Igneous and Metamorphic Rocks from Patagonia, Argentina

By Brian Kaeter and Darin Wilwand

NDSU Petrology

Geol 422 May 6, 2014

Introduction

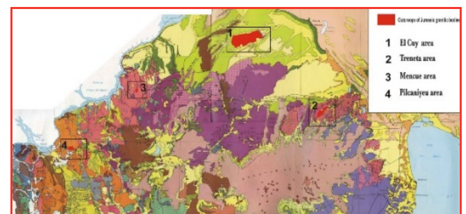
- Geography of northern Patagonia
- Guiding question
- Tectonic setting
- Granites
- Shear Zones
- Mylonites
- Geologic relationship and background
- Conclusion

Geography

Argentina, SA

Patagonia, Argentina

El Cuy Region



Rio Negro Province, Patagonia

Guiding Question

- How does composition of the granites and the pattern in the micro-structures of the mylonites relate to the formation of northern Patagonia?

Determining Tectonic Setting from Granitoids

- Trace elements have long been used to determined tectonic settings of basalts
  - Volcanic Arc
  - Within Plate
  - Ocean Ridge
- Many times the only exposed products of a magmatic/ tectonic event are plutonic rocks, particularly granite
  - This is the case in the El Cuy region
- Two main reasons granites have received less attention than basalts as tectonic indicators:
  - Difficulty of sampling granites of known setting
  - Granites have a more complicated petrogenetic history than basalts

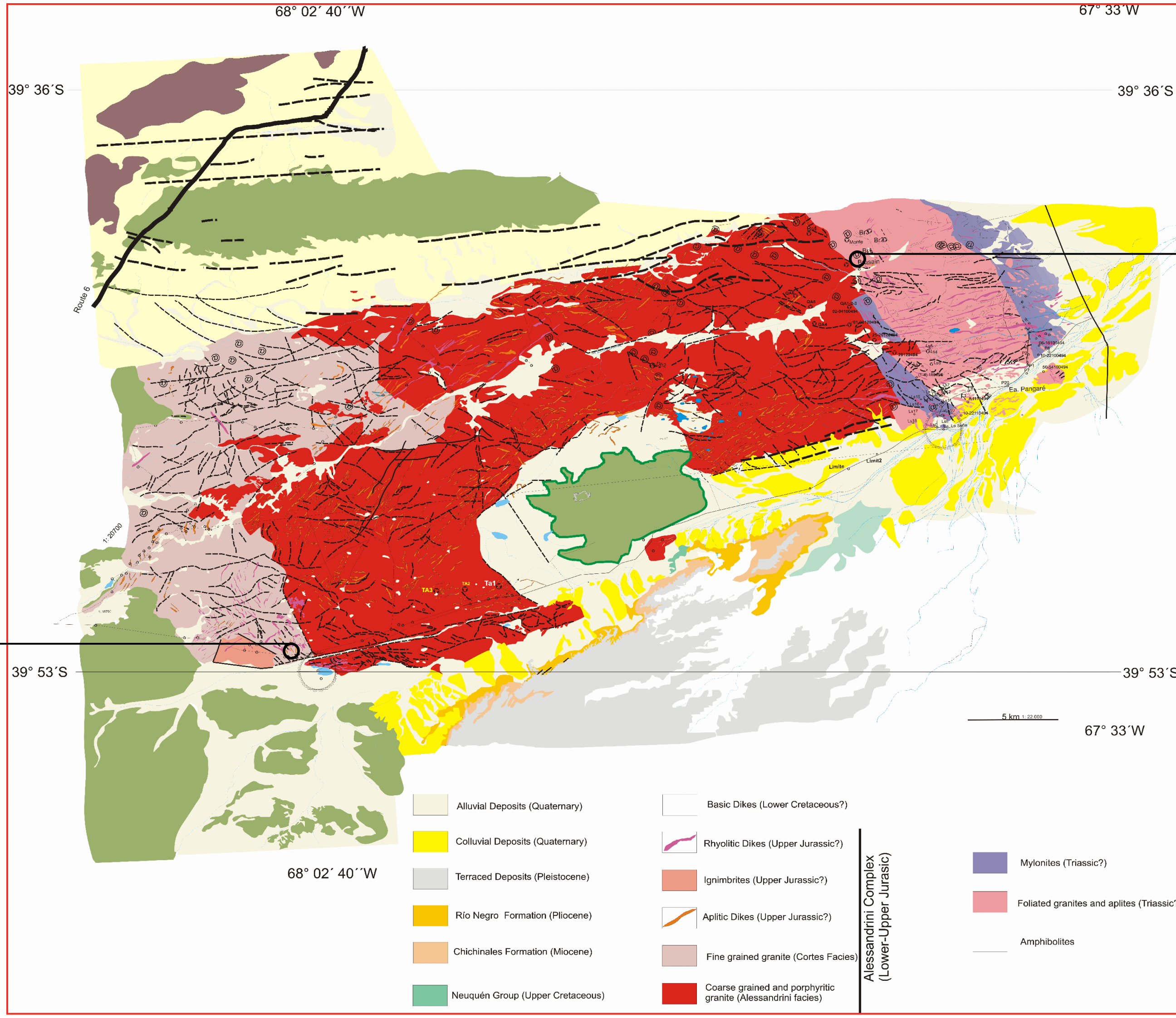
Determining Tectonic Setting from Granitoids (Continued)

