Petrophysical properties across scales and compositions

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The scales at which observations from geophysical imaging are made are orders of magnitude larger than those made in field-based studies of fossil subduction and collision zones. Even more so, the determination of petrophysical properties of rocks is typically based on millimeter to centimeter-scale samples, and the so-obtained information is then used to inform large-scale geophysical imaging studies. Information on how such properties can be up-scaled to geophysically relevant scales is rare, underlining the need to combine petrophysical properties with structural data, obtained from relevant field analogues.

We provide results from three field analogues; (1) Tenda massif, Corsica, (2) Monte Mucrone, Sesia Zone, western Alps, and (3) Holsnøy, Lindås nappe, Scandinavian Caledonides. The bulk rock compositions cover a gradient from felsic (1-2) to mafic (3), as would be expected in the upper and lower continental crust, respectively. Petrophysical properties (P and S wave velocities and their ratios and anisotropies) were determined by direct measurement (ultrasonic pulse transmission technique) and calculated (based on texture data from neutron diffraction measurements). The data set is then used for numerical modeling (finite element method) of meter to kilometer-scale structural associations as mapped in the field (3).

The obtained results show that high-pressure metamorphism of mafic rocks results in significant increase in both P and S wave velocities, that in principle would generate a sufficient impedance contrast to be imaged by seismic methods. While structures observed in the field are typically below the scale of geophysical imaging techniques, our considerations of bulk petrophysical properties indicate that significant anisotropy may still be detectable on the kilometer scale. On the other hand, the increase of P and S wave velocities of felsic rocks during high pressure metamorphism is much smaller, however, as such compositions have a higher potential to form rocks with high mica contents, they display a large variability in seismic anisotropy, hinting at the potential to link relatively low seismic velocities, combined with high anisotropy to fluid intake during metamorphism.