Partial melt or aqueous fluid in the mid-crust of Southern Tibet? Constraints from INDEPTH magnetotelluric data

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SUMMARY

The INDEPTH project has applied modern geophysical techniques to the study of the crustal structure and tectonic evolution of the Tibetan Plateau. In the Lhasa Block, seismic reflection surveys in 1994 detected a number of bright-spots at 15–20 km depths that indicate zones of crustal fluids (aqueous fluids or partial melt). Coincident magnetotelluric (MT) data collected in 1995 detected a major zone of high electrical conductivity at the same depth as the bright-spots. Using constrained inversion, the MT data require a minimum crustal conductance of 6000 S. This abnormally high electrical conductance can be best explained by a layered model with fluids: partial melt, aqueous fluids or a combination of partial melt and aqueous fluids. The non-uniqueness of the MT method means that a wide range of melt fraction–thickness combinations for the above models could all explain the 6000 S conductance. To distinguish between these three models, other geophysical and geological data are required. Reflection seismic data suggest that a high fluid content (>15 per cent) is present at the top of the layer. The amplitude-versus-offset data suggest that the top of this layer may be aqueous fluids rather than partial melt. Passive seismic data imaged a 20 km thick layer of lower fluid content that is probably partial melt. Petrological studies suggest that concentrations of aqueous fluids above 0.1 per cent at mid-crustal depth cannot be sustained. Taken together, these data show that the high conductivity in Southern Tibet is most probably the result of a relatively thin layer of aqueous fluids (100–200 m) overlying a thicker zone of partial melt (>10 km).

Key words: electrical conductance, electrical conductivity, magnetotellurics (MT), partial melt, saline fluid, seismic bright-spots, Tibetan Plateau.

1 INTRODUCTION

The India–Asia continent–continent collision has created the most spectacular topographic feature on the surface of the Earth. The Tibetan Plateau has an area approximately half the size of the conterminous United States with an elevation above 5 km. It represents a key location for understanding the processes of mountain building and plateau formation during continent–continent collisions. Although our understanding of the geological structure and history of the Tibetan Plateau has significantly improved over the previous two decades, many first-order structural questions are still under debate. Numerous models have been proposed to explain the tectonic processes that have thickened the crust; and span the spectrum from underthrusting of the Indian plate (Argand 1924) to distributed thickening of the Tibetan crust (Dewey & Burke 1973). Other processes that need to be considered include fluid injection into the Tibetan lower crust (Zhao & Morgan 1987), eastward extrusion of the crust and mantle (Tapponnier *et al.* 1982) and southward subduction of Asian lithospheric mantle (Willett & Beaumont 1994).

The first detailed geophysical studies in Southern Tibet were made during Sino–French studies in the 1980s that gave evidence for partial melting from high heat flow and high electrical conductivity (Francheteau *et al.* 1984; van Ngoc *et al.* 1986). The INDEPTH (International Deep Profiling of Tibet and the Himalayas) project was initiated in 1992 to continue the investigation of the structure and evolution of the Tibetan Plateau. The INDEPTH corridor in Southern Tibet extends from the High Himalaya to the centre of the Lhasa Block (Fig. 1). Along this profile active and passive seismic, magnetotelluric (MT) and geological data were collected. Combined with data collected by the Sino–French team, the INDEPTH data suggested that the middle crust beneath Southern Tibet is partially molten (Nelson *et al.* 1996). The evidence for partial melt included high heat flow (Francheteau *et al.* 1984), seismic bright-spots at a depth of 15–20 km (Brown *et al.* 1996), high electrical conductivity