- Julian Pearce published a groundbreaking paper in 1984 describing empirical trace element relationships in granites to tectonic settings
  - Used an enormous data set from sites from all over the world representing all tectonic settings
  - Many papers since than have more or less confirmed his ideas and expanded upon his ideas
- Tectonic settings can now be estimated using Y (Yttrium) and Nb (Niobium) concentrations in granites in the same way that they were estimated in basalts

Experimental Methods

- Dr. Eidukat performed 20 XRF trials
  - Granites mylonites, and aplitic dikes
- Brian performed 4 XRF trials (3 samples that haven't been tested)
  - 1 was practice to learn how to make pellet, but was a mylonite
    - Not applicable but matches Dr. Eidukat's data
  - 1 was mistakenly read as a course grain granite when it was actually an aplitic dike
    - Not applicable
    - Due to conversion issues maps are a little off and hard to read
  - 1 fine grain granite
  - 1 foliated granite
- When these results are combined they represent trace elements of all El Cuy granite types

Kaeter Granite Samples



BR-1-BJK

COR-14-BJK

Kaeter Granite Sample

COR-14-BJK
Fine Grained Granite

XRF Data

Formula	COR-14-BJK
SiO_2	76.84%
Al_2O_3	13.71%
Fe_2O_3	0.61%
CaO	0.65%
MgO	0.27%
MnO	0.03%
Na_2O	3.46%
K_2O	4.28%
P_2O_5	0.00%
TiO_2	0.07%

