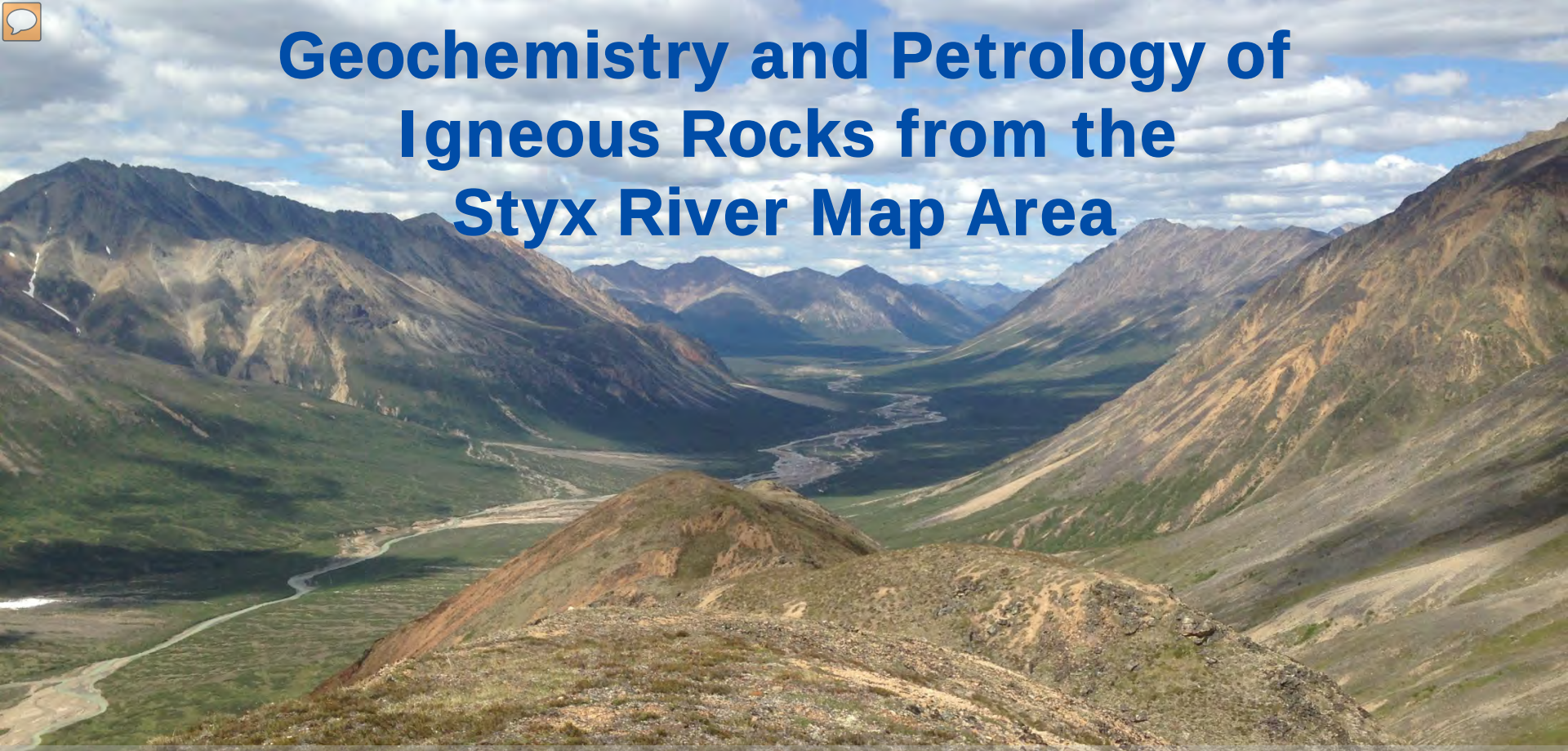
Geochemistry and Petrology of Igneous Rocks from the Styx River Map Area



K.R. Sicard[1], A. Wypych[1], E. Twelker[1], L.K. Freeman[1], R.J. Newberry[2] , E.N. Bachmann[1], D.A. Reioux[1], A.L. Tuzzolino[2,1] , and T.C. Wright[2,1]

[1]Alaska Division of Geological & Geophysical Surveys
[2]Department of Geology & Geophysics, University of Alaska Fairbanks

AMA Biennial Fairbanks Alaska Mining Conference
April 9, 2014 – Fairbanks, Alaska

Outline

- Location
- Geologic background
- Summer accomplishments
- Geochemical methods
- Geochemical results
  - Pluton comparisons
  - Cu, Au, As, Ag, Mo, Bi occurrences
  - Sericite alteration patterns
- Conclusions

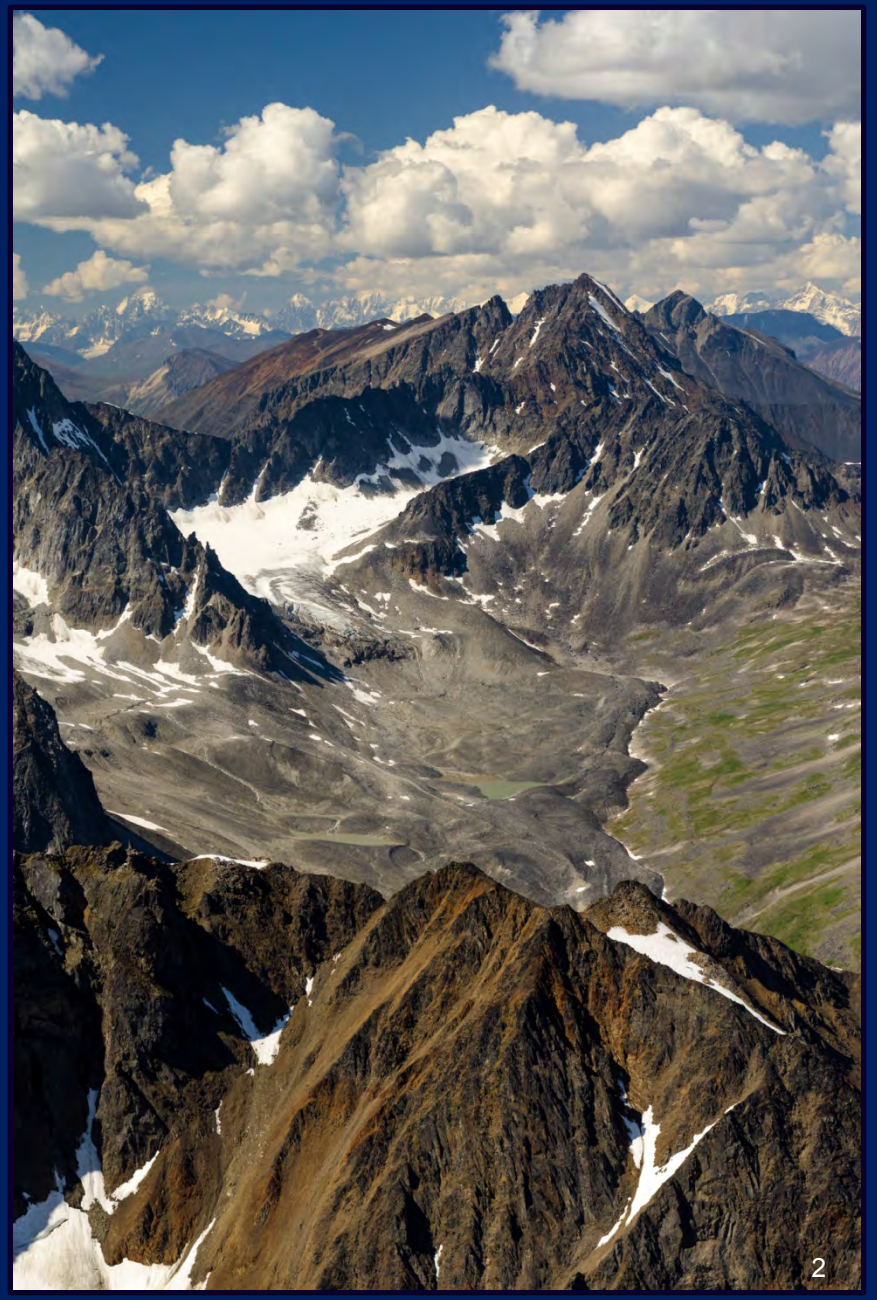


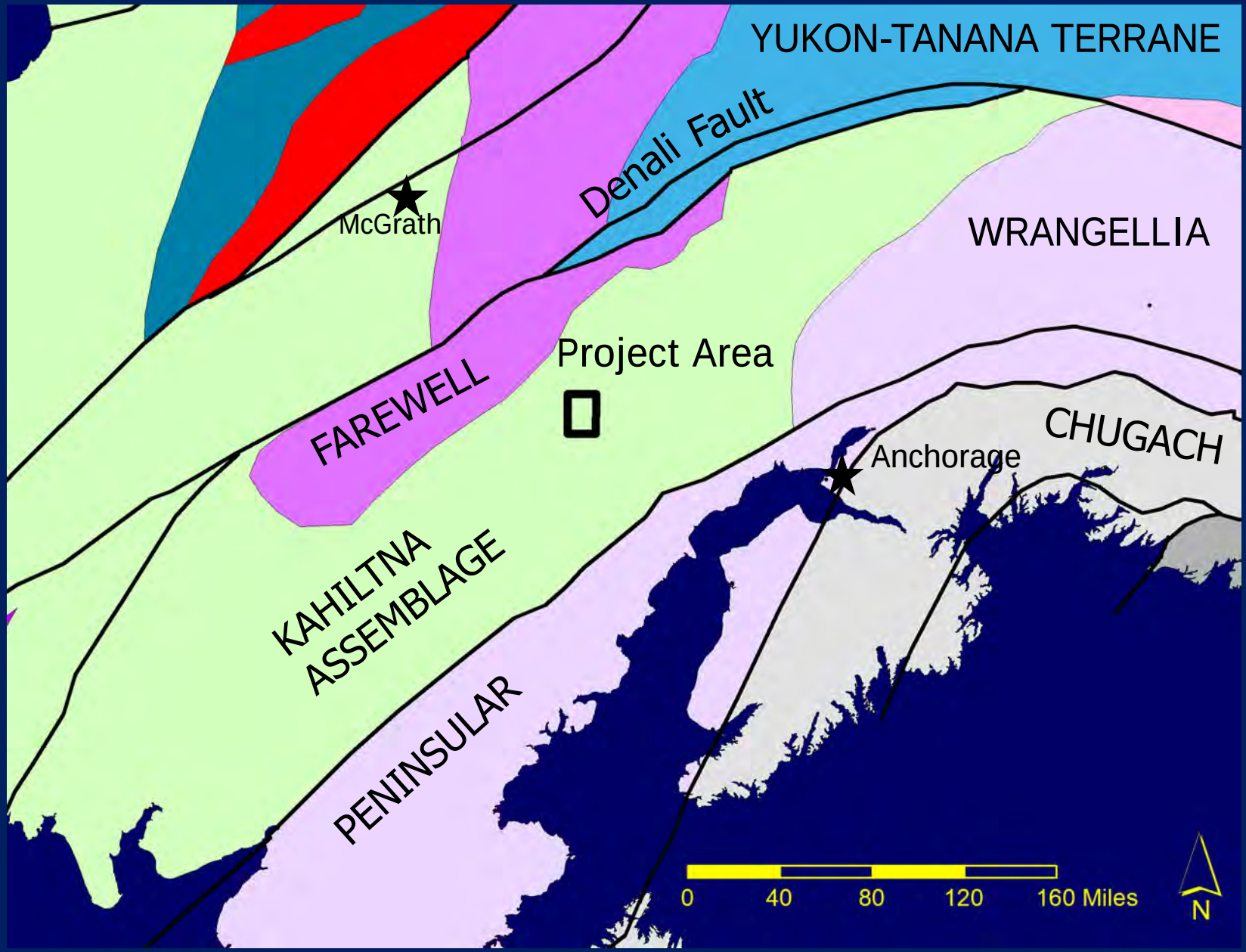
Photo by T.C. Wright

Styx River Map Area

Funded by the Legislature as part of the Governor's Strategic and Critical Minerals Assessment Capital Improvement Project which supplements the ongoing Airborne Geophysical/ Geological Mineral Inventory

