Compaction-driven fluid localization and stagnation can explain lower crustal low-resistivity zones

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SUMMARY

We present electrical resistivity models that show discrete zones (width of ~25 km, vertical extent of <10 km) of low resistivity (<30 Ωm) in the lower crust (>20 km depth), from magnetotelluric data collected across the intracontinental Bulnay region, Mongolia. The top of these features is located approximately 5 km below the brittle-ductile transition zone and they are imaged as laterally extended (tube-like) features over 300 km long, parallel to the Bulnay fault zone, and perpendicular to the far-field compressive tectonic stress. Such features may be caused by unaccounted-for electrical anisotropy. However, when anisotropy is considered in the modeling, the features remain. We investigate an alternative explanation: we show evidence for a conceptual hydrodynamic model of fluid localization and stagnation by thermally activated compaction. We demonstrate that this is compatible with the observed low-resistivity zones, which are consistent with the presence of saline metamorphic fluids. Based on the thermal structure of the crust, the conceptual model predicts the size and shape of the zones: the fluid domains should have a vertical extent of ~9 km and their centres should be <9 km below the brittle-ductile transition zone. The conceptual model gives plausible values for the activation energy for viscous creep (270-360 kJ/mol), suggesting that the mechanism is dislocation creep. The electrical resistivity models constrain the lower crustal viscous compaction-length to be ~25 km, in this region. This length scale is consistent with independent estimates of hydraulic and rheological properties. The model can be used to independently constrain the lower crustal effective viscosity, the fluid salinity, and the porosity. Overall, the results imply tectonic deformation and compaction processes, rather than lithological-structural heterogeneity, control the regional lower crustal fluid flow.

Keywords: fluid; compaction; anisotropy; brittle-ductile transition; resistivity