Australian National University

Platinum Group Element geochemistry to track magmatic evolution of the Yerington porphyry copper district (Nevada, USA)

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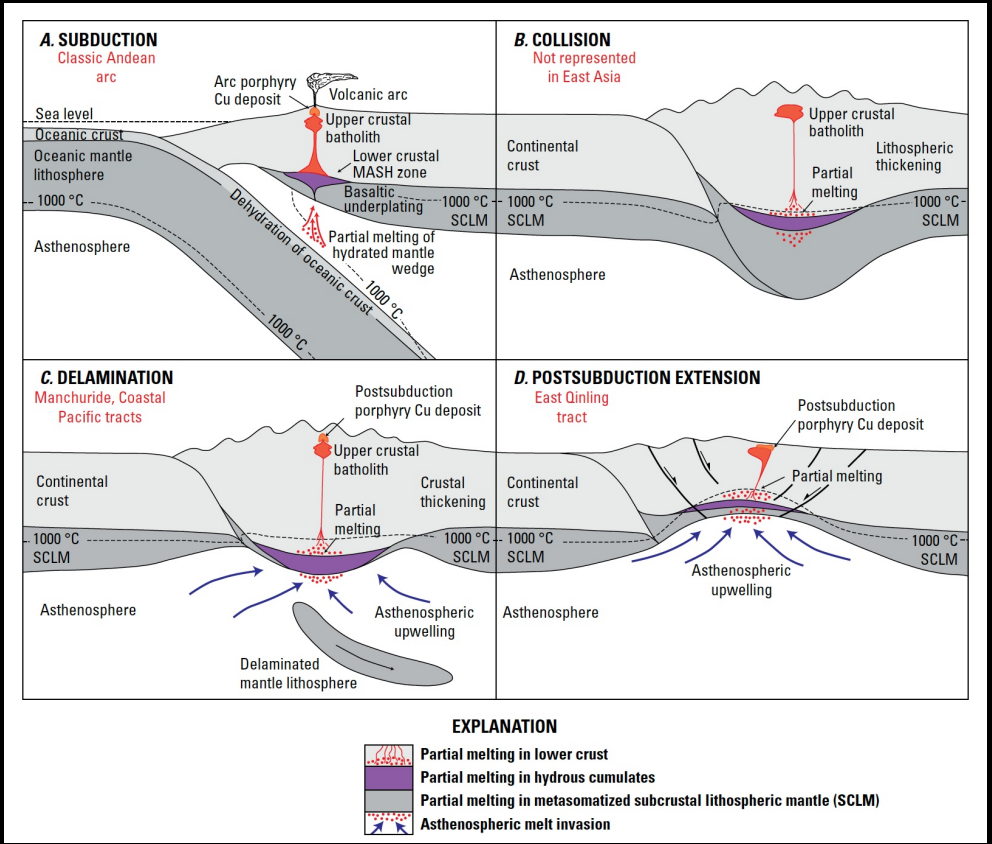
Porphyry deposits

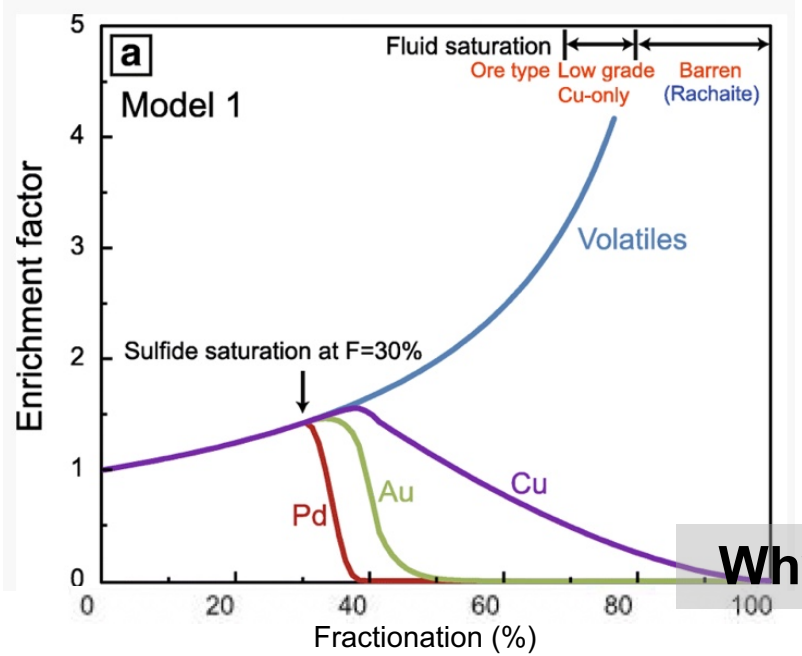
- Primary source of world`s Cu, Au, Mo and major source of Ag and Sn
- Mostly associated with subduction zones
- Factors controlling formation of such deposits:
  - ✓ Volume of magma
  - ✓ Duration of magmatic activity
  - ✓ Oxidation state of magma
  - ✓ Water content of magma
  - ✓ Capacity of hydrothermal systems to transfer metals
  - ✓ Others

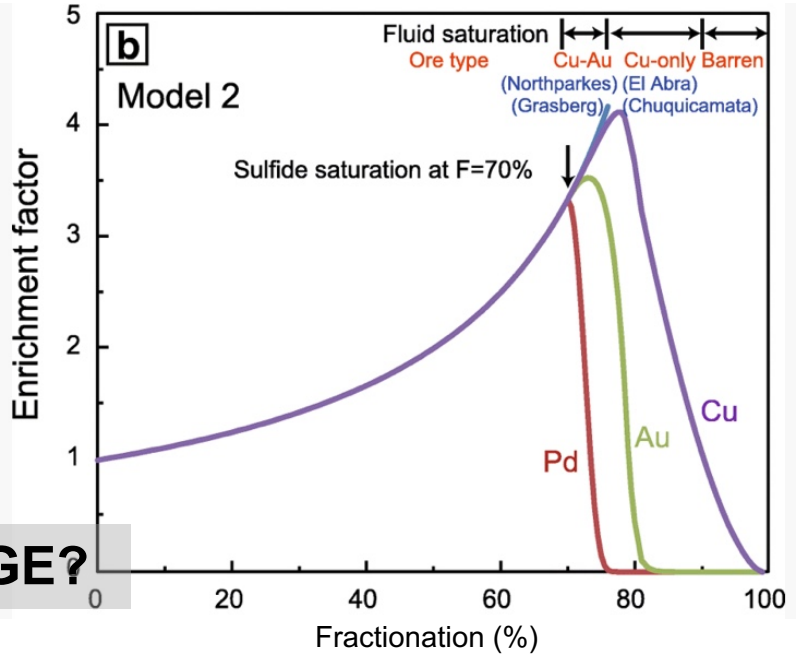


Ludington S., Mihalsky M. J., Hammarstrom J. M., Robinson G. R>, Frost T. P., Gans K. D., Miller R. J., Alexeiev D. 2012

Hypothesis

Timing of sulfide saturation, relative to volatile saturation is one of the most important factors controlling magma fertility and determines whether the ore is Au-Cu-Pd, Cu-Au or Cu only



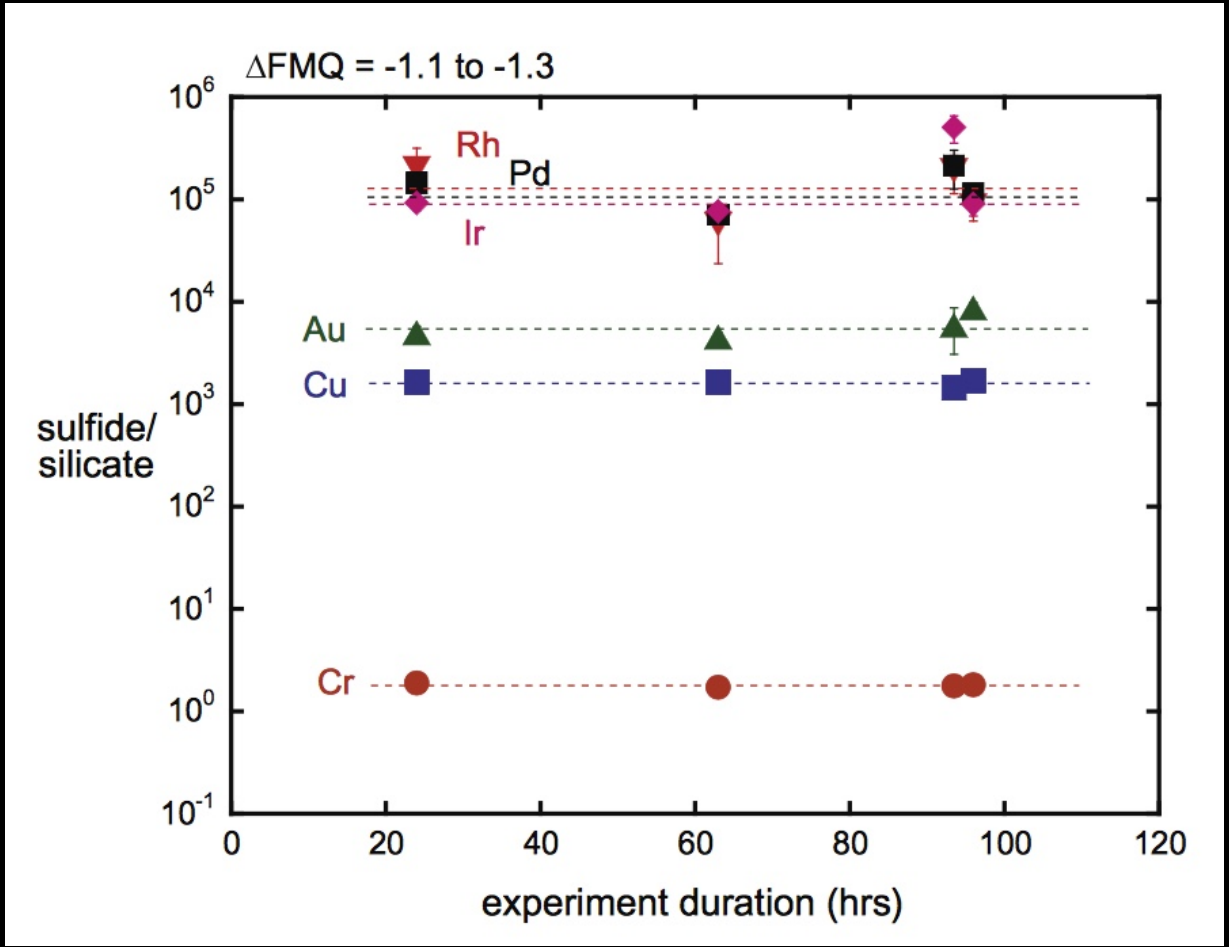


Why PGE?

