Structural and Geochemical Analysis of Fluid Compartmentalization in Normal Fault Zones of Central Italy

Jordan W. Wang and Juliet G. Crider // *ESS Department, University of Washington*

Introduction

Fluid-rock interactions and fluid migration in fault zones are dynamic processes influenced by fault zone architecture and seismogenesis.

Fault Zone Hydrogeology

Fault zones can be divided into two structural regions based on material properties and permeability structures:

- **Fault Core (FC)**: pulverized inner region
- **Damage Zone (DZ)**: fractured outer region

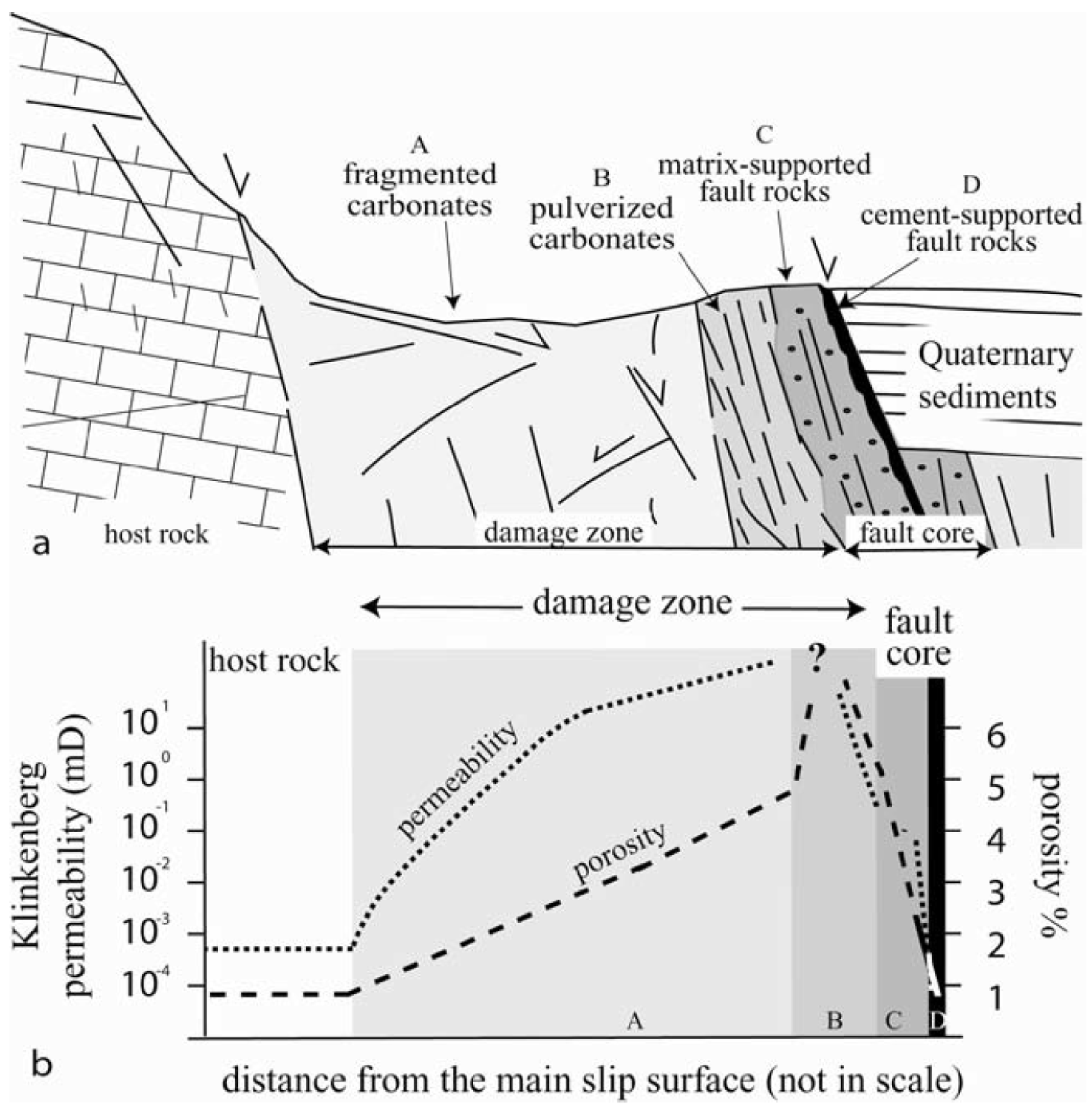
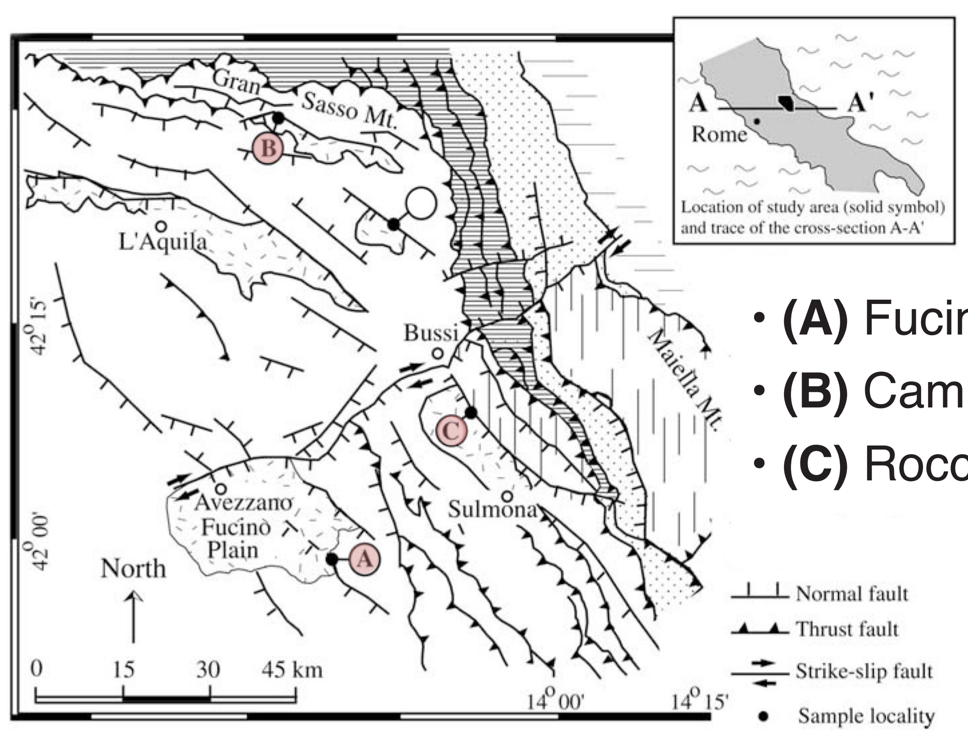


