Grain-boundary fluids, chemical transport, and rheology: An Alpine perspective and resulting questions

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Experimental studies on wetting behavior of fluids have profound implications for understanding a variety of chemical and physical processes during synchronous metamorphism and deformation. The difficulty comes in determining how field and petrographic observations relate to the experimental data. Examples from the Eastern Alps will be used to document scales of fluid communication during metamorphism, to estimate wetting behavior of the fluids, and to explore effects on rock rheology: (1) Mineral and stable isotopic compositions in banded eclogites are homogeneous parallel to foliation but heterogeneous across foliation. Sharp interfaces rule out cross-foliation diffusion or fluid flow on a mm scale. Any interconnected porosity at high P was thus confined to layer-parallel networks. (2) Diffusive mass transfer during deformation of clast-bearing micaceous quartzites required an inter-connected fluid phase during amphibolite-facies shearing, but was ultimately self limiting. Rheologic cycling resulted from feedback effects between mass transfer and changes in deformation mechanisms. (3) Schists in the same shear zone contain carbonic fluid inclusions in graphitic layers vs. H_2O inclusions in nongraphitic layers. Strain was accommodated by repeated fracturing in graphitic layers and by crystal plasticity in nongraphitic horizons. Non-wetting carbonic fluids in graphitic schists experienced significant volume expansion during decompression, causing fracturing (and possible seismogenic faulting). (4) Preliminary rock-deformation experiments confirm the role of CO_2 in promoting high-T embrittlement of quartz-rich rocks, and also show development of rheologic stratification in samples deformed in the presence of immiscible H_2O-CO_2 fluids.

These studies show that variations in fluid wetting behavior control both mass transfer and rock rheology. They also raise questions: How does deformation affect fluid wetting behavior? What role does fluid immiscibility play in controlling rheology during deformation? What data are needed from natural samples to infer paleo wetting behavior? Does wetting behavior play a role in the earthquake cycle? Closer collaboration between field and experimental scientists is needed to address these questions.

Garnet morphology and the kinetics of deep crustal reactions

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The kinetics of deep crustal reactions have important implications for rates of fluid release and the impact of fluids on rock strength and seismic hazard. We focus on growth textures preserved in garnets from two rock units within the Acadian Orange-Milford Belt, CT: meta-ultramafic rocks found in the Maltby Lakes Metavolcanics (MLM) and metapelitic rocks of the Wepawaug Schist (WepS).

And-Grs-Uv garnets of the MLM rocks nucleated on relic spinels and have rounded, “petal-like” shapes. Garnet to Kyanite zone garnets in graphitic rocks of the WepS contain anhedral or “star-shaped” cores with relatively few inclusions. The cores abrubtly give way to sub- to euhedral rims rich in inclusions of graphite and Fe-Ti oxides. Cores have larger Ca, Mn, and Fe/Mg than rims. Core-rim boundaries are marked by agglomerations of graphite. Similar features in graphitic metapelitic rocks elsewhere define “textural sector zonation” (TSZ; Rice and Mitchell, 1991). Garnets with TSZ are found only in graphitic WepS rocks, ruling out graphite precipitation events at core-rim transitions. Instead, the organic matter was present prior to garnet nucleation, but it was excluded from the garnet cores as they grew.

The garnet morphologies imply rapid growth and fluid release far from equilibrium at large delta G of reaction. Morphology diagrams (e.g., Xiao et al., 1988) suggest that the petal-like shapes of the MLM garnets represent the fastest growth rates farthest from equilibrium. The WepS garnet cores represent somewhat slower, but still highly overstepped, growth that was followed by slower, more euhedral rim growth. We suggest that rapid growth coincided with rapid regional heating, consistent with recent geochronology (Lancaster et al., 2005).

References

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