Park J.-W., Campbell I. H., Malaviarachchi S. P. K., Cocker H., Hao H., Kay S. M. 2018

PGE

- High partitioning into sulfides ➡ very sensitive indicators of sulfide saturation
- Easily affected by changes in the system
- Solubility in hydrothermal fluids is low ➡ less mobile than Cu and Au



Mungall J. E., Brenan J. M., 2014

Methods

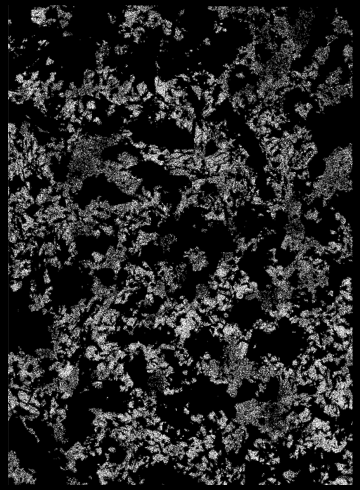
XRF
major elements

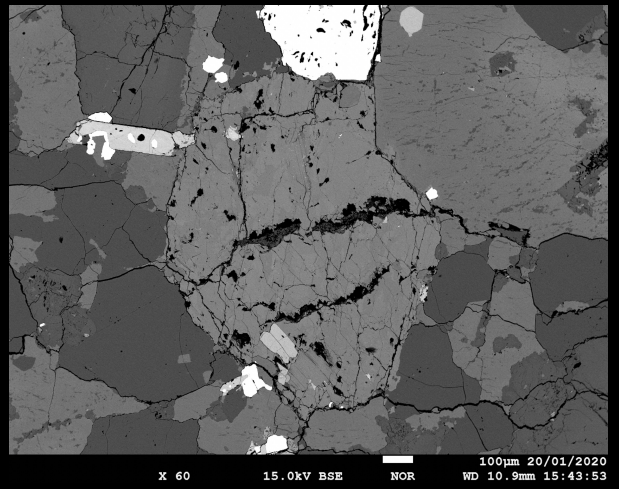
LA-ICP-MS
trace elements

Fire-assay isotope dilution
PGE

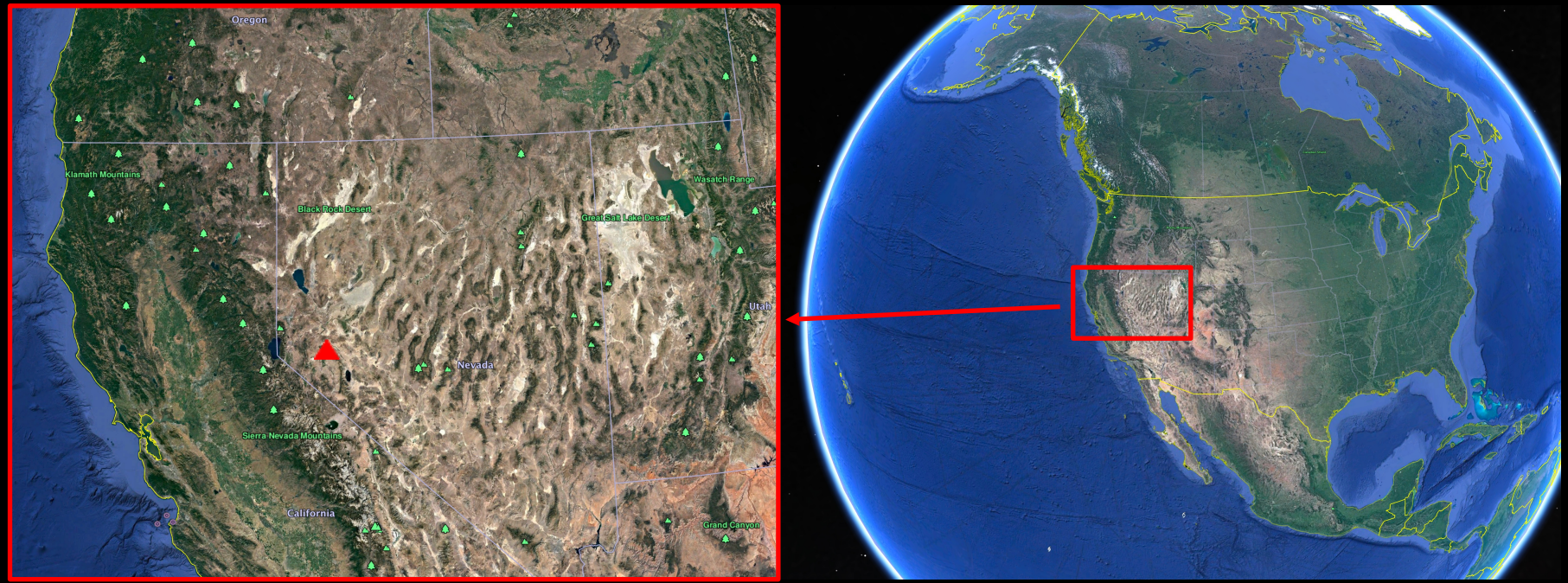
QEMSCAN
mineral and elemental distribution maps, quantitative reports