Sample	Y PPM	Nb PPM
COR-14-BJK	25.0	15.0

Kaeter Granite Sample

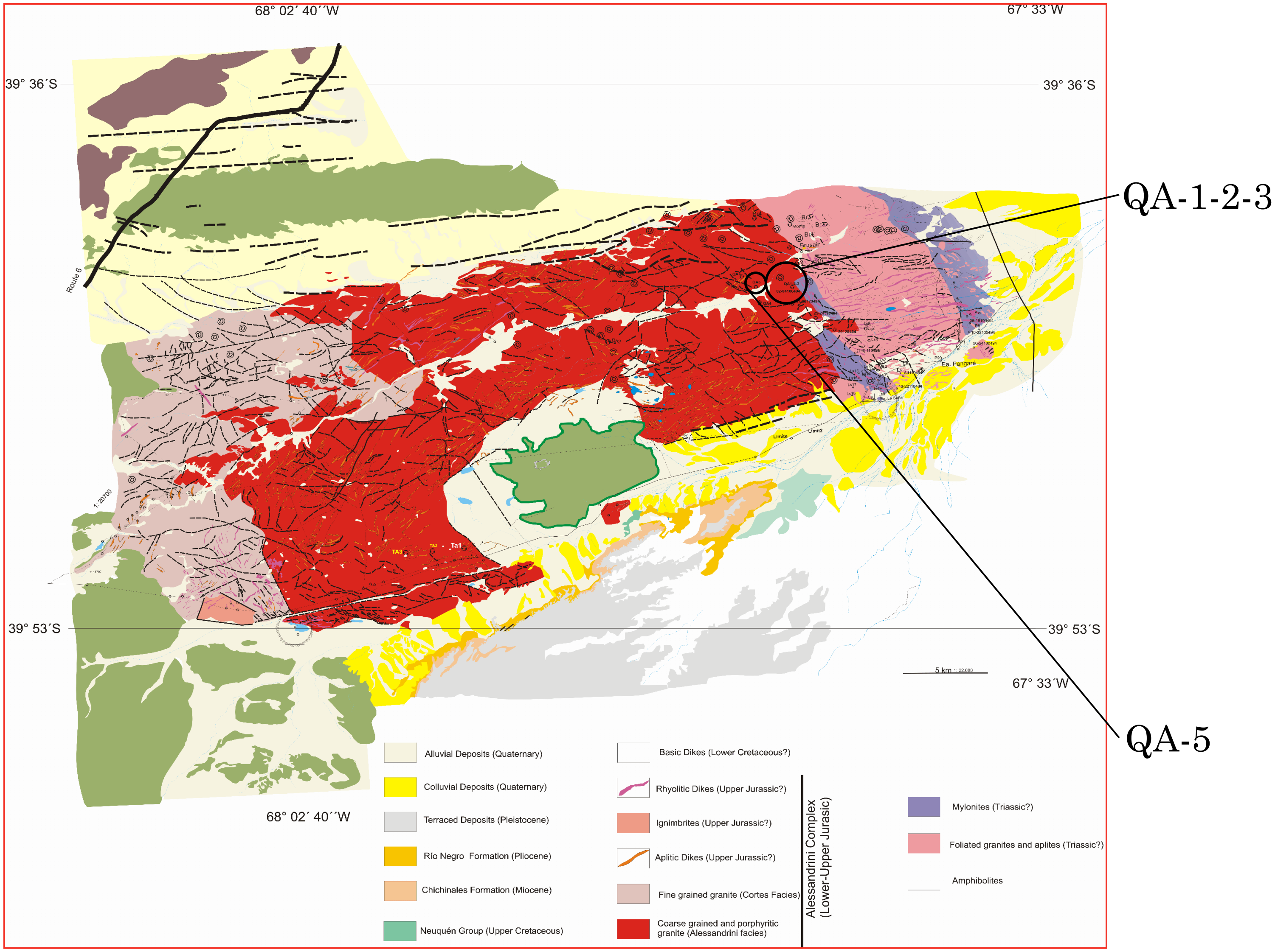
BR-1-BJK
Foliated Granite

XRF Data

Formula	BR1-BJK
SiO_2	69.59%
Al_2O_3	15.62%
Fe_2O_3	1.69%
CaO	1.94%
MgO	0.83%
MnO	0.05%
Na_2O	3.44%
K_2O	6.31%
P_2O_5	0.06%
TiO_2	0.24%

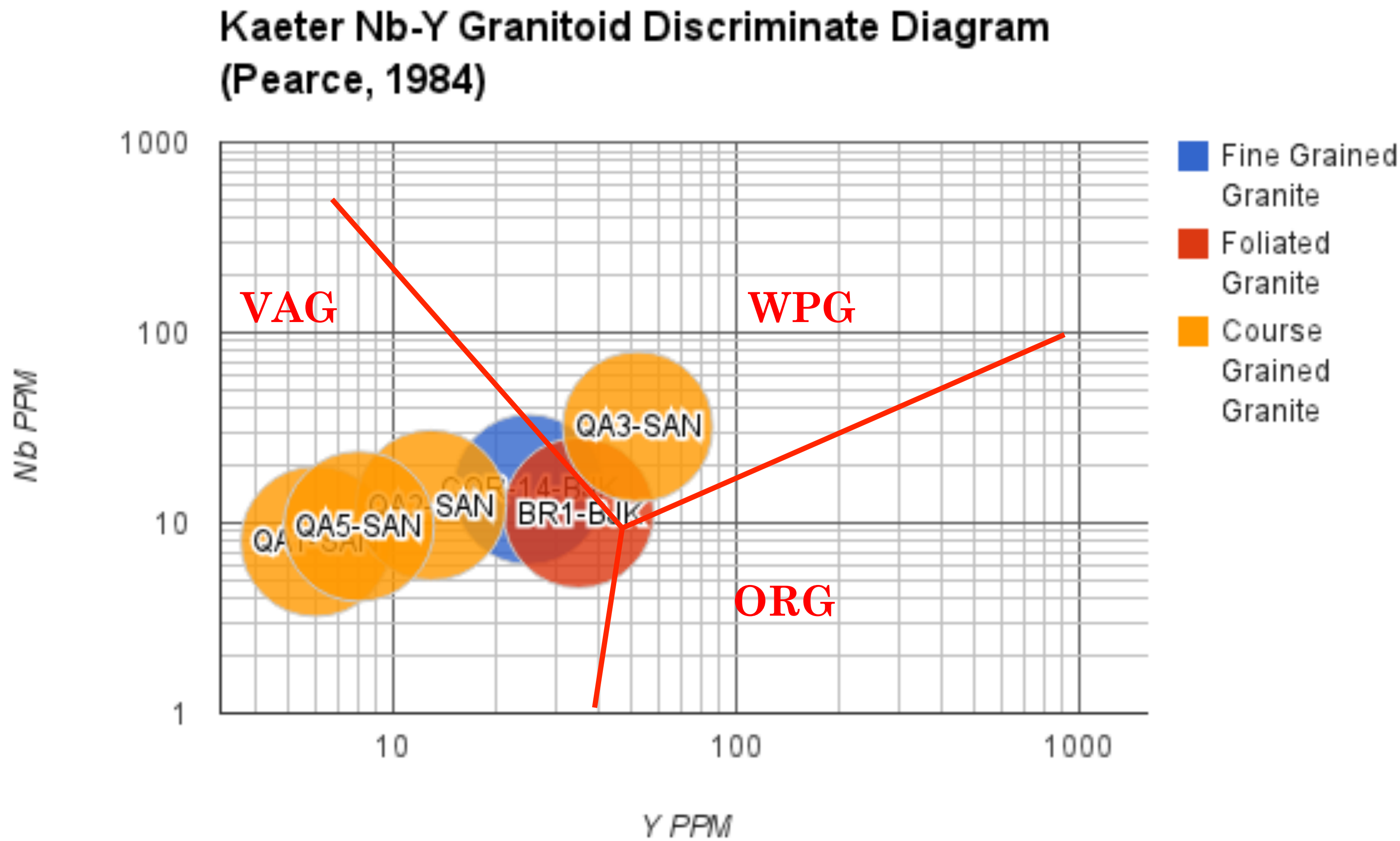
Sample	Y PPM	Nb PPM
BR1-BJK	35.0	11.3

Eidukat Samples (Course Grained Granite)



Kaeter and Saini-Eidukat Y and Nb Concentrations

Sample	Y PPM	Nb PPM	Granite Type
COR-14-BJK	25.0	15.0	Fine Grained Granite
BR1-BJK	35.0	11.3	Foliated Granite
QA1-SAN	6	8.0	Course Grained Granite
QA2-SAN	13	12.4	Course Grained Granite
QA3-SAN	52	32.0	Course Grained Granite
QA5-SAN	8	9.6	Course Grained Granite



Almost all samples plot as Volcanic Arc Granites!

