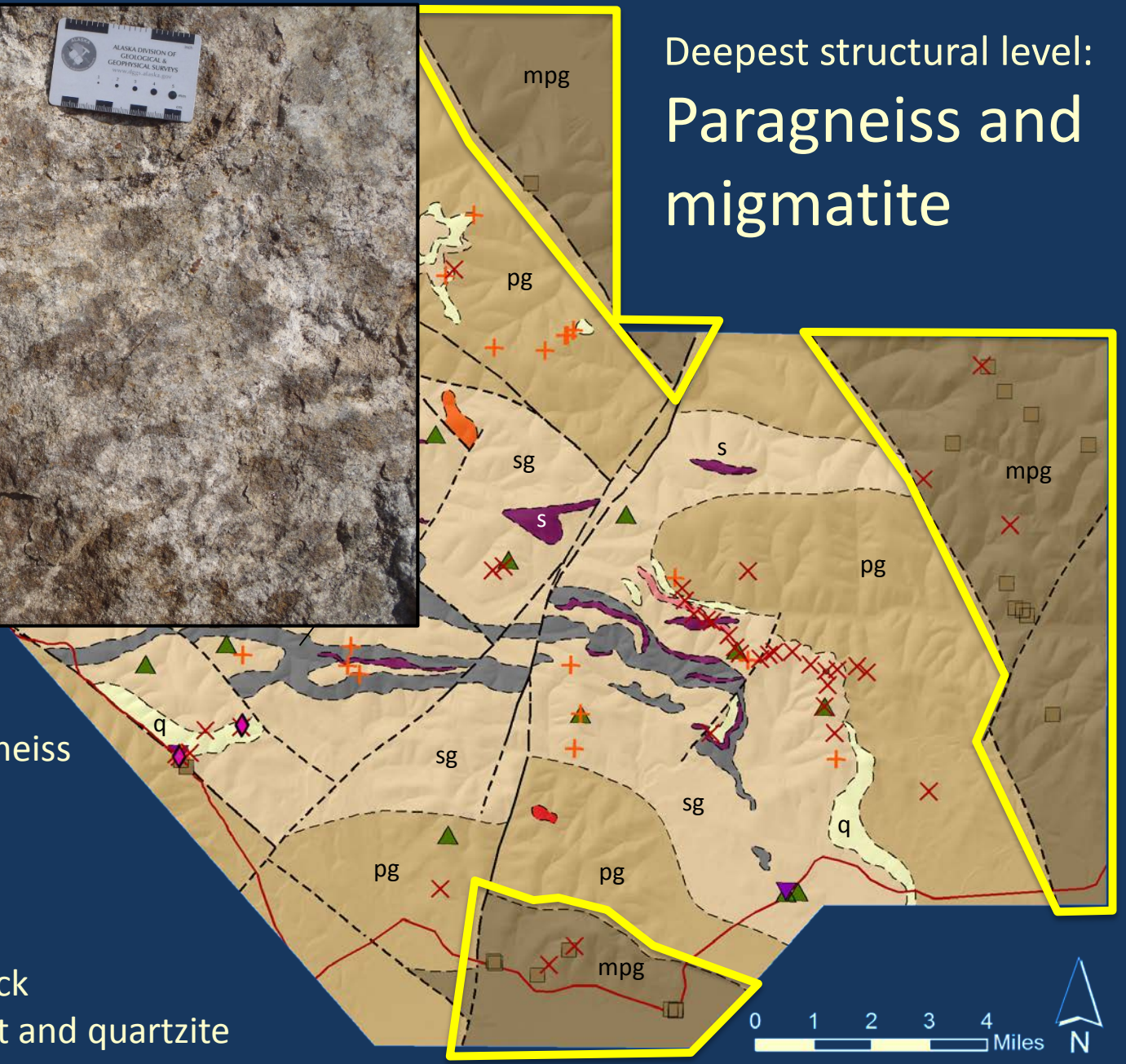


- A structural dome, but…
- Dome core records *lower* grades
- Center of fluid/reset event
- Relict higher grades are regional
- Structure at greenschist-amphibolite boundary??
  (but that's a bigger question)

mpg = paragneiss with migmatitic textures

Deepest structural level:

Paragneiss and migmatite



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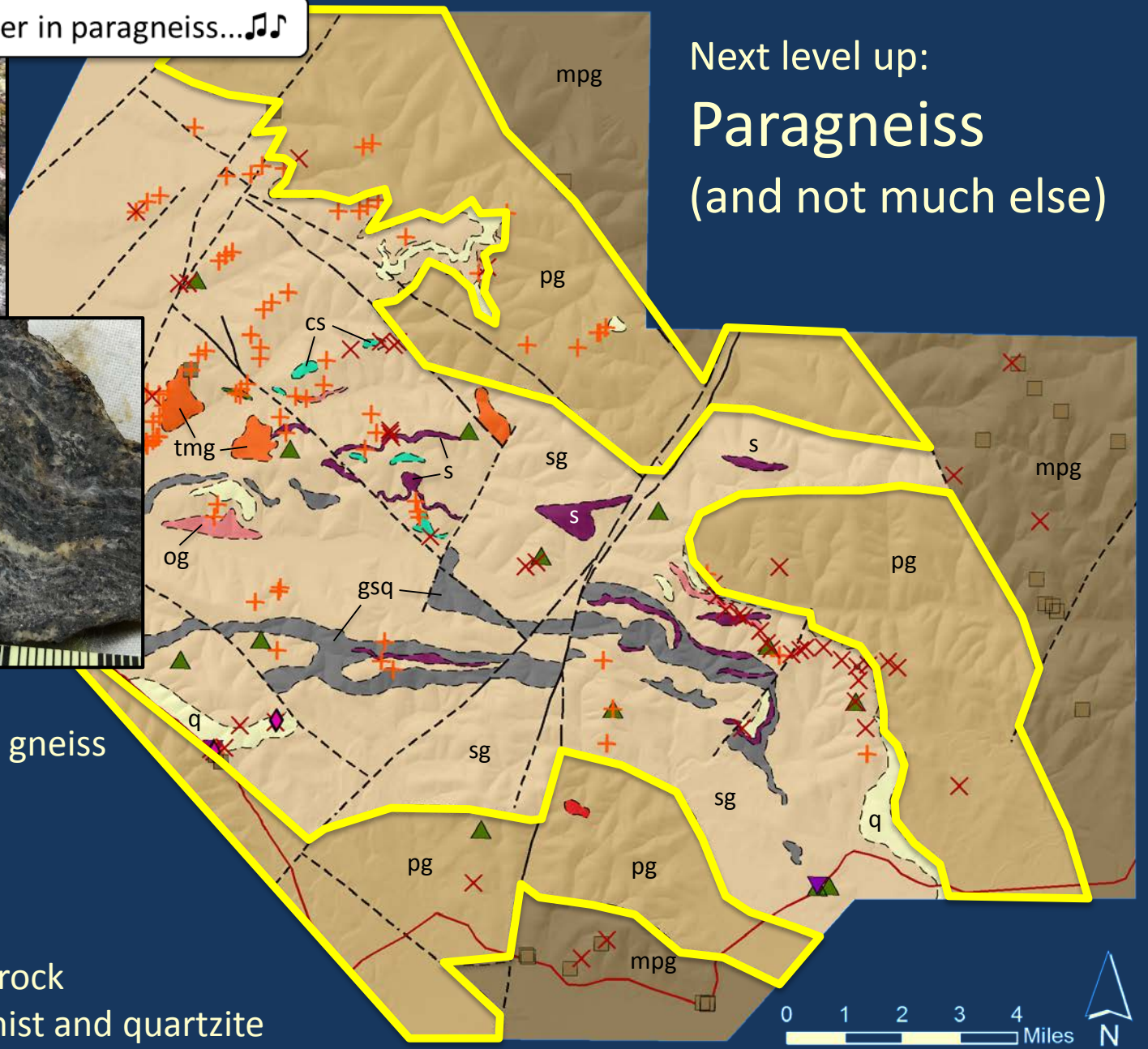
- mpg — Paragneiss and migmatite

♫ cheese burger in paragneiss...♫♪

Next level up:

Paragneiss

(and not much else)