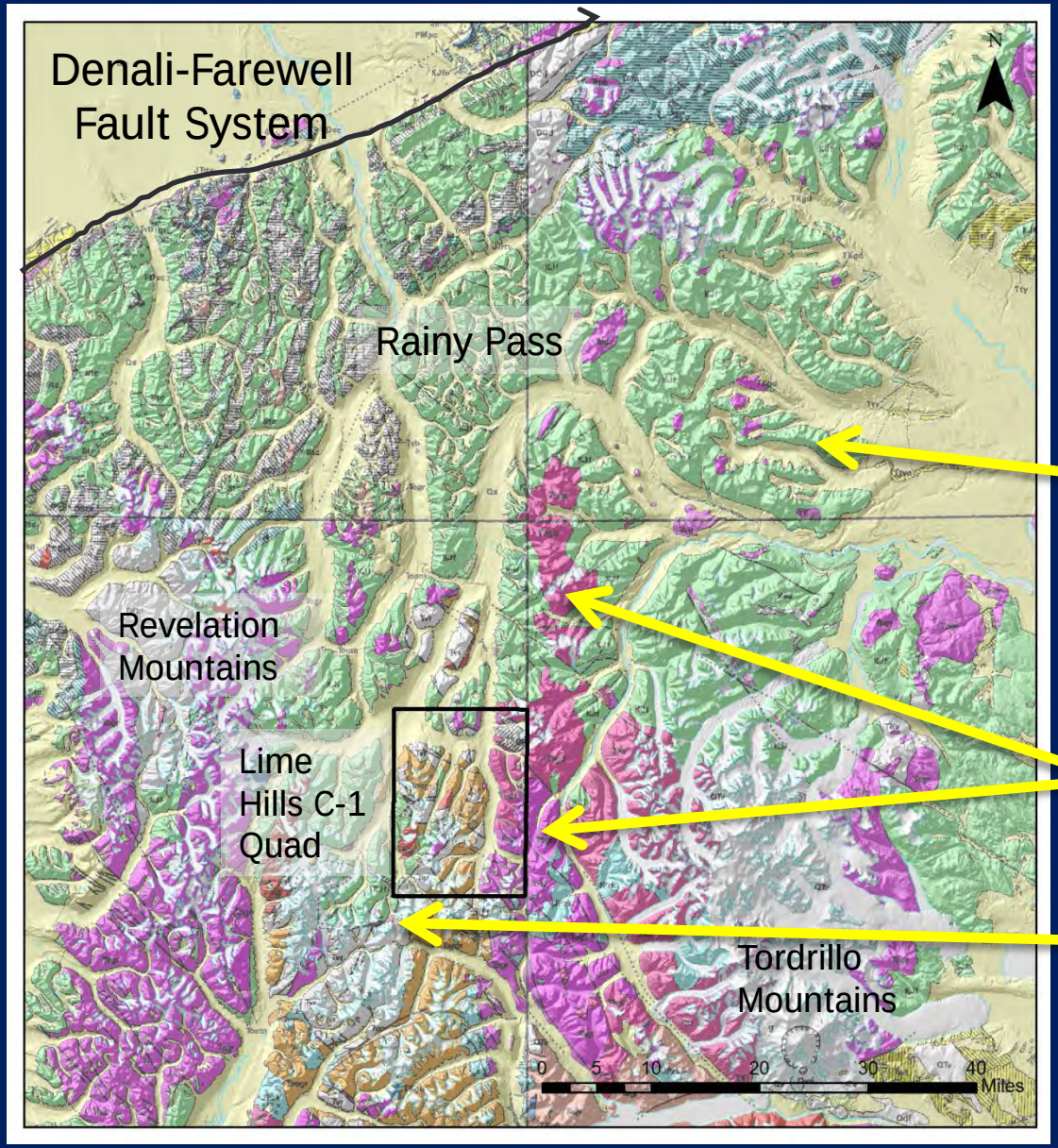
Lime Hills C-1 Quadrangle

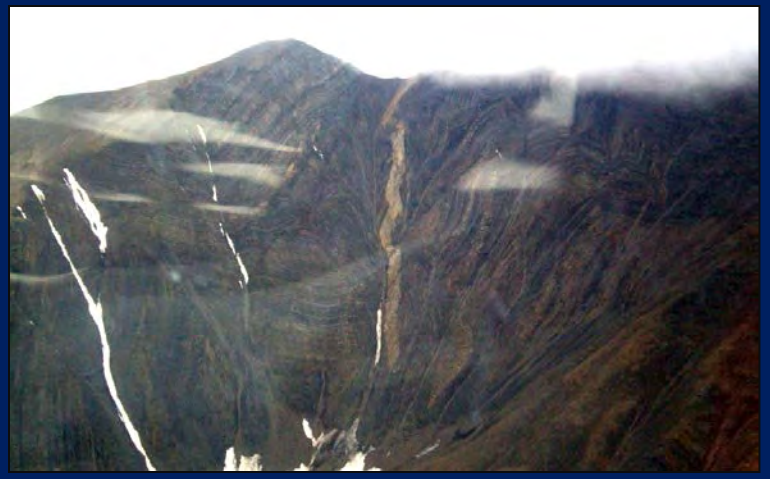
Geologic Setting: Terrane Map



Modified from Colpron and Nelson, 2011

Styx Project Geologic Setting





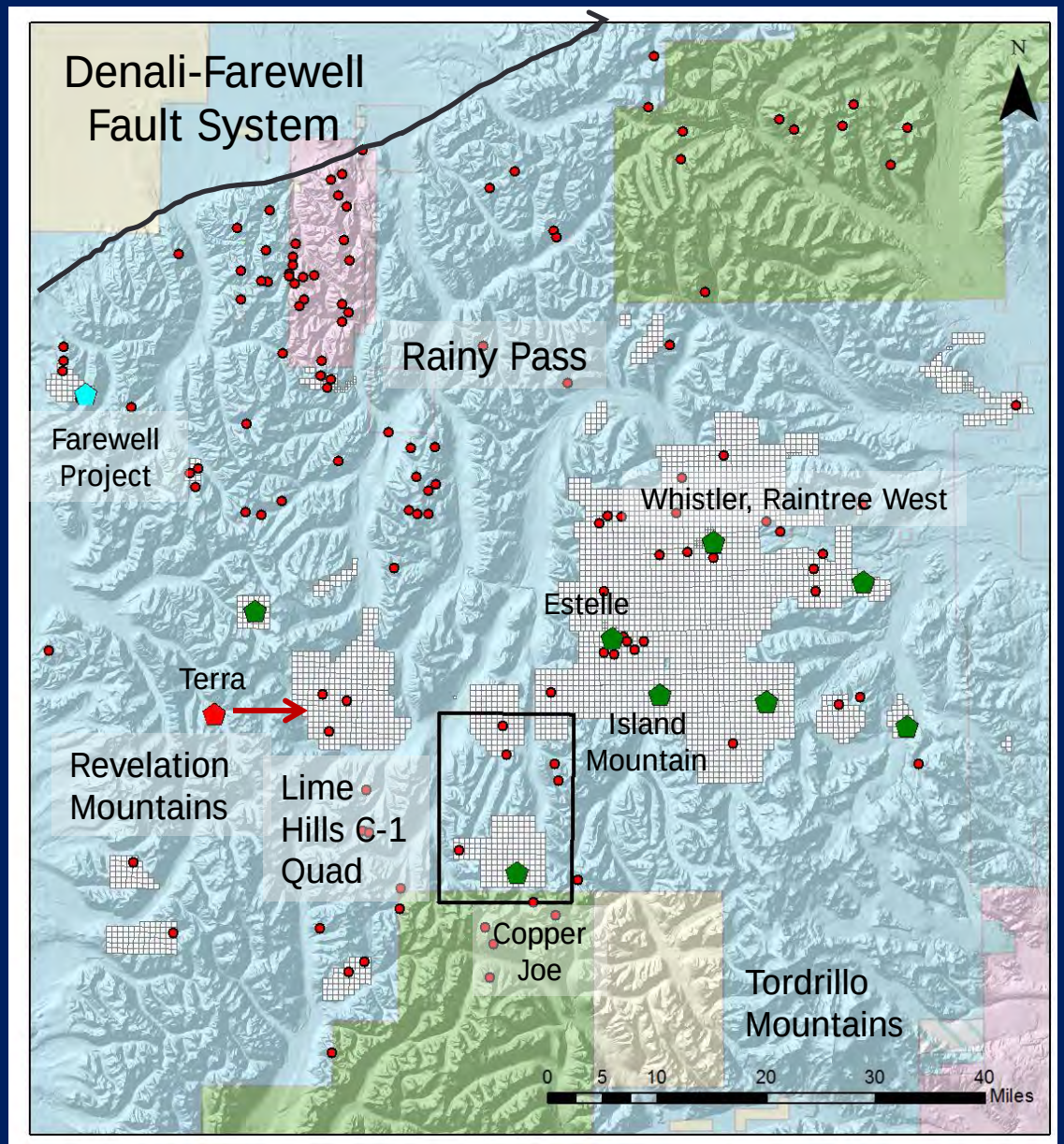
Jurassic-Cretaceous
flysch

Cretaceous and Tertiary
plutonic rocks

Tertiary **volcanics**

Map modified from Wilson and others, 1998

Land Status and Mining Claims



LEGEND

Land ownership

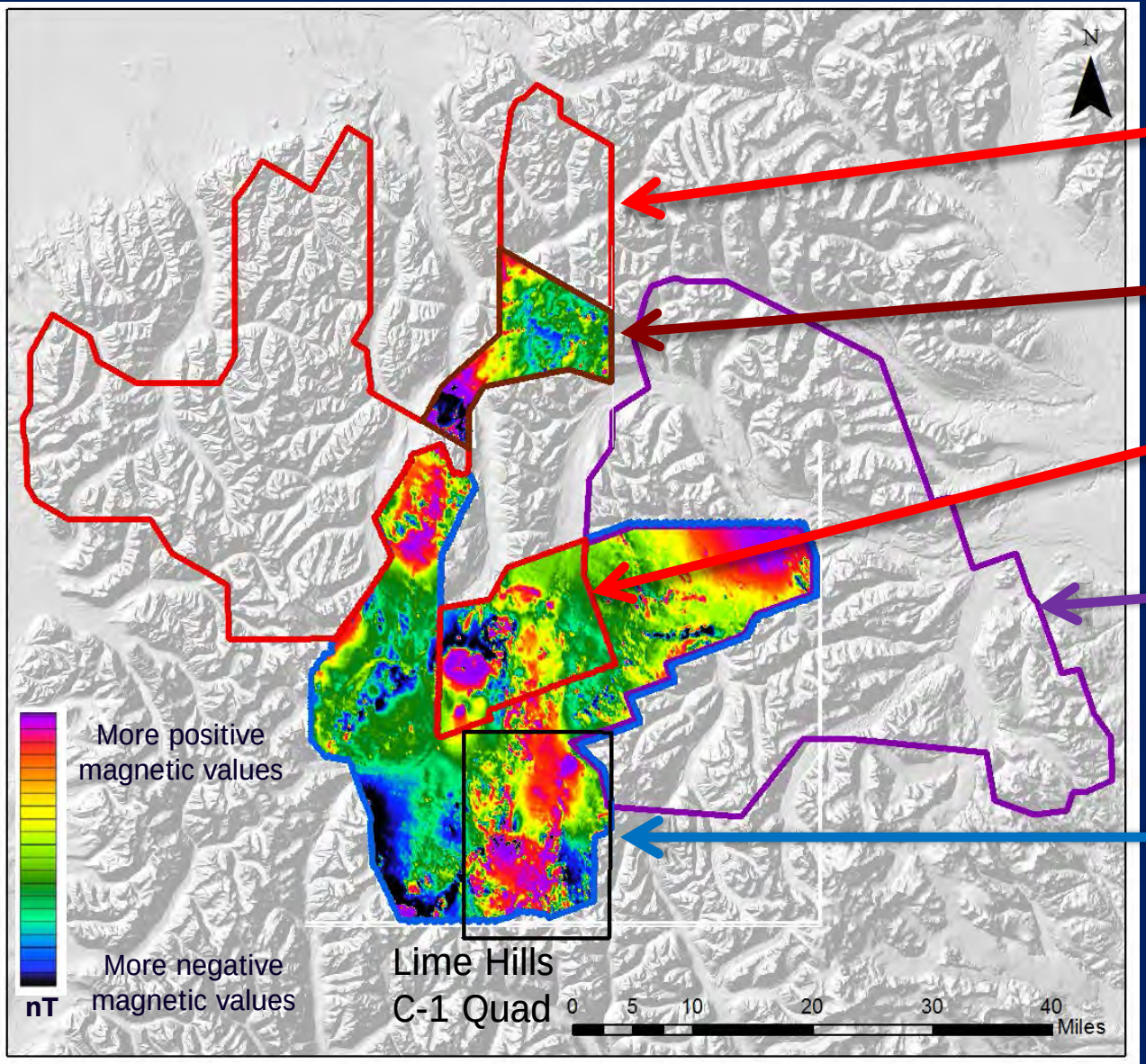
- Bureau of Land Management
- National Park Service
- Native Patent or IC
- State Patent or TA
- State Selected

LEGEND

Mineral Exploration

- Cr, Ni, PGE
- Au
- Porphyry (Cu, Au, Mo)
- ARDF lode deposits
- State Mining Claims

Geophysical Surveys



Farewell Survey (2014)

Dalzell Creek Survey (2013)

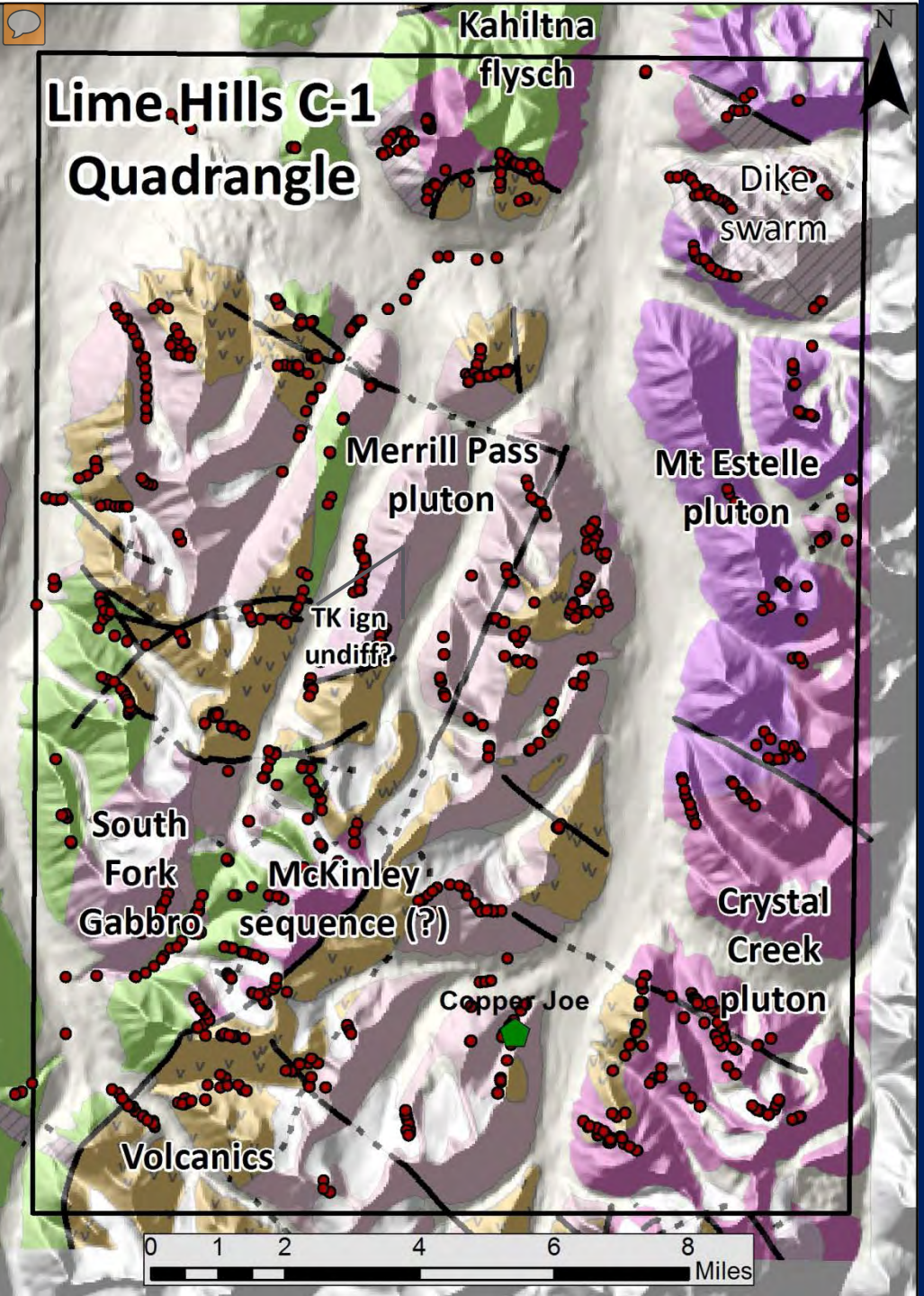
Middle Styx Survey (2013)