Electron Microprobe
mineral phases





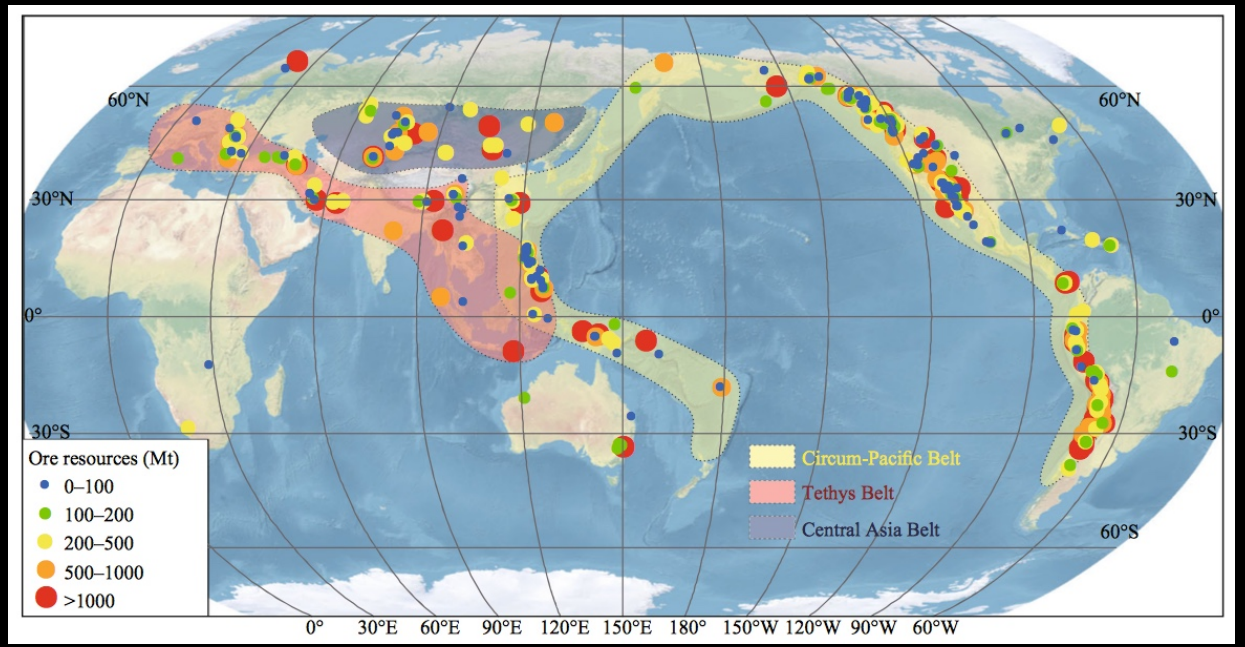
Yerington- location



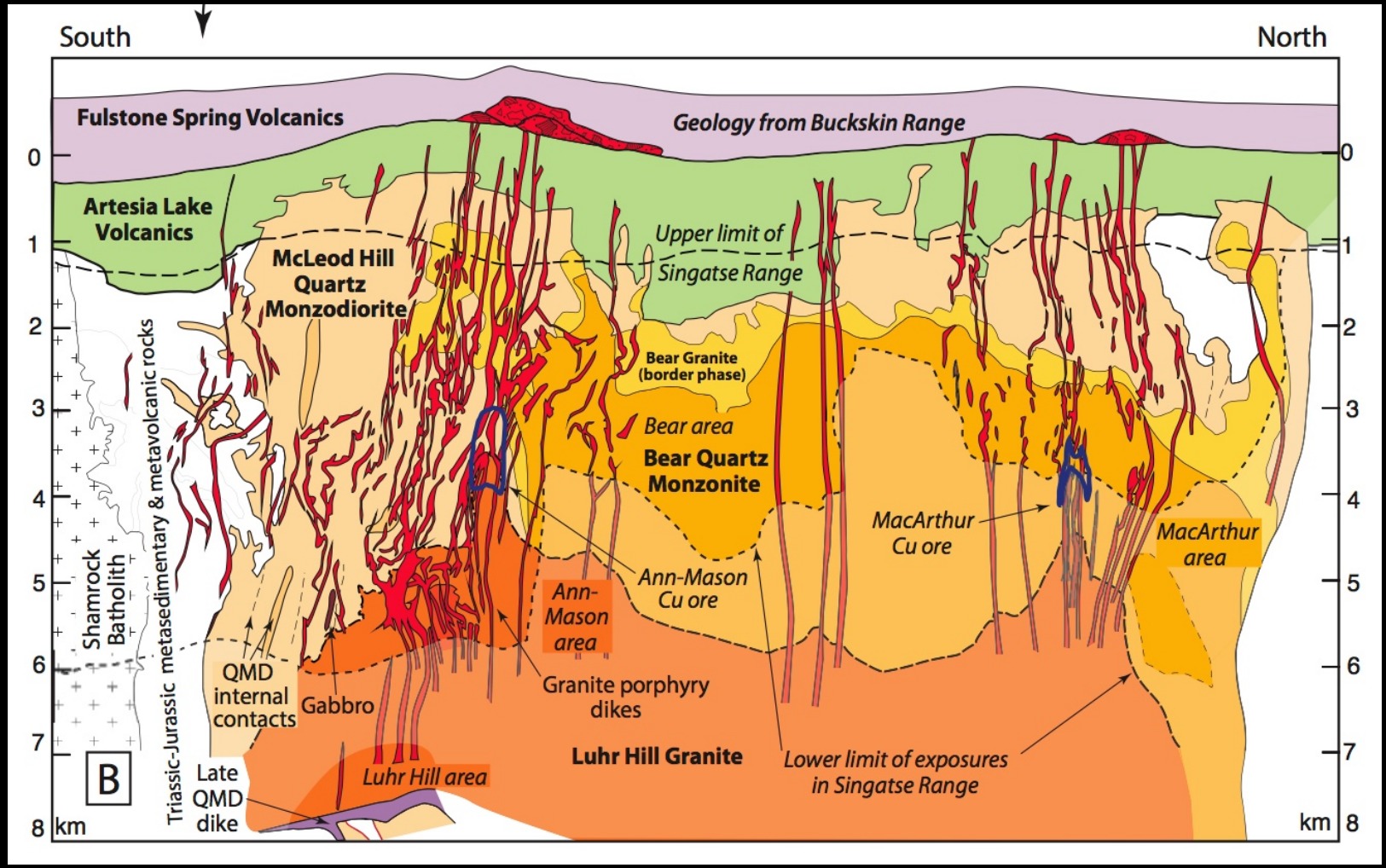
Google Earth Pro

Tectonic setting

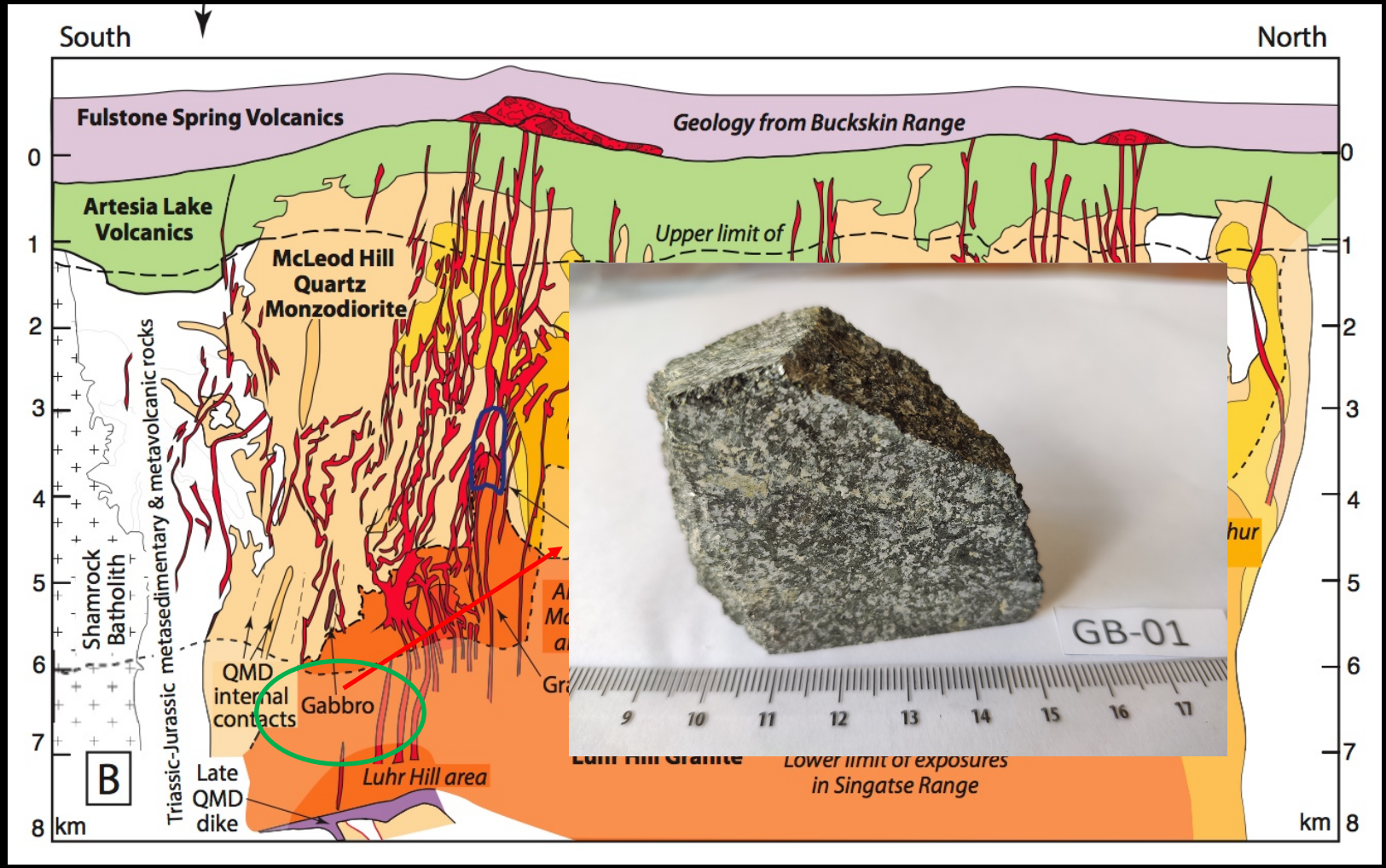
- Batholith in western Nevada within the volcanic-arc area
- 15 km in diameter, 7-8 km in the vertical dimension
- Emplaced into Triassic and Jurassic volcanic and sedimentary rocks ca. 168 Ma
- Part of a belt of Andean-type arc magmatism
- Cut by 3 sets of faults so it is now exposed in cross-section



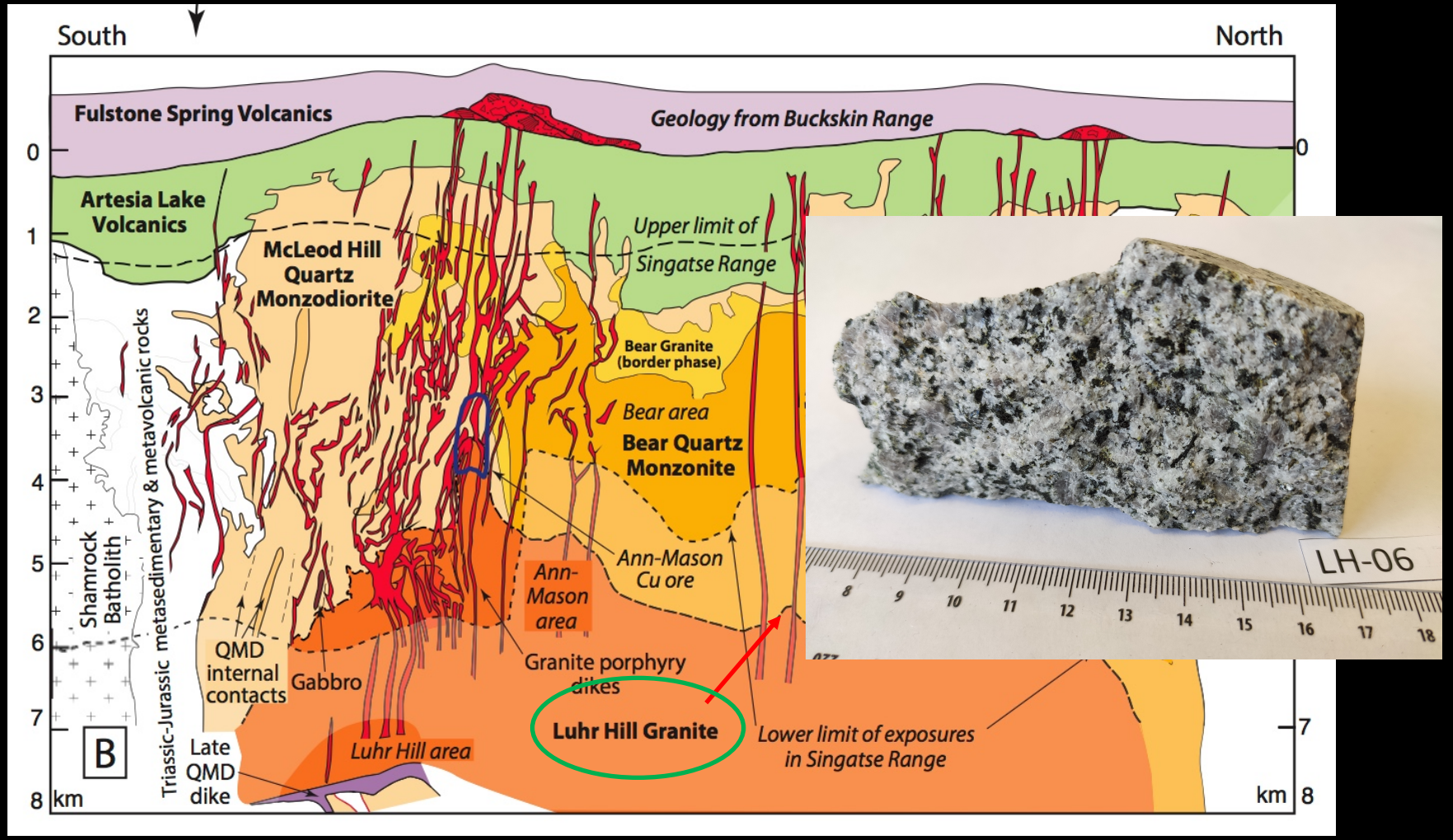
LiuH., Liao R.-Q., Zhang L., Li C., Sun W., 2019