Metamorphic rocks

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- a — Amphibolite
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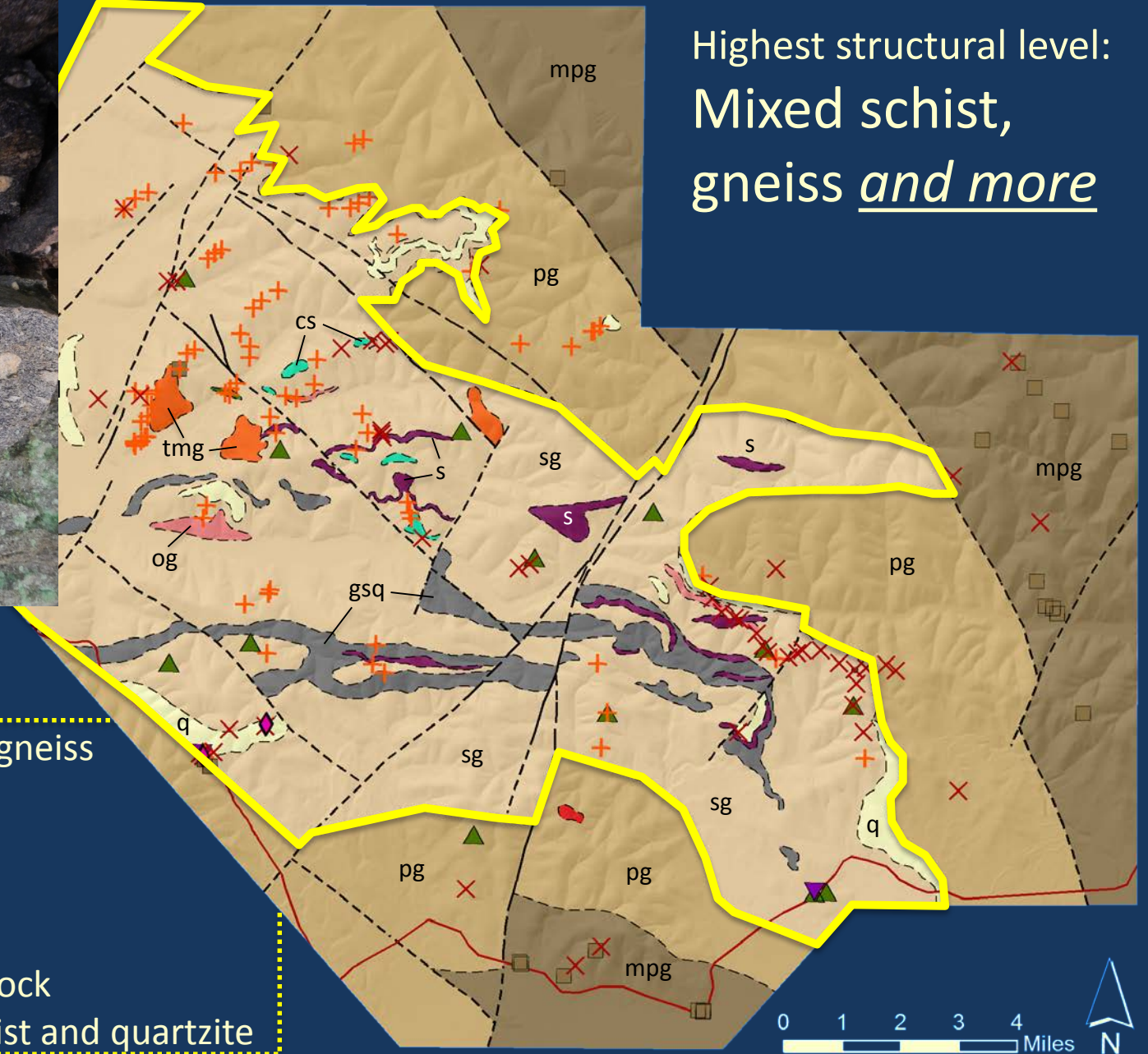
- gsq — Graphitic schist and quartzite
- pg — Paragneiss
- mpg — Paragneiss and migmatite

Highest structural level:

Mixed schist, gneiss *and more*



Metamorphic rocks

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- s — Serpentinite
- a — Amphibolite
- cs — Calc-silicate rock
- gsq — Graphitic schist and quartzite
- pg — Paragneiss
- mpg — Paragneiss and migmatite

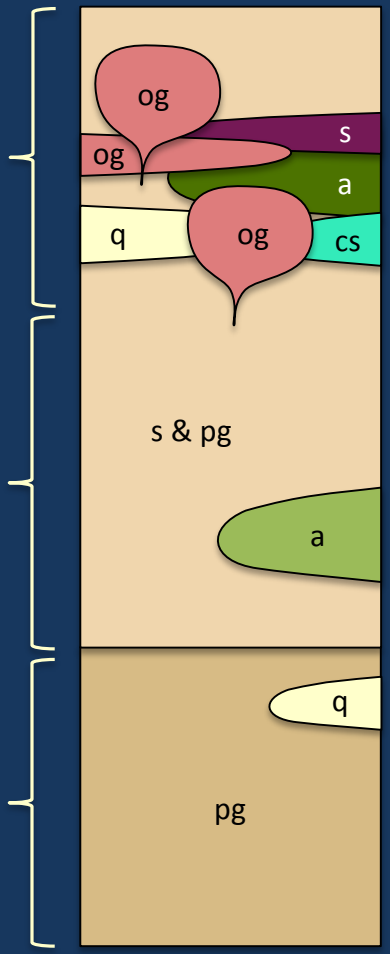
Pogo-area comparison: Generalized stratigraphy

Upper package:
- Schist, paragneiss
- Orthogneiss
- Amphibolite (arc)
- Ultramafics
- Quartzite, calc-silicate

Mid package:
- Schist, paragneiss
- Amphibolite (rift)
- Quartzite

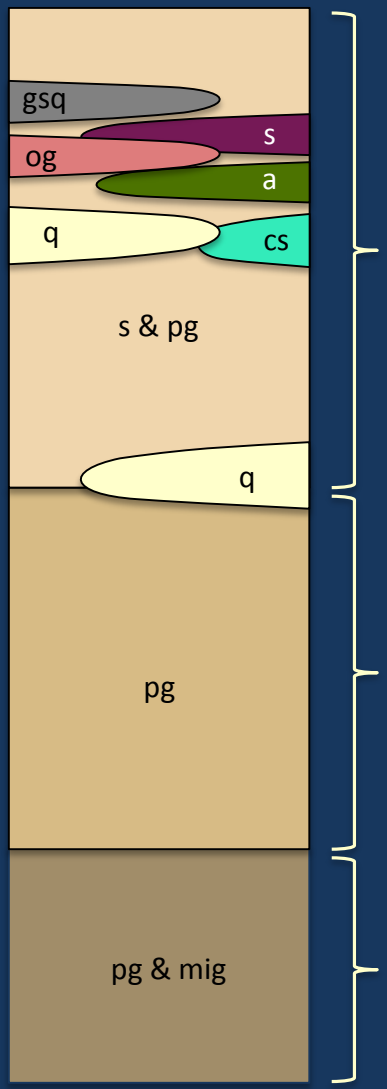
Lower package:
- Paragneiss
- Local quartzite

Salcha-River Pogo



Generalized from mapping of Werdon et al (2004)

Richardson, Uncle Sam



This study

Mixed package:
- Paragneiss, schist
- Orthogneiss
- Amphibolite (arc)
- Graphitic schist, qtzt
- Serpentinite
- Quartzite, calc-silicate