East Styx Survey (2014)

Styx River Survey (2008)

2013 Field Mapping

- 1863 stations with geologic observations
- Collected samples
- Refined map contacts significantly



Geologic map modified from Gamble and others, 2013

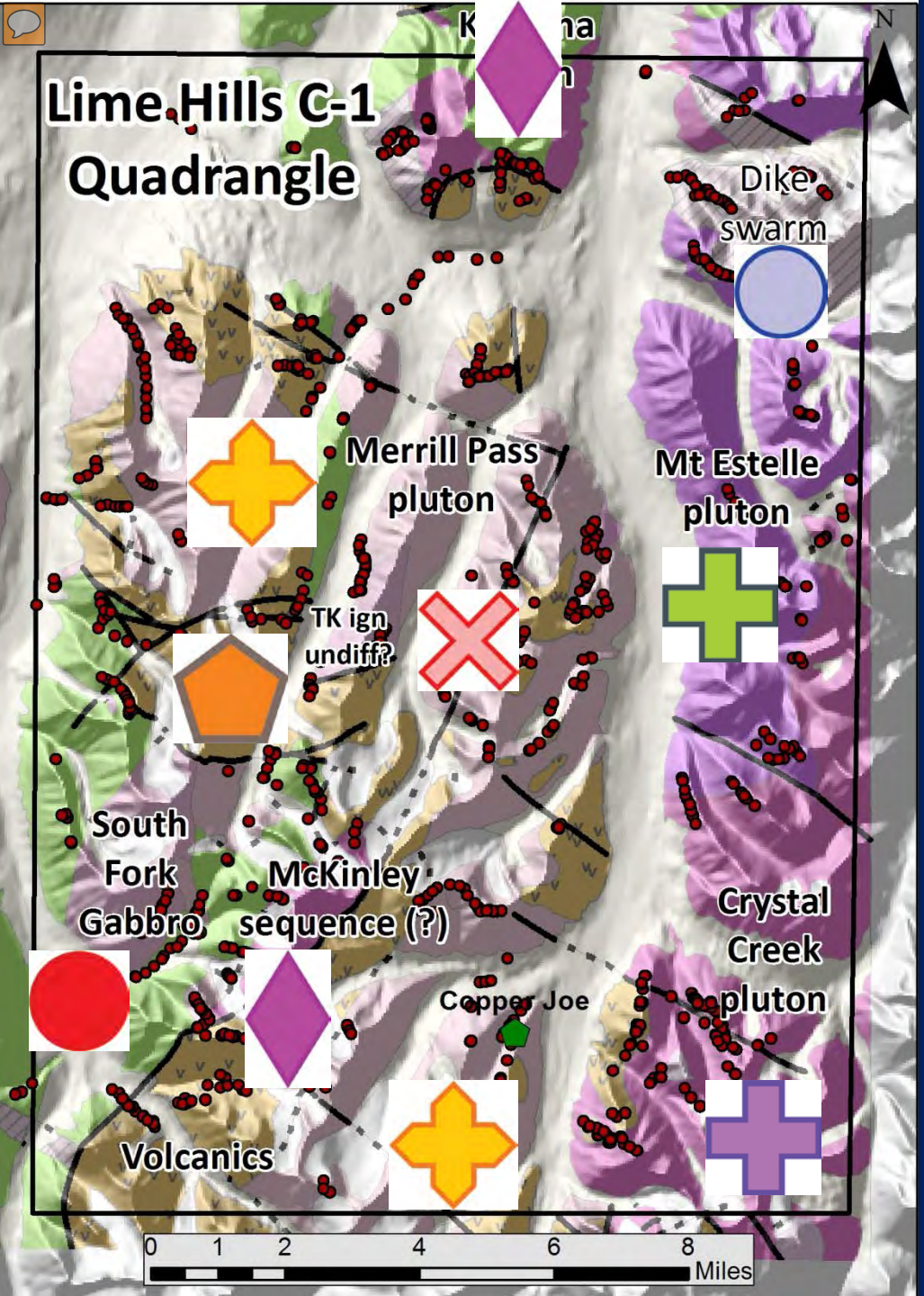
- How does this data help us refine unit contacts, and improve mapping?
  - Do the pluton compositions overlap?
  - Do they cluster or have broad ranges?
  - Can we split or combine plutons based on these trends?
- How does our data compare to USGS data and to mineralized plutons in the area such as the Terra pluton and the Mt Estelle pluton?
- Where do we see mineralization and why is it there?

Geochemical Analysis Methods

- Broad lens XRF analyses (UAF)
- ALS Geochemical Analyses
  - Bulk Rock: Major oxide, trace element with ICP-MS, four-acid digestion for Au-Pt-Pd
- Stained slabs
  - HF acid, K stain

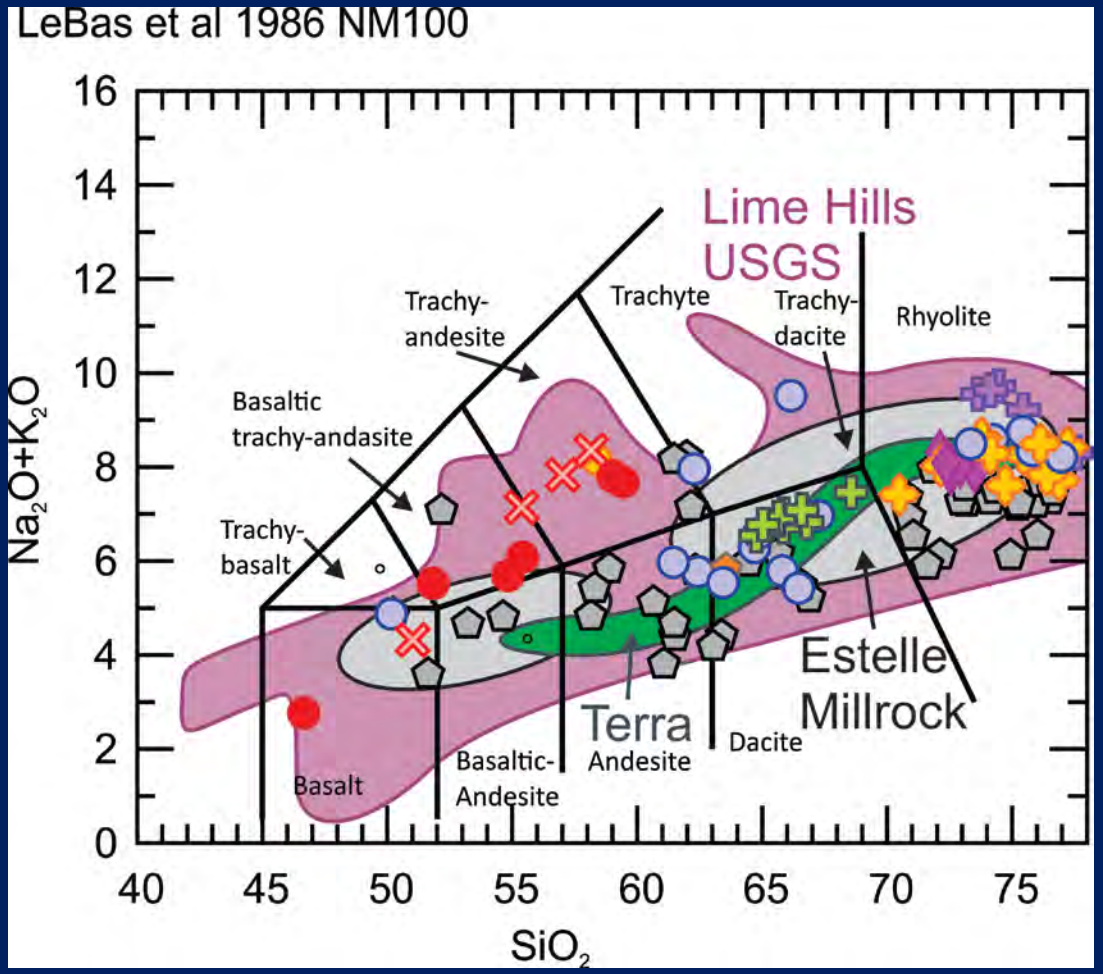
Photo by T.C. Wright

Geologic Map with Geochemical Symbology



Geologic map modified from Gamble and others, 2013

Pluton trends: Total Alkalis vs. Silica

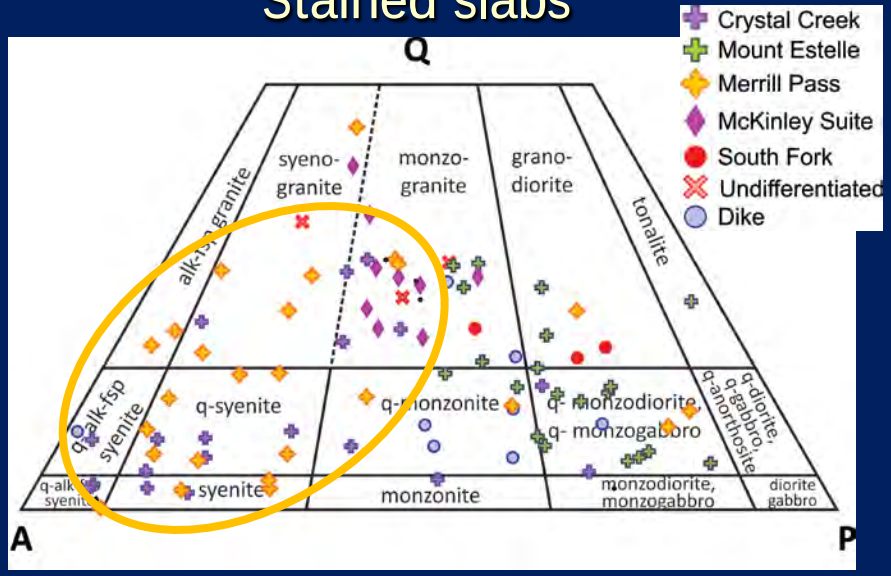


- This new data compares with previously published USGS data and industry data

Merrill Pass pluton (Tmp)

40.0-41.6 Ma (Ar/Ar)

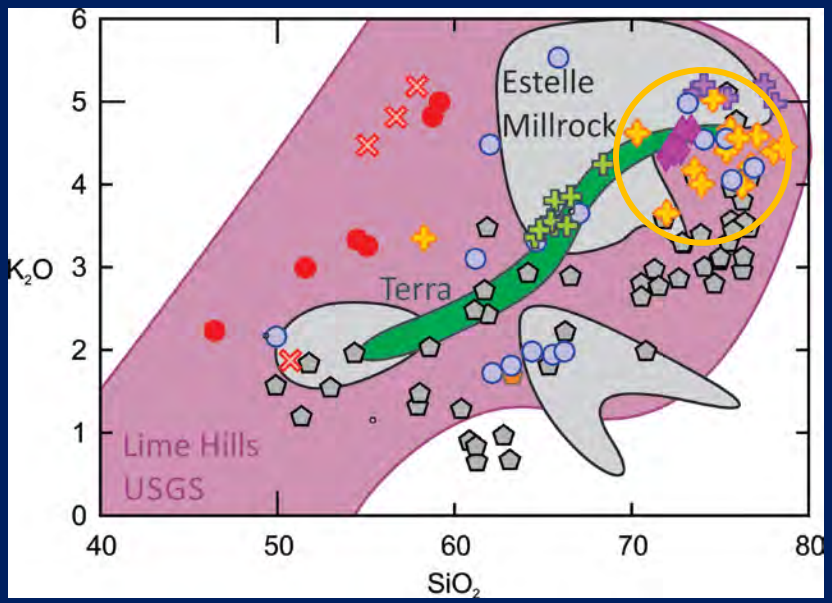
Stained slabs

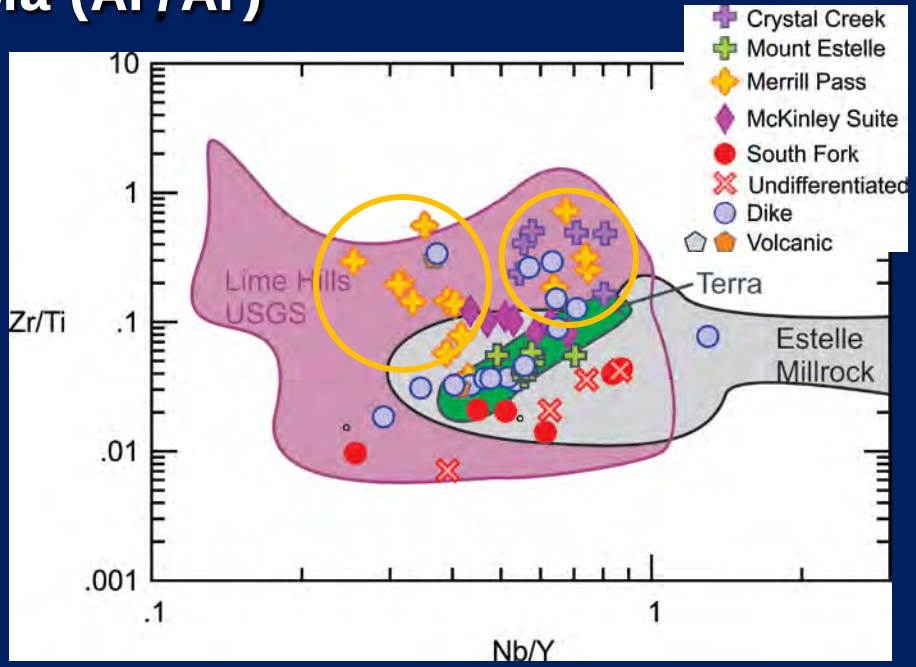


- Biotite granite to granodiorite to alkali-feldspar granite
- Hypidiomorphic granular textures with miarolitic cavities
- Intrudes upwards into Tertiary volcanics (Tv)