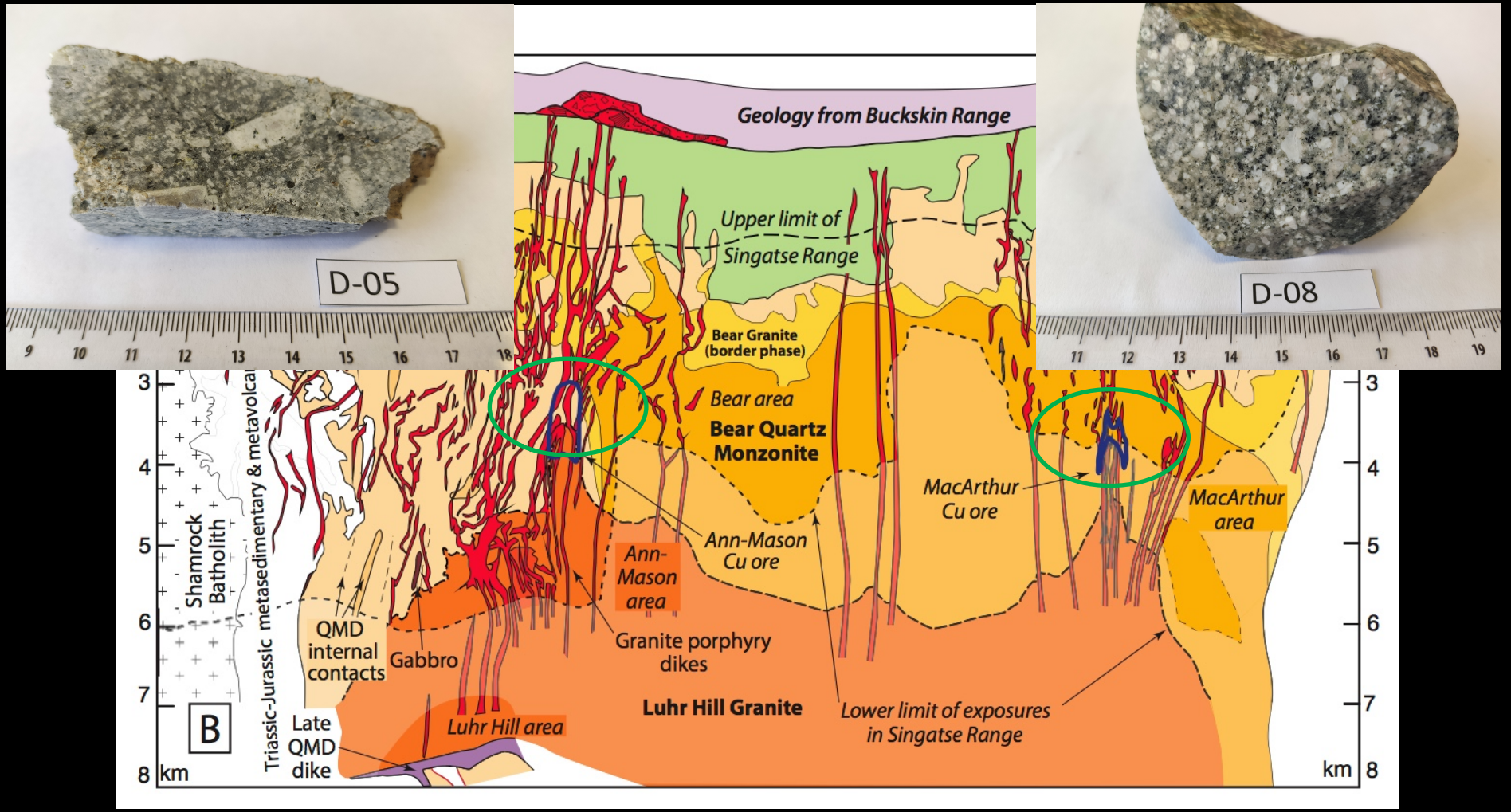
Schöpa A., Annen C., Dilles J. H., Blundy J., Sparks S., 2017



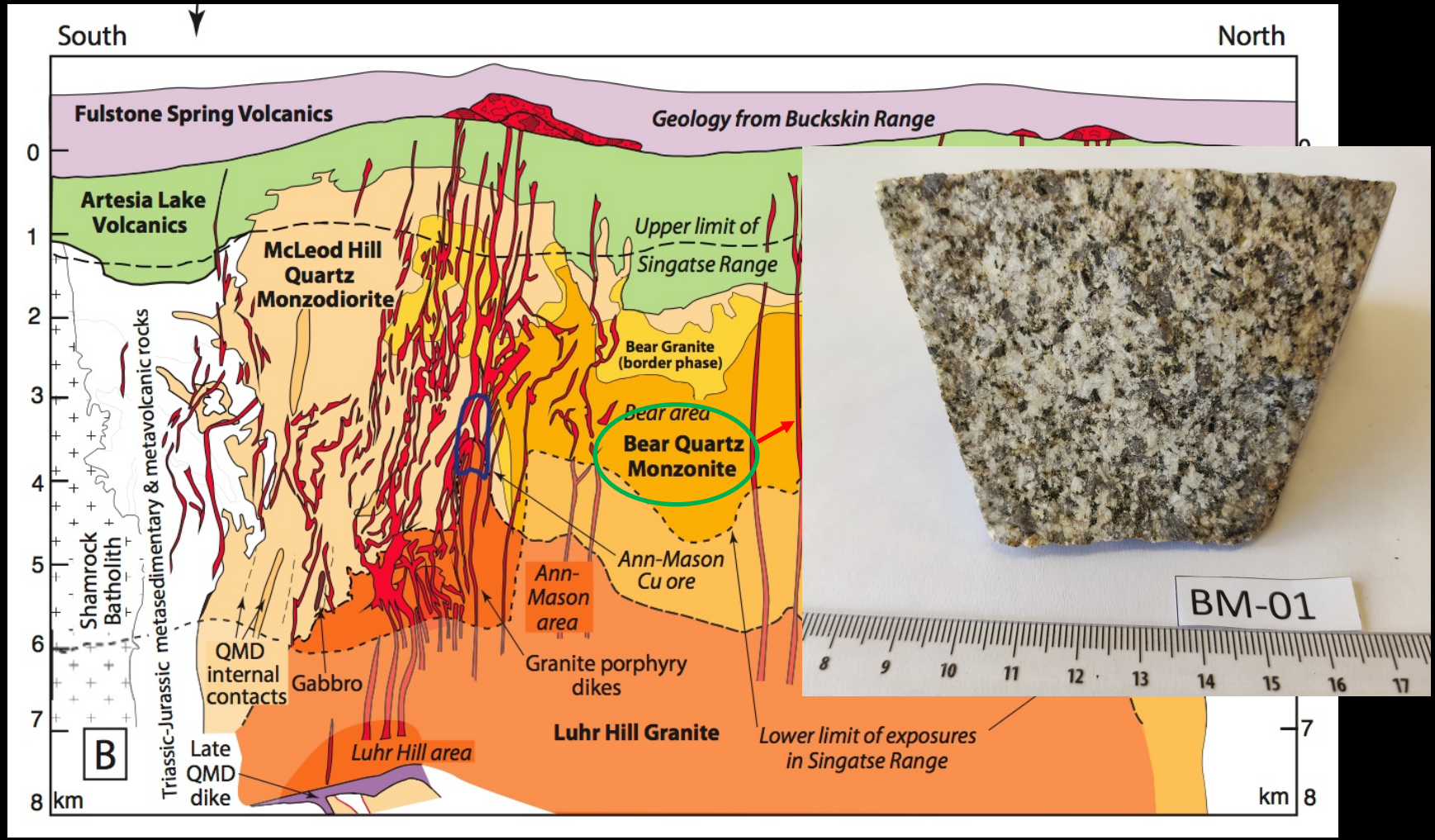
Schöpa A., Annen C., Dilles J. H., Blundy J., Sparks S., 2017



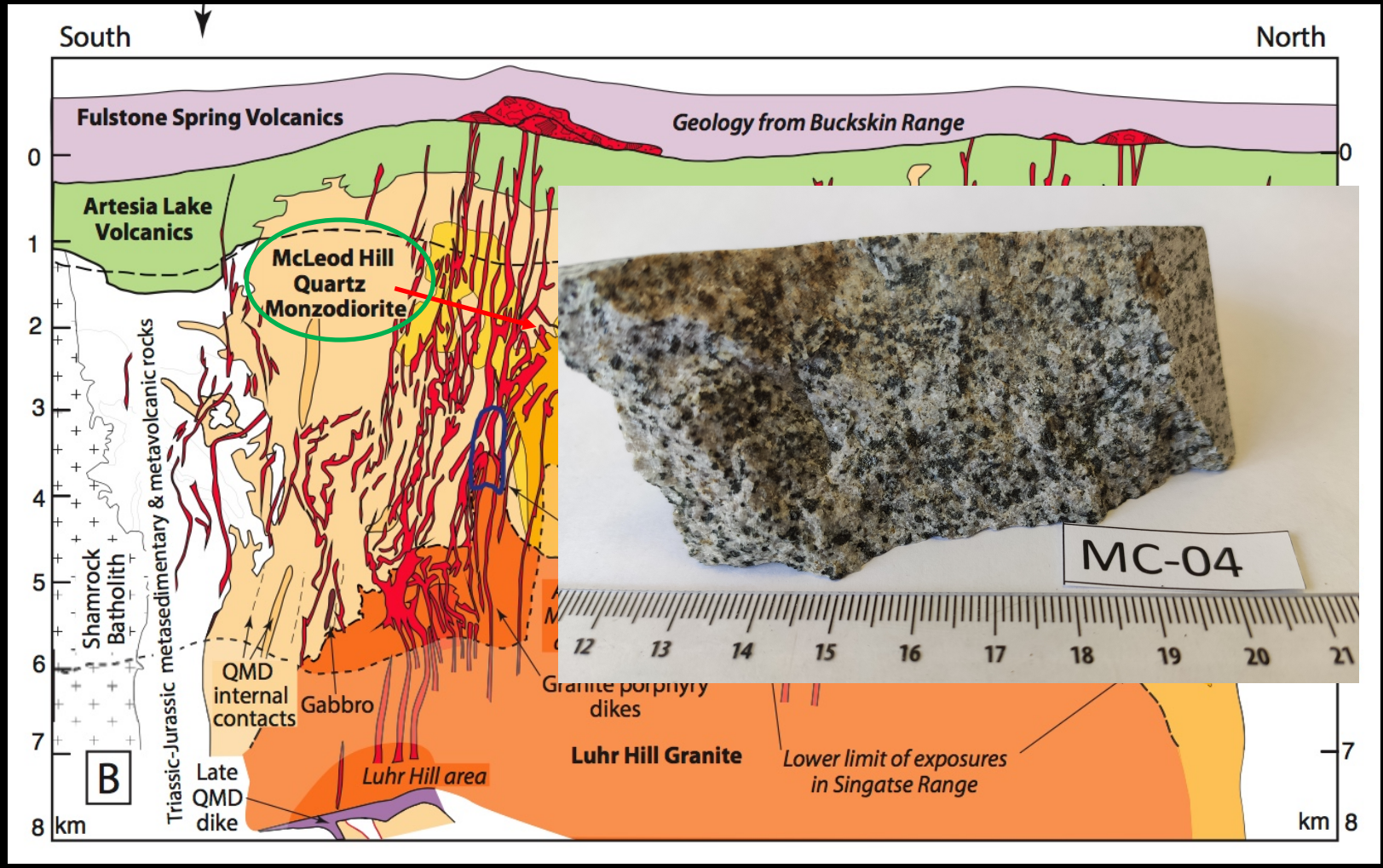
Schöpa A., Annen C., Dilles J. H., Blundy J., Sparks S., 2017



