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Microstructural controls on the fracture toughness of serpentinite-derived nephrite jade: An integrated EBSD, synchrotron, and mechanical analysis

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Nephrite jade is a monomineralic rock composed of fine-grained interwoven amphibole fibres of the tremolite-actinolite series. Depending on its genetic setting, nephrites can be divided into serpentinite-related and dolomite-related deposits. The current study focuses on assemblages genetically associated with serpentinite systems from New Zealand, Canada, and USA.

In this study, we investigate the relationships between structural, chemical, physical and mechanical properties in nephritic amphibole using a combination of electron backscatter diffraction (EBSD), Scanning Electron Microscopy - Energy Dispersive Spectroscopy (SEM-EDS), synchrotron X-ray diffraction (SXRD), synchrotron projection X-ray microscopy (PXM), synchrotron transmission X-ray microscopy (TXM), ultrasonic wave velocity measurements, and mechanical testing.

EBSD mapping was used to characterise grain size distributions, aspect ratio, crystallographic orientations, and fabric strength. SEM-EDS measurements were used to obtain data on mineral chemistry. Synchrotron measurements quantified hkl-specific lattice strains from SXRD peak shifts, microcrack distributions and porosity. P- and S-wave velocities were obtained in ambient laboratory conditions to compare the measured seismic anisotropy with the intrinsic anisotropy predicted from EBSD data. Mechanical properties such as fracture toughness and flexural strength were measured using a universal testing machine equipped with a four-point bending setup, hardness and reduced modulus were obtained through nanoindentation.

Nephrite jade's exceptional toughness has been attributed in the literature to fine-scale microstructural organisation and crystallographic fabric development during deformation and hydration. While its fracture resistance is empirically linked to its fibrous microstructure, quantitative studies integrating crystallographic fabric analysis with direct mechanical measurements are lacking to date. The results of this study demonstrate a systematic correspondence between amphibole crystallographic organisation and macroscopic mechanical response. These observations have implications for understanding the mechanical role of serpentinite-derived rocks in lithospheric processes and their contribution to elastic and seismic anisotropy.