Shear Zones

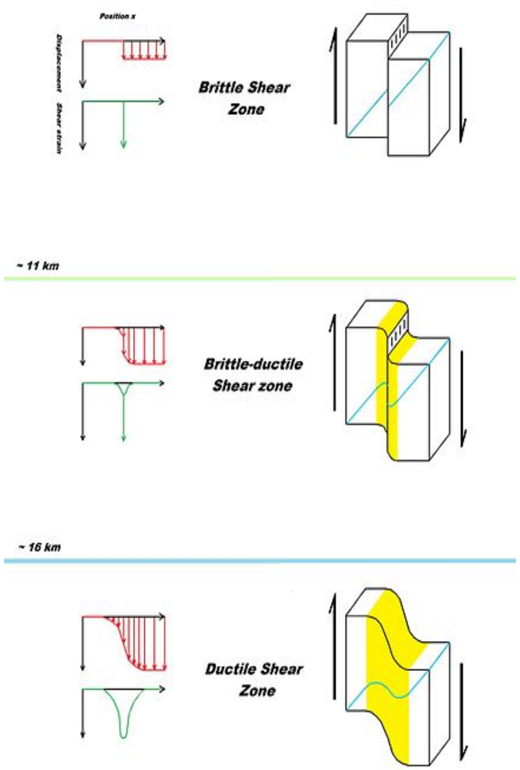
- A high-strain zone with lateral displacement of wall rock segments with respect to each other

2 Types of shear zones

- **Brittle fault**- lower temperature and pressure, fragments break in an angular fashion
  - This is typically known as a fault
- **Ductile zone**- higher temperature and pressure, deformation occurs without the breaking of fragments but as bending and flowing

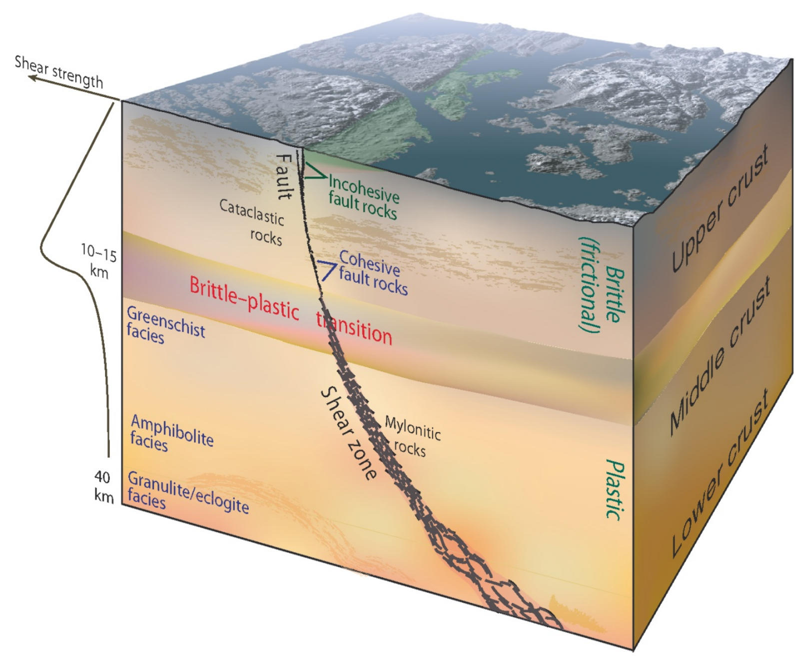
Surrounding rock is generally unaffected by shear zones.

Shear Zones (Continued)



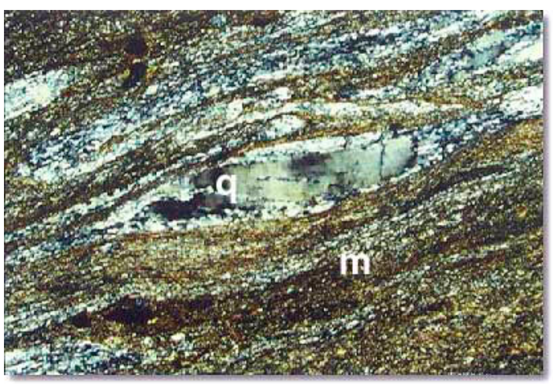
Depiction of the transition from brittle frictional breaking to ductile deformation.

Diagram showing the brittle-plastic transition zone where ductile deformation begins with increased metamorphic conditions.



Mylonites

- Exclusively a structural term, no indication of mineralogy or composition
- Form in high-strain ductile shear zones
- Foliated and usually lineated rock that show a strong sense of deformation
- Small grain size compared to surrounding rock
- Presence of porphyroclasts, remnants of resistant mineral grains, are an indication of a mylonite



A porphyroclast of quartz surrounded by matrix

Classification of Mylonites

Mylonites are classified according to the metamorphic grade at which deformation took place or according to the lithotype or mineralogy in which they are developed.

