Deformation mechanisms in naturally-deformed blueschist facies metabasalts: constraints from exhumed subduction complexes in Greece and California

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The strength, or viscosity, of the subduction interface is a key parameter in subduction dynamics, influencing both long-term subduction plate speeds and short-term transient deformation styles. Fossil subduction interfaces exhumed from downdip of the megathrust record ductile deformation accommodated by diverse lithologies, including metasedimentary and metamafic rocks. Existing flow laws for quartz-rich rocks predict relatively low viscosities, in contrast to high viscosities predicted for basalt and eclogite, but the rheological properties of blueschists representative of metamorphosed oceanic crust of the down-going slab are poorly constrained. Two key questions remain: 1) are there significant viscosity contrasts between blueschists and quartz- or mica-rich metasedimentary rocks, and 2) what are the microscale mechanisms for creep in naturally deformed blueschists and how do they vary with pressure and temperature? To address these questions, we characterized deformation in natural samples from the Condrey Mountain Schist (CMS) in northern California, USA, and the Cycladic Blueschist Unit (CBU) on Syros Island, Cyclades, Greece, using outcrop-scale structural observations, optical microscopy, and Electron Backscatter Diffraction. The CMS and CBU record pressure-temperature conditions of 0.8-1.1 GPa, 350-450°C and 1.4-1.8 GPa, 450-550°C, respectively.

In the field, blueschists form m- to km-scale lenses that are interfolded with quartz schists, ultramafics, and, in the CBU, eclogites and marbles. At the outcrop scale in both localities, quartz-rich schists and blueschists each exhibit strong foliations and lineations and planar contacts at lithological boundaries. At the thin section scale, the prograde foliation and mineral lineation in blueschists are commonly defined by Na-amphiboles elongated in the lineation direction. Crystallographic preferred orientations in Na-amphibole in all samples have c-axes parallel to lineation and a-axes predominantly defining point-maxima perpendicular to the foliation, suggesting some component of dislocation activity for all temperature conditions in our sample suite. Microtextures in lower temperature CMS samples suggest strain accommodation primarily by dislocation glide and kinking in Na-amphibole, with extremely high-aspect-ratio grains and limited evidence for climb-controlled dynamic recrystallization. Some higher temperature CBU samples show large porphyroclasts with apparent ‘core-and-mantle’-type recrystallization textures and subgrain orientation analyses consistent with the (hk0)[001] slip systems. In contrast, epidote grains accommodate less strain than Na-amphibole, via some combination of rigid rotation, brittle
boudinage, and minor intracrystalline plasticity.

Observations of evenly-distributed strain, despite lithological heterogeneity, suggest low viscosity contrasts and comparable bulk strengths of quartz schists and blueschists. Our microstructural observations suggest that Na-amphibole was the weakest phase and accommodated the majority of strain in mafic blueschists. Dislocation activity, and not just rigid-body-rotation or diffusional processes, accommodated some component of strain and possibly transitioned with increasing temperature from glide- to climb-controlled. Although effective viscosities appear to be similar, subduction interface shear zones dominated by blueschists may exhibit a power-law rheology consistent with dislocation activity, in contrast to the common inference of Newtonian creep in metasediments. Complementary experimental work on CMS and CBU rocks will also be presented at this meeting (see Tokle et al. and Hufford et al.).