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Transient effects of a pre-existing lattice preferred orientation on the strength of foliated quartzite

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Much of our understanding of the strength of the continental crust is based on flow laws derived from homogeneous mono-mineralic aggregates (quartzites). However, crystal plastic deformation of rocks in the middle to lower continental crust during orogenic events forms foliations, lineations and lattice preferred orientations (LPOs) which produce physical and viscous anisotropies in rocks. In some of these orogenic events, such as in the Appalachian mountains, multiple deformation events form different, cross-cutting foliations and overprint existing LPOs. In order to determine the effects foliation/lineation and preexisting LPO have on the strength of rocks in the middle crust, we deformed a natural quartzite with a cross-girdle LPO from the Moine Thrust in Scotland with the compressive stress at six different primary orientations relative to the foliation and lineation. This quartzite has aligned but distributed fine-grained muscovite which defines a foliation and lineation. The cores were deformed at the same temperature (800°C), pressure (1500 MPa) and strain rate ($1.6*10^{-6}$/s) to similar strains (50-58%), leaving the foliation/lineation orientation as the only difference between experiments. Peak stresses occur at strains of 10-20% and are lowest for the sample with foliation at 45^{o} to the compression direction (400 MPa, the weak orientation). All other cores (hard orientations) have peak strengths of 600 to 1100 MPa and highest for the cores with lineation perpendicular to the compression direction (1100 MPa). These cores in hard orientations all strain weaken to a similar stress (~500 MPa), but are still ~100 MPa stronger than the core with both foliation and lineation initially oriented at 45 degrees to the compression direction. Optical microstructures include undulatory extinction, deformation lamellae, and at high strain (58%), the quartzite is more than 50% recrystallized. Scanning electron microscope electron backscatter diffraction analyses indicate that recrystallized grains in all cores reflect the deformation conditions of the experiment and original grains retain their initial LPO. Strength anisotropy at low strains is due to placing the foliation and lineation at non-ideal (hard) orientations relative to the compression direction and is greatest in cores with the lineation perpendicular to the compression direction. The evolution to a similar strength at high strains indicates that dynamic recrystallization creates new grains oriented for easy slip in the second (experimental) deformation event. These results suggest that differences in lineation and foliation orientations and a pre-existing LPO may cause strength anisotropy in rocks in the mid to lower continental crust, but this anisotropy may be transient and unlikely to exist to high strains.