Predominantly paragneiss

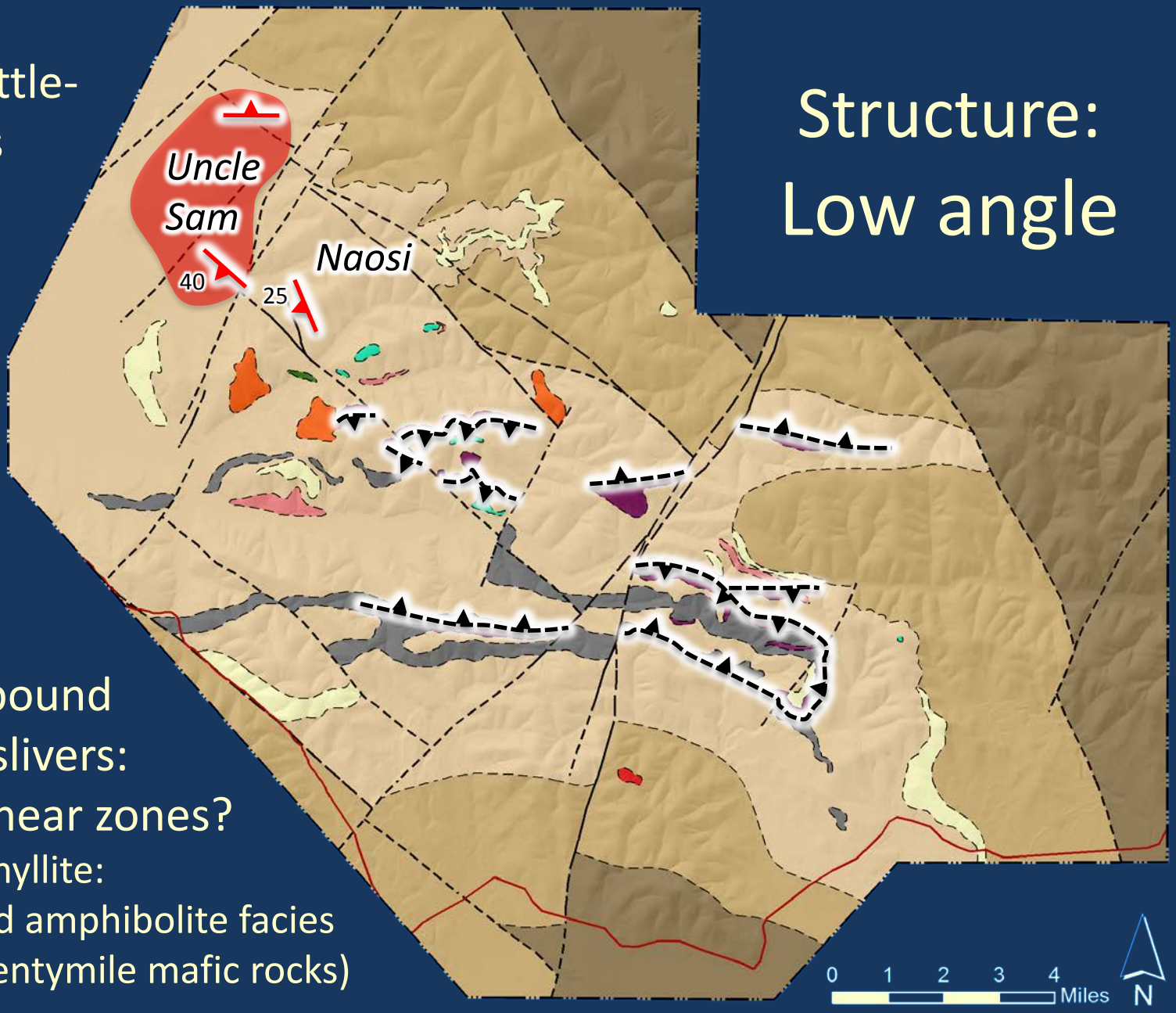
Paragneiss, locally migmatitic

Structure: Low angle

Core drilling:

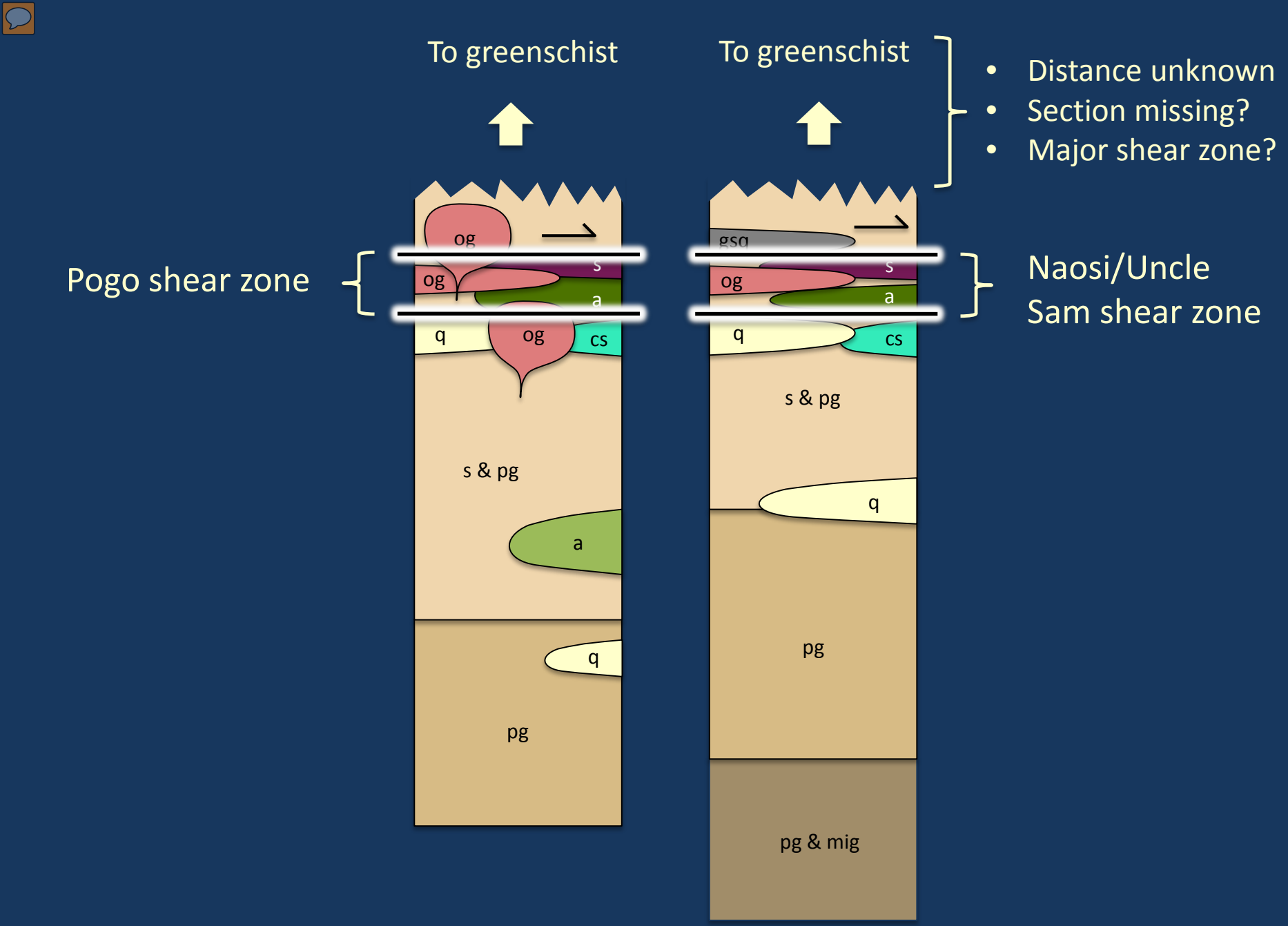
Low angle brittle-ductile shears host gold at Naosi, Uncle Sam

Beppu (2015), Eden (2010)



Structurally-bound serpentinite slivers: may reflect shear zones?

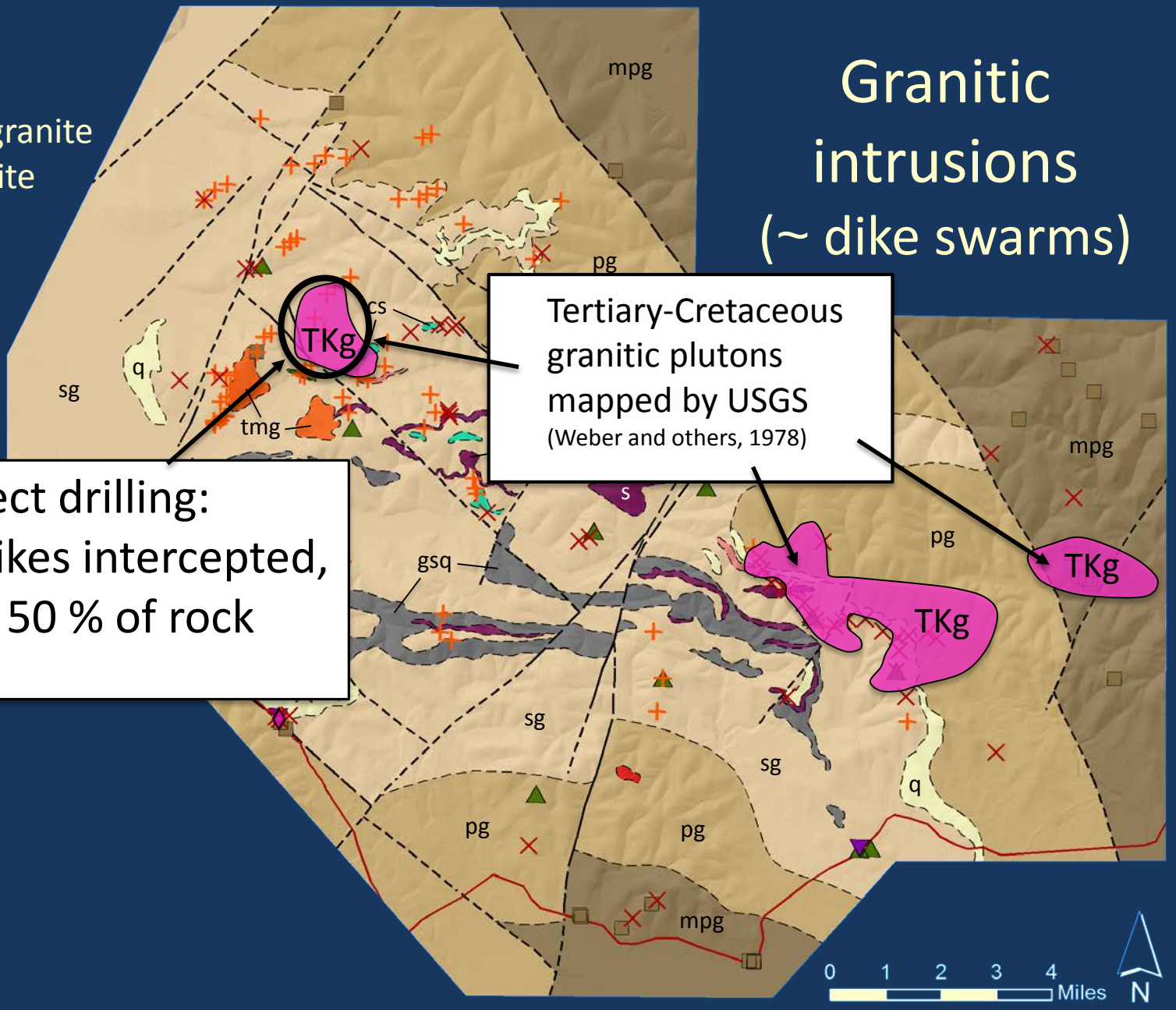
- talc, anthophyllite: experienced amphibolite facies (unlike Seventymile mafic rocks)


