The Emigrant Gap Complex: Origins and Emplacement of a Jurassic Intermediate-Ultramafic Pluton

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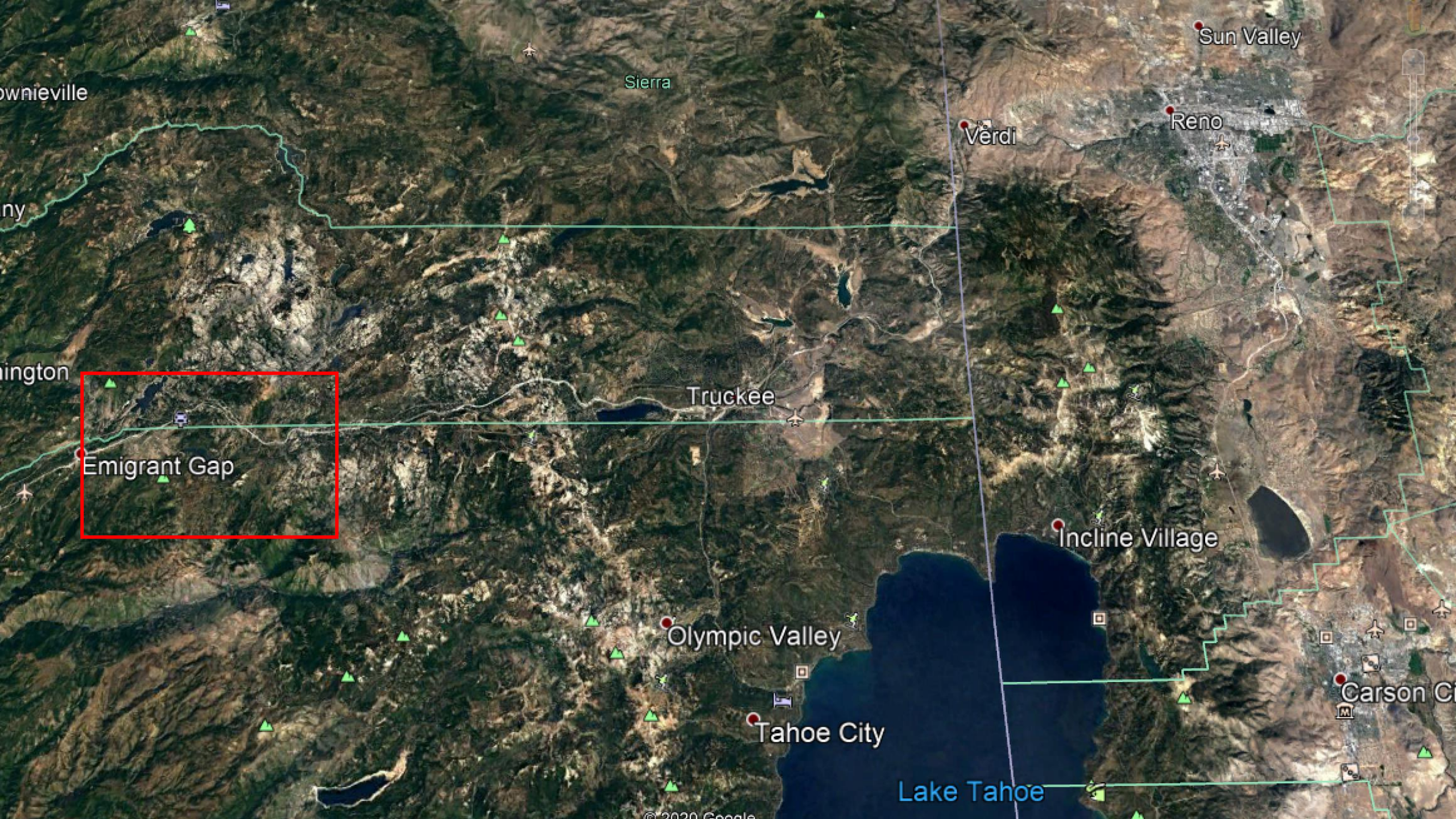
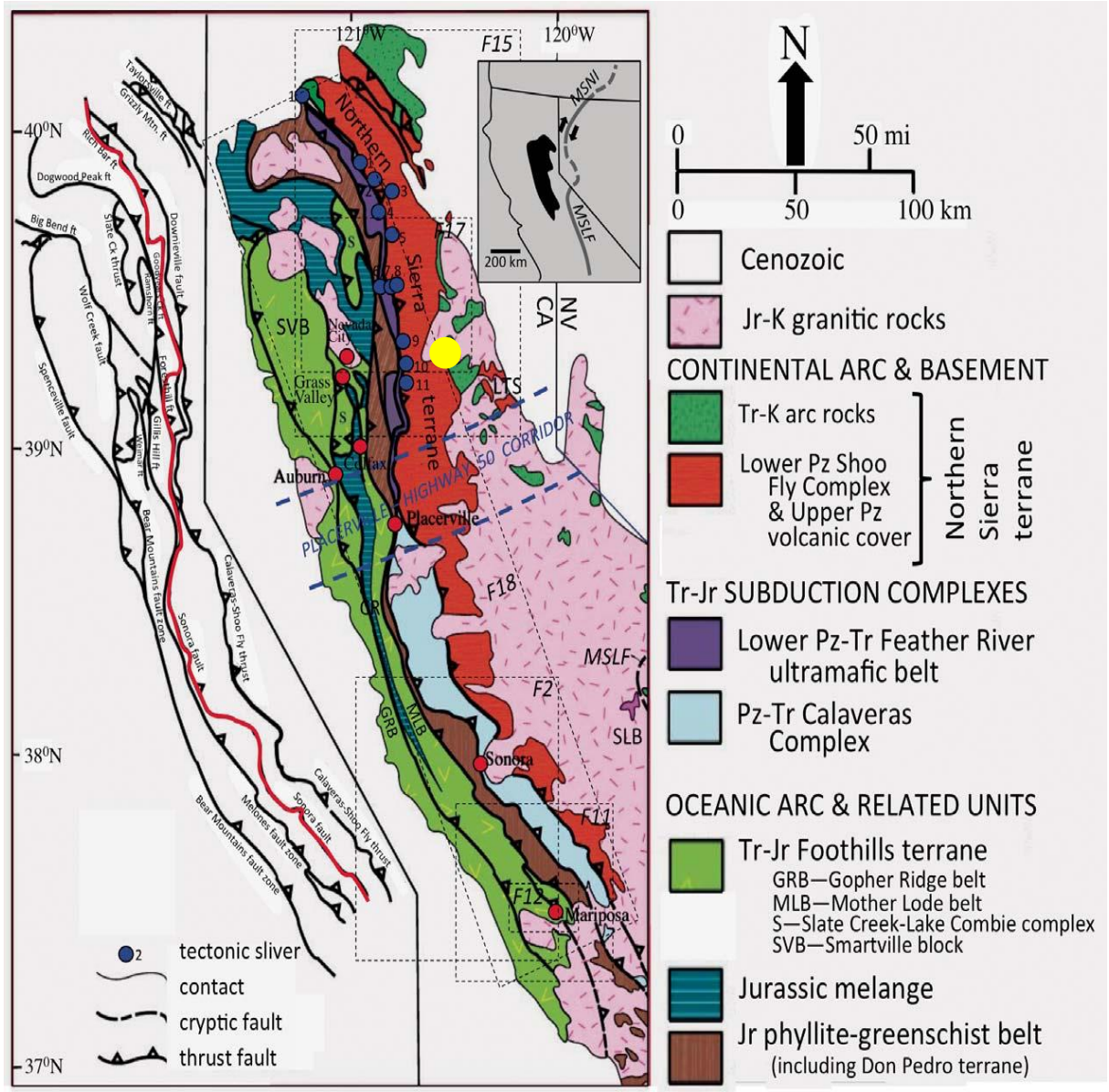

Sun Valley
Sierra
Verdi
Reno
Truckee
Emigrant Gap
Incline Village
Olympic Valley
Tahoe City
Lake Tahoe

Regional Context

- The Northern Sierra Terrane (NST) accreted to North America as part of a series of collisions termed the Nevadan Orogeny in the middle Jurassic (Schweickert, 2015)

- The NST is composed of the Shoo Fly Complex, a Devonian-Ordovician accretionary prism, along with overlying Paleozoic sedimentary rocks and Triassic-Jurassic arc rocks

- The Emigrant Gap Complex (EGC, yellow dot) intruded the Northern Sierra Terrane (NST) just after the Nevadan Orogeny (Girty et al., 1995)



Schweickert 2015, GSA-SP 513

Previous Work

James 1971

- Only paper published specifically on the ultramafic rocks at Emigrant Gap
- Mapped the ultramafics and studied their petrology
- Found all rocks in the intrusive complex to be related, from dunite to granodiorite
- Argued that the intrusive complex formed by fractional crystallization and flowage differentiation
- Identified similarities of the Emigrant Gap rocks with Ural-Alaska Complexes

Gary Girty 1990-1995

- Focused on the Emigrant Gap pluton
- Argued the EGC was emplaced roughly 164-168 Ma at around 10 km depth
- Found it postdated the Nevadan Orogeny