Figure 1. Fault zone permeability structure

Together, the FC and the DZ are said to form a "combined conduit-barrier system" which may separate and channel fluids in fault zones. To test this idea, we examine carbonate fault precipitates from three normal fault zones predicted to contain two unique fluids separated between the FC and DZ.

Geologic Setting



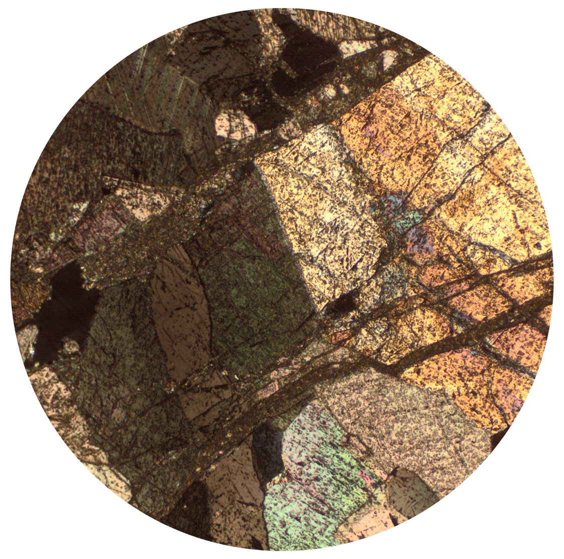
- **(A)** Fucino
- **(B)** Campo Imperatore
- **(C)** Roccacasale