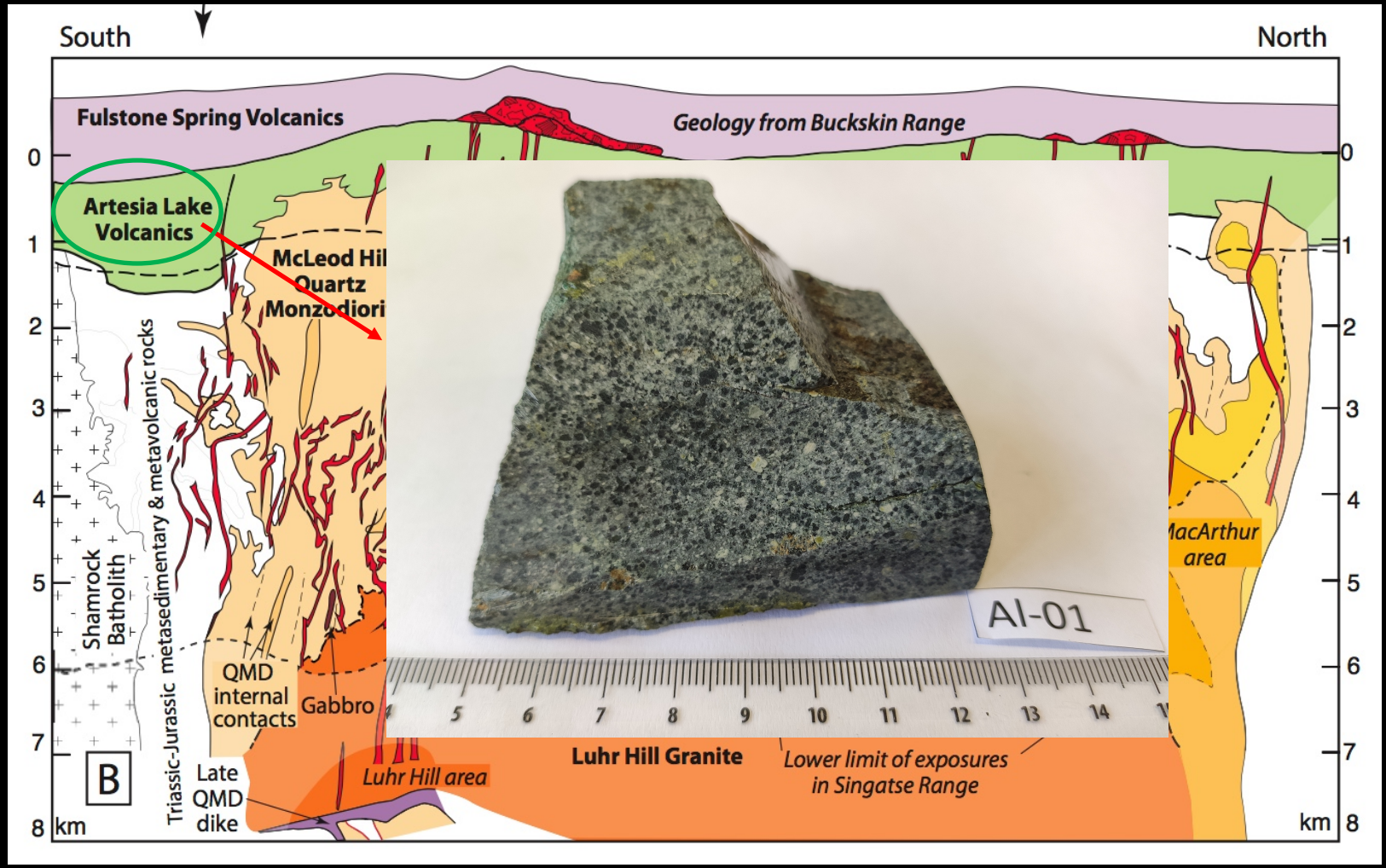
Schöpa A., Annen C., Dilles J. H., Blundy J., Sparks S., 2017



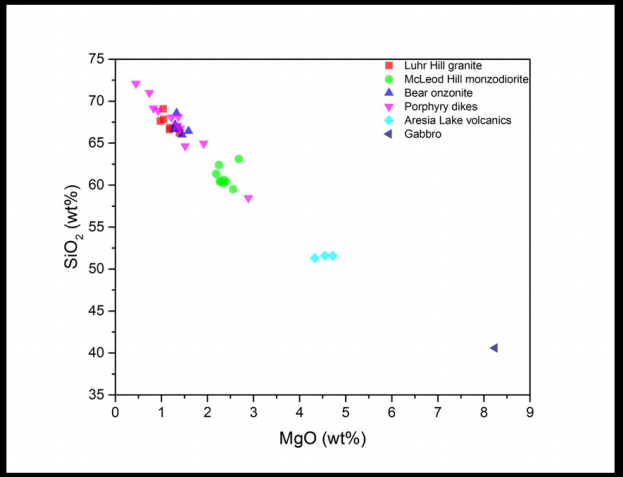
Schöpa et al., 2017

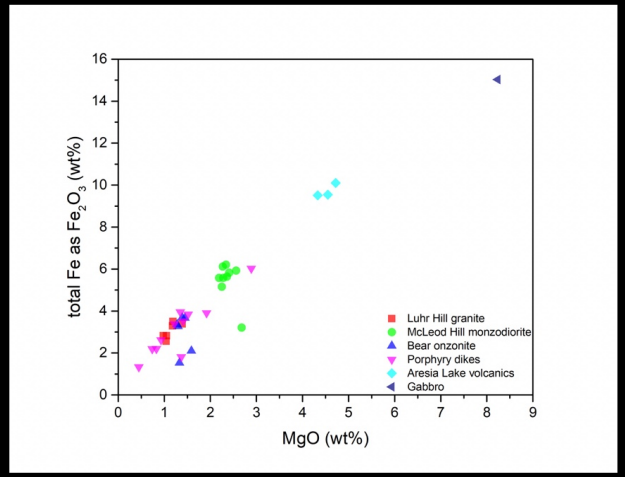


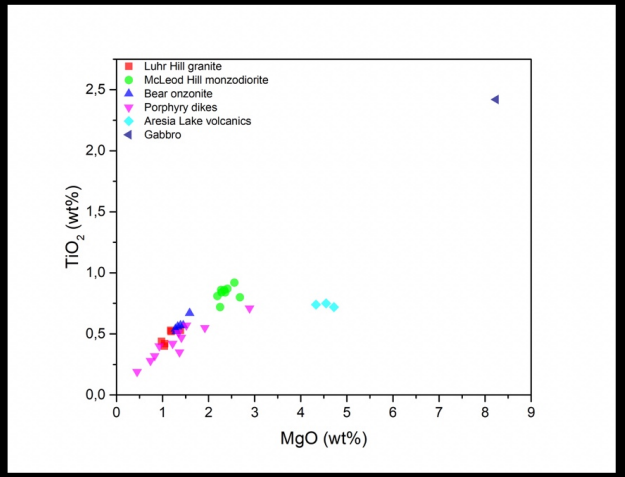
Schöpa A., Annen C., Dilles J. H., Blundy J., Sparks S., 2017

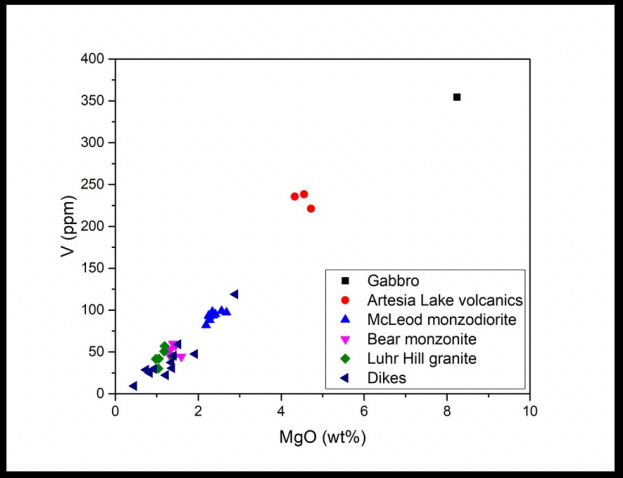


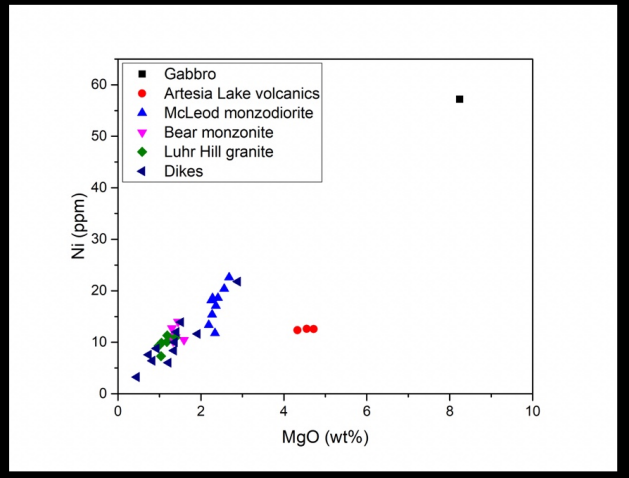
Schöpa A., Annen C., Dilles J. H., Blundy J., Sparks S., 2017