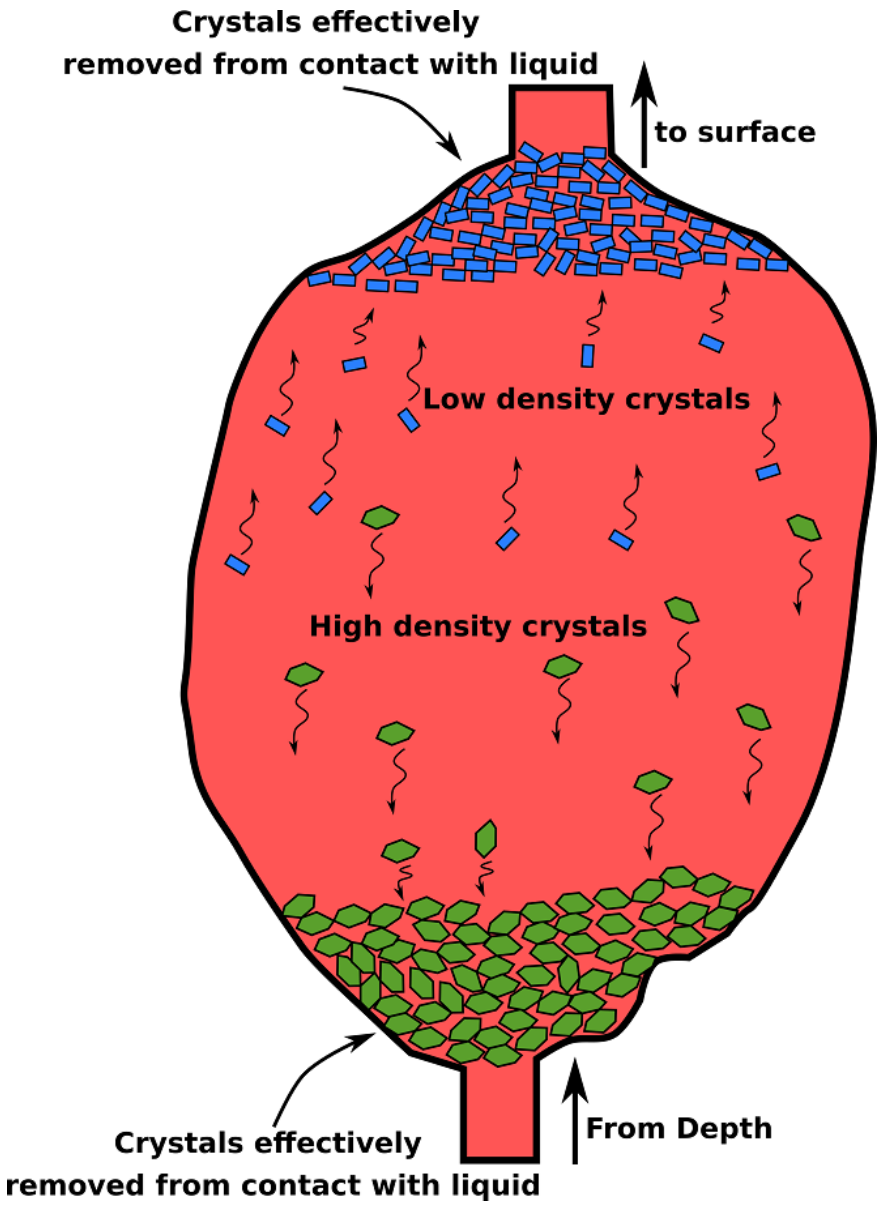
California Geological Survey 2014 Map of Eastern Placer County

- Did not remap the ultramafics
- Remapped and redefined the sedimentary country rocks

Research Questions

- What was the petrogenesis of the EGC? I have three models: a single intrusion of mafic magma, a transcrustal magma system, or a translithospheric ultramafic diapir.

- If the EGC originated as an ultramafic magma, how does a negatively buoyant ultramafic magma intrude the felsic upper continental crust?



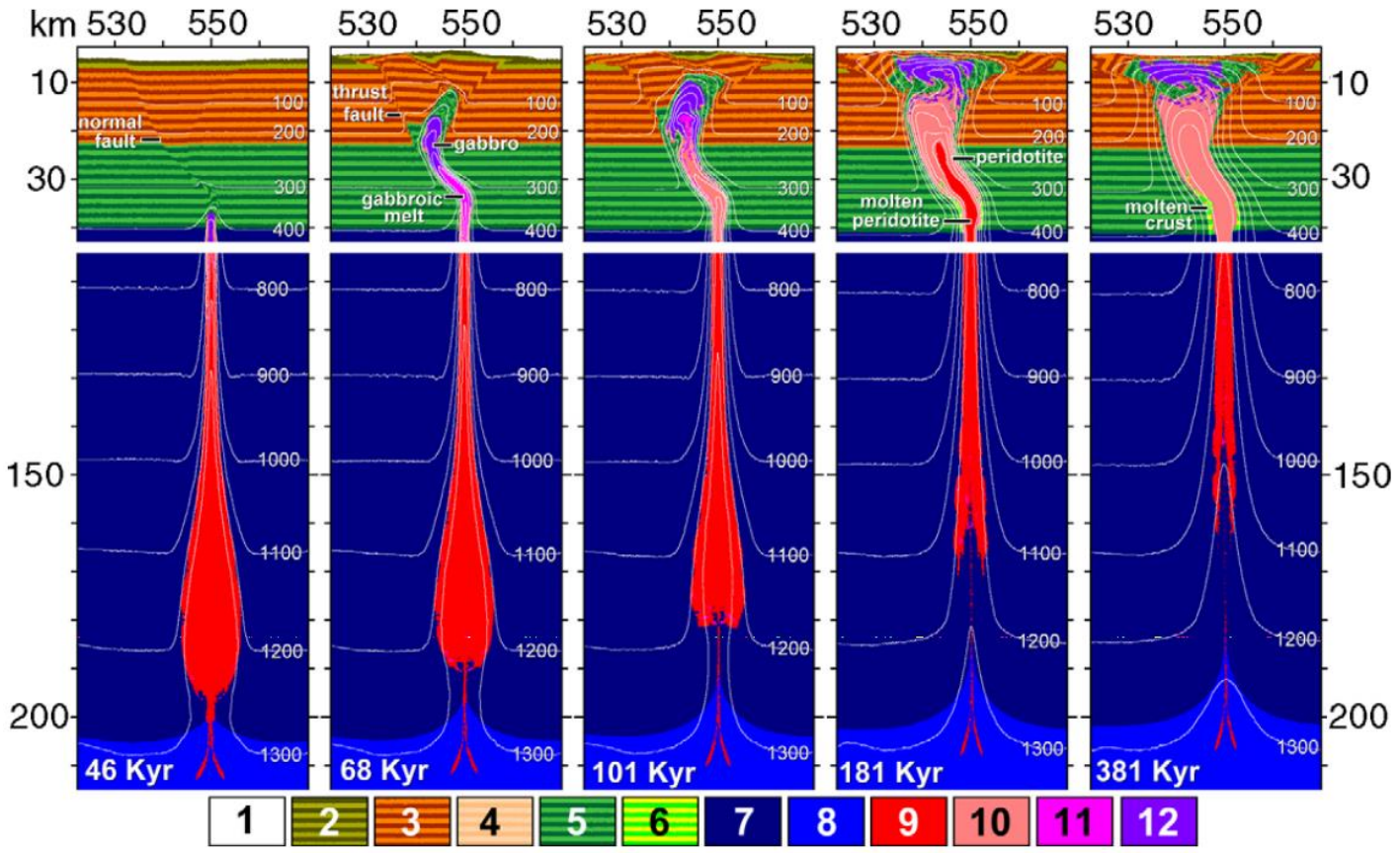
http://www.alexstrekeisen.it/english/pluto/cumulate.php

Singular Intrusion of Mafic Magma

- Proposed by James (1971)
- Produces coeval igneous rocks with shared history and geochemistry throughout the EGC
- Predicts ultramafic bodies formed by in-situ fractional crystallization and flowage differentiation

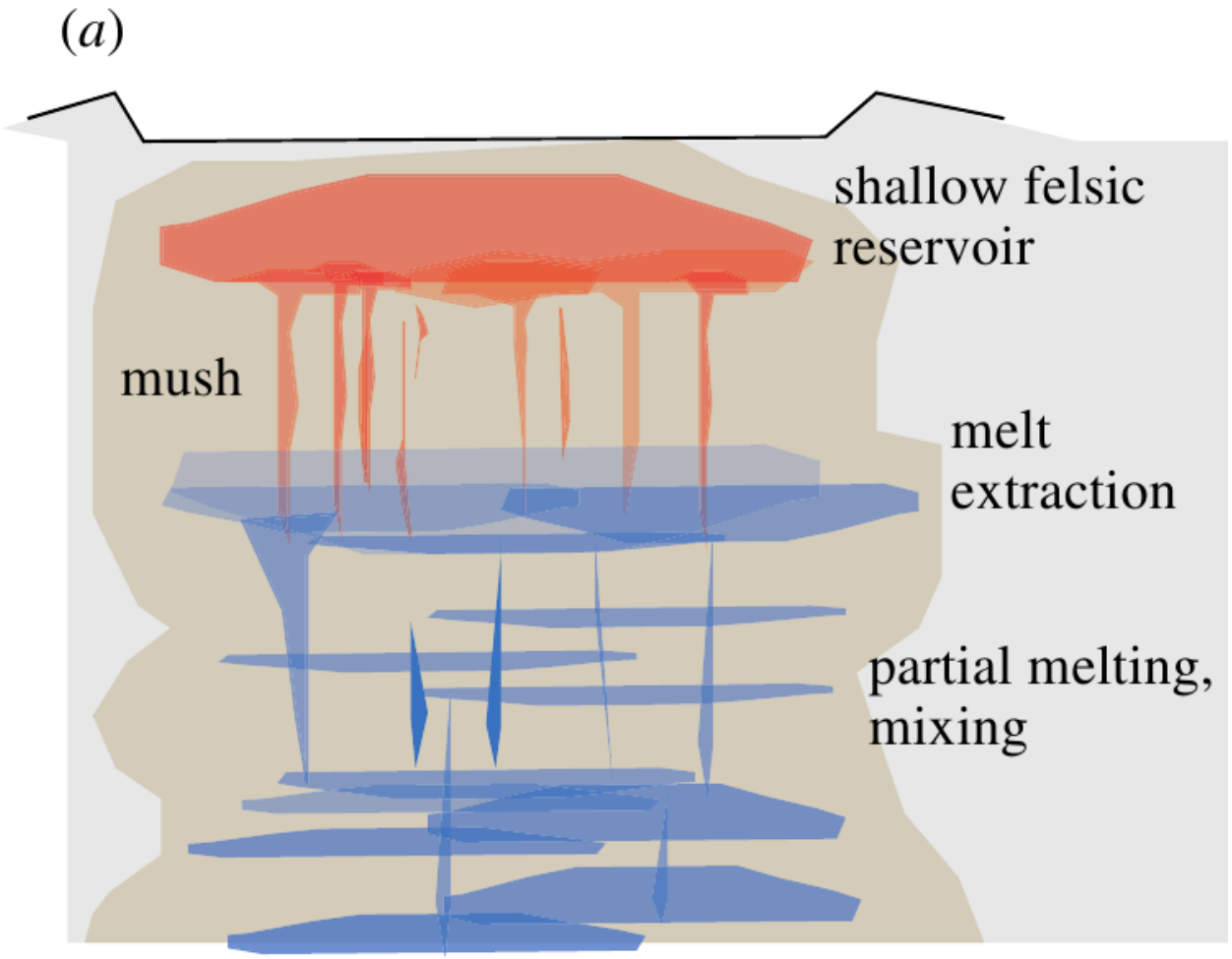
TRANSLITHOSPHERIC ULTRAMAFIC DIAPIR

- Recent modelling (Gerya and Burg, 2006, Guillou-Frottier et al., 2014) suggests that ultramafic magmas can directly intrude the upper continental crust
- Found that such diapirs require a strong lower crustal rheology and a weak crustal conduit
- However, modeled a homogenous crust
- Predicts the EGC forcefully intruded the upper crust from an origin at the base of the lithosphere



