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Petrofabric Derived Seismology - What it Reveals About Crustal Anisotropy: The Nanga Parbat Case Study

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The Nanga Parbat Massif (NPM) is an exhumed tract of Indian continental crust in the Pakistan Himalaya. As an area of active crustal thickening and rapid exhumation, the NPM offers an insight on how localised thrust faults at the Earth's surface couple with more distributed strain at depth. There are several conflicting models proposed to explain the kinematics of the exhumation and emplacement of the NPM. The most effective way to elucidate which model best describes the processes active at NPM is through seismic imaging. Natural and controlled source seismology can be used as a remote sensing tool to characterise sub-surface geology.

Seismic anisotropy is increasingly used to infer information on structures induced by large-scale geodynamic processes at depth within the Earth. However, the veracity of interpretation of any observed seismic anisotropy depends critically upon knowledge of the seismic properties of the rocks involved. It is well known that natural deformation mechanisms in rocks are responsible for inducing anisotropy of the inherent petrophysical properties. The seismic anisotropy can be assessed by measuring the crystal lattice preferred orientation (LPO) of the constituent mineral phases (e.g. using scanning electron microscope electron backscatter diffraction, SEM-EBSD) and averaging the individual LPO to calculate the bulk elastic constants of the rock aggregate.

This contribution considers how seismic waves propagate through the recently deformed Indian continental crust of the NPM and how they are affected by both dis-

tributed and localised deformation. Gneissic, mylonitic and cataclastic rocks emplaced at the surface were sampled as proxies for lithologies and deformation fabrics currently accommodating deformation at depth. SEM-EBSD is used to determine the LPO of individual minerals in the samples, from which the elastic constants, 3D seismic velocities and anisotropies were predicted. Petrofabric analyses reveal that the micas are the main contribution to the bulk anisotropy of the gneissic samples and it is only when there is a low mica content, or a weak to random LPO, that the other minerals control the anisotropic properties. The magnitude of anisotropy is observed to vary with deformation style. This work suggests that in some regions shear zones and faults are characterised by regions of low anisotropy.

The calculated elastic constants are used to construct simple elastic models based on current ideas of NPM tectonics. P-, S- and converted waves were then ray traced through these models. The foliation, which is considered as a proxy for kinematics, has dramatic effects on seismic waves. A rock with predicted 9.5% shear wave splitting and a vertically aligned foliation persistent throughout the crust induces 1.2s of shear wave splitting, compared to a horizontal alignment which only induces 0.2s splitting. Mode conversions and transverse component energy are also diagnostic of the degree and orientation of foliation. Therefore, the models indicate that it should be possible to discriminate between different deformation processes active at depth using seismic measurements.