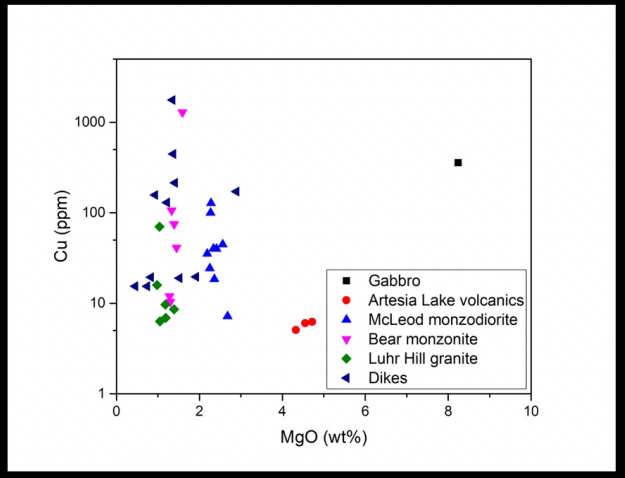

Luhr Hill granite
McLeod Hill monzodiorite
Bear onzonite
Porphyry dikes
Aresia Lake volcanics
Gabbro
SiO2 (wt%)
MgO (wt%)

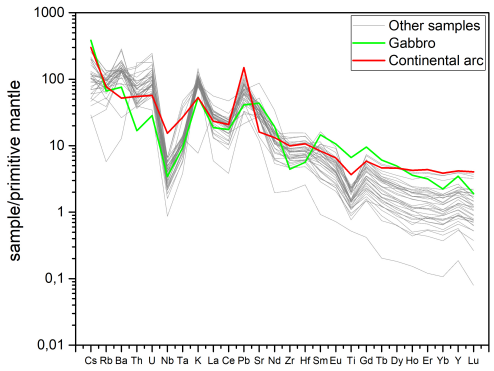

Luhr Hill granite
McLeod Hill monzodiorite
Bear onzonite
Porphyry dikes
Aresia Lake volcanics
Gabbro
total Fe as Fe2O3 (wt%)
MgO (wt%)


Luhr Hill granite
McLeod Hill monzodiorite
Bear onzonite
Porphyry dikes
Aresia Lake volcanics
Gabbro
TiO2 (wt%)
MgO (wt%)


Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes
V (ppm)
MgO (wt%)


Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes
Ni (ppm)
MgO (wt%)


Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes
Cu (ppm)
MgO (wt%)


sample/primitive mantle
1000
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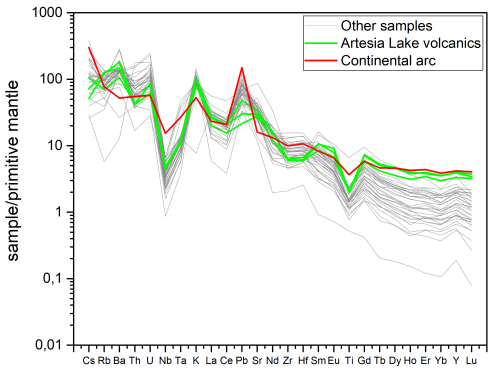
10
1
0,1
0,01
Cs Rb Ba Th U Nb Ta K La Ce Pb Sr Nd Zr Hf Sm Eu Ti Gd Tb Dy Ho Er Yb Y Lu
Other samples
Gabbro
Continental arc


sample/primitive mantle
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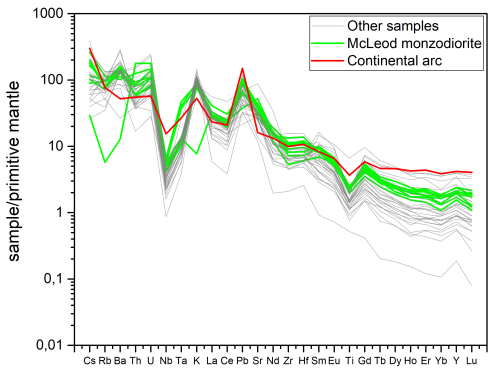
Cs Rb Ba Th U Nb Ta K La Ce Pb Sr Nd Zr Hf Sm Eu Ti Gd Tb Dy Ho Er Yb Y Lu
Other samples
Artesia Lake volcanics
Continental arc


sample/primitive mantle
1000
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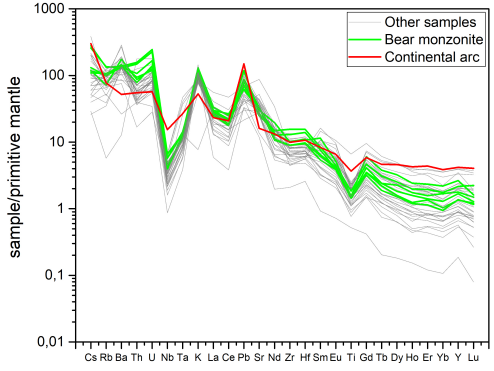
Other samples
McLeod monzodiorite
Continental arc


sample/primitive mantle
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0,01
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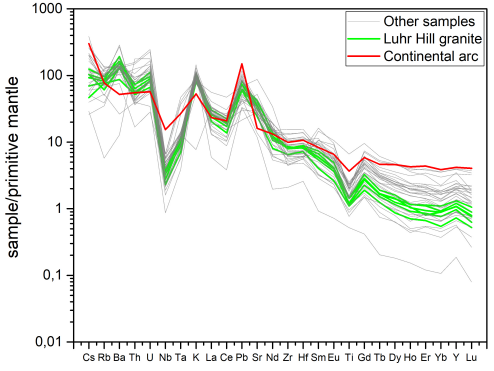
Other samples
Bear monzonite
Continental arc


sample/primitive mantle
1000
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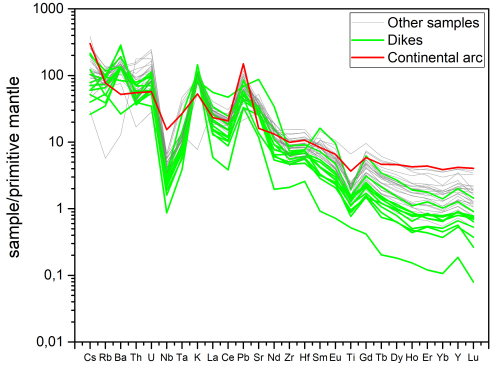
Cs Rb Ba Th U Nb Ta K La Ce Pb Sr Nd Zr Hf Sm Eu Ti Gd Tb Dy Ho Er Yb Y Lu
Other samples
Luhr Hill granite
Continental arc


sample/primitive mantle
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0,01
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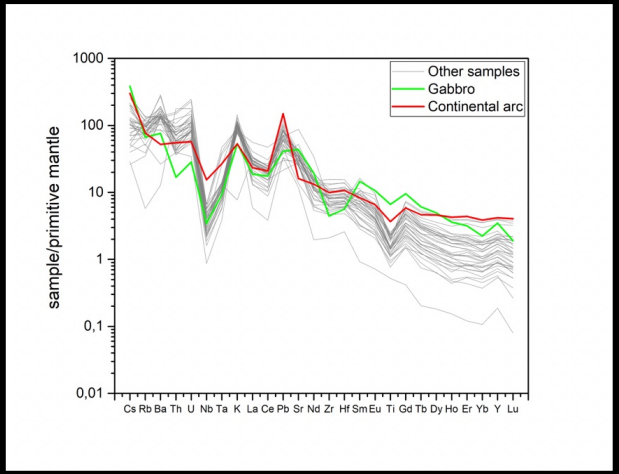
Other samples
Dikes
Continental arc


sample/primitive mantle
1000
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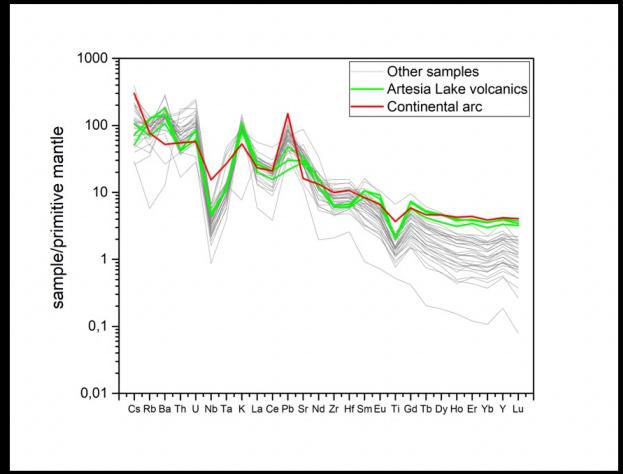
0,01
Cs Rb Ba Th U Nb Ta K La Ce Pb Sr Nd Zr Hf Sm Eu Ti Gd Tb Dy Ho Er Yb Y Lu
Other samples
Gabbro
Continental arc


sample/primitive mantle
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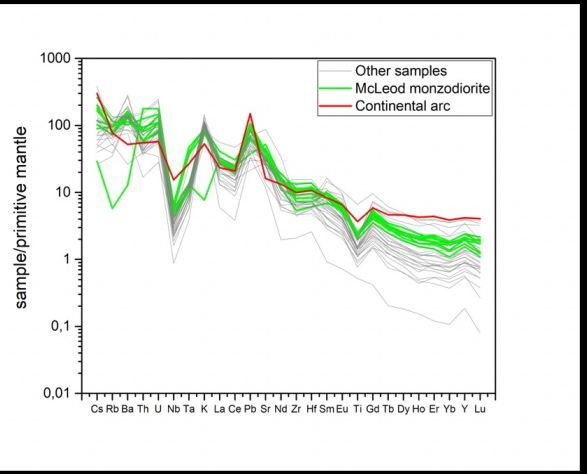
Other samples
Artesia Lake volcanics
Continental arc