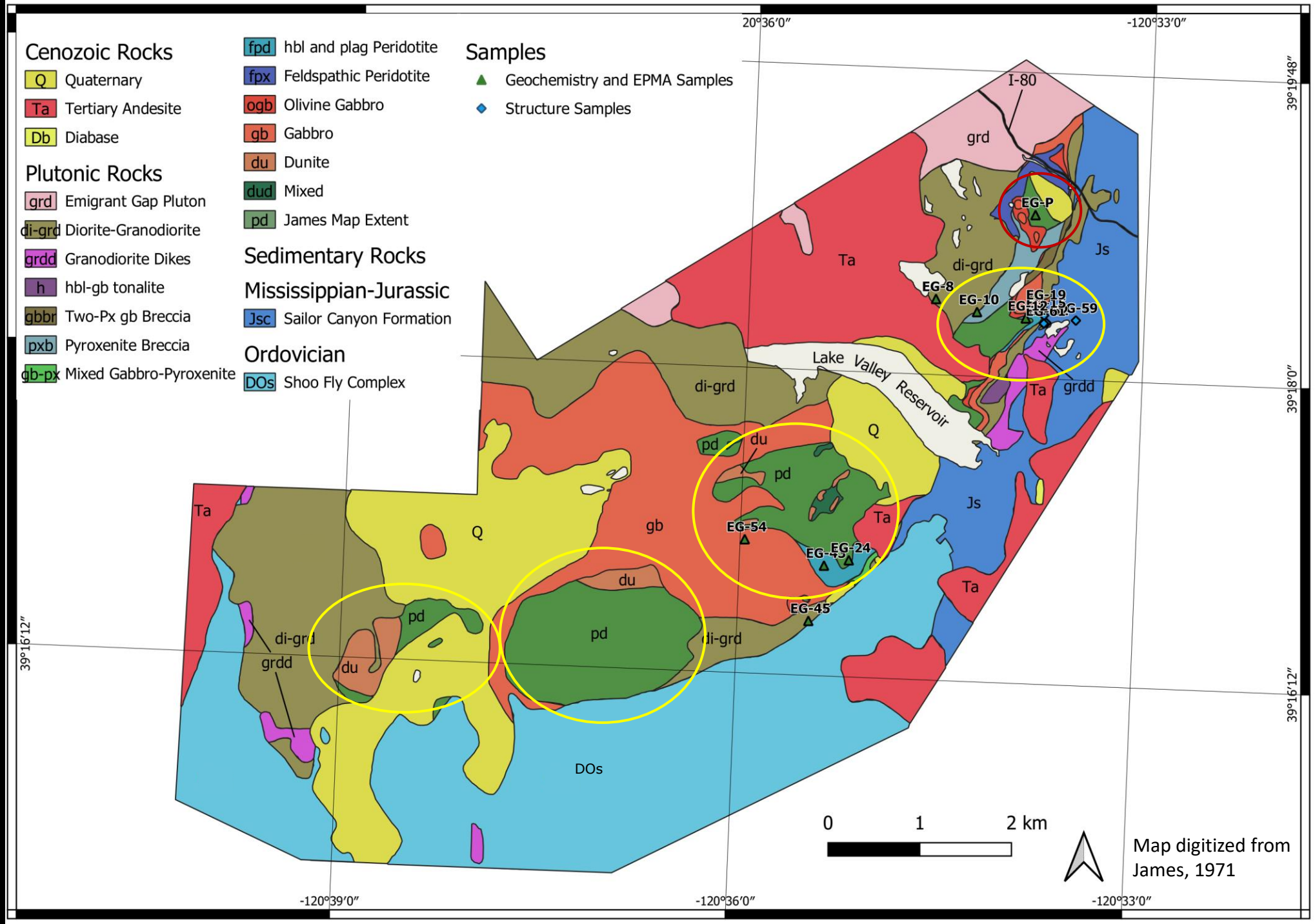
Gerya and Burg, 2006

Transcrustal Magma System



Edmonds et al., 2019

- Pooling and mixing of magma in lower and mid crustal reservoirs
- Produces igneous rocks with complex, multistage crystallization histories
- Predicts ultramafic bodies produced by several distinct intrusions over several Myr with crystallization at variable depths


Cenozoic Rocks
Q Quaternary
Ta Tertiary Andesite
Db Diabase
Plutonic Rocks
grd Emigrant Gap Pluton
di-grd Diorite-Granodiorite
grdd Granodiorite Dikes
h hbl-gb tonalite
gbbr Two-Px gb Breccia
pxb Pyroxenite Breccia
gb-px Mixed Gabbro-Pyroxenite
fpd hbl and plag Peridotite
fpx Feldspathic Peridotite
ogb Olivine Gabbro
gb Gabbro
du Dunite
dud Mixed
pd James Map Extent
Sedimentary Rocks
Mississippian-Jurassic
Jsc Sailor Canyon Formation
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Samples
Geochemistry and EPMA Samples
Structure Samples
20°36'0"
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-120°39'0"
-120°36'0"
I-80
grd
Ta
di-grd
Js
EG-P
EG-8
EG-10
EG-19
EG-59
Lake Valley Reservoir
grdd
Q
pd
du
gb
EG-54
EG-24
EG-45
DOs
0
1
2 km
Map digitized from James, 1971