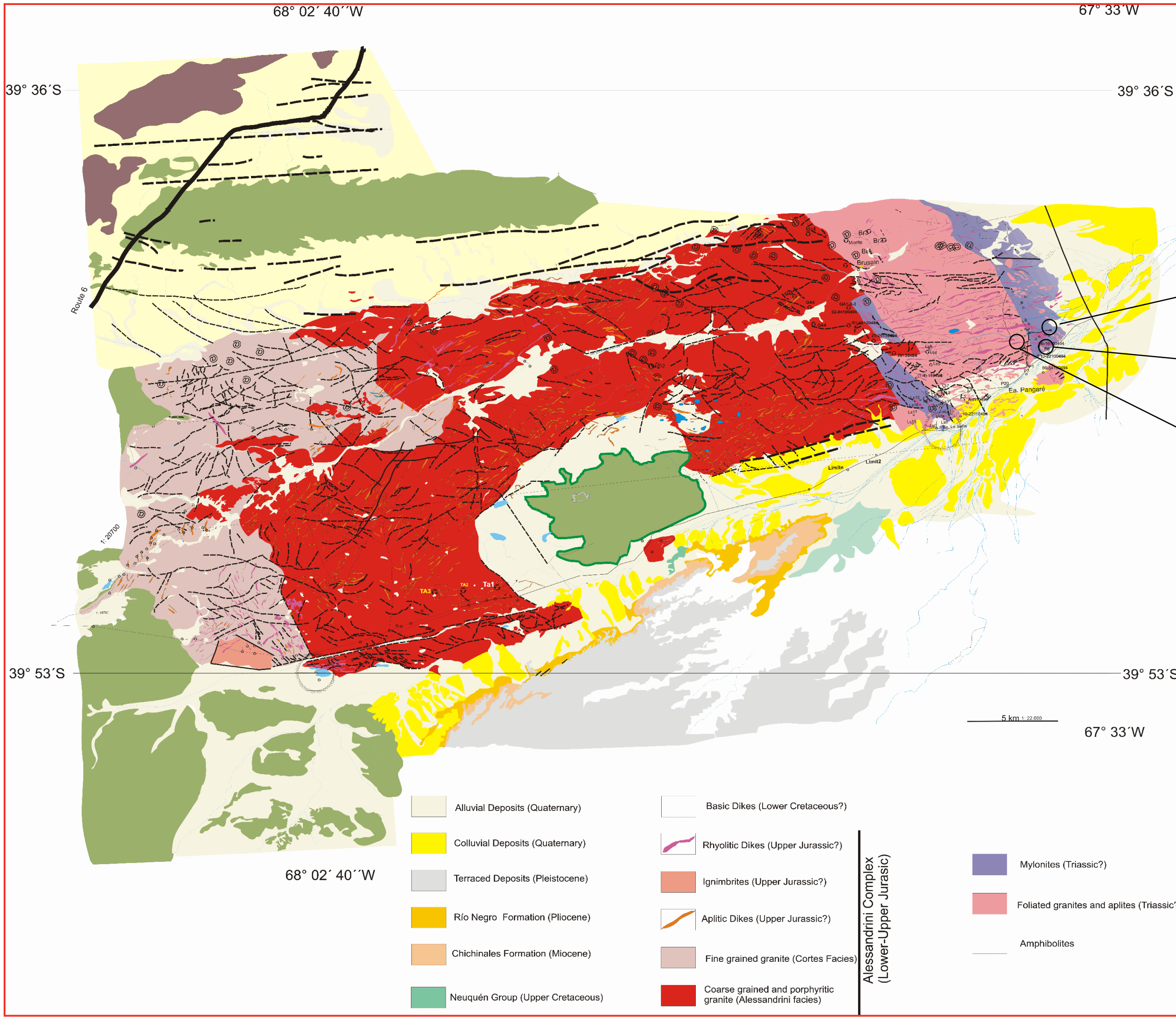
- Protomylonites- rocks composed of 10-50% matrix
- Mylonites- rocks composed of 50-90% matrix
- Ultramylonites- rocks composed of greater then 90% matrix