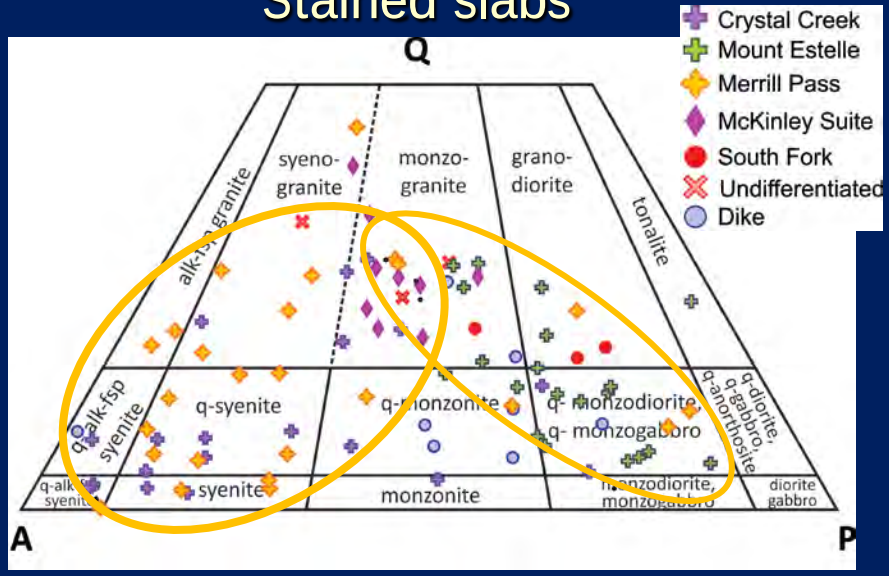
Merrill Pass pluton (Tmp)

40.0-41.6 Ma (Ar/Ar)



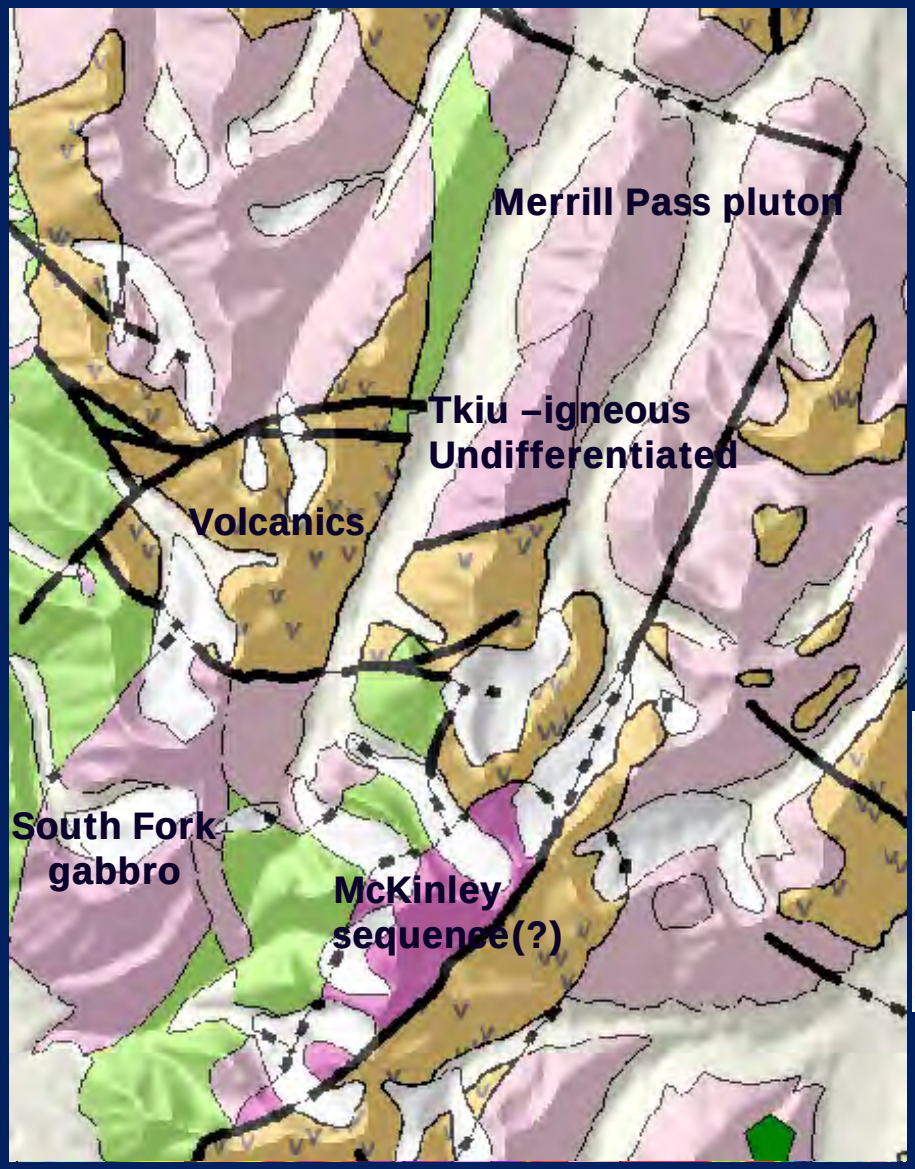


Stained slabs



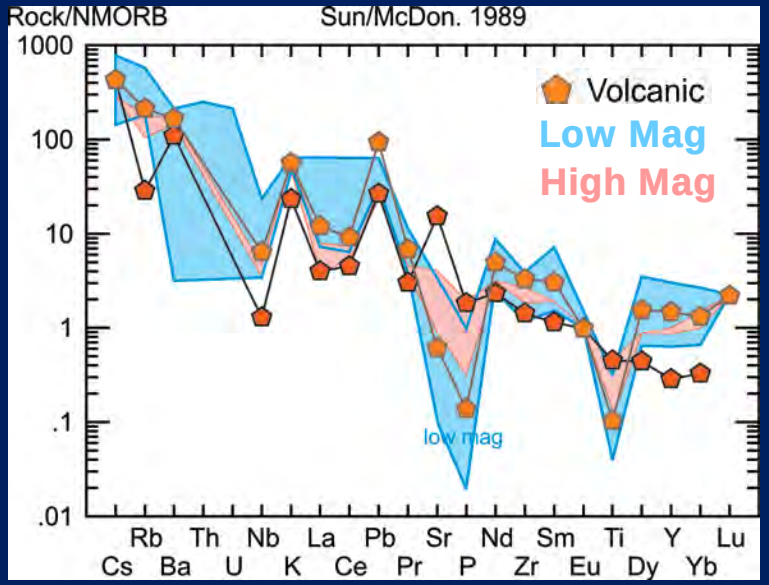
- Compares to USGS and industry data
- At least two phases of Tmp
- Highly magnetic phase may have a separate trace element signature

High and Low Magnetic Merrill Pass



More positive magnetic values

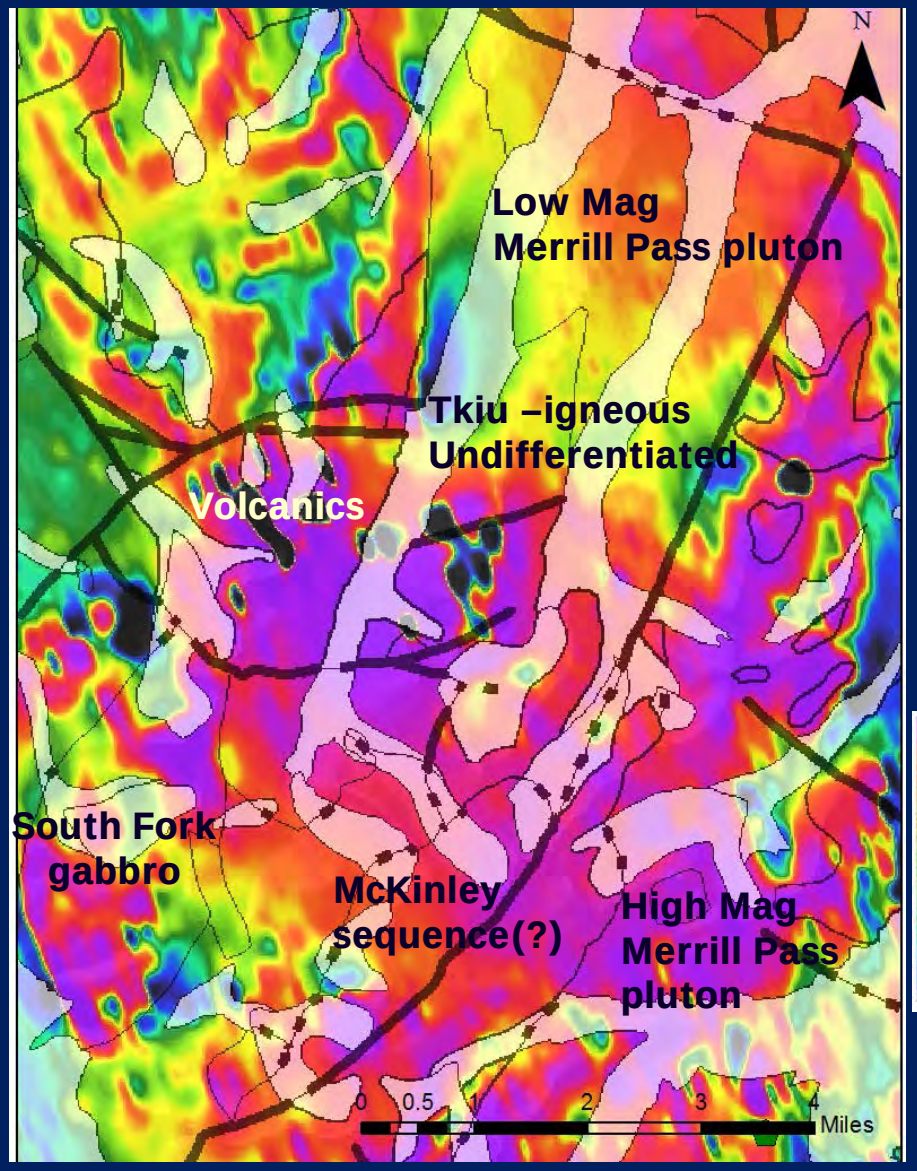
More negative magnetic values



- Trace element signatures of high and low mag appear the same in spider diagram
- Some of the volcanic rocks are similar to Merrill Pass pluton

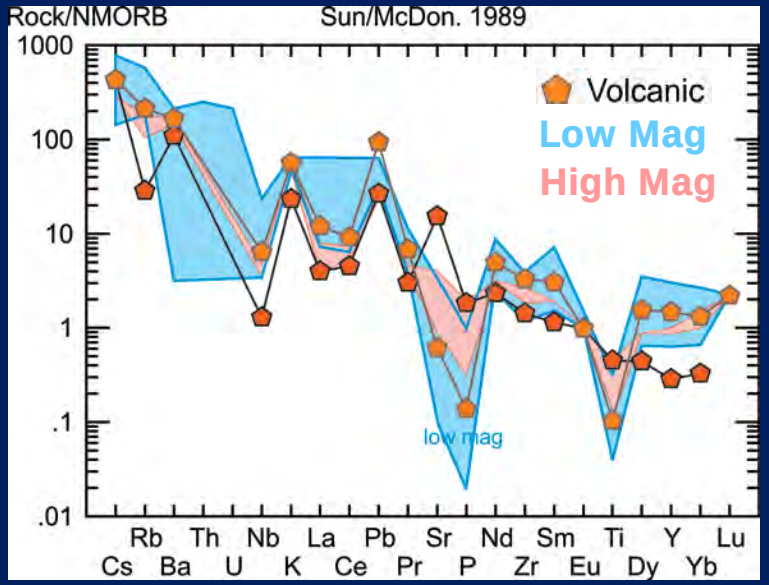
Geologic Map contacts from Gamble and others, 2013

High and Low Magnetic Merrill Pass



More positive magnetic values

More negative magnetic values



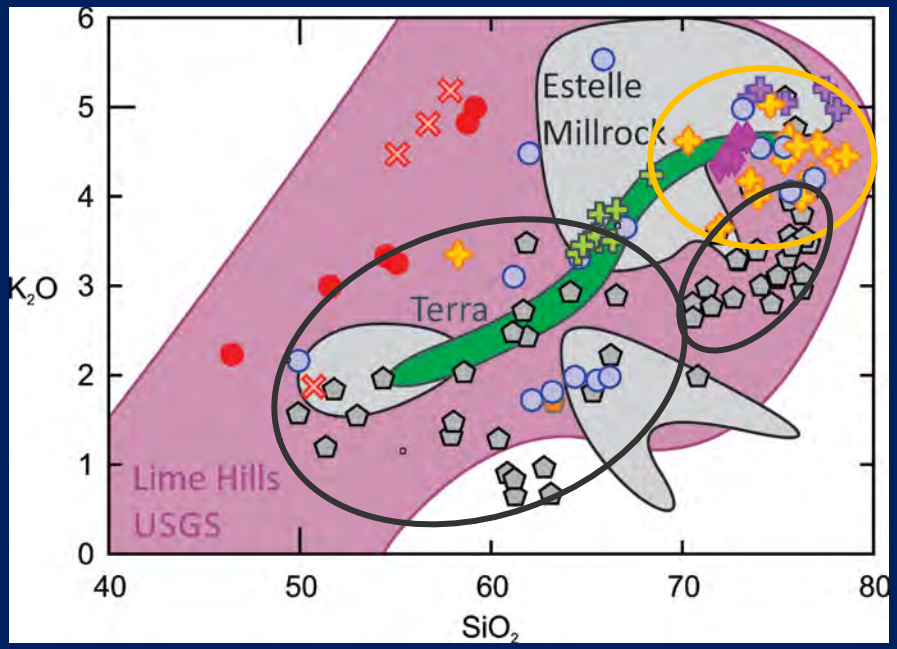
- Trace element signatures of high and low mag appear the same in spider diagram
- Some of the volcanic rocks are similar to Merrill Pass pluton

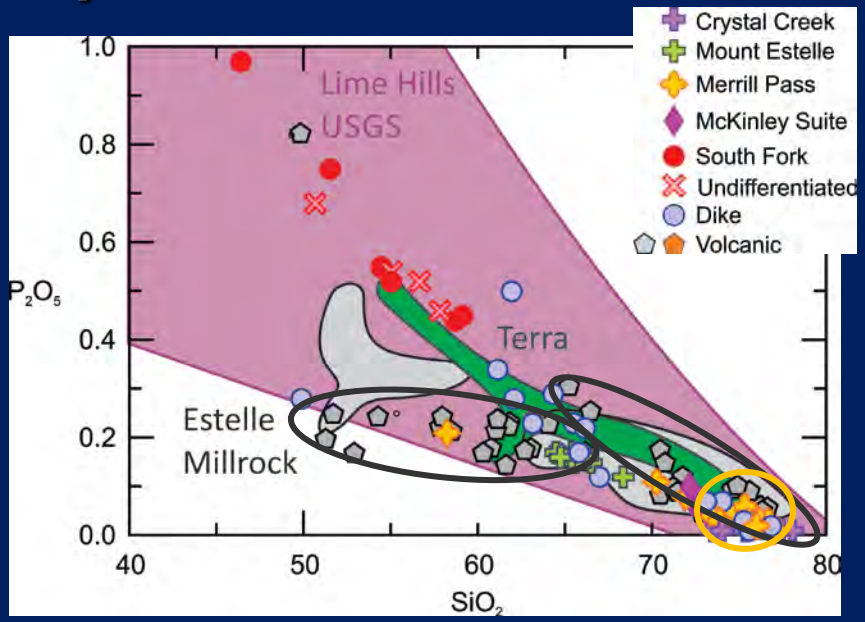
Geologic Map contacts from Gamble and others, 2013