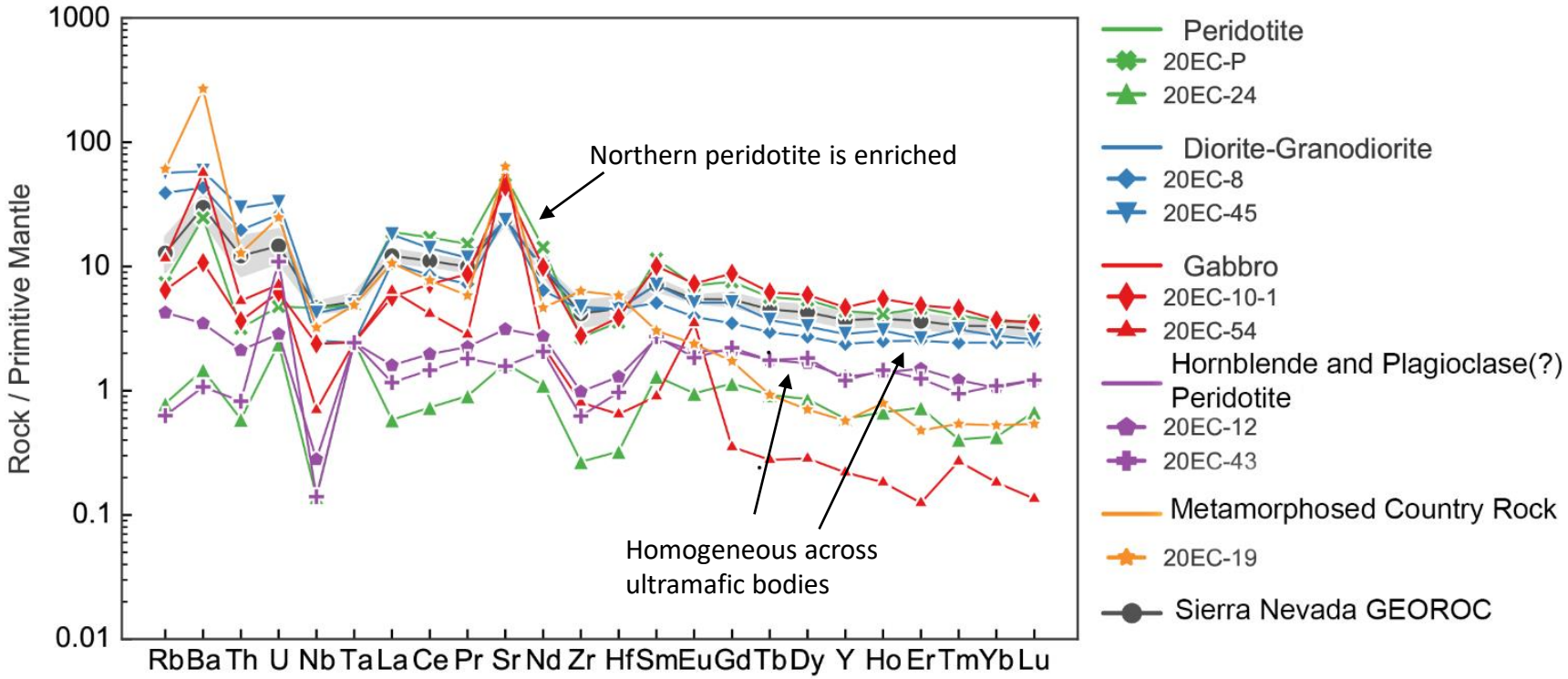

Dunite with large olivine crystals defining foliation
Serpentine veins


Coarse grained peridotite
Block of fine grained peridotite


Gabbro


GSA
CM
IN
mm
Diorite-granodiorite

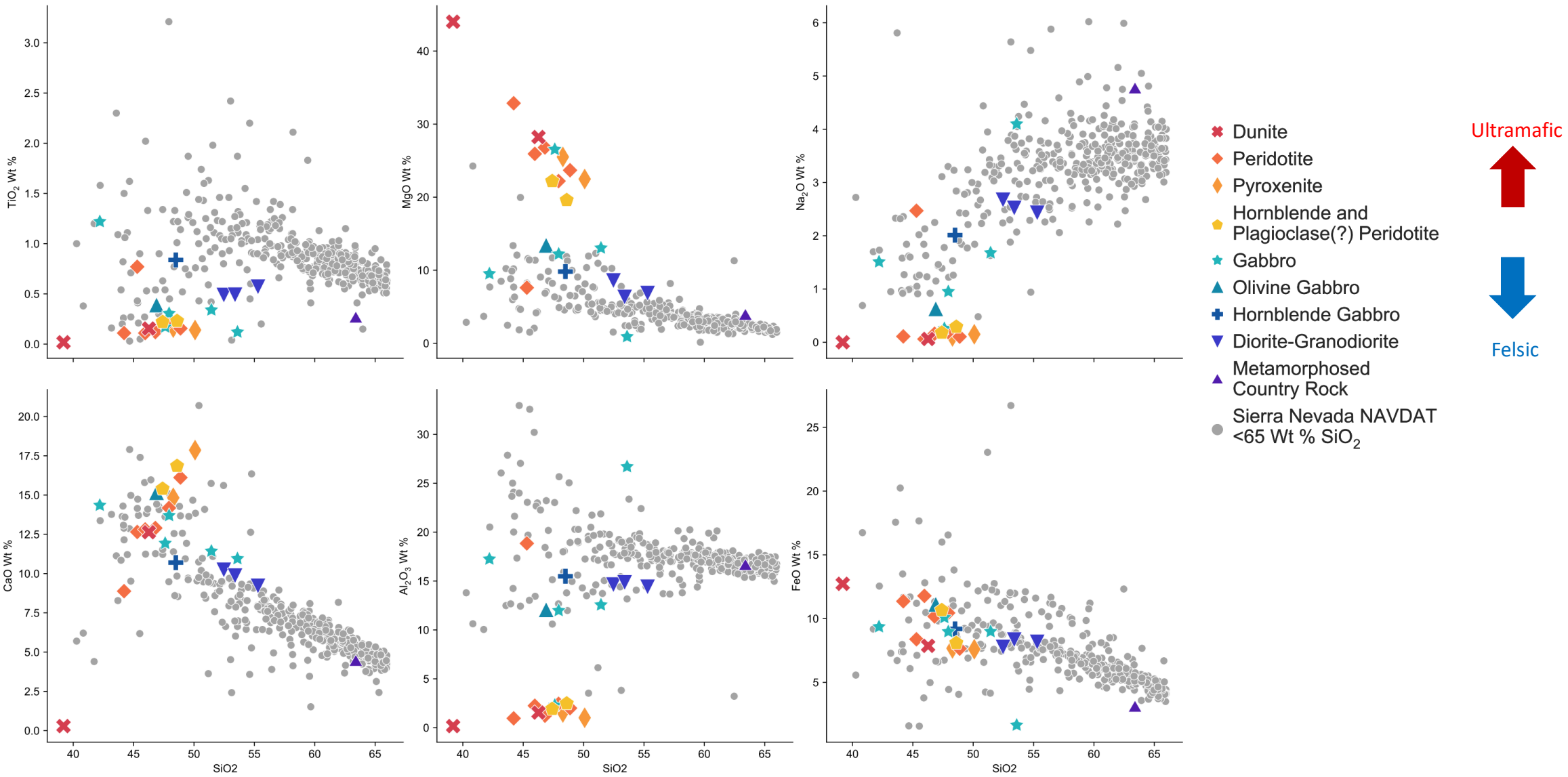
Trace Element Geochemistry



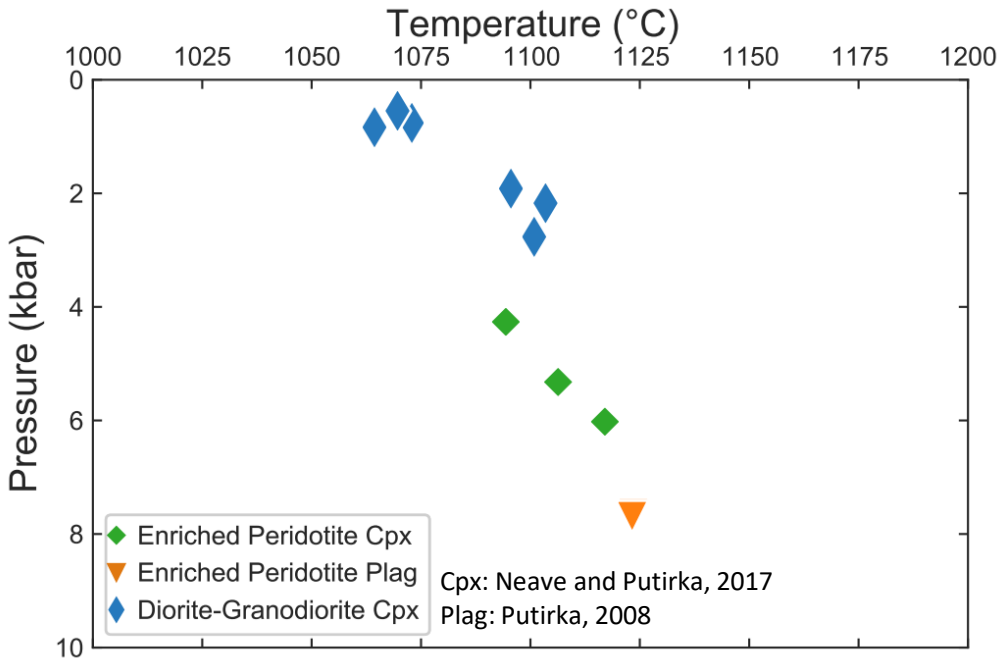
- Incompatible trace elements behave like arc magmas

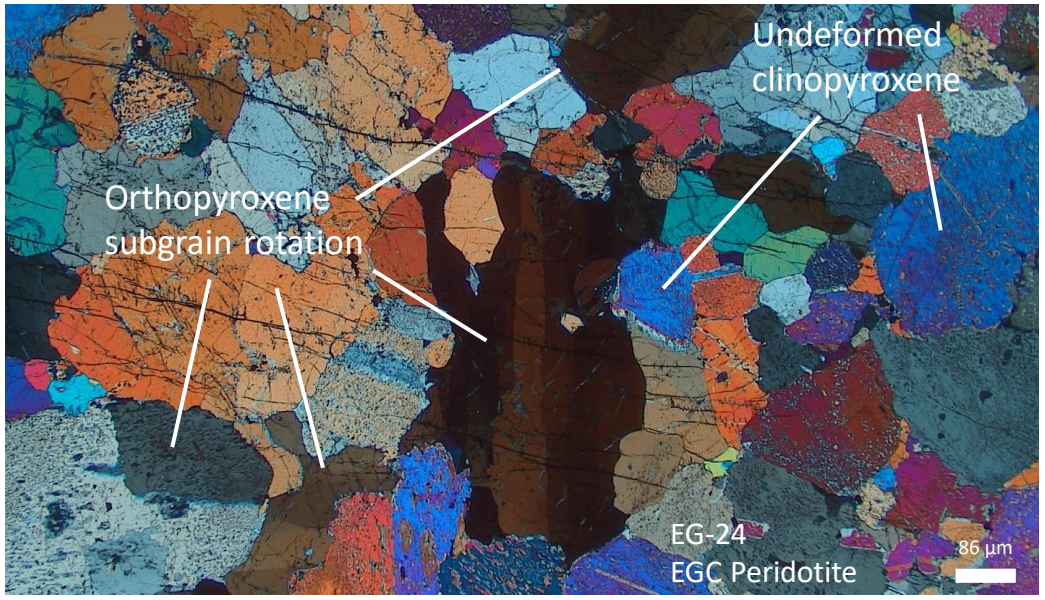
- EGC rocks homogeneous across ultramafic bodies