* The higher matrix composition indicates a higher degree of metamorphism

El Cuy, Patagonia

West

East

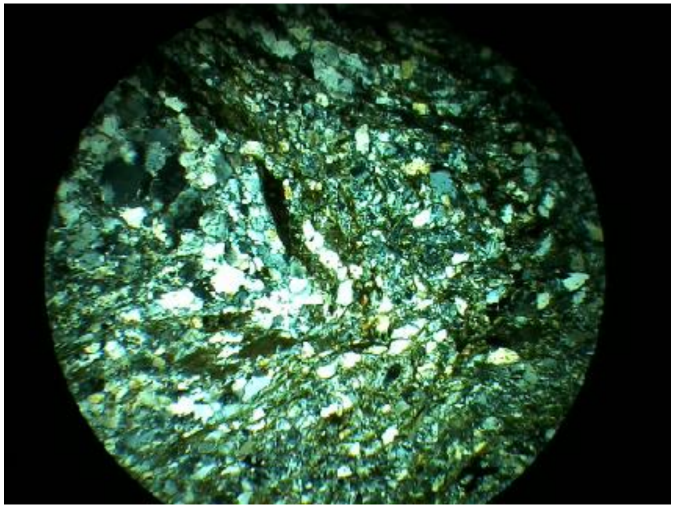


P-5

P-6

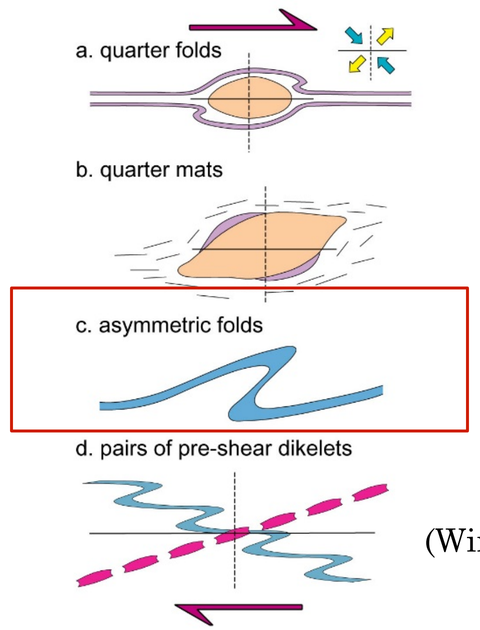
P-18

Sample P-5



Objective: 10x
FOV: 2 mm

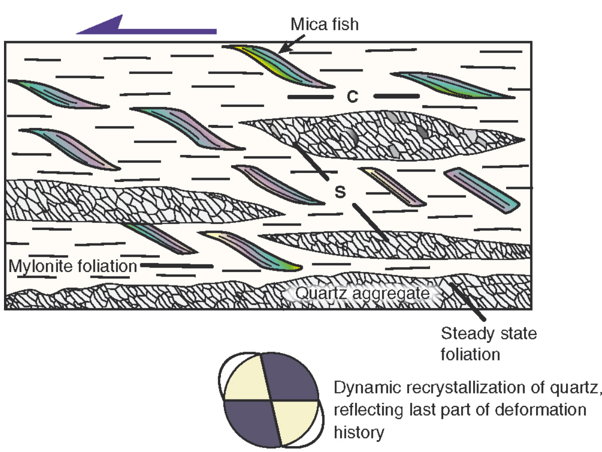
- Protomylonite (10- 50% matrix)
- Strong asymmetrical folding indicating sinistral (left-lateral) shear direction.



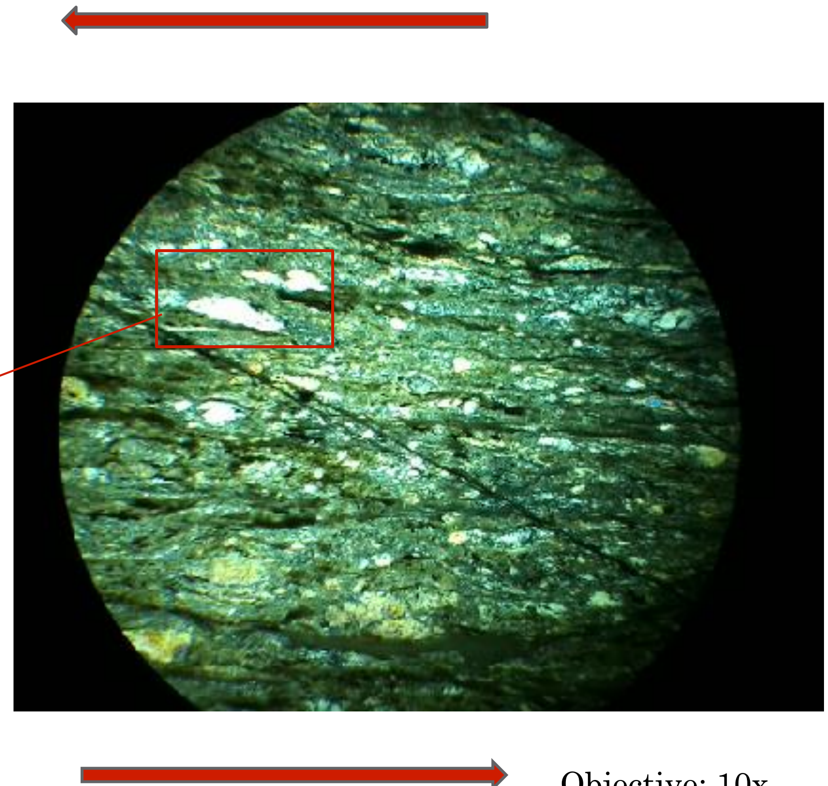
(Winter, 2010)

Sample P-5A

- Ultramylonite (greater then 90% matrix)
- Presence of mica fish indicate sinistral movement