Figure 2. Map of faults in the Abruzzo region of central Italy

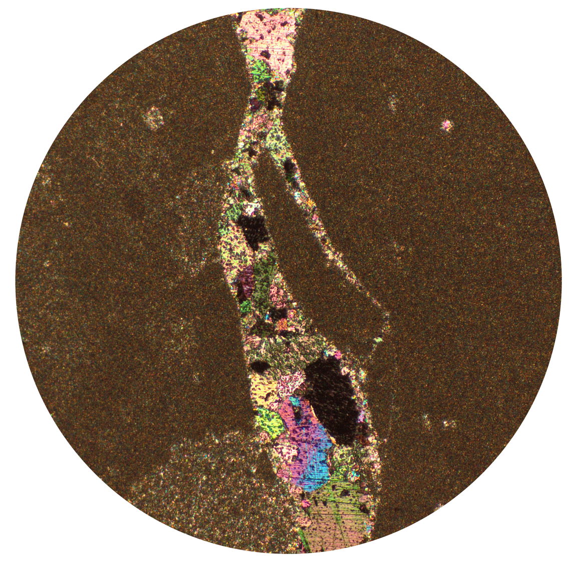
Methods

Carbonate precipitates record the history of fluids in fault zones. By measuring the $\delta^{13}C$ and $\delta^{18}O$ stable isotope and $\Delta 47$ clumped isotope compositions of carbonate precipitates within their structural context, we can learn about fluids in fault zones without directly observing them.

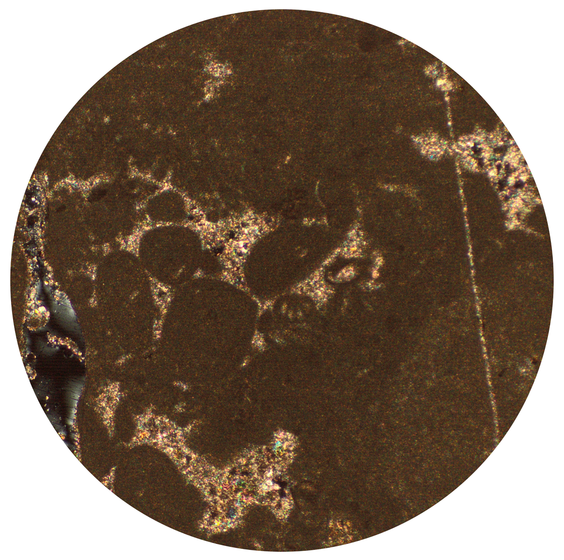
Carbonate Fault Rock Petrography



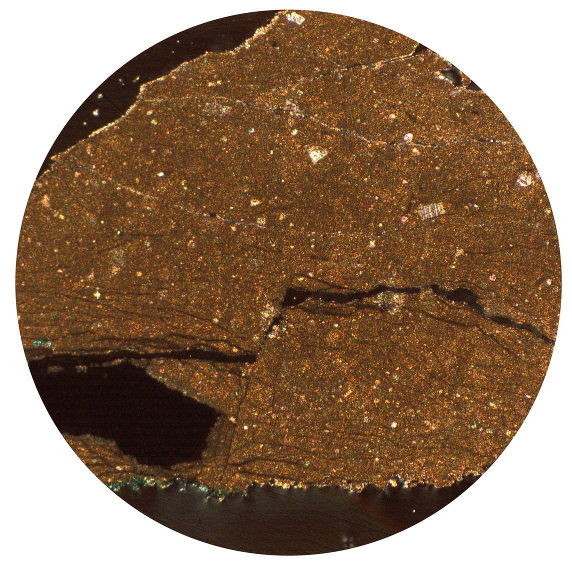
Large **homogeneous** equant spar calcite veins, ~ 2 cm. Most of these larger spar crystals are crosscut by smaller 30µm fractures near the vein-host rock boundaries.



Small **homogeneous** equant spar calcite veins, ~ 50 - 450 µm. Primary small prismatic fringes separate the secondary equant spar from micritic host rock and micritic breccia survivor clasts.



Heterogeneous mixed drusy/peloidal cements in intrasparites, oosparites, biosparites, and fault breccias. These materials are dominated by clotted calcite spar.



Heterogeneous carbonate cataclasites and ultracataclasites, characterized by intermixed quasi-fractal matrix and carbonate survivor clasts. Within any given FC hand sample, there are often several unique cataclasites.