To greenschist
To greenschist
• Distance unknown
• Section missing?
• Major shear zone?
Pogo shear zone
Naosi/Uncle Sam shear zone
og
s
og
a
q
og
cs
s & pg
a
q
pg
gsq
s
og
a
q
cs
s & pg
q
pg
pg & mig
Salcha-River Pogo
Richardson, Uncle Sam

Granitic intrusions (~ dike swarms)

Intrusive rocks

- Porphyry
- Musc-tour granite
- Biotite granite
- Diorite



Tertiary-Cretaceous granitic plutons mapped by USGS
(Weber and others, 1978)

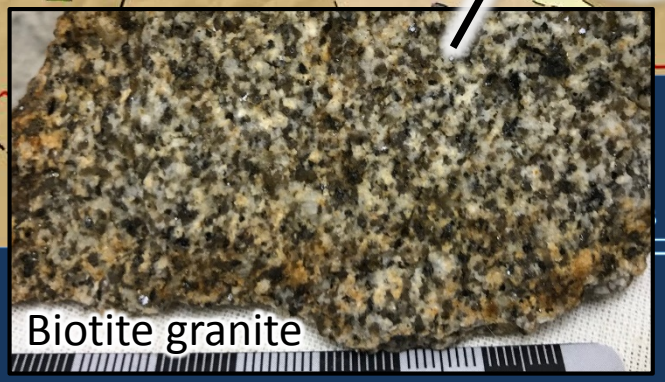
Naosi prospect drilling:
Numerous dikes intercepted,
max roughly 50 % of rock
(Beppu, 2015)

Granitic intrusions (~ dike swarms)

Intrusive rocks

- Porphyry
- Musc-tour granite
- Biotite granite
- Diorite


Muscovite-tourmaline granite


Biotite granite

Composition similar to the ± 114 Ma muscovite-bearing dikes to southwest of map area (Graham, 2002)

4 Miles

N

Granitic intrusions (~ dike swarms)

Intrusive rocks

- Porphyry
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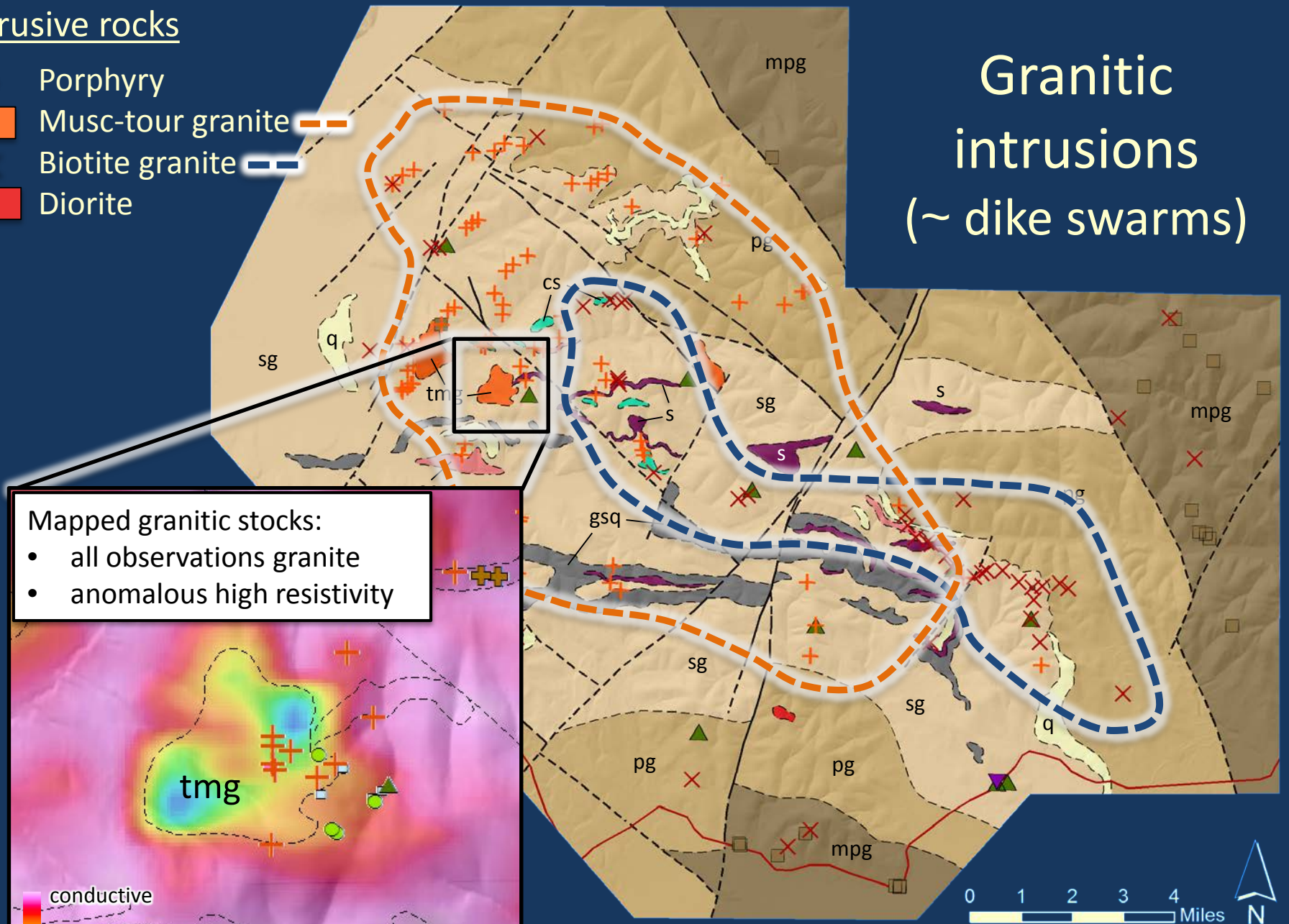
- Biotite granite
- Diorite



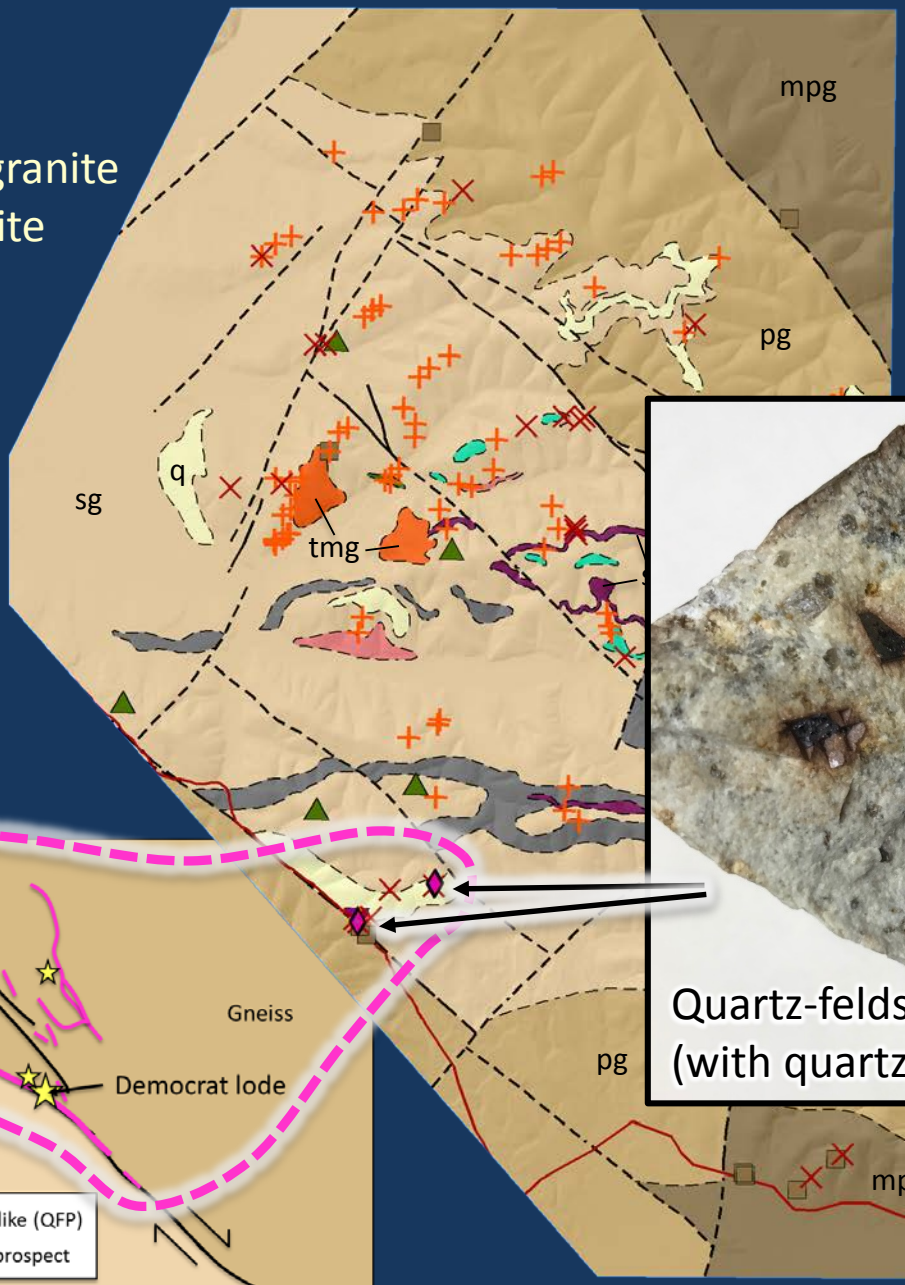
Mapped granitic stocks:

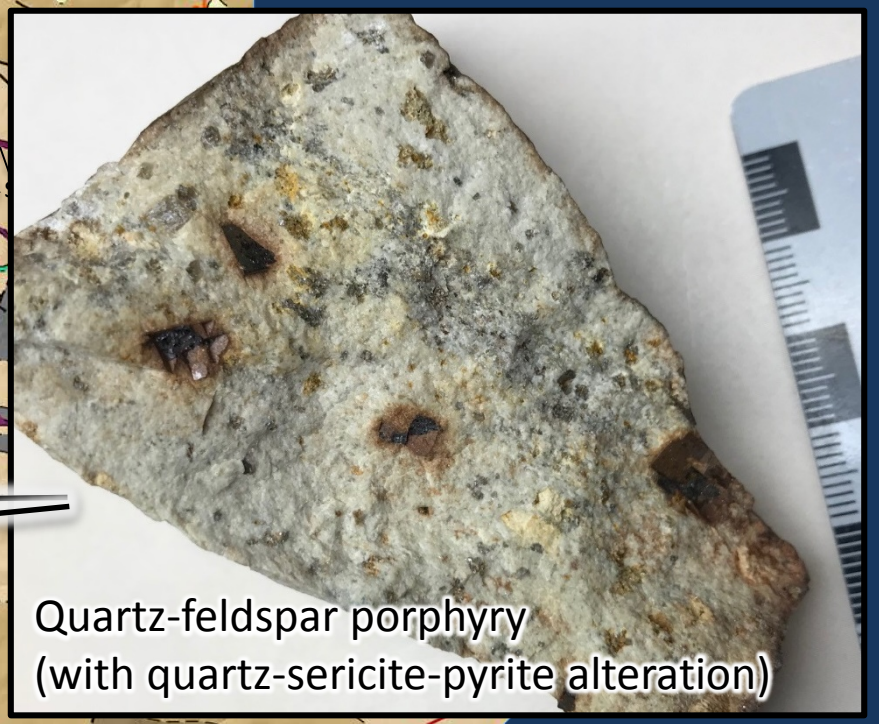
- all observations granite
- anomalous high resistivity

Altered porphyry intrusions: Correlate with Democrat dikes?