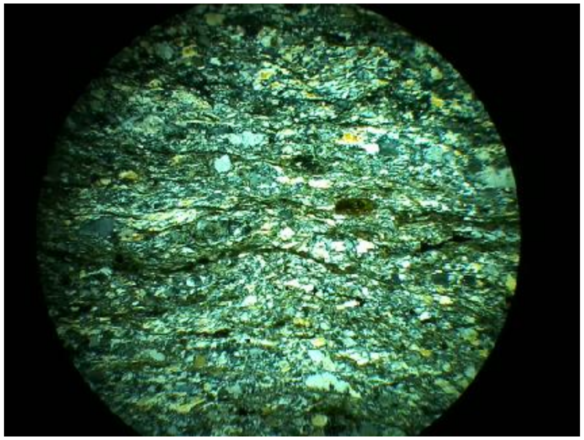


Mica fish



Objective: 10x
FOV: 2mm

Sample P-6



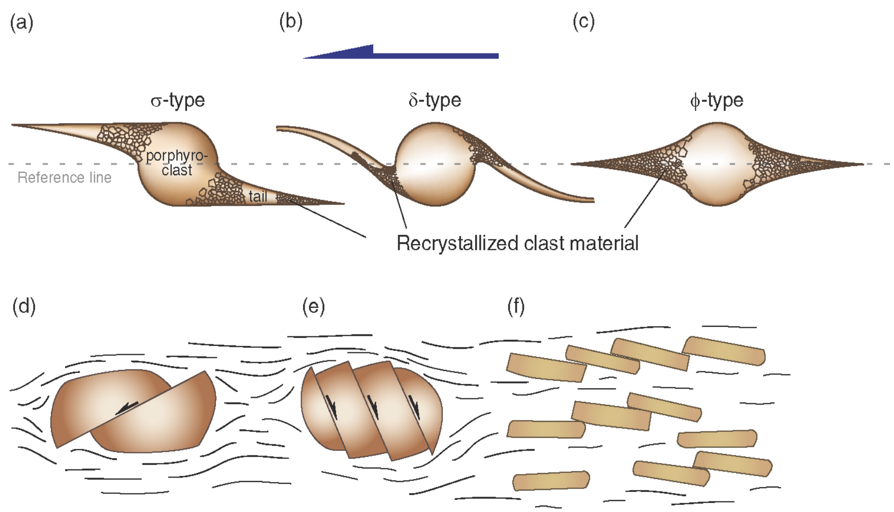
Objective: 10x
FOV: 2mm

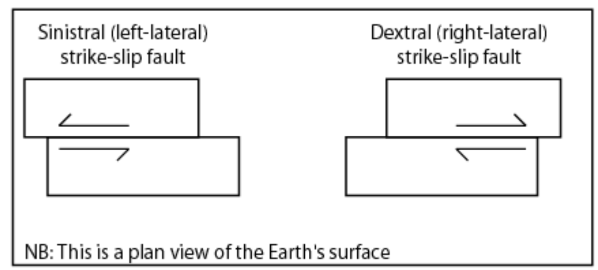
- Mylonite (50-90% matrix)
- Strong foliated texture
- Direction is not indicated

Porphyroclastic Augen

- Porphyroclasts can be used to determine whether a rock exhibits sinistral or dextral shear movement

- By looking at the recrystallized tails on the sides of the augen (eye) porphyroclasts, σ (sigma), δ (delta), or ϕ (phi) type deformation can be inferred



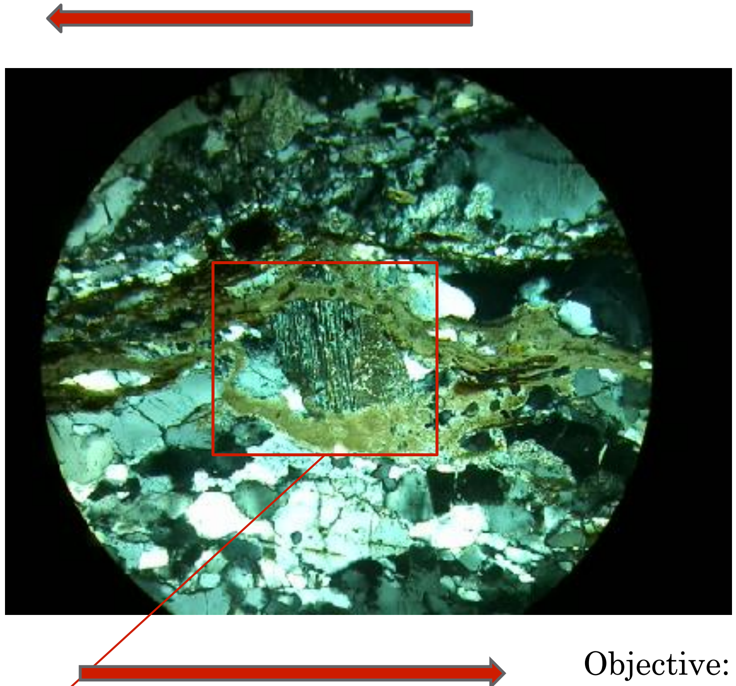


Sinistral vs. Dextral shear movement.