Figure 3. Photomicrographs of four key carbonate materials found in our fault rocks. All images ~ 2mm in diameter.

Stable Isotopes: Fluid Tracers and Thermometers

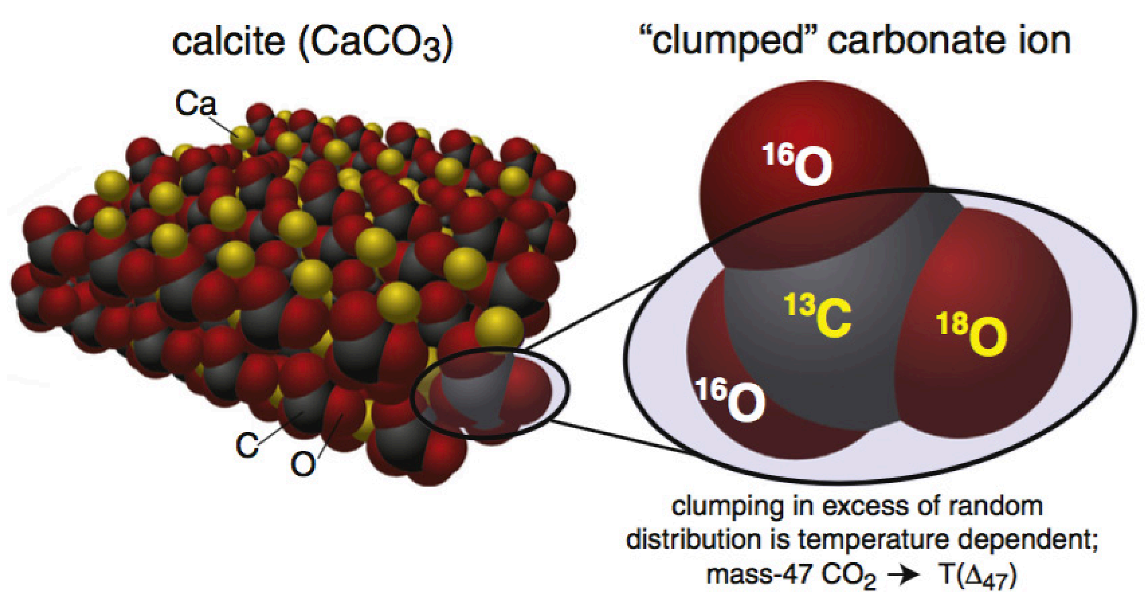


Figure 4. Mass-47 CO_2 clumped isotope diagram showing heavy carbon and oxygen makeup.

- **$\delta^{13}C$ Isotopes** trace the origin of fluids and their environmental conditions during precipitation
- **$\delta^{18}O$ Isotopes** also trace the origin of fluids and their environmental conditions during precipitation
- **$\Delta 47$ Clumped Isotopes** measure fluid temperatures during precipitation. Using this thermometer and $\delta^{18}O$ values, we can calculate exact isotopic compositions of the original fluids.

Results and Interpretations

To contextualize the isotopic compositions we measure, we consider the fluid-rock interactions that occur within these fault zones.