Intrusive rocks

- Porphyry
- Musc-tour granite
- Biotite granite
- Diorite

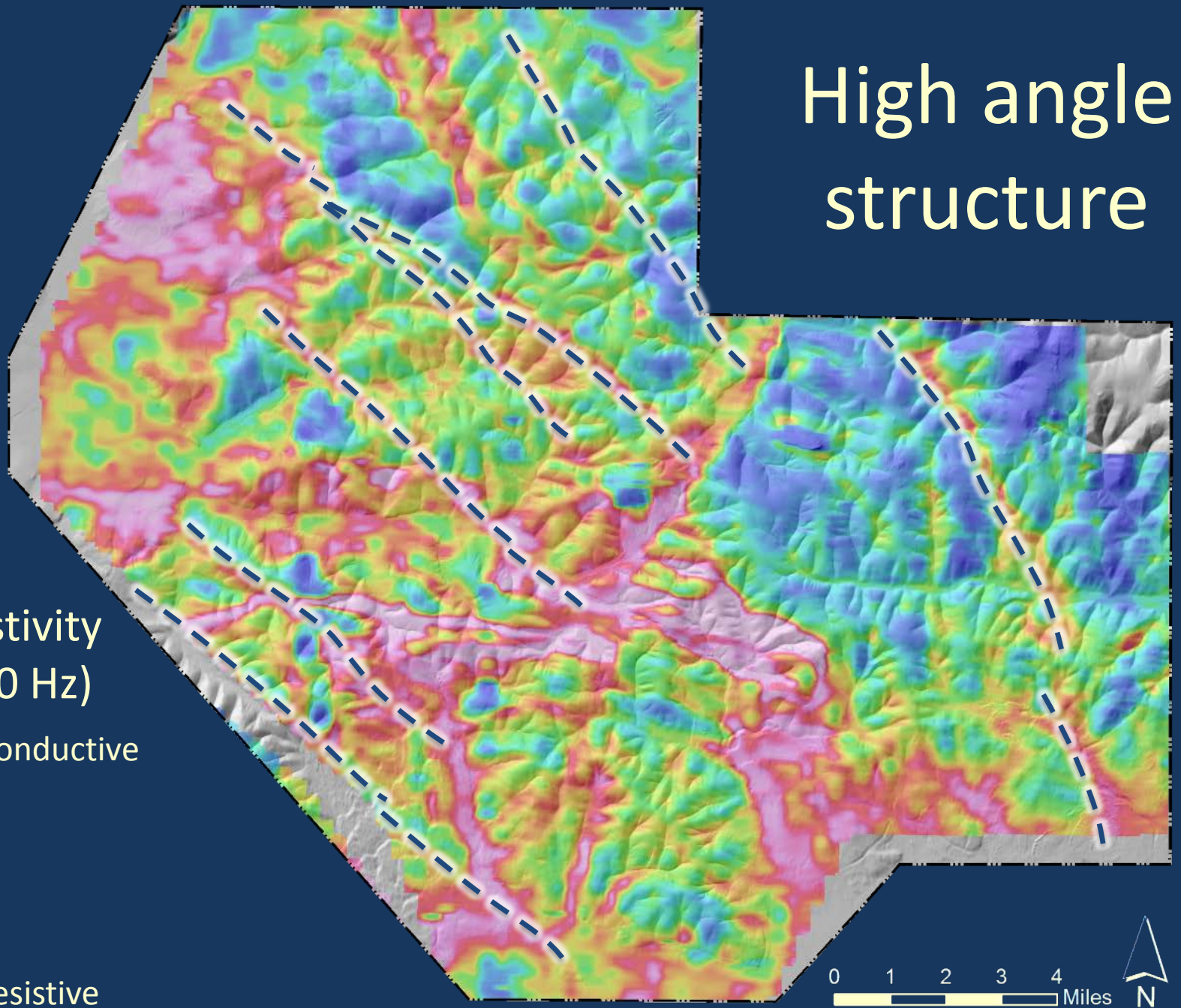




0 1 2 3 4 Miles N

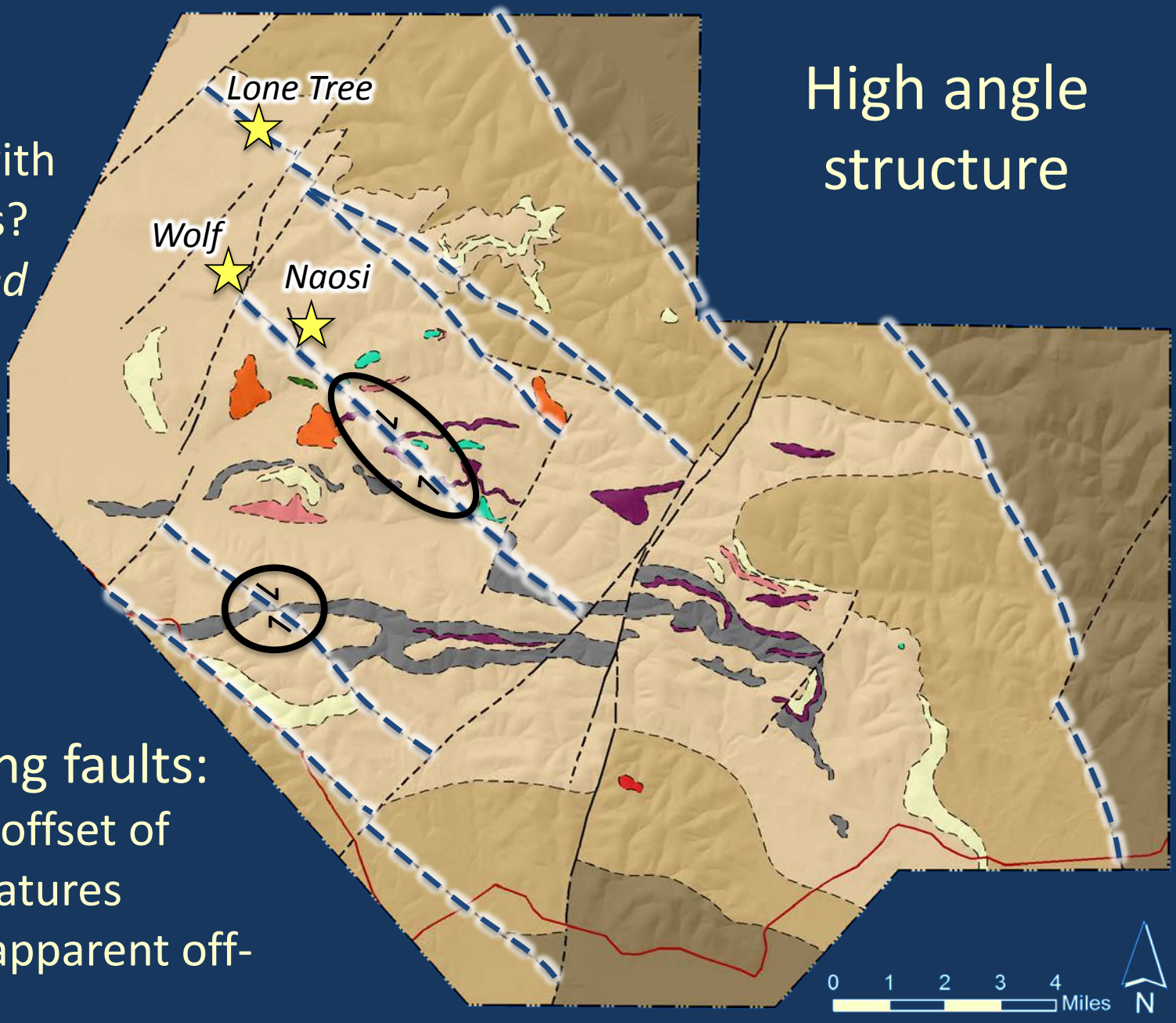
Age is ~ 90 Ma if related to Democrat dike

High angle structure



East Richardson geophysical survey (Burns and others, 2006)

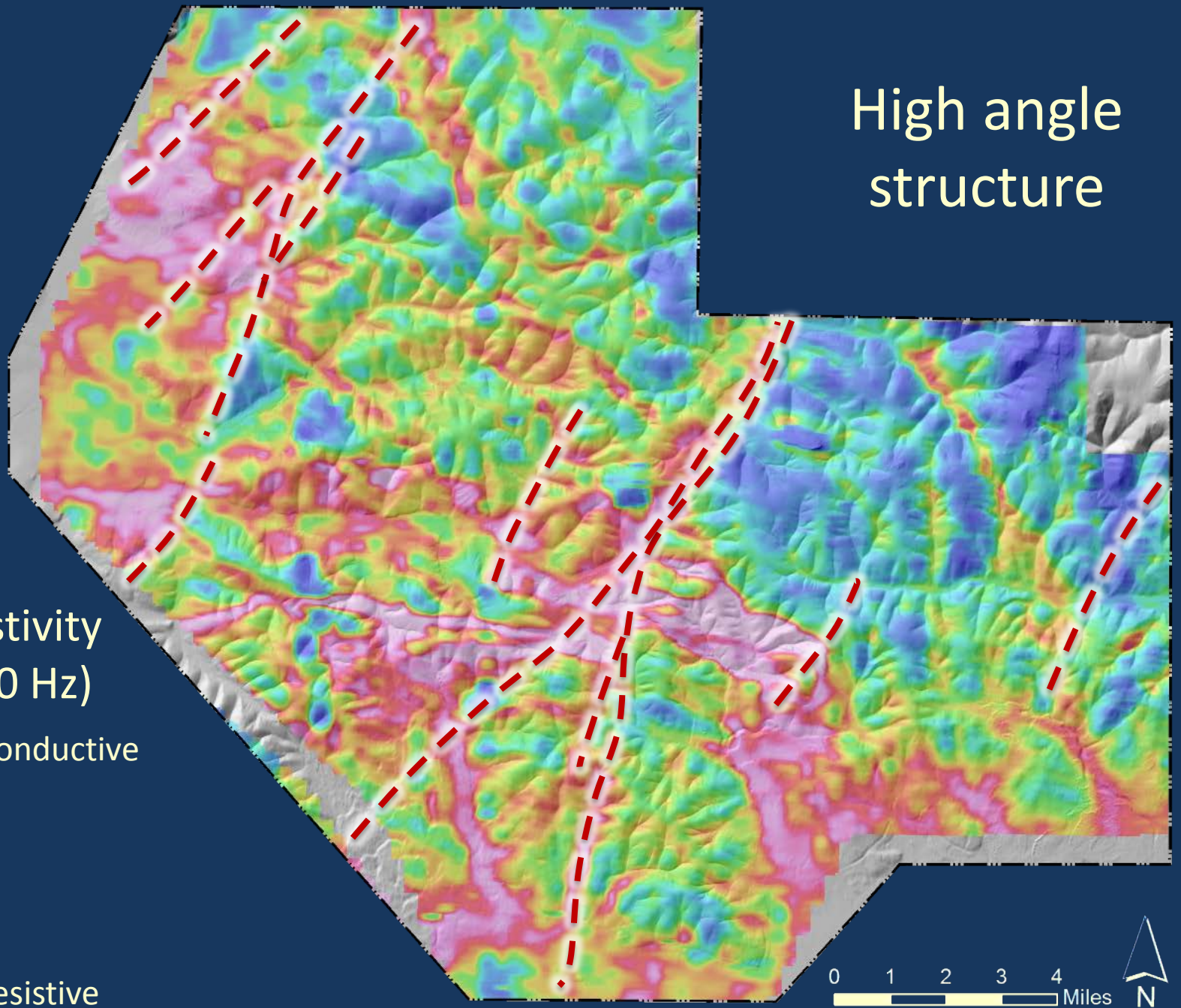
Prospects:
Generalized association with NE-structures? (even if *hosted* by low angle shears)



High angle structure

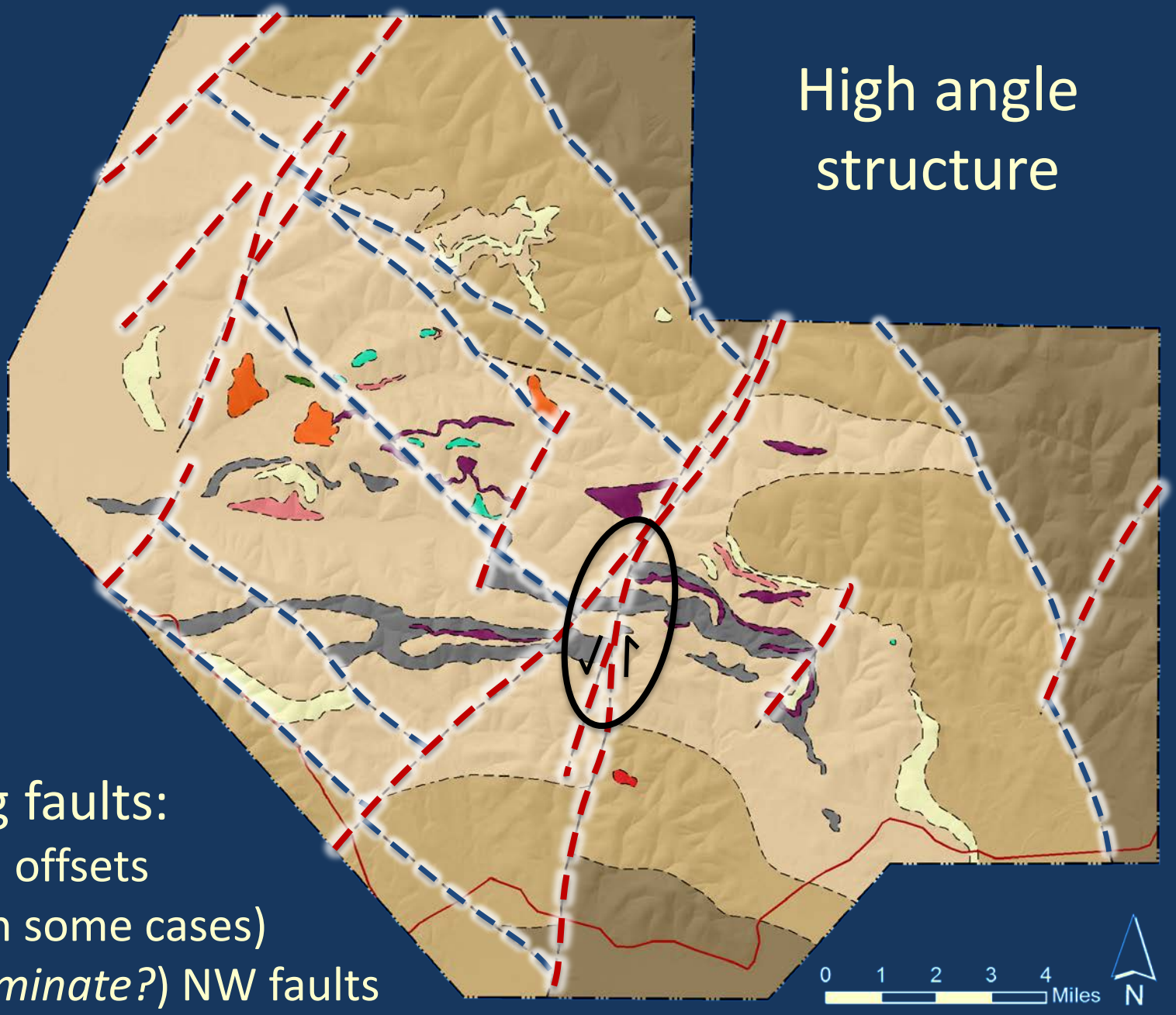
NW-trending faults:
Right-lateral offset of geological features (even more apparent off-map to SW)