sample/primitive mantle
1000
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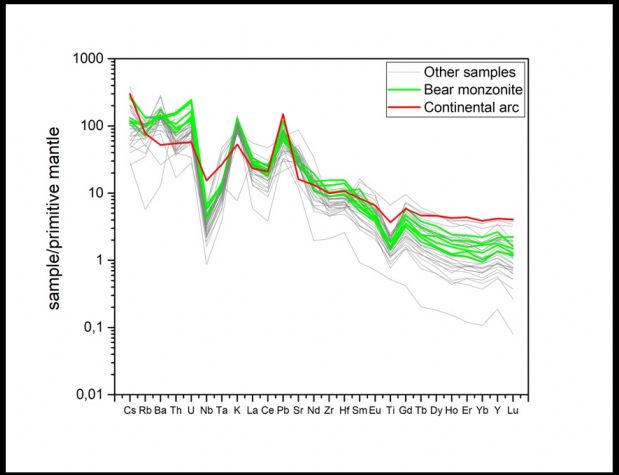
Other samples
McLeod monzodiorite
Continental arc


sample/primitive mantle
1000
100
10
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0,1
0,01
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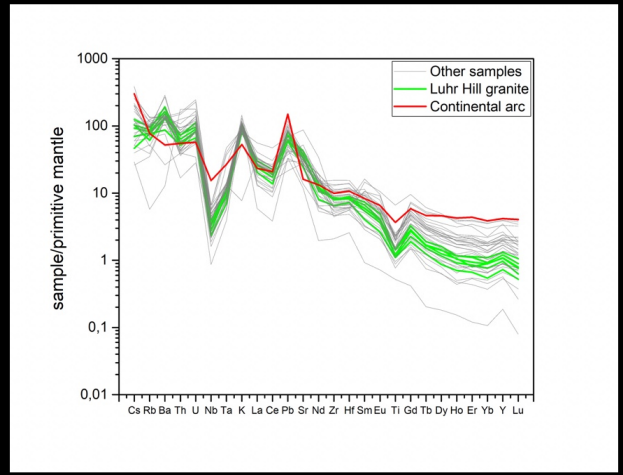
Other samples
Bear monzonite
Continental arc


sample/primitive mantle
1000
100
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0,1
0,01
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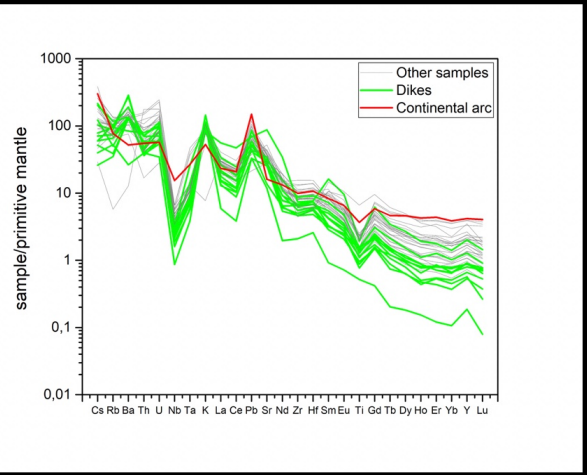
Other samples
Luhr Hill granite
Continental arc


sample/primitive mantle
1000
100
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1
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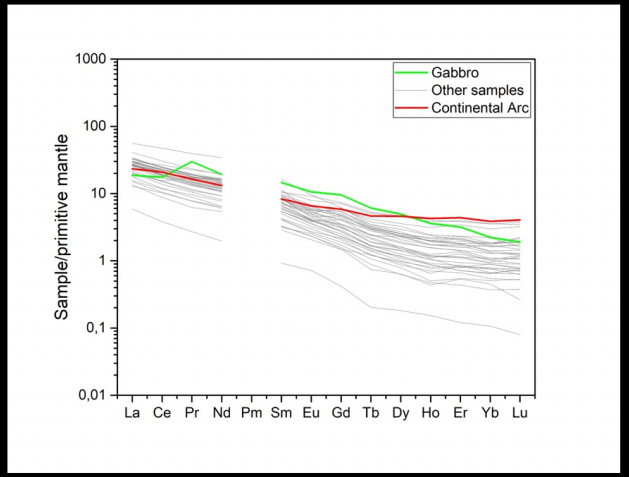
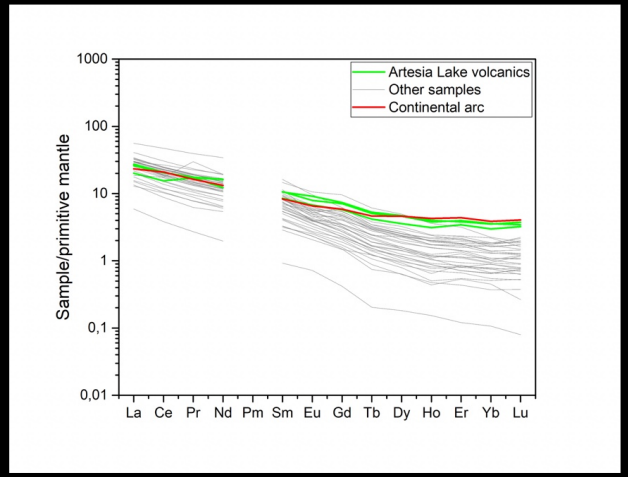
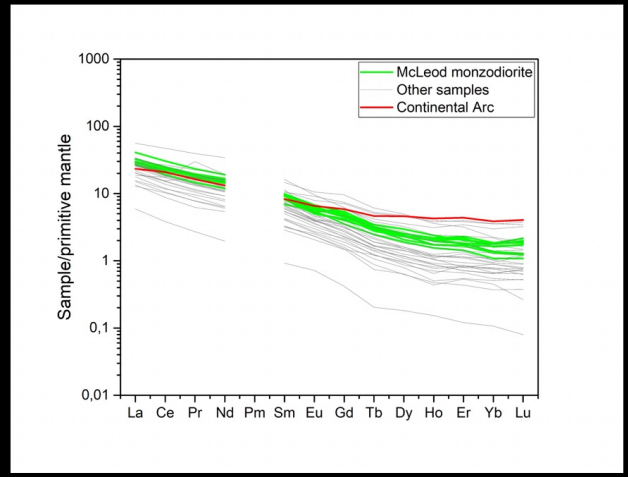
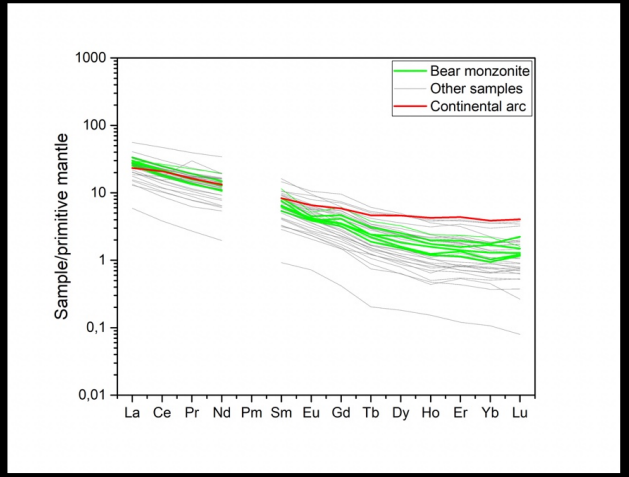
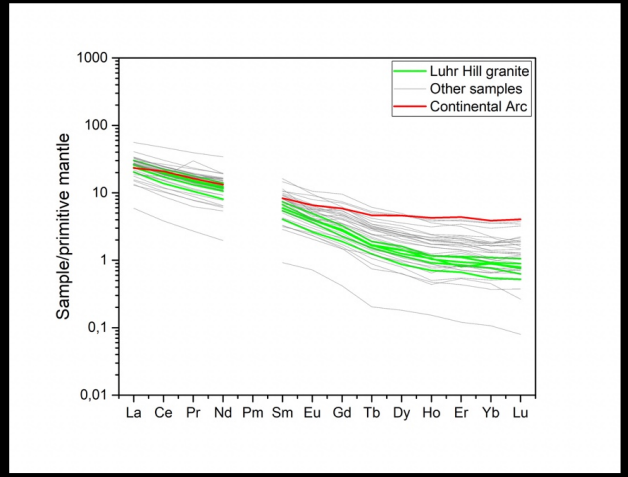
0,01
Cs Rb Ba Th U Nb Ta K La Ce Pb Sr Nd Zr Hf Sm Eu Ti Gd Tb Dy Ho Er Yb Y Lu
Other samples
Dikes
Continental arc

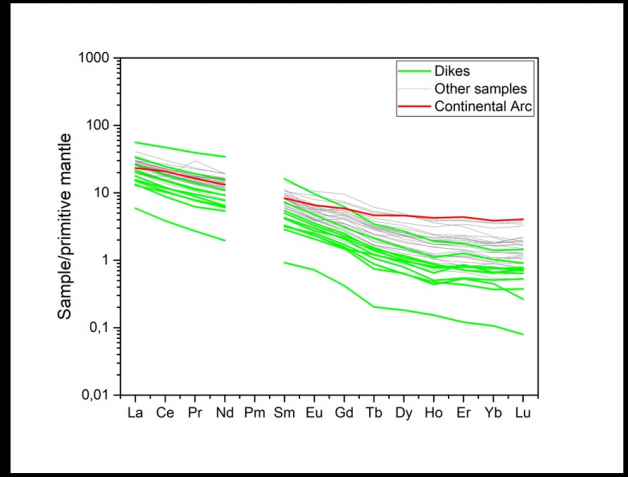

Gabbro
Other samples
Continental Arc
Sample/primitive mantle
1000
100
10
1
0,1
0,01
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Yb Lu