Volcanic rocks (Tv) and dikes

XRF ICP-MS

33.6 to 41.0 Ma (Ar/Ar) and 51-58 Ma





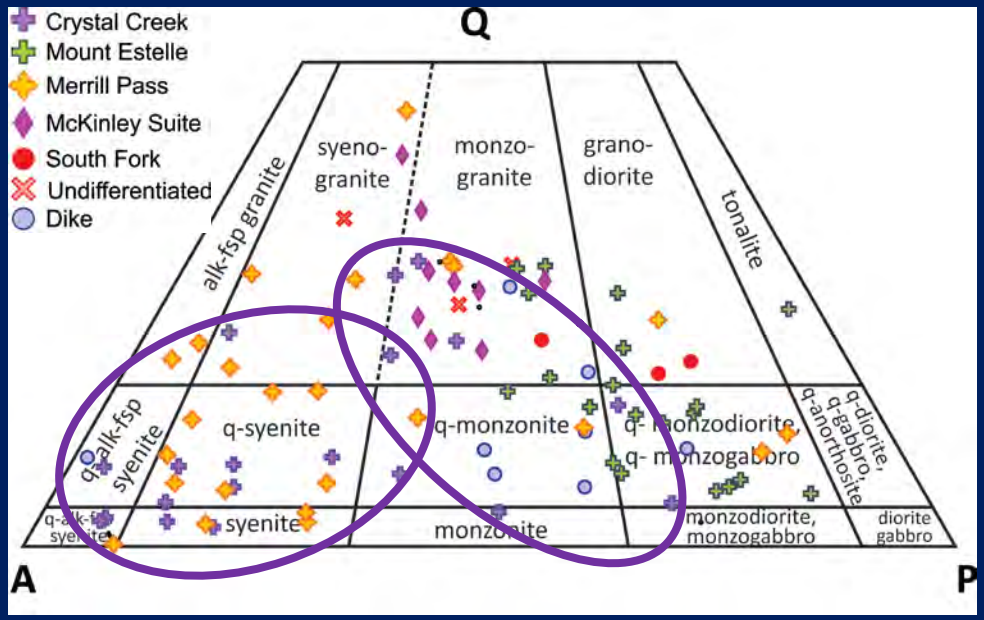
- At least two separate trends

- Mafic to felsic compositions
- Aphanitic to porphyritic
- Cutting through sedimentary rocks and the Mt Estelle pluton
- Locally contain py and sericite alt'n
- Mafic dikes dated by USGS as 51-58 Ma, NNW striking, W dipping

Crystal Creek pluton (Tcc)

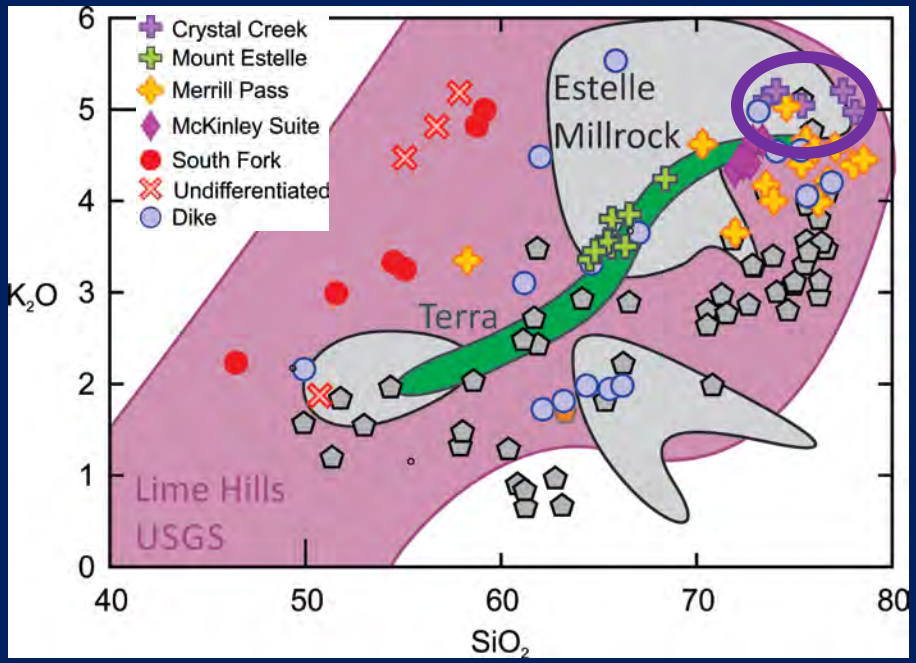
60.0 Ma (K/Ar)

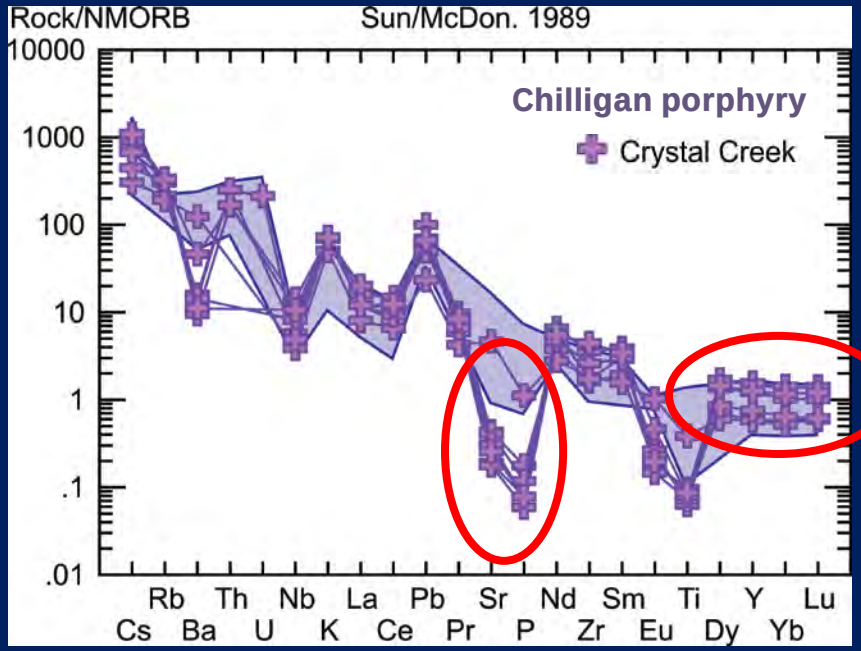
- Biotite-hornblende alkali-feldspar granite to granodiorite
- Medium to coarse-grained, seriate to porphyritic, hypidiomorphic-granular
- May correlate with Chilligan porphyry (unpublished data)
- Has two groups



Crystal Creek pluton (Tcc)

60.0 Ma (K/Ar)



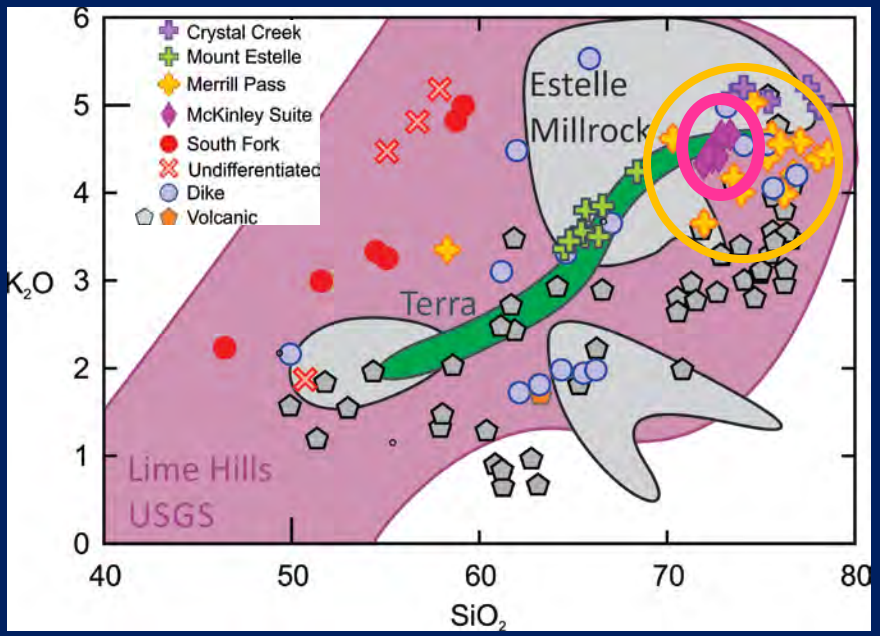


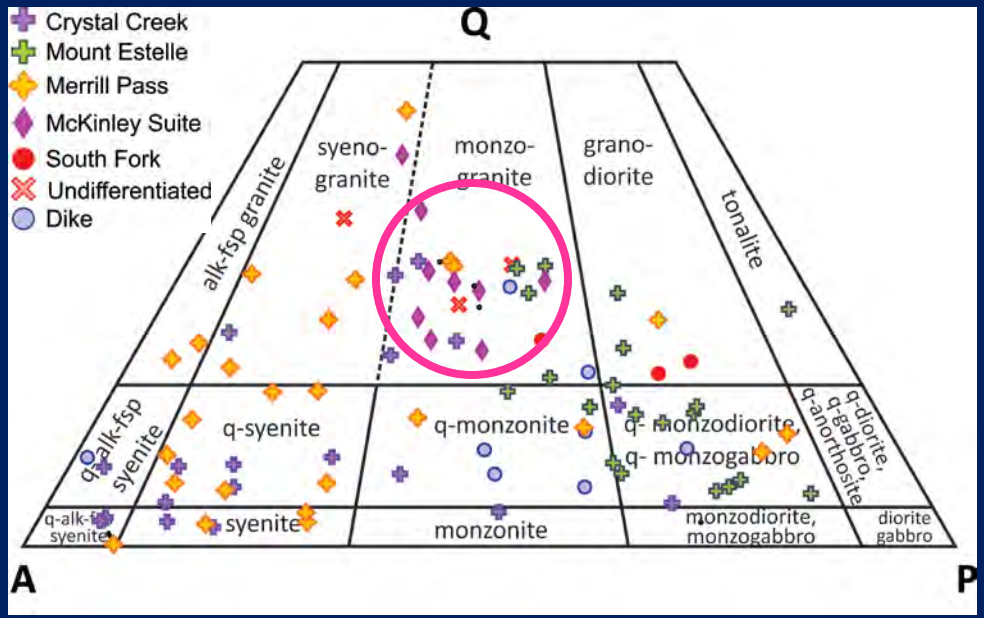
- Likely correlates with Chilligan porphyry
  - Similar trace element signatures
  - Fractionalization of plagioclase (Sr) and apatite (P)
- Two phases of Crystal Creek pluton

McKinley suite(?) granites (Tms)

65.0 Ma (Ar/Ar)

- Biotite granite
- Fine- to coarse-grained seriate, hypidiomorphic-granular or porphyritic, megacrystic
- Does not correlate with other ages for this plutonic sequence

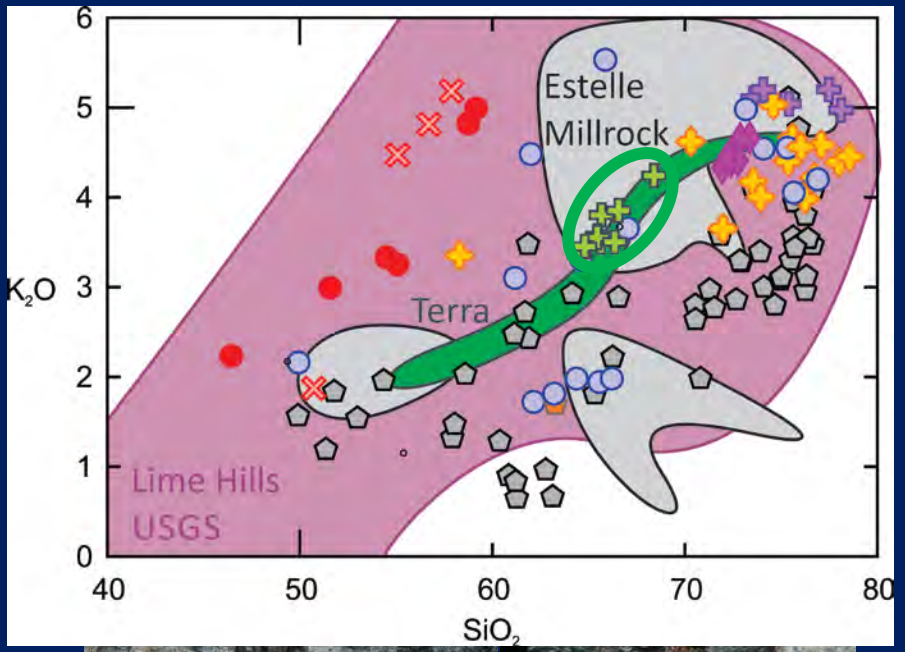


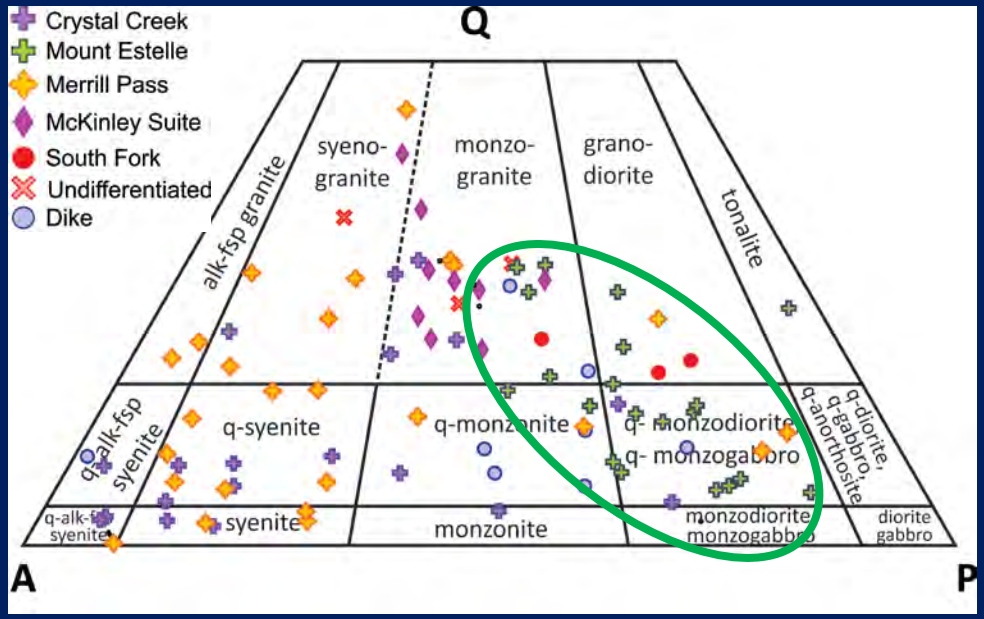


Mount Estelle pluton (Tme)