High angle structure



East Richardson geophysical survey (Burns and others, 2006)

High angle structure

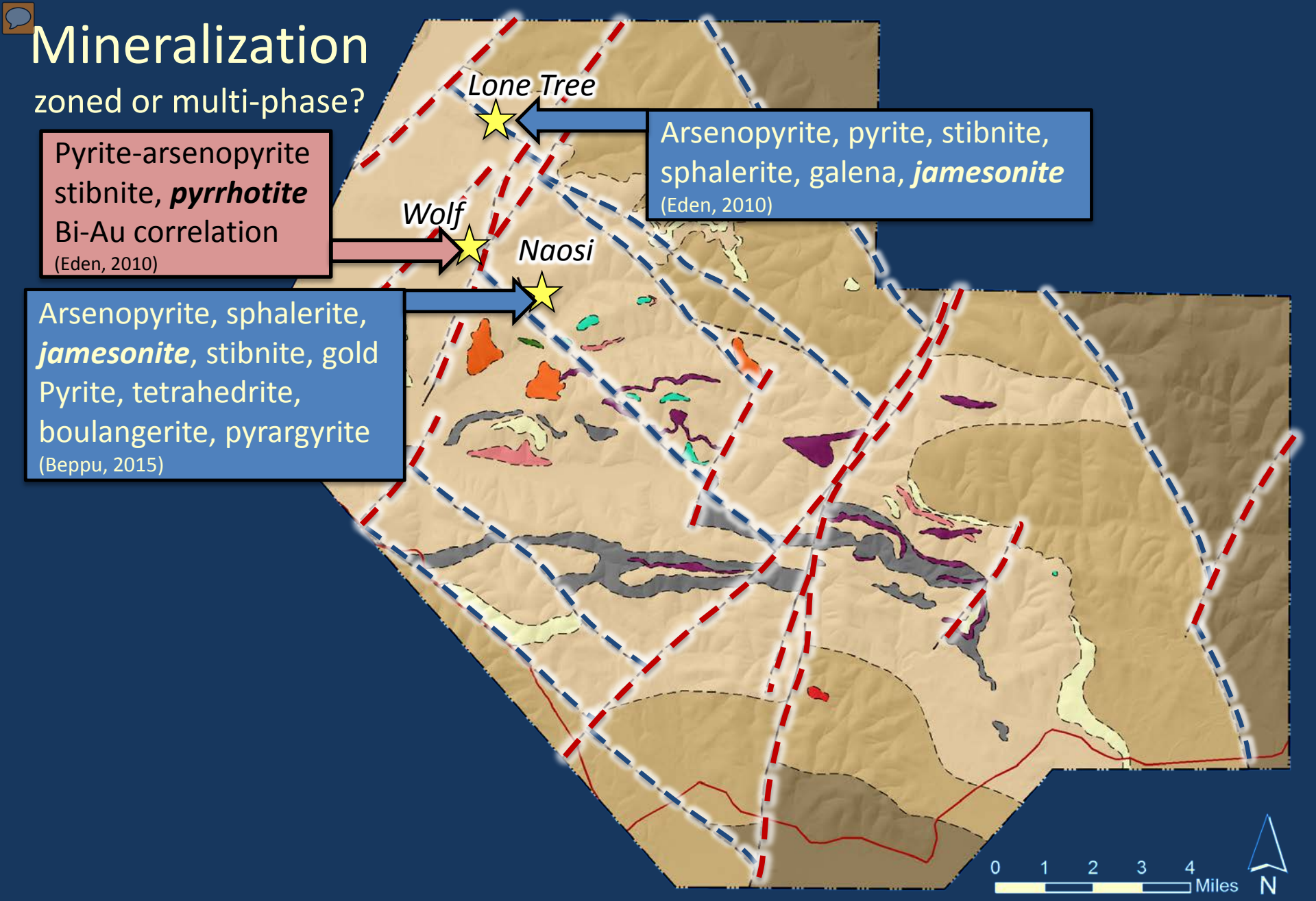


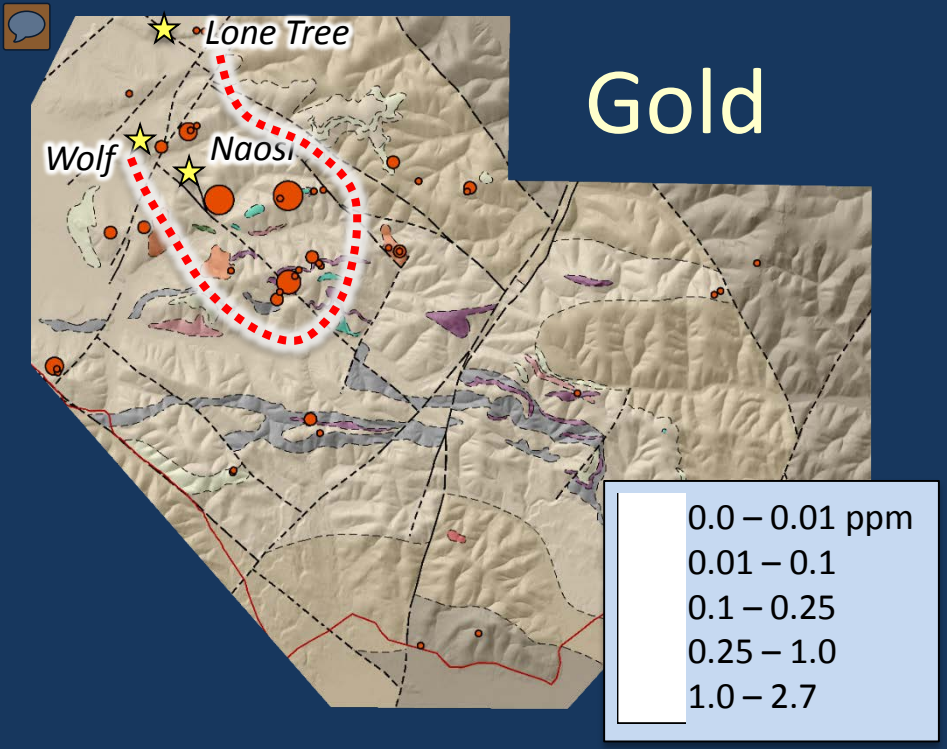
NE-trending faults:

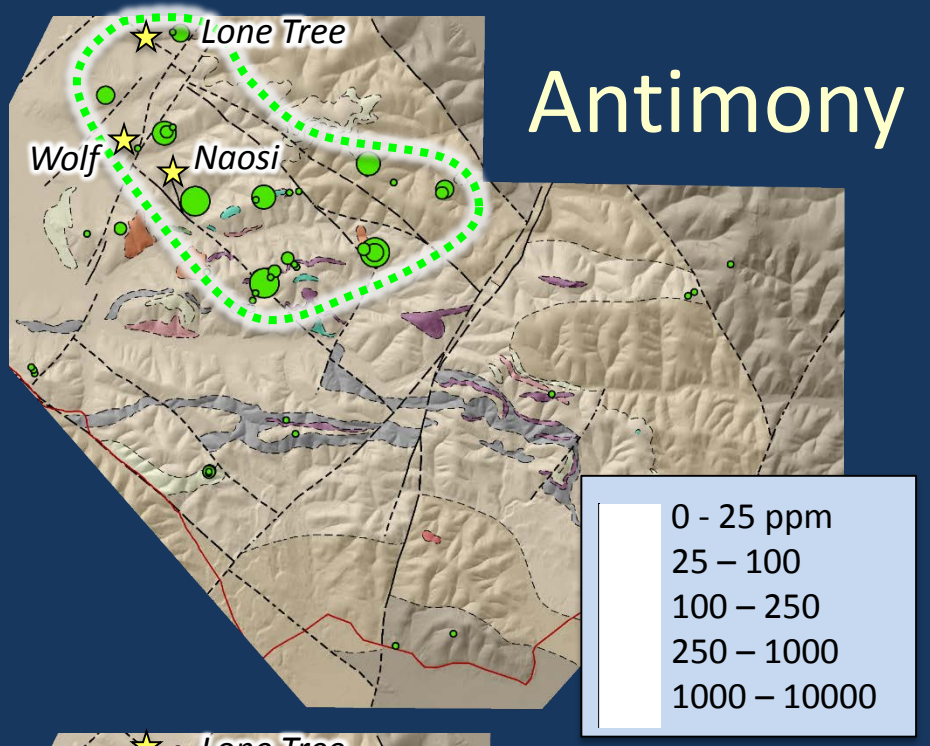
- Left-lateral offsets
  (at least in some cases)
- Cut (or *terminate?*) NW faults
- Conjugate fault system?