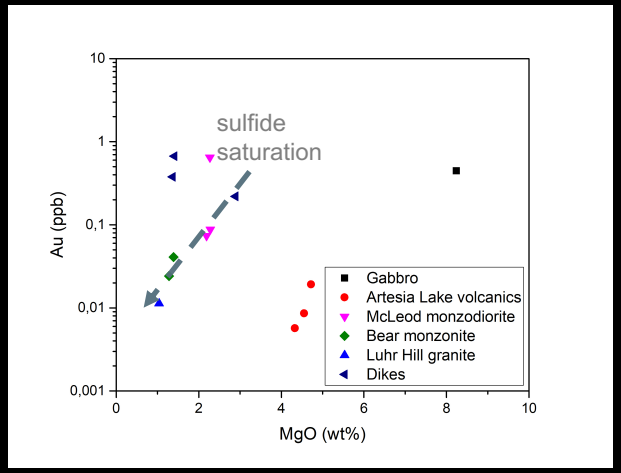

Artesia Lake volcanics
Other samples
Continental arc
Sample/primitive mantle
1000
100
10
1
0,1
0,01
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Yb Lu

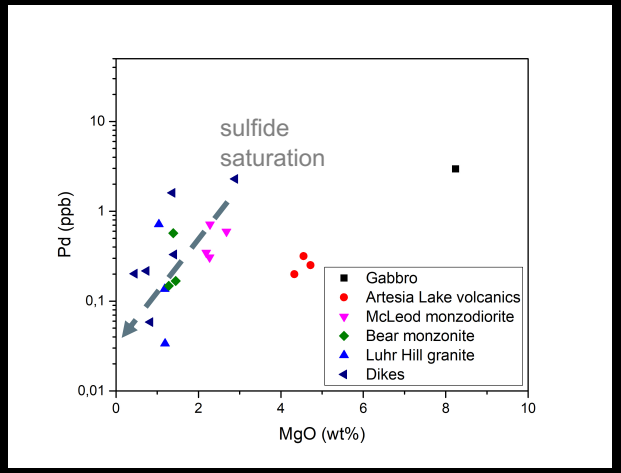

McLeod monzodiorite
Other samples
Continental Arc
Sample/primitive mantle
1000
100
10
1
0,1
0,01
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Yb Lu

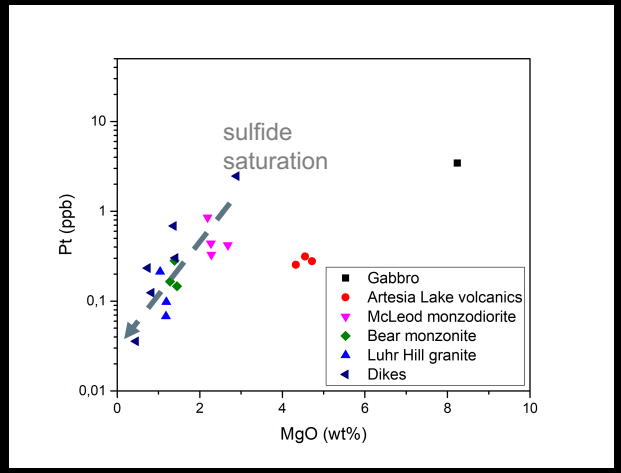

Bear monzonite
Other samples
Continental arc
Sample/primitive mantle
1000
100
10
1
0,1
0,01
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Yb Lu

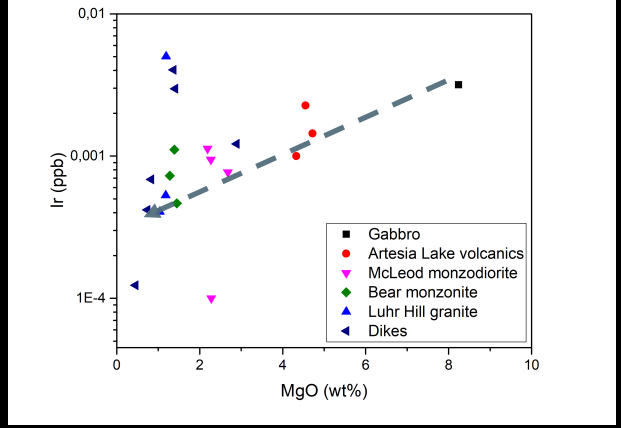

Luhr Hill granite
Other samples
Continental Arc
Sample/primitive mantle
1000
100
10
1
0,1
0,01
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Yb Lu

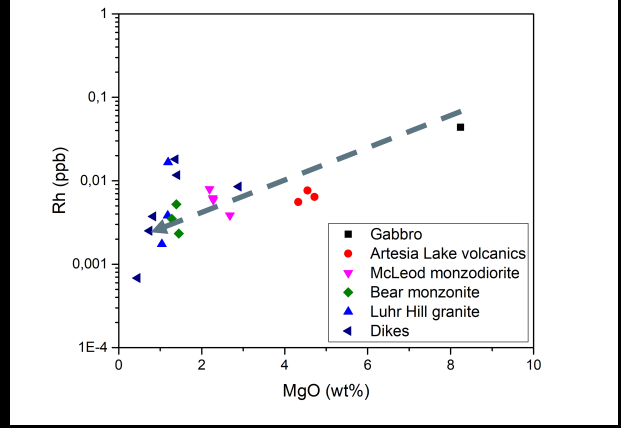

Dikes
Other samples
Continental Arc
Sample/primitive mantle
1000
100
10
1
0,1
0,01
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Yb Lu

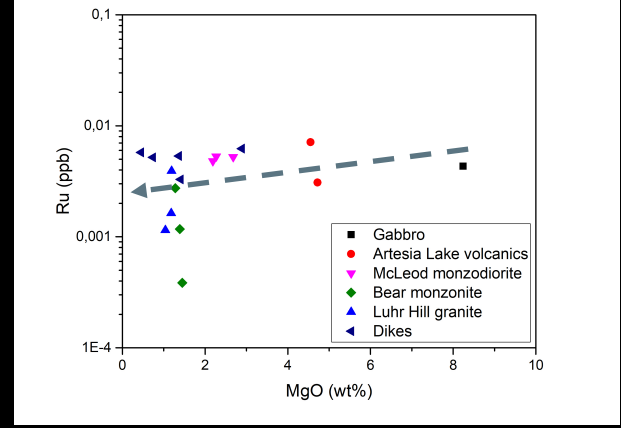

sulfide
saturation
Au (ppb)
MgO (wt%)
Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes


sulfide
saturation
Pd (ppb)
MgO (wt%)
Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes


sulfide
saturation
Pt (ppb)
MgO (wt%)
Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes


Ir (ppb)
MgO (wt%)
Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes


Rh (ppb)
MgO (wt%)
Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes

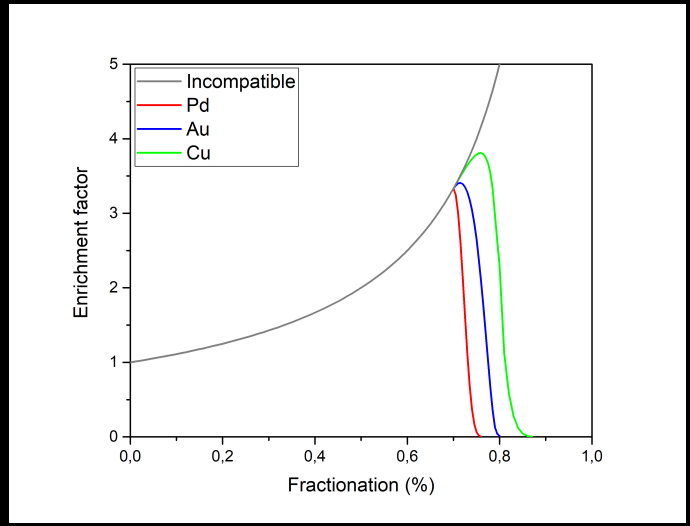

Ru (ppb)
MgO (wt%)
Gabbro
Artesia Lake volcanics
McLeod monzodiorite
Bear monzonite
Luhr Hill granite
Dikes

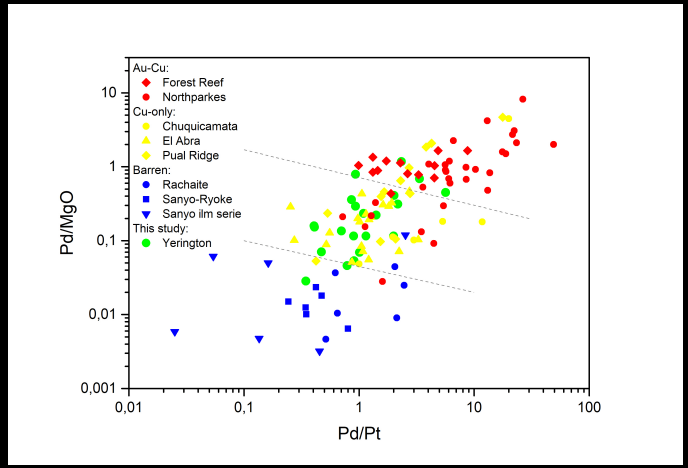
Modelling of fractionation requires to assume the amount of fractional crystallization at the moment of sulfide saturation. For that, 2 methods were used:

- Petrolog3 software modelling
- Rayleigh equation on incompatible elements

Both methods estimated that magma had undergone ca. 70% of fractional crystallization at the moment of sulfide saturation (3 wt% MgO)

Fractionation modelling shows that the enrichment factor of metals will be close to 3-3.5.





Plotted ratio Pd/MgO against Pd/Pt divides suites into barren, Cu-only and Au-Cu.

All the samples from Yerington fall within, or very close, to the Cu-only field of the model, confirming the accuracy of the model with the characteristics of the deposit.

Conclusions

1) Plots of whole-rock concentrations major, trace elemtns and REE show that all samples, including cumulate and volcanic rocks, are likely to be related by fractional crystallization
2) Scattering in concentrations of Cu, with no clear correlation, is attributed to hydrothermal mineralization overprinting and cannot be used to determine the timing of sulfide saturation
3) Due to the much higher partition coefficient, PGE were used to determine the timing of sulfide saturation
4) Late sulfide saturation indicates Cu-only mineralization


Thank you