From chemical zoning to the long-term stress-state in the continental lithosphere

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Convection vigor in the Earth's mantle drives tectonic plates where along the plate boundaries earthquakes and volcanic eruptions occur as a result of building and releasing the lithospheric stresses. Knowledge of the response of the Earth's lithosphere to a stress increase, rock rheology, helps us to understand and predict geodynamic processes in the Earth's interior as well as natural hazards. Yet, the challenge lies in the extrapolation of the non-linear relation between stress and deformation rate from experimental to geological conditions and timescales. This makes the rheological parameters the least certain inputs in the geodynamic models. Here, we present that metamorphic rocks produced in orogenic belts as an outcome from natural processes over geological time scales may be a source of unique rheological constraints and a calibration for the extrapolation of laboratory measurements. We relate the microstructural observations in rocks to the nonlinearity of long-term creep at time scales unattainable by laboratory measurements. We applied the new relation to plagioclase, the most abundant mineral of the lower crust. The resulting rheology data derived directly from natural samples document that crustal rocks can sustain stresses much larger than expected from experimental measurements. We propose that the new finding may help to resolve long standing enigmas in geodynamic modelling of processes in the continental lithosphere such as long term strength of the lower crust, megathrust earthquakes and source heat for metamorphism during mountain building.