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# Detection of the deep crustal structure of the Qiangtang terrane using magnetotelluric imaging

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ABSTRACT

To determine the deep electrical structure of the Qiangtang terrane, northern Tibetan Plateau, we reanalysed three broadband magnetotelluric (MT) profiles collected by China University of Geosciences (Wuhan) in 1993–1994 and derived corresponding 2-D resistivity models. In these models, a remarkable high-conductivity layer that was divided into northern and southern parts and that had formed an antiformal zone of high conductivity beneath the central Qiangtang terrane was visible. This high-conductivity layer corresponds well with the trace of the southward subduction of the mélange from the Jinsha River suture inferred from surface geology. According to our resistivity models, the crust of the northern Qiangtang terrane is mostly composed of mélange. The underplated mélange may be closely related to the formation of the high-conductivity layer and provide a reasonable explanation for the cause of special geophysical features in this area. In addition, the similarity between these resistivity models provides evidence that the Qiangtang anticlinorium extends eastward to at least 92°E, whereas the differences between them may offer an explanation for the gradual narrowing of the metamorphic belt from west to east in the central Qiangtang terrane.

## 1. Introduction

Since the closing of the Tethys Ocean, the ongoing collision between the Indian and Asian continents created the Tibetan Plateau, which is the most spectacular topographic feature on the surface of the Earth. A wide range of geodynamic models have been proposed for the evolution of the Tibetan Plateau, including the northward injection of the Indian crust (Zhao and Morgan, 1985), block extrusion along principal strike–slip faults (Tapponnier et al., 1982, 1990), and flow in a weak lower crustal layer (Rodyen et al., 1997, 2008). In the past decades, numerous geological and geophysical studies have been conducted in the Tibetan Plateau (Chen et al., 1996; Kind et al., 2002; Makovsky and Klemperer, 1999; Nelson et al., 1996; Owens and Zandt, 1997; Tilmann et al., 2003; Unsworth et al., 2005; Wei et al., 2001). In contrast to southern Tibet, the Qiangtang terrane (Fig. 1a) exhibits a high crustal Poisson's ratio (Owens and Zandt, 1997), inefficient Sn propagation (Xu et al., 2011; Zhao et al., 2010), strong SKS anisotropy (Huang et al., 2000), high-conductivity anomalies (Unsworth et al., 2004; Wei et al., 2001), and widespread Cenozoic volcanism (Kapp et al., 2005; Yin and Harrison, 2000). At present, the contribution of the north–south variations in the Tibetan crustal structure to these geological and geophysical features is the subject of heightened research interest.

A band of blueschist-bearing metamorphic core complexes approximately 600 km long and 300 km wide is exposed in the central Qiangtang terrane (Fig. 1b), and the origin of these complexes remains a topic of debate. Currently, there are three main models of its origin: (1) an in situ palaeo-Tethyan suture that separates the northern and southern Qiangtang terrane (Li et al., 2006; Zhai et al., 2013), (2) an intracontinental subduction zone that the southern Qiangtang continental block subducted towards the northern Qiangtang block along the Shuanghu suture (Zhang et al., 2006a,b, 2011), and (3) an early Mesozoic mélange that was underthrust from the Jinsha River suture (JRS) and was then exhumed in the interior of the Qiangtang terrane (Kapp et al., 2000, 2003, 2005). These three models imply fundamental differences in the first-order crustal structure of the northern Tibetan Plateau (Zhang et al., 2006a). Hence, the origin of the central Qiangtang metamorphic belt is important to understand the evolution of the northern Tibetan Plateau, and it is also significant to reveal the deep crust of the Qiangtang terrane. However, due to the inhospitable climate and the difficulty of gaining access to this area, very few geophysical observations have been obtained from the Qiangtang terrane.

Magnetotelluric (MT) exploration can determine the conductivity of the crust and upper mantle by measuring variations of naturally occurring electromagnetic fields at the Earth surface. Previously, the INDEPTH 500-line and 600-line were collected traversing the Qiangtang terrane, and two-dimensional resistivity models derived by different researchers based on these data showed that the conductive crust found in southern Tibet is also present in northern Tibet (Unsworth et al.,