Fluid Composition Variability

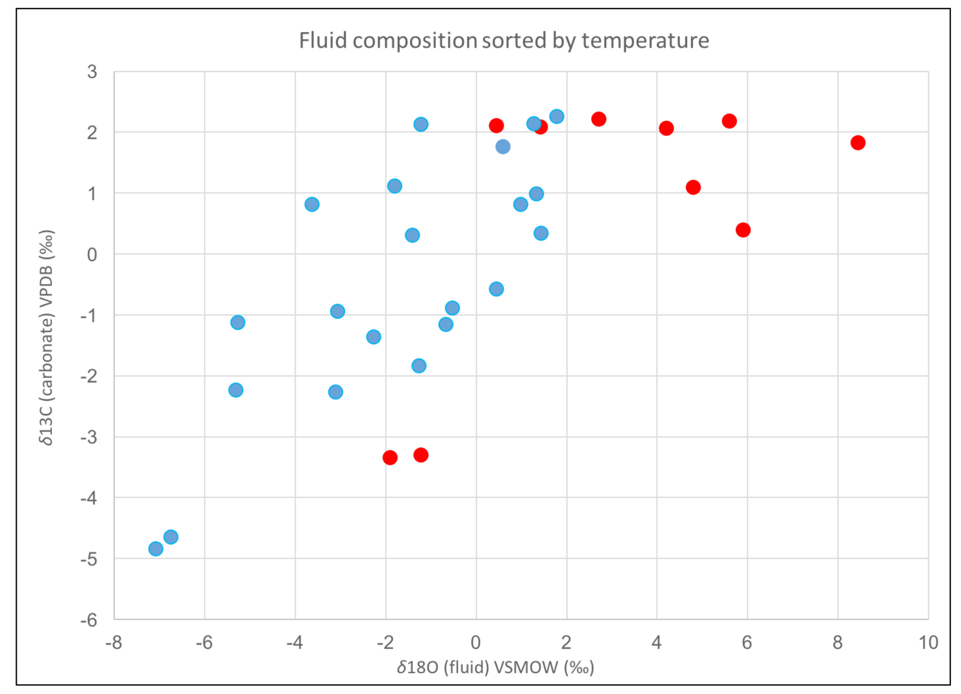


Figure 5. Calculated fluid composition sorted by $\Delta 47$ clumped isotope temperatures. Red indicates temp above 35 °C. Blue indicates temp below 35 °C.

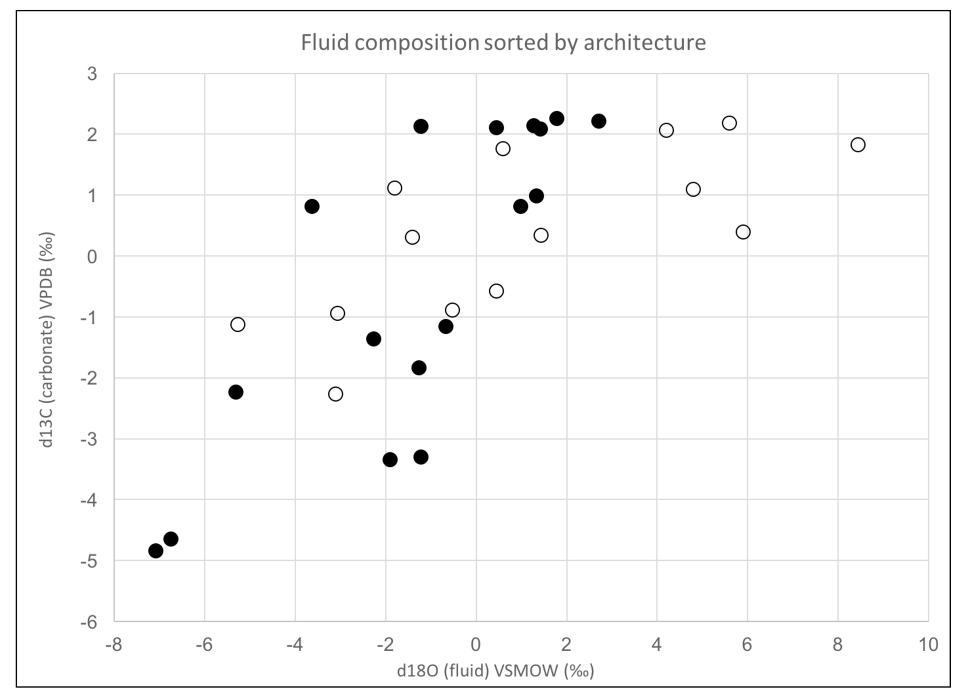


Figure 5. Calculated fluid composition sorted by location in fault (FC vs DZ). Open symbols show DZ samples. Filled symbols show FC samples.

Discussion

- Sample position in the FC or DZ does shows a weak correlation to fluid temperature and composition.
- The presence of both hot and cold fluids in the FC and DZ eliminates the possibility of true fluid compartmentalization between the two regions.
- Fluids may be compartmentalized in discrete architectural units within the FC and DZ.
- Relating sample fluid composition, carbonate petrography, and sample location within the fault zone can further constrain the dynamics between faults and fluids.

Acknowledgements

We would like to thank the Washington NASA Space Grant Consortium and the Mary Gates Endowment for Students for helping to fund this research. We would also like to thank Andrew Schauer, Kate Huntington, Keith Hodson, Fabrizio Agosta, and IsoLab for excellent mentorship and expertise.