62.1 Ma, 64.1 Ma (K-Ar), 69.7 Ma (U/Pb)

- Biotite-hornblende granodiorite
- Chiefly medium- to coarse-grained, seriate, hypidiomorphic-granular
- Contains aplite and lamprophyre dikes (NW trending) with quartz, arsenopyrite, chalcopyrite, and magnetite veins

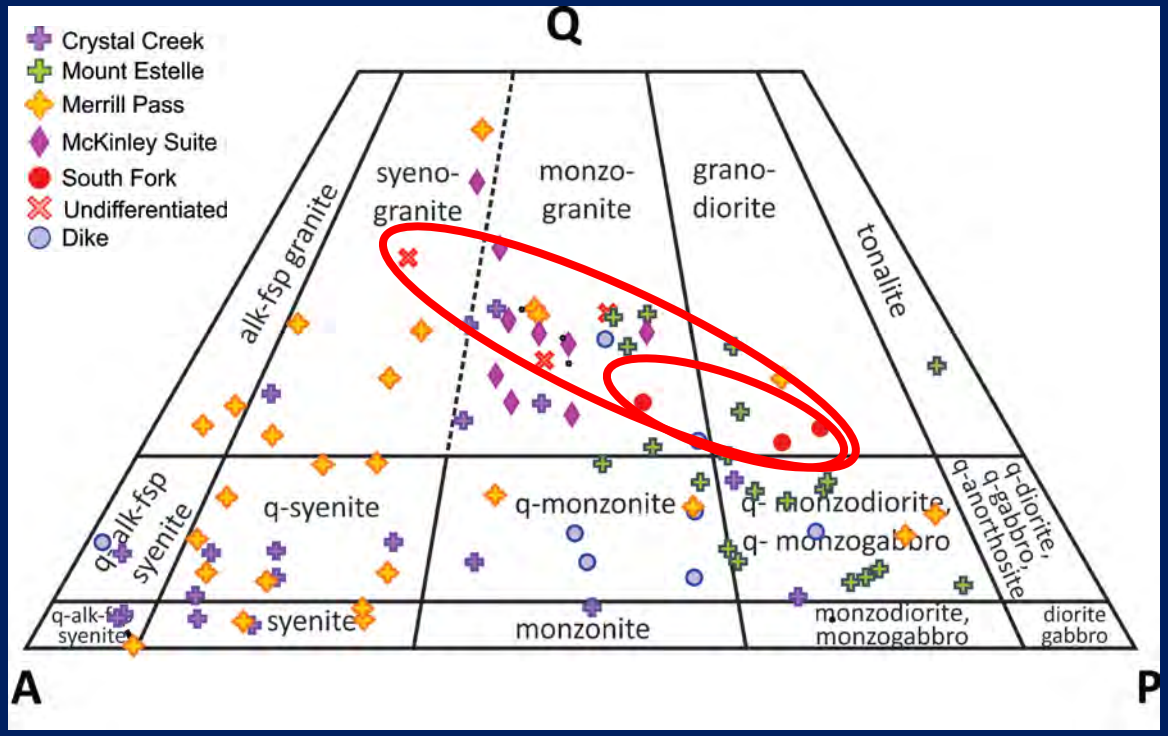




South Fork pluton (Kgb)
71.4 Ma (K-Ar)

& Igneous undifferentiated (TKiu)

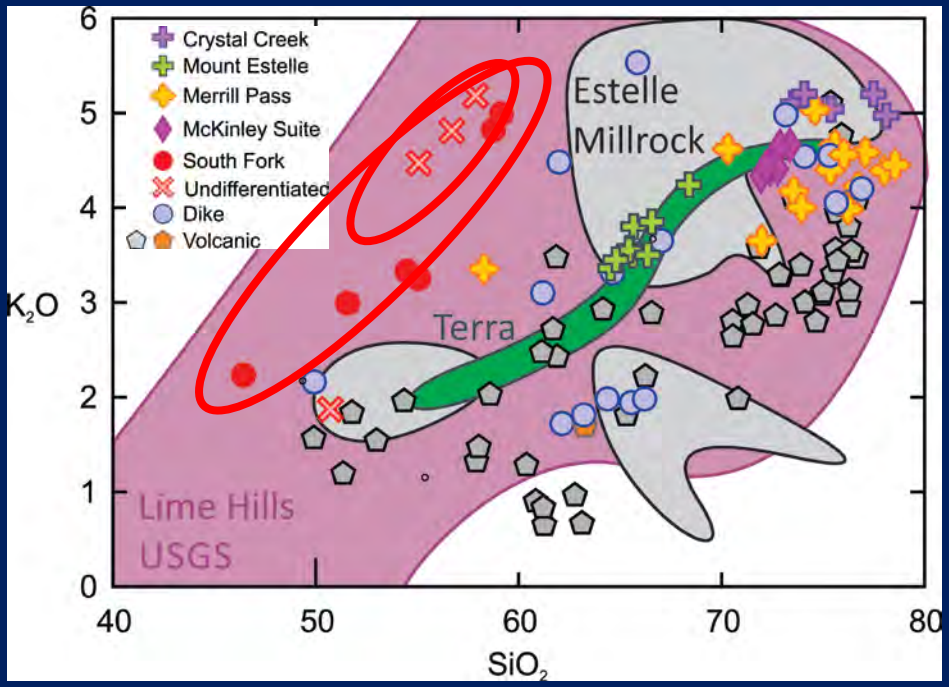
- Hornblende-pyroxene-biotite gabbro
- Fine- to medium-grained, seriate, hypidiomorphic-granular
- Cretaceous
- Cu, Au, Ag mineralization

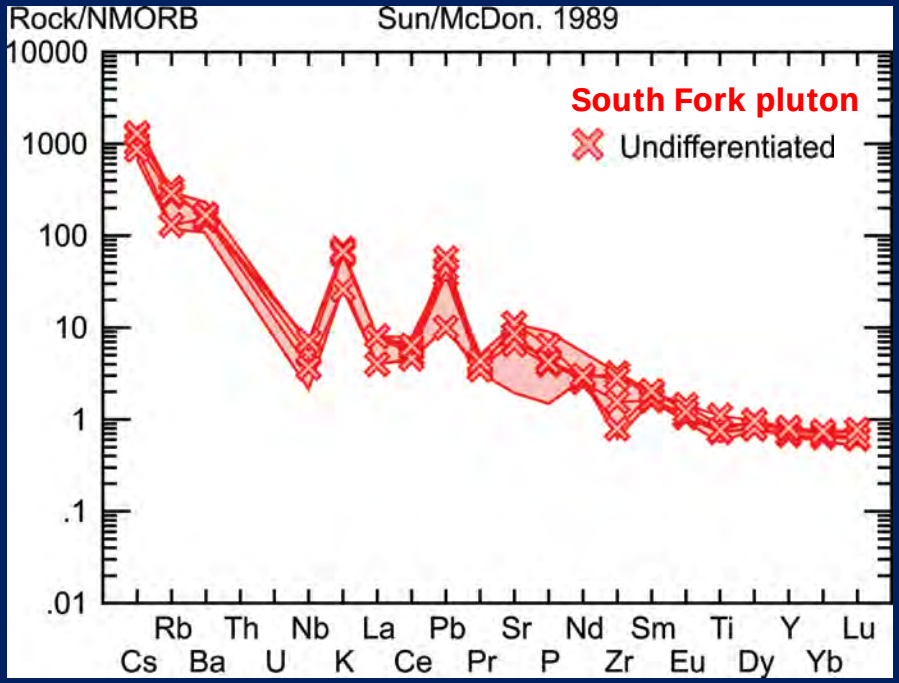


South Fork pluton (Kgb)
71.4 Ma (K-Ar)

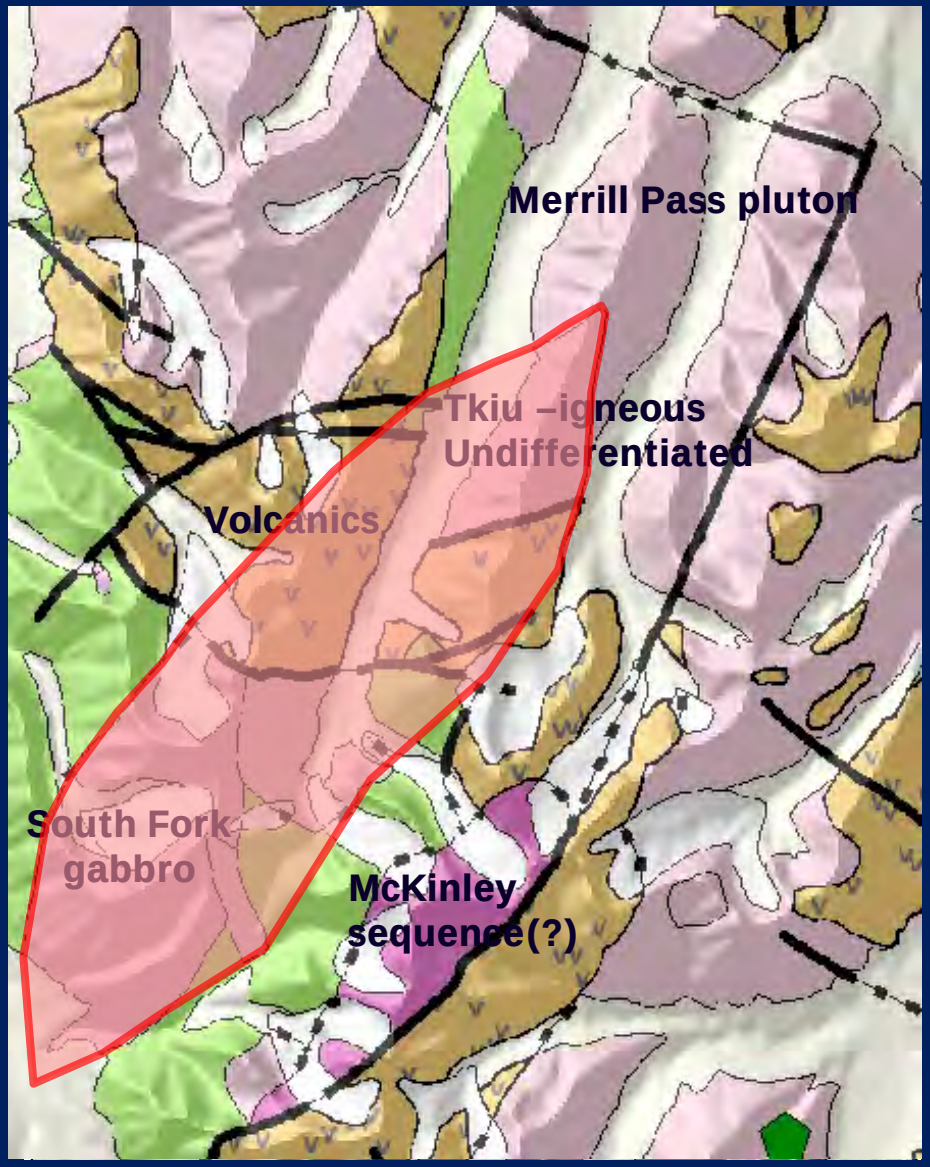
& Igneous undifferentiated (TKiu)

- Identical spider diagram pattern shows relationship of South Fork (Kgb) to TKiu





Unit Contact Improvements

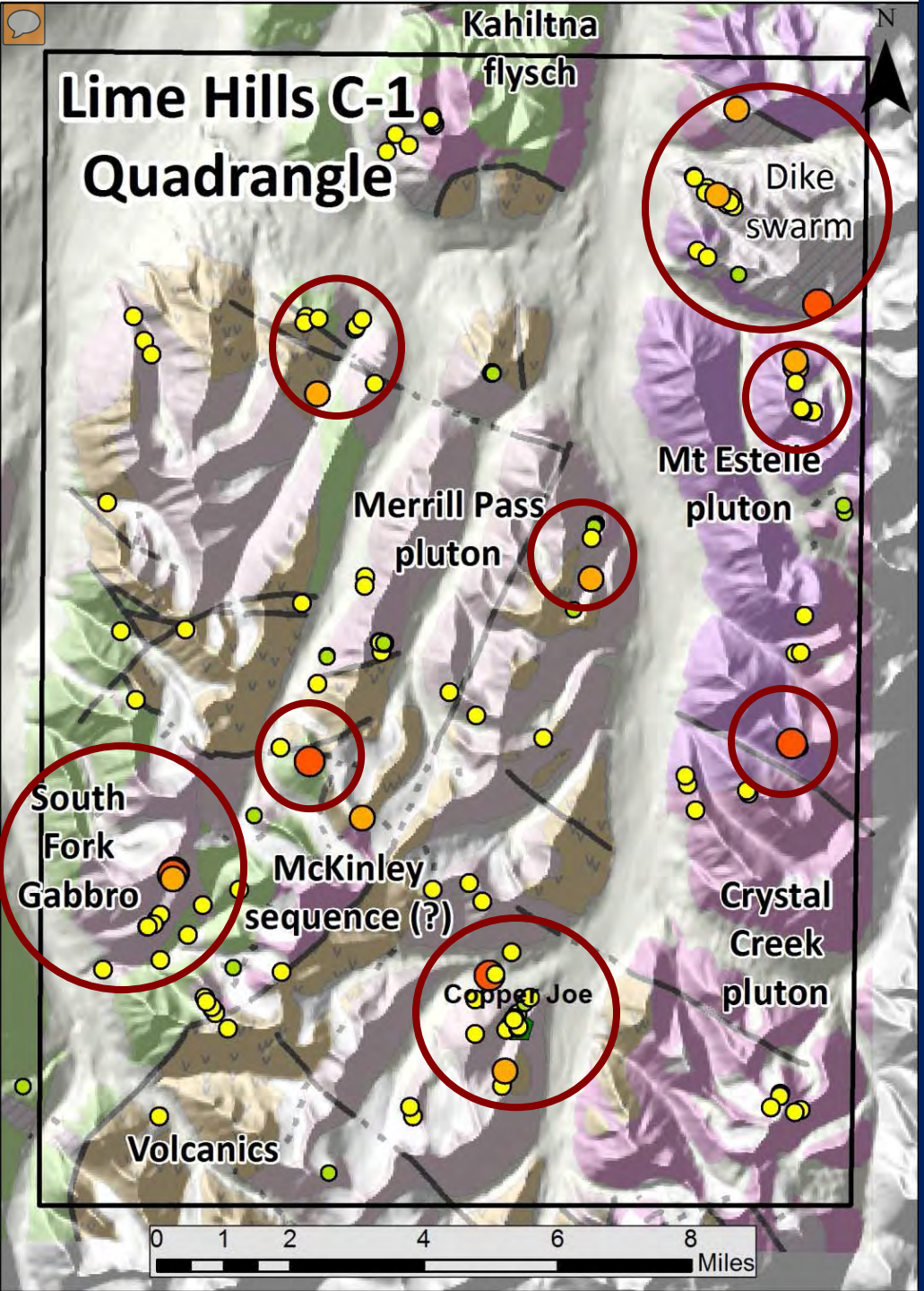


- South Fork pluton identical to TKiu—igneous undifferentiated
- Differentiate the highly magnetic Merrill Pass Pluton from the weakly magnetic unit with more trace element data
- Subdivide Crystal Creek pluton
- Many more