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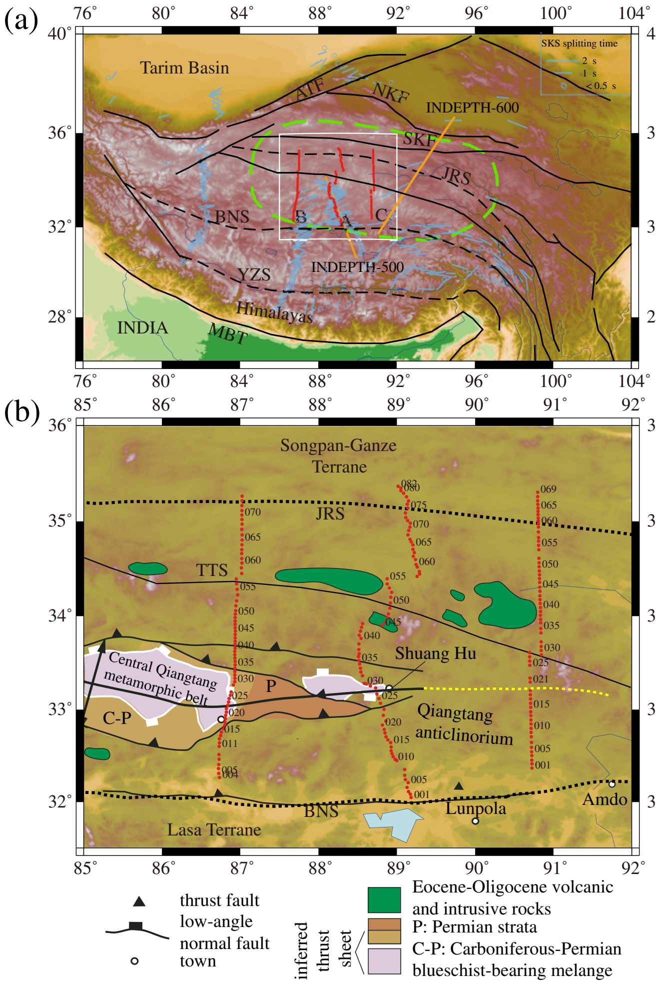

**Fig. 1.** (a) Map showing the topography of Tibet. The white rectangle indicates the position of the study region and the detailed map in (b). The orange lines mark the INDEPTH 500 and 600 lines. The green dashed line denotes the limits of the zone of inefficient Sn propagation (Zhao et al., 2010). The light blue line and circle denote the SKS anisotropy (Zhao et al., 2010). (b) Tectonic map with background topography modified from Kapp et al. (2005). The red dots mark the MT stations along the profiles, and the digits are station numbers. The yellow dashed line denotes the supposed trace of the central Qiangtang anticlinorium. Abbreviations are as follows: YZS = Yarlung–Zangbo suture; JRS = Jinsha River suture; BNS = Bangong–Nujiang suture; TTS = Tanggula Thrust System.

2004; Wei et al., 2001), and the electrical structure in the southern Qiangtang terrane differs from the northern Qiangtang terrane. In addition, three north–south trending MT profiles spanning the Qiangtang terrane were collected at densely spaced sites by the China University of Geosciences (Wuhan) in 1993–1994. This survey used state-of-the-art methods for the time, and the interpretation was more focused on the shallow sedimentary structure of the Qiangtang terrane for the purpose of oil and gas exploration (Zhang et al., 1996). In this work, we have reanalysed these three MT profiles using modern, more advanced processing, analysis, and modelling techniques to compare the similarities and differences in the electrical structures between the eastern and western Qiangtang terrane and provide additional evidence to resolve the controversial issues mentioned above.

## 2. Regional geology

The Qiangtang terrane, located in the central and north Tibetan Plateau, was accreted to Asia in the Late Triassic or Early Jurassic. It lies between the Bangong–Nujiang suture (BNS) and Jinsha River suture and is adjacent to the Lhasa terrane in the south and Songpan–Ganze terrane in the north. The Qiangtang terrane can be divided into three second-order tectonic units: the northern Qiangtang terrane, the southern Qiangtang terrane, and the central Qiangtang uplift (or Qiangtang anticlinorium) (Fig. 1). The first-order geologic framework of Qiangtang is characterized by dominantly metamorphic rocks and Late Palaeozoic shallow marine strata in the north and Triassic–Jurassic shallow marine carbonate rocks interbedded with terrestrial clastic and volcaniclastic strata in the south (Yin and Harrison, 2000). In the northern Qiangtang terrane, the Tanggula Mountain is parallel to the north–northwest strike and has extensive granitic intrusions exposed on the surface. In addition, Cenozoic volcanic rocks are widely distributed in the northern Qiangtang terrane. The petrology of these volcanic rocks suggests that they originated from melting of subcontinental lithospheric mantle or the crust–mantle transitional zone (Ding et al., 2003; Lai, 2000). The central Qiangtang metamorphic belt is structurally exposed beneath low-grade Carboniferous–Triassic strata in the footwalls of domal Late Triassic–Early Jurassic normal faults and is comprised of a strongly deformed matrix of metasedimentary and mafic schists (Kapp et al., 2003). The presence of metabasite, metagraywacke, chert, and minor ultramafic material within the Qiangtang metamorphic belt is consistent with it having been derived from fragments of, and sediments deposited on, oceanic lithosphere (Kapp et al., 2003).

## 3. Collection and analysis of magnetotelluric data

Phoenix MTU instruments were used to collect broadband (320–0.00055 Hz) MT data at a total of 215 sites along three north–south trending profiles, which were oriented perpendicular to the dominant geo-electrical strike direction of the northern Tibetan Plateau. Measurements were made at stations spaced approximately 3–5 km