Lower crustal low-resistivity zones caused by compaction-induced fluid localization and stagnation – recent results from electromagnetic data in an intracontinental setting

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We investigate how a conceptual hydrodynamic model consisting of fluid localization and stagnation by thermally activated compaction can explain low-resistivity anomalies observed in the lower crust (>20 km depth). Electrical resistivity models, derived from magnetotelluric data collected across the intracontinental Bulnay region, a subset of a larger regional array across central Mongolia, are generated. They reveal low-resistivity (3 - 30 Ωm) domains with a width of ~25 km and a vertical extent of <10 km in the lower crust, with their tops ~5 km below the brittle-ductile transition zone. In 3-D these features appear as laterally extended (tube-like) structures, 300 km long, rather than disconnected ellipsoids. The features are oriented parallel to the adjacent Bulnay fault zone segments and perpendicular to the far-field compressive tectonic stress (i.e., northward motion from China and Tibet). These low-resistivity domains are consistent with the presence of saline metamorphic fluids. Deeper features imaged with the data include a large upper mantle conductor that we attribute to an asthenospheric upwelling, and thin lithosphere, related to intraplate surface uplift and volcanism, in agreement with recent geodynamic modelling of lithospheric removal in this region.

Based on the observed thermal structure of the crust, and assuming the mean stress at the brittle-ductile transition is twice the vertical load, the hydrodynamic model predicts that fluids would collect in zones <9 km below the brittle-ductile transition zone, and the zones would have a vertical extent of ~9 km, both in agreement with the resistivity models across the Bulnay region. The hydrodynamic model also gives plausible values for the activation energy for viscous creep (270 - 360 kJ/mol), suggesting that the mechanism is dislocation creep.

From the electrical resistivity models, the lower crustal viscous compaction-length is constrained to be ~25 km - in this region. Within the conceptual model, this length-scale is entirely consistent with independent estimates for the specific hydraulic and rheological properties of this region. In fact, this can be used to independently constrain acceptable ranges for the lower crustal effective...
viscosity, which is found to be low (on the order of $10^{18}$ Pas). Accordingly, the results indicate that low-salinity fluids (likely 1 - 0.01 wt% NaCl), and correspondingly low porosities (likely 5 - 0.1 vol%), are the most plausible. These key findings suggest partial melts are not favoured to explain the anomalies. Overall, the results of this contribution imply that it is tectonic and compaction processes that control lower crustal fluid flow, rather than lithological or structural heterogeneity.