Geologic Map contacts from Gamble and others, 2013

Mineralization Highlights

- Copper Joe porphyry system: impressive qtz-sericite-py alteration zone
  - Is it related to the **Tertiary** Merrill Pass pluton as mapped?
- Cretaceous Mt Estelle granodiorite with Qtz-Cpy veins, Au?
- Jimmy Lake epithermal system, related to NW trending dikes,
  - Alteration and mineralization (gossan)
- Many samples collected for analysis



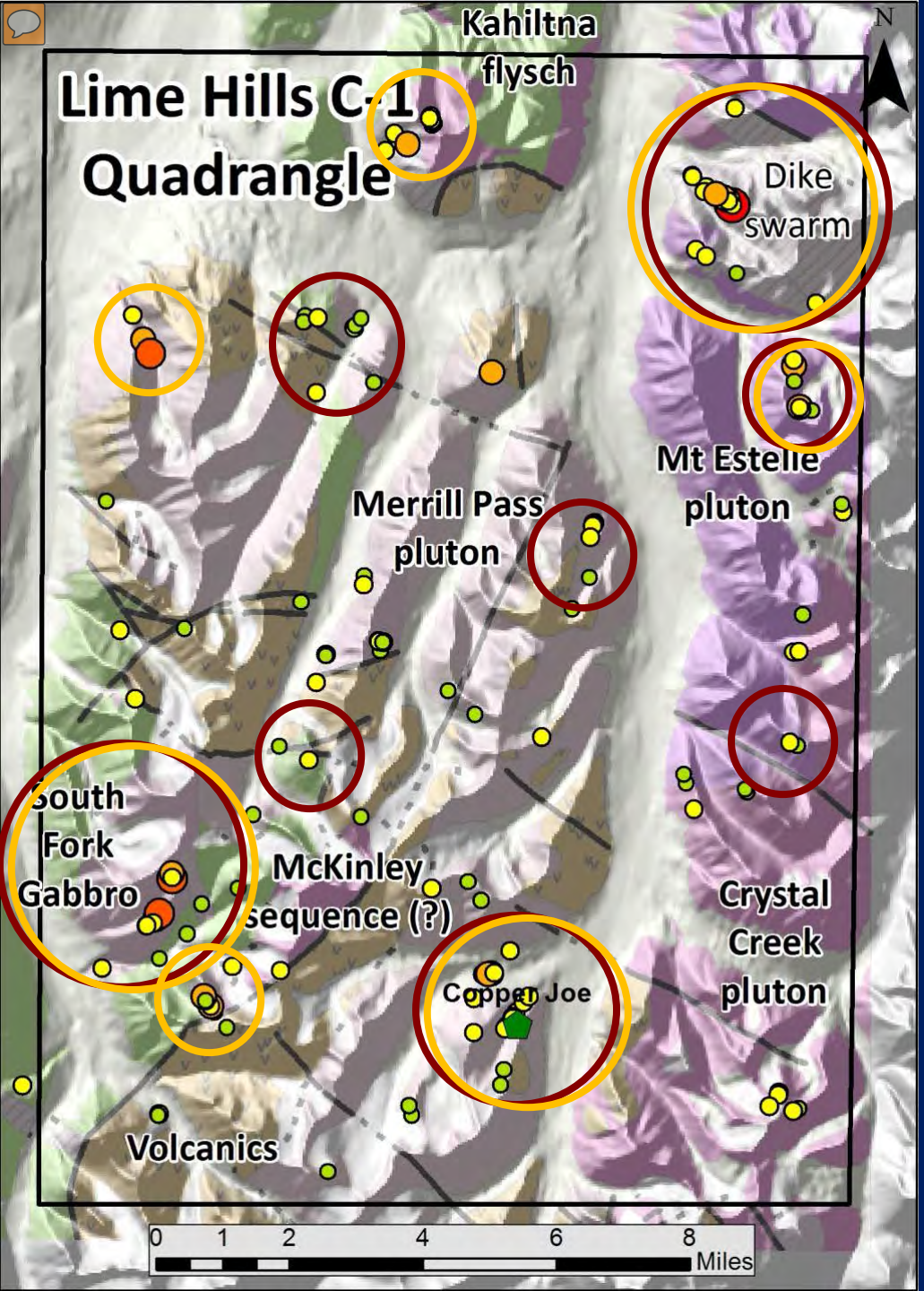
Copper occurrences

- Points are colored by standard deviations above or below the mean
- Z = value-mean / std dev

(Actual values will be released in geochemical reports)

Legend

- 3 - 4
- 2 - 3
- 1 - 2
- -1 to 1
- -2 to -1
- -3 to -2



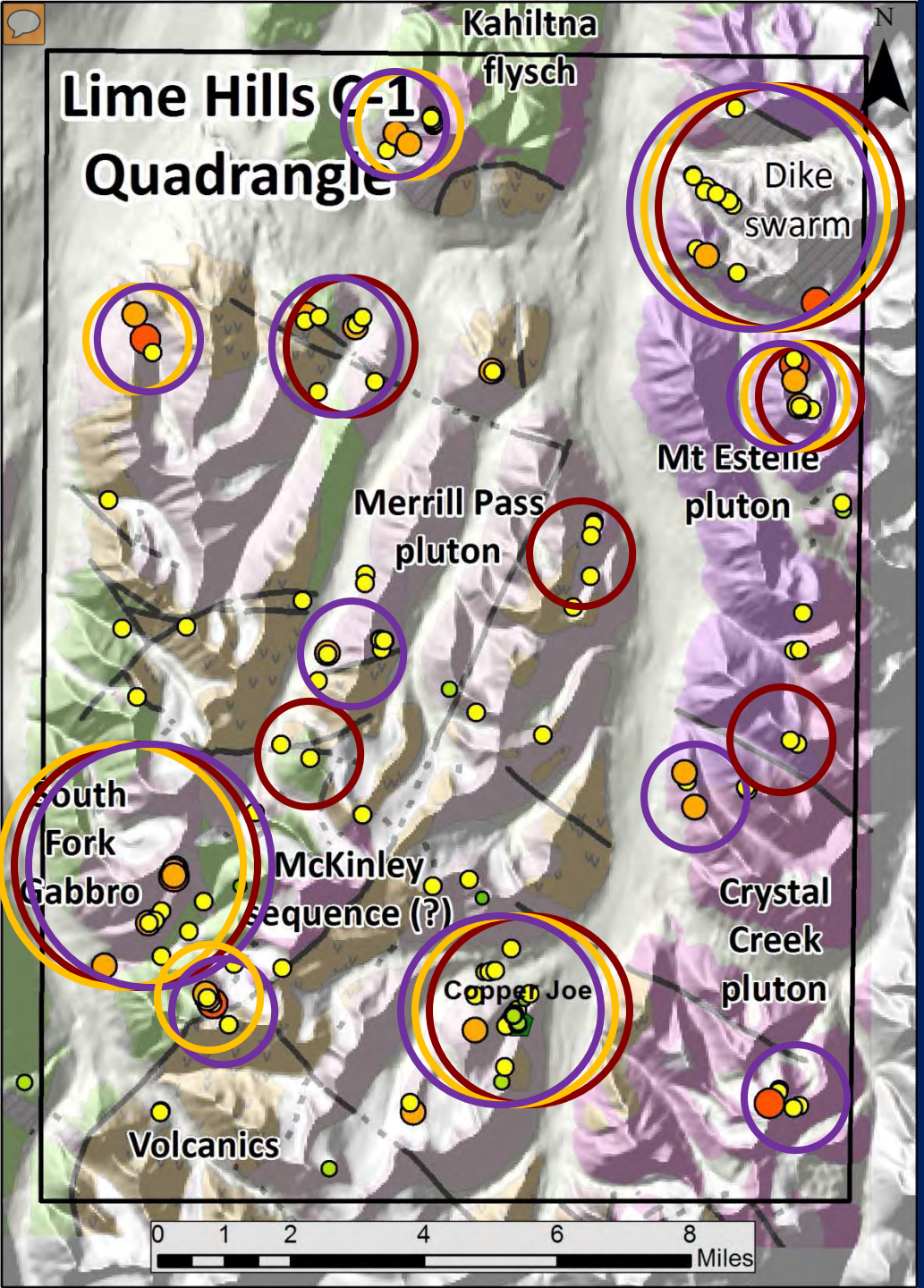
Copper & Gold occurrences

- Points are colored by standard deviations above or below the mean
- Z = $\frac{\text{value-mean}}{\text{std dev}}$

(Actual values will be released in geochemical reports)

Legend

- 3 - 4
- 2 - 3
- 1 - 2
- -1 to 1
- -2 to -1
- -3 to -2



Arsenic, Gold & Copper

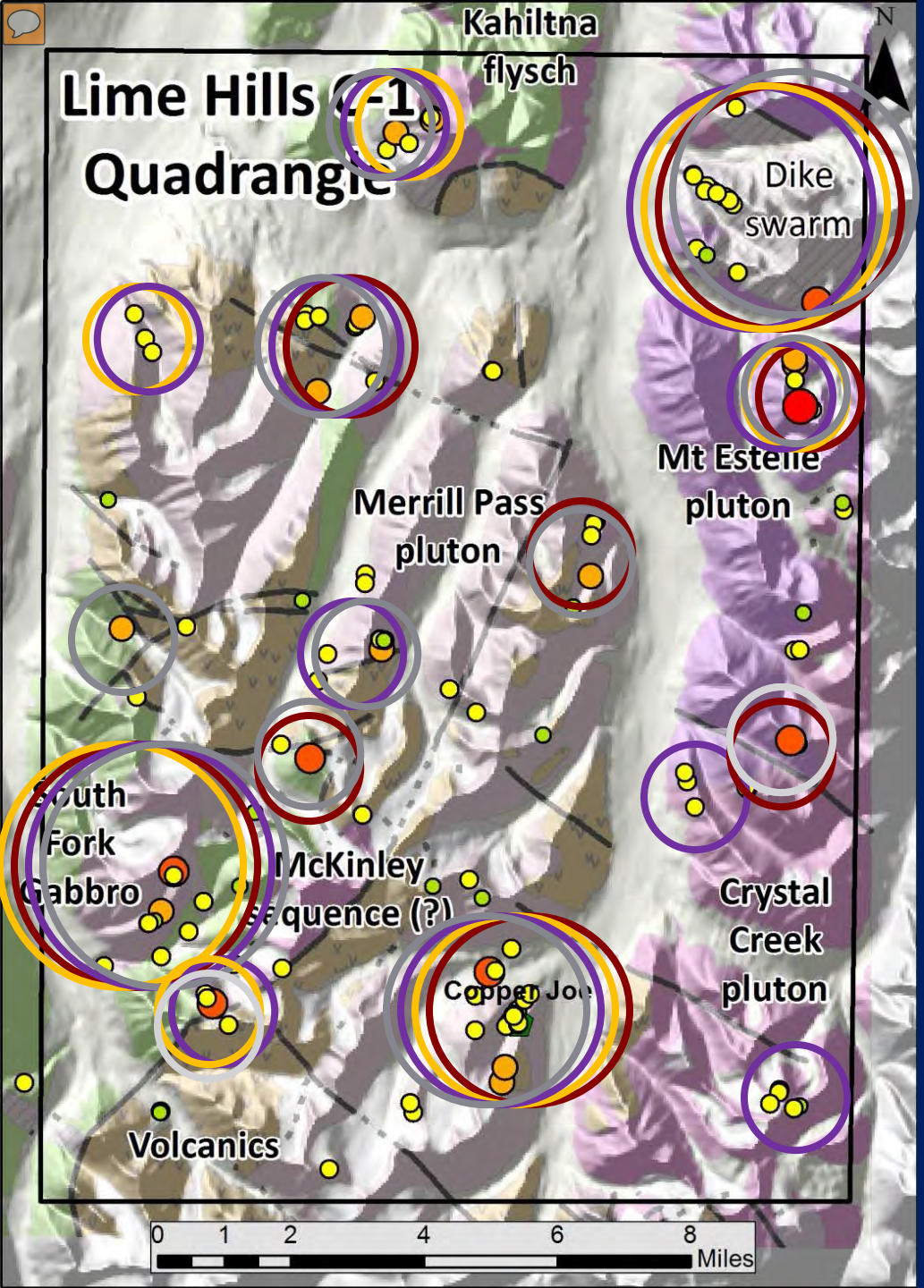
- Points are colored by standard deviations above or below the mean
- Z = value-mean / std dev

(Actual values will be released in geochemical reports)

Legend

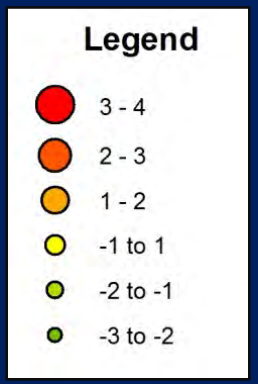
- 3 - 4
- 2 - 3
- 1 - 2
- -1 to 1
- -2 to -1
- -3 to -2