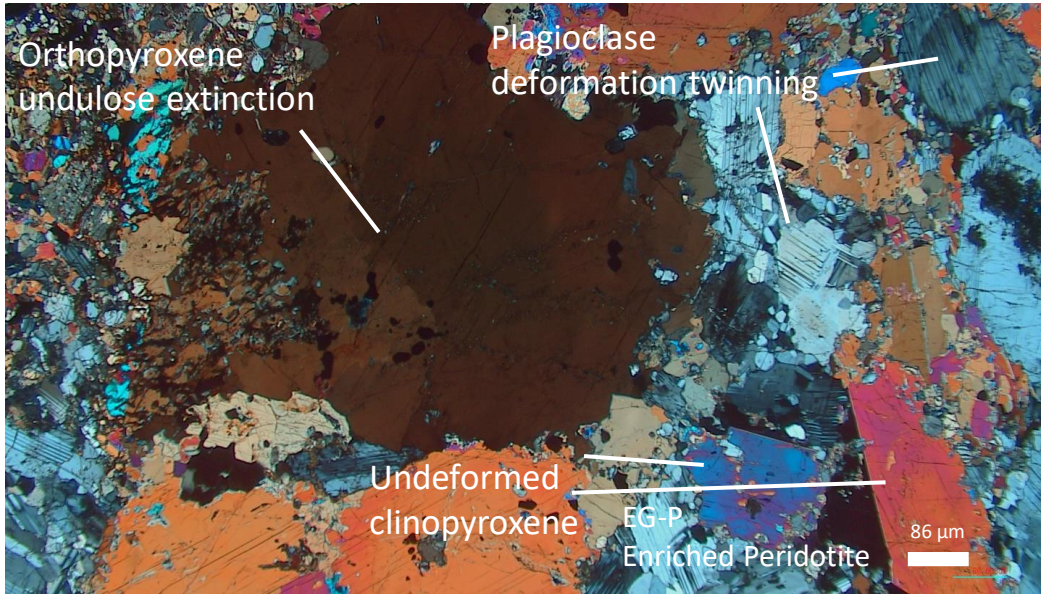
Major Element Geochemistry

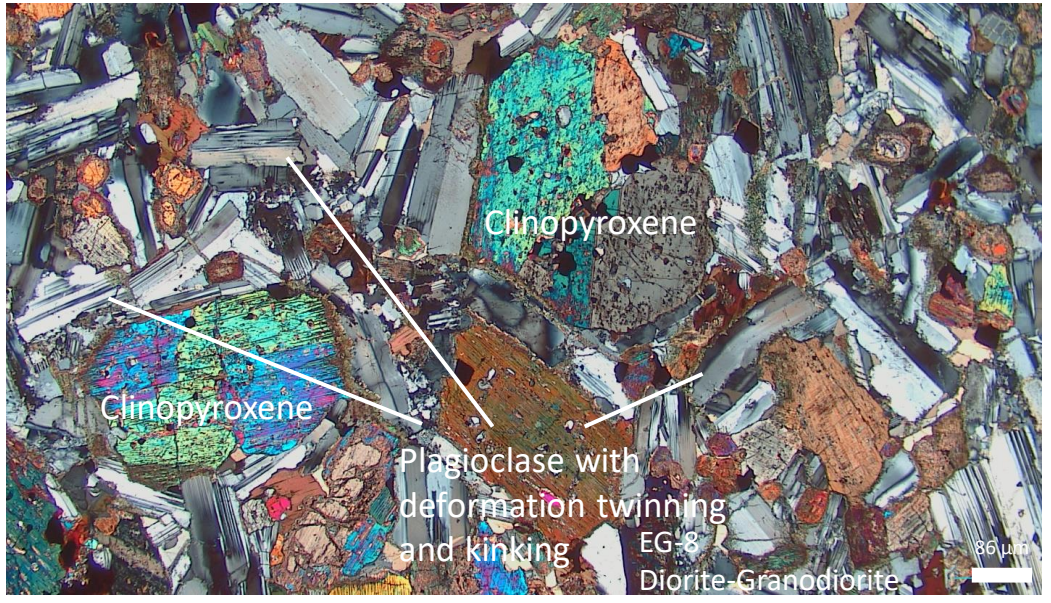


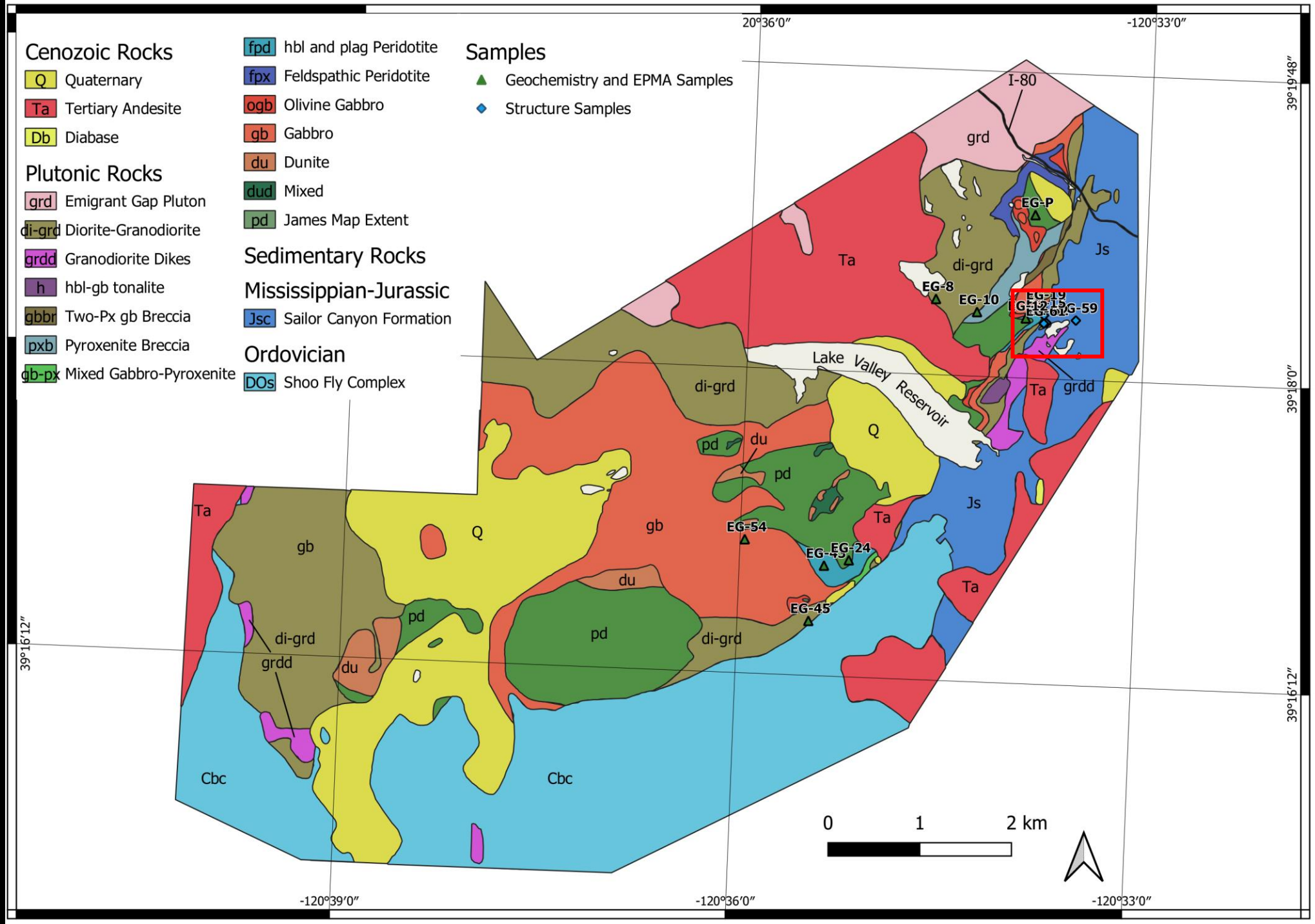
P-T of Crystallization







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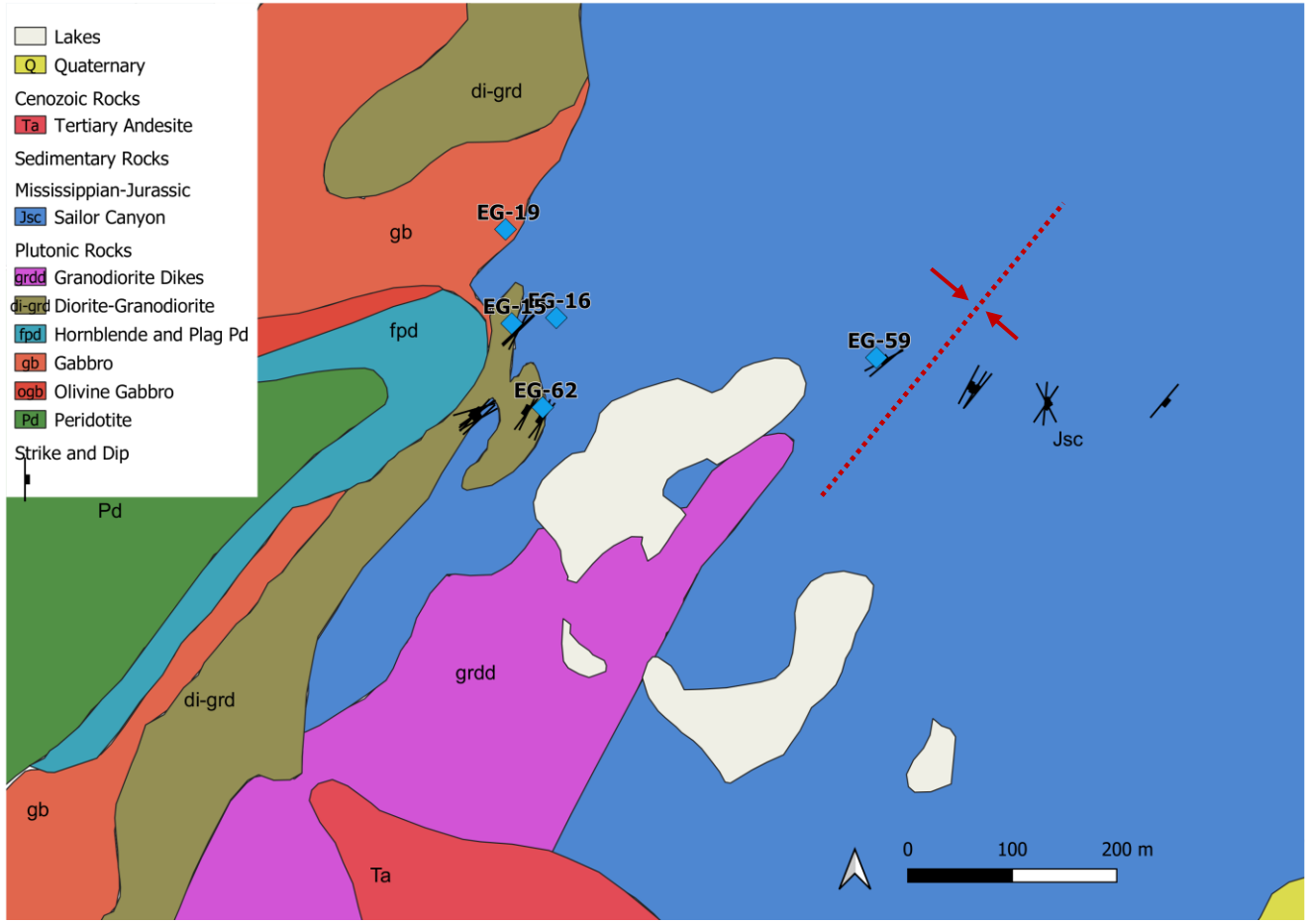
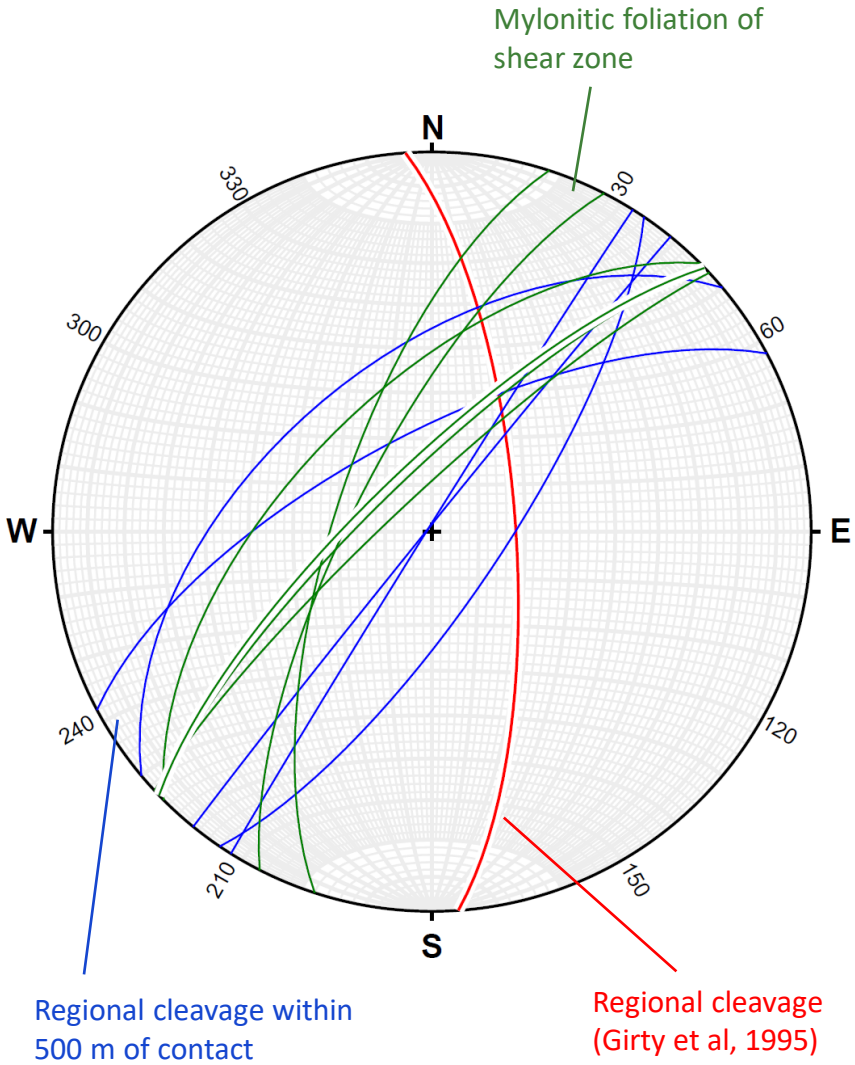
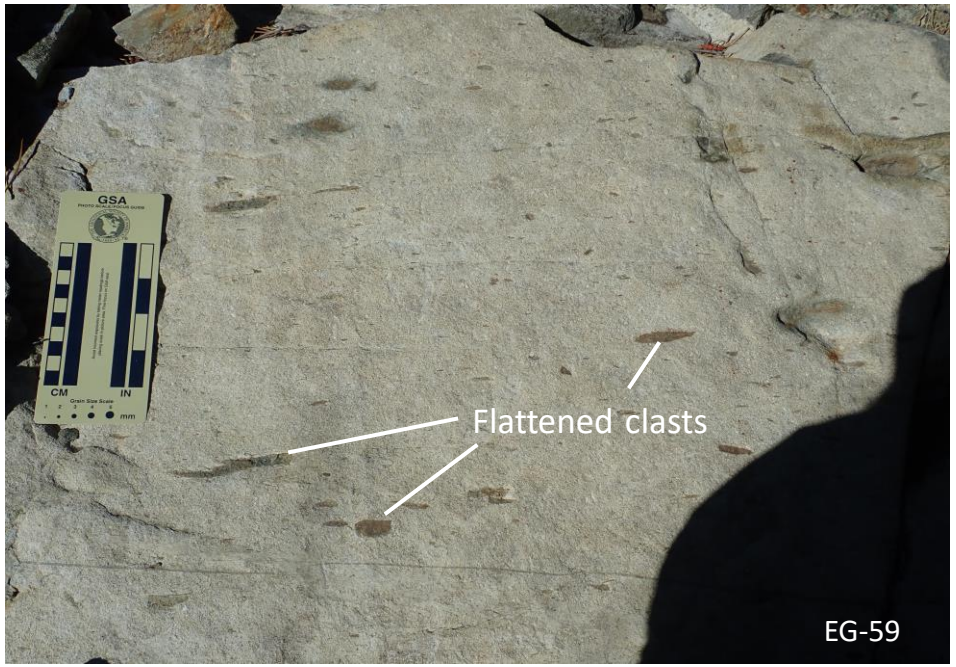
Lake Valley Reservoir
EG-P
EG-8
EG-10
EG-59
EG-54
EG-24
EG-45
0
1
2 km