(Winter, 2010)

Sample P-18

- Granitic Augen-Mylonite
- Shear direction is indicated by the porphyroclast in center.
- Tails show σ (sigma) and δ (delta) shear movement.
- Indicates sinistral movement



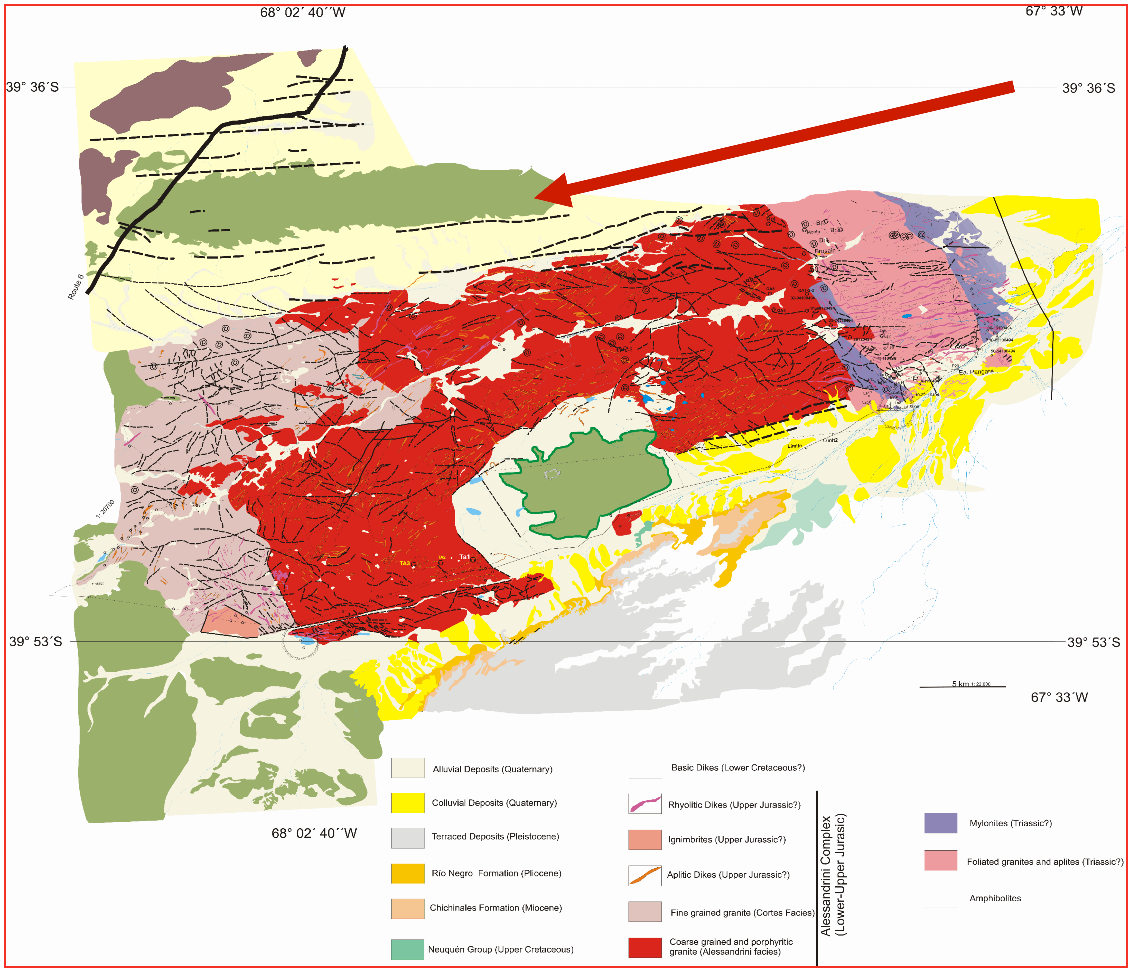
Objective: 10x
FOV: 2mm

Augen (eye)

Mylonite Summary

- Presence of mica fish, augen, and asymmetrical folding are an indication of sinistral (left-lateral) shear movement
- Generally, the deformation in the mylonite samples increases as they move west
- These micro features can be used to determine the nature of the formation of the landscape on a macro scale

- Geologic event causing compression coming from the east



Competing Hypotheses

Autochthony

- Patagonia is a native landmass that underwent intraplate deformation generated block movement
  - Resulted in the formation of mylonites due to regional shearing

*Supported by tectonic granite trace element discrimination through XRF

Allochthony

- Patagonia is a foreign landmass that collided with continental Gondwana

Conclusion

- Results of XRF conclude that the El Cuy granite are Volcanic Arc in origin
- Mylonites are foliated rocks formed in ductile shear zones under metamorphic conditions
- The mylonite thin sections suggest a sinistral (left-lateral) shear stress direction
- The presence of both the mylonites and Volcanic Arc granites support the autochthony hypothesis

References

Benedini, L., Gregori, D., Martinez, J., Saini-Eidukat, B., Kostadinoff, J., Alvarez, G., Block transcurrence and granite emplacement model during the Gondwanide orogeny in northern Patagonia, Argentina: (Unpublished)

Gregori, D.A., Saini-Eidukat, B., Migueles, N. and Strazzere, L., The Pangare and La Sena mylonitic belts: evidence of transcurrence in the north Patagonian Massif, Argentina and constraints to the Patagonia allochthony: (Unpublished)

Passchier, C.W. and Trouw, R.A.J., 1996, Microtectonics: New York, Springer-Verlag Berlin Heidelberg.

Pearce, J. A., 1984. Trace Element Discrimination Diagrams for the Tectonic Interpretation of Granitic Rocks. Department of Earth Sciences, The Open University, Milton Keynes, KM76AA, Bucks, England.

Winter, J.D., Principles of igneous and metamorphic petrology (second edition): Upper Saddle River, Pearson Education, Inc.

The End