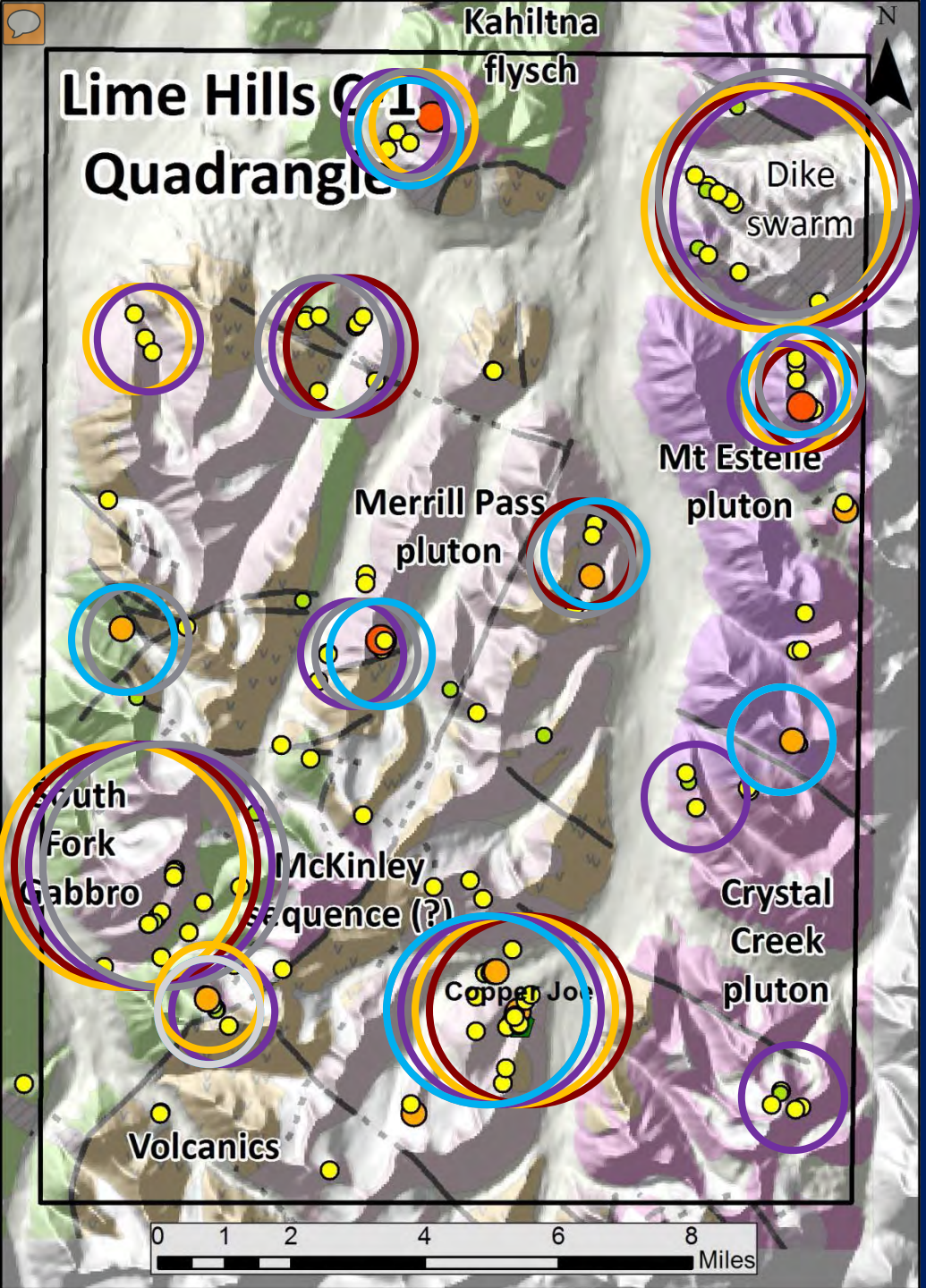
Silver, Arsenic, Gold & Copper



- Points are colored by standard deviations above or below the mean
- Z = value-mean / std dev

(Actual values will be released in geochemical reports)





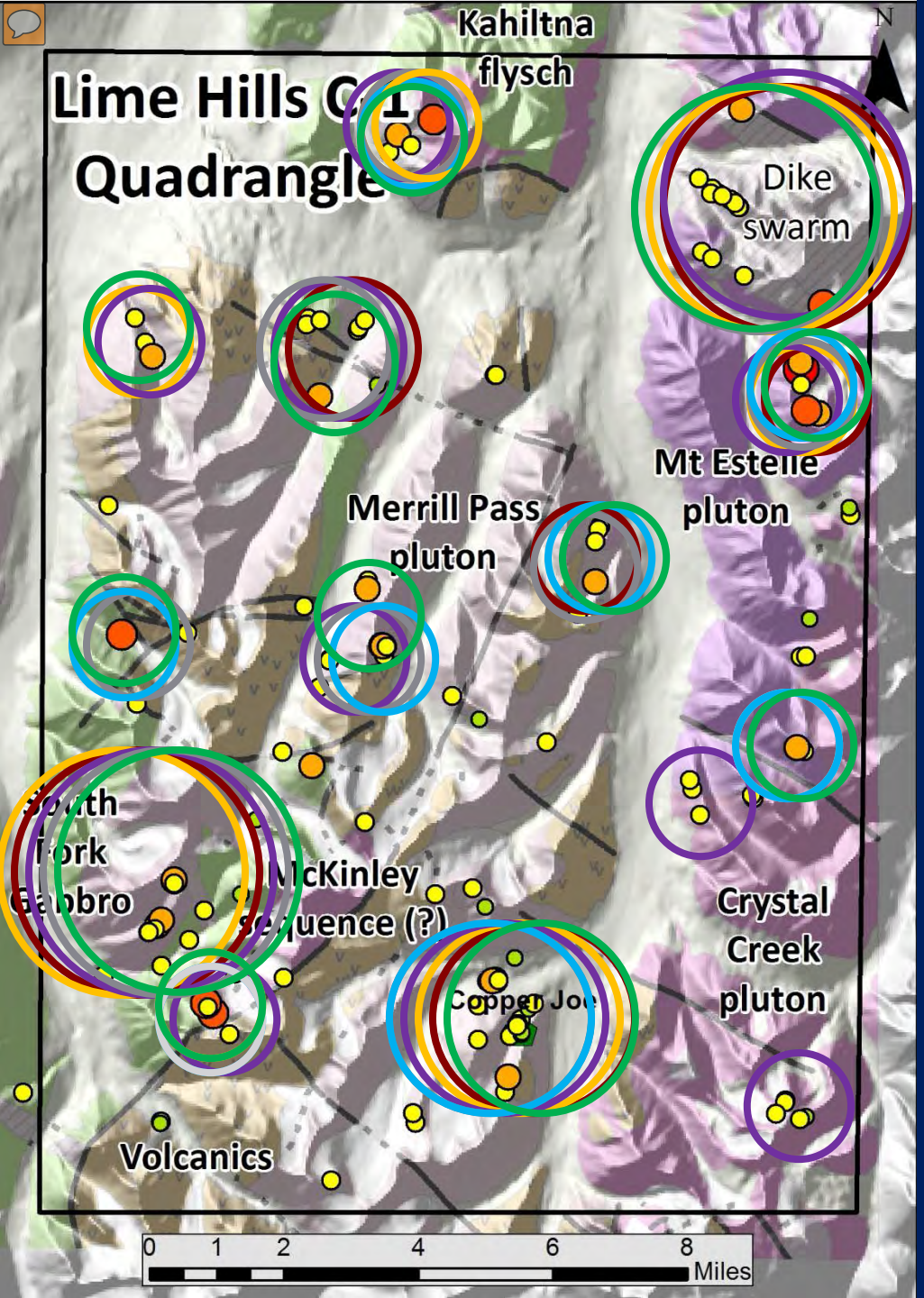
Molybdenum, Silver, Arsenic, Gold & Copper

- Points are colored by standard deviations above or below the mean
- Z = $\frac{\text{value-mean}}{\text{std dev}}$

(Actual values will be released in geochemical reports)

Legend

- 3 - 4
- 2 - 3
- 1 - 2
- -1 to 1
- -2 to -1
- -3 to -2



Bismuth, Molybdenum, Silver, Arsenic, Gold & Copper

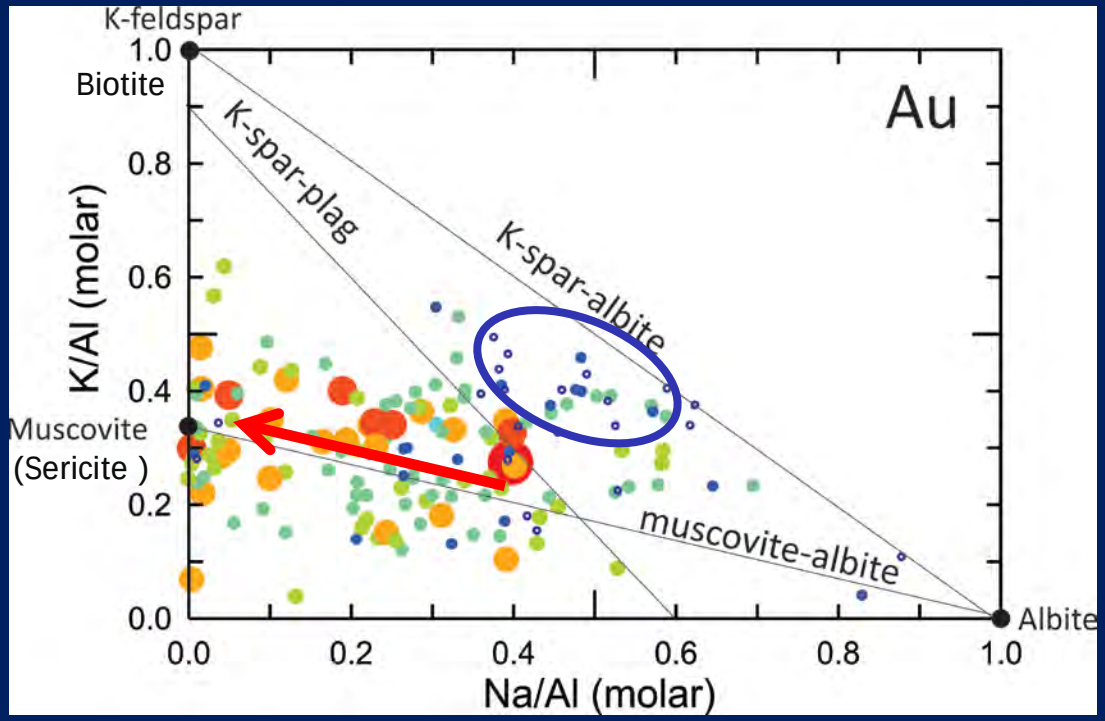
- Points are colored by standard deviations above or below the mean
- Z = value-mean / std dev

(Actual values will be released in geochemical reports)

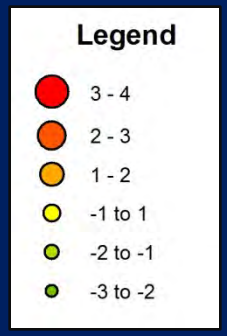
Legend

- 3 - 4
- 2 - 3
- 1 - 2
- -1 to 1
- -2 to -1
- -3 to -2

Sericite alteration and Gold



- Blue circle = unaltered rock
- Red line shows alteration trend of sericitization
- Trend corresponds with gold enrichment zone



- How does this data help us refine unit contacts, and improve mapping?
  - Do their compositions overlap? Yes, some are more similar than others
  - Do they cluster or have broad ranges? McKinley Suite, Estelle, & South Fork cluster
  - Can we split or combine plutons based on these trends? Merrill Pass & Crystal Creek are broad and can be divided, TKiu undifferentiated is = to South Fork
- How does our data compare to USGS data and to mineralized plutons in the area such as the Terra pluton and the Mt Estelle pluton?

  There are similarities as expected, further trace elements analysis can help
- Where do we see mineralization and why is it there?

  There are highlighted areas of mineralization, and stay tuned...

Future work & Acknowledgements

- Detailed geologic map of the Lime Hills C-1 Quadrangle with explanatory text
- Analyze and release structural data
- Analyze and release age data
- Geochemical data report coming soon:

  www.dggs.alaska.gov

Thank you:

- Alaska Miners Association
- USGS Western Alaska Range Project (WARP)
- Millrock, WestMountain (Corvus), Kiska, Alaska Earth Sciences

Contact: karri.sicard@alaska.gov


Thanks for your attention
Contact: karri.sicard@alaska.gov
Photo by T.C. Wright

Works Cited

Bundtzen, T.K., Harris, E.E., and Gilbert, W.G., 1997, Geologic map of the eastern half of the McGrath Quadrangle, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 97-14A, 34 p., 1 sheet, scale 1:125,000. DOI: 10.14509/2549

Burns, L.E., Fugro Airborne Surveys Corp., and Stevens Exploration Management Corp., 2008, Line, grid, and vector data, and plot files for the airborne geophysical survey of the Styx River Survey, southcentral Alaska: Alaska Division of Geological & Geophysical Surveys Geophysical Report 2008-3, 27 sheets, 1 DVD. DOI: 10.14509/16561

Colpron, M. and Nelson, J.L., 2011, A Digital Atlas of Terranes for the Northern Cordillera: British Columbia Ministry of Energy and Mines, BCGS GeoFile 2011-11.

Gamble, B.M., Reed, B.L., Richter, D.H., Lanphere, M.A., 2013, Geologic Map of the East Half of the Lime Hills 1:250,000-scale Quadrangle, Alaska, U.S. Geological Survey Open-File Report 2013-1090.

Sicard, K.R., Wypych, Alicja, Twelker, Evan, Bachmann, E.N., Freeman, L.K., Newberry, R.J., Reioux, D.A., Tuzzolino, A.L., and Wright, T.C., 2014, Major-oxide, minor-oxide, and trace-element geochemical data from rocks in the Styx River area, Lime Hills C-1 Quadrangle, Lime Hills, McGrath, Talkeetna, and Tyonek quadrangles, Alaska: Alaska Division of Geological & Geophysical Surveys Raw Data File 2014-6, 4 p. DOI:10.14509/27289

Wilson, F.H., Dover, J.H., Bradley, D.C., Weber, F.R., Bundtzen, T.K., and Haeussler, P.J., 1998, Geologic map of Central (Interior) Alaska: U.S. Geological Survey Open-File Report 98-133-A, 62 p., 3 sheets.