Contact Aureole

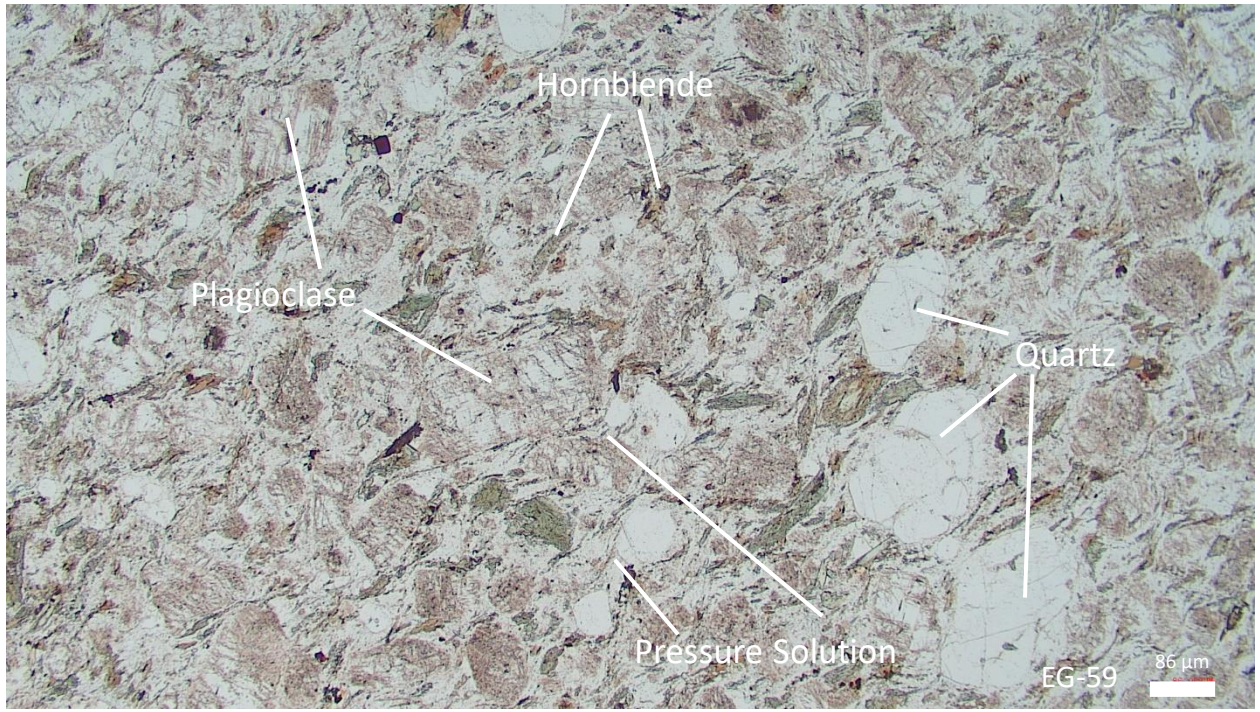


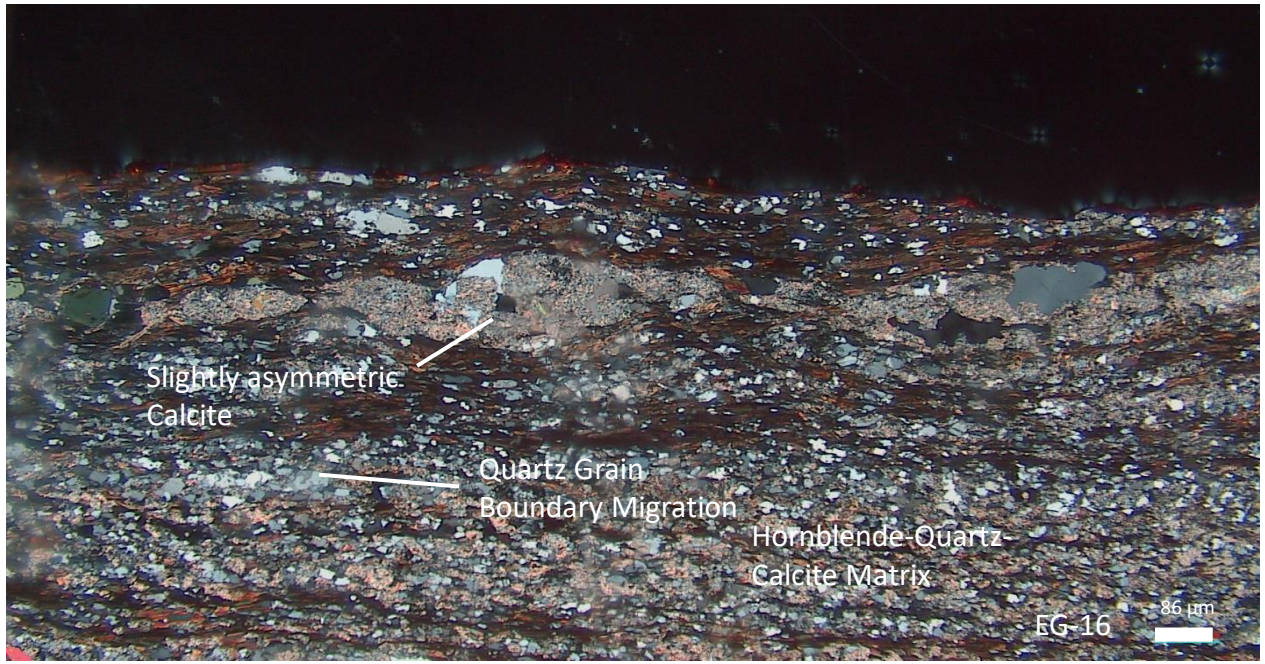




Country Rock away from Contact

- ~300 m from contact
- Slaty volcaniclastic sandstone
- Quartz and plagioclase phenocrysts with quartz and hornblende groundmass
- Shows pressure solution (<350 ^{o}C)
- Consistent with regional greenschist facies metamorphism (Girty et al., 1995)

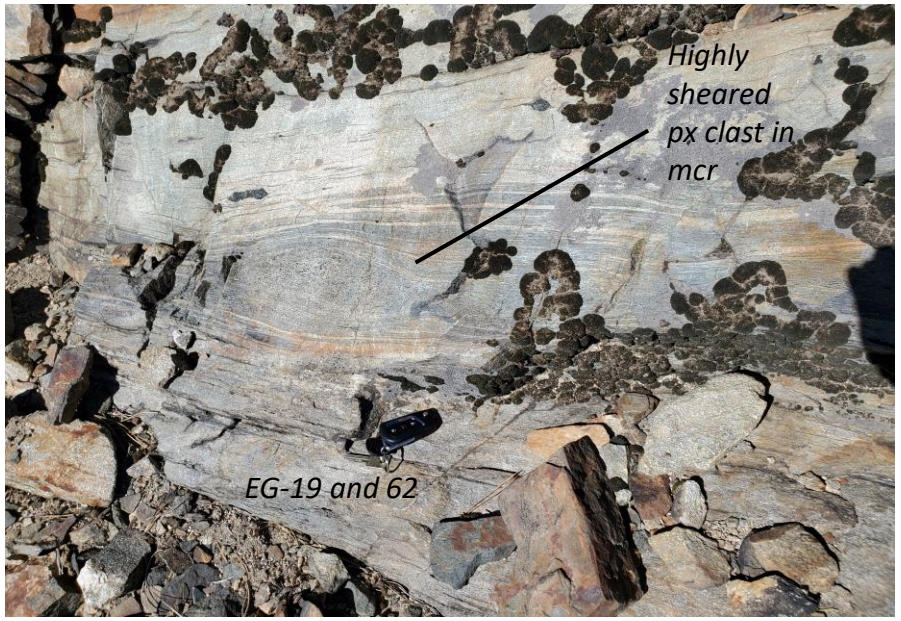


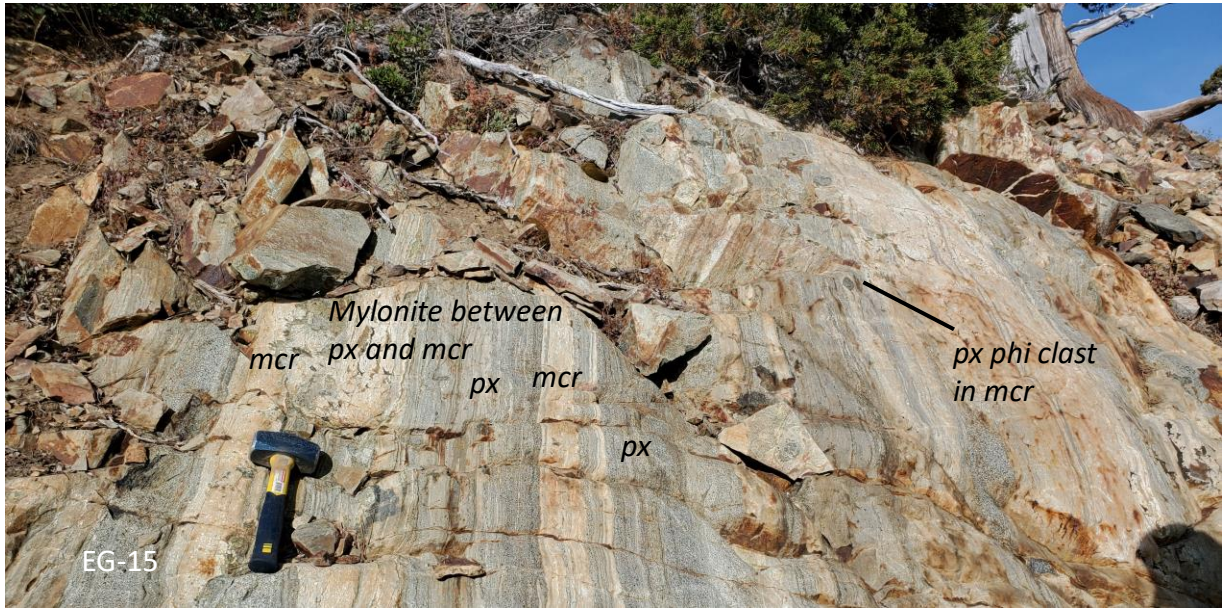


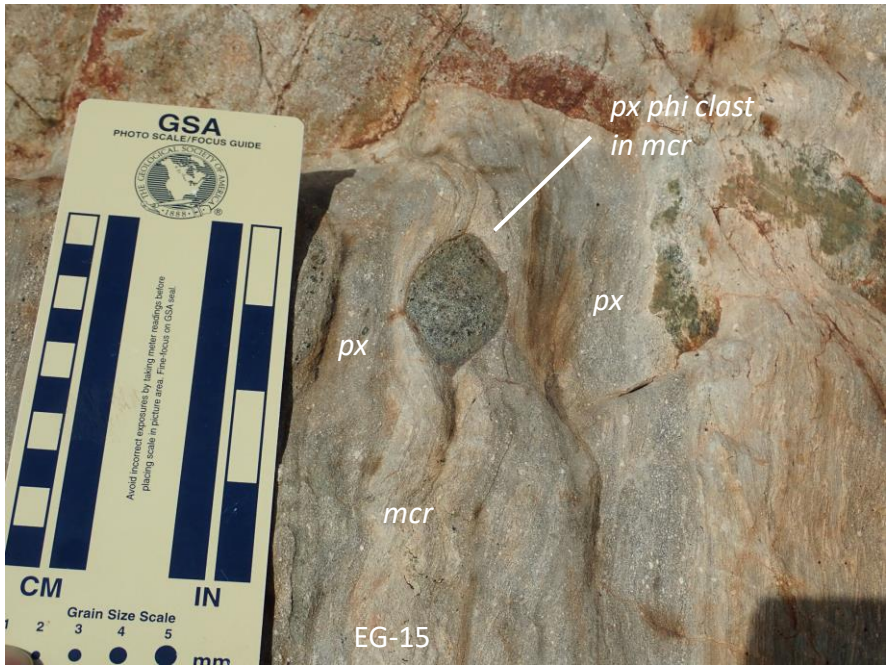
Country Rock near Contact

- ~10 m from contact
- Quartz and calcite porphyroclasts
- Phyllitic-schistose cleavage
- Shows quartz grain boundary migration (>500 ^{o}C)
- Mostly symmetrical porphyroclasts show primarily pure shear

Shear Zone at Contact

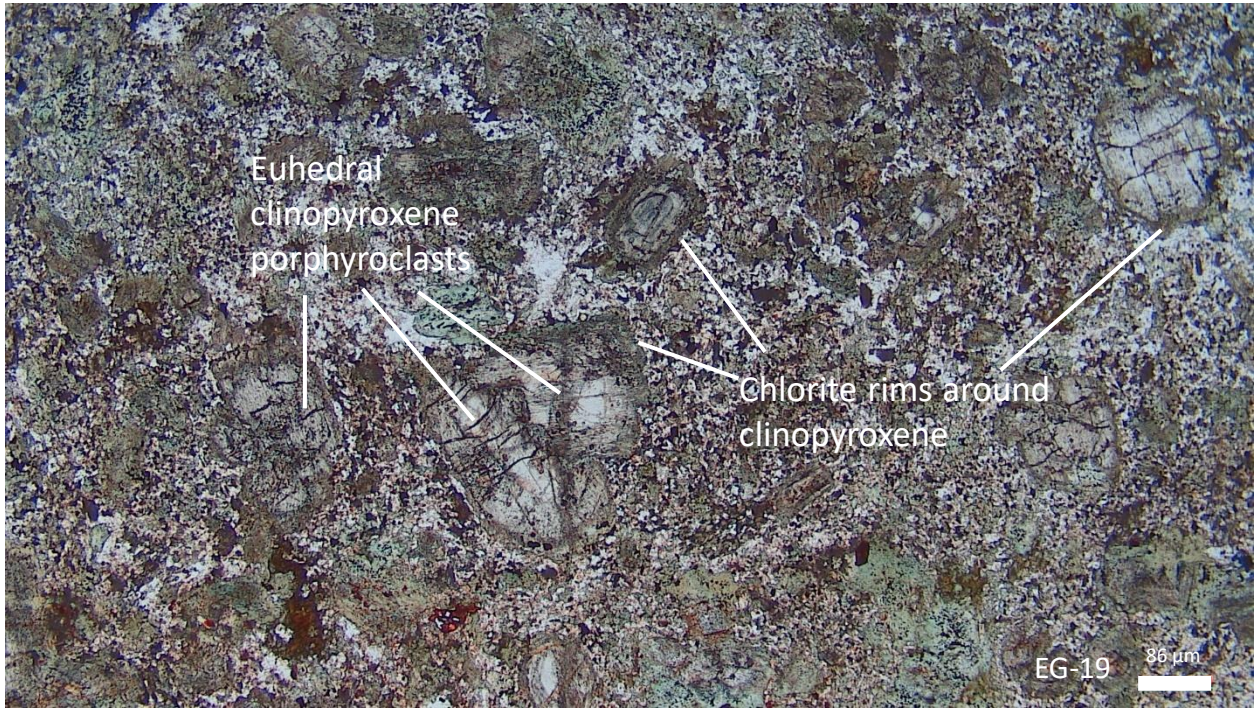


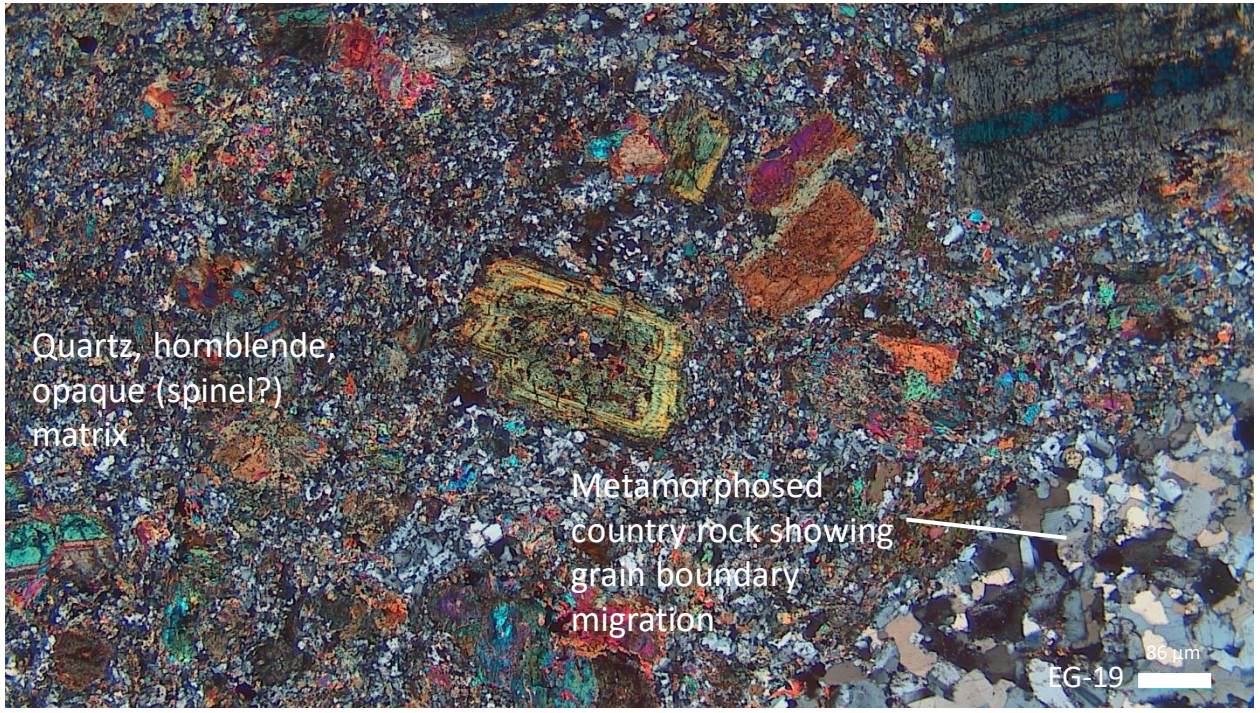




px- pyroxenite

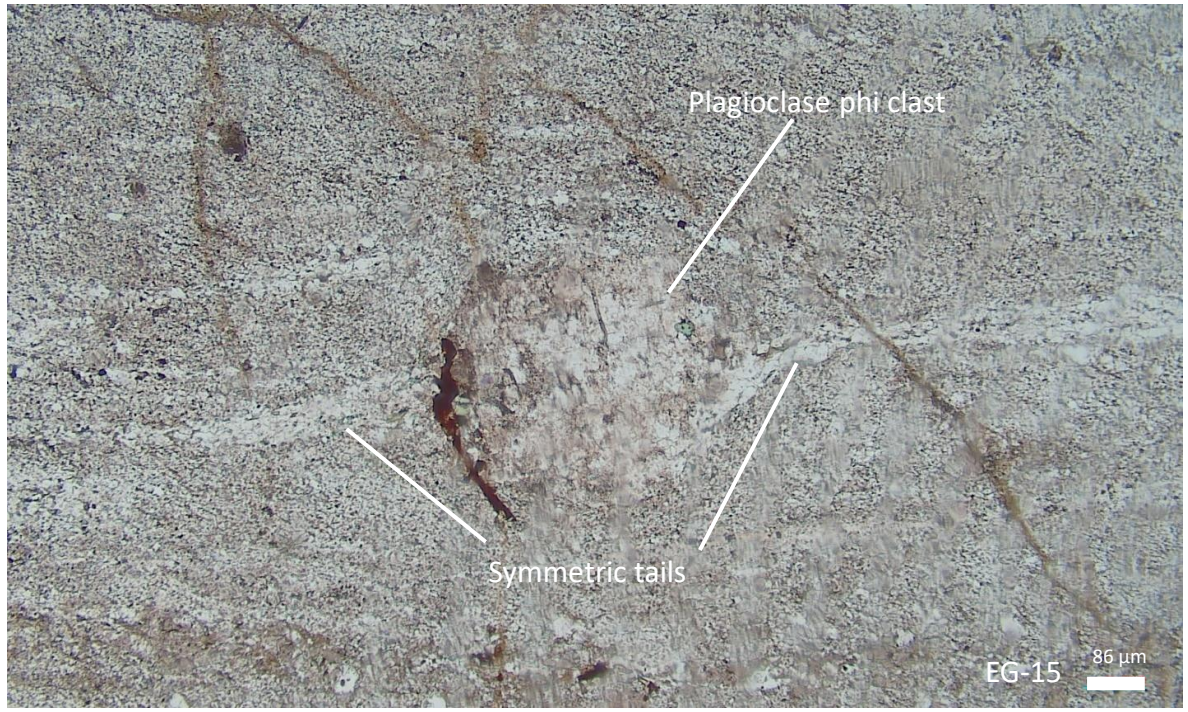
mcr- metamorphosed country rock

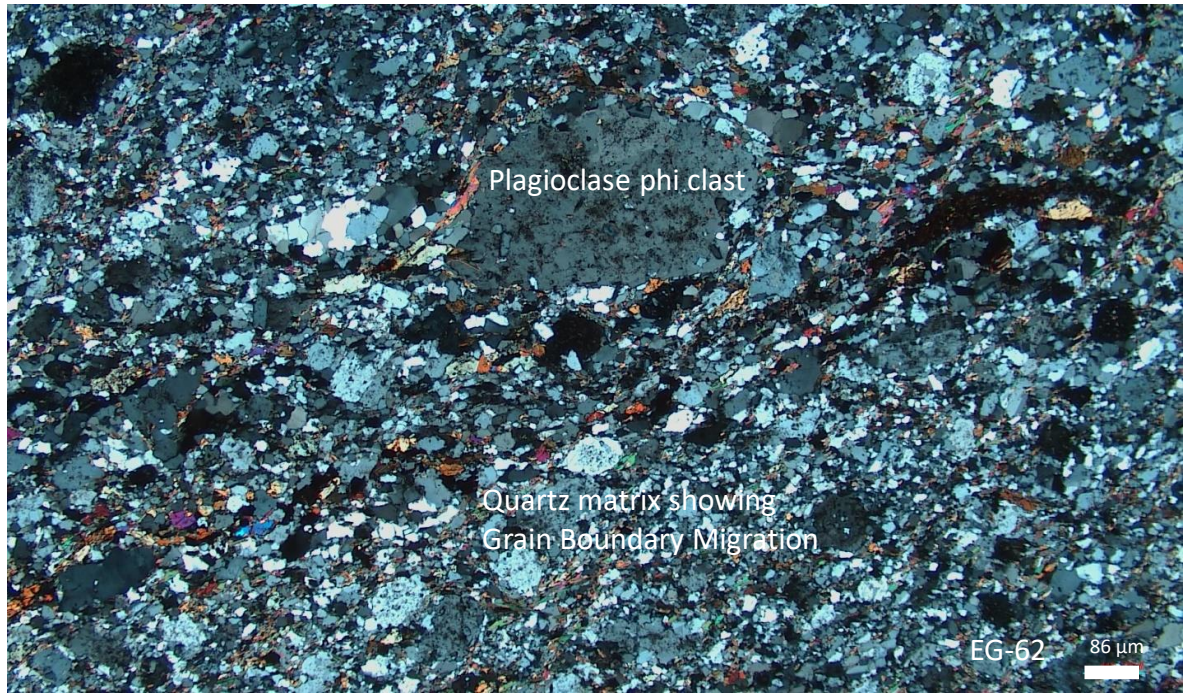




Pyroxenite

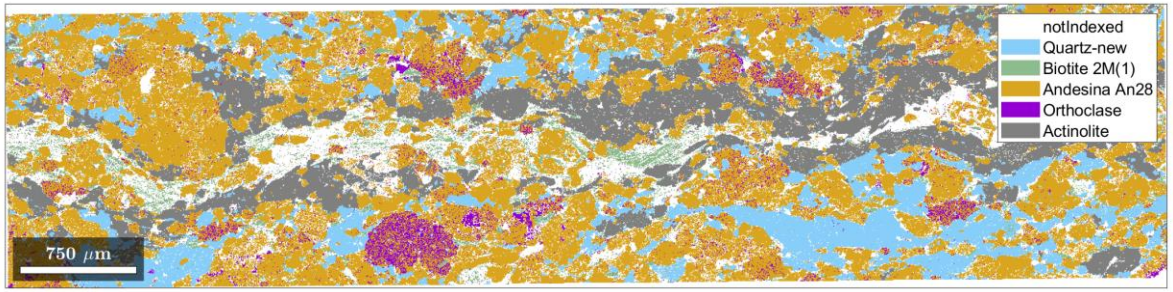
- Euhedral clinopyroxene phenocrysts with quartz, hornblende, and opaque (spinel?) matrix
- Clinopyroxenes often have a chlorite rim
- Felsic matrix likely represents incorporation of country rock

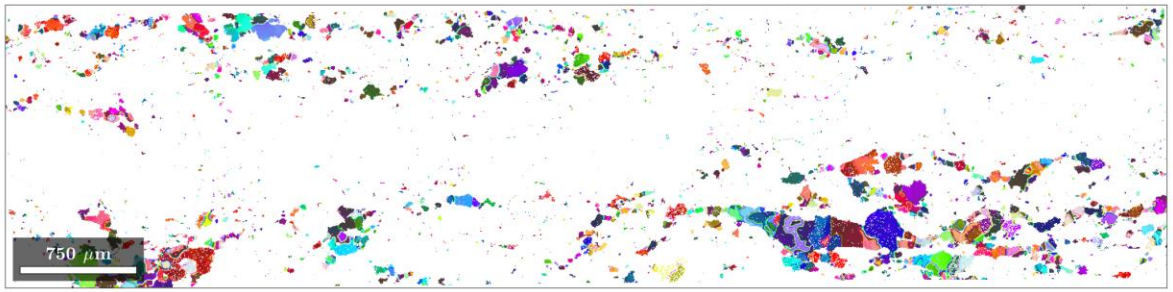


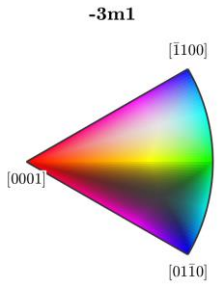


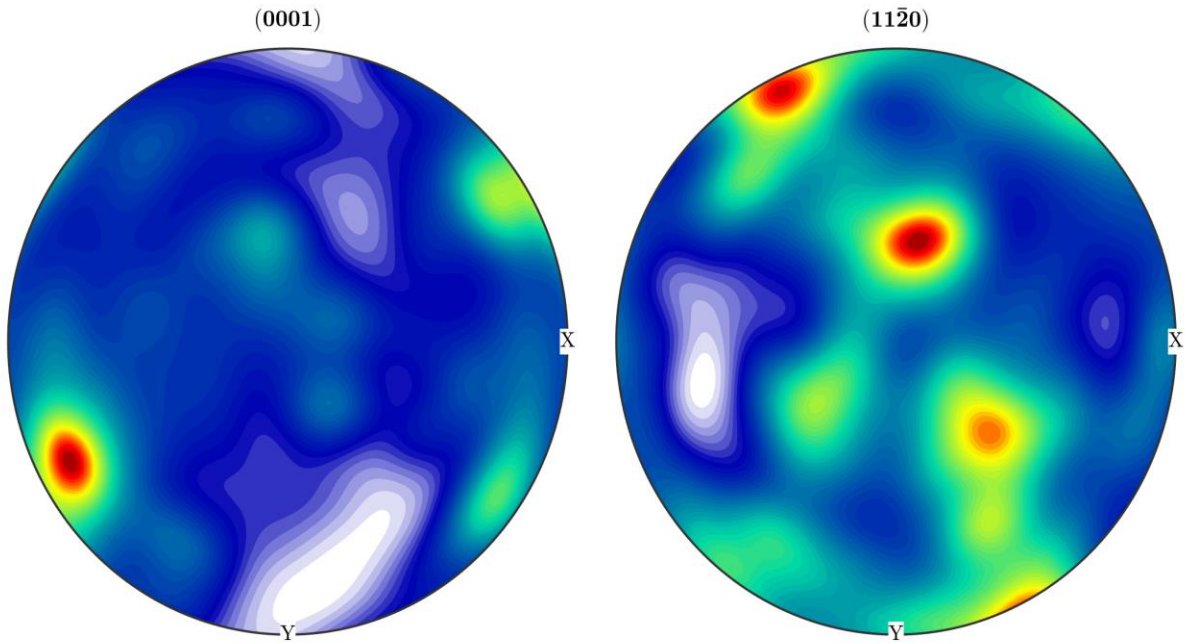
Metamorphosed Country Rock (MCR)

- Mylonitized country rock
- Plagioclase porphyroclasts with a quartz, hornblende, and plagioclase matrix
- Quartz shows grain boundary migration (>500 ^{o}C)
- Phi clasts common, suggesting pure shear









Electron Backscatter Diffraction (EBSD) of Metamorphosed Country Rock

- Quartz c-axis indicative of prism <c> slip (>700 ^{o}C)
- Asymmetry suggests left-lateral shear sense

Preliminary Conclusions

- Despite its unusual composition, major and trace element geochemistry shows the EGC likely formed in a subduction setting
- Preliminary P-T data and thin section observations indicate the EGC crystallized clinopyroxene and plagioclase throughout the middle and upper crust
- Field evidence and microstructures reveal a <300 m contact aureole with deformation and strain increasing towards the contact
- EBSD, field evidence, and microstructures show the shear zone deformed at >700 ^{o}C, which is consistent with P-T data showing upper crustal crystallization at >1000 ^{o}C, and that the EGC intruded primarily through pure shear with a component of to-to-the-left simple shear
- Field evidence and microstructures show that the EGC forcefully intruded into the upper crust, ductilely pushing country rock away >500 m
- P-T and structural data indicate the EGC likely formed somewhere between the transcrustal and tranlithospheric diapir models, not as a single mafic intrusion
- The EGC did not form as a closed system. It had a multistage evolution that included variable depths and temperatures of crystallization as well as mechanical and chemical interactions with country rock during its ascent and emplacement into the upper crust.

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