Mineralization

zoned or multi-phase?



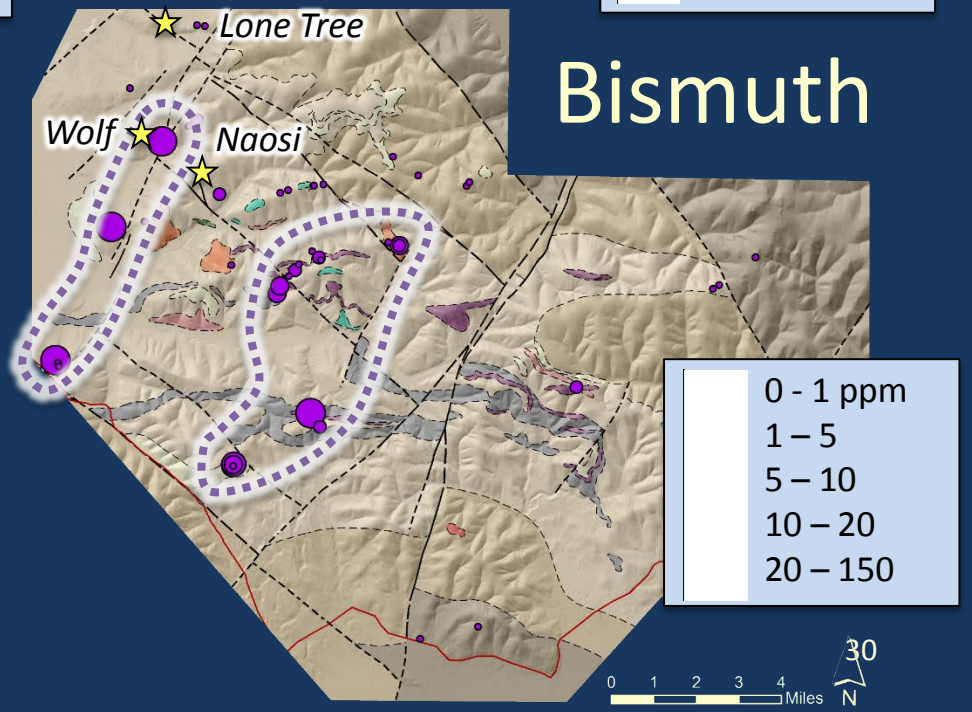




DGGS rock sample geochem results

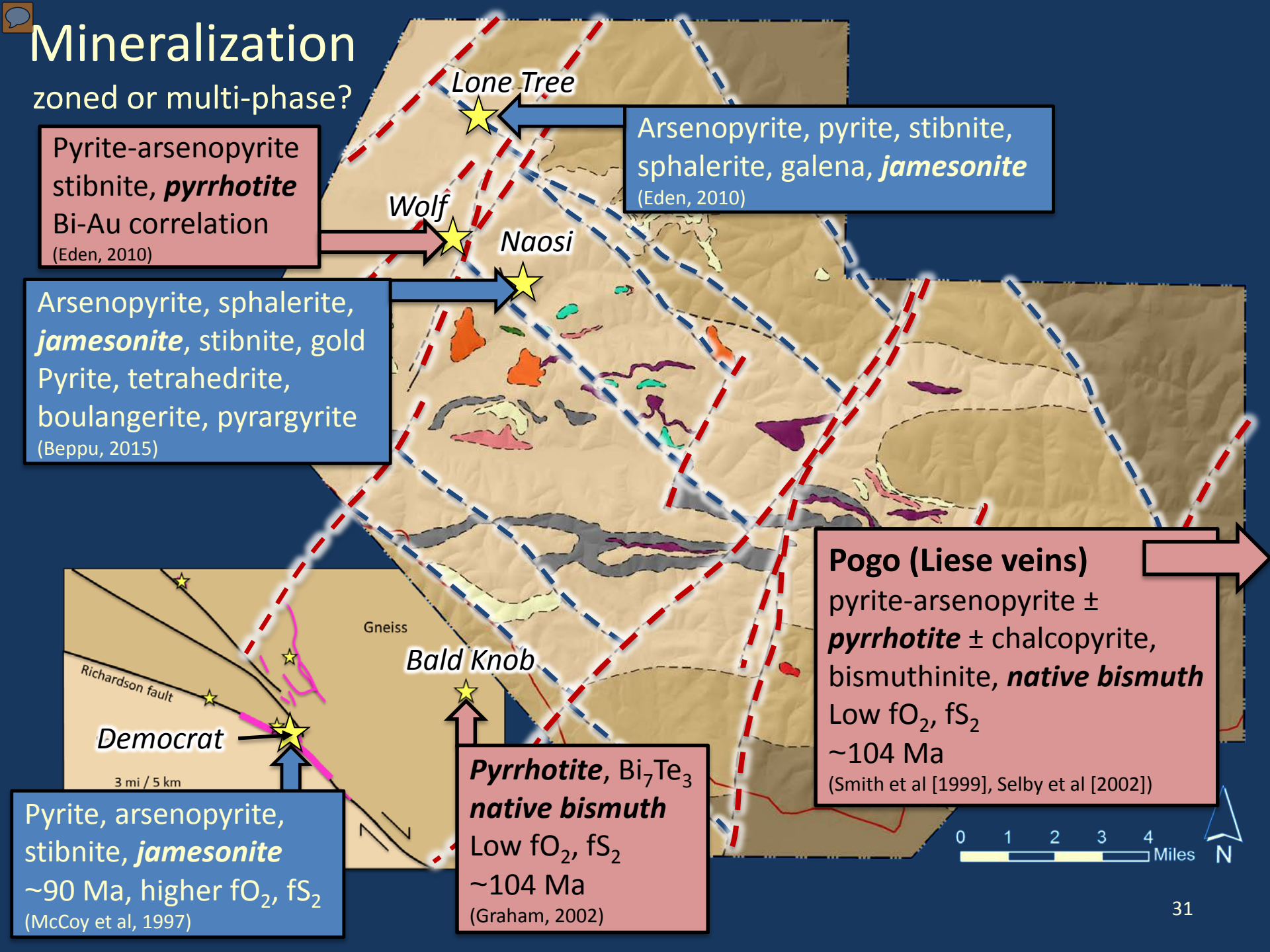
New data released at dggs.alaska.gov (RDF 2017-11)

non-systematic sampling, especially the more covered Uncle Sam area



Mineralization

zoned or multi-phase?



Pyrite-arsenopyrite stibnite, ***pyrrhotite*** Bi-Au correlation
(Eden, 2010)

Arsenopyrite, pyrite, stibnite, sphalerite, galena, ***jamesonite***
(Eden, 2010)

Arsenopyrite, sphalerite, ***jamesonite***, stibnite, gold
Pyrite, tetrahedrite, boulangerite, pyrargyrite
(Beppu, 2015)

Pogo (Liese veins)
pyrite-arsenopyrite ± ***pyrrhotite*** ± chalcopyrite, bismuthinite, ***native bismuth***
Low fO_2, fS_2
~104 Ma
(Smith et al [1999], Selby et al [2002])

Pyrrhotite, Bi_7Te_3
native bismuth
Low fO_2, fS_2
~104 Ma
(Graham, 2002)

Pyrite, arsenopyrite, stibnite, ***jamesonite***
~90 Ma, higher fO_2, fS_2
(McCoy et al, 1997)

Conclusions

- General metamorphic ‘stratigraphy’ of the area is similar to that of the Salcha River-Pogo area
- Shear zone(s) may occupy the same structural position, ‘slippery’ lithologies as at Pogo
  - top of amphibolite facies, transition to greenschist?
- Intrusions here are small stocks and dike swarms
  - Compare to plutons, batholith around Pogo
- Richardson/Uncle Sam is mostly more “distal”, oxidized, lower T compared to Pogo, however:
  - Exploits some of the same structural preparation?
- We suggest multiple stages of mineralization, but…
  - More work needed
  - Richardson District is a great place to study this question

Thanks!

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