Geophysical Research Abstracts
Vol. 12, EGU2010-8966-1, 2010
EGU General Assembly 2010

Nano-scale dynamic porosity in mid-crustal ultramylonites revealed by Synchrotron X-ray tomography

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Recently, we have found evidence for a creep cavitation induced dynamic porosity in greenschist facies shear zones (Fusseis et al., Nature 459, 2009). The key observation was that microporosity increased with decreasing grain size in the shear zone. In a Synchrotron X-ray tomographic investigation we were able to follow this trend down to the detection limit of 1.3 microns. We postulated that creep cavitation dominated porosity formation below detection limits. In order to investigate this hypothesis further we used the nano-tomograph at Sector 32-ID at the Advanced Photon Source (APS) to study two quartz-feldspar-mica ultramylonites from another location in the Redbank shear zone, central Australia. Both samples show grain sizes <5 micron and a compositional layering where polyphase mineral mixtures alternate with monomineralic quartz layers. While the former are relatively devoid of any pores, the latter exhibit grain boundaries cavities. We aimed at documenting the morphology and distribution of the pores to identify the porosity-generating mechanism.

The sub-micron scale of the pores required a three-dimensional imaging technique that covers this scale with a sufficient resolution. Sector 32-ID at the Advanced Photon Source (USA) provides an X-ray tomography setup that delivers a resolution of ∼35 nm, at a sample size of < 25 micron. The non-random distribution of the nano-pores required in-situ sampling with a dual-beam FESEM to cut micron-sized cuboids from the monomineralic quartz layers. We used a micro-manipulator to extract the cuboids and mount them on 20 micron diameter tungsten wires, where they were milled to cylinders with a diameter of ∼15 microns. Six datasets were collected at sector 32-ID to obtain phase-contrast tomographic projections, which were reconstructed to derive three-dimensional models of the pores.

A preliminary analysis of these models proved that nanotomography does allow to study sub-micron sized pores in detail. We could discriminate the pores and establish their relationship with other mineral phases in the samples. The tomography data support the hypothesis that the pores formed by creep cavitation. Creep cavitation is a common porosity-generating mechanism during shearing at mid-crustal conditions.