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Depth distribution of seismicity and crustal rheology of the northern Main Ethiopian Rift

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We investigate thermo-mechanical properties of the crust in the northern Main Ethiopian Rift (MER) by analyzing the interrelationships between the depth distribution of seismicity, geothermal gradient, composition, and crustal strength, We use both hypocentral depth as well as moment magnitudes of ∼2000 well constrained earthquakes from the EAGLE catalogue (2001-2003) with +/- 2 km hypocentral error, which allows us to quantify the depth distribution of seismicity in the northern MER at high accuracy.
The seismicity pattern is compared to crustal yield strength envelopes employing linear frictional failure in the brittle crust and power law dislocation creep in the ductile regime. These strength envelopes are computed using hydrostatic and near-lithostatic pore fluid pressure, surface heat flow that implies a temperature of ∼1300°C at the base of the lithosphere, 1D heat conduction with exponentially decreasing heat generation and spatially variable strain rates compatible with independent geodetic observations.
The best rheological model that fits with the depth distribution of seismicity is a 16 km thick granitic upper crust and mafic-granulite dominated lower crust with hydrostatic and near-lithostatic pore fluid pressure, respectively. High pore fluid pressure in the lower crust allows brittle failure to occur to a depth of 18 km (i.e. within the hypocentral uncertainty of earthquakes) and explains 98% of the observed seismicity. Brittle deformation and hence earthquakes in the lower crust are facilitated by localized high pore fluid pressure migrating from the upper mantle - an argument supported by several observations from different sectors of the East African Rift. The low viscosity in the lower crust due to high temperature allows the formation of ductile shear zones as prolongations of upper crustal brittle faults. Our study has important implications for studying volatile transport in continental rift zones and occurrences of high CO_2 flux at